# Modeling and Forecasting Effects of Land-Use Change in China Based on Socioeconomic Drivers

Boston University
Department of Geography
Principal Investigator: Robert K. Kaufmann

Co-Investigators: Curtis E. Woodcock
Dennis G. Dye
Karen C. Seto

Chinese Collaborators: Lu Jinfa
Li Xiaowen
Wang Tongsan
Huang Xiuhua
Liang Youcai

# Summary of Talk

Project Overview

Remote Sensing Methodologies
- Atmospheric Correction
- Change Detection Methodologies
- Land-Use Change Map, Accuracy Assessment, & Area Estimates

Biophysical and Biogeochemical Effects

Time of Change

Economic Data

Research Findings to Date

# Project Overview

Goals

- Quantify rate and amount of land conversion
- Quantify socioeconomic drivers of land-use change
- Quantify effects of land-use change on biophysical properties and biogeochemical processes

Steps

- Quantify land-use change from satellite images
- Model relation between land-use and socioeconomic variables
- Explore the effect of land-use change on biophysical attributes and biogeochemical processes
- Forecast land-use change under various scenarios for economic development

# List of Atmospheric Correction Methods

DOS1:

Chavez, P.S. 1989.

DOS2:

Chavez, P.S. 1996.

DOS3:

Use Tz and Tv of Rayleigh atmosphere, Edown (downwelling diffuse irradiance) from 6S with Rayleigh atmospheric optical thickness and mid-latitude winter atmosphere model.

DOS4:

Image based estimate of Tz, Tv, and Edown

Liang et al. 1997.

rho (TM1) = 0.25*rho(TM7)  rho (TM3) = 0.50*rho(TM7)

References:

Chavez, P.S. 1989. Radiometric Calibration of Landsat Thematic Mapper Multispectral Images. PE & RS. 55: 1285-1294.

Chavez, P.S. 1996. Image-Based Atmospheric Corrections -- Revisited and Improved. PE & RS. 62: 1025-1036.

Liang, et al. 1997. An Operational Atmospheric Correction Algorithm for Landsat Thematic Mapper Imagery over the Land. Journal of Geographical Research. 102:17, 173-17, 186.

# Land-Use Categories (Stable)

Water

Natural Vegetation

- Eucalyptus, Pine, Fast Growing Trees, Shrubs

Agriculture

- Fish Ponds, Field Crops, Rice Fields, Orchards

Urban

- Old urban, transition to new urban

# Land-Use Categories (Change)

Agriculture to Water
- new reservoirs

Natural Vegetation to Water
- new reservoirs

Water to agriculture
- water to fish ponds, rice fields, or bananas

Natural to Urban (non-economic use to developed)
- water or natural vegetation to urban/transition

Agriculture to Urban (some economic use to developed)
- fish ponds, rice fields, field crops, or orchards to urban/transition

# Test Dataset

- 809 sites
- 7807 pixels
- 23 classes
- 9 classes
- Sites based on field visits and image interpretation
- Training and testing done on successive 80/20 splits
- No testing data ever seen in prior training

  (No cheating allowed!)

# Econometric Techniques - Logit Models

## Specification

- Dependent variable: Land cover type
- Independent variables: DN values for bands 1-5, 7, brightness, greenness, wetness

## Diagnostic Statistics

- Independent variables generally significant
- In sample cases correct generally greater than 95%

# Artificial Neural Networks

(Help from Gopal and Woodcock's NSF project)

Multiple ways of formulating Fuzzy Artmap
(Carpenter et al., 1991)

1. El-Gasim's Methods (Abuelgasim et al., in press at RSE)
   - Used to identify change due to Gulf War
   - Train on classes in initial date
   - Used trained net on second date
   - Allows identification of new land cover categories
   - Uses fuzzy membership values for multiple classes to determine change

# Artificial Neural Networks (cont'd)

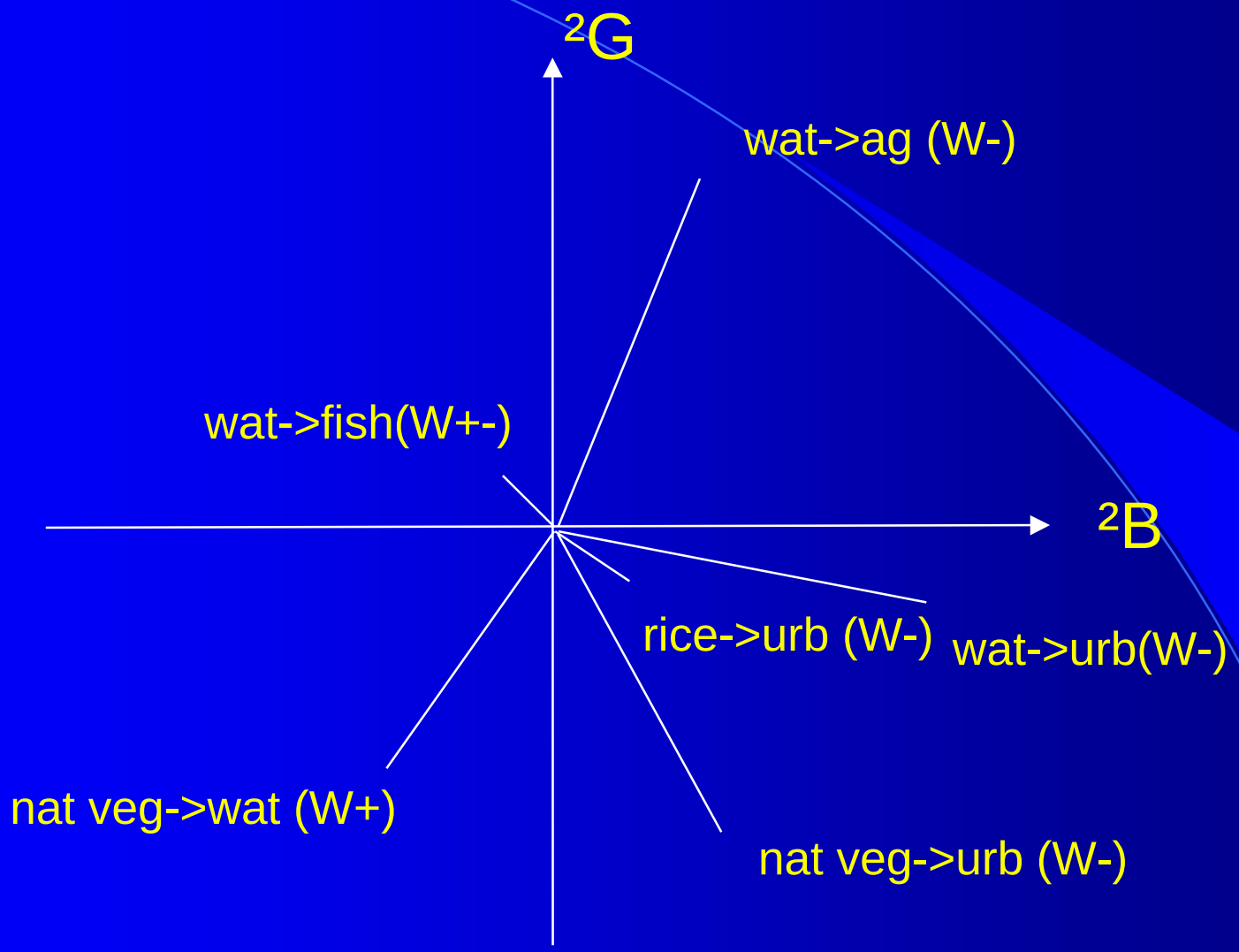
2. Two-date Classification
   - Input both dates of spectral data, including examples of change classes
   - Output is both stable and change classes
3. All-date classification
   - Input all 9 dates of imagery
   - Output is both stable and change classes

References

Abuelgasim, A.A., Ross, W. D., Gopal, S., and C. E. Woodcock, In Press. Change Detection using adaptive fuzzy neural networks: Environmental damage assessment after the Gulf War. RSE.

Carpenter, G. A., Grossberg, S. and J.H. Reynolds, 1991. A neural network architecture for object recognition by evidence accumulation, IEEE Transactions on Neural Networks, 6(4): 805-818.

# BGW Change Vector




Inputs: Tasseled Cap BGW in 1988, and ²B, ²G, ²W
Output: Stable and Change Classes
Classification: Bayesian Maximum Likelihood

# Preliminary Results on Test Data

| Methodology | 23 Categories | 9 Categories |
|---|---|---|
| • Artificial Neural Nets | 76 percent | N/A |
| • BGW Change Vector | 74 percent | 82 percent |
| • Logit Model | 80 percent | 86 percent |

# Time of Change

Problem

- Existing map identifies land-use categories in 1988 and 1996
- Need to know date at which land-use changes have occurred

Methodologies

- Neural Nets
- BGW change vector
- Time series techniques

# Artificial Neural Networks for Time of Change

Multiple configurations of Fuzzy Artmap available

1. El-Gasim's Method
   - Could be sequentially applied to successive pairs of images to identify time of change
2. Two-date classification
   - Could be sequentially applied to successive pairs of images to identify time of change
3. All-date classification
   - To identify both type and time of change would require examples of all kinds of change at all possible times for training
   - Not viable option for this project

# BGW Change Vector Time of Change

Approach:

- Once the 1988-1996 classification is trained, any pair of dates can be used
- Plan is to apply existing training statistics on images in a pair-wise fashion

Method of Atmospheric Correction:

- Ridge Method of DN Matching

# Time Series Techniques

Estimate models for constant classes

- Dependent variables: DN value bands 1-5, 7, brightness, greenness, wetness, NDVI
- Independent variables:  solar zenith angle, aerosol optical depth, minimum DN value, seasonal dummies

Estimation technique

- Stack as seemingly unrelated regressions
- Fixed effects estimators

# Time Series Techniques (cont'd)

Predict pixel values

- Use classification technique to determine land-use categories
- Simulate all possible dates of change

Choose best model

- Pair-wise comparison of change dates
- Choice criterion – Predictive accuracy tests developed by Diebold and Mariano (1995)

Reference:

Diebold, F. X. and R. S. Mariano. 1995. Comparing Predictive Accuracy. Journal of Business and Economic Statistics. 13(3): 253-263.

# Accuracy Assessment and Area Estimates

| | Ground Truth | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Map Class | water | nat veg | ag | urban | ag>wat | nat>wat | wat>ag | nat>urb | ag>urb | total | map prop |
| water | **49** | | | | | | | | | 49 | 7.82 |
| nat veg | | **85** | 6 | | | | | | | 91 | 44.13 |
| ag | | 1 | **109** | 1 | | | | | 2 | 113 | 37.68 |
| urban | | | 2 | **53** | | | | 1 | | 56 | 2.67 |
| ag->wat | 2 | | 11 | | **15** | 1 | | | | 29 | .06 |
| nat->wat | | | | | 8 | **22** | | | | 30 | .02 |
| wat->ag | | | | | | | **24** | | | 24 | .56 |
| nat->urb | 1 | 2 | 4 | | | | | **27** | 17 | 51 | 1.96 |
| ag->urb | | | 5 | 2 | | | | 5 | **41** | 53 | 5.10 |

Total # sites:496

Area Weighted Accuracy:93.50%

| Class | Map Estimate (% of total area) | Corrected Estimate (% of total area) | Net Change (%) |
|---|---|---|---|
| water | 7.76 | 7.82 | .77 |
| nat veg | 46.80 | 44.13 | -5.71 |
| ag | 35.06 | 37.68 | 7.47 |
| urban | 2.31 | 2.67 | 15.58 |
| ag->water | .1 | .06 | -.4 |
| nat->water | .03 | .02 | -.33 |
| water->ag | .56 | .56 | 0 |
| nat->urban | 2.78 | 1.96 | -29.49 |
| ag->urban | 4.60 | 5.10 | 10.87 |

# Biophysical Effects

- Albedo of urban areas is surprisingly low (previously observed in Egypt)
- The effect of a dramatic increase in albedo due to urbanization is only true for a limited number of years (less than a decade)
- Approach - tracking of albedos derived from Landsat TM imagery through time for urbanized sites

# Biogeochemical Effects
# Change in Surface Carbon Flux

- Intent is to include both the change in surface carbon flux due to land-use change and also emissions due to increased fossil fuel consumption
- Resources limit our abilities to do detailed estimates of surface carbon fluxes
- Expect fossil fuel consumption changes to swamp surface flux changes

# County Level Socioeconomic Data

Sources:

Professor Lu Jinfa, Institute of Geography,
Chinese Academy of Science

Liang Youcai, Vice Director, Economic Forecasting
Department, State Information Center

Statistical Yearbook of Guangdong Province (1985–1998)

- Value added by sector
- Urban/Rural Population
- GDP
- Income
- Agricultural output
- Number of vehicles

# Socioeconomic Data Compilation and Analysis

Dr. Lee Xinzhong, Institute of Quantitative and Technical Economics Chinese Academy of Social Science, World Bank Visiting Scholar, Boston University Summer of 1999

# Research Findings to Date

- The degree of atmospheric correction required is related to the methods used for change detection and research question
- New modifications to dark-object-subtraction methods do not significantly improve change detection accuracies
- We have been able to map land-use change with high accuracy (93.5%), particularly with respect to the ultimate land-use classes
- The amount of developed land has tripled between 1988 and 1996

# Research Findings to Date (cont'd)

- Application of innovations from time series econometrics and artificial neural networks improve monitoring of change and time of change in a series of images (relative to conventional methods)
- Effects of urbanization on albedo do not seem to follow expectations
- Spatially disaggregated socioeconomic data are available for the study period
- Period of analysis limited because Landsat images are unavailable 1982 – 1987