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Title:  Simulating of Land Use Dynamics in Southeast Asia:  A Cellular Automaton Approach

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Abstract:

This project, using recently developed cellular automaton and agent-based modeling procedures along with a temporally, substantively rich case study, is developing spatially-explicit model-based simulations of future LCLUC scenarios for Nang Rong, Thailand and the broader Southeast Asian region, including Vietnam, Cambodia, and China. The research draws heavily on recent work in remote sensing, demography, sociology, complexity theory, and related social and biophysical disciplines. The scenarios are based on empirically observed relationships in the following areas: a) history and spatial pattern of village settlement; b) road development, expansion of available vehicles, and changing geographic accessibility; c) migration and household formation; d) land titling and linkages to investment in various land uses; e) climate and monsoon history; f) global economic factors, including world cassava prices and the 1997 economic crisis; and g) electrification, and the accompanying rise in TV viewership and consumerism. Results of the simulations will be used to examine the spatial distribution and composition of LCLUC.

The project exploits a rich collection of interlinked data sets for Nang Rong, some of which were developed under previous NASA funding. There is a collection of previously analyzed Landsat images (TM and MSS) dating back to 1973. Other remotely sensed data available includes AVHRR, SPOT, and SAR, as well as aerial photos dating back to the1950s. Community and household level surveys are available for 1984, 1994, and 2000. Out-migrants have been followed, and in-migrants added to the data set. Digital coverages showing roads, rivers, elevation, soil types and other spatial-thematic data are available within our GIS. Daily precipitation and temperature data are available since 1965. Human dimensions and Landsat derived land use data can be linked at the village level for 1984, 1994, and 2000, and at the household level for approximately 9,000 households in 2000.

After developing, calibrating, and validating the cellular automaton modeling scenarios for Nang Rong through the use of a deep satellite time series, spatially explicit LCLUC patterns will be derived for the period 1950- 2020. We will increase the extent of our geographic reach into the surrounding region, including Cambodia, China, and Vietnam, by relating LCLUC patterns in these countries and their drivers to our scenarios for Nang Rong. These are countries with significant extant forest coverage, some of which has likely been preserved due to their difficult political and social histories in the past 50 years. While prediction is difficult, it seems that at least a sub-set of these countries is poised for substantial social and economic change, with resulting implications for LCLUC and the carbon cycle.

Keywords:

1. Research  Fields: Biogeography, Demographics, Land Use Modeling
2. Geographic Area/Biome:  Cropland, Southeast Asia
3. Remote Sensing: Aerial Photography, AVHRR, Landsat
4. Methods/Scales: Data Fusion, GIS, Local Scale

Questions, goals, approaches:

NASA ESE scientific questions addressed by the project: a) what are the changes in land cover/use; b) what are the causes of LCLUC; and c) what are the consequences of LCLUC.

Proportion of the project that involves social science: 75%

Proportion of the project that involves the following themes:
Carbon: 25%
Water: 25%
Nutrients: 25%
GOFC: 50%

Goals for project period (9/1/02-8/31/03), as projected in our proposal and progress towards meeting those goals:

1. The CA model building will yield methodological papers including "Plots vs. Pixels in CA Modeling of LCLUC", and "Validation Issues in the Development of a CA Model". No papers have yet been prepared on CA modeling; but an agent-based modeling paper has been prepared and will soon be submitted to a journal. This paper also covers validation issues.

Original approach/method: Our proposed approach was two-fold. First we would use appropriate statistical analyses to develop rules to be used in the CA modeling. Then we would use CA modeling techniques. We have not made any modifications or adjustments to these methods. But we have added consideration of agent-based models for some of the modeling work. If our evaluation of the agent-based models is positive, we will incorporate them into the overall modeling effort. The evaluation was positive and we have incorporated agent-based modeling into our model of village settlement patterns. Later, the agent-based and CA modeling approaches will be merged.

Progress Report

A workshop was held at our study site in Thailand in February 2003. The 'To Do' List constructed in March 2002 was revisited and updated. During the portion of the workshop held in Nang Rong, validation work on the agent-based model was conducted.

A basic CA model has been built and rules for rice and upland crops have been written. These rules are being incorporated into the model for some initial runs. The model will incorporate six different terrain classes.

A village settlement pattern animation was developed in Year 1, and analysis has been proceeding on factors affecting village settlement patterns. A paper entitled "Dynamics of Village Settlements in a Frontier Region: Nang Rong, Thailand" written by Barbara Entwisle, Jeffrey Edmeades, Ronald R. Rindfuss, and Stephen J. Walsh was prepared and presented at the annual meetings of the Population Association of America, Minneapolis.

A paper expanding on our settlement analyses has been accepted for presentation at the Open Meeting of the Human Dimensions of Global Environmental Change in October 2003.

A paper, "Village Location in Thailand: Visualization of Agent-Based Modeling with Follow-on Interviews" by Wenwu Tang, George Malanson, Barbara Etnwisle, and Steve Walsh is being submitted for publication.

The analysis of monsoonal variability is complete.

The electricity animation is complete.

Work on the road network is still underway.

Crop price information has been collected.

Land policy documentation is on file.

There have been two surprises that arose from integrating our modeling efforts and qualitative work. First, as expected, throughout most of the district, the location of surface water was a key factor in the siting of villages; but in the Southeast this was not the case. Qualitative research indicated that in the Southeast, water flowing one to two meters below the surface was critical. Second, it now appears that charcoal making was an important reason for deforestation in Nang Rong. Some charcoal was used for cooking by Nang Rong households, but most was sold to merchants who then resold it in urban areas.

Conclusions:

The empirical work is still in progress, so we have no over-arching conclusions. Technically, we are pleased with the combination of both CA and agent-based models, and using qualitative approaches to back-up and validate the models.