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Environmental Influences on Human Migration in Rural Ecuador

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Abstract

The question of whether environmental conditions influence human migration has recently gained considerable attention, driven by claims that global environmental change will displace large populations. Despite this high level of interest, few quantitative studies have investigated the potential effects of environmental factors on migration, particularly in the developing world and for gradual but pervasive forms of environmental change. To address this, a retrospective migration survey was conducted in rural Ecuador and linked to data on topography, climate, and weather shocks. These data were used to estimate multivariate event history models of alternative forms of mobility (local mobility, internal migration, and international migration), controlling for a large number of covariates. This approach is generalizable to other study areas and responds to calls for the development of more rigorous methods in this field. The results indicate that adverse environmental conditions do not consistently increase rural out-migration and, in some cases, reduce migration. Instead, households respond to environmental factors in diverse ways, resulting in complex migratory responses. Overall, the results support an alternative narrative of environmentally induced migration that recognizes the adaptability of rural households in responding to environmental change.

Keywords

International migration; Internal migration; Climate; Environment; Event history

Introduction

As the evidence of global environmental change has accumulated over the past decade, academicians, policy makers, and the media have given more attention to environmental influences on human migration. At issue is the extent to which factors such as climate variability and soil degradation serve as push factors for migration among vulnerable populations, particularly in the rural developing world, where livelihoods are highly dependent on natural resources. Early discussions of this issue assumed that households usually had few options with which to respond to deteriorating environmental conditions, inevitably leading to large-scale, long-distance, and permanent population displacements (e.g., Myers 1997). Neo-Malthusian claims of this type remain common in the popular press and in policy documents (e.g., Stern 2007; Warner et al. 2009), but the academic literature has become more skeptical, noting that the evidence is weak and that better methodological approaches are needed (François 2011; Kniveton et al. 2008; Laczko and Aghazarm 2009).

Linking demographic and spatial methods may offer a way forward. Population-based household surveys can be used to collect representative data on migration, migrants can be linked to their environmental context using spatial methods and/or community-level survey data, and multivariate analyses can be used to account for other potential influences on migration. Previous studies have used these and other similar approaches to examine the effects on migration of climate variability (Dillon et al. 2012; Gray and Mueller 2012a, b; Henry et al. 2004); large-scale natural disasters (Groen and Polivka 2010; Halliday 2006; Smith and McCarty 1996, 2009); and local environmental conditions, such as soil quality and fuel-wood availability (Gray 2011; Leyk et al. 2012; Massey et al. 2010). These studies show that adverse environmental conditions tend to increase migration, but not always (Gray and Mueller 2012b). However, further insights have been limited by the lack of a generally accepted methodology, particularly when panel data are absent, and by the absence of studies that investigate small-scale and incremental environmental changes, such as soil degradation.

To move toward a stronger quantitative methodology and broaden the range of environmental factors addressed in this field, we designed and implemented a new survey to examine an array of environmental influences on migration in rural Ecuador. Data on out-migration from rural households were collected using an innovative approach that combined multistage stratified sampling with the collection of event histories at various scales. These data were then linked to multiple biophysical data sets and used to estimate multinomial event history models of local mobility, internal migration, and international migration. These models investigate the effects of land quality, topography, long-term climate, and rainfall variability on migration while accounting for a host of control factors at individual, household, community, and regional scales. The approach expands on previous studies by including measures of static and slowly changing environmental conditions as well as weather shocks, testing whether the former also have important influences on migration.

This article is organized as follows. First, we review theoretical perspectives on environmentally induced migration and previous empirical studies. This is followed by a discussion of the study area and data collection methods, including household and community surveys and integration with other data sets. Then the multivariate analytical approach is described, followed by a presentation and interpretation of findings. We conclude with recommendations for further research and policy implications.

Environmental Influences on Human Migration

Theoretical Perspectives

Previous discussions have commonly identified two pathways for environmental influences on population mobility, one *fast* and one *slow* (Bates 2002; Gray 2009a; Laczko and Aghazarm 2009). In the *fast* pathway, rapid environmental changes—such as weather shocks and natural disasters—can be viewed as a form of covariate risk to which households are unpredictably exposed, leading to the loss of assets and/or income (Dercon 2002). Because these environmental events often affect large areas, they can overwhelm local interhousehold insurance mechanisms, such as informal lending, that are common in the developing world (Kazianga and Udry 2006). Thus, following an environmental shock, households may send labor migrants as part of an investment strategy (Stark and Bloom 1985), with the expectation of receiving remittances that will replace lost income and assets. However, in other cases, migration of part or the entire household is necessary to seek shelter or reduce consumption needs because of the extreme nature of the shock. Indeed, most environmentally induced moves can be thought of as lying along a spectrum from forced to voluntary (Hugo 1996).

Following repeated shocks, households may invest in migration as an *ex ante* diversification strategy (Dillon et al. 2011). Given that migrants' earnings in a distant or urban destination are unlikely to be correlated with shocks in the origin, this form of diversification provides insurance against further shocks (Rosenzweig and Stark 1989). Thus, both environmental shocks and environmental variability may increase migration. However, shocks may also have negative effects on mobility by leading to an influx of aid (Halliday 2006) or by pushing households below an asset threshold under which investments in migration are not possible (Barrett 2008).

In the *slow* pathway, in contrast, environmental characteristics—such as land quality and long-term climate norms—can be viewed as assets or amenities that affect the productivity of natural resource-based livelihood activities, such as agriculture. Positive environmental characteristics, which could be described as natural capital (Ellis 2000), are expected to reduce out-migration by increasing the desirability of the origin area. Conversely, slow forms of environmental degradation, such as soil erosion, are expected to lead to out-migration (Gray 2011). However, if the proceeds from natural capital can be invested in migration, it is also theoretically possible that access to natural capital could increase out-migration (Gray 2009a). In comparison with fast forms of environmental change, slow forms (such as soil degradation and gradual climate change) almost certainly affect far more people (e.g., Sanchez 2002) but have received much less attention in the literature (Gray 2011) because these effects are less spectacular and sudden and because of difficulties in measurement.

Previous Studies

A number of previous studies have discussed the potential for environmental factors to influence human migration (Laczko and Aghazarm 2009), but few have used demographic or econometric methods to estimate the significance and magnitude of the effects. Most of the latter have focused on fast forms of environmental change, such as hurricanes in the United States (e.g., Smith and McCarty 1996, 2009). In particular, the ramifications of Hurricane Katrina have been the focus of multiple studies, revealing that 1.5 million people were displaced, with the poor more vulnerable to long-term displacement (Fussell et al. 2010; Groen and Polivka 2010). For the developing world, far fewer high-quality data sets are available on natural disasters and migration, but a study on El Salvador (Halliday 2006) found that although international migration increased following agricultural shocks as expected, migration *decreased* following a large earthquake in 2001, perhaps reflecting the return of migrants to work in reconstruction. In addition, a study of Bangladesh found that floods had only weak effects on migration, in contrast to large-scale crop failures (Gray and Mueller 2012b). These studies highlight the need to reconceptualize the role of environmental factors in migration as well as to compare different types of environmental influences.

Several studies have investigated the effects of rainfall on migration in the rural developing world, where agricultural households are vulnerable to weather shocks and climate variability (Kazianga and Udry 2006). These studies reveal that migration tends to increase with drought, but not always (Gutmann et al. 2005; Munshi 2003). For example, Findley (1994) found that total migration rates did not change during a drought in Mali, but the proportion of moves made by women and children increased; and Henry et al. (2004) found that rural-rural migration was more common and international migration was less common following droughts in Burkina Faso. Dillon et al. (2011) and Gray and Mueller (2012a) showed that in Nigeria and Ethiopia, respectively, migration of men increased following drought while migration of women decreased, highlighting the gendered nature of these processes. We build on these studies by testing for effects of rainfall shocks on local, internal, and international migration in Ecuador, as well as by testing for nonlinear effects and heterogeneity across gender and farm size.

Relative to studies of fast forms of environmental change, the effects of slow forms have received much less attention. However, at least three studies have investigated these effects. Our pilot study showed that in a small area in the southern Ecuadorian Andes, households with higher long-term rainfall were less likely to send migrants to either internal or international destinations (Gray 2009a), and households with self-reported soil degradation were also less likely to send international migrants, contrary to expectations (Gray 2010). In lowland Nepal, Massey et al. (2010) found that out-migration increased with time to gather firewood, perceived declines in agricultural productivity, and the proportion of the community without vegetation. However, these effects were important only for local moves and only for low-caste individuals. Finally, Gray (2011) showed that out-migration decreased with soil quality in Kenya but marginally increased in Uganda. These three studies are too few and diverse to draw any conclusions about the impacts of slow-changing environmental characteristics on migration, but they suggest that these effects are potentially important. The current study expands this small literature by investigating the effects of long-term climate and land quality on three forms of population mobility in rural Ecuador.

Data Collection

To address these issues, a retrospective migration survey was conducted in three study areas in rural Ecuador. Key elements of this approach are that the study areas were selected to be environmentally and demographically diverse, a flexible sampling strategy was used to oversample rare migrant types, event histories were collected at multiple scales, and links were created with multiple biophysical data sets. This approach builds on previous retrospective and multilevel studies of migration in Ecuador and elsewhere (Barbieri et al. 2008; Bilsborrow et al. 1987; Gray 2009a). The approach has limitations relative to the use of panel or longitudinal data (e.g., Gray and Mueller 2012a; Halliday 2006), including the possibility of recall or proxy errors as well as limits to the information that can be collected about whole departed households. However, we argue that the magnitudes of these errors and omissions are likely to be small, and the advantage of our approach is that it can be applied in the many contexts where environmental influences on migration are of interest but high-quality panel data are not available. In this way, our approach responds to multiple calls for a robust, generally applicable methodology for this field (François 2011; Kniveton et al. 2008).

The Study Areas

The study was conducted in three areas of rural Ecuador in the Andean highlands and the Pacific coastal plain (Fig. 1). The areas were selected, based on previous site visits, census data, and various sources of environmental data, as both environmentally diverse and important sources of out-migrants. Each study area comprises five to six contiguous cantons,[1] and altogether they contained 7 % of Ecuador's rural population in 2001. The Santo Domingo study area is located in the transition zone between the Andes and the Pacific coastal lowlands, encompassing a wide range of environments from mountainous, forested areas in the north/east to flat and intensively cultivated areas in the south/west. The climate is humid, but temperatures vary with elevation from subtropical to tropical. Key crops include heart of palm, cacao, coffee, and plantains, and landownership is mixed between smallholder farms and large cattle ranches. Out-migration is primarily to internal

[1]Cantons are administrative units that are roughly equivalent to counties in the United States.

destinations in the Pacific lowlands. The area has also received significant in-migration since the 1970s.

The high-elevation Chimborazo/Cañar study area, which covers parts of these two provinces, includes both high-elevation grasslands and densely settled valleys with temperate climates. Smallholder agriculture is the dominant form of land use, and key crops are maize, beans, and potatoes. This area is part of Ecuador's international out-migration heartland: migration to the United States rose in the 1990s and was later superseded by emigration to Spain in 1997–2003 (Jokisch 2007; Jokisch and Pribilsky 2002). The third area, in western Loja province, lies in the western Andean foothills and has a dry climate with recurrent droughts. Coffee-centered agroforestry and maize-centered smallholder agriculture are key agricultural activities, with land-use intensity and population densities lower than the other areas. This region is a traditional sending region of internal migrants to urban, coastal, and Amazonian destinations.

Sampling

In each of the three study areas, households were selected using a stratified, three-stage cluster sampling method that included procedures to oversample both migrant-sending areas and households with out-migrants. This approach produced data representative of the rural population at risk of migration, and allowed us to sample enough migrants to investigate three different forms of mobility despite the relative rarity of particular forms of migration.[2] In the first stage, we used data on internal and international migration from the 2001 population census to estimate total propensities of out-migration from each rural parish (administrative units within cantons) in the 17 study cantons, with propensities calculated as the proportion of the population in 1996 that left by 2001. We then sampled parishes within each study area with probabilities of selection proportional to the out-migration propensity, for a total of 29 parishes (Table 1). In the second stage, census sectors were randomly selected within sample parishes, leading to a sample of 55 census sectors, constituting the ultimate area units. Majority urban parishes and census sectors located in urban areas were excluded *a priori* because of our interest in rural areas.

In the third and final stage of sampling, a two-phase approach was used to select households in the sample sectors (Bilsborrow et al. 1997). First, all resident households were listed in each sector, recording the number of members by broad age group and whether someone had left the household since January 2000 to a local, urban-internal, rural-internal, Amazonian, or international destination. Households without such a migrant were classified as nonmigrant households, and those with no migrants and no current member in the age group 15–39 were listed but excluded from the sampling frame as not at risk.[3] The result is six strata. Households with migrants to more than one destination type were classified in the stratum with the highest likelihood of being selected. To select households from these strata in each community, supervisors were trained to apply written procedures to oversample households with rare migrant types, regardless of the number of households in the community and in each of the six strata.[4]

[2]This three-stage sampling procedure provides less-precise estimates than a simple random sample of households but offers considerable cost and logistical advantages, particularly for sampling rare migrant types.

[3] This is consistent with previous studies showing migration rates of older adults in rural Ecuador are very low (Barbieri et al. 2008; Bilsborrow et al. 1987; Gray 2009a).

[4] For example, in communities with 10–19 at-risk households, up to 4 households were selected from each stratum, with a minimum total of 7 households and a maximum of 10. In a community with 10 nonmigrant households, 5 households sending a migrant to an urban destination, and 2 sending a migrant to an international destination, the sample selected would comprise the 2 sending to an international destination, 4 to an urban destination, and 4 nonmigrant households, yielding a total of 10. If instead there were 16 nonmigrant households, 1 urban-sending household, and 1 international-sending household, 4 nonmigrant households would be selected at random to go with the single urban-sending and international-sending households, and 1 additional household would be selected at random—in this case from the nonmigrant stratum—to attain a minimum of 7 households.

Listed households were linked to locally recognized communities based on maps from the Ecuadorian Census Institute and discussions with local residents. The 55 sample census sectors were found to contain 106 rural communities. Overall, 2,732 households were listed, and 869 households sampled, with the following composition (and sampling fractions) by stratum: 22 households sending migrants to the Amazon (100 %), 163 to international destinations (69 %), 56 to rural destinations (98 %), and 247 to urban destinations (72 %), along with 381 nonmigrant households (26 %). Because the sample is not self-weighting, all descriptive statistics and multivariate models described herein are based on weighted data, with weights calculated as the inverse of the probability of selection. Among sample households, 843 completed the household questionnaire, providing an overall response rate of 97 %.

Questionnaires

Fieldwork was conducted from June to November 2008. Households were interviewed by using a structured questionnaire that collected information on individual, household, and farm characteristics for each year from 2000 to 2008. An individual history was collected for each current household member ages 14 and older as well as any member who left the household at age 14 and older beginning in the year 2000. The individual history collected annual data on place of residence, economic activity, and demographic characteristics. The interviewee was almost always the household head or spouse, who served as the proxy respondent for out-migrants and other absent adult household members. Recall and proxy response errors were controlled by (1) the collection of information in annual time steps, aiding recall; (2) the modest 8-year recall period[5] (shorter than many previous studies; e.g., Massey and Zenteno 2000); (3) close relationships between the proxy respondent and the target individual (commonly parent-child); and (4) the questionnaire format that allowed comparison of characteristics over time, permitting internal crosschecks (see Glasner and van der Vaart 2009).

The household questionnaire collected a similar annual history on characteristics of the household and of each agricultural parcel since 2000, including parcel ownership, size, and primary use. Additional data were also collected regarding farm characteristics at the time of the survey and in the baseline year 2000, including perceived soil quality, road accessibility, and the stock of migrants who had left the household prior to 2000.

Finally, a community questionnaire was implemented with community leaders to obtain cross-sectional and retrospective information about community infrastructure, road connections, economic activities, and environmental characteristics. Data were also collected on population size and changes since 2000, including the out-migration of entire households for whom data are inevitably missing in retrospective origin-area surveys (Bilsborrow et al. 1984). These data indicate that the ratio of departed to resident households was small (0.06) and that the vast majority of adult migrants departed as individuals rather than entire households.[6] Because of the small number of these households and the limited information that could be collected about them, we focus on individual migration in our analysis.

[5] The most relevant previous study evaluating recall in migration surveys is Smith and Thomas (2003), who found in Malaysia that retrospective recall of the same move after a 12-year lag introduced a median date error of less than 1 year and underreported number of interdistrict moves by only 5 %.

[6] Using these data, we estimate that 75 % of local movers, 70 % of internal migrants, and 85 % of international migrants departed as individuals rather than as part of whole households.

Biophysical and Census Data

Global Positioning System (GPS) points were collected for community centers, sample dwellings, and a subset of agricultural plots. For the present analysis, we used the community points to extract values from three existing environmental data sets using geographic information system (GIS) software. First, a 30 m Digital Elevation Model (DEM) (Souris 2006) was used to extract mean land slope for a 1 km buffer centered on each community. Second, we used the global WorldClim data set, which contains interpolated historical climate information at 1 km resolution, to extract values over the period 1950–2000 of the mean annual precipitation and temperature as well as the mean week-to-week variation in these values (Hijmans et al. 2005). Finally, GIS was used to link study communities to the closest rainfall station maintained by the Ecuadorian National Institute of Meteorology and Hydrology (INAMHI). Rainfall data for the closest 20 stations were available for 1982–2008 and were used to extract the long-term median rainfall and total rainfall for each year from 2000 to 2008. Additional contextual measures were derived at the parish level from the 2001 census, including the proportion of the labor force in nonagricultural jobs, the propensities of internal and international migration, and the proportion of population in poverty (World Bank 2004).

Analysis

Person-Year Data Set

To investigate environmental influences on migration, the data described in the previous section were used to create a person-year data set on both migrants and nonmigrants. The data set contains time-varying and time-invariant variables at individual, household, community, and parish levels, with each case representing a year in the life of a person at risk for out-migration. 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 (year $t - 1$). This also reduces the possibility of endogeneity with the migration decision, and means that complete data are available for 2001–2008 (year t). Following exploratory regressions, household heads and spouses as well as individuals under age 14 and older than age 39 in year t were excluded from the analysis because of low propensities for out-migration. These exclusions are consistent with previous studies of migration in Ecuador (Barbieri et al. 2008; Bilsborrow et al. 1987; Gray 2009a). After these exclusions, the data set comprises 585 households and 1,670 persons at risk for out-migration during the study period (Table 1). Children of the head and other nonhead household members enter the data set in 2000; subsequently when they turn age 15; or, if a new household member, one year after joining the household. Individuals leave the data set when they out-migrate, turn age 40, or are censored at data collection in 2008. Return migrants reenter the data set one year after rejoining the household.

Migration is defined as a departure from the origin household for six months or longer in year t, representing at least one year in the annual history in which the individual was recorded to be away. Moves in which the first place of residence was in another country were considered to be international migration, moves within the country but outside the canton were considered to be internal migration, and moves within the canton were defined to be local mobility. Most internal moves were to urban areas, but all are classified here together as internal migration. Corresponding to these categories, the outcome variable is coded 1 to 3 for person-years in which migration occurred, and 0 when it did not.

The data set contains 898 nonmigrants (contributing 4,231 person-years) and 772 migrants who departed their origin household one or more times (contributing 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 2 who returned twice and departed a third time, the data set contains 112 local moves, 514 internal migrations, and 165 international migrations (Table 1). The total annual weighted rate of mobility for at-risk individuals is 10.1 %, including 1.5 % who moved locally, 6.0 % who migrated internally, and 2.6 % who migrated internationally. As indicated in Table 1, international out-migration is concentrated in the Chimborazo/Cañar region, with internal out-migration more common in other two study regions.

Environmental Factors

To investigate environmental influences on these migration flows, six environmental measures were derived from the data sets described earlier, including five static or slowly changing factors and one rapidly changing factor. The slowly changing factors include access to irrigation and agricultural land quality at the household level, as well as steepness of topography, mean rainfall, and rainfall seasonality at the community level. The single rapidly changing factor measures the intensity of annual rainfall shocks (Table 2).

Access to irrigation was measured as a dichotomous time-varying indicator of whether any land parcels used by the household were irrigated, which was the case for 21 % of person-years. In this context, irrigation commonly occurs though communally managed gravity-driven systems, is used for both agricultural crops and pastures, and reduces household reliance on seasonal rainfall. The measure of land quality was derived by using polychoric principal components analysis (Kolenikov and Angeles 2009) to combine 10 dichotomous and positively correlated time-varying land-quality measures collected in the household survey. The first component explained 34 % of the variance, and the results are consistent with expectations, with positive weights for reported flat topography, black soil, sandy soils, and good soil quality; and negative weights for steep topography, gravel soils, yellow/red soils, and poor soil quality (Table 8 in the appendix). The index was scaled to vary from 0 to 10, and set to 0 for landless households. This measure is time-varying and can change if the household sold or purchased land, but such transactions were rare.

Topographic slope was extracted from the DEM described earlier, and ranges from 2 % to 26 %. To capture historical climate conditions,[7] we include the historical mean annual rainfall and a measure of rainfall seasonality, which are uncorrelated ($r = .04$, $p = .69$). These were extracted from the WorldClim data set, with rainfall seasonality measured as the coefficient of variation of weekly rainfall, using weekly means across years (Hijmans et al. 2005). Mean annual rainfall ranged from 59 to 413 cm per year, and rainfall seasonality ranged from 21 % to 119 %. Time-varying weather shocks are measured as the total annual rainfall in year $t - 1$ divided by median annual rainfall for the period 1982–2008. This value was then divided by 10 so that it ranges from 3.6 to 22.7, and is referred to as the yearly rainfall deviation. As with other time-varying predictors in the model, this value was lagged one year behind the year of potential migration.[8] The 2000–2008 study period was dry relative to historical norms, so the mean value was 9.5, representing an annual rainfall at 95 % of the long-term median.

To demonstrate how these measures vary over space and time, we estimated ordinary least squares (OLS) regression models with these measures as the outcomes and varying levels of fixed effects (i.e., spatial and temporal indicators) as the predictors, with the unit of analysis the same as the unit of measurement (Table 3). This reveals that irrigation and land quality are largely uncorrelated within study areas and display considerable variation within

[7] As an alternative specification of the environmental context, indices combining various measures of topography (e.g., slope, elevation, and aspect) and climate (e.g., rainfall, temperature, and seasonality) were examined, but the measures described earlier provided as good a fit and a more parsimonious explanation.

[8] Additional temporal lags (e.g., two years) were explored but were consistently found to be nonsignificant.

communities, but vary little over time within households. Among community-level variables, approximately one-half of variation in slope and rainfall seasonality occurs within study areas, compared with only 9 % of variation in mean annual rainfall. The yearly rainfall deviation, in contrast, is largely uncorrelated within communities over time but covaries within years across the study areas. For all variables but mean annual rainfall, considerable variation exists within study areas and within study years, which we take advantage of in the multivariate analysis. Given the theoretical importance of mean annual rainfall, we retain it in the analysis and, as described in the results section, find significant effects on migration despite its limited variation.

These measures were selected to capture key elements of the environmental context of rural livelihoods in the study areas based on our field experience, previous studies, and preliminary analysis. It should be noted that this research is inherently exploratory given that many of these effects have not been previously investigated in the context of migration, and the measures used cannot be presumed to capture all aspects of the environment potentially relevant to rural households. Nonetheless, descriptive analyses indicate that our selected measures are highly correlated with key household economic activities that depend on natural capital. Table 4 presents pairwise correlations between the six environmental factors and four measures of household economic activities, revealing strong and significant correlations in the expected directions. Thus, irrigation, land quality, mean annual rainfall, and the yearly rainfall deviation are associated with higher farm incomes and can thus be interpreted as positive environmental characteristics. Rainfall seasonality is associated with specialization in agriculture, reflecting the agricultural difficulties associated with year-round rainfall in the tropics, such as agricultural pests and waterlogged soils. Steep slopes are associated with lower agricultural production, but this is partially compensated by higher animal production. Relationships with income from agricultural wage labor are primarily negative, indicating a specialization in own-farm production where environmental conditions are favorable.

Control Variables

To account for the array of other factors that has been shown to influence migration, the analysis also incorporates 23 control variables at individual, household, community, and parish levels. Selection of the control variables was guided by previous studies of the determinants of migration (e.g., Bilsborrow et al. 1987; Massey and Espinosa 1997) and by our view of migration as a life course transition (Johnson and DaVanzo 1998), a household diversification strategy (Stark and Bloom 1985), and a coping strategy for environmental shocks (Hugo 1996). In particular, we build on the rural livelihoods framework (Ellis 2000), which views migration as a household diversification strategy that reflects the household's socioenvironmental context as well as access to human, social, natural, and physical capitals. Consistent with these frameworks, we include measures of demographic characteristics, wealth, infrastructure, and migration networks as control variables.

Demographic controls include gender, age, relationship to the household head, marital status, and level of completed education at the individual level, as well as gender of the head and age composition at the household level. Wealth is measured by homeownership and the total area of agricultural land. Accessibility is measured by distance from the dwelling to the nearest school (representing access to local services) and distance to a paved road. To capture the economic context, three predictors are included at the parish level: whether the parish contains the canton capital (i.e., an urban area), the proportion of parish employment that was nonagricultural, and the proportion of the parish population in poverty. Migration networks are captured by whether the individual had previously lived outside the canton; the number of previous local, internal, international migrants from the household; and parish-level propensities of internal and international out-migration from 1996 to 2001.

The Statistical Model

The data were analyzed using a multinomial, discrete-time event history model, which is appropriate to examine exposure 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 other than the reference category (nonmigrant)—that is, for out-migration to local, internal, and international destinations. To account for baseline differences in migration across time and space, indicators are included for the year and study area (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

$$\log\left(\frac{\pi_{rit}}{\pi_{sit}}\right)=\alpha_{rt}+\alpha_{ra}+\boldsymbol{\beta}_r\mathbf{X}_{it-1},$$

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_{ra} is the baseline hazard of mobility to destination type *r* in study area *a*; $\mathbf{X}_{it-1}$ 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. We present the parameters of this model later in exponentiated form (e^{β}). This value, known as the odds ratio, 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 study area accounts for national-scale time-varying factors and for time-invariant factors at the scale of the study area as long as the effects are linear. Thus, the coefficients can be interpreted as comparing two individuals in the same study area who are exposed to the same changing national context over time. 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).

We additionally extend this model in two ways. First, we test for nonlinear effects of the environmental variables by decomposing the five continuous variables into quartiles and estimating the effects of these indicators. This allows us to address the hypothesis that human-environment systems such as this one are characterized by thresholds and nonlinearities (Liu et al. 2007). Second, we examine the heterogeneity of the environmental effects across gender and farm size (a key indicator of wealth) by estimating the model separately (1) for men and women and (2) for households with less than 1 hectare (ha) of farmland versus those with 1 ha or more.[9] This allows us to test the hypothesis that potentially vulnerable populations, such as women and the land-poor, will be more strongly affected by the environment (Fussell et al. 2010).

Results

The results of the event history analysis are presented in Tables 5–7, including odds ratios, significance tests, and Wald tests of joint significance across equations and across predictors. Table 5 presents the main model; Tables 6 and 7, respectively, present environmental effects from the nonlinear specification and by subpopulation. We first

[9] Men and women contribute 4,024 and 3,265 person-years, respectively, to the data set. Similarly, land-poor and nonpoor households contribute 2,992 and 4,297 person-years, respectively.

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discuss the overall importance of the environmental variables before considering each migration stream separately, commenting on both the main results and alternate specifications. We then conclude with a brief discussion of the results for the control variables. Throughout, coefficients with $p < .05$ are considered to be statistically significant.

Overall, the environmental effects are highly significant. In the primary specification, nine of eighteen coefficients are statistically significant, and five of six predictors are jointly significant across all three migration streams, with mean annual rainfall only marginally significant (Table 4, far-right column). When the six effects are tested jointly for each migration stream, they are highly significant for all three streams (Table 5, bottom panel); and when all 18 coefficients are tested jointly, their overall significance is similar to that of migration networks, which are widely recognized to have important influences on migration (e.g., Massey and Espinosa 1997). When the effects of the environmental variables are allowed to be nonlinear, their joint significance increases considerably, both overall and for each type of migration (Table 6, bottom panel). Comparing across subpopulations, environmental effects are stronger for men and land-poor households relative to women and nonpoor households (Table 7, far-right column).

For local moves, three environmental factors had large and significant effects in the primary specification: land quality, mean rainfall seasonality, and yearly rainfall deviation (Table 5). The odds of local movements increased 19 % with each unit of the land-quality index, increased 3 % with each unit of mean rainfall seasonality, and decreased 10 % with each unit of yearly rainfall deviation. Interpreted in terms of standard deviations of the predictors (SD), the odds of local moves increased 59 % with 1 SD of land quality, increased 87 % with 1 SD of rainfall seasonality, and decreased 29 % with 1 SD of rainfall deviation. When the environmental effects are allowed to be nonlinear (Table 6), it becomes clear that individuals exposed to low land quality, low rainfall seasonality, and low rainfall deviation (i.e., drought) are particularly unlikely to move locally. Estimating the models separately by gender and farm size (Table 7) additionally reveals that the land-quality effect is strongest for men and the land-poor, and that the seasonality and rainfall deviation effects are stronger for women and the nonpoor.

Among the three migration streams, environmental factors were least important for internal migration. In the primary specification (Table 5), only the yearly rainfall deviation has a significant effect, increasing the odds of migration by 8 % per unit or by 22 % per SD. The nonlinear specification (Table 6) indicates that internal migration peaks when the rainfall deviation was in the third quartile (i.e., moderately positive). Estimating the model separately by gender and farm size (Table 7) shows that the rainfall deviation effect is most important for men and the land-poor. The nonlinear specification (Table 6) also reveals a nonlinear effect of rainfall seasonality in which internal migration peaks at intermediate levels of seasonality.

International migration, in contrast, was the most strongly influenced by environmental factors. The odds of international migration increased by 15 % with each unit of land quality, and decreased by 31 %, 7 %, 16 %, and 22%, respectively, with each unit of topographic slope, mean annual rainfall, and yearly rainfall deviation, as well as with access to irrigation. Expressed in terms of standard deviations of the continuous predictors, the odds of emigration decreased by 45% per SD of slope, by 60 % per SD of rainfall deviation, and by 138 % per SD of mean annual rainfall; the odds of emigration increased by 49 % per SD of land quality. Allowing the effects to be nonlinear shows that individuals exposed to high land quality, low topographic slope, and low rainfall deviation are particularly likely to make international moves (Table 6). Allowing the effects to differ by gender and farm size additionally reveals that the topographic slope effect is particularly important for men, land quality is most important for women, and irrigation and rainfall deviation are most important for the land-poor.

Finally, the effects of the control variables are overall highly significant and are consistent with previous studies and theoretical expectations. Movements across all three streams increased with education, increased with access to destination-specific migrant networks, and peaked at ages in the mid-20s. Among other notable effects, local movers were disproportionately female, married, and from land-poor households; internal migrants left disproportionately from female-headed households and from poor parishes; and international migrants were disproportionately male and from nonpoor households. These salient differences highlight the distinctiveness of the three types of migration.

Discussion

Taken together, the results confirm the importance of both "fast" and "slow" environmental factors for migration in our study areas. The complexity and nonlinearity of these effects also make clear that no single theory or narrative can easily explain all environmental influences on migration, including the conventional narrative that adverse conditions will increase migration. However, the results also point toward the potential utility of considering environmental characteristics to be part of at least two separate domains: climate variability and land suitability.

Among the six environmental measures, four capture fast and slow aspects of exposure to climate variability, including access to irrigation, historical climate norms, and time-varying weather shocks. For these variables, the view that climate variability is a form of risk and the prediction that migration will increase with adverse conditions holds in almost all cases, although the pattern of effects across migration streams is complex. Thus, international migration decreased with access to irrigation and historical rainfall, both of which indicate exposure to lower climatic risk, and local mobility increased with the seasonality of rainfall, indicating higher climatic risk. Both local mobility and international migration also increased following exposure to drought. Only for the case of internal migration and rainfall shocks is the sign reversed, with these flows increasing following years of normal-to-high rainfall. Given that internal migrants originate disproportionately from poor areas, this response may indicate that these households do not typically have the resources to invest in internal migration and that positive rainfall shocks enable them to escape from a poverty trap (Barrett 2008). Overall, though, the results support the idea that increased climate variability will result in increased migration.

Two additional environmental factors—the land-quality index and topographic slope—capture land suitability. In both of these cases, migration increased with positive environmental conditions, contrary to the conventional narrative. Specifically, local mobility and international migration increased with land quality (a positive characteristic), and international migration decreased with topographic slope (a negative characteristic). Thus, for the case of land suitability, it appears that natural capital is being converted into investment in migration. Likely mechanisms for this effect are that (1) the additional production gained from land quality is being invested in migration, and (2) land is serving as collateral for loans, allowing investments in costly forms of migration. The lack of significant effects on internal migration may reflect the fact that it is a less-desirable option for migration. The effects on local and international migration are generally consistent with at least two previous studies (Gray 2010, 2011), reinforcing the importance of investigating slowly changing and nonclimatic dimensions of the environment in migration studies.

The results also reveal across considerable heterogeneity in the effects across gender and farm size. Overall, environmental effects were more important for men, a result that is consistent with their stronger direct engagement in agricultural activities in this setting.[10] Nonetheless, the positive effect of rainfall seasonality on local mobility can be entirely accounted for by women's moves (Table 6). This may reflect that (1) seasonality is associated with household specialization in agriculture versus animal production, and (2) in rural Ecuador, women's labor is particularly important in animal production (Gray 2009b), potentially allowing women more freedom to move under seasonal climates. Overall, the environmental effects were also much more important for land-poor households, particularly for local and internal moves. This is consistent with the conventional narrative that the poor are more likely to be displaced by environmental factors, and likely reflects stronger general constraints on livelihood decision-making by poor households.

Conclusions

This article presents a robust, broadly applicable methodology for investigating environmental influences on human migration and an application of the methods in rural Ecuador. Relative to previous studies, we investigate a large number of environmental factors, including static and slowly changing characteristics that have received little attention from previous studies, and additionally investigate three distinct migration streams. While preliminary in many respects, the results nonetheless have important implications for migration-environment theory, research methods, and development practice.

Regarding theory, the results reveal complex and nonlinear effects, many of which are not consistent with the conventional narrative in which migration universally increases with environmental adversity. In multiple cases, positive environmental conditions—such as high land quality and positive rainfall shocks—instead appear to facilitate migration, including local, internal, and international population movements. This finding is consistent with previous quantitative studies (see the section Previous Studies), which have commonly found environmental effects on migration that are of opposite sign or weaker than expected. Taken together with those studies, the results presented here point toward an alternative paradigm of environmentally induced migration in which rural households display considerable agency in responding to environmental conditions, leading to complex effects that differ across environmental domains, migration streams, and subpopulations.

With respect to research methods, we build on previous studies of migration to develop a retrospective, multilevel approach that we argue is robust and generally applicable in the developing world. Key elements include (1) the use of a multistage sampling strategy to include of a large and diverse population of migrants; (2) a questionnaire design that facilitates collection of retrospective annual data on households and individuals; (3) the use of GIS to link communities to environmental data sets; and (4) the use of multivariate event history models incorporating a large set of controls. This approach enables cost-effective data collection from a diverse set of migrant-sending households across a wide range of environmental conditions, which in turn makes it possible to draw plausible conclusions about environmental influences on migration while taking into account a wide variety of non-environmental factors. This approach is particularly relevant when high-quality panel data are not available, which is the case for most developing countries.

Beyond these developments, future methodological advances will also be necessary to conclusively address these issues. Among potential data sources and measures on climate

[10] For example, 63 % of adult men in the study areas worked in own-farm agriculture and 43 % worked in off-farm agriculture in 2008 versus 47 % and 9 % of women, respectively.

variability and land suitability, only a handful are investigated here. Future studies should investigate additional data sources such as remotely sensed imagery and soil samples, as well as additional measures, such as temperature and vegetation greenness (see Gray 2011; Leyk et al. 2012), with the goal of identifying a subset of measures that are consistently important across settings. Regarding survey data, in addition to specialized migration surveys such as this one, productive use can also be made of existing general-purpose panel surveys such as described by Halliday (2006), Massey et al. (2010), and Gray and Mueller (2012a, b).

Finally, this study also has implications for ongoing discussions about future population displacements under global climate change. Both climate models and observed changes to date indicate that global climate change is likely to result in changes to both baseline conditions and the frequency and severity of extreme events (IPCC 2007). Our study indicates that both types of climate changes (fast and slow) are likely to influence human migration, although not necessarily in the expected directions; and in fact, it is possible that more potential migrants will be trapped in place than displaced by changing climates (Black et al. 2011). For this reason, climate assistance policies that focus on identifying and assisting "climate refugees" (e.g., Biermann and Boas 2010) are likely to be unsuccessful, particularly given that migration is nearly always multicausal. Instead, we support climate assistance policies that focus on real-time monitoring of environmental conditions in vulnerable areas, such as through remote sensing and rapid population surveys (Brown 2008). This allows more effective targeting of affected populations, most of whom are likely to remain in place or to move only locally.

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Appendix

Table 8

Results of the polychoric principal components analysis of land quality

Category	Indicator	Mean	Value	Coefficient
Topography	Flat land	0.21	0	−0.12
			1	0.44
	Hilly land	0.35	0	−0.09
			1	0.17
	Steep land	0.54	0	0.33
			1	−0.29
Soil type	Black soil	0.50	0	−0.32
			1	0.32
	Sandy soil	0.10	0	−0.03
			1	0.22
	Gravel soil	0.28	0	0.20
			1	−0.51
	Yellow/red soil	0.21	0	0.06
			1	−0.23
Soil quality	Good soil	0.47	0	−0.30
			1	0.34
	Regular soil	0.52	0	0.19
			1	−0.17
	Poor soil	0.09	0	0.06
			1	−0.61

Note: Indicators are based on household ownership of one or more parcels with the characteristic in year $t - 1$, and are thus are not mutually exclusive for households owning multiple parcels.

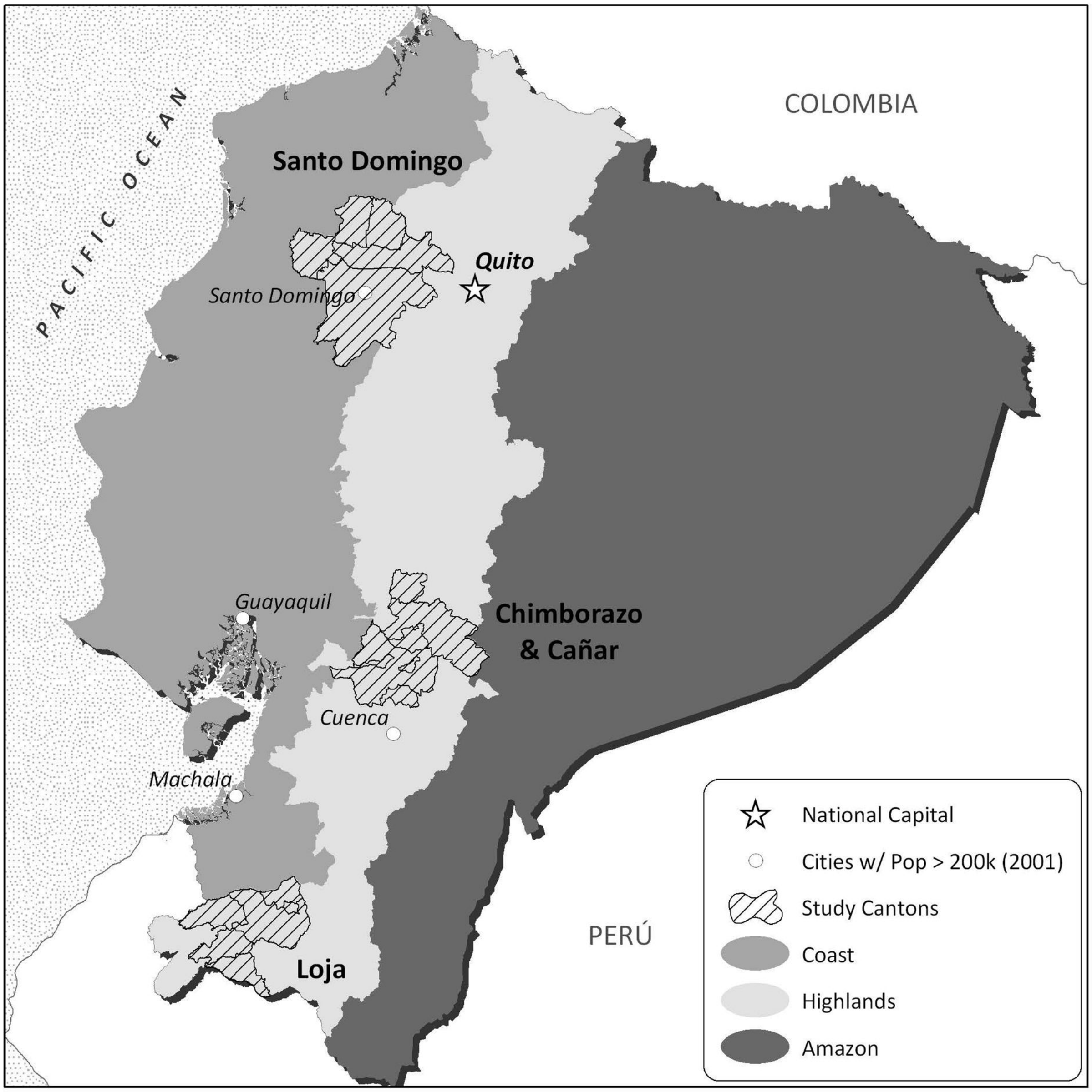

Fig. 1.
Map of Ecuador showing the three study areas

Table 1

Characteristics of the person-year analytical data set

Characteristic	Full Sample	Santo Domingo	Chimborazo/Cañar	Loja
Sample Size				
Cantons	17	5	6	6
Parishes	29	5	14	10
Sectors	55	15	21	19
Communities	106	27	35	44
Households	585	134	215	236
Individuals	1,670	398	577	695
Person-years	7,289	1,624	2,452	3,213
Number of Moves				
Local moves	112	52	22	38
Internal moves	514	142	111	261
International moves	165	17	115	33
Annual Rate of Migration (%)				
Local moves	1.5	2.7	0.7	1.7
Internal moves	6.0	7.3	4.1	7.9
International moves	2.6	0.7	4.9	0.6

Note: Rates of migration are weighted annual rates for at-risk individuals; see the text.

Table 2

Definitions and mean person-year values of the independent variables

Predictor	Unit	Level	Time-Varying	Mean	SD
Environmental Factors					
Irrigation on farm	1/0	HH	Yes	0.21	0.40
Land quality index	0–10	HH	Yes	3.46	3.18
Topographic slope	%	Com.	No	13.80	6.50
Mean annual rainfall	dm/year	Com.	No	15.10	8.70
Mean rainfall seasonality	%	Com.	No	70.90	26.20
Yearly rainfall deviation	%/10	Com.	Yes	9.55	2.75
Demographic Characteristics					
Female	1/0	Indiv.	No	0.46	0.50
Age 14–16	1/0	Indiv.	Yes	0.32	0.47
Age 17–19	1/0	Indiv.	Yes	0.24	0.42
Age 20–24	1/0	Indiv.	Ref	0.22	0.42
Age 25–29	1/0	Indiv.	Yes	0.11	0.32
Age 30–39	1/0	Indiv.	Yes	0.10	0.31
Child of head	1/0	Indiv.	Yes	0.86	0.35
Married or partnered	1/0	Indiv.	Yes	0.12	0.32
Less than primary education	1/0	Indiv.	Ref	0.14	0.34
Complete primary education	1/0	Indiv.	Yes	0.77	0.42
Secondary education or more	1/0	Indiv.	Yes	0.09	0.29
Female head	1/0	HH	Yes	0.22	0.41
HH members aged <15	#	HH	Yes	2.01	1.90
HH members aged 15–39	#	HH	Yes	2.79	1.23
HH members aged 40–59	#	HH	Yes	1.11	0.81
HH members aged 60+	#	HH	Yes	0.46	0.73
Wealth and Infrastructure					
Owns home	1/0	HH	Yes	0.88	0.32
Small farm (<1 ha)	1/0	HH	Ref	0.46	0.50
Medium farm (1–3.9 ha)	1/0	HH	Yes	0.26	0.44
Large farm (4–14.9 ha)	1/0	HH	Yes	0.16	0.37

Predictor	Unit	Level	Time-Varying	Mean	SD
Very large farm (≥15 ha)	1/0	HH	Yes	0.12	0.33
Distance to school	km	HH	No	1.07	1.06
Distance to paved road	km	HH	No	1.09	2.28
Parish with canton capital	1/0	Parish	No	0.42	0.49
% Nonfarm employment	%	Parish	No	24.20	8.60
% In poverty	%	Parish	No	69.40	11.50
Migration Networks					
Personal migration experience	1/0	Indiv.	Yes	0.18	0.38
HH local movers	#	HH	Yes	0.83	1.44
HH internal migrants	#	HH	Yes	1.05	1.68
HH international migrants	#	HH	Yes	0.41	0.89
Parish internal migration propensity	%	Parish	No	8.44	4.85
Parish international migration propensity	%	Parish	No	6.02	3.65

Notes: 1/0 indicates a dichotomous variable;

# indicates a count variable.

Indiv. = Individual, HH = Household, Com. = Community, Ref. = Reference, dm = decimeter, ha = hectare.

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Table 3

OLS fixed-effects analysis of spatial and temporal variation in the environmental measures

	R^2 by Level of Fixed Effects					
Environmental Variable	**Study Area**	**Community**	**Household**	**Year**	**Unit of Analysis**	**Sample Size**
Irrigation on Farm	.07	.28	.97	.00	Household-year	7,542
Land Quality Index	.04	.35	.94	.00	Household-year	7,542
Topographic Slope	.49	—	—	—	Community	106
Mean Annual Rainfall	.91	—	—	—	Community	106
Mean Rainfall Seasonality	.53	—	—	—	Community	106
Yearly Rainfall Deviation	.00	.16	—	.43	Community-year	954

Notes: R^2 values from OLS models containing only fixed effects (i.e., spatial and temporal indicators) at the indicated levels. The unit of analysis is the same as the unit of measurement.

Table 4

Pairwise correlations between the environmental variables and measures of productive activity

Environmental Variable	Area Planted in Annuals	Income From Agricultural Production	Income From Animal Production	Income From Agricultural Wage Labor
Irrigation on Farm	−0.01	0.07	0.26***	−0.19***
Land Quality Index	−0.02	0.21***	0.36***	−0.14**
Topographic Slope	0.02	−0.15***	0.08*	−0.45***
Mean Annual Rainfall	0.17***	0.30***	−0.07†	0.41***
Mean Rainfall Seasonality	0.40***	0.21***	−0.20***	−0.12*
Yearly Rainfall Deviation	0.31***	0.09*	0.02	−0.21***
Number of Households	403	510	709	428

Notes: Values for productive activities are for participating households only and have been transformed by ln(x + 1). Area planted in annuals is the total area planted in annual crops (ha). Income from agricultural production, animal production, and agricultural wage labor are the estimated total income from these sources, including subsistence production of agricultural and animal products (USD).

† $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$

Table 5

Results from the multinomial event history model of migration to local, internal, and international destinations (odds ratios and significance tests)

Predictor	Local	Internal	International	Joint Test
Environmental Factors				
Irrigation on farm	1.86	1.31	0.69 *	***
Land quality index	1.19 ***	1.00	1.15 ***	***
Topographic slope	1.01	1.00	0.93 **	*
Mean annual rainfall	1.01	0.99	0.84 *	†
Mean rainfall seasonality	1.03 **	1.00	1.00	**
Yearly rainfall deviation	0.90 ***	1.08 ***	0.78 *	***
Demographic Characteristics				
Female	3.36 ***	1.32 †	0.28 ***	***
Age 14–16	0.24 ***	0.46 ***	0.16 ***	***
Age 17–19	1.29	0.72 †	0.54 †	*
Age 25–29	1.29	0.54 †	1.83 *	*
Age 30–39	0.72	0.73	0.21 *	**
Child of head	2.02	1.92 **	0.41 †	*
Married or partnered	6.29 **	1.50 †	1.61 †	*
Complete primary education	1.62 *	1.38 *	2.14 *	*
Secondary education or more	2.54 **	1.94 **	2.75 *	***
Female HH head	1.22	0.63 **	0.65	*
HH members aged < 15	1.04	1.00	0.86	
HH members aged 15–39	1.04	0.99	1.01	
HH members aged 40–59	0.55 ***	1.32 *	0.72 †	***
HH members aged 60+	0.62 *	0.79	0.53 **	***
Wealth and Infrastructure				
Owns home	0.23 ***	1.18	6.31 **	***
Medium farm	0.50 *	0.78	0.69	
Large farm	0.19 ***	0.68	0.36 †	***
Very large farm	0.21 ***	0.42 ***	4.26 *	***
Distance to school	0.77 †	1.12 **	1.08	**
Distance to paved road	1.13 **	0.92 ***	1.06	***
Parish with canton capital	1.35	1.25	0.45 *	†
% Nonfarm employment	0.97 *	0.99	0.97 *	**
% In poverty	1.04 †	1.05 **	1.01	**
Migration Networks				

Predictor	Local	Internal	International	Joint Test
Personal migration experience	0.45 *	2.13 **	0.84	**
HH local movers	1.23 *	0.79 **	0.84 †	***
HH internal migrants	0.79 **	1.19 ***	0.76 *	***
HH international migrants	0.68	0.71 **	1.06	***
Parish internal migration propensity	1.09 †	1.08 **	1.08 *	***
Parish international migration propensity	0.82 *	0.95	1.15 *	**
Regional Indicators				
Santo Domingo	2.21	1.59	2.11	
Loja	0.25 *	0.62 †	0.24 **	***
Joint Tests (chi-square statistics)				
Environmental factors	27.5 ***	17.5 **	65.6 ***	279.4 ***
Demographic characteristics	305.8 ***	165.9 ***	181.8 ***	2,718.3 ***
Wealth and infrastructure	62.5 ***	70.2 ***	33.0 ***	60,667.2 ***
Migration networks	33.4 ***	80.1 ***	35.9 ***	297.3 ***
Regional indicators	9.2 **	6.2 *	27.4 ***	70.4 ***
Year indicators	72.4 ***	20.5 **	95.6 ***	328.7 ***

Notes: Reference categories are male, age 20–24, less than primary education, and small farm. The model also includes indicators for the year (not shown). Joint tests are Wald tests of the joint significance of selected groups of coefficients as indicated.

† $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$

Table 6

Results from the multinomial model with nonlinear specifications of the environmental variables (odds ratios and significance tests)

Predictor	Local	Internal	International	Joint Test
Irrigation on Farm	1.88	1.30	0.79	*
Land Quality Index				
2nd quartile	2.19	0.80	0.93	—
3rd quartile	4.72 **	1.05	1.40	—
4th quartile	4.08 ***	0.94	3.04 ***	—
Joint test	17.8 ***	1.3	25.7 ***	***
Topographic Slope				
2nd quartile	3.22 *	1.23	0.38 ***	—
3rd quartile	2.39	1.57 *	0.48 **	—
4th quartile	3.36 †	1.28	0.26 ***	—
Joint test	4.5	7.2 †	17.6 ***	***
Mean Annual Rainfall				
2nd quartile	1.65	0.55	1.93 †	—
3rd quartile	1.90	0.60	1.10	—
4th quartile	1.07	0.99	0.11	—
Joint test	1.8	5.8	4.2	***
Mean Rainfall Seasonality				
2nd quartile	3.12 †	1.31	1.19	—
3rd quartile	4.69 *	1.91 **	1.56	—
4th quartile	4.97 *	1.69 *	4.84	—
Joint test	6.2	10.0 *	4.7	***
Yearly Rainfall Deviation				
2nd quartile	0.26 **	1.16	0.59	—
3rd quartile	0.29 ***	1.64 *	0.46 *	—
4th quartile	0.26 **	1.60	0.33 *	—
Joint test	17.4 ***	6.8 †	8.7 *	***
Joint Test of All Factors	70.8 ***	70.8 ***	91.5 ***	3,015.7 ***

Notes: For predictors categorized into quartiles, the first quartile serves as the reference category. The model also includes control variables and indicators for the year and region (not shown). Joint tests are Wald tests of the joint significance of selected groups of coefficients as indicated.

† $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$

Table 7

Results for the mutinomial model for four subpopulations (odds ratios and significance tests)

Predictor	Local	Internal	International	Joint Test
Subpopulation: Men Only				
Irrigation on farm	0.85	1.39	0.73	
Land quality index	1.24**	0.99	1.08†	**
Topographic slope	1.12†	0.97	0.91**	**
Mean annual rainfall	0.89	1.03	0.85*	†
Mean rainfall seasonality	1.01	1.01	0.99	
Yearly rainfall deviation	0.96	1.13**	0.74*	*
Joint test	17.1**	10.3	42.9***	197.5***
Subpopulation: Women Only				
Irrigation on farm	3.21*	1.22	0.50	*
Land quality index	1.10*	1.02	1.35**	*
Topographic slope	1.01	1.02	0.94	
Mean annual rainfall	1.00	0.96	0.79**	*
Mean rainfall seasonality	1.04***	1.00	1.00	***
Yearly rainfall deviation	0.87*	1.06	0.81**	**
Joint test	26.4***	6.0	32.6***	102.8***
Subpopulation: Small Farm Only				
Irrigation on farm	1.01	1.10	0.11**	†
Land quality index	1.29***	1.02	1.19*	***
Topographic slope	1.07	1.01	0.92	
Mean annual rainfall	0.98	0.98	0.81	
Mean rainfall seasonality	1.06***	1.01	1.00	***
Yearly rainfall deviation	0.86†	1.13**	0.62***	***
Joint test	55.0***	23.8***	34.3***	279.8***
Subpopulation: Medium, Large, and Very Large Farm Only				
Irrigation on farm	2.79*	1.17	0.85	†
Land quality index	0.90	1.05	1.20**	*
Topographic slope	0.94	1.01	0.92	
Mean annual rainfall	0.99	1.05	0.82*	†
Mean rainfall seasonality	1.00	0.99	0.99	
Yearly rainfall deviation	0.90	1.02	0.85*	*
Joint test	10.8†	7.2	31.3***	130.8***

Notes: Models also include control variables and indicators for the year and region (not shown). Joint tests are Wald tests of the joint significance of selected groups of coefficients as indicated.

† $p < .10$;

*$p < .05$;

**$p < .01$;

***$p < .001$