Pattern to Process: Research and Applications for Understanding Multiple Interactions and Feedbacks on Land Cover Change (NAG 5 – 9232).

Human Drivers and Forest Fragmentation In an Amazonian Region

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Scientific Questions posed by Study:

The project is attempting to answer the questions:

1) what are the causes of land cover and land use change?
2) what are the consequences of land cover and land use change?
3) what are the actual changes occurring in land cover in certain parts of the world?

Project resources and activities are broken down as follows:

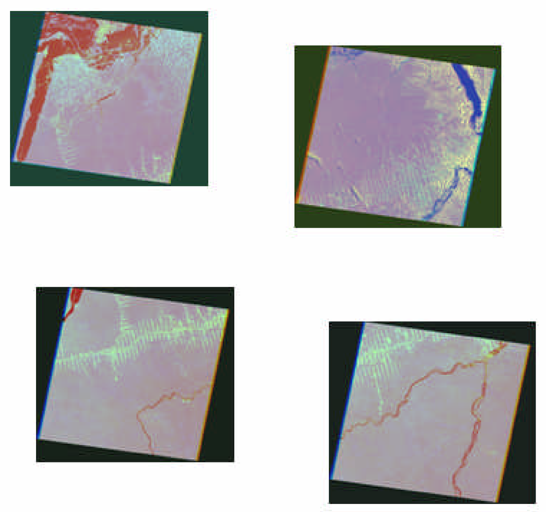
33 1/3 %: Human Dimensions
33 1/3 %: GOFC (mapping/monitoring of forest cover and change detection)
33 1/3 %: Biodiversity

This poster reports on the Human Dimensions component of the project, which is building a model of landscape change, the "Human Drivers Model," and in the process utilizing remote sensing products as inputs for conducing error assessments of model performance. Results for the Biodiversity component of this project were presented by Catherine Lindell and Walter Chomentowski, in the poster, *Land Cover Patterns and Avian Biodiversity in Southern Costa Rica: General Model or Unique Case.*

Advances on the **Human Drivers Model** have occurred primarily in two areas. **First**, an abstract model was deployed in an artificial colonization space, consisting of property boundaries and a transportation system. An ARC-INFO aml was developed to create real-time simulations of landscape evolution, driven by the theoretical model. Once the model prototype was developed and implemented, it was adapted to an actual region in the eastern Amazon near the town, Uruará. The adaptation required a digital map of property boundaries, and the ARC-INFO aml was deployed using the actual colonization space. **Second**, a statistical component was introduced to the overall effort, enabling the incorporation of household level variables into the simulation model, and the evaluation of model performance through error assessment. In, particular, variables form the theoretical framework were measured through regression analysis and use of field data, and the map accuracy literature was adapted to provide measures of model performance using statistics such as "producer's accuracy."

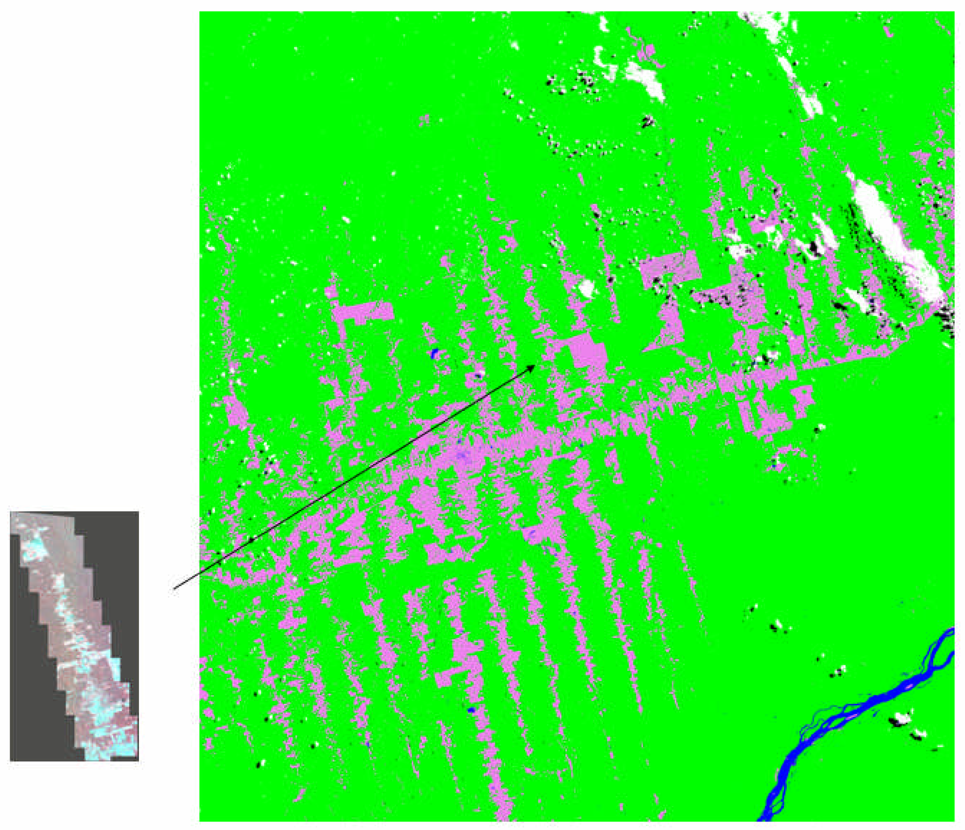
Final steps will include (1) introducing spatial effects into the simulation model by using results from spatial regression, and (2) integrating a road-building component into the model architecture in order to reflect agent interactions between colonists and loggers.

REMOTE SENSING APPLICATION



ETM + 1999

Classified Mosaic, 1999
Uruará region, Brazil



IKONOS IMAGE 2001

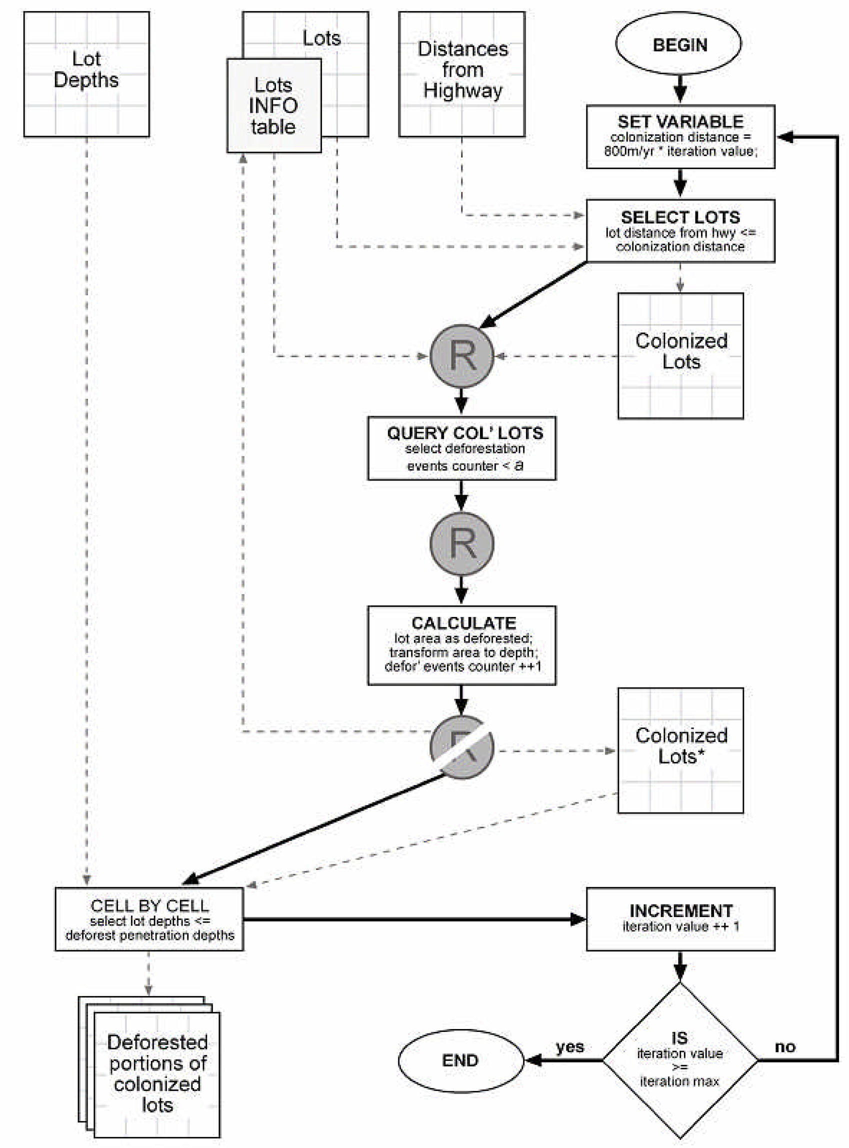
Remote sensing

The remote sensing products used in the errors assessment were produced as follows. First, an initial land cover mosaic was created using four adjacent Landsat 7 Enhanced Thematic Mapper plus (ETM+) scenes for 1999. These included the scenes 227-62, 227-63, 226-62, and 227-63. Locational error was minimized using ground control points along the Transamazon Highway and recognizable features on the settlement roads. The mosaic and original scenes were geographically corrected for axis translation and the vector file of digitized lot boundaries used for the simulations was registered to the processed mosaic using the Trans-Amazon highway as reference, to at most ± 4 pixels, or ± 120 meter error. Six-band composites were derived from the rectified scenes, which were then corrected for atmospheric and bi-directional reflectance effects. The low gain thermal band (Band 6a, ETM+) was resampled to 30 x 30 meter resolution, and reinserted to derive a seven-band ETM+ composite. Signatures for fourteen classes were taken from band 543 composites, seven-band principal component analysis composites, and a Red - Near-Infrared derivative image was used in supervised classifications to derive five themes. The five-theme images were mosaicked, clipped to the extents of the lot boundary, reclassed to two classes (forested and deforested), and overlain with the simulations to produce the necessary measures for error assessment.

Land cover evolution is determined at lot level, and is defined on the basis of four attributes, namely the number of deforestation events (a), associated magnitudes (r), distance from the development highway, and distance from the lot front. Two of these attributes, a and r, are random variables generated from a probabilistic model which functions as follows. First, the number of deforestation events, a, is determined as a discrete random variable following a uniform distribution, or $a \sim U(1, a_u)$, where the upper bound to the distribution, a_u, is allowed to vary for sensitivity analysis. Next, a prediction of total deforestation is made in regression format as $Y = \beta_0 + \beta_1 X + \xi$, where β_0 and β_1 are parameters, X is a lot-specific variable measuring distance of the lot from the main highway, and ξ is a normal random variable distributed as $N(0,\sigma^2)$. The parameter, β_0, is also allowed to vary for sensitivity analysis, while β_1 is fixed by regression results, as is the variance of the error term, σ^2. Once a and Y have been given for a lot, it is straightforward to calculate the deforestation event magnitude as $r = a/Y$. The regression analysis was based on a sample of 261 farm households in the study region, undertaken in 1996. Using a sub-sample restricted by satellite coverage, a bivariate regression was run to obtain the value for the β_1 coefficient and the estimate of the error.

Land cover change on a lot begins with colonization, which occurs earlier at short distances from the development highway. With colonization -- defined as the occupation of a lot -- land clearing occurs from front to back in individual deforestation events. By assumption, a lot possesses a fixed number of events and a fixed event magnitude, and r hectares are cleared every year for a years until the process stops. Lots with the same number of deforestation events may deforest at different times as a function of distance from the development highway, with distant lots possibly starting the process after near properties have finished. Since the deforestation event magnitude is fixed at lot level, the total amount of deforestation occurring on any individual lot is given as the product of the number of events and their magnitude, or $a * r$. For modeling purposes, this is converted to a proportion of lot size, and maximum deforestation on any given lot may range up to 100 percent. The process as described is depicted by the cartographic model in the figure to the right which, for simulation purposes, was translated into the Arc Macro Language (AML), a software-specific scripting language provided by ESRI for use with ARC/INFO software and data formats. The model was deployed using a grid of digitized lot boundaries provided by the Brazilian Institute for Colonization and Agrarian Reform, or INCRA.

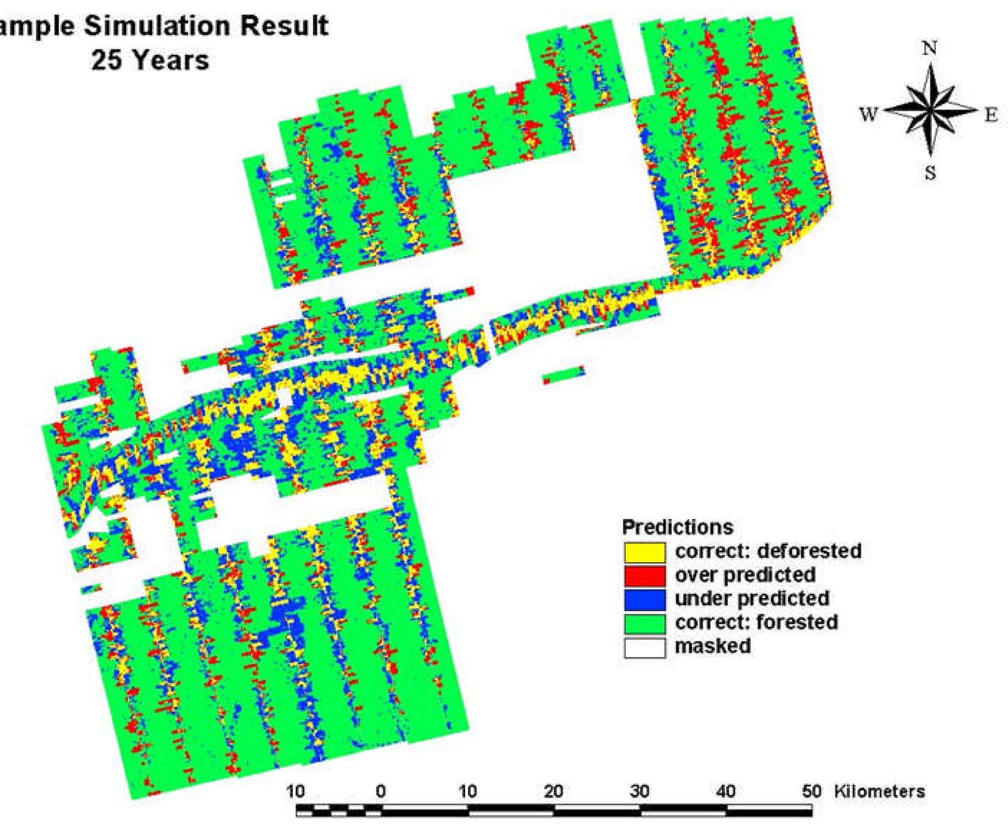
LANDSCAPE MODEL APPLICATION

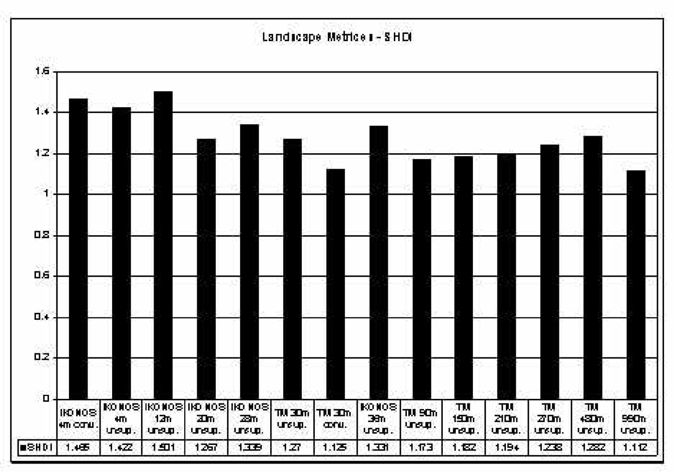


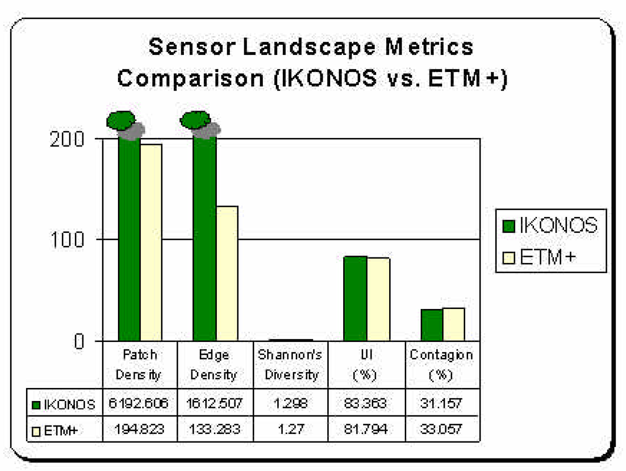
Results

The figure to the right is a graphic depiction of the outcome of a simulation under one set of parameters. Remote sensing provided the template for this graphic information. In particular, the simulation results were overlaid with the classified mosaic, and pixel by pixel comparisons were made determining whether the model predicted correctly for two land cover classes, forested or deforested. Over predictions occur where the model indicates deforestation but none has occurred. Under predictions are pixels for which the model fails to predict actual deforestation. Areas occupied by large land holders and agro-industrial interests have been masked.

Sample Simulation Result 25 Years







Forest Fragmentation

An important part of the project involves assessments and predictions of forest fragmentation. Here are presented several measures of forest fragmentation, using common indicators, for part of the study area. In particular, an IKONOS image acquired in 2001 covers about 20 kilometers of one of the settlements roads in the region. The graphic and tabular data show the considerable sensitivity of landscape metrics to the resolution of the imagery used in analysis and classification. Such landscape metrics will be calculated for the model predictions, providing another measure that can be used to test model performance.

Results

A set of results are assessed in the table, showing parameter values and resulting magnitudes of deforestation as well as producer's accuracy, which is the probability the model predicts deforestation given deforestation has actually occurred. Overall deforestation as measured from the satellite images for the study area is 25 percent, by 1999.

Predicted deforestation after 25 years.

a_u	*Colonization rate (m)*	β_0	*# of cells deforested*	*Area in hectares*	*% of total area deforested*	*Producer's Accuracy*
6	800	40	1,174,936	46,997	15.16%	29%
6	800	60	1,877,162	75,086	24.22%	43%
6	800	80	2,544,173	101,767	32.83%	54%
6	1600	40	1,489,755	59,590	19.22%	34%
6	1600	60	2,651,827	106,073	34.21%	54%
6	1600	80	3,815,645	152,626	49.23%	69%