# Landscape dynamics in Kazakhstan: seasonal baselines for land cover change detection


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## OVERVIEW

At 2.72 million km$^2$, Kazakhstan is more than one-third the size of the conterminous US or roughly equal in area to all of Western Europe including the British Isles. It is bounded by China on the east, Kyrgyzstan and Uzbekistan on the south, the Caspian Sea and a small section of Turkmenistan in the west, and Russia in the north. Since the abrupt institutional changes surrounding the disintegration of the Soviet Union in the early 1990s, Kazakhstan has reportedly undergone extensive land-cover changes[1].

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. 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


To be able to assess the significance of changes in vegetation indices, it is necessary to examine the observational record and to place this episode within the larger context of interannual climatic variability and landscape dynamics. We used a standard global dataset to characterize the expected and actual spatio-temporal dynamics of the vegetated land surface.

## Data Source

- Pathfinder AVHRR Land (PAL) maximum Normalized Difference Vegetation Index (NDVI) 10-day (dekad) composites
- Temporal extent of image time series: 7/81-12/99 (330 images)
- Spatial resolution of image time series: 8 km
- Seasonal subset of the image time series ranged from 4/82 to 9/99 (276 images)
- Two dekads of September 1994 are missing due to sensor failure.

## Processing Methods

### A: *Identification of Kazakhstan Ecoregions*

- To segment Kazakhstan into broad ecoregions, the image time series from May through September (276 images) was submitted to an unsupervised K-means clustering (D=0.05, iterations=3).
- April images were excluded from the clustering due to high interannual variation in extent of snow cover.
- Three ecoregions were obtained: North, West, and South.

### B: *Seasonal Baselines*

- The spatial dependence structure of NDVI was estimated by scale of fluctuation (SOF) analysis using random walk resampling[2-5] for the entire country and each of the three derived ecoregions.
- A stopping criterion of 5% and $10^4$ random walks were used for each image date.
- The result sampling distributions were summarized using simple descriptive statistics: mean, median, coefficient of variation, interquantile range, etc. In this poster, we present results for mean values of the SOF and NDVI and their respective coefficients of variation (CV%). The CV% is a relative measure of dispersion found by expressing the standard deviation as a percentage of the arithmetic mean.

### C: *Outlier Identification*

- Plots of CV% of SOF of West clearly showed that there are a number of outlying periods. Investigation of these images showed that CV% is increased due to image stripes. All regions were checked for outlying points in the CV% and for 18 dates with outlying values, corresponding images were deleted.

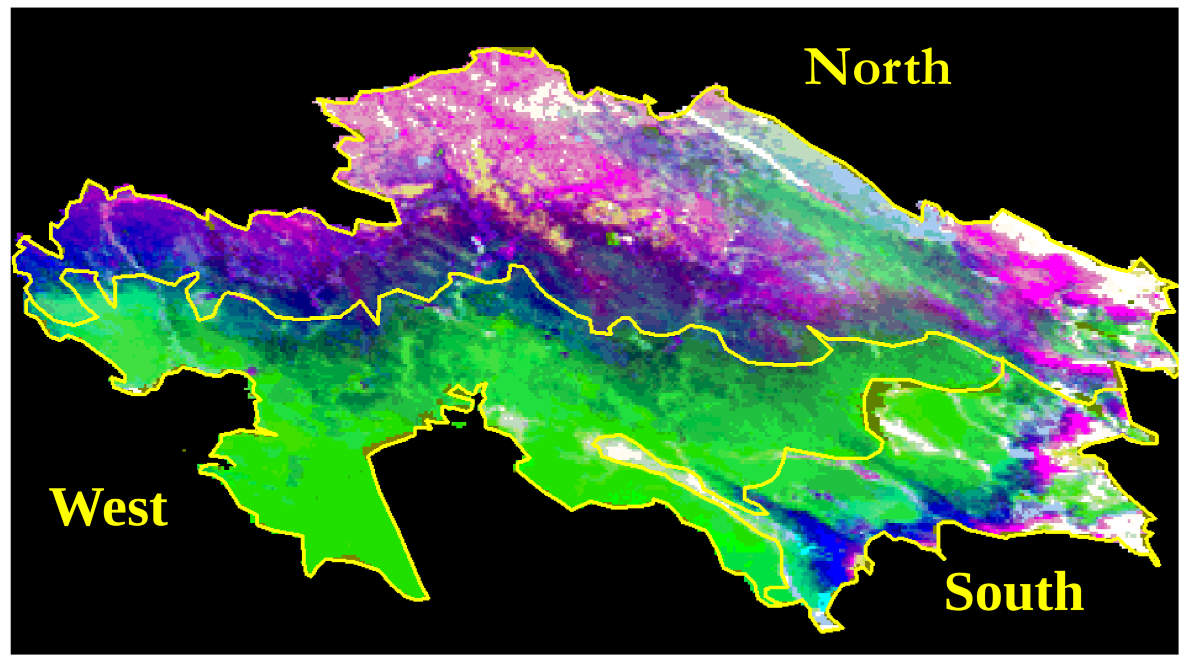
### D: *Interannual Variation Assessment*

- Resulting data were plotted and periods that captured accentuated or attenuated interannual variation in regional NDVI and/or SOF metrics were identified. These "watchpoints" can serve for detection of different regimes of land-atmospheric interaction.

## A: Identification of Kazakhstan Ecoregions

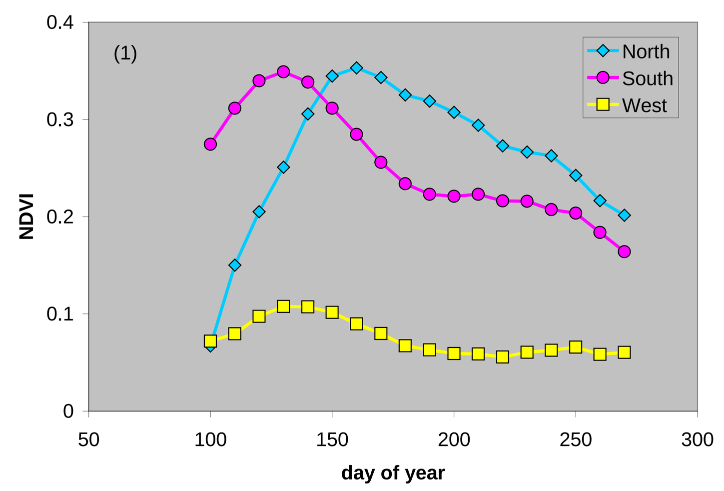
The K-means clustering divided the image into three regions: North, South and West. The region borders are plotted over an image obtained through a principal component analysis on the image time series. The image displays the first three principal components as RGB=3,1,2.

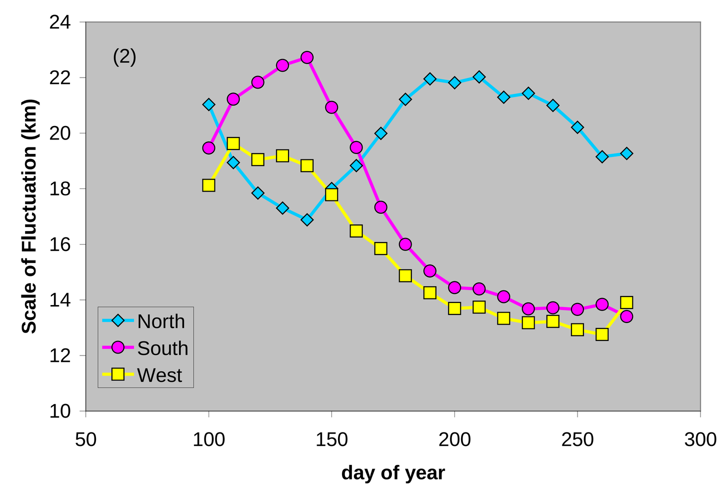
- The North ecoregion is characterized by very fertile soils that are intensively cultivated with spring wheat and other cereal grains.
- The South ecoregion is characterized by cotton, fruits, and vegetables cultivated under irrigation.
- The West ecoregion is mostly arid grasslands and deserts that support livestock grazing.

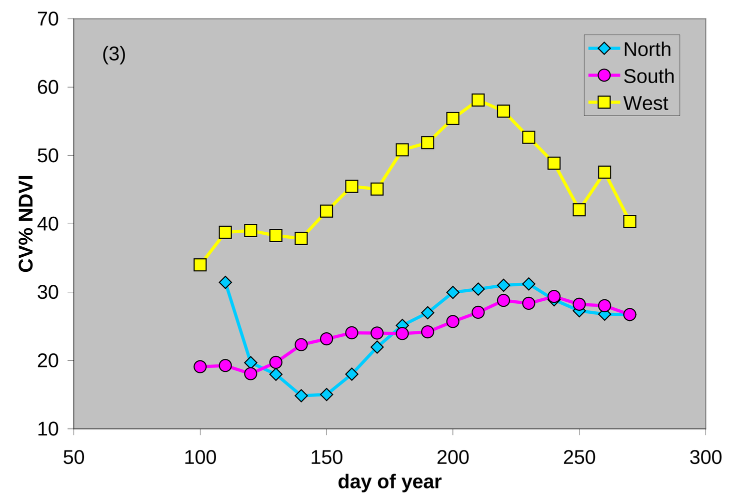


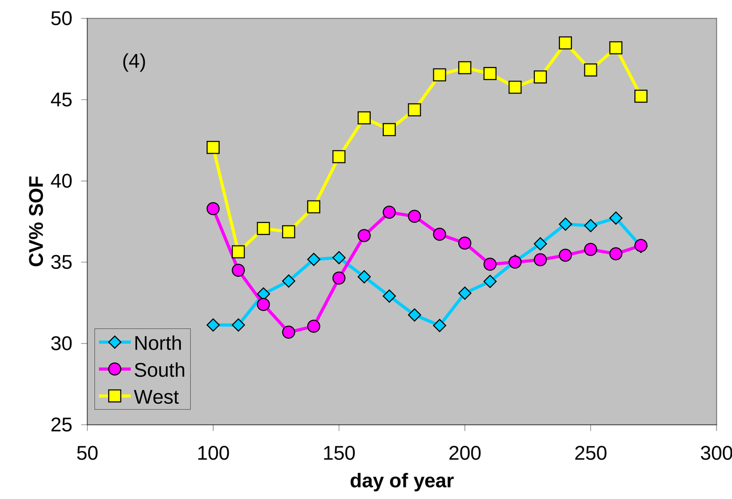

## B: Seasonal Baselines

The seasonal trend for the Scale of Fluctuation (SOF) and the trend for the NDVI are not similar (Figs. 1,2). South and West have an early NDVI peak, around day 130, while North peaks later around day 160. SOF (Fig. 2) peaks for South and West around day 140. After the peak, the SOF of both South and West decrease for the rest of the season. SOF in the North increases to a peak around day 200. North and South almost describe an opposite pattern. A similar opposition can be found in the CV% of SOF of North and South (Fig. 3). In the West, the CV% for both the SOF and the NDVI is much higher than for the other regions (Fig. 3,4), but this is not unexpected as the means in this arid region are relatively lower.



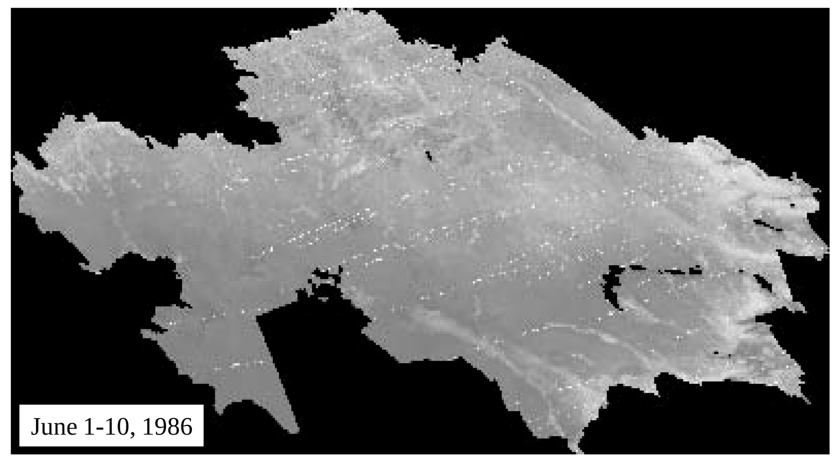



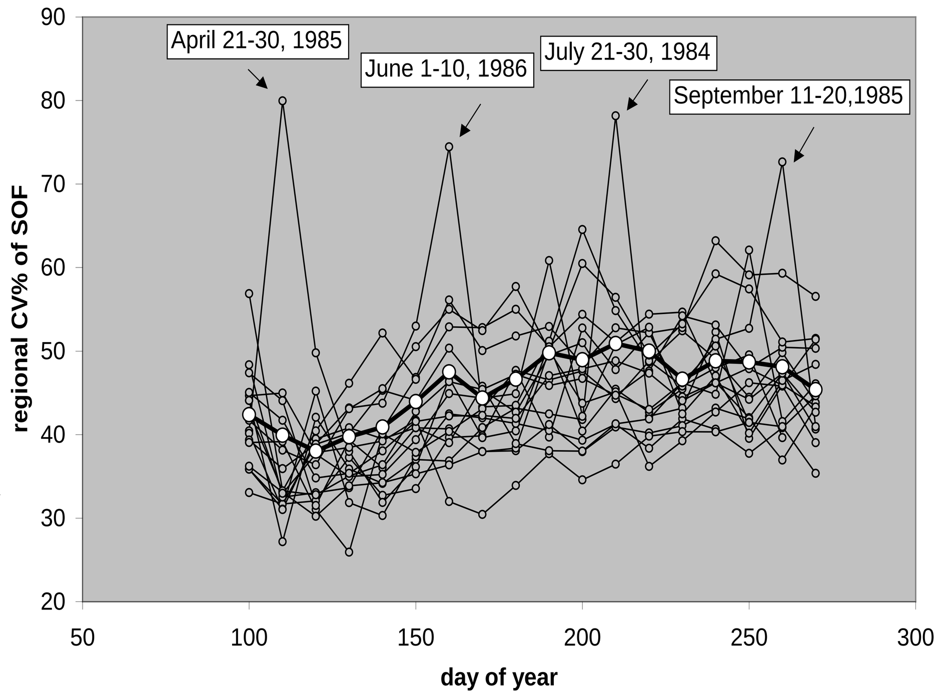




The CV% of NDVI (Fig. 3) in the West increases during the year, to a peak at day 200. This peak is much later than the NDVI peak in the West. The North has a trough in the CV% NDVI when it has a peak in the NDVI; whereas, the South just shows a slight increase in the CV% NDVI during the season. Diverse processes occurring across these ecoregions, such as grazing in the West and differential harvests in the North and the South, may cause these seasonal patterns in spatial structure and may be revealed by imagery at finer spatial resolutions. (In the next phase of our investigation, we will examine sparser time series of finer resolution imagery.)

## C: Outlier Identification




(Above) The image of the first dekad of June clearly shows an unusually noisy image and thus these data were eliminated from the analysis.




(Right) The regional CV% of SOF of the West shows four dates with outlying points.

After examination of all graphs with outliers and the corresponding images, 18 dates were removed from the subsequent analyses.

## D: Interannual Variation Assessment

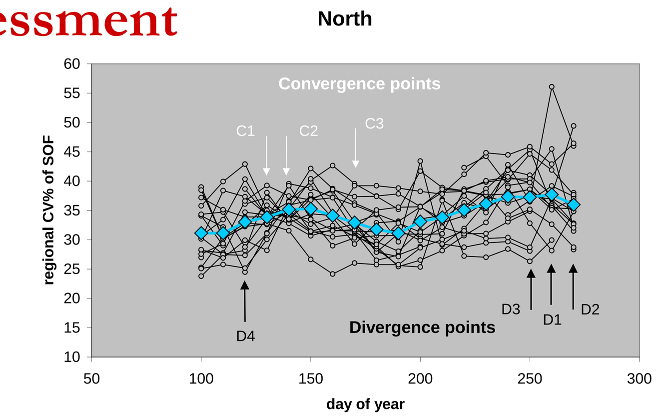
It is possible to determine "watchpoints" for each metric (mean NDVI and SOF; CV% NDVI and SOF), but here we present only the interannual variation assessment for the CV% of SOF.

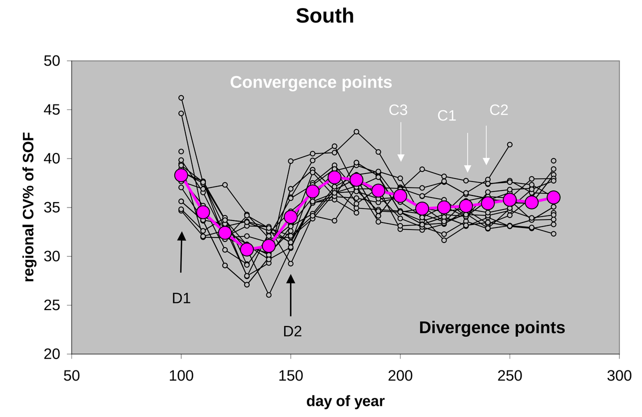
***How do you interpret "regional CV% of SOF"?***

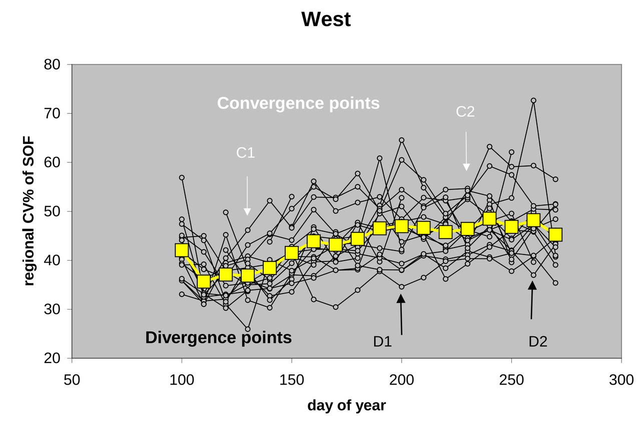
The spatial dependence of NDVI is estimated using a resampling technique[3-5] which generates a distribution of values. The CV% calculated from this distribution summarizes the regional variability in SOF found through the many random walk transects that explore the study area. Thus, the regional CV% of SOF describes the spatial heterogeneity in the spatial dependence structure.

Convergence points correspond to compositing periods in which interannual variation of the spatial heterogeneity of SOF is lower. Divergence points, in contrast, correspond to periods of higher interannual variation.

These watchpoints were found by rank ordering the interannual CV% of the regional CV% of the SOF. The two highest-ranking were designated as divergence points and two lowest-ranking were designated as convergence points. If two or more watchpoints occurred in sequence, then an additional watchpoint was identified, e.g., D4 in North and C3 in South.




## OUTLOOK

- Detecting land cover change is easier than assessing its significance, especially in regions with high climatic variability. In the first phase of a multi-year investigation, we have developed a strategy to characterize spatio-temporal variation into complementary aspects.
- Applying this strategy to the PAL imagery of Kazakhstan has led to the determination of seasonal baselines of NDVI and its spatial structure for three ecoregions. Each region manifests distinctive dynamics which are a complex result of climate and land use.
- We are currently investigating how much of the interannual variation observed in the metrics can be explained by meteorological forcings and parsed into different climatic regimes.
- We have found in related work[6] that the variability in spatial structure in some ecoregions is significantly different before and after 1992.
- The next phase involves change analyses at finer spatial but sparser temporal resolution.

## References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