Progress Report 2004

Grant number: NCC5-699

Investigation Group: LC-01

Title: 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

PIs:
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1. Narrative of 2004 activities:

(a) Research Symposium in Quito, Ecuador; June 10, 2004, *Drivers of Land Use/Land Cover Dynamics in the Ecuadorian Amazon*

The UNC-Chapel Hill Ecuador-NASA Project Team, led by Co-PIs Richard E. Bilsborrow and Stephen J. Walsh, presented research findings associated with the NASA Ecology-LBA Phase I and Phase II projects funded to Bilsborrow and Walsh through the NASA Land Cover/Land Use Change Program, Dr. Garik Gutman, Program Manager. The half-day Symposium was presented at the Hotel Quito to Ecuadorian government officials, non-government organizations, university faculty and students, consultant groups, and other interested parties. Nearly 100 participants heard presentations from the UNC Project Team, viewed power-point graphics, and received a CD-ROM of selected project papers (abstracts translated into Spanish), data sets, maps, and contact information of project team members and the UNC Ecuador and NASA Project web sites.

(b) Training of Mr. Bolier Torres, Ministry of the Environment, Quito, Ecuador; September, 2004. Training at the UNC Carolina Population Center centered on questionnaire survey design and data linking for tracking the interactions between people, place, and the environment.

(c) Field research was conducted in the northern Ecuadorian Amazon during the summer of 2004 that emphasized the (a) links between household farms (*fincas*) and local and regional communities within the Ecuadorian Amazon to inform our multi-level modeling activities; (b) validation of a detailed LCLU classification scheme and fractional cover assessment implemented for the assembled Landsat TM time-series of the region; (c) characterization of secondary forest succession and *rastrojo* (young successional vegetation) to guide the development of spatial simulation models of LCLU change through growth or transition rules within a cellular automata (CA) environment.

(d) Considerable progress has been made in the development of a CA model of LCLU change. The primary LCLU types included in our model include primary forest, successional forest (secondary forest/*rastrojo*), agriculture, pasture, urban/barren, and water. Thus far, our models have been limited to the two 90,000 ha intensive study areas in the northern Ecuadorian Amazon center on the principal cities of Lago Agrio and Coca. We have used 1986 as our initial conditions created using our Landsat TM classification of LCLU patterns. The primary features of the model includes (1) starts with 1986 LULC classification, (2) stochastic parameter are used to randomly select cells and "turned on" as new cells of the LCLU class, (3) threshold values are set to determine whether the focal cell of the kernel should change based upon the other cells and a suitability scoring of the input layers, (4) input layers are processed using GIS functions -- greater values indicate a greater likelihood of a cell changing from its initial state to possible outcome state (s), (5) suitability scores are derived to indicate areas of greater/lesser likelihood of change based on multiple criteria, and (6) a masking parameter is applied to the suitability scores to regulate change/no-change cells. The model employs a series of transition rules to guide the simulation process. For instance, for forest/non-forest Vegetation the following rules are used: travel distance to nearest of 3 major communities (lower, greater change probability); travel distance computed as Euclidean distance to the nearest road and then distance along network to the community of reference; Euclidean distance to nearest road (lower, greater change probability); community gravity model (estimated yearly population divided by the log distance to the nearest community; 1990/1999/2000 population counts for most communities from survey data); stochastic parameters (0.001), kernel threshold (6 cells), masking threshold (0.6).

(e) A series of experiments have been devised to assess image change detection approaches for LCLU change mapping. Traditional and experimental approaches have been evaluated for accuracy and appropriateness. They are briefly described below:

- Channel/scene integration: near-infrared channels (e.g., channel 4 of Landsat TM) from scenes of different periods composited as a qualitative method of assessing regional change.
- Multidate composite: multiscene data stack representing different time periods used as the input or feature set for an unsupervised classification for defining change and no-change spectral clusters.
- Principal components analysis: change is assessed through the derivation of eigenvectors that relate spectral channels from scenes collected at different time periods to generate components, and eigenvalues that indicate the percent variance associated with each of the defined components.
- Image algebra: two channels of the same spectral region and wavelengths for two different time periods are ratioed, and image differencing is achieved by subtracting the spectral responses of one date from that of the other.
- Binary mask: uses a multidate image composite recoded into a binary mask consisting of areas, which have changed and not changed between two dates.
- Post-classification: classification of two scenes from different dates assessed on a pixel-by-pixel basis and reported through a change matrix -- two scenes at a time; result is a change image for each date pair, containing a number of change pairs equal to the square

of the number of classes minus some number of illogical change pairs (e.g. Water-Primary Forest)

- Panel Data Analysis: stacks all classification dates together to generate a pixel "life history." Hypothesis is that the nature of the trajectory is associated with the function of the land at that pixel and its neighborhood of similarly related pixels.
- Change Vector Analysis: the change in DN values for multiple spectral bands between two dates (t1 and t2) are analyzed using Euclidean geometry to derive change magnitude (D) and direction.
- Linear Mixture Modeling: decompose pixels into their LULC proportions using endmembers of "pure" pixels using the Ikonos imagery or other "trusted" data sets. Changes can be developed in the continuous patter of LULC proportions using multiple Ikonos images and/or field techniques.
- Markov Transition Probabilities: generates from-to change classes across the image time-series that are based upon probabilities of change.

2. Narrative of 2005 workplan:

(a) Training of Ms. Janina Olmedo, CLIRSEN, Quito, Ecuador

Ms. Olmedo will visit the Carolina Population Center, University of North Carolina – Chapel Hill as a research fellow in our Fogarty International Center Training Program from January, 2005 through May, 2005. The Fogarty Training Grant is designed to provide advanced training in research methods and foster collaboration between research institutions in the U.S. and developing countries. Ms. Olmeda is a spatial analyst at CLIRSEN, a government organization in Quito, Ecuador that emphasizes the mapping and analysis of the environment for studies involving natural resources, population, and development. Ms. Olmedo will work with the Ecuador project team in devising and implementing spatial analyses that transform discrete population variables to continuous representations for linking demographic data to satellite imagery, critical in our study of patterns and drivers of land use/cover change caused by deforestation. In addition, she will help process remotely sensed images, construct maps of roads and other important features of the regional infrastructure of the NEA, generate spatial rules of how people, place, and the environment are integrated, and participate in documentation efforts through the generation of journal papers. Ms. Olmedo's work will be supported by CPC from our Fogarty Training Grant. All travel expenses (airfare, ground transportation, insurance, and per diem) will be covered through this source. Office space and computer network access will also be provided by CPC.

(b) LCLU change in and around the Cuyabeno Wildlife Reserve, located in the northeastern portion of our study area, is being examined using social survey and remote sensing data sets. The Cuyabeno Wildlife Reserve is an approximately 600,000-ha tract of land located in the Northern *Oriente* region of the Ecuadorian Amazon. It was created in 1979 to protect a region of critically important ecological diversity. Its primary rainforest is the home to a host of endemic plants and animals, and ancestral territories of several indigenous groups including the Cofán, Siona, Secoya, and Quichua. Despite its status as a protected area afforded by the Ecuadorian government, the Cuyabeno has been subjected to significant exploitation. In addition, towns adjacent to the Reserve are expanding and indigenous communities living in the Reserve are becoming more integrated into the commercial economy of the region, with serious potential

implications for land use and the Reserve itself. We will examine (1) the former Reserve lands that were surrendered to colonization in 1991 by considering the socio-economic and demographic characteristics of the colonists and land transformation patterns that led to the redrawing of the Cuyabeno boundary; (2) the direct and indirect effects of nearby communities on the Reserve and its immediate vicinity; (3) the importance of the road that cut through the Reserve and focused development along it and intensified the in-migration of colonists leading to a redefinition of the Reserve boundary; and (4) the characteristics of the surveyed indigenous groups living in the Cuyabeno and the implications for the Reserve. In addition, we will examine land use/cover patterns within the context of the conflicts attributed to the emergent land tenure systems within the vicinity of the Reserve and the redefinition of the boundary of the Cuyabeno. We will conduct remote sensing image change detections and track the trajectories of land use/cover change at the patch level to examine the evolving landscape pattern within and adjacent to historical and current boundaries of the Reserve. Using multivariate models, we will relate land use/cover change patterns to characteristics of nearby communities, patch dynamics of forested areas, distance from the historical and contemporary Reserve boundary, accessibility afforded through an expanding road network, and land tenure systems within the region. We will also generate deviations from a neutral model and the uncorrelated pattern metrics as part of the analyses.

(c) As part of our work in Complexity Theory and cellular automata models of LCLU change, we will assess error and uncertainty in spatial simualtion models. The true measure of spatial complexity as applied in a complex model context is one not yet fully realized in the literature. One of the challenges is to use spatial simulations in general and complexity-based methods in particular is answering the question of “what is a good fit?” when spatial simulations are developed for antecedent and future time periods. Without further development of the theoretical underpinnings of complexity theory and spatial pattern, addressing for example, “what is a good fit,” the models run the very real risk of over-specification and unverifiable results. Unanswered questions about the effects of the ecological fallacy and the modifiable areal unit problem can influence model outcomes by affecting the apparent strength and magnitude of relationships between variables. Beyond composition and pattern of model outcomes is the concern to understand complex processes and their characteristics.

(d) Multi-level models will be further developed and applied to our work in the northern Ecuadorian Amazon by estimating the effects of farm-level variables on LCLU taking into account the contextual setting (community) for each farm. Farm-level variables may include demographic characteristics, natural resources, spatial location/distance variables, land tenure, and duration of residence, whereas community-level variables may consist of transportation services/linkages, economic infrastructure such as sawmills, coffee roasters, and the presence of agricultural market, availability of schools, and health facilities. The advantages of multi-level models includes the ability to incorporate a broader theoretical framework, and can be adapted to incorporate spatial tendencies by using measures of spatial autocorrelation. The roadblocks to the use of multi-level models includes the difficulty of linking farms to communities (e.g., farms in same sector sometimes link to different or multiple communities), and the need to develop linking criteria. In addition, the theory to incorporate spatial autocorrelation in multi-level models is not completely worked out and existing software needs to be modified.

3. Description of any difficulties encountered: NA

4. Description of training activities conducted in 2004, including lectures, public outreach, and short courses:

Presentation/Lectures:

Bilsborrow, R.E. 2004. Población, Uso de Tierra y Deforestación en la Amazonía Ecuatoriana: Implicaciones para le Parque Nacional Yasuní. II Congreso Anual sobre las Investigaciones del Bosque Tropical de Ecuador, Mindo, Ecuador.

Erlien, C.M. 2004. Distance Effects on Birth Control and Location of Birth in the Ecuadorian Oriente. Association of American Geographers, Philadelphia, Pennsylvania.

Frizzelle, B.G., S.J. Walsh, C.F. Mena, C.M.. Erlien. 2004. Land Use Change Patterns of Colonists and Indigenous Groups in the Northern Ecuadorian Amazon: A Comparison of Landsat TM Spectral and Spatial Analyses. American Society for Photogrammetry and Remote Sensing, Baltimore, Maryland.

Gray, C.L., J. Bremner, R.E. Bilsborrow. 2004. Land Use by Indigenous Populations in the Northern Ecuadorian Amazon. Association of American Geographers, Philadelphia, Pennsylvania.

Gray, C.L., J. Bremner, F. Holt. 2004. Indigenous Populations and Land Use in the Northern Ecuadorian Amazon. Population Association of America, Boston, Massachusetts.

Holt, F.L. and R.E. Bilsborrow. 2004. Population Pressure and Market Integration among Ecuadorian Native Amazonians: Impacts on Land and Resource Use. Ecological Society of America Annual Meeting, Portland, Oregon.

Malanson, G.P., Y. Zeng, S.J. Walsh. 2004. Frontiers as Frontiers. Association of American Geographers, Philadelphia, Pennsylvania.

Mena, C.F. and S.J. Walsh. 2004. Demographic and Socioeconomic Drivers of Forest Succession in the Northern Ecuadorian Amazon. Association of American Geographers, Philadelphia, Pennsylvania.

Pan, W.K. and C.M. Erlien. 2004. Impact of population-environment dynamics on human health in the Ecuadorian Amazon. American Public Health Association, Washington, D.C.

Torres, B., R.E. Bilsborrow, A.F. Barbieri. 2004. Causes and Consequences of Low Farm Income and Land Use Change from 1990 to 1999: Agro-socio-economic Approaches in the Northern Ecuadorian Amazon. Rural Poverty Reduction through Research for Development and Transformation meeting, Berlin, Germany.

Walsh, S.J. Approaches and Challenges for Characterizing Landscape Dynamics in Coupled Human-Natural Systems. Taaffe Colloquium Series, Department of Geography, Ohio State University, Columbus, Ohio.

Walsh, S.J., 2004. Ecotones and Frontiers: An Overview of Research in Natural and Coupled Human-Natural Systems. Department of Geosciences, Oregon State University, Corvallis, Oregon.

Walsh, S.J. 2004. LCLUC in Thailand & Ecuador: Pattern-Process Relations and Some Research Challenges. Keynote Research Results Presentation at the Land Cover/Land Use Change

Science Meeting: Significant Results, National Aeronautics and Space Administration, College Park, Maryland.

Walsh, S.J. 2004. Linking People and Environment through Studies of Deforestation in the Ecuadorian Amazon. Explore Carolina, University of North Carolina at Chapel Hill.

Walsh, S.J. 2004. Linking People and Place: Assessing Pattern and Meaning through Spatial Digital Technologies. School of Social Work, University of North Carolina at Chapel Hill.

Walsh, S.J., R.E. Bilsborrow, J.P. Messina, G.P. Malanson, C.F. Mena, C.M. Erlien, 2004. Pattern-Process Relationships of Land Use/Land Cover Dynamics in the Ecuadorian Amazon. International Geographical Union, Glasgow, Scotland, UK.

Walsh, S.J., C. Mena, J.P. Messina. 2004. Complexity in the Ecuadorian Amazon Frontier: Influence of Urbanization and Landscape Pattern on LULC Dynamics. Association of American Geographers, Philadelphia, Pennsylvania..

Zeng, Y., G.P. Malanson, S.J. Walsh. 2004. Searching for Complexity on Landscapes. Presented at the 100th Annual Meeting of the Association of American Geographers, Philadelphia, Pennsylvania.

5. NASA Web Site – Registering metadata; sharing data sets with the LBA community; linking publications to data sets registered in the LBA-DIS; and providing good documentation for data sets to be archived (complied and updated).

6. List of LC-01 Publications (2004):

Malanson, G.P., Zeng, Y., Walsh, S.J., 2004. Complexity at Advancing Ecotones and Frontiers. Environment and Planning A. in review.

Malanson, G.P., Zeng, Y., Walsh, S.J., 2004. Frontiers as Frontiers in Landscape Ecology and GIScience. Annals of the Association of American Geographers, in review.

Messina, J.P. and Walsh, S.J., 2004. Dynamic Spatial Simulation Modeling of the Population-Environment Matrix in the Ecuadorian Amazon. Environment and Planning B, in press.

Pan W.K.Y., Walsh S.J., Bilsborrow R.E., Frizzelle, B.G., Erlien, C.M., Baquero, F. (2004) Farm-level models of spatial patterns of land use and land cover dynamics in the Ecuadorian Amazon. Agriculture Ecosystems & Environment, 101, 117-134.

Quattrochi, D.A., S.J. Walsh, J.R. Jensen, M.K. Ridd, 2004. Remote Sensing: Prospects, Challenges, and Emergent Opportunities .In: Geography in America at the Dawn of the 21st Century (G.L. Gaile and C.J. Willmott, editors), Oxford University Press, 376-416.

Rindfuss, R.R., Walsh, S.J., Turner II, B.L., Fox, J., Mishra, V., 2004. Developing a Science of Land Change: Challenges and Methodological Issues. Proceedings of the National Academy of Science, 101(939): 13976-13981.

Rindfuss, R.R., Turner II, B.L., Entwisle, B., Walsh, S.J., 2004. Land Cover/Use and Population. Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface (G. Gutman, editor), Springer Publishers, Publishers, Chapter 20.

Rindfuss, R.R. Walsh, S.J., Turner II, B.L., Moran, E.F., Entwisle, B., 2004. Linking Pixels and Pixels. Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface (G. Gutman, editor), Springer Publishers, Chapter 22.

Walsh, S.J., K.A. Crews-Meyer, T.W. Crawford, W.F. Welsh, 2004. Population and Environment Interactions: Spatial Considerations in Landscape Characterization and

Modeling. Scale and Geographic Inquiry: Nature, Society, and Method (E. Sheppard and R. B. McMaster, editors), Blackwell Publishers, 41-65.

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: Geography and Technology, (S.D. Brunn, S.L Cutter, J.W. Harrington, Jr., editors), Kluwer Academic Publishers, 491-519.

Walsh, S.J., Messina, J.P., Zonn, L. 2004. Deforestation of the Ecuadorian Amazon: Characterizing Patterns and Associated Drivers of Change. World-Minds: Geographical Perspectives on 100 Problems (D.G. Janelle, B. Warf, K. Hansen, editors), Kluwer Academic Publishers, 299-304.

Theses & Dissertations

Doctoral Dissertations

Name	**Year**	**Department**	**Title / *Topic***
Alisson Barbieri	*In progress*	City & Regional Planning	*People, Land, and Context: Temporal and Sp Dimensions of Population Mobility in the Ecu Amazon*
Jason Bremner	*In progress*	City & Regional Planning	*Population Mobility and Land Use among Indigenous Peoples of the Ecuadorian Amazon*
Christine M. Erlien	*In progress*	Geography	*Community Effects on Household Land Use and Land Cover in the Northern Ecuadorian Amazon.*
Clark Gray	*In progress*	Geography	*Rural Out-migration and the Environment in Southern Ecuador.*
Carlos F. Mena	*In progress*	Geography	*Composition, Configuration, and Trajectories of Agricultural and Forest Transitions in the Northern Ecuadorian Amazon: Socio-Economic Drivers and Spatial Simulations*
Michael Bacon	*In progress*	Geography	*Predictions of anthropogenic land cover and use change in the Ecuadorian Amazon using complex models*

7. Participants in LC-01 (see updated affiliations of project participants below)

Name	**Role**	**Organization**
Eduardo Arguello	Parti	Cepar, Quito, Ecuador
Francis Baquero	Parti	EcoCiencia, Quito, Ecuador
Alisson Flavio Barbieri	Parti	Department of City and Regional Planning & Carolina Population Center, University of North Carolina at Chapel Hill
Richard E. Bilsborrow	US-P	Department of Biostatistics & Carolina Population Center, University of No Carolina at Chapel Hill
Jason Lee Bremner	Parti	Department of City and Regional Planning & Carolina Population Center, University of North Carolina at Chapel Hill
Christine Erlien	Parti	Department of Geography & Carolina Population Center, University of No

		Carolina
Brian Frizzelle	Parti	Spatial Analysis Unit, Carolina Population Center, University of North Caro Chapel Hill
Clark Gray	Parti	Department of Geography & Carolina Population Center, University of Nor Carolina at Chapel Hill
George P. Malanson	Parti	Department of Geography, University of Iowa
Galo Medina	Parti	EcoCiencia, Quito, Ecuador
Carlos Mena	Parti	Department of Geography & Carolina Population Center, University of Nor Carolina at Chapel Hill
Joseph P. Messina	Parti	Department of Geography, Michigan State University
William Pan	Parti	Department of International Health, Johns Hopkins University
Stephen J. Walsh	US-P	Department of Geography & Carolina Population Center, University of Nor Carolina at Chapel Hill

a. People to remove from LC-01 participant list:

David Romo
Kelley Crews-Meyer

b. People to add to LC-01 participant list:

Michael Bacon, Department of Geography & Carolina Population Center, University of North Carolina at Chapel Hill; baconm@email.unc.edu.

Bolier Torres, Ministry of the Environment, Quito, Ecuador; boliert@yahoo.com.