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Agricultural Colonization in the Ecuadorian Amazon: Population, Biophysical, and Geographical Factors Affecting Land Use/Land Cover Change and Landscape Structure

Investigation Group: LC-01

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1. Narrative of activities

The purpose of the project was to collect and examine data on human-environment interactions in the northern Amazon region of Ecuador through a Geographic Information Science (GISc) perspective and statistical modeling. Data collected included a remote sensing time-series from 1973 to 2001, which is combined with data from air photography, road maps, topographic maps, and on-the-ground data collection and survey data into a GIS to assess land resources and changes in land cover and land use (LCLU) at local and regional scales. The project also builds upon detailed household survey data collected in an earlier project for 1990 by collecting household data in 1999 and community data in 2000, which created a longitudinal household survey dataset (observations in 1990 and 1999 on all households found residing on a scientifically representative sample of farm plots originally selected in 1990) to measure demographic and socio-economic conditions, agricultural land use and technology, and changes over time at the farm or household level. The community survey was administered in 2000 to community leaders, farmers, teachers, women, and health workers in places ranging from tiny communities to the largest city, Lago Agrio, collecting data on population size and growth, the local economy, land area and distribution, transportation linkages, employment distribution and wage levels, and a wide range of infrastructure. The two types of survey data were used to explore linkages between LCLU and characteristics of farm households, including local natural resource conditions and the characteristics and policies of local communities.

The biophysical data collection and subsequent analysis has created a multi-thematic, spatially-explicit database to address deforestation and agricultural extensification in northeastern Ecuador, and a hybrid digital classification for repeatable LCLU characterizations for selected Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) images assembled within a time-series. The latter have been used to derive pattern metrics to assess the composition and spatial organization of the landscape through trajectories of landscape structure, and to carry out image change detections, including change vector analysis and a panel approach to defining "pixel histories" as trajectories of LCLU dynamics. At the same time, data from the household and community surveys have been used to determine demographic and socio-economic, biophysical,

and geographical (e.g., access to roads, towns and infrastructure) characteristics of farm households and to thereby assess drivers of LCLU dynamics at the farm household, local community or sector, and larger regional levels or scales using Generalized Linear Models and preliminary multi-level models. This work is leading to the development of new statistical techniques and algorithms, and to useful findings on the effects of local natural resource endowments and the policy environment on farm decisions pertaining to extensification and intensification of LCLC and their trade-offs.

Future work will involve more integration of the spatial-biophysical and socio-economic data and analytical approaches to test and adapt existing methodology, as well as to extend it (e.g., by taking into account spatial autocorrelation in multilevel modeling; improve land use classification through additional on-the-ground data collection and analysis) and to address key issues on integration of data on the ground with space-based data. We will also extend work on cellular automata (CA) approaches, which have been applied to the Lago Agrio area, to the entire region to simulate LCLU patterns for antecedent and future periods, given historical and current LCLU patterns. This work will also be extended to integrate parameters from the multivariate statistical analysis of farm household behavior into the CA model to better explain the transitions of pixels from forests to agriculture and urban areas. Simulations into the future will provide important ways of examining the implications of various alternative demographic, socio-economic, and policy scenarios. The methodology should be useful to not only Ecuadorian policy-makers concerned with the development of sustainable policies for the Amazon but also scholars elsewhere investigating the future of the Amazon forests under increasing human intervention.

Preliminary analyses of the longitudinal household survey data indicate the importance of demographic processes leading to extensive subdivision of sample *fincas* since 1990, especially along roads and close to main towns. This has led to a substantial reduction in the mean size of family landholdings (a decline in the mean size of family farms from 46 to 25 ha in only 9 years). This is due to both sales of parts of plots to new agricultural colonists migrating into the region and to subdivision of plots among children of settlers resulting from their previous high fertility. Analyses of pattern metrics, calculated from the classified satellite time-series, indicate that the northern Amazon study region, the area of heavy in-migration rapid colonization due to the discovery and exploitation of extensive deposits of petroleum in the area since 1967, has undergone a rapid conversion from high-density forest to cropping and pasture as well as to low and medium density forest resulting from incipient secondary plant succession. The sequence of changes over time is due to (a) initial deforestation by migrant households settling along roads built by petroleum companies, beginning in the early 1970s and continuing, though less intensively, to the present; (b) a second stage of clearing of forests by migrant colonists to expand subsistence agriculture to commercial activities, including coffee and cattle raising; and (c) modest secondary plant succession of agricultural lands related to declining soil fertility. Simulation models using (CA) in the northern part of the study region indicate the important role of Lago Agrio and of road networks on changes in land use in the region around Lago Agrio. CA models indicate the effects of urbanization on the absorption of land and the increasing fragmentation of agricultural plots through population growth and agricultural extensification, resulting in remaining forest areas being more patchy and farther from Lago Agrio. Areas around Lago Agrio are thus developing a more mature land use pattern, with a mix of crops, pasture, and residential/commercial development, while high-density forest areas, previously in large tracts, are being converted to heterogeneous low to medium density forest tracts on farms, mixed with agriculture and pasture.

The goals of the research included to (1) collect extensive additional survey data and biophysical and related data (see above) to conduct a scale-dependent analysis of LCLU change at

the farm, local community or sector, and regional levels, and to compare/contrast and analyze the similarities and differences observed at the different scales; (2) conduct analyses of patch dynamics as a first approximation of threats of colonization to biodiversity through fragmentation of habitats, which goes beyond the simple loss of forest cover per se; (3) use multivariate analysis to examine a wide range of possible factors responsible for variations in LCLU of migrant farm settler households and in their changes over time, and explore the use of multilevel models to take into account structural and contextual factors affecting LCLU in a hierarchical model, including closeness of farm plot to the nearest road and road distance to nearest reference community, key characteristics of that community, including socio-economic infrastructure, employment structure and wage levels, population size and dynamics, land distribution, technical assistance, and transportation linkages to the nearest main towns in the region (Lago Agrio, Coca, Shushufindi, and Joya de los Sachas); (4) examine extensification-intensification trade-offs over time at farm household and larger scales, that is, the extent to which each occurred and the relationships between them over the period of longitudinal data collection for households, 1990-99. We also examine the extent of fallow land and secondary succession at the farm level. Tradeoffs between intensification and extensification and secondary plant succession both have important implications for habitat preservation and vegetation cover. (5) We develop and explore a cellular automata simulation model for the northern area around Lago Agrio. Future work will ensure that the growth rules in the CA model will be enhanced by explicitly linking social, biophysical, geographical drivers of LCLU change. To accomplish this, the CA modeling environment has been exported from ERDAS Imagine software to the IDL software environment; Monte Carlo simulation protocols have been established; and better validation procedures for CA models have been developed that include, but are not limited to, the expanded use of pattern metrics to compare the spatial organization of simulated versus observed LCLU patterns and the compositional makeup of the landscape; and explore growth dynamics of the CA models in simulations to 2010 and beyond. Finally, (6) we explore the use of new Ikonos data as a calibration and validation tool for a subset of survey farms that have been precisely inventoried (a process which will be extended) and mapped as to LCLU dynamics and the factors affecting the composition and spatial organization of land cover types. While only a single date of Ikonos imagery has been acquired for only a subset of our requested survey farms thus far, other images have already been approved for acquisition. We are also using sketch maps produced by the survey team and the landowner to depict LCLU on every farm. These sketch maps have been digitized as well, which makes it possible to link them to Landsat TM and Ikonos data for calibration and validation of spatial simulation of LCLU dynamics.

See also project web site at http://www.cpc.unc.edu/projects/ecuador/, which includes an overview of the project, information on the socioeconomic/demographic data utilized, substantive findings, presentations and publications related to the project, as well as theses and dissertations.

2. Participants:

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Nationality: USA

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Nationality: USA

Name: Mario Garcia (Galo Medina, as of 7/1/01)
Role: Ecuador – Principal Investigator of subcontractor
University/Organization: Ecociencia, Quito, Ecuador
Nationality: Ecuador

Name: Alicia Ruiz
Role: Ecuador – Investigator/subcontractor
University/Organization: CEPAR, Quito, Ecuador
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Name: Alisson Barbieri
Role: Graduate Research Assistant
University/Organization: Department of City and Regional Planning and Carolina Population Center, University of North Carolina
Nationality: Brazil
Degree Sought: PhD
Dissertation Title: Under development

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Name: Laura P. Boschini
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Nationality: USA
Degree Sought: MA
Provisional Thesis Title: *Fertility on the Frontier: Contraceptive Behavior in the Sierra de Lacandon National Park, Guatemala*

Name: Kelley A. Crews-Meyer
Role: Post Doctoral Student and Consultant/Investigator
University/Organization: Department of Geography, University of North Carolina (Post-Doc in 2001); currently, Assistant Professor of Geography, University of Texas – Austin
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Name: Christine Erlien

Role: Graduate Research Assistant
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Name: Brian G. Frizzelle
Role: Spatial Analyst
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Name: Katie Glaser
Role: Undergraduate Research Assistant
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Name: Courtney Hart
Role: Spatial Analyst, stationed at Ecociencia, Quito, Ecuador (9/00-7/01)
University/Organization: Carolina Population Center, University of North Carolina
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Name: Stephen J McGregor
Role: Investigator/Associate Director for Spatial Analysis
University/Organization: Carolina Population Center, University of North Carolina
Nationality: USA

Name: Carlos Mena
Role: Graduate Research Assistant
University/Organization: Department of Geography and Carolina Population Center, University of North Carolina
Nationality: Ecuador
Degree Sought: PhD (MS completed at Florida Atlantic University in 2001); currently enrolled in the PhD program, Department of Geography, University of North Carolina -- Chapel Hill.
Master's Thesis Title at FIU: *An Exploratory Analysis of Socio-economic Determinants of Change in Land Use in the Upper Napo Basin at Different Scales in the Ecuadorian Amazon*
PhD Dissertation Title: Under development

Name: Joseph P. Messina
Role: Originally Graduate Research Assistant, Subsequently Investigator/Consultant
University/Organization: Assistant Professor, Department of Geography, Michigan State University, East Lansing
Nationality: USA
Degree: Completed PhD in 2001
Dissertation Title (completed at UNC): *A Complex Systems Approach to Dynamic Spatial Simulation Modeling: Landuse and Landcover Change in the Ecuadorian Amazon*

Name: Philip A. McDaniel
Role: Graduate Research Assistant
University/Organization: Department of Geography, University of North Carolina – Chapel Hill
Nationality: USA
Degree: MA in 2000
Thesis Title: *Household and Community Drivers of Land Clearing: Human-Environment Interactions in the Ecuadorian Amazon*

Name: Laura Murphy
Role: Co-Investigator
University/Organization: Department of City and Regional Planning & Carolina Population Center, University of North Carolina; as of 1/1/01, Assistant Professor, Department of International Health, Tulane University
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Name: William Pan
Role: Graduate Research Assistant
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Degree Sought: PhD
Provisional Dissertation Title: *A multilevel statistical and spatial analysis to examine the interaction between population and environment*

Name: Gabriela Valdivia
Role: Graduate Research Assistant
University/Organization: Department of Geography, University of North Carolina – Chapel Hill
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Degree: MA in 1999 (currently PhD student in Department of Geography, University of Minnesota)
MA Thesis Title: *Colonization, Comunas, and Reserves: The Ecology of Land Use and Land Cover Change in Indigenous Communities of Northeastern Ecuador*

Name: Lea Wessaman
Role: Undergraduate Research Assistant
University/Organization: Department of Economics, University of North Carolina
Nationality: USA

3. Description of training activities conducted, including lectures, public outreach, and short courses:

(a) <u>Ecociencia, Ecuador (our collaborator and NGO)</u>

We substantially strengthened the capabilities of Ecociencia (and its staff) as in-country experts in geographic information science (GISc). Large training costs were incurred and

hardware/software for GIS and remote sensing images were purchased and donated to them. Our Ecuadorian collaborators listed above as well as some of the 20 other Ecuadorians involved in conducting the surveys have expressed interest in participating in more training and dissemination activities than was originally budgeted. In particular, two CPC staff spent considerable time in Ecuador starting in October, 2000, installing new Imagine and Arcview software and training Ecociencia staff in their use, which has made possible their subsequent collaboration in the analysis. We also expect to organize two dissemination workshops on project results and new agricultural technologies and recommended approaches to land use, to be held for farmers and community and NGO leaders in the Amazon study region during the summer of 2003 (delayed due to political unrest and security risks), as well as a conference for scholars and government officials in Quito.

In addition, a recent graduate of the Department of Geography at the University of North Carolina (Courtney Hart) was hired from 9/00 to 7/01 by the Carolina Population Center at UNC to work on the Ecuador project (funded mostly through other funds) to be stationed at Ecociencia in Quito, Ecuador. Hart provided technical support on image processing and field data collection and trained Ecociencia staff, as well as other spatial specialists in Quito, in a one-week workshop at Ecociencia. Through a grant of the Fogarty Foundation to the UNC Carolina Population Center, funds were awarded to Bilsborrow and Walsh to bring Francis Baquero to UNC from Ecociencia for 4 months in the spring of 2002 for further training and participation in analysis. Having been involved extensively in the field data collection in the Amazon and in introductory data processing and analysis through UNC on-site training by Hart, Baquero was able to benefit from additional advanced training in remote sensing at UNC and collaborated in data analysis. While at UNC he was able to interact with the PIs, the full project team, and the Spatial Analysis Unit of CPC, as well as with the Landscape Characterization and Spatial Analysis Lab in the Department of Geography. Following this advanced training, he returned to Ecuador where he collaborated through December in data analysis and interpretation. Finally, Carlos Mena, a key collaborator in charge of the original GPS training and data collection by the 20 interviewers, while working for Ecociencia, visited UNC for 2 weeks in December, 2001, to present his MA research and inquire about applying to UNC-Chapel Hill for a doctoral program in geography. He was subsequently admitted and is a pre-doctoral trainee at the Carolina Population Center.

20 other Ecuadorians were also recruited and trained for two weeks in Quito in techniques of data collection via household and community-level surveys, which included an introduction to project goals, the nature of Amazonian development in Ecuador, and how to administer a questionnaire with modules on demographic and socio-economic data, agricultural crops, cattle raising, health and family planning, migration, work away from the farm, etc., in the Amazon. Two interviewers later completed their theses based on the data: Bolier Torres, *Analisis de los Impactos del Proyecto Agroforestal PROFORS sobre Uso de Tierra en la Provincia de Sucumbios, 1991-99*, (Univerisdad Tecnica Estatal de Quevedo, Ecuador, 2000); y Luis Alonso Vallejo, *Diagnostico Agroeconomico de los Cultivos de Café (Coffea canephora) y Cacao (Theobroma cacao) en la Provincia de Sucumbios* (Univerisdad Tecnica Estatal de Quevedo, Ecuador, 2001). Bilsborrow was a member of the thesis committee of both theses.

(b) University of North Carolina

The Carolina Population Center at UNC has a pre-doctoral traineeship program in which students from academic units throughout the campus can apply for financial support through the

Center and research training through a formal assignment with a faculty and research fellow preceptor. Greg Taff (Department of Geography) and Brandie Sullivan (Ecology Curriculum) were awarded traineeships in 2001 to work with Professors Walsh and Bilsborrow, respectively, on elements of the NASA-Ecuador research.

In addition, data sets acquired and generated by this project have been used in a number of university courses as part of lab exercises and teaching materials. Geography 191 (Technical Issues in GIS/Professor Walsh), Geography 192 (Applied GIS/Professor Walsh), Geography 303 (Seminar in Population and Environment Interactions/Professor Bilsborrow), Plan 270 Interdisciplinary Seminar on International Development/Professor Bilsborrow), and Biostatistics 170 (Demographic Techniques I/ Professor Bilsborrow) are courses which have integrated research materials and findings into the instructional environment.

Bilsborrow and Walsh have given seminars to large audiences of UNC graduate students at CPC in 1999-2001 on the methodology and findings of the Ecuador NASA project, as well as at US universities.

(c) Presentations &/or Abstracts

Mena C.F., Erlien C., Walsh S.J., Bilsborrow R.E., Baquero F. 2003. Modeling the Scale Dependent Drivers of LCLU Dynamics in Northeastern Ecuador: Population, Biophysical, and Geographical Factors. Association of American Geographers, New Orleans, LA.

Barbieri, A. F., R. E. Bilsborrow, C. Mena, W. Pan and B. Torres. 2003. Analyzing Changes in LULC over Time in the Ecuadorian Amazon based on Longitudinal Survey Data. Association of American Geographers, New Orleans, LA. Bilsborrow, R.E., W.K.Y. Pan, A. Barbieri, C. Mena. 2003. Analyzing Changes in LULC Over Time in the Ecuadorian Amazon Based on Longitudinal Survey Data. Association of American Geographers, New Orleans, LA.

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

Bilsborrow, R.E. 2002. Migration and Land Use in the Ecuadorian Amazon. Global Science Panel Meeting, Laxenburg, Austria.

Bilsborrow, R.E. 2002. Urbanization, Infrastructure Change and Development in the Ecuadorian Amazon. Population Association of America, Atlanta, GA.

Bilsborrow, R.E. 2002. Población, Uso de Tierra y Deforestación en La Amazonía Ecuatoriana. Instituto Peruano de Administración de Empresas, Iquitos, Peru.

Bilsborrow, R.E. 2002. Cambios Demográficos y el Medio Ambiente en la Región Amazónica de los Países Andinos, at Conference on Population, Development and the Environment in Andean Countries, sponsored by Instituto de Investigaciones Amazonicas Peruanas (Iquitos), Consorcio de Investigaciones Economicos y Sociales (Lima) and University of Michigan Population and Environment Program (Ann Arbor, Mich.), Iquitos, Peru.

Bilsborrow, R.E., and David L. Carr, 2002. Proximate and Ultimate Drivers of Deforestation in the Northern Ecuadorian Amazon. Workshop on Land Cover Dynamics in the Amazon, at II LBA Scientific Conference, Manaus, Brazil.

Bilsborrow, R.E. 2002. Población, Uso de Tierra y Deforestación en La Amazonía Ecuatoriana. Presented at II LBA Scientific Conference, Manaus, Brazil.

Carr, D.L. and W. Pan. 2002. Fertility Determinants on the Frontier: Longitudinal Evidence from the Ecuadorian Amazon. Population Association of America, Atlanta, GA.

Erlien, C.M. 2002. Neural Networks: Identifying Clouds in Remote Sensing Imagery. Southeastern Division of the Association of American Geographers, Richmond, VA.

Mena, C.F. 2002. Deforestation in the Napo Region: Socioeconomic Factors, Spatial Patterns, and Metrics. Southeastern Division of the Association of American Geographers, Richmond, VA.

Mena, C.F., C. Erlien, S. 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, LA.

Pan, W. and D.L. Carr. 2002. Links Between Fertility, Farm Size and Land Use on the Frontier: Evidence from the Ecuadorian Amazon. American Public Health Association. Philadelphia, PA.

Pan, W. 2002. A Multilevel Statistical and Spatial Analysis to Examine the Relationship between Population & Environment. Pacific Northwest National Laboratory.

Bilsborrow, R. E. 2001. *Demographic Aspects of Land Use by Migrant Colonists in the Ecuadorian Amazon*. Paper presented at Workshop of Center for Population Studies, National Institute of Child Health and Human Development, NIH, Rockville, Md.

Bilsborrow, R. E., and W. Pan 2001. Population Growth, Fragmentation of Plots and Implications for Land Use and Deforestation in the Ecuadorian Amazon. Paper presented at International Population Conference, International Union for the Scientific Study of Population, Salvador, Bahia, Brazil.

Pan, W., L. Murphy, R. Bilsborrow, and B. Sullivan.2001. Population and Land Use in Ecuador's Northern Amazon in 1999: Intensification and Growth in the Frontier. Paper presented at Population Association of America, Washington DC.

Pan, W. 2001. LCLUC Models that account for Spatial Patterns in the Ecuadorian Amazon. Presentations at the International Biometric Society – Eastern North American Region Spring Meeting.

Messina, J.P. and S.J. Walsh, 2001. Simulating Land Use and Land Cover Dynamics in the Ecuadorian Amazon through Cellular Automata Approaches and an Integrated GIS. Open Meeting

of the Human Dimensions of Global Environmental Change Research Community, Special Session, Integrated Modeling of LCLUC, Rio de Janeiro, Brazil.

Bilsborrow, R.E., W. Pan, S.J. Walsh, and K.A. Crews-Meyer, 2001. Change Patterns of Population and Land Use in Ecuador's Northern Amazon. Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Special Session, Contributions of the Large-Scale Biosphere Atmosphere Experiment in Amazonia Project to Understanding the Human Dimensions of Land Use and Land Cover Change, Rio de Janeiro, Brazil.

Walsh, S.J., 2001. Mapping and Modeling Approaches for Characterizing Population-Environment Interactions: A Geographic Information Science Perspective. University of Oklahoma, Department of Geography.

Walsh, S.J., 2001. GIScience for Mapping and Modeling Landscape Dynamics: Some Challenges and Opportunities. University of North Carolina at Greensboro, Department of Geography.

Bilsborrow, R. E. 2001. Demographic Factors and Land Use in the Ecuadorian Amazon, Population Studies Center, Brown University.

Walsh, S.J. 2001. Mapping and Modeling Approaches for Characterizing Population-Environment Interactions in Thailand and Ecuador: A Geographic Information Science Perspective. Department of Geography, Southwest Texas State University.

Walsh, S.J., K.A. Crews-Meyer, J.P. Messina, R.R. Rindfuss, B. Entwisle, 2001. Landscape Variation in Frontier Environments: Deforestation and Agricultural Extensification in Ecuador and Thailand. Global Change Open Science Conference -- Challenges of a Changing Earth, Amsterdam, The Netherlands.

Walsh, S.J., J.P. Messina, K.A. Crews-Meyer, S.J. McGregor, and B.G. Frizzelle, 2001. Assessing Landscape Dynamics in the Ecuadorian Amazon: Application of Satellite Change-Detections and Cellular Automata Simulations. Association of American Geographers, New York.

Walsh, S.J., R.E. Bilsborrow, S.J. McGregor, J.P. Messina, K.A. Crews-Meyer, B. Frizzelle, and W. Pan, 2001. Landscape Dynamics in the Ecuadorian Amazon: Characterizing Patterns and Processes of Deforestation and Agricultural Extensification through Space and Time Dependent Models of Change. Open Meeting of Ecology LBA, Atlanta.

Pan, W. and Bilsborrow, R.E. 2000. Change in Ecuadorian Farm Composition Over Time – Population Pressures, Migration, and Changes in Land Use. Paper presented at Population Association of America Annual Meeting, Los Angeles, CA.

Messina, J.P., Walsh, S.J., and Crews-Meyer, K.A., 2000. Scale Dependent Pattern Metrics and Panel Data Analysis as Applied in a Multiphase Hybrid Land Cover Classification Scheme. American Society of Photogrammetry and Remote Sensing, Washington, DC.

Walsh, S.J., Crews-Meyer, K.A., Messina, J.P., 2000. Plant Biomass Variation in Frontier Environments: The Case of Deforestation and Agricultural Extensification in Thailand and Ecuador. Fourth International Conference on Integrating GIS and Environmental Modeling, Banff, Canada.

Bilsborrow, R. E. 2000. Migrant Colonists, Agriculture and Deforestation in the Ecuadorian Amazon. Triangle Area Population Society, Durham, NC.

Walsh, S.J., 2000. Emerging Technologies for Remote Sensing and Geo-Spatial Data. A Workshop on Moving Remote Sensing from Research to Applications: Case Studies of the Knowledge Transfer Process, National Academy of Sciences, Washington, DC

Messina, J.P. and Walsh, S.J., 2000. Analysis of Land Change Across Spatial Scales Using Geographic Techniques: A Comparison of Deforestation in Ecuador and Thailand. Latin America Studies Association, Miami, FL.

Mena, C., Taff, G., Frizzelle, B., and McGregor, S.J., 2000. Integrating Geographic Information Science Techniques and Household Socio-economic Surveys of Population Environment Research: A Preliminary Report. Latin America Studies Association, Miami, FL.

Murphy, L. and Pan, W., 2000. Permanence and Adaptation Among Settler Households in Ecuador's Amazon. Latin America Studies Association, Miami, FL.

Taff, G., Pan, W., Bilsborrow, R.E., 2000. Population Pressure, Subdivision and Land Clearing in the Ecuadorian Amazon. Latin America Studies Association, Miami, FL.

Crews-Meyer, K.A. and Valdivia, G., 2000. Land Use Change in Rural Thailand and the Ecuadorian Amazon: A Comparative Study. Latin America Studies Association, Miami, FL.

Valdivia, G., 2000. The Evolution of a Landscape: Consequences of Agricultural Migration in the Ecological and Human Re-structuring of the Ecuadorian Amazon. Latin America Studies Association, Miami, FL.

Araya, I., 2000. Participacion de comunidades locales en la gestion de areas protegidas: Primeros pasos en la formacion de un consejo de manejo compartido en la Reserva de Produccion Faunistica Cuyabeno, Amazonia Ecuatoriana. Latin America Studies Association, Miami, FL.

Walsh, S.J., 2000. Population and Environment Interactions: Spatial Considerations in Landscape Characterization and Modeling. University of Minnesota, Department of Geography, Series on Scale in Geography.

Messina, J.P., 2000. The Application of Non-Traditional Pattern Metrics in the Development of a Multiphase Hybrid Classification Scheme: Land Use/Land Cover Dynamics in the Ecuadorian Amazon. Association of American Geographers, Pittsburgh, PA.

Messina, J.P., 2000. A Cellular Modeling Approach to Dynamic Systems Characterization: Deforestation and Agricultural Extensification in the Ecuadorian Amazon. University Consortium for Geographic Information Science, Portland, OR.

Messina, J.P., 2000. The Classification and Attribution of Remotely Sensed Data for Tropical Environments: A Case Study in the Ecuadorian Amazon. Southeastern Division of the Association of American Geographer, Chapel Hill, NC.

McGregor, S.J. and Bilsborrow, R.E., 1999. Integrating Geographic Information Science in the Data Collection Phase of Population-Environment Research. Population Association of America Annual Conference.

Messina, J.P., 1999. The Application of Cellular Automata Modeling for Enhanced Land Cover Classification in the Ecuadorian Amazon. Applied Geography Conference, Charlotte, NC.

4. Data set descriptions, including status of metadata registration and online data availability. LBA DIS policy encourages metadata registration for data sets in preparation.

Metadata (e.g. content, quality, condition, and other characteristics of geospatial data) compliant with the Content Standard for Digital Geospatial Metadata (CSDGM), version 2, 1998 established by the Federal Geographic Data Committee (FGDC) are available at the following website: http://www.cpc.unc.edu/projects/ecuador/spatial_metadata.html.

Socioeconomic/Demographic Data

1999 Household Survey in the Northern Ecuadorian Amazon	Socioeconomic and demographic survey data for jefe, esposa, and community in the colonist settlement study area, in the Northern Ecuadorian Amazon. Not available from http://lba.cptec.inpe.br. Contact the Carolina Population Center.
Sample Fincas (farms) from the Northern Ecuadorian Amazon 1999 Household Survey	All sample farms, or fincas, in the colonist settlement study area, in the Northern Ecuadorian Amazon. Not available from http://lba.cptec.inpe.br. Contact the Carolina Population Center.
Detailed Plot Data for Fincas (farms) from the Northern Ecuadorian Amazon 1999 Household Survey	Detailed LULC data at the plot level for four sample fincas madres in the Northern Ecuadorian Amazon. Not available from http://lba.cptec.inpe.br. Contact the Carolina Population Center.

Spatial data

Ecuador national boundary	The national boundary of Ecuador. Available from http://lba.cptec.inpe.br
Ecuador Provincial Boundaries	The most recent provincial boundaries of Ecuador. Available from http://lba.cptec.inpe.br

East Intensive Study Area Boundary	The boundary of the Eastern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Elevation Contour Vectors for the East Intensive Study Area	The 20-meter elevation contours for the East Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Elevation Contour Vectors for the North Intensive Study Area	The 20-meter elevation contours for of the North Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Elevation Points for the North Intensive Study Area	Point elevation features for the North Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Elevation Contour Vectors for the South Intensive Study Area	The 20-meter elevation contours for of the South Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Elevation Points for the South Intensive Study Area	Point elevation features for the South Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Boundary of the Southwest ISA	The boundary of the Southwest Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Eastern Intensive Study Area Terrain Aspect	The terrain aspect for the Eastern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Aspect is the downslope direction of the maximum rate of change on a hillside. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the compass direction, in degress clockwise from 0 at north, in which the hillside faces. The raster resolution of the data set is based on the resolution of the source DEM, in this case, 30 meters. Available from http://lba.cptec.inpe.br
Digital Elevation Model for Eastern Intensive Study Area	The digital elevation model (DEM) contains hydrologically-correct terrain elevation data in a digital raster format for the Eastern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. It consists of a sampled array of elevations interpolated from elevation contours and a sampled array of elevations for ground positions at a relatively normally spaced interval. The spatial resolution of this DEM is 30 meters, meaning that each raster pixel represents a 30 m by 30 m area on the ground, and each pixel has one elevation value, in meters above sea level. Available from http://lba.cptec.inpe.br
Eastern Intensive Study Area Terrain Slope	The terrain slope for the Eastern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. For a raster terrain data set, slope is the rate of maximum change in the elevation values from the surrounding eight

	pixels, through the pixel of interest. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the slope, in degrees. The raster resolution of the data set is based on the resolution of the source DEM, in this case, 30 meters. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area Terrain Aspect	The terrain aspect for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Aspect is the downslope direction of the maximum rate of change on a hillside. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the compass direction, in degrees clockwise from 0 at north, in which the hillside faces. The raster resolution of the data set is based on the resolution of the source DEM, in this case, 30 meters. Available from http://lba.cptec.inpe.br
Digital Elevation Model for Northern Intensive Study Area	The digital elevation model (DEM) contains hydrologically-correct terrain elevation data in a digital raster format for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. It consists of a sampled array of elevations interpolated from elevation contours and a sampled array of elevations for ground positions at a relatively normally spaced interval. The spatial resolution of this DEM is 30 meters, meaning that each raster pixel represents a 30 m by 30 m area on the ground, and each pixel has one elevation value, in meters above sea level. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area 1986 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area 1989 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area 1996 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area 1999 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Northern Intensive Study Area Terrain Slope	The terrain slope for the Northern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. For a raster terrain data set, slope is the rate of maximum change in the elevation values from the surrounding

	eight pixels, through the pixel of interest. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the slope, in degrees. The raster resolution of the data set is based on the resolution of the source DEM, in this case, 30 meters. Available from http://lba.cptec.inpe.br
Southern Intensive Study Area Terrain Aspect	The terrain aspect for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Aspect is the downslope direction of the maximum rate of change on a hillside. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the compass direction, in degrees clockwise from 0 at north, in which the hillside faces. The raster resolution of the data set is based on the resolution of the source DEM, in this case, 30 meters. Available from http://lba.cptec.inpe.br
Digital Elevation Model for Southern Intensive Study Area	The digital elevation model (DEM) contains hydrologically-correct terrain elevation data in a digital raster format for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. It consists of a sampled array of elevations interpolated from elevation contours and a sampled array of elevations for ground positions at a relatively normally spaced interval. The spatial resolution of this DEM is 30 meters, meaning that each raster pixel represents a 30 m by 30 m area on the ground, and each pixel has one elevation value, in meters above sea level. Available from http://lba.cptec.inpe.br
Southern Intensive Study Area 1986 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Southern Intensive Study Area 1996 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Southern Intensive Study Area 1999 LULC Classification (General)	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Southern Intensive Study Area Terrain Slope	The terrain slope for the Southern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Oriente of Ecuador. For a raster terrain data set, slope is the rate of maximum change in the elevation values from the surrounding eight pixels, through the pixel of interest. It is derived from a digital elevation model (DEM). Each pixel is attributed with a value that represents the slope, in degress. The raster resolution of the data set is based on the resolution of the source DEM, in

	this case, 30 meters. Available from http://lba.cptec.inpe.br
Community locations in the Northern Ecuadorian Amazon	All of the primary communities in the colonist settlement study area in the northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Boundary for the North ISA	The boundary of the North Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Boundary of the South ISA	The boundary of the Southern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Point Elevations for Eastern Intensive Study Area	Point elevation features for the Eastern Intensive Study Area (ISA) of the CPC Ecuador Projects, in the northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Boundary of the Cuyabeno Wildlife Reserve	The boundary of the Reserva de Produccion Faunistica Cuyabeno, or Cuyabeno Wildlife Reserve, in the Northern Oriente of Ecuador. Available from http://lba.cptec.inpe.br
Northern Ecuadorian Amazon Aerial Photographs (1979 and 1990)	A collection of 1:60,000-scale air photos taken in 1979 and 1990. The 1990 photos cover the core of the study area, and the 1979 photos are on the less-developed periphery. The photos were scanned at 300 dpi as TIFF images. The images have not been georeferenced or mosiacked. A scanned reference index can be provided as needed. Not available online, but available through the Carolina Population Center.
Northern Ecuadorian Amazon Hydrography (1:250,000 – PROFORS)	Hydrography coverage for the northern Ecuadorian Amazon. The hydrography was digitized from a 1:250,000-scale topographic map. Available from http://lba.cptec.inpe.br
Northern Ecuadorian Amazon Landsat MSS Imagery (1973 - 1987)	Early time series of Landsat-4 MSS satellite imagery in ERDAS Imagine (.img) format. None of the images have been georectified. Below is a list of the image Path/Row (P/r) scenes dates (YYYYMMDD) for images. P9r60 - 19730207, 19850124, 19860823 P9R61 - 19860823, 19871208. Not available online, but available through the Carolina Population Center.
Northern Ecuadorian Amazon Landsat TM Imagery (1984 - 2002)	Extensive time series of Landsat-5 TM and Landsat-7 ETM satellite imagery in ERDAS Imagine (.img) format. Some of the images have been georectified to UTM Zone 18 South, WGS84 Datum. The remainder of the images are raw (i.e. have not been georectified). Below is a list of the image Path/Row (p/r) scenes and dates (YYYYMMDD) for the rectified and un-rectified images. RECTIFIED: p8r60 - 20000830, 20020108 p8r61 - 20020108 p9r60 - 19860823, 19890807, 19961021, 19991115, 20020912 p9r61 - 20001109, 20010824, 20020912 RAW: p8r60 - 19841216, 19870123, 19880423, 19891222, 19910219, 19960811, 19970830 p8r61 - 19870123, 19891222, 19910219, 19960811, 19970830 p9r60 - 19900428, 19960903,

	19970906, 19970906, 19990624, 20010824, 20010909 p8r61 - 19860823, 19870911, 19900428, 19920714, 19960903, 19970906, 19990710. Not available online, but available through the Carolina Population Center
Major Cities in the Northern Ecuadorian Amazon	The boundaries of the four major cities in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Land Use Land Cover Classification (1986) for the East Intensive Study Area in the Northern Ecuadorian Amazon	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Eastern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Land Use Land Cover Classification (1996) for the East Intensive Study Area in the Northern Ecuadorian Amazon	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Eastern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Land Use Land Cover Classification (1999) for the East Intensive Study Area in the Northern Ecuadorian Amazon	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Eastern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Land Use Land Cover Classification (1996) for the Southwest Intensive Study Area in the Northern Ecuadorian Amazon	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Southwestern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Land Use Land Cover Classification (1999) for the Southwest Intensive Study Area in the Northern Ecuadorian Amazon	Four general land use/land cover (LULC) classes -- excluding clouds and shadows -- for the Southwestern Intensive Study Area (ISA) in the Northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Boundary of the Yasuni National Park	The boundary for the Yasuni National Park. Available from http://lba.cptec.inpe.br
Road network for Northern Ecuadorian Amazon	The road network for the northern Oriente of Ecuador, circa 2002. Only portions of the network are current to 2002, while others are current to either 2000 or 1990. The road network was originally digitized from 1:50,000 scale topographic maps from 1990, and appended together. The more current portions have

	been updated using a combination of GPS data from the field and satellite imagery. The original attribution was current to 1990, and the surface attributes for the majority of the roads have been updated between 1999 and 2002. Available from http://lba.cptec.inpe.br
Northern Ecuadorian Amazon Morphology and Edaphology	Morphologic and edaphologic features in the northern Ecuadorian Amazon. Available from http://lba.cptec.inpe.br
Household and Finca GPS Data from the 1999 Northern Ecuadorian Amazon Household Survey	All of the GPS data collected during the 1999 household survey in the colonist settlement study area, in the Northern Ecuadorian Amazon. Not available from http://lba.cptec.inpe.br. Contact the Carolina Population Center.

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