2001-2002 Progress Report for NASA LCLUC project

**CONSEQUENCES OF INSTITUTIONAL CHANGE:
LAND-COVER DYNAMICS IN KAZAKHSTAN 1960-2000**

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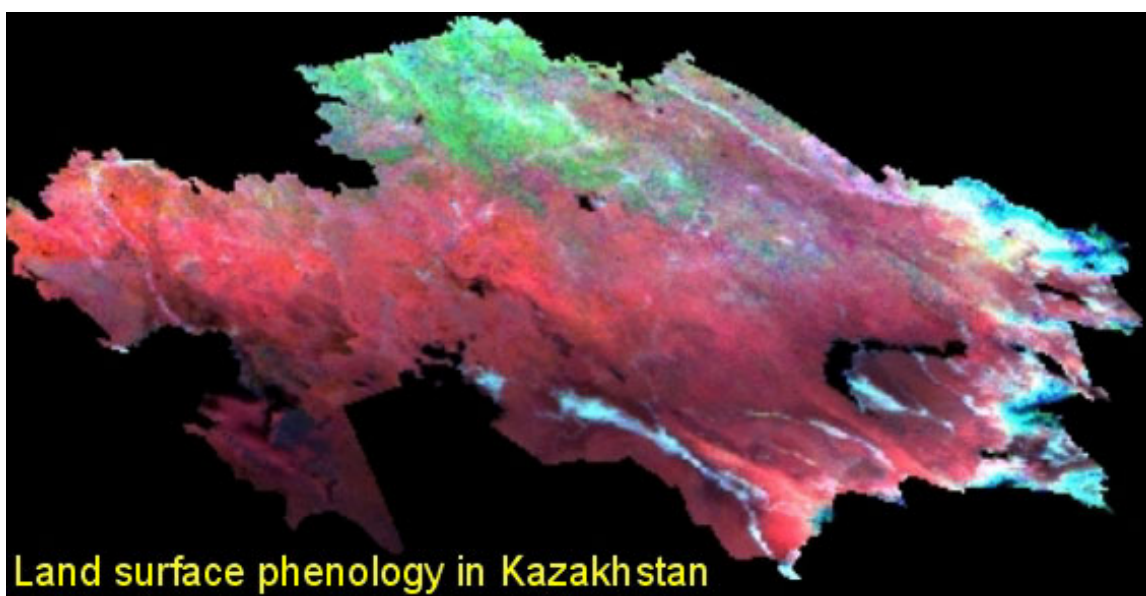**Geoffrey M. Henebry, Ph.D.**
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Land surface phenology in Kazakhstan

Abstract

Kazakhstan is the largest of the Newly Independent States (NIS) that formed following the Soviet Union's collapse. At 2.7 million square kilometers, Kazakhstan is nearly four times the size of Texas and more than one-third the size of the conterminous US. The country is mostly rangeland: almost 70% of the land area is grazed by cattle, sheep, goats, and other livestock. Since the abrupt institutional changes surrounding the disintegration of the Soviet Union in the early 1990s, the Kazakhstan region has undergone extensive land-cover changes. A recent official study suggests two-fold decreases in agricultural lands and state holdings and a nine-fold increase in settled areas. Marked decreases in livestock and meat production accompany increases in productive rangelands, as measured by vegetation indices, suggesting that institutional change and its socio-economic consequences are primary drivers of the region's land-cover change. However, few details are known about the pace or extent of land-cover change, due to the collapse of regional environmental monitoring networks in the early 1990s.   We propose to reconstruct the pace and extent of recent land-cover change in the Kazakhstan region and to place this episode within the larger context of climatic variability and landscape dynamics since 1960. We shall use a multi-resolution approach to model the spatio-temporal dynamics of rangeland production. At the broadest scale, we shall use standardized 8km AVHRR image time series since 1982 in conjunction with regional 1km direct readout AVHRR data since 1995 and MODIS data since 1999 to establish patterns of seasonal and interannual variability. We shall focus on local land-cover dynamics in five areas of interest using RESURS, Landsat MSS, TM, and ETM+ imagery, as well as Corona declassified intelligence satellite photos from 1960-1972. This work builds upon significant prior work by the PI and Kazakhstani collaborators. Products from this research will include a library (available on the Web and as CD-ROMs) containing the assembled image time series and corresponding spatio-temporal analyses, including the "landscape trajectories" and "coordinate constellations" that capture land-cover dynamics in Kazakhstan at multiple resolutions using archived standard image products.

Keyword Lists

(1) Research Fields: Agriculture; Change Detection; Desertification; Grazing; Irrigation; Land Abandonment; Rangeland Management; Urbanization; Vegetation Structure; Water Bodies

(2) Geographic Area/Biome: Central Asia; Grasslands; Semi-arid; Arid, desert; Croplands

(3) Remote Sensing: ASTER; AVHRR; IKONOS; Landsat; MODIS; Pathfinder; SWIR; VIS,near-IR; Quickbird; Corona

(4) Methods/scales: Data fusion; GIS; Local Scale; Micro Scale; Regional Scale; Stochastic Processes; Time Series Analysis

Questions

The Kazakhstan project engages the following LCLUC Science Questions:

(1) Where are land cover and land use changing, what is the extent and over what time scale?

(2) What are the causes and what are the consequences of LCLUC?

(3) What are the impacts of climate variability and changes on LCLUC and what is the potential feedback?

Allocation across LCLUC themes

Human Dimensions: <25%
Carbon: 25%
Water: 25%
Nutrients: 0%
GOFC: 0%
Other: GOLD   >25%

Goals

During this first project year, we had as our primary goals (as detailed in the timetable of our 2001 workplan): (1) completed spatio-temporal analyses of the Pathfinder AVHRR Land NDVI data at the *National* scale using PCA and LTA; (2) commenced analyses at the *Regional* scale with data from multiple sensors; (3) commenced identifying and ordering data for *Local* scale analysis; and (4) completed a background document on institutional factors affecting land cover change in KZ. We have accomplished most of these goals (see narrative below); however, some adjustments in timing and specific objectives have been necessary.

Although we have envisioned a simple background document on institutional factors affecting land cover change, it became clear during background research that a geographically broader (Central Asia) and temporally deeper (late 18th century to present) context was needed to place myriad institutional factors into proper context. We have and are continuing to glean insights on KZ from scholarship in related fields (cf. bibliography available at project website).

Approach

Our original approach was to use several methods of spatio-temporal analysis (PCA: Principal Components Analysis; LTA: Landscape Trajectory Analysis; CVA: Change Vector Analysis) on image time series at multiple resolutions to reconstruct the pace and extent of land cover change in KZ since 1991. We have tuned implementations of the PCA and LTA methods to compare efficacy of information extraction. PCA on the 8km PAL NDVI data was done both using the covariance matrix on the entire seasonal image series and on NDVI minima by compositing period. The latter method yielded better phenological separation for subsequent classification. LTA using random walk resampling has been successful in establishing dynamical baselines for change assessment. We shall be implementing CVA in the Regional analyses in the coming year.

Narrative on Project Progress

The Kazakhstan Land Cover Dynamics Project (KZ LCDP) has completed the first year of research with several notable accomplishments and discoveries. In late September 2001, we advertised the availability of a doctoral position on three listservs (IMAGRS-L, USIALE-L, and ai-geostats) and in EOS. We successfully recruited Kirsten M. de Beurs, who received in 2000 her M.Sc. in Agricultural System Engineering (specializations in Statistics, Remote Sensing, and GIS) from Wageningen Agricultural University, The Netherlands. Ms. de Beurs enrolled in the doctoral program in Natural Resources at the School of Natural Resource Sciences, University of Nebraska-Lincoln, in January 2002.

We have established a project website (www.calmit.unl.edu/kz/) to which we have posted background information, presentations, and papers. We will continue to develop this website as the project matures. We have assembled and continue to assemble a bibliography on Kazakhstan and Central Asia, which is available at the website. A central question with respect to land cover change in regions with strongly continental climates is the separability of interannual climatic variation from anthropogenic change. We have completed a series of analyses on the 8km PAL NDVI data and have found significant differences in the temporal development of spatial pattern before and after 1991. We are pursuing parallel and comparative analyses with various types of meteorological data to parse the climatic and anthropogenic signals at the National scale. For Regional scale analyses, we have adopted a simplified map of KZ ecoregions developed by the World Wildlife Fund and are in the process of identifying suitably deep image time series of the key KZ ecoregions. At the Local scale, we have identified archived low cloud imagery for ASTER, MSS, TM, ETM+ and Corona for Astana, Almaty, and Atyrau and are in the process of acquisition. We have underway an analysis of the impact of rising Caspian Sea levels on Atyrau. We applied successfully to the SDB for IKONOS and Quickbird acquisitions over Astana and Almaty. These data will be compared against Corona imagery scanned from film diapositives due to the lack of archived Landsat imagery for these cities prior to Landsat 7.

Our contact and interactions with our KZ collaborators were hindered post-9/11 by problems with internet connectivity. We have subsequently been able to retrieve some high resolution imagery by ftp and are arranging for access to more data. We have also requested selected official land use / land cover statistics from our collaborators based on tables of contents from official reports.

Next Steps

- Once the reprocessing of the MODIS data is complete, we shall be acquiring and assembling these data for PCA and LTA and comparison with AVHRR.

- Parsing the influence of climatic variability using data from first order stations, gridded surface moisture variables, and selected data from the NCEP Reanalysis.

- Regional analyses using Landsat image series within WWF simplified ecoregions.

- Local analyses of urban areas using Corona, IKONOS, and Quickbird data.

- Ingest MODIS 250m data from KZ collaborators

Most Significant Results

- **New finding:** LCLUC studies have traditionally been conducted at finer spatial and coarser temporal resolutions. However, linkage with numerical weather prediction and general circulation models require coarser spatial and finer temporal resolution. A new finding of our project is that land cover changes occurring at finer spatial resolutions can produce significant changes in spatio-temporal patterns observed at coarser resolutions.

- **New potentials:** Random Walk Resampling (RWR) offers potential to assess statistically significant changes in the face of spatial nonstationarity. Low pass Fourier filtering of spatial metric time series (cf. slide 14 of 2002 IGARSS presentation on website) and analysis of integrated anomalies of spatial metric time series (cf. slide 15 of 2002 IGARSS presentation) show promise to extract change signatures from high variability data.

- **New products:** The project website (www.calmit.unl.edu/kz/) has illustrative examples under both the "Fine Resolution Analysis" and "Coarse Resolution Analysis" pages. In addition, under "Project Information" page, the presentation and posters in PowerPoint format contain further illustrations and quantifications of land cover dynamics.
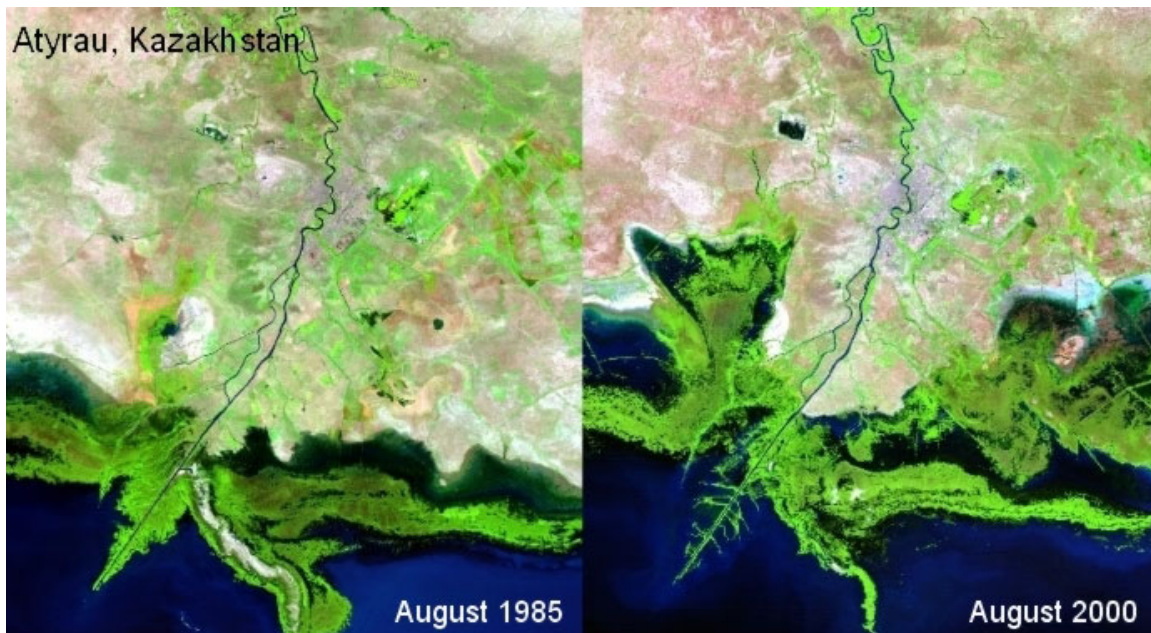
Conclusions

The Kazakhstan Land Cover Dynamics Project is proceeding on schedule. We have discovered significant changes in the spatio-temporal seasonality and variability of 8km PAL NDVI image time series since 1991. We have developed and are currently refining new methods of spatio-temporal change assessment for image time series. We shall be focusing in the next project year on Regional and Local scale analyses of multiple sensor image series.

Project Outreach

Project Website
www.calmit.unl.edu/kz/
Presentations at Scientific Meetings

(1) de Beurs, K.M., and G.M. Henebry. 2002. Landscape dynamics in Kazakhstan: seasonal baselines for land cover change detection. US-IALE annual meeting, Lincoln, NE, April. 23-27.

(2) Henebry, G.M., and K.M. de Beurs. 2002. Land surface dynamics in Kazakhstan: dynamic baselines and change detection. IGARSS 2002. Toronto, Canada, June 24-28.

Published Proceedings

(1) Henebry, G.M., K.M. de Beurs, and A.A. Gitelson. 2002. Land surface dynamics in Kazakhstan: dynamic baselines and change detection. *Digest of IGARSS 2002*, IEEE, Piscataway NJ. II:1060-1062.

Manuscripts in Preparation

(1) Land cover dynamics in Kazakhstan: change assessments from image time series. Target journal: *Regional Environmental Change.*

(2) Change analysis in image time series. Target journal: *IEEE Transactions on Geoscience and Remote Sensing*, Special Issue on Analysis of Multitemporal Remote Sensing Images (submission deadline: 2002/09/30).

(3) Landscape trajectory analysis using low-pass Fourier filtering. Target Journal: *International Journal of Remote Sensing*.