HUMAN MIGRATION IMPACTS ON LAND USE IN THE AMAZON

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INTRODUCTION

Human migration is central to understanding our central fabric as a species. Where and why people move has implications related to individual, familial, cultural, economic, political, environmental, health, and other outcomes that consistently influence our daily lives. The eternal question of "Where do we come from?" should begin with an understanding of where we are and why we decided to live here in the first place. Unfortunately, several scientific fields that have blossomed in the past 20 years have stopped exploring this question and we are increasingly at a loss of better understanding fundamental issues in science. A simple example of this loss of understanding is directly addressed by this paper, namely, the impact of human migration and settlement decisions on land use changes in the Amazon. With climate change at the forefront of science and policy discussion (i.e., (Brondizio & Moran, 2008), the importance of tropical forests in mitigating global consequences of climate change is increasing. Through this new impetus, human migration decisions are increasingly being recognized as a fundamental aspect driving change in forest frontiers. Examples of social and environmental impacts due to human migration in forested areas range from human fertility (Carr, Pan, & Bilsborrow, 2006; Kulu, 2005), disease emergence (Marques, 1987; Nybro, 2002; Patz, Daszak, Tabor, Aguirre, Pearl, Epstein et al., 2004), resource extraction (Godfrey, 1992; Rudel & Richards, 1990), and, most relevant to this research, land use change (Carr, 2004; Carr & Bilsborrow, 2001; Geist & Lambin, 2002; Rudel & Roper, 1996).

Several conceptual and empirical studies have contributed to our understanding of how migration patterns and associated factors relate to land use change. From a theoretical perspective, it begins with Ravenstein's laws of migration that established the ideas that migration: rates from a location are inversely related to the distance being traveled; occurs in waves; is moderated by transportation and commerce with movement primarily from agricultural to industrial areas; usually is done by adults; is primarily from rural to urban areas; is more often done internally by women, but externally by men; and economic factors are the main cause of migration (Ravenstein, 1885, , 1889). Several researchers have debated the relevance of these laws (i.e., (Tobler, 1995), while others have directly refuted or maintained their eminence (Barbieri & Carr, 2005; Ezra, 2001; Laurian, Bilsborrow, & Murphy, 1998). Following Tobler's insightful recommendations to incorporating migration into research, we contribute to this rapidly growing literature by recognizing that migration decisions and resulting land use outcomes are intertwined and highly dependent on the spatial location of a settlement area, the timing of relocation and the duration settlement. Thus, our approach will construct a simultaneous equations model in which two sets of equations are estimated: first, we predict waves of migration in five time intervals to defined settlement sectors in the northern Ecuadorian Amazon (prior to 1980, 1980-84, 1985-89, 1990-94, 1995-99); and second, we estimate land use cover (forest, pasture, perennials, annuals) in 1990 and 1999 along with an estimate of changes over time from predicted values. The model is still in development, but is provided conceptually in the methods section, along with a description of the data.

METHODS

Data & Variable definitions

Data are from longitudinal household surveys conducted in the northern Ecuadorian Amazon in 1990 and 1999. Details of the surveys and sample selection have been described in previous studies (Bilsborrow, Barbieri, & Pan, 2004; Pan & Bilsborrow, 2005; Pichón, 1997). Briefly, a 2-stage sample was drawn in 1990 in which the first stage 60 settlement sectors were randomly selected and the second stage involved random selection of government-defined agricultural plots, or *fincas*. *Fincas* ranged in size generally from 40-60 hectares and in 1990 were occupied primarily by one family (i.e., approximately 450 *fincas* were selected from which 405 *fincas* had agricultural activity and 418 families were occupying the land). In 1999, rapid in-migration and subdivision of *fincas* to relatives resulted in over 950 families identified on 395 *fincas* (10 *fincas* were not revisited due to safety concerns along the Colombian border). Household survey were administered in 1990 and 1999 to obtain data pertaining to land use, migration origin, household composition, agricultural yields, employment, biophysical characteristics of the plot, and tenure status, among several other topics.

For this analysis, inference and data will be defined at the *finca* and sector levels. We recognize that this does not directly correlate to household inference, but the overall goal for this analysis will be to determine (1) factors associated with areas of high / low migration and (2) the relationship between migration rates and land use cover / change. We will reconstruct household rosters prior to 1980, 1980-1984, 1985-89, 1990-94, and 1995-99 to determine rates of in- and out-migration from the plot and define biophysical (soil, topography), geographic (distances to major towns, markets, communities centers, and roads), demographic (births and deaths), and land use factors associated with migration decisions. Note that land use is defined only for two time points (1990 and 1999), thus, land use will not be included in equations prior to 1990. However, in building our land use equations, land use in 1990 will be considered a function of migration rates prior to 1990, while land use in 1999 will be a function of all migration rates prior to 1999. Both land use equations will include other relevant variables not included in migration equations, but recognized in literature as important factors associated with land use.

Statistical Methods

The simultaneous equations to be employed are still under development. We expect our equations to follow those outlined by (Haily & Rosenberger, 2004), in which population, economic agents, and agricultural land are simultaneously modeled. Simultaneous equation approaches are common in the economics literature and generally are estimated using 2- or 3-stage least square, or using instrumental variables. It is recognized that 2SLS and 3SLS both provide unbiased estimates of predictors; however, 2SLS ignores the correlation between error terms for the equations, thus is not efficient. 3SLS does take this into account. Instrumental variables are promising, but leave open critiques regarding choices of the instrument. Thus, for this research we will attempt to apply 3SLS in estimating our equations.

As stated, our equations are still under development. We have outlined general forms for each set of equations. Set 1 (migration) and 2 (land use) are given below with y representing migration rates, z representing land use, t0-t4 represent each time interval chronologically, and *i*, *j* refer to *finca* and sector:

Set 1 (Migration equations)

$$y_{t0,i,j} = (soil)_i + (topo)_i + (dist\_town)_i * (pop\_town)_i + (road\_access)_i + (births)_{t0,i} + (deaths)_{t0,i} + e_{t0,i,j}$$
$$y_{t1,i,j} = (SAME\_AS\_ABOVE)_i + y_{t0,i,j} + e_{t1,i,j}$$
$$y_{t2,i,j} = (SAME\_AS\_ABOVE)_i + y_{t0,i,j} + e_{t2,i,j}$$
$$y_{t3,i,j} = (SAME\_AS\_ABOVE)_i + y_{t0,i,j} + e_{t3,i,j}$$
$$y_{t4,i,j} = (SAME\_AS\_ABOVE)_i + y_{t0,i,j} + e_{t4,i,j}$$

Set 2 (Land use equations)

$$z_{90,i,j} = y_{t0,i,j} + y_{t1,i,j} + y_{t2,i,j} + (OTHER\_VARS)_{i,j} + u_{90,i,j}$$
$$z_{99,i,j} = y_{t0,i,j} + y_{t1,i,j} + y_{t2,i,j} + y_{t2,i,j} + y_{t2,i,j} + z_{90,i,j} + (OTHER\_VARS)_{i,j} + u_{t1,i,j}$$

Subscripts for soil, topography and road access indicate that these measurements are taken from the 1990 survey and are thus “back-applied”; distance and population of the nearest major town is the computed distance in 1999 multiplied by the population of the town at the mid-point of the time interval (1975 for prior to 1980); and births and deaths indicate all births and deaths occurring after settlement in the Amazon, recorded from the household surveys in 1990 and 1999. Other variables listed for the land use equations will include maximum duration of settlement for a family currently living on the plot, land tenure status, off-farm employment, and estimated population density during time intervals prior to survey administration.

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