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Consequences of Out-Migration for Land Use in Rural Ecuador

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Abstract

In rural Ecuador and elsewhere in Latin America, the departure of migrants and the receipt of migrant remittances have led to declining rural populations and increasing cash incomes. It is commonly assumed that these processes will lead to agricultural abandonment and the regrowth of native vegetation, thus undermining traditional livelihoods and providing a boon for biodiversity conservation. However, an increasing number of household-level studies have found mixed and complex effects of out-migration and remittances on agriculture. We advance this literature by using household survey data and satellite imagery from three study areas in rural Ecuador to investigate the effects of migration and remittances on agricultural land use. Multivariate methods are used to disaggregate the effects of migration and remittances, to account for other influences on land use and to correct for the potential endogeneity of migration and remittances. Contrary to common assumptions but consistent with previous studies, we find that migrant departure has a positive effect on agricultural activities that is offset by migrant remittances. These results suggest that rural out-migration alone is not likely to lead to a forest transition in the study areas.

Keywords

land use; agriculture; forest transition; migration; remittances

1. Introduction

Rural out-migration, or the departure of people from rural areas, is a key transformative process in agricultural regions of the developing world. In Latin America, out-migration and fertility decline have led to low or negative population growth rates in many rural areas, some of which have also received substantial remittances from international migrants (Carr et al., 2009; UN 2010). Out-migration thus has important implications for both the incomes and labor resources of agricultural households and communities, but the net effect of these processes on livelihoods and land use change are unclear. Many authors have argued that out-migration and remittances undermine traditional agricultural activities and lead to land abandonment and the regrowth of native vegetation (Aide and Grau 2004; Hecht 2010). These changes could potentially contribute to "forest transitions" that protect biodiversity in these areas (Rudel et al., 2005).

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However, there are good theoretical and empirical reasons to be skeptical of this argument. From a theoretical perspective, this view does not account for the fact that many rural households allocate their labor to other economic activities beyond agriculture (Ellis 2000), and that remittances can be invested in labor-saving agricultural inputs (Rozelle et al., 1999). From an empirical perspective, several recent studies using econometric and spatial approaches, as well as traditional ethnographic approaches, have found mixed or weak effects of migration and remittances on agriculture in origin areas. Complementing the in-depth but small-scale understanding of processes that come from ethnographic studies (e.g., Jokisch 2002), econometric approaches offer the opportunity to clearly distinguish between the effects of migration and remittances while at the same time explicitly accounting for the selectivity of migration (Rozelle et al., 1999). Studies using spatial and remote-sensing methods provide the ability to view the landscape as a whole, and thus to derive conclusions about the overall environmental impacts of migration (Müller et al., 2009). Up to now very few studies have combined these approaches in a single study area (but see Rudel et al., 2002).

We investigate these issues in the context of rural Ecuador, a highly biodiverse country that is an important origin area of international migrants. We use a novel approach that combines a household-level econometric analysis of land use with a community-level remote-sensing analysis of vegetation change. These analyses draw on data from an original household and community survey conducted in three study areas in rural Ecuador, as well as from a linked spatial analysis of satellite imagery and other data sources. In the household-level analysis, we use data from 440 households to model the effects of migration and remittances on agricultural activities while accounting for other influences as well as the potential for endogeneity. In the community-level analysis we use data from 80 communities to model the effects of outmigration on changes in vegetation greenness while accounting for other social and biophysical characteristics of communities. Together the two analyses provide insights into both the economic and ecological effects of migration, with results that challenge common assumptions about these processes. This work considerably expands our previous study on this topic (Gray 2009a), and complements recent work by ourselves and others on other aspects of the migrationenvironment nexus (Carr 2008; Gray 2009b; Massey et al. 2010; Fussell et al. 2010; Dillon et al. 2011; Gray and Mueller 2012; López-Carr 2012; Gray and Bilsborrow 2013).

2. Literature Review

2.1. Theoretical perspectives

In the rural developing world, households commonly draw on a variety of assets to invest in a diverse portfolio of livelihood activities, including subsistence agriculture, cash cropping, wage labor and migration (Ellis 2000). Migration is often part of a household strategy to diversify into a new income source in the form of migrant remittances (Stark and Bloom 1985), though participation in migration is often constrained by lack of access to financial capital and migrant networks (Massey and Espinosa 1997). The participation of individuals in migration and agricultural activities is also highly selective, and in the case of rural Latin America, men are often more likely to both participate in agricultural labor and to become international migrants (Katz 2003). In this context, the departure of a household member reduces household labor supply, which will reduce labor inputs to agriculture and other activities unless there is a compensating increase in effort by the remaining household members. If the migrant sends remittances, these could be used directly for household consumption, substituting for agricultural production, and/or for hiring labor to compensate for the absent household member. Remittances could also be invested in the intensification of land use and the purchase of agricultural inputs such as fertilizer or pesticides. The

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outcome in particular cases will depend on the risks and opportunities represented by various livelihood strategies, among other factors.

Despite these many options available to rural households, many authors in environmental studies and development studies have argued that out-migration and remittances will lead to agricultural decline and disintensification (e.g., a reduction in agricultural intensity). In environmental studies, this idea is part of "forest transition theory", in which rural out-migration is viewed as a key mechanism leading to land abandonment and the subsequent regrowth of native vegetation (Rudel et al., 2005). In the development studies literature, out-migration and remittances are often seen to undermine traditional livelihood activities, such as subsistence agriculture, as part of a "migrant syndrome" (Reichert 1981; Jones 2009). These perspectives do not account for the diversified nature of rural livelihoods, the significant adaptability of rural households in the face of demographic and economic change (Bilsborrow 1987; Netting 1993), and the numerous alternative pathways of adaptation of described above. Both the forest transition and migrant syndrome frameworks have been widely criticized as overly simplistic (Taylor et al., 1996; Perz 2007; García-Barrios et al., 2009; Robson and Berkes 2011), but the view that agricultural decline and environmental restoration follow out-migration remains common (Aide and Grau 2004; Kauppi et al., 2006; Meyerson et al., 2007; Hecht 2010).

2.2. Previous empirical studies

Previous studies of the consequences of migration for agriculture have employed qualitative, econometric and spatial methods, and have variously found evidence of positive, negative and zero net effects.

Numerous qualitative and small-scale studies have approached this issue through ethnography and intensive observation of a small number of communities. Among these studies, several have found evidence of disintensification of agriculture (Zimmerer 1993; Preston et al 1997; Schmook and Radel 2008; Jones 2009; Qin 2010; Robson and Berkes 2011), while others have observed small or zero net effects (Black 1993; Klooster 2003) or intensification through the investment of remittances (McKay 2005; Taylor et al., 2006; De Haas 2006). Three studies have examined Ecuador specifically. Preston and Taveras (1980) investigated agricultural change following outmigration in six rural communities in the Ecuadorian highlands, and found that in most cases land belonging to internal migrants was rented out or sold for further use instead of abandoned. Jokisch (2002) later examined two communities in the central Ecuadorian highlands, and found that, despite rapid international out-migration and large remittance inflows, smallholder agriculture continued mostly unchanged. Finally, Rudel et al., (2002) similarly observed significant out-migration from a rural community in the Ecuadorian Amazon without significant land use change.

A number of econometric studies have also investigated this issue, typically using cross-sectional or longitudinal survey data in instrumental-variable regression models. Migration and remittances are potentially *endogenous* because they are not randomly assigned but instead reflect selection on both observed and unobserved characteristics. This issue complicates simple comparisons of migrant-sending and non-migrant-sending households because any differences between these households may be due to either the drivers or consequences of migration. The instrumental variable approach directly addresses this concern, but it requires the use of one or more variables, known as *instruments*, that affect migration and/or remittances but do not affect the final outcome of interest (Wooldridge 2001). Rozelle et al., (1999) pioneered the use of this approach to study migration in a study of smallholder agriculture in China, drawing on migrant networks and remittance norms as instruments. This study revealed that out-migration and remittances had countervailing negative and positive effects, respectively, on maize yields.

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Several other studies have since used similar approaches (e.g., Mendola 2008; Miluka et al., 2010; Atamanov and Van den Berg 2012), including four from Latin America. Pfeiffer and Taylor (2007) found that participation in cash cropping in Mexico declined with the departure of international migrants, particularly for male migrants, but that growing staple crops was unchanged. Damon (2010) similarly showed that area in cash crops in El Salvador declined following international migration, but the area in staple crops unexpectedly increased. In contrast, Vanwey et al., (2012) found in Amazonian Brazil that cash crops increased with remittances and that migrant departure had no effect, though this study did not account for endogeneity. Finally, in a study from Ecuador, Vasco (2011) showed that fertilizer use and cattle ownership unexpectedly increased with migrant departure while remittances had no effect. Thus, consistent with qualitative studies, econometric studies find mixed and diverse effects from migration and remittances on household agricultural activities.

Finally, a small number of studies have used spatial methods, including geographic information systems and remote sensing, to evaluate the consequences of migration for agriculture. In an early study that foreshadowed this approach, Rudel et al., (2000) linked data on reforestation from 650 field plots in Puerto Rico to census data on demographic change and other factors, revealing that reforestation increased as the local population declined due to out-migration. This approach has since been extended to include satellite data sources by multiple studies from Europe (Gellrich and Zimmermann 2007; Sikor et al., 2009; Müller et al., 2009; Bauman et al., 2011) and two studies from Latin America. López et al., (2006) found a positive correlation at the municipal scale between out-migration and the expansion of shrublands in rural Mexico, and Hecht and Saachti (2007) similarly found a positive correlation between the receipt of remittances and forest cover at the provincial scale in El Salvador. However, neither of these two studies controlled for the effects of other factors on land use change, so the results may not be robust to multivariate controls.

Our study draws upon the econometric and spatial approaches described above to investigate the consequences of out-migration and remittances flows for agricultural land use in rural Ecuador. A special aspect of this study is our use of independent data from both household reports of land use and community-level measures of vegetation change in the same study areas, allowing us to compare the results of these two distinct perspectives on land use change. In both cases, we control for potential confounders, and in the household case we attempt to explicitly account for the potential endogeneity of out-migration and remittances. We also considerably expand upon a pilot study (Gray 2009a), which found mixed and weak effects of migration on agriculture in a smaller Ecuadorian study area, but did not include corrections for endogeneity or incorporate satellite data.

3. Data Collection

To investigate these relationships, we conducted a household survey in three study areas in rural Ecuador, along with a parallel analysis of vegetation change using satellite imagery.

3.1. Study areas

Based on site visits, census data and environmental data sources, three study areas were selected in the Andean highlands and transition zone to the Pacific coastal plain to capture a variety of biophysical environments and patterns of out-migration (Figure 1). Each area consists of 5–6 contiguous cantons (administrative units roughly equivalent to US counties), which together contained 7% of Ecuador's rural population in 2001. In the analyses described below, we combine data from all three areas to provide additional statistical power and to produce results generalizable across multiple agricultural contexts.

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The Santo Domingo study area is located in the transition zone between the Andes and the Pacific coastal lowlands and encompasses a wide range of environments, from mountainous, heavily forested areas in the east to flat and intensively cultivated areas in the west. The climate is humid and tropical, key crops include heart of palm, cacao and plantains, and land ownership is mixed between small farms and large ranches or plantations. Out-migration is primarily to other coastal provinces.

The high-elevation Chimborazo/Cañar study area overlaps these two provinces, and includes both high-elevation grasslands and densely-settled valleys with temperate climates. Smallholder agriculture is the dominant land use in settled areas, and key crops include maize, beans and potatoes. This area is part of Ecuador's international out-migration heartland. Migration to the United States became common in the 1990s and was later superseded by a (nationwide) trend of migration to Spain beginning in the late 1990s (Jokisch and Pribilsky 2002).

The third study area, in western Loja province, lies in the western Andean foothills but has an unusually dry climate with recurrent droughts. Coffee-centered agroforestry, cattle raising and maize-centered agriculture are the key agricultural activities, but population densities and land use intensity are low relative to the other two study areas. This region is a traditional sending region of internal migrants, to urban, coastal and Amazon destinations, though international migration, primarily to Spain, also became common after 2000 (Jokisch and Pribilsky 2002)

Results from the household survey, described below, provide additional insight into the nature of the agricultural systems in the three study areas. The overall mean farm size is approximately 6 hectares, with 10% rented in or loaned to the household. Farms in Chimborazo/Cañar are smaller on average (4 hectares) while those in Santo Domingo are much larger (16 hectares). Across all three areas, the largest proportion of land use is allocated to pasture (37%), with annuals, perennials and forest each constituting about 20%, and the small remainder in fallow and other uses. Annuals such as corn and beans are produced primarily for subsistence, whereas cattle, wage labor, remittances, and perennial crops are the main sources of cash income. Participation in agriculture is highly gendered, with 80% of young men (ages 15–29) reporting participation in farm work compared to 44% of young women.

3.2. Sampling and interviews

In each of the three study areas, sample communities and households were selected using a stratified, multi-stage cluster sample which included procedures to oversample both migrantsending areas and households. Full details of the sampling methodology are available in Gray and Bilsborrow (2013). Briefly, rural parishes (administrative units nested within cantons) from the 17 study cantons were selected in the first stage with probabilities of selection proportional to the rate of out-migration in 1996–2001, derived from the 2001 census. In the second stage, 1–3 census sectors were randomly sampled within the sample parishes, reflecting differences in the population sizes of parishes across the three study areas. Sample sectors were then visited to identify the constituent rural communities and to list all resident households and migrants who had departed since January 1, 2000. Listed households were classified into strata based on the destination of out-migrants, and a stratified sample was drawn using a set of sampling rules that oversampled households with migrants, and more so for those with rare migrant types. The final sample contained 29 parishes, 55 census sectors, 106 rural communities and 869 households, 97% of whom provided a complete household interview.

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Fieldwork was carried out in June-December 2008 by a team of Ecuadorian interviewers. Interviewers used a structured questionnaire to collect information on livelihood activities in the past year and a variety of retrospective information dating back to 2000. Detailed data was collected on livelihood activities in the past year, including production, use of inputs and sales from agriculture as well as the value and frequency of migrant remittances received. Plot-level information was also collected on land use and perceived land quality. Additionally, retrospective information was collected back to the year 2000 using an annual time step and a format that allowed comparisons across related topics. This included data on the agricultural and other economic activities of household members, as well as the location/residence of each current member and all adult out-migrants. Limited information was also collected for the period prior to 2000, including the destinations of out-migrants from the household prior to 2000.

Finally, a community questionnaire was implemented with community leaders to obtain crosssectional and retrospective information about population size, migration, infrastructure and economic activities.

3.3. Spatial analysis

Global Positioning System points were collected at community centers, the location of each household, and a subset of agricultural plots. For the present analysis, community territories were defined to encompass a 1 km radius from the community center, a radius consistent with our field observations and the distribution of household plots. These territories were used to extract values from two existing environmental datasets and four satellite images. First, we used a Digital Elevation Model of Ecuador with 30 m resolution (Souris 2006) to extract mean elevation, mean slope and the standard deviation of slope, a measure of terrain unevenness. Second, we used the global WorldClim dataset to obtain historical measures of annual precipitation and temperature as well as their seasonal variation. This dataset contains interpolated climate information at a 1 km resolution, estimated as a historical mean from 1950–2000 (Hijmans et al., 2005).

To measure vegetation change, we acquired four cloud-free Landsat ETM+ satellite images with 30 meter resolution, two covering the Cañar/Chimborazo study area (from Nov 3, 2001 and Aug 31, 2007) and two covering the Loja study area (from Oct 31, 2000 and Sept 19, 2008). Adequate cloud-free imagery was not available for the Santo Domingo study area in any year since 2000, necessitating the omission of that area from the community-level analysis. Cloud-free data was available for 78 study communities. Two measures of vegetation greenness, the Normalized Difference Vegetation Index (NDVI; Pettorelli et al., 2005) and the Enhanced Vegetation Index (EVI; Huete et al., 2002), were then derived from these images and extracted using 1 km buffers as described above. These indices are transformations of the strength of reflectance in different spectral bands and measure the extent of plant growth and photosynthetic activity, i.e. “greenness”. Both indices range from −1 to 1, but here all values have been multiplied by 10 to facilitate interpretation of the results. While these values cannot be directly interpreted in terms of land cover, a supplementary land use classification of the 2007–2008 images revealed that greenness was highest for annual crops, followed by coffee, forest, pasture and fallow.

4. Analysis

To investigate the consequences of migration and remittances for agriculture, we use the datasets described above to conduct two sets of analyses, one at the household level using survey-derived outcomes and the other at the community level using satellite-derived outcomes. These two sets of analyses have different strengths and thus serve as a robustness check on our findings.

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4.1. Household-level analysis

The first set of analyses examines the influence of migrant departure and receipt of remittances on household agricultural activities in the 12 months prior to interview. We use data from the 441 households who grew crops during this period and who were also resident in the study community in the baseline year 2000. To avoid reverse causation between migration and agriculture, we examine the effects of previous migration and remittances on current agricultural outcomes while controlling for pre-migration characteristics, capitalizing on the retrospective nature of the survey. The four outcomes are area planted in annual crops, expenditures on modern agricultural inputs, days of labor hired, and total production of annual crops. We focus on annual crops and inputs used on all plots in the past year because the production of long-lived perennials such coffee and cacao, as well as livestock such as cattle[1], reflects decisions made many years prior.

Descriptive statistics for the outcomes are shown in Table 1. 83% of households grew annual crops with a mean area of 1.1 hectares, 68% used modern inputs with a mean cost of US$241, 35% hired agricultural laborers with a mean duration of 20 person-days, and the average production of annuals was valued at US$598. 53% of households sold crops in the past year. For crops consumed rather than sold, production was valued at the mean price obtained by households who sold the crop. Maize was the most common primary annual crop, followed by beans, potatoes and peanuts. Expenses on inputs went primarily towards fertilizers and herbicides, followed by pesticides and improved seeds. Because the four outcome variables are censored at zero and right-skewed, they were transformed by ln(y+1) prior to analysis and we use regression models appropriate for censored outcomes as described below.

To capture the effects of migration and remittances, four predictors were constructed: the number of migrants sent by the household in the period 2000–2008, the numbers of male and female migrants separately, and the value of monetary remittances received in the previous 12 months (Table 1). Migrants were defined as individuals resident in the household in 2000 who by 2008 lived outside of the canton. On average, households sent less than one migrant (0.8) and received approximately US$290 in remittances. Among migrants, 59% of were male and 32% went to international destinations. International migrants, primarily to Spain and United States, remitted $1040 on average, representing 90% of all remittances received, versus $50 on average for internal migrants.

Fourteen control variables capturing pre-migration characteristics of the household and community in the year 2000 are also included in the analysis to account for other potential influences on land use. Selection of the control variables was motivated by the rural livelihoods framework as described above (Ellis 2000). Household-level controls include farm area, ownership of flat land, ownership of land with black soil, irrigation and/or perennials, an index of non-agricultural wealth, the number of cattle owned, household size, and the gender, age, and employment status of the household head. Values of farm area and the number of cattle are right-skewed and were thus transformed by ln(x+1) prior to analysis to reduce the influence of outlying values. The wealth index was created by using polychoric principle components analysis (Kolenikov and Angeles 2009) to combine several dichotomous and categorical measurements of housing quality and ownership of various assets. Community-level control variables include the type of road surface and a climate index measuring the extent to which the site had a tropical (versus temperate) climate. This index was created by taking the first principal component of the climate variables derived

[1]For this reason we do not examine cattle ownership as an outcome in the household-level analysis. However it is worth noting that cattle ownership did increase over the study period from 3.4 to 3.9 cattle per household, potentially leading to an increase in pasture and affecting vegetation greenness, as we note below.

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from WorldClim as described above. Finally, largerscale contextual factors are accounted for by canton-level fixed effects as described below.

To examine the influences of these factors on agriculture, we first estimate a series of tobit models using various specifications of migration and remittances. Tobit models are an extension of multiple regression that are appropriate for censored outcomes, i.e., outcomes with a large proportion of zeroes. To account for the clustering of observations within sample sectors and for larger-scale contextual effects, all standard errors have been adjusted for clustering (Angeles et al., 2005) and all models include canton-level fixed effects, i.e., an indicator variable for each canton. All models and descriptive statistics also incorporate sampling weights, derived as the inverse of the probability of selection. We first estimate three tobit models with the following specifications of migration and remittances: total migrants only, total migrants along with the value of remittances, and, finally, migrants separated by gender as well as the value of remittances. We present coefficients and significance tests for these models, and later derive marginal effects of the predictors conditional on the outcome being greater than zero. Outcome values are missing for three households on the area and production of annuals, four households on input expenditures, and two households on the person-days of hired labor, resulting in slightly different sample sizes for the four models.

To examine whether these effects are due to endogeneity, we then re-estimate these models as linear instrumental variable models. In this approach, migration and remittances are each separately considered to be a function of the control variables plus a collection of instrumental variables which are assumed to influence migration and remittances from 2000–2008 but not agricultural activities in 2008. Consistent with previous econometric studies (e.g., Rozelle et al., 1999), instrumental variables included indicators for the detailed age composition of the household in 2000, the number of internal and international migrants sent by the household prior to 2000, and the propensities of internal and international migration from the parish prior to 2000 (derived from census data). To allow convergence for models with multiple endogenous variables, models were estimated as linear instrumental variable models rather than tobit models, and thus account for endogeneity but not censoring. All models reported here meet suggested thresholds for the strength, significance and exogeneity of instruments, and all models also include adjustments for clustering and canton-level fixed effects. Descriptive statistics for the instrumental variables and detailed results for the instrumental variable models are available upon request.

4.2. Community-level analysis

The second set of analyses examines the influence of migration on vegetation change at the community level. As described above, we focus on 78 study communities where cloud-free imagery was available. Our outcomes are the change in two measures of vegetation greenness, NDVI and EVI, from 2000–2001 to 2007–2008, multiplied by 10 for ease of interpretation. A positive value indicates increasing greenness over time, and, as shown in Table 2, both values are positive on average, consistent with an increasing trend of rainfall over the same period. To examine the influences of migration on these outcomes, we estimated multiple regression (OLS) models, which as described above included sampling weights, corrections for clustering at the level of the sample sector, and fixed effects at the level of the canton.

Consistent with the larger scale and remotely-sensed outcome of this analysis, a distinct set of predictors was developed. A measure of migration and 16 control variables were extracted from the community survey, the household survey, and the biophysical datasets described above. Migration here is measured as the total number migrants from 2000–2008 divided by the adult population of the community in 2008, i.e., the ratio of migrants to non-

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migrants, using data derived from the household listing. (A measure of total remittances was not available at the community level.) Biophysical and social variables that are likely to affect agriculture and potentially correlated with migration were selected as control variables. Controls extracted from the biophysical datasets include mean annual precipitation and temperature, seasonal variation in these values, mean terrain slope, variation in slope, and baseline values of NDVI and EVI. Control variables derived from the community survey include the occurrence of a drought from 2000–2008, mean farm size, population size in 2000, frequency of transportation interruptions, and whether the following crops were cultivated in 2000: maize, coffee, potatoes and peanuts. Finally, the mean level of adult education in the community in 2000 was extracted from the household survey.

5. Results

5.1. Household-level results

The results of the household-level analysis are presented in Table 3. We first briefly describe the effects of the control factors, focusing on Specification 1, before turning to the effects of migration and remittances across all three specifications.

The control factors had jointly significant effects on all four outcomes that are broadly consistent with expectations. The area planted in annuals increased with farm size and access to a paved road and decreased with land in perennials and with irrigation, the latter effect likely reflecting the intensive cultivation of a smaller area. Expenses on modern inputs in turn increased with flat land, tropical climates, and nonagricultural employment and wealth, both of which facilitate the purchase of inputs. Input expenses also decreased with access to a paved road, perhaps due to lower prices in these areas. Days of labor hired-in to the farm increased with farm size, irrigation, education of the head, nonagricultural wealth, and the location on a gravel road, potentially reflecting lower labor costs in these semi-remote areas. Finally, the production of annuals decreased with land in perennials, female household headship, and tropical climates, and increased with the presence of a gravel road. The canton indicators were also jointly highly significant in all models, indicating the importance of accounting for large-scale contextual factors.

To test the effects of migration and remittances, three specifications are presented in order of increasing complexity. Specification 1 includes only the total number of migrants, and reveals only weak and non-significant effects on each of the four dependent variables, results which are confirmed in the instrumental variable models. Thus while the area in annuals marginally increased with the number of out-migrants ($p = 0.09$), this effect becomes non-significant in the model that includes corrections for endogeneity.

Specification 2 adds the value of remittances as a predictor, and an intriguing countervailing pattern on the area in annuals is revealed. The area planted in annuals increased with the departure of migrants ($p = 0.002$) but decreased with the receipt of remittances ($p = 0.001$), results confirmed by the instrumental variable approach. To more clearly present the magnitude of these effects, we derive marginal effects of the predictors for non-zero outcomes, simulate the effects for a household with 1 hectare of annual crops, and translate the results back into the original non-logarithmic units. This simulation reveals that the departure of one migrant would increase cropped area slightly to 1.12 hectares, with a 95% confidence interval of 1.05–1.20 hectares. The departure of a single migrant accompanied by $1000 in remittances (the average sent by an international migrant) would have a net negative effect, decreasing the area in annuals to 0.75 hectares, with a confidence interval of 0.52–1.03 hectares. Finally, the effects of migration and remittances on the other agricultural outcomes remain non-significant, results again confirmed by the instrumental variable models.

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Specification 3 examines whether there is a difference in the effects depending on the gender of the out-migrant. This reveals that the magnitude of the effect of migrant departure on area in annuals in similar for both male and female migrants, but the effect is highly significant for men ($p = 0.009$) and only marginally significant for women ($p = 0.098$), a result that holds once endogeneity is corrected. The effects of migration and remittances on the other three agricultural outcomes remain largely non-significant. While the number of male out-migrants is positively associated with person-days of hired labor, this result is not robust to corrections for endogeneity.

5.2. Community-level results

The results of the community-level analysis are seen in Table 4. The control variables generally had significant and similar effects on both measures of change in vegetation greenness. Both measures increased with seasonal variation in precipitation, reports of past drought, maize cultivation, and more frequent transportation interruptions, and decreased with mean annual temperature, mean farm size, mean education and the cultivation of potatoes. The change in NDVI also increased with the mean land slope and decreased with the variation in slope and baseline NDVI. Together these results indicate that remote, mid-elevation sites with variable climates, small farms and low education experienced the most greening, potentially reflecting recovery from past droughts and the expansion of agriculture in poorer and remote areas. Finally, with respect to the key variable of interest, the effect of the ratio of migrants to non-migrants is positive and significant for both change in NDVI ($p = 0.047$) and change on EVI ($p = 0.038$). At the mean value of migration, this effect accounts for 4.1% and 6.3% of the vegetation greening as measured by NDVI and EVI respectively.

6. Discussion

Contrary to common assumptions, both the household and community-level results suggest that migrant departure led to an *expansion* of cultivated area in rural Ecuador. At the household level, migration and remittances appear to have countervailing effects, with the area in annuals increasing with the number of migrants (particularly male migrants) and declining with the value of remittances. Given that these changes in area occur without any concurrent changes in inputs or production, the results suggest that households are expanding the agricultural area while disintensifying production, i.e. lowering inputs and production per unit area. This may reflect a strategy to maintain production by planting a larger area but devoting less attention to laborintensive tasks such as weeding, a change which could also increase vegetation greenness. The negative effect of remittances on cultivated area suggests that remittances are substituting for agricultural production, allowing a decrease in agricultural effort. This interpretation is consistent with the negative but non-significant effects of remittances on the other three outcomes. For an international migrant who sends the average value of remittances, the net effect is to slightly decrease the area in annuals.

At the community level, out-migration had significant positive effects on both measures of change in vegetation greenness. Given that annual crops have the highest levels of greenness among regional land covers, this result suggests that migration led to an overall increase in the area in annual crops, though it could also be partly accounted for by an increase in irrigated pastures. Increasing greenness could also potentially indicate regrowth of native vegetation on previously barren areas, but this interpretation is not consistent with the household-level results described above or with our site visits to the study areas, where land abandonment within 1 km of the community center was rarely observed.

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7. Conclusions

Drawing on original household survey data and a novel analysis combining econometric and remote-sensing methods, we examine the effects of out-migration from rural areas and the receipt of remittances on agricultural land use in rural Ecuador. Contrary to common assumptions, we find evidence that rural out-migration leads to an *expansion* of agricultural area, with remittances having a countervailing negative effect. These results are generally consistent with the three most relevant previous studies, which found that the area planted in staples increased with out-migration in El Salvador (Damon 2010) and that the effects of male departure were greater than female departure in Mexico and southern Ecuador (Pfeiffer and Taylor 2007; Gray 2009a). More broadly, the results are also consistent with the literature as a whole in finding mixed, countervailing and relatively weak effects of migration and remittances on agricultural activities (Jokisch 2002; Gray 2009a). Taken together, these studies undermine common arguments that out-migration and receipt of remittances will lead to agricultural abandonment and the regrowth of native vegetation in the rural developing world (Aide and Grau 2004; Hecht 2010). Future studies should instead recognize the significant flexibility of rural households in responding to demographic and environmental change, and the important ways in which these household strategies mediate population-environment relationships.

Future studies could also benefit from adapting and extending the methodological approach described here. We show that combining econometric and GIScience approaches in the same study area can contribute to better insights and more robust findings. Desirable extensions of our approach for understanding migration-environment relationships include the incorporation of panel survey data, the construction of a linked time-series of classified remotely-sensed images, and linking households to land though the geolocation of agricultural plots. In the context of human-environment research, the approach of combining survey and remote sensing data has been pioneered in the study of frontier land use (Walsh and Crews-Meyer 2002; Fox et al 2003).

We show here that these approaches are also relevant and complementary for the investigation of migration-environment relationships, and indeed could also be productively combined to study a wide variety of the other human-environment topics such as common property resources, forest product collection, and the impacts of agricultural interventions.

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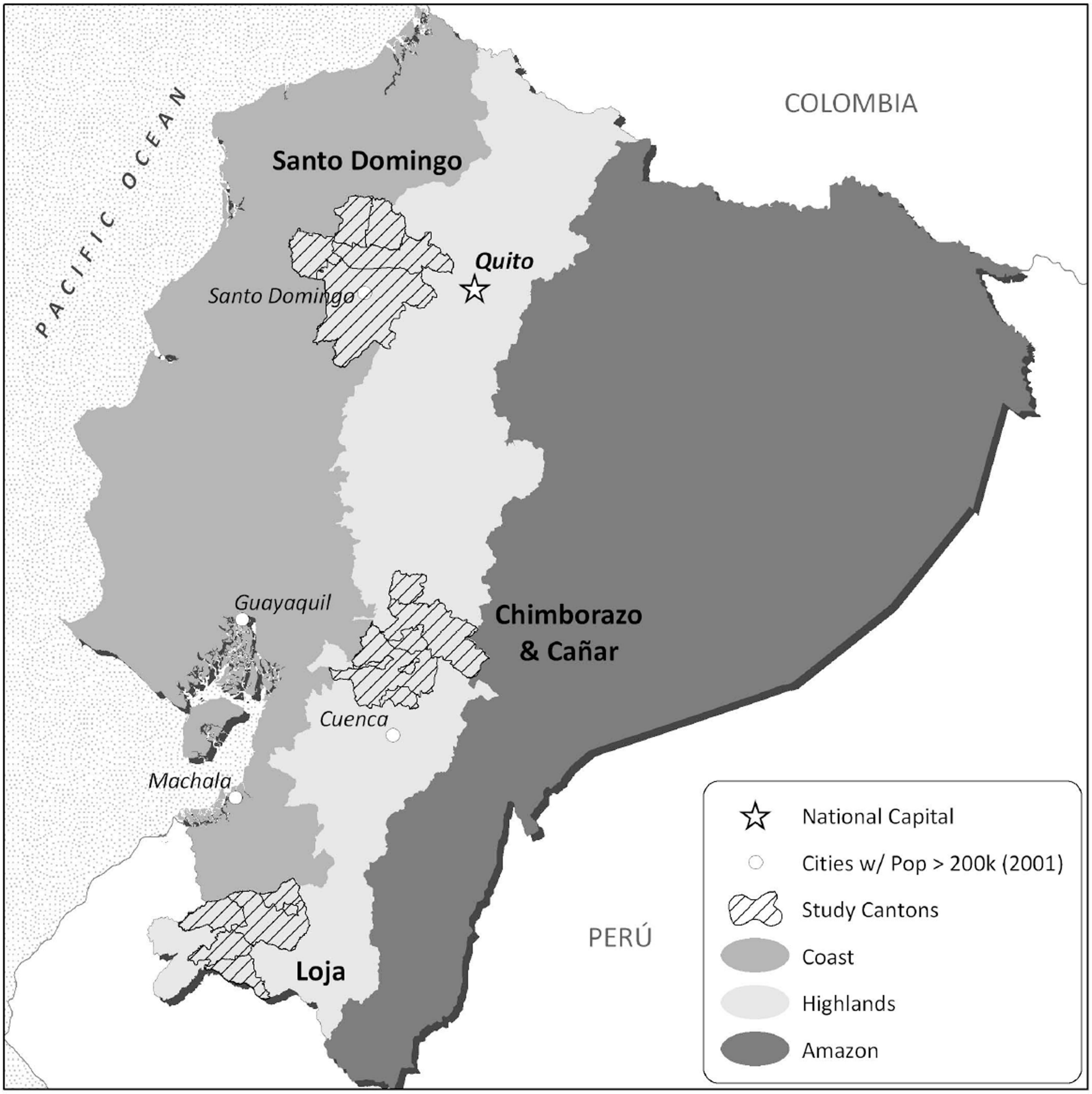

Figure 1.
Map of Ecuador showing the three study areas.

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Table 1

Mean values of outcomes and predictors by migrant-sending status for the household-level analysis.

Variable	Full sample	No migrants	Migrants but no remittances	Migrants and remittances
Outcome variables				
Grew annual crops, 2008 (0/1)	0.83	0.83	0.82	0.84
Area in annual crops, 2008 (ha)	1.13	1.00	1.46	1.03
Used modern inputs, 2008 (0/1)	0.68	0.63	0.80	0.63
Expenditures on modern inputs, 2008 (US$)	241	304	234	99
Hired agricultural labor, 2008 (0/1)	0.35	0.32	0.41	0.36
Days of hired labor, 2008 (person-days)	20.1	13.4	38.6	11.9
Production of annual crops, 2008 (US$)	598	569	564	712
Migration and remittances				
Number of migrants, 2000–2008, (#)	0.80	0.00	1.49	1.80
Number of male migrants, 2000–2008 (#)	0.47	0.00	0.84	1.10
Number of female migrants, 2000–2008 (#)	0.33	0.00	0.65	0.69
Value of remittances, 2008 (US$)	293	0	0	1357
Control variables				
Area of land owned, 2000 (ha)	5.14	3.55	6.07	7.71
Owned flat land, 2000 (0/1)	0.18	0.20	0.12	0.23
Owned land with black soil, 2000 (0/1)	0.39	0.42	0.28	0.47
Owned land with irrigation, 2000 (0/1)	0.23	0.19	0.20	0.34
Owned land with perennials, 2000 (0/1)	0.29	0.27	0.30	0.30
Number of cattle, 2000 (#)	3.44	2.86	2.79	5.63
Household size, 2000 (#)	5.20	4.23	6.17	6.26
Female head, 2000 (0/1)	0.25	0.30	0.11	0.29
Age of head, 2000 (years)	45.7	44.5	44.0	50.5
Education of head, 2000 (years)	4.60	4.35	5.71	3.76
Nonagricultural work by head, 2000 (0/1)	0.15	0.12	0.27	0.06
Nonagricultural wealth score, 2000 (0–10)	3.16	3.18	3.32	2.92
Paved road, 2000 (0/1)	0.18	0.24	0.11	0.13
Gravel road, 2000 (0/1)	0.42	0.37	0.50	0.42
Dirt or no road, 2000 (0/1)[1]	0.40	0.39	0.39	0.45
Tropical climate index (0–10)	4.30	4.57	4.39	3.54
$N_{households}$	441	183	131	127

[1]Reference category

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Table 2

Mean values of outcomes and predictors by region for the community-level analysis.

Variable	Full	Cañar/ Chimborazo	Loja
Outcomes			
Change in NDVI x10, 2000–08	2.56	3.93	0.65
Change in EVI x10, 2000–08	2.95	4.47	0.82
Predictors			
Ratio of migrants/nonmigrants, 2000–08 (%)	0.30	0.28	0.32
Mean annual precipitation (cm)	100	78	129
CV of monthly precipitations (%)	6.97	5.14	9.51
Experienced drought, 2000–08 (0/1)	0.23	0.28	0.15
Mean annual temperature (°C)	16.8	13.3	21.7
SD of monthly temperatures (°C)	3.01	3.24	2.69
Mean land slope, 2000 (%)	16.9	15.9	18.3
SD of land slope, 2000 (%)	7.18	7.33	6.97
Mean farm size, 2008 (ha)	3.03	2.21	4.17
Maize cultivated, 2000 (0/1)	0.83	0.77	0.91
Coffee cultivated, 2000 (0/1)	0.18	0.00	0.42
Potatoes cultivated, 2000 (0/1)	0.44	0.75	0.00
Peanuts cultivated, 2000 (0/1)	0.27	0.00	0.64
Population size, 2000 (#)	302	457	87
Mean education, 2000 (years)	4.70	3.97	5.70
Rare transport interruptions, 2000–2008 (0/1)[1]	0.11	0.15	0.07
Occasional transport interruptions, 2000–08 (0/1)	0.32	0.20	0.49
Regular transport interruptions, 2000–08 (0/1)	0.36	0.41	0.29
Frequent transport interruptions, 2000–08 (0/1)	0.20	0.24	0.15
NDVI x10, 2000	0.77	−0.06	1.92
EVI x10, 2000	0.84	0.15	1.81
$N_{communities}$	78	34	44

[1]Reference category

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Table 3

Household-level tobit models of the effects of migration and remittances on agricultural outcomes.

Predictors	Specification 1: Migrants only				Specification 2: Migrants & remittances				Specification 3: Gender & remittances			
	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)
Migration and remittances												
Number of migrants	0.04 †	0.03	0.32	−0.04	0.09**	0.12	0.36	0.02				
Number of male migrants									0.10**	0.12	0.50*	−0.04
Number of female migrants									0.08†	0.11	0.11	0.10
Ln(value of remittances)					−0.04***	−0.08	−0.03	−0.05	−0.04***	−0.08	−0.03	−0.05
Control variables												
Ln(area of land owned)	0.19***	0.36	1.37***	0.18	0.18***	0.35	1.36***	0.17	0.18***	0.35	1 39***	0.17
Owned flat land	0.21	1.28 †	0.95	0.02	0.22	1.31 †	0.94	0.04	0.22	1.31 †	0.94	0.03
Owned land with black soil	−0.08	−0.51	−0.49	−0.73	−0.07	−0.50	−0.48	−0.73	−0.07	−0.50	−0.41	−0.74
Owned land with irrigation	−0.20**	0.28	1.55**	0.41	−0.20**	0.27	1.55**	0.41	−0.20**	0.27	1 57**	0.40
Owned land with perennials	−0.45***	0.04	−0.60	−2.42***	−0.43***	0.08	−0.57	−2 38***	−0.43***	0.08	−0.58	−2 38***
Ln(number of cattle)	0.02	0.15	−0.15	0.27	0.04	0.17	−0.14	0.28	0.03	0.17	−0.15	0.28
Household size	0.01	0.09	−0.19	0.06	0.02	0.09	−0.20	0.06	0.02	0.09	−0.19	0.06
Female head	−0.11	−0.50	0.48	−0.71 **	−0.07	−0.41	0.51	−0.65 *	−0.07	−0.41	0.51	−0.65 *
Age of head	0.00	−0.04*	0.00	0.00	0.00	−0.04*	0.00	0.00	0.00	−0.04*	0.01	0.00
Education of head	−0.02	0.08	0.27**	0.00	−0.02	0.08	0.27**	0.01	−0.02	0.08	0.27***	0.01
Nonagricultural work by head	−0.03	1.64*	−0.44	−0.01	−0.07	1.55*	−0.48	−0.07	−0.07	1.55*	−0.49	−0.06
Nonagricultural wealth score	0.01	0.36†	0.41**	0.06	0.01	0.36*	0.41**	0.06	0.01	0.36*	0.40**	0.07
Paved road	0.19†	−1.45**	0.08	0.32	0.17†	−1.48**	0.09	0.31	0.17†	−1.48**	0.13	0.30
Gravel road	0.07	−0.72	2.02**	0.81*	0.06	−0.74	2.03**	0.80*	0.06	−0.74	1.99**	0.82*
Tropical climate index	0.00	0.44*	0.14	−0.27†	−0.02	0.40 †	0.13	−0.30†	−0.02	0.40 †	0.14	−0.30†
Constant	0.31	−0.19	−7.24***	4.83 ***	0.38†	−0.06	−7.20***	4.93***	0.38†	−0.06	−7 25***	4 94***
Sigma	0.46***	2 53***	2.38***	2.02***	0.45***	2.52***	2.37***	2.01***	0.45***	2.52***	2.37***	2.01***
Canton fixed effects (joint F)	10.9***	19 3***	7.0 ***	3.1***	11.1***	12.0***	7.2***	3 2***	11.4***	11.8***	7.3***	*3.5****
Linear instrumental variable model[1]												
Number of migrants	0.06	−0.47	0.06	−0.11	0.22**	0.16	0.18	0.42				

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Predictors	Specification 1: Migrants only				Specification 2: Migrants & remittances				Specification 3: Gender & remittances			
	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)	Ln(area in annuals)	Ln(input expenses)	Ln(days hired labor)	Ln(production of annuals)
Number of male migrants									0.22**	0.13	0.18	0.32
Number of female migrants									0.22+	0.40	0.13	1.13+
Ln(value of remittances)					−0.12***	−0.44+	−0.08	−0.38	−0.12***	−0.45+	−0.08	−0.43
$N_{households}$	438	437	439	438	438	437	439	438	438	437	439	438

[1] Selected coefficients from a parallel set of linear instrumental variable models that correct for the potential endogeneity of migration and remittances.

+ p<0.10

* p<0.05

** p<0.01

*** p<0.001

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Table 4

Community-level OLS models of the effects of migration on vegetation greenness.

Predictor	Change in NDVI	Change in EVI
Ratio of migrants/nonmigrants	0.35 *	0.63 *
Mean annual precipitation	0.00	0.01
CV of monthly precipitations	0.28 ***	0.40 ***
Experienced drought	0.22 **	0.25 +
Mean annual temperature	−0.22 ***	−0.34 ***
SD of monthly temperatures	−0.11	−0.05
Mean land slope	0.04 *	0.02
SD of land slope	−0.12 **	−0.06
Mean farm size	−0.03 **	−0.04 **
Maize cultivated	0.21 *	0.41 **
Coffee cultivated	0.10	0.11
Potatoes cultivated	−0.40 ***	−0.61 **
Peanuts cultivated	0.03	0.31
Ln(population size)	−0.01	−0.06
Mean education	−0.08 *	−0.13 *
Occasional transport interruption	0.26 *	0.32 *
Regular transport interruption	0.45 *	0.56 *
Frequent transport interruption	0.54 **	0.79 *
NDVI x10	−0.35 ***	-
EVI x10	-	0.11
Canton fixed effects (joint F)	24.1 ***	20.9 ***
Constant	5.81 ***	6.56 ***
$N_{communities}$	78	78

+ p<0.10

* p<0.05

** p<0.01

*** p<0.001