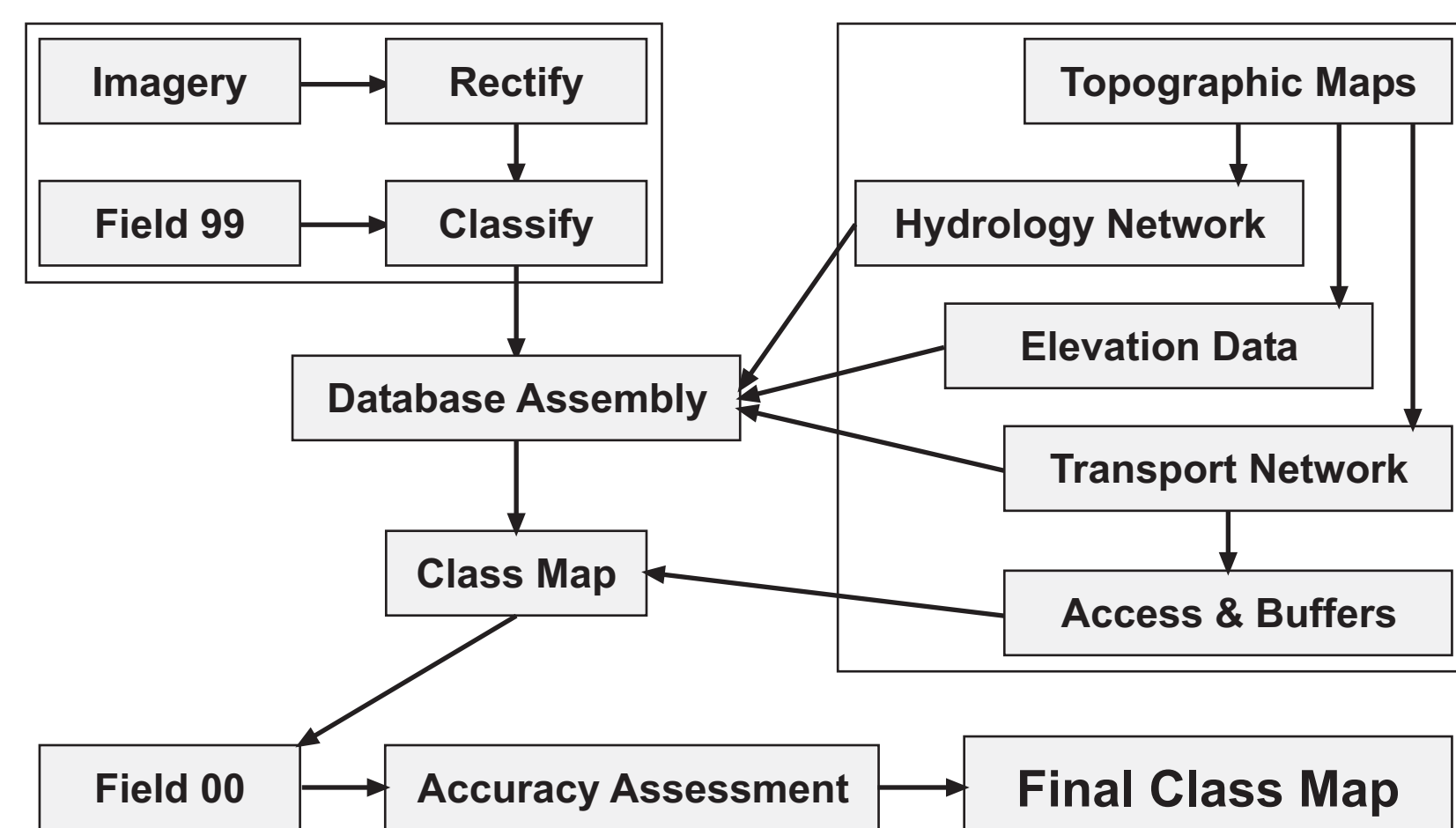


Simulating the Effects of "Plan Colombia" on Land Use and Land Cover in the Ecuadorian Amazon: A Complex Systems Approach

Abstract

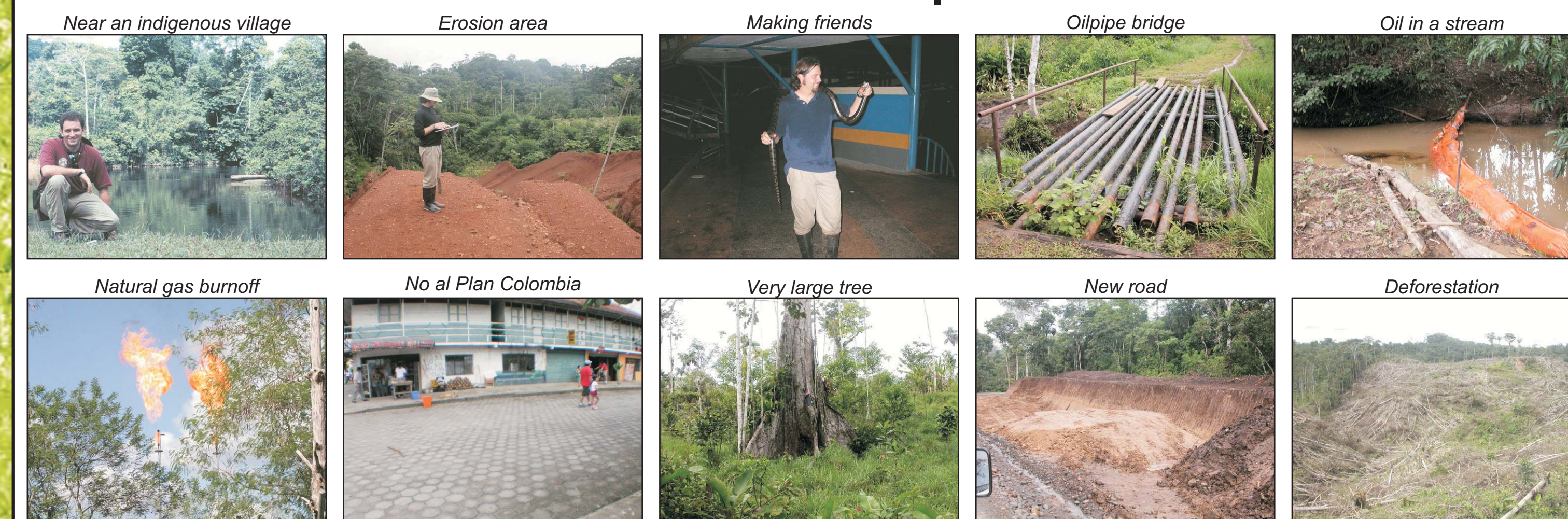
This research, using recently developed cellular automaton modeling procedures and a temporally rich case study, develops spatially-explicit model-based simulations of future land use and cover change (LUCC) scenarios for the Northwestern Amazon, specifically the humid tropics along the Colombian border. The research draws heavily upon recent work in remote sensing, complexity theory, and related social and biophysical disciplines. Remote sensing techniques, including fractional coverage (fc), are developed and presented that map and model landscape level changes. A cellular automaton (CA) model representing LUCC is developed, calibrated, and validated using a time series of remotely sensed images and sketch maps from the region in Northeastern Ecuador linked to spatially referenced biophysical and socioeconomic coverages as input data combined with "rules" derived from empirical analyses of those data. Further, dynamic spatial simulation models are used to explore LUCC resulting from Plan Colombia (the US based program to eradicate drug production in bordering Colombia). Finally, Deviation from Neutral (DFN), a new landscape modeling technique, is presented to illustrate the nature of change throughout the region.

Land Use and Land Cover Classification



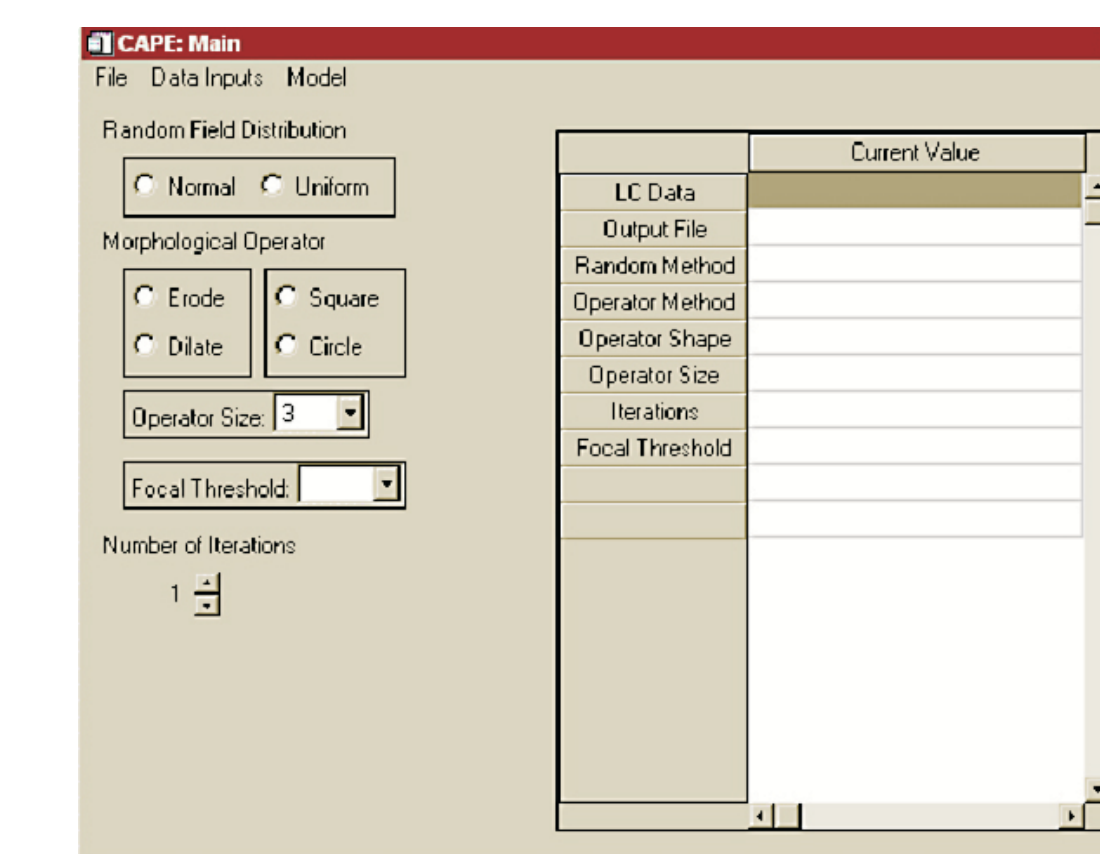
with Paul Delamater, PhD student, Department of Geography, MSU

Field Work 1999 - present

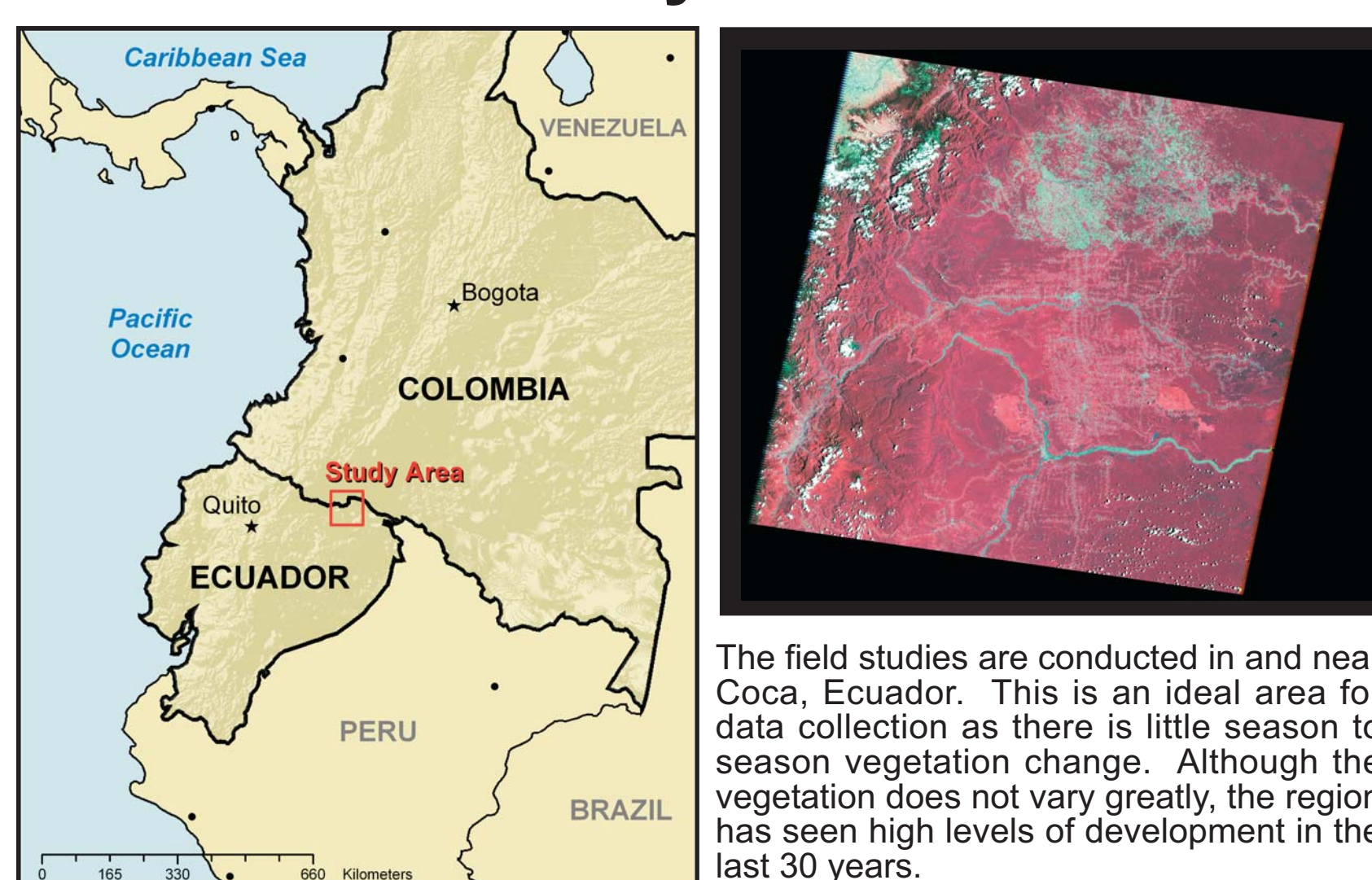


with Chris Barber, MA student, Department of Forestry, MSU

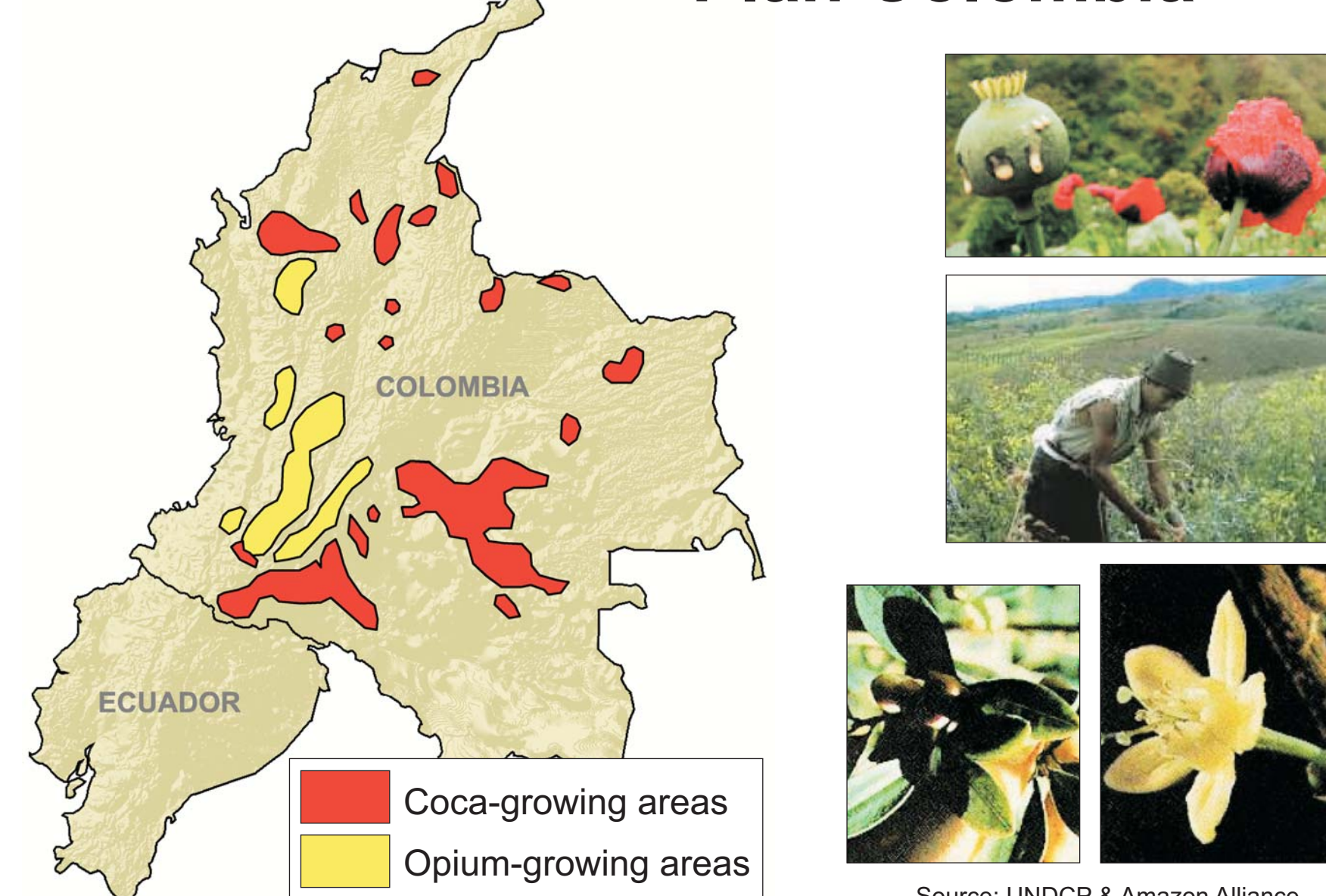
CAPE: Cellular Automata Potential Energy



Study Area



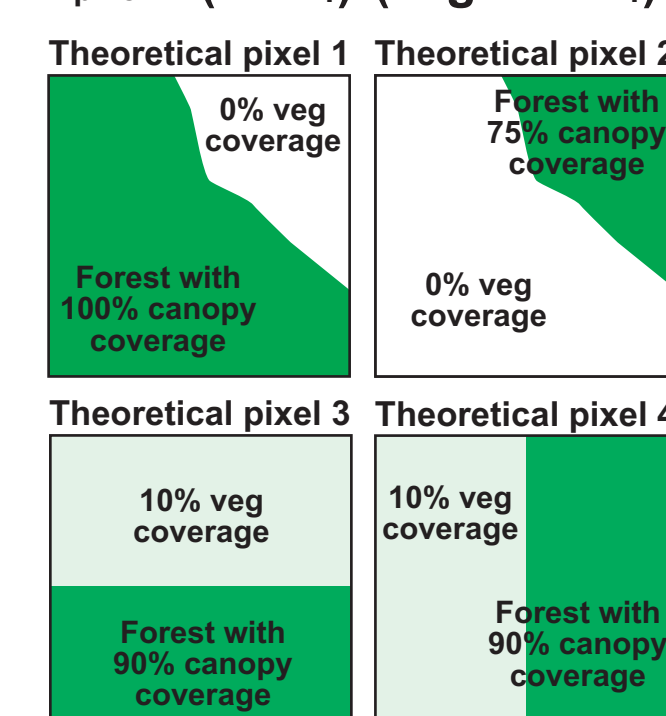
Plan Colombia



Fractional Coverage

Green Fractional Coverage (fc) is the percent of a pixel covered by green vegetation. Considering the heterogeneity existing in most pixels, fc is a representation of the sum of the percent vegetation cover within the pixel boundary:

$$fc_{pixel} = (area_1) * (veg\ cover_1) + (area_2) * (veg\ cover_2) + \dots + (area_n) * (veg\ cover_n)$$



The signal received by the satellite is a mix of the elements present on the ground, thus:

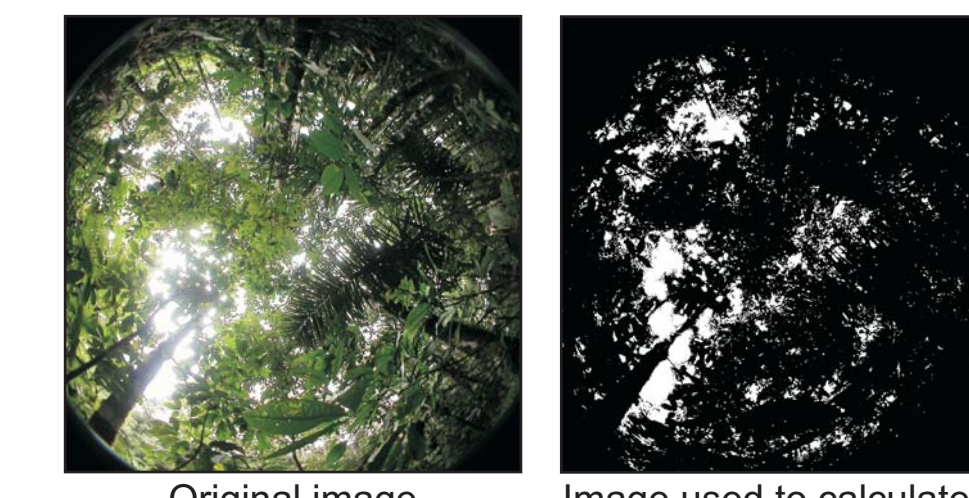
$$fc_{pixel\ 1} = (75\%)*(100\%) + (25\%)*(0\%) = 75\%$$

$$fc_{pixel\ 2} = (25\%)*(75\%) + (75\%)*(0\%) = 18.75\%$$

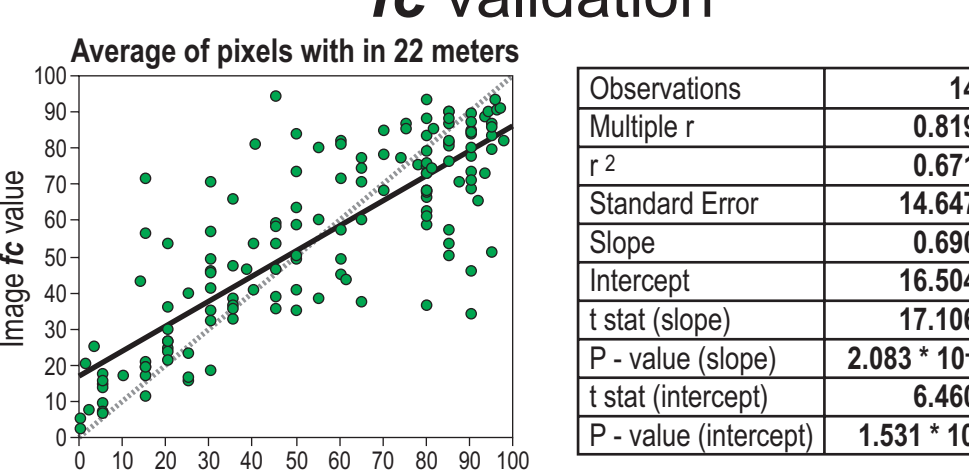
$$fc_{pixel\ 3} = (50\%)*(90\%) + (50\%)*(10\%) = 50\%$$

$$fc_{pixel\ 4} = (50\%)*(90\%) + (50\%)*(10\%) = 50\%$$

fc data collection



fc validation



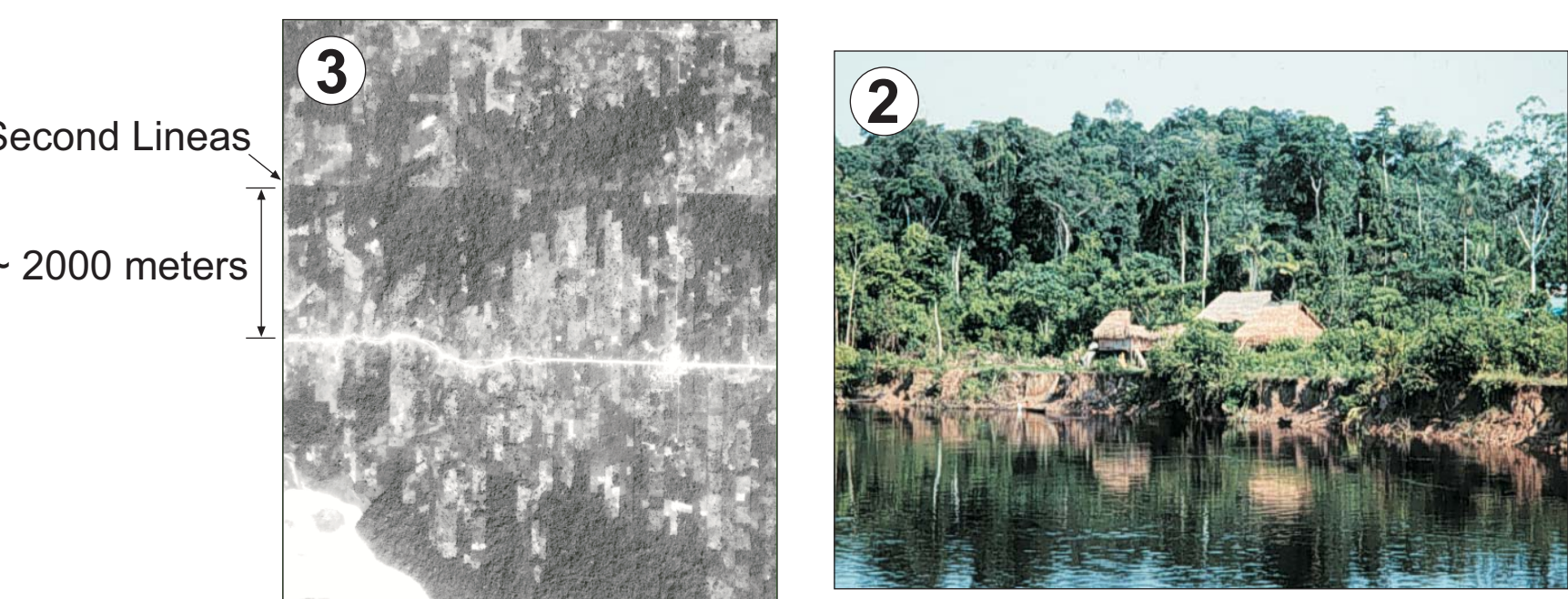
Spraying Effects

- Intercropping
- Drift



Development Pathways

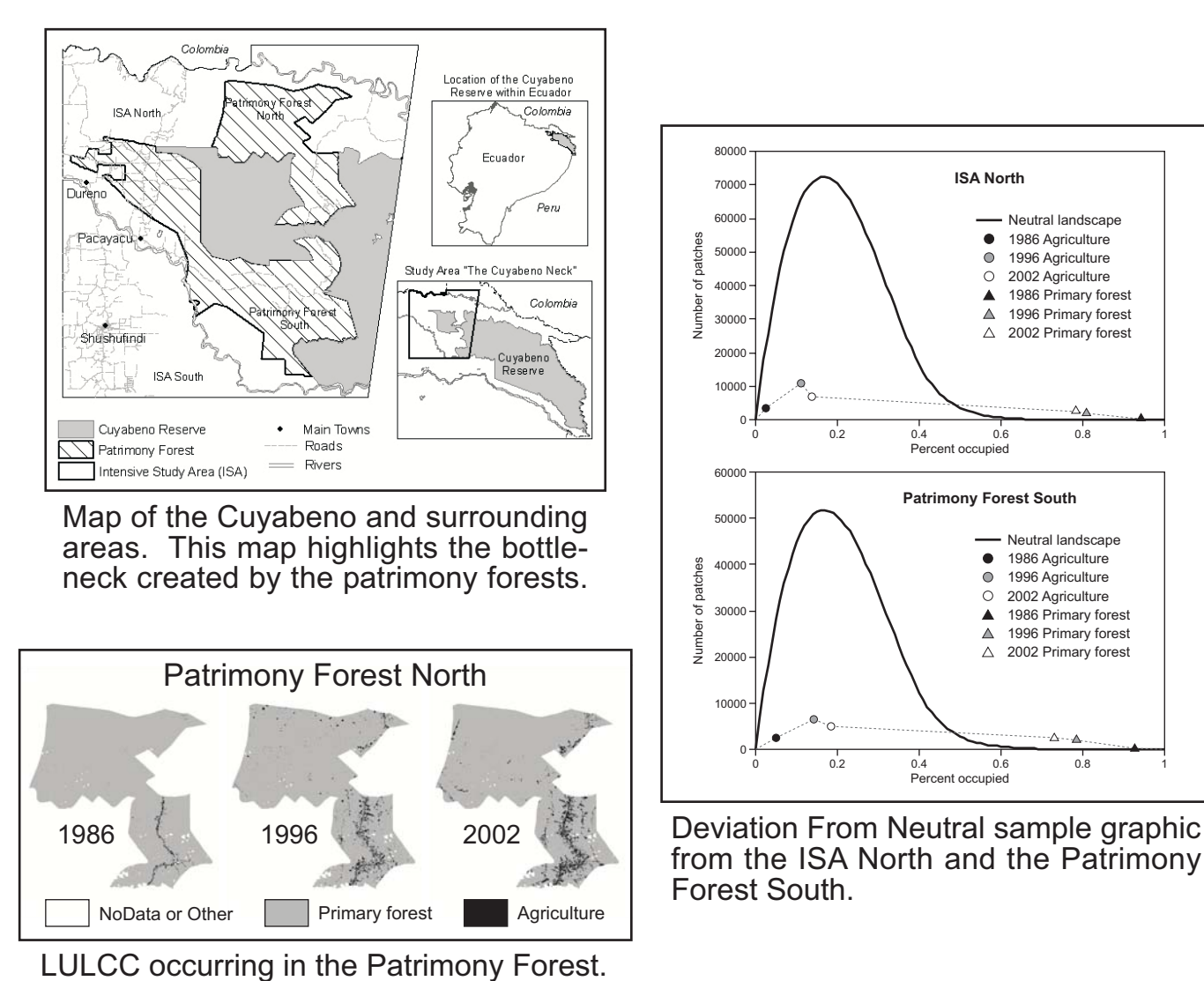
- Urban Areas (Lago Agrio)
- Along Rivers (Puerto Bolivar)
- Settlement Patterns



Ecuadorian National Parks

Messina, J.P., S.J. Walsh, C.F. Mena, and P.L. Delamater. (under review). "Land Tenure and Deforestation Patterns in the Ecuadorian Amazon: Conflicts in Land Conservation in Frontier Settings." *Applied Geography: People and Parks*.

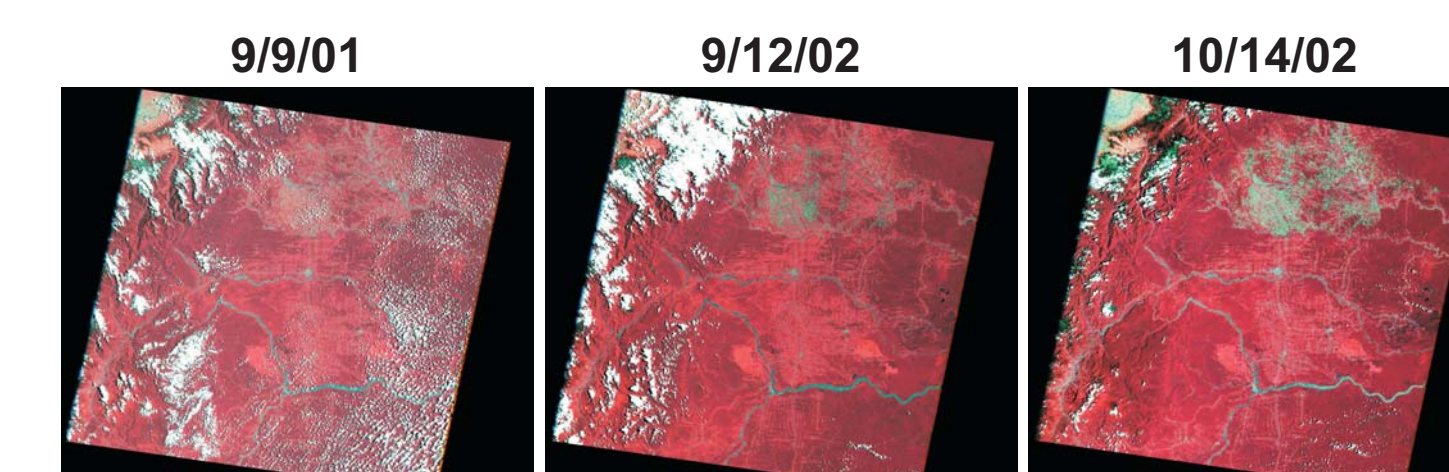
ABSTRACT: The Cuyabeno Wildlife Production Reserve (Cuyabeno Reserve), located in the northeastern Ecuadorian Amazon, is a special protected area within the broader protected areas of Ecuador. Here, land use and land cover patterns are examined within the context of the conflicts attributed to the emergent land tenure systems within the vicinity of the Cuyabeno Reserve. Using a satellite image time-series, landscape ecology and evolving boundary definitions, shifts in landscape composition are described that focus on the spatial and temporal dynamics of land use and cover change (LUCC). Changes in land tenure and the implementation of protection buffers around and within the Reserve have increased the process of deforestation and fragmentation. Further, variations between communal and private ownership and their management strategies confound and exacerbate LUCC patterns, rates, and trajectories.



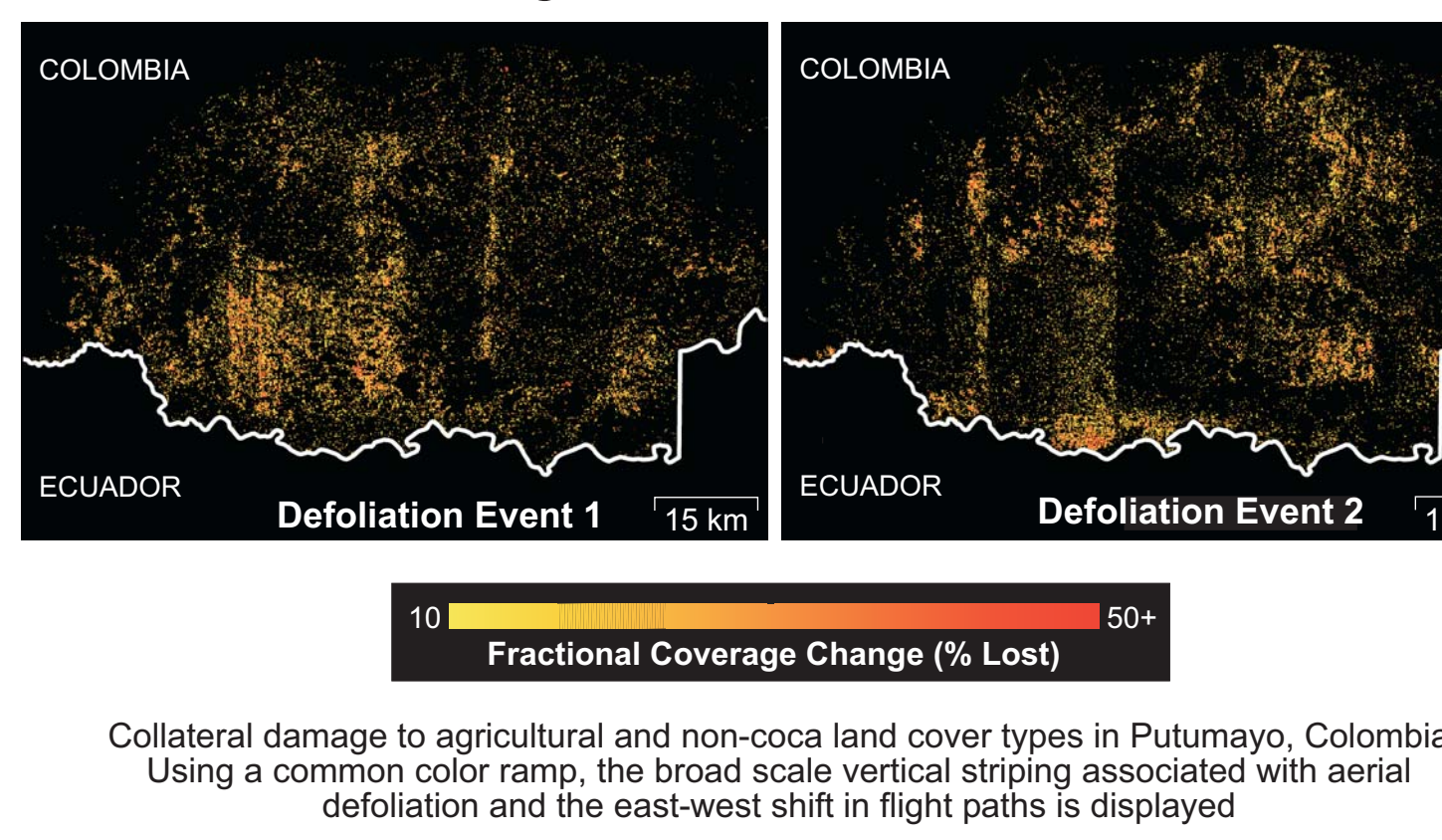
Plan Colombia Defoliation

Messina, J.P., and P.L. Delamater. (under review). "Defoliation and the War on Drugs in Putumayo, Colombia." *International Journal of Remote Sensing*.

Visual changes in the Putumayo region



Using fc to highlight areas with greater than 10% loss



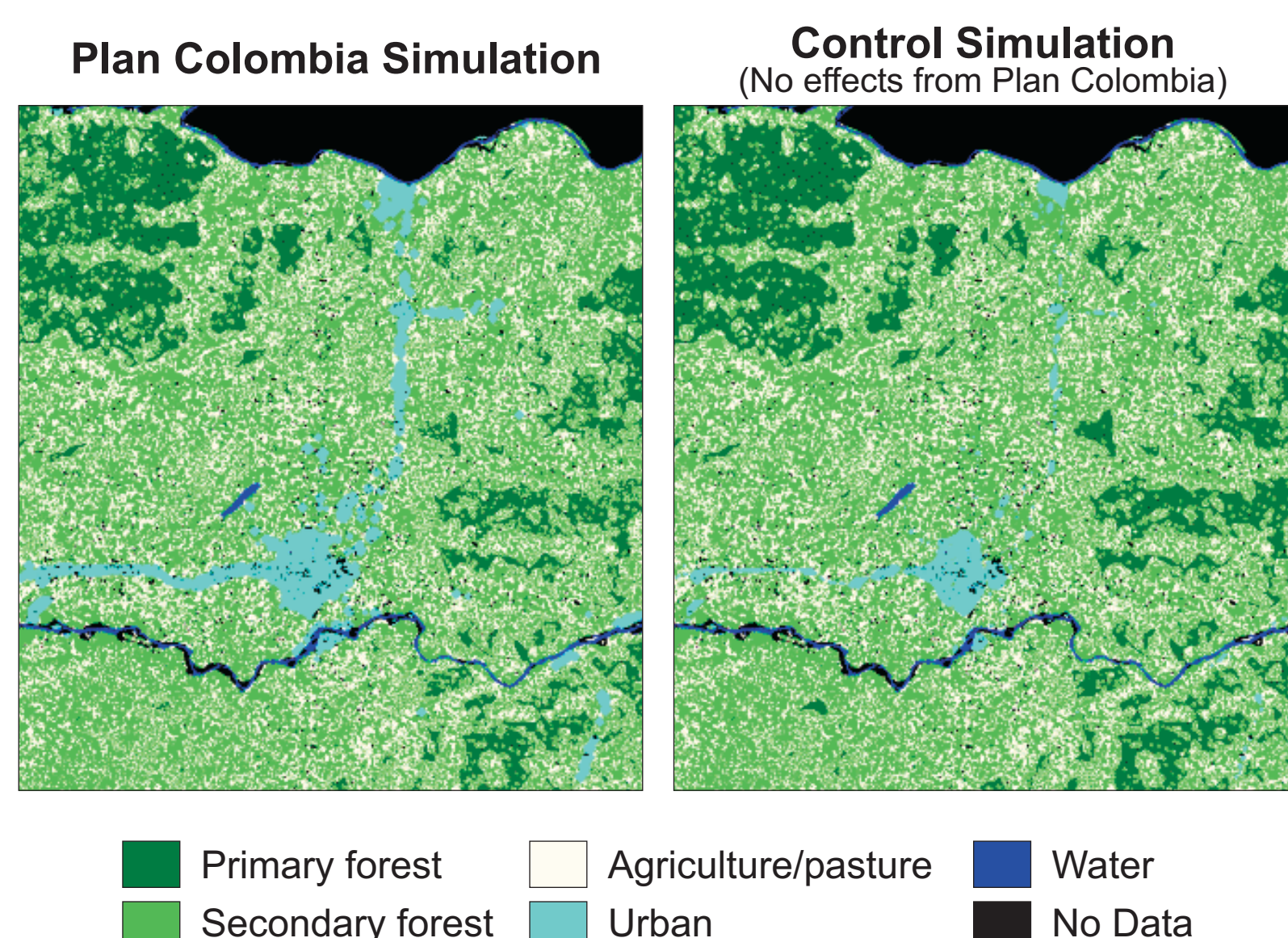
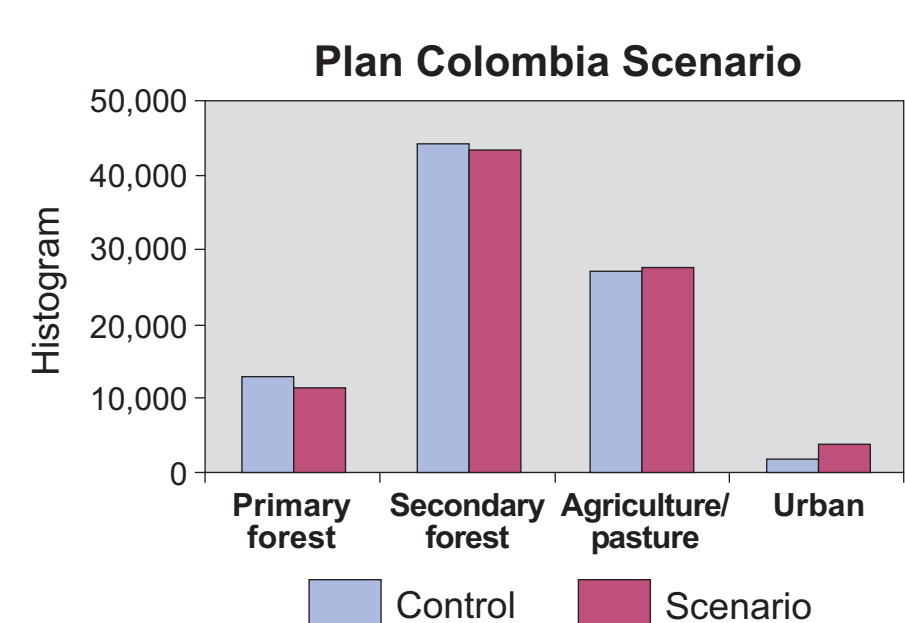
Complex Systems Modeling

- Spatial and aspatial LUCC predictions
- Alternative theoretical framework for modeling the world

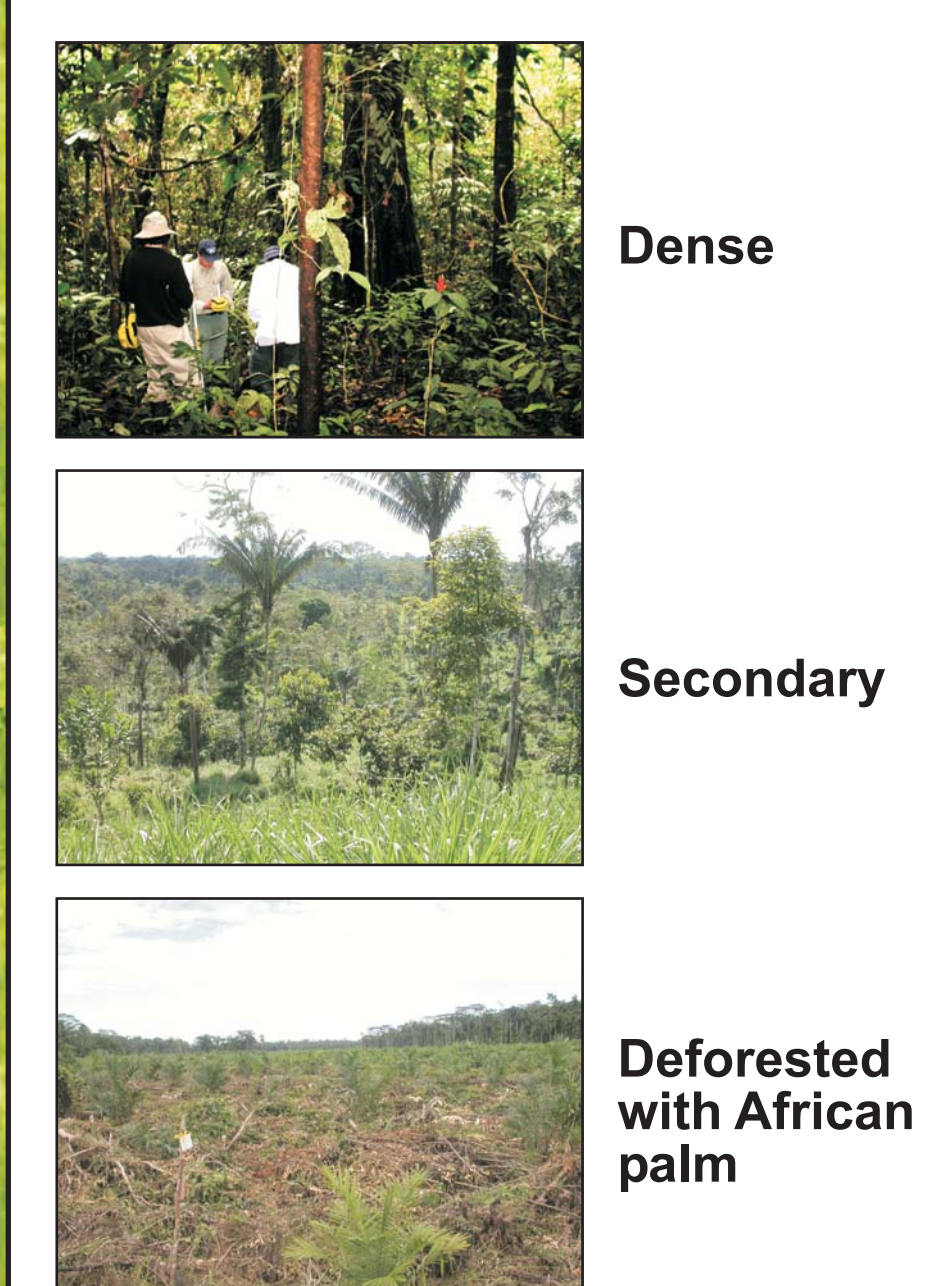
Plan Colombia Comparative Test Simulation through 2010

Conditions for Plan Colombia Simulation

- Initial 1999
- Increased urbanization
- Decreased effect of relief
- Increased effect of access
- Equal likelihood of pasture or secondary forest

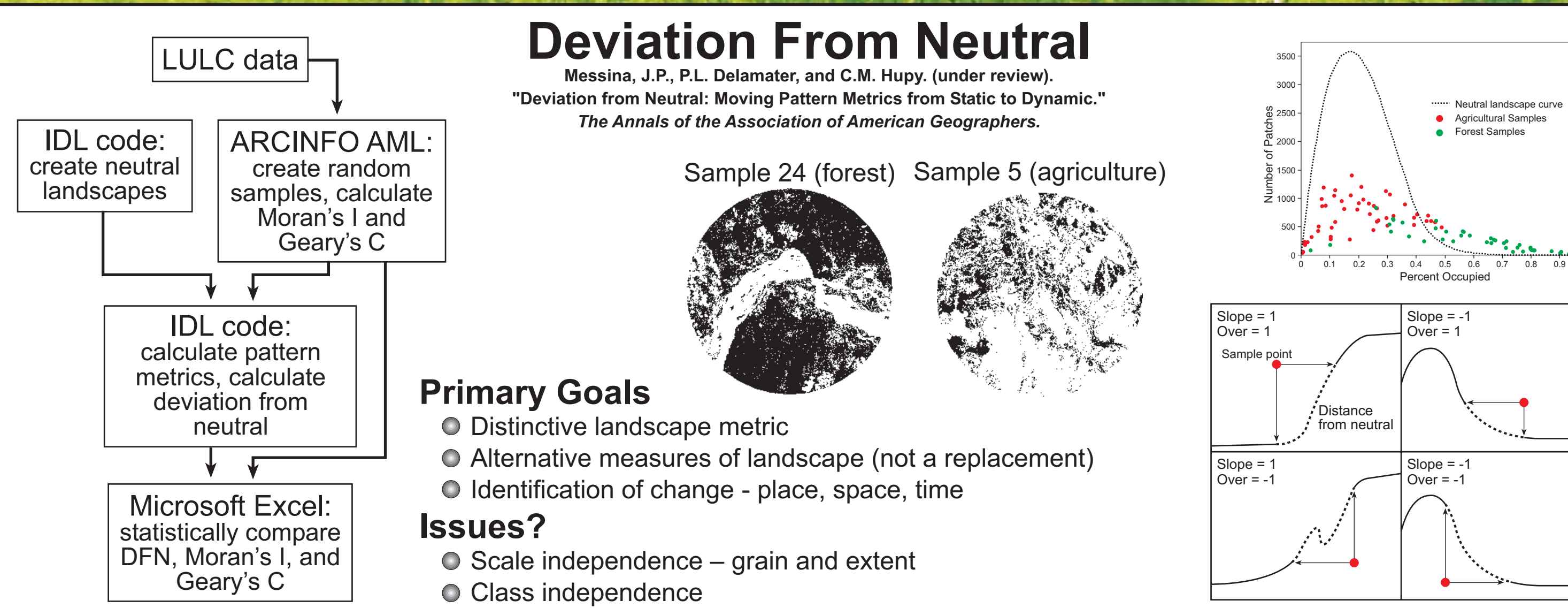


Forests In Transition



Deviation From Neutral

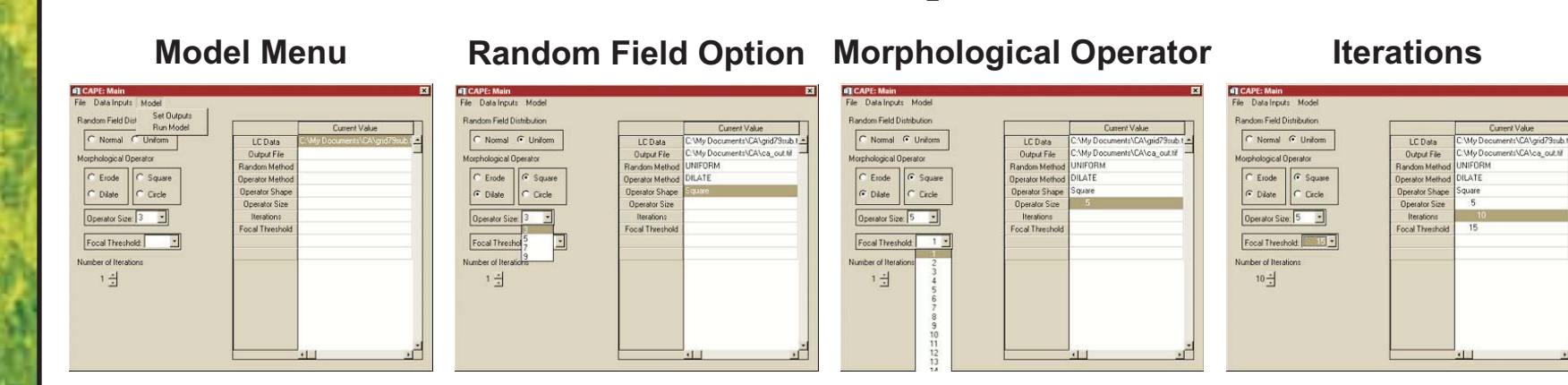
Messina, J.P., P.L. Delamater, and C.M. Hupp. (under review). "Deviation from Neutral: Moving Pattern Metrics from Static to Dynamic." *The Annals of the Association of American Geographers*.



Cellular Automata: How it works

- Dynamic, discrete space-time systems
- Regular grid of cells each in a finite state
- Iteratively updated via discrete time steps
- A cell state is determined by the states of the neighboring cells in the previous time step
- Ability to grow, vary rates, or reverse direction
- Capability to infuse concepts of thresholds, feedbacks, and hierarchy

CAPE: Inputs



CAPE CA Model Processes:

- Read input 'initial-state' LC data layer
- Binary decomposition of input LC data to single class binary layers
- Combination of each LC class w/ new random value field and default PE layers
- Thresholding of combination layer
- User-defined morphological operator
- Result recombined with original LC class
- All classes recombined at end of iteration
- Result decomposed for next iteration or written to output file

Significant Milestones

- 12 papers/chapters/proceedings published or in press
- 16 presentations including to the Ecuadorian Minister of the Environment and the Director of Intelligence of the Drug Enforcement Agency
- Field work in 2003 and 2004
- Graduate Student Thesis, "Mapping and Modeling Tropical Defoliation: A Case Study on the Effects of Plan Colombia" Paul Delamater, May 2004
- Deviation from Neutral Landscape Metric

Future Work

- Field work in 2005
- Acquisition, classification and validation of non-TM imagery
- Completion and distribution of CAPE model version 1 (Cellular Automata Potential Energy)
- Development of complex system rule sets for LUCC along the border between Ecuador and Colombia
- Teaching materials on CA modeling
- Development of a Landscape Metric software package focusing on Deviation from Neutral