Modeling and Forecasting Effects of Land Use Change in China Based on Socioeconomic Drivers: Progress Report

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Introduction

This project report covers the 16-month period from May, 1998 - November, 1999. During this period, we have: 1) evaluated various atmospheric correction techniques for our time series of images; 2) developed and tested algorithms for classifying land cover and identifying dates of change; 3) generated annual estimates of land conversion; 4) acquired and analyzed socioeconomic data; 5) created a map of land-use change; 6) assessed the accuracy assessment of land-use change map from field visits; 7) started the analysis of 8-km intra-annual composites of AVHRR data to evaluate changes in NDVI as a function of land conversion and associated changes in carbon stock; 8) begun econometric modeling of the relation between development and land-use change. This report describes the progress made in each of these areas during this period.

1 Atmospheric Correction

To compare our images across time and seasons, we correct for changes in the composition of the atmosphere. To ensure the accuracy of the classification, we compare seven absolute atmospheric correction algorithms and a relative normalization technique. The first set of methods are physically-based absolute atmospheric corrections in which digital numbers (DNs) are converted to surface reflectances. The methods tested rely only on atmospheric properties available from the imagery because *in-situ* measurements of optical depth are not available for the eight images. Several of these techniques extend the dark-object subtraction methods proposed by Moran et al. (1992) and Chavez (1988, 1996). The other set of methods are relative calibrations that depend on empirical calculations.

The efficacy of these corrections are evaluated by the ability of algorithims to classify land cover and to detect changes in land cover from the corrected data. Using these criteria, all corrections improve the data quality. Best results are obtained using a new method which adds the effect of Rayleigh scattering to conventional dark object subtraction. More complicated algorithms do not necessarily improve performance of classification and change detection. Details of the methods tested and their relative performance are documented in Song *et al*., (1999).

2 Testing Classification and Change Detection Techniques

We have tested a number of different classification techniques: multi-date Tasseled-Cap transformation, artificial neural networks, and logit models. The accuracy of three methods is assessed by evaluating out of sample classifications for 23 land cover categories. When average across these 23 categories, the accuracy of the three methods varies between 65 and 80 percent. This range expands when we evaluate the ability of the three methods to assign pixels to individual land use categories. We are writing a paper that describes the use of logit models to classify land use types and a second paper that compares the results generated by the three techniques.

We also have developed and tested a series of techniques to identify the date at which a pixel changes from one land use category to another. One technique uses techniques developed by time series econometricians. In the first step, we use fixed effect estimators to generate equations for each of six DN bands for each of seven constant land use categories. We use these equations to make predictions for the DN values for each of the six bands for each land cover category. Using these values, we assemble models that simulate the change in land use for each of the eight possible dates. These models are compared to the actual DN values. The best model, the one in which the date of change most accurately describes the actual DN values is identified using tests of predictive accuracy developed by Diebold and Mariano (1995). This technique and the more traditional alternative, identify the correct date of change 40 - 96 percent of the time, depending on the threshold for certainty. Details of this technique are presented in Kaufmann and Seto (in progress).

3 Estimates of Land-Use Change

Using the techniques described above, we evaluate annual estimates of land-use change. We transfer the data to a GIS (ARC/INFO) which we use to extract the land-use data by county. The timing of land use changes coincides with the visit of Deng Xiaoping to the Pearl River Delta in 1992. The total change in land use indicates that the area occupied by development and urban expansion increased 300 percent between 1988 and 1996. The data for the annual rate of change in land use will be used as the dependent variables in our analysis of the socioeconomic drivers of change.

4 Acquisition and Analysis of Socioeconomic Data

We have compiled a detailed database of key demographic and economic variables which will be used in the modeling of the effects of development on land-use. The data have been collected at the county and city levels for 23 units from 1985 to 1997. These data are extracted from annual Statistical Yearbooks of Guangdong. We received considerable help from Dr. Xinzhong Li from the Institute of Quantitative and Technical Economics, Chinese Academy of Social Science. Dr. Li is supported by a World Bank Fellowship as a visiting scholar in our research group.

5 Creating a Land-Use Change Map

We have created a two-date land use map of our study area. The map shows the areal extent of urbanization, particularly in Shenzhen and efforts to expand agricultural production into the Delta. Details of the methods used to make the map are documented in Seto et al. (1999b).

6 Field Work and Accuracy Assessment

To assess the accuracy of the land-use map, we organized a three week fieldwork campaign. Lu Jinfa, from the Institute of Geography and Huang Xiuhua, from the Institute of Remote Sensing Applications, flew in from Beijing once again to assist with the field work. Using a random stratified sampling scheme, we selected 496 sites to validate. Prior to the trip, each site was labeled independently by at least two analysts. If both analysts agreed on the class type, the site was assigned to that class. If there was any discrepancy between two of the analysts, or if either analyst was unsure of the class for a site, the site was visited in the field. The initial screening of sites in the lab avoided the effort in the field of finding places where the land-cover type was obvious, such as sites in the water of the Delta, in downtown Guangzhou, or in the forested mountains. Site assessments both in the lab and in the field were made without previous knowledge of the other analyst's choice of class type, nor of the final classification in the map. Based on these effort, we were able to classify 345 sites prior to our trip. During field work in March and April, 1999, 151 sites were analyzed. Results from the accuracy assessment confirm a high overall accuracy of the change map of 93%. Confusion matrices comparing field assessments with map categories and true marginal proportions of the classes are presented in Tables 2 and 3.

7 Biophysical Modeling

This component seeks to quantify the effects of land cover changes on regional carbon storage and vegetation-atmosphere carbon exchange. We use a two-pronged approach. First, we use a simple book-keeping model to analyze the amount and spatial distribution of annual carbon storage and fluxes. To do so, we combine our estimates for land cover with literature estimates for standing biomass and annual NPP. The second approach uses satellite-derived data to model directly the spatial patterns in seasonal and annual NPP. We combine existing time-series data on vegetation PAR absorption (fPAR, from AVHRR) and incident photosynthetically active radiation (PAR, from TOMS) in a production efficiency model (PEM) of terrestrial NPP. Currently we are compiling literature estimates for biomass and NPP and processing and analyzing the FPAR and PAR data sets. In the final six months, we will implement the bookkeeping analysis and the PEM.

8 Modeling development and land-use change

We have assembled the data on land cover and demographic, economic, and technical into a panel. The panel includes data for twenty counties for the years 1985 through 1996. Data prior the first image are included so that the models can specify lags without loosing degrees of freedom. Data are not available for all counties and all periods, therefore, the panel is missing observations. Consistent with these missing observations, we are estimating the equations using fixed and random effects that are designed for unbalanced panels.

9 Other Efforts

We presented preliminary results at the Annual ASPRS conference in Portland, Oregon (Seto et al., 1999a) and at the International Symposium of Geoinformatics and Socioinformatics in Ann Arbor (Seto, 1999c). In December, Robert Kaufmann will present the new technique for identifying the date of change at a meeting on land use change at Wageningen University in the Netherlands.

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