Progress Report -- Investigation Group: LC-01

Modeling the Scale Dependent Drivers of LCLU Dynamics in Northeastern Ecuador: Simulating Patterns of Landscape Change and Assessing their Cause and Consequence through Multi-Level Models and Cellular Automata

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1. Narrative of 2003 activities:

Using longitudinal household survey data collected in 1990 and 1999, a 2000 community survey, a multi-resolution remote sensing time-series, GIS coverages of resource potentials and endowments, and field verification and geodetic control data, we analyze the determinants of changes in LCLU at the plot, sector, and regional levels, and for annual and decadal periods. The fundamental research questions revolve around (a) the rates, patterns, and mechanisms of forest conversion to agricultural and urban uses; (b) the relative importance of exogenous and endogenous variables on these land uses; (c) the associated ~~scale dependent~~ drivers of LCLU dynamics and patterns operating across socio-economic and demographic, biophysical, and geographical domains and different scales; (d) rates and patterns of land conversion from forest to agricultural crops, pasture, secondary plant succession, and urbanization, as well as ~~the rate and pattern~~ of land abandonment at the farm level; and (e) plausible scenarios of future land cover change and their policy implications as assessed through multi-level models that are responsive to multi-scale effects as well as spatial simulations of LCLU dynamics through a cellular automata (CA) approach.

The survey periods and the assembled satellite time-series images serve as our reference dates that are integrated to define relationships through (1) multivariate logit models of LCLU for 1990, 1999, and for changes between those two survey periods; (2) satellite image classifications and change-detections of LULC dynamics, space-time trajectories of pixel histories, and pattern metrics of landscape organization to define LCLU composition and spatial structure; (3) LCLU simulation through cellular automata (CA), informed by the satellite and multivariate models of LCLU change, to create spatial simulations of LCLU dynamics; and (4) multi-level models to integrate variables and effects from multiple scales into an integrated model of LCLU dynamics to assess the scale dependence of variable interactions on LCLU patterns.

The analysis is framed within a dynamic systems approach that emphasizes non-linear relationships, feedback mechanisms, and critical thresholds in population-environment interactions. Theoretical foundations include principles involving the interplay of political ecology, human ecology, landscape ecology, and complexity theory. ~~Did we mention complexity th in the proposal? I doulbt if we will get to it without nsf $. Is it desirable to mention it here, in~~

~~case of later not doing it? Also, we should talk about what feedbacks might be some day, and where they could fit it.~~

The multi-level models are used to integrate household, community, and regional variables that impact household decision-making and hence the mapped LCLU patterns at the farm level. The spatial simulations are developed through CA approaches at the annual and decadal scales. Linear and non-linear responses or "critical landscapes" are studied to model the ecological responses to a range of spatial patterns of LCLU derived through hypothetical, modeled, and observed conditions. The multi-level models are assessed through statistical measures of model performance, whereas the derived CA patterns are compared to the actual patterns represented in the satellite time-series and assessed through image change-detections, change trajectories or pixel histories, and summary correlations and pattern metrics for comparisons of expected vs. observed LCLU patterns. System behaviors are interpreted within a policy-relevant context by comparing simulated LCLU scenarios to targeted land management outcomes. Multiple LCLU change scenarios are developed around defined policy goals. Model convergence and variable sensitivity are examined relative to the LCLU patterns, model variables, and policy goals and expectations.

Specific areas of research are briefly described below:

(a) Longitudinal studies examining socio-demographic and other contextual factors are vital to understanding landscape change. Landscape structure, function, and change were assessed for the northern Ecuadorian Amazon by examining the composition and spatial organization of deforestation, agricultural extensification, and secondary plant succession at the farm level in 1990 and 1999 through the integration of data from a satellite time-series, a longitudinal household survey, and GIS coverages. Pattern metrics were calculated at the farm level through the generation of a hybrid land use and land cover (LCLU) digital classification of Landsat Thematic Mapper (TM) data. Population, labor, and other household variables were generated from a scientific sample of survey farms or *fincas* interviewed in 1990 and resurveyed in 1999. Topography, soils, distance, and geographic accessibility measures were derived for sample farms through a GIS as well as qualitative assessments from household surveys. Generalized linear mixed models (GLMMs) were generated for 155 and 157 *fincas* in 1990 and 1999, respectively, using pattern metrics at the landscape level as dependent variables, and biophysical, geographical, and socio-economic/demographic variables as independent variables. The models were derived to explore the changing nature of LCLU at the *finca* level by assessing the variation in the spatial structure or organization of farm landscapes in 1990 and 1999. Results indicate rapid population growth causing substantial subdivision of plots, which in turn has created a more complex and fragmented landscape in 1999 than in 1990. Key factors predicting landscape complexity are population size and composition, plot fragmentation through subdivision, expansion of the road and electrical networks, age of the plot ~~(1990 only)~~, and topography. ~~The r~~Research results demonstrate~~s~~ that the process of combining data from household surveys, satellite time-series images, and GIS coverages provide an ideal framework to examine population–environment interactions, and that the statistical models develop~~present~~ed are powerful tools to combine such data in an integrated way.

(b) Multi-thematic and spatially-explicit data were combined from a longitudinal socio-economic and demographic survey conducted in 1990 and 1999, GIS coverages of resource endowments

and geographic accessibility, and a classified Landsat Thematic Mapper (TM) satellite time-series. The goal was to combine such data with expert knowledge, a set of analytic results, and dynamic modeling approaches to describe, explain, and explore the causes and consequences of LCLUC in the northern *Oriente* region of the Ecuadorian Amazon. First, a cellular automaton (CA) model representing LUCC was developed using a time-series of remotely sensed Landsat TM images for a 90,000 ha intensive study area (ISA) within the region and calibrated using alternate images from the time-series. The classified images were linked to spatially-referenced biophysical and socio-economic coverages used as input data, and then combined with "rules" derived from empirical analyses. Second, the CA model was used in dynamic simulations to explore LCLUC as both causes and consequences of: (a) road development, (b) agricultural extensification and land abandonment, (c) major shifts in world markets and crop prices, and (d) urban expansion of the central city, Lago Agrio, within the region. Should we say the following sentence? Finally, Complexity Theory was explored within the spatial and temporal dynamics associated with population-environment interactions, particularly, deforestation and subsistence and commercial cultivation of agricultural crops on lands made accessible by petroleum company-built roads and the corresponding in-migration of spontaneous colonists beginning in the late 1960s. This research contributes to the study of population-environment interactions in a frontier environment, and examines how dynamic and complex systems can be modeled using cellular automata-based spatial simulations.

(c) Isnt this nsf instead? Geographic phenomena derive from nonlinear interactions among heterogeneous agents across space-time scales and can be characterized as complex systems. Such complex systems call for the perspectives of complexity theory. Complexity theory offers richer insights, particularly, for dynamic systems, including land use and land cover dynamics and ecological dynamics. Recent development of computational framework such as cellular automata and agent-based modeling developed in tandem with this paradigm. The principles of complexity theory and its application on geographic research were examined. An analysis of treeline advance in an alpine ecotone was described which reveals endogenous fractal dynamics in power laws showing Self-Organized Complexity in power laws in space and time. Further, we examined how the principles elucidated at treeline could help understand land-use/land-cover change dynamics in Amazonian Ecuador, where the spatial pattern of deforestation resulting from nonlinear relationships with feedbacks also follows power laws. Complexity theory is useful for generating hypotheses of geographic phenomena where systems have spatially mediated positive feedbacks.

(d) Ecuador had the highest deforestation in South America between 1990 and 2000, with most of the forest clearing occurring in the Amazon. While tThere have been several studies of that explain the factors driving deforestation, however, the study of successional forests has received little attention. In the Ecuadorian Amazon study region of migrant colonists, few forest patches can be considered pristine, primary forests, in the sense that they always have been human spaces. Therefore, demographic and socioeconomic changes over the past three decades have been drivinge the development of successional vegetation. The objectives of this sub-study are to: (a) quantify the extent, rate, and pattern of forest regeneration; and (b) model itsthe demographic and socioeconomic drivers of forest succession and the landscape strata of land conversion through deforestation, agricultural extensification and intensification, and urbanization (direct and indirect effects). The analysis is based partly on a satellite image time-

series to estimate extent, rate, and pattern of secondary successional forest. Longitudinal household survey data (1990 and 1999) and a community survey (2000) are also used to explore demographic and socioeconomic drivers of regeneration. Multivariate statistics are used to establish the significant relations between succession rates and patterns and socioeconomic and demographic drivers, within the context of a frontier environment, with implications for . ~~The research will be framed within~~ environmental policy and management ~~as it informs questions~~ of ~~development and~~ conservation.

2. Narrative of 2004 Workplan:

The tropical rainforest of northeastern Ecuador is an area of complex interactions among a number of important and diverse stakeholders -- (a) spontaneous colonists who have in-migrated from other regions of the country and settled on household farms; (b) newly emerging communities and market centers that are~~have~~ consolidat~~ed~~ing services, providing~~offe~~ off-farm employment to colonists, and influencing~~affect~~ land use/land cover (LULC) through direct and indirect ways; (c) indigenous people who follow traditional subsistence practices, but are increasingly affected by increasing ~~the rise of~~ commercial~~ization of their~~ agriculture, oil production ~~with~~in their ~~historical~~ territories, and a~~n ongoing~~ transition to a consumer-market based economy; (d) oil companies~~exploiters~~ which ~~who~~ have built roads and laid pipelines for petroleum extraction in both colonist and indigenous areas; and (e) conservation and protected areas established by the government to impede~~d~~ development and retain biodiversity in a rapidly transforming frontier environment.

The greatest changes on the land are those created by agricultural colonists following in the wake of oil exploration who gained access on roads that made isolated forest domains~~areas~~ accessible for development. However, interactions among the actors above ~~groups and the regions that they've settled~~ are complex, partly because of f~~f~~eedbacks ~~between spatial patterns and rates of change are known to occur at advancing fronts, particularly in frontier environments. Feedbacks~~ which alter~~constrain the~~ changes in LULC ~~by viewing them as system dynamics~~ in state space. Thus~~In this way~~, properties emerging from local non-linear feedbacks (such as power-law distributions of land change in space and time and regional linear correlations) constrain the evolving patterns of land use. We hypothesize that critical points in the spatial structure of LULC patterns and feedbacks have produced a system with potential alternative states and dynamics characterized by phase changes. Fundamental questions revolve around (a) rates, patterns, location, and mechanisms of deforestation and agricultural extensification and intensification by spontaneous colonists and indigenous communities, urbanization patterns and road accessibility, conservation forests, and feedbacks between LULC patterns and processes, (b) identification of critical thresholds and feedbacks that alter the trajectories of LCLU patterns, and (c) uncertainties between LULC change patterns and processes due to system dynamics. This project is examining these questions.

~~This research builds on our prior studies within the Ecuadorian Amazon in which a diverse set of data were collected -- longitudinal surveys of colonist households and farms (1990 & 1999), a survey of colonist communities (2000), a survey of households within indigenous communities (2001), an ethnographic survey of indigenous groups (2001), an assembled satellite time series (1973-2002), and GIS coverages of infrastructure, geographic access, and resource~~

~~endowments. Ok, but dup of above.~~ Using logistic regression and multilevel models, the data are being~~will be~~ integrated to examine LULC decision-making at the household level as the basis for defining transition or growth rules for ~~our~~ cellular automata simulations of LCLU change. Our agent-based models use data from the surveys and ~~will act on LCLU mapped by the~~ satellite time-series to produce parameters incorporated in ~~and simulated through~~ the CA models, which~~,~~ in turn~~, will~~ create additional layers of information for CA model updates.

In sum, our research seeks to understand complex relationships between ~~ity in a~~ human behavior and land use on a settlement frontier by examine~~consider~~ing the roles of ~~positive~~ feedbacks in the spatial patterns of LCLU change. We are ~~will~~integrating~~e~~ exogenous and endogenous drivers to represent a complex and diverse set of forces and factors operating in the Ecuadorian Amazon, which together affect LCLU change patterns in fundamental ways. This work will have important policy implications, which we have positioned ourselves for in 2003 through workshops in the Ecuadorian Amazon and in Quito, and developing a written agreement with the main policy-makers responsible for the region, ECORAE and the Ministry of Environment.

Examples of specific research topics for 2004 are briefly described:

(a) Human settlements in frontier environments combine endogenous and exogenous drivers; are characterized by a number of positive feedbacks between the spatial pattern of settlement and socio-economic, demographic, and ecological processes; and can be viewed ~~are described~~ as complex systems exhibiting emergence, self-organizing processes, and criticality. Using a longitudinal survey of farms in 1990 and 1999, a community survey in 2000, a satellite time-series, and GIS coverages of geographic accessibility and resource endowments, CA models will be developed to examine LCLU dynamics in the northeastern Ecuadorian Amazon. Beginning in the early 1970s, roads were built by the petroleum companies in the northern Ecuadorian Amazon to explore and extract oil by laying pipelines. Once the region became accessible, many families migrated to the region in search of land. Forests were cleared, and farms of about 50- ha were established to cultivate crops for subsistence and sale. While these small-scale farmers have been the primary direct agents of land conversion in the region, local communities also affect LCLU both directly through urban expansion and indirectly through providing off-farm employment, markets for sale~~local consumption~~ of farm and forest products, and ~~market~~ links to the global economy. CA models will be developed to assess the effects of urbanization on the "absorption" of land and the increasing fragmentation of forests and agricultural plots resulting from increasing accessibility and population growth~~through in-migration and high fertility levels~~. Positive feedbacks between spatial patterns and development ~~processes~~ will be constrained by ecological settings and socio-economic conditions.

(b) Socioeconomic, demographic, geographic and natural resource conditions~~land use factors~~ are being currently investigated~~will be used~~ to explain income levels and differences of~~among~~ farm households in the Ecuadorian Amazon, with important practical implications for improving farmer livelihoods and policy. It is a considerable undertaking to estimate settler household incomes from survey data for 1999, and to compare it with earlier estimates for 1990, but this work has been mostly completed. We are~~will also~~ thus now able to compar~~e~~ the results for 1999 with those found by Murphy et al. (1997) based on the 1990 sample in the same study area, to study factors responsible for improvements and declines in settler family welfare over time. and

use GIS to determine levels of accessibility and to characterize the spatial distribution and patterns of income in 1999. We expect that the~~Our~~ results will~~are likely to~~ show that income level~~s~~ and inequality are ~~is mainly explained~~affected by ~~the effects of~~population growth as well as the development of roads and local market towns in the Amazon region, ~~due both to high fertility and continuing in-migration,~~ with population growth increasing~~in extending~~ pressure~~s~~ on the limited supply of land. Furthermore, increasing population mobility of settler households manifest mostly in out-migration of children reaching adulthood (another topic of current study) as a way to diversify risk and income sources has not significantly attenuated poverty in the Ecuadorian Amazon.

(c) Agricultural expansion on small farms in the tropics has been identified as the primary cause of global forest clearing. Virtually all frontier dwellers make their living through agriculture. Variations in land clearing are dependent on farmer trade-offs between agricultural intensification and extensification (the increase in production per unit area over time and the expansion of agricultural production to undeveloped land, respectively). Policy i~~I~~nterventions aimed at promoting intensification and discouraging extensification can modify farm management strategies to the benefit of people and forests. Despite a spate of literature on the determinants of forest clearing on the frontier, we know ~~relatively~~ little about the determinants of adopting agricultural intensification strategies and their correlation to LCLUC. This research examines changes in agricultural intensification in the Northern Ecuadorian Amazon from 1990 to 1999 through novel applications of statistical analysis, and addresses a number of methodological deficiencies in current research. First, longitudinal data will be used to ascertain causal mechanisms that can more faithfully inform policy interventions. R~~elated~~ research to date draws~~makes~~ inferences based ~~solely~~ on case studies ~~derived~~ from cross-sectional data, which have inherent limitations relative to longitudinal data. Second, we are using ~~propose~~a range of intensification measures derived from~~based upon~~ household survey responses ~~that are able~~ to ~~detect (1)~~identify various manifestations of ~~actual~~ intensification occurring over time, determine what are the main factors affecting intensification decisions, and what are the trade-offs with extensification (or further land clearing). ~~and (2) means to intensification. Third, we will apply the first~~ M~~m~~ulti-level ~~model to the analysis of household land use strategies (i.e., intensification vs. extensification). These~~ models ~~will~~are being estimated to ~~enable an~~ assess~~ment of~~ the effects of household, community, and regional demographic, political, socioeconomic, ecological, and geographical factors on~~influencing~~ household-level changes in ~~pasture and crop~~ extensification ~~on the one hand,~~ and agricultural intensification~~ on the other~~. Households in our ~~sample~~sample have now been~~are~~ linked to the~~ir~~ nearest community, which is itself nested within the influence spheres of one of four primary "cities" in the region, reflecting the apparent flow of goods and services from larger to smaller communities and eventually to/from farm households. These household-community linkages form the basic hierarchical structure of the statistical model and assist in the formulation of a spatial and temporal neighborhood. One of the underlying themes for this research, which affects the statistical validity of ~~any~~ inferences ~~made~~, is the extent to which demographic, socioeconomic, and ecological factors are spatially autocorrelated. Spatial autocorrelation decreases the amount of information available to test hypotheses. The applied statistical models are~~will~~ therefore explicitly test~~ing~~ and controll~~ing~~ for ~~any~~ autocorrelation ~~present~~.

(d) Recent studies on the Amazon have focused on deforestation and changes in land use using data from remote sensing imagery, and, to a lesser extent, household surveys. The focus has been on the environmental degradation of tropical forests rather than the living conditions of the migrant settler families directly responsible for much of the degradation. Our~~This~~ research is~~will~~ explicitly examin~~e~~ing settler wealth and incomes in the area of most intensive colonization in the Ecuadorian Amazon. Following the discovery of petroleum in 1967, oil companies built roads ~~to lay pipelines to extract oil for piping across the Andes for export. The roads~~which opened the region to massive spontaneous in-migration of families ~~from origin areas characterized by lack of land and rural poverty~~. As a result, settlers cleared forests to establish farms (40-50 ha), where they planted subsistence and cash crops (coffee) and over time acquired cattle, resulting in further forest clearing. A representative probability sample of farms was selected in this area of intense in-migration in 1990 to implement a household survey on land use of colonist families on 408 farm plots. The survey provide~~s~~d information on agricultural production, inputs, assets, earnings from off-farm work, net remittances, etc., which permitted determining levels of income and wealth of all families. This revealed generally low income levels, often even lower than in places of origin. ~~Factors determining levels of and variations in household income were analyzed as well. In 1999 a follow-up survey was carried out on all farm households living on the same plots of land visited in 1990, providing longitudinal data. However, many plots had been subdivided in the intervening years, resulting in fragmented plots, further deforestation, increased off-farm employment, and less cattle raising.~~ In recent work~~this paper~~, we present estimates of household incomes and wealth in 1999, and compare them with 1990, to assess changes in settler family welfare over time, as well as what socioeconomic, demographic, land use, and other factors explain the difference. As far as we are aware, this has not been done before in studies of land use in the tropics.

3. Description of any difficulties encountered or any issues to resolve (if needed):NA

4. Description of training activities conducted in 2003, including lectures, public outreach, and short courses:

Through funds granted to the Carolina Population Center through the Fogarty Foundation, ~~a~~ proposals w~~as~~ere developed and funded to have two Ecuadorian collaborators, Francis Baquero and Bolier Torres, participate in project research and obtain training in remote sensing, GIS, ecological analysis, and demographic survey techniques on the campus of the University of North Carolina–Chapel Hill ~~with~~in the Carolina Population Center and the Department of Geography, for a 6-month period beginning in ~~mid-~~January 2003. In addition, they participated in a graduate-level seminar in Geography taught by Professor Stephen J. Walsh on population-environment interactions with an emphasis on landcover/landuse dynamics and modeling approaches. Professor Richard E. Bilsborrow also participated in the Seminar through a guest lecture on elements of the Ecuador project, ~~on~~ the longitudinal nature and advantages of the socio-economic and demographic survey and how multi-level models can be~~are~~ used to integrate household- and community-level effects in statistical models. Baquero worked mainly in the Spatial Analysis Lab of the Carolina Population Center on image processing and GIS activities, while Torres focused ~~on elements of~~ estimating household incomes for 1999 from the

socio-economic and demographic survey data, working with Bilsborrow and a UNC doctoral student from Brazil. In addition, Baquero accompanied Walsh and the Spatial Team to Ecuador for summer 2003 field work, and Torres accompanied Bilsborrow to Quito and the Oriente for to design and implement very successful workshops and to develop the written agreement with key government policy institutions, cited above. and socio-economic and demographic field work The visit of the Spatial Team Team to collect additional data in the field also included other students from the UNC-Department of Geography (Chris Erlien and Carlos Mena), Professor Joe Messina (a project sub-contractor at Michigan State University) and his doctoral student, as well as the lead UNC spatial programmer (Phil Page) and spatial analyst (Brian Frizzelle). Data were collected to validate LCLU classifications and fractional cover classifications. Erlien, funded through other sources, also attended a short course for Spanish language training in Ecuador following the field work.

Conference Presentations:

Barbieri, A.F. and R.E. Bilsborrow. 2003. Population Distribution on the Frontier: Changing Migration Patterns and Urbanization in the Ecuadorian Amazon in the 1990's. International Conference on Social Sciences, Honolulu, Hawaii.

Barbieri, A.F., R.E. Bilsborrow, C.F. Mena, W. Pan, B. Torres. 2003. Changes in Land Cover and Land Use Over Time in the Ecuadorian Amazon. Association of American Geographers, New Orleans.

Barbieri, A.F. and D.L. Carr. 2003. Gender-Specific Out-Migration and Deforestation in the Ecuadorian Amazon. International Young Scientists' Global Change Conference, Trieste, Italy.

Barbieri, A.F., C.F. Mena, C.M. Erlien, R.E. Bilsborrow, B. Torres. 2003. Settler Welfare and Land Use in the Ecuadorian Amazon. Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Montreal, Canada.

Bilsborrow, R. E., and B. Torres, 2003. Settler Incomes and Welfare in the Amazon in 1999. Presentation to Ministry of Environment and ECORAE. Quito, Ecuador. July.

Bilsborrow, R. E., B. Torres, C. Mena, and F. Baquero, 2003. Settler Incomes and Welfare in the Amazon in 1999. Workshops (in Spanish) for migrant colonist households and policy makers. Lago Agrio, Coca, Ecuador. July.

Carr, D., R.E. Bilsborrow, A.F. Barbieri. 2003. Population, Agricultural Land Use and the Environment in Latin America at the Turn of the Millennium. Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Montreal, Canada.

Frizzelle, B.G., S.J. Walsh, C.M. Erlien and C.F. Mena. 2003. Establishing Control in a Frontier Environment: The Case of the Ecuadorian Amazon. Annual Conference of the American Society for Photogrammetry and Remote Sensing, Anchorage, Alaska.

Mena, C.F., C.M. Erlien, S.J. Walsh. 2003. Modeling the Scale Dependent Drivers of LCLU Dynamics in Northeastern Ecuador: Simulating Patterns of Landscape Change and Assessing their Cause and Consequences through Multi-Level Models and Cellular Automata. Association of American Geographers, New Orleans.

Pan, William, A.F. Barbieri and R.E. Bilsborrow. 2003. Agricultural Change in the Ecuadorian Amazon: Land use Transitions from 1990 to 1999. International Workshop "Transition in Agriculture and Future Land Use Patterns", Wageningen, The Netherlands.

Pan, W.K.Y. and D. Carr. 2003. Multi-Level Factors Influencing Land Use Changes in the Ecuadorian Amazon. International Young Scientists Global Change Conference, Trieste, Italy.

Walsh, S.J. 2003. Trajectories of Land Change in Southeast Asia. Focus 1 – Land Use Dynamics, Indiana University, Bloomington, Honolulu, Hawaii.

Walsh, S.J., R.R. Rindfuss, B. Entwisle, Y. Shao, D.J. Weiss, P.M. McDaniel, R.E. Pullen, 2003. Characterizing Land Use/Land Cover Change in Northeast Thailand and Analyzing the Causes and Consequences of Landscape Dynamics. 30th International Symposium on Remote Sensing of Environment, Honolulu, Hawaii.

Walsh, S.J., B.L. Turner II, R.R. Rindfuss, V. Mishra, J. Fox, 2003. Challenges in Understanding Human Impacts on Land-Use and Land-Cover Change. Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Montreal, Canada.

Walsh, S.J. and J.P. Messina, 2003. LULC Dynamics in the Northern Ecuadorian Amazon. The Ecuadorian Minister of the Environment, Quito, Ecuador.

Walsh, S.J. 2003. Biocomplexity and Geographers – How can Geographers be Leaders in the NSF Biocomplexity in the Environment Program (Panelist). Association of American Geographers, New Orleans, LA.

Zeng, Y., G.P. Malanson, S.J. Walsh, 2003. Searching for Geographic Complexity. East-West Division, Association of American Geographers, Kalamazoo, MI.

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6. The LBA-ECO Program Manager strongly supports the goal articulated in November by the LBA Science Steering Committee in Fortaleza that all LBA publications be linked to data sets registered in the LBA DIS.

Data sets and related publications (DO NOT EDIT HERE):

Data Set Title: 1999 Household Survey in the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Social/Ecuador_socioec_surveys.doc
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Social/Esposa_household.pdf
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Social/Jefe_household.pdf

Data Set Title: 2.5D Morphogenesis: Modeling Landuse and Landcover Dynamics in the Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Boundary for the North ISA in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/bnd_nisa.e00

Data Set Title: Boundary of the Cuyabeno Wildlife Reserve
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/cuyabeno.e00

Data Set Title: Boundary of the East ISA in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/bnd_eisa.e00

Data Set Title: Boundary of the South ISA in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/bnd_sisa.e00

Data Set Title: Boundary of the Southwest ISA in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/bnd_swisa.e00

Data Set Title: Boundary of the Yasuni National Park
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/yasuni.e00

Data Set Title: Community locations in the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Shapefiles/communities_primary_shp.zip

Data Set Title: Detailed Plot Data for Fincas (farms) from the Northern Ecuadorian Amazon 1999 Household Survey
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Digital Elevation Model for Ecuadorian Eastern Intensive Study Area

Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/east_dem.e00

Data Set Title: Digital Elevation Model for Ecuadorian Northern Intensive Study Area
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/north_dem.e00

Data Set Title: Digital Elevation Model for Ecuadorian Southern Intensive Study Area
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/south_dem.e00

Data Set Title: Eastern Intensive Study Area Terrain Aspect
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/east_aspect.e00

Data Set Title: Eastern Intensive Study Area Terrain Slope
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/east_slope.e00

Data Set Title: Ecuador National Boundary
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/bdr_ecuador.e00

Data Set Title: Ecuador Provincial Boundaries
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/ec_provinces.e00

Data Set Title: Elevation Contour Vectors for the East Intensive Study Area in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/ctr_east.e00

Data Set Title: Elevation Contour Vectors for the North Intensive Study Area in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/ctr_north.e00

Data Set Title: Elevation Contour Vectors for the South Intensive Study Area in Ecuador
Related Publications: None currently listed

Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/ctr_south.e00

Data Set Title: Elevation Points for the North Intensive Study Area in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/pt_north.e00

Data Set Title: Elevation Points for the South Intensive Study Area in Ecuador
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/pt_south.e00

Data Set Title: Household and Finca GPS Data from the 1999 Northern Ecuadorian Amazon
Household Survey
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Land Use Land Cover Classification (1986) for the East Intensive Study Area in
the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class86_eisa.e00

Data Set Title: Land Use Land Cover Classification (1996) for the East Intensive Study Area in
the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class96_eisa.e00

Data Set Title: Land Use Land Cover Classification (1996) for the Southwest Intensive Study
Area in the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class96_swisa.e00

Data Set Title: Land Use Land Cover Classification (1999) for the East Intensive Study Area in
the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class99_eisa.e00

Data Set Title: Land Use Land Cover Classification (1999) for the Southwest Intensive Study
Area in the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):

ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class99_swisa.e00

Data Set Title: Major Cities in the Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Shapefiles/oriente_cities_poly_shp.zip

Data Set Title: Northern Ecuadorian Amazon Aerial Photographs (1979 and 1990)
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Northern Ecuadorian Amazon Hydrography (1:250,000 - PROFORS)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/hy_profors.e00

Data Set Title: Northern Ecuadorian Amazon Landsat MSS Imagery (1973 - 1987)
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Northern Ecuadorian Amazon Landsat TM Imagery (1984 - 2002)
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Northern Ecuadorian Amazon Morphology and Edaphology
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/morfo.e00

Data Set Title: Northern Intensive Study Area 1986 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class86_nisa.e00

Data Set Title: Northern Intensive Study Area 1989 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class89_nisa.e00

Data Set Title: Northern Intensive Study Area 1996 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class96_nisa.e00

Data Set Title: Northern Intensive Study Area 1999 LULC Classification (General)
Related Publications: None currently listed

Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class99_nisa.e00

Data Set Title: Northern Intensive Study Area Terrain Aspect
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/north_aspect.e00

Data Set Title: Northern Intensive Study Area Terrain Slope
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/north_slope.e00

Data Set Title: Point Elevations for Ecuadorian Eastern Intensive Study Area
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/pt_east.e00

Data Set Title: Road network for Northern Ecuadorian Amazon
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/trn_oriente03.e00

Data Set Title: Sample Fincas (farms) from the Northern Ecuadorian Amazon 1999 Household
Survey
Related Publications: None currently listed
Data Download URL(s):

Data Set Title: Southern Intensive Study Area 1986 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class86_sisa.e00

Data Set Title: Southern Intensive Study Area 1996 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class96_sisa.e00

Data Set Title: Southern Intensive Study Area 1999 LULC Classification (General)
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/class99_sisa.e00

Data Set Title: Southern Intensive Study Area Terrain Aspect
Related Publications: None currently listed

Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/south_aspect.e00

Data Set Title: Southern Intensive Study Area Terrain Slope
Related Publications: None currently listed
Data Download URL(s):
ftp://lba.cptec.inpe.br/lba_archives/LC/LC-01/Erlien/Coverages/south_slope.e00

7. List of publications (2003-2004) in the primary scientific literature (in print, in press, and submitted) directly funded by NASA's LBA-ECO component.

Barbieri, A.F. 2003. Comment on "Proximate Causes and Underlying Driving Forces of Tropical Deforestation", published by Helmut Geist and Eric Lambin (2002) in *Bioscience* 52(2): 143-150. *Expert Panel on Population and Deforestation*, *Population and Environment Research Network*.

Fox, J., Rindfuss, R.R. Walsh, S.J., Mishra, V. (editors). 2003. *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*. Kluwer Academic Publishers: Boston, 319p.

Frizzelle, B.G., Walsh, S.J., Erlien, C.M., Mena, C.F. 2003. Collecting Control Data for Remote Sensing Applications in the Frontier Environment of the Ecuadorian Amazon. *Earth Observation Magazine*, 12 (7): 20-24.

Frizzelle, B.G., Walsh, S.J., Erlien, C.M., Mena, C.F., Baquero, F.D. 2003. Establishing Control in a Frontier Environment: The Case of the Ecuadorian Amazon. *Proceedings, American Society for Photogrammetry and Remote Sensing*, Anchorage, Alaska (CD-ROM).

Rindfuss, R.R., Walsh, S.J., Mishra, V., Fox, J., Dolcemascolo, G.P., 2003. Linking Households and Remotely Sensed Data: Methodological and Practical Problems. In: *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS,* (J. Fox, R.R. Rindfuss, S.J. Walsh, V. Mishra, editors), Kluwer Academic Publishers: Boston, 1-29.

Walsh, S.J., Bilsborrow, R.E., McGregor, S.J., Frizzelle, B.G., Messina, J.P., Pan, W.K.T., Crews-Meyer, K.A., Taff, G.N., Baquero, F.D. 2003. Integration of Longitudinal Surveys, Remote Sensing Time-Series, and Spatial Analyses: Approaches for Linking People and Place. In: *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS,* (J. Fox, R.R. Rindfuss, S.J. Walsh, V. Mishra, editors), Kluwer Academic Publishers: Boston, 91-130.

Walsh, S.J. and Welsh, W.F., 2003. Approaches for Linking People, Place, and Environment for Human Dimensions Research. *GeoCarto International* 18(3): 51-61.

Pan, W., S.J. Walsh, R.E. Bilsborrow, B. Frizzelle, C. Erlien, F. Baquero. 2004. Farm-Level models of Spatial Patterns of Land Use and Land Cover Dynamics in the Ecuadorian Amazon. *Agriculture, Ecosystems and Environment*, in press.

Rindfuss, R.R., Turner II, B.L., Entwisle, B., Walsh, S.J., 2003. *Land Cover/Use and Population. Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface* (G. Gutman, editor), Kluwer Academic Publishers, in press.

Rindfuss, R.R. Walsh, S.J., Turner II, B.L., Moran, E.F., Entwisle, B., 2003. Linking Pixels and Pixels. *Land Change Science: Observing, Monitoring, and Understanding Trajectories of*

Change on the Earth's Surface (G. Gutman, editor), Kluwer Academic Publishers, in press.

Walsh, S.J., Crews-Meyer, K.A., Crawford, T.W., Welsh, W.F. 2004. Population and Environment Interactions: Spatial Considerations in Landscape Characterization and Modeling. *Scale and Geographic Inquiry: Nature, Society, and Method* (R. McMaster and E. Sheppard, editors), Blackwell Publishers, in press.

Walsh, S.J., Evans, T.P., Turner II, B.L., 2004. Population-Environment Interactions with an Emphasis on LULC Dynamics and the Role of Technology. In: *Technology and Geography: A Social History* (S.D. Brunn, S. Cutter, J.W. Harrington, Jr., editors), Kluwer Academic Publishers, in press.

Walsh, S.J., Messina, J.P., Zonn, L. 2004. Deforestation of the Ecuadorian Amazon: Characterizing Patterns and Associated Drivers of Change. *WorldMinds* (Warf, B., Janelle, D., Hansen, K., editors). Association of American Geographers, in press.

Bilsborrow, R.E., A. Barbieri, W. Pan, 2004. Changes in Population and Land Use over Time in the Ecuadorian Amazon. ~~Submitted to~~ *Acta Amazonica* (Brazil), in review.~~.~~

Malanson, G.P., Y. Zeng, S.J. Walsh. 2003. Complex Frontiers in the Ecuadorian Amazon. *Environment & Planning A*, in review

Mena, C.F., R.E. Bilsborrow, M.E. McClain. 2003. Socioeconomic drivers of deforestation in the Napo Basin of Ecuador. *Environmental Management*, in review.

Messina, J.P. and Walsh, S.J., 2003. Dynamic Spatial Simulation Modeling of the Population-Environment Matrix in the Ecuadorian Amazon. *Environment and Planning B*, in review

Pan, W.K.Y., R.E. Bilsborrow, L. Murphy, 2004. Household Socio-demographic and Ecological Factors Affecting Land Use in the Northern Ecuadorian Amazon. ~~Submitted to Demography~~, in review.~~.~~

8. Any other publications that you would like to include (e.g. commentaries, letters to the editor, articles in popular magazines): NA

9. Participants: Please indicate in the "People to Remove from LC-01" section any people listed below who are no longer participating with your team. In the "People to Add to LC-01" section, please give the name and email address of any person currently participating with your team but who is not listed below.

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