Ecological Monitoring in semi-arid Central- and West-Asia (EMCWA): Drivers and Trajectories

Roland Geerken and Ron Smith

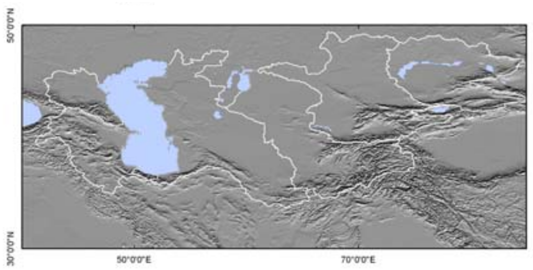
Yale University, Dept. of Geology and Geophysics, New Haven, CT, U.S.A.

Project Summary

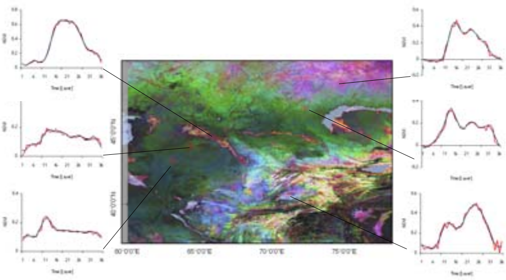
Thematic emphasis is on ecological changes in semi-arid Central- and West-Asia, with the objective to investigate possibilities for a more meaningful, regional assessment of eco-system health from space. Though the primary interest is a regional one the results are intended to be detailed enough in order to be useful for local decision making. Conventional regional assessments of vegetative resources either lack the necessary ecological details or they lack temporal compatibility and hence are not suitable for regular updating. This affects our ability to reliably and appropriately detect features that define degradation, as well as the successful identification of mutual influences and causal relationships between vegetation change and possible drivers like human, climate and hydrology.To overcome this limitation we focus on the classification of functional characteristics of vegetation expressed in the shapes of their growing cycles (NDVI-cycles) . Biophysical and hydro-meteorological characteristics described in the functional vegetation groups will be used in change detection analyses, in hydrologic modeling, and to study the changes and the feedbacks between vegetation and hydrology. The study focuses on the following major landscapes / land use areas:

- Mountain areas, representing the most important source for river water.
- Cultivated areas, forming the main consumer of natural resources particularly irrigation water.
- The rangelands which are often exposed to a growing pressure imposed by the expansion of cultivation and/or the intensification of animal grazing.

Spatial-temporal variations in resource availability and their impact on agricultural production and on agricultural strategies will be analyzed and projections be made under different climate change scenarios.



The geographic focus of our project is on the watersheds of the Balkash Basin, the Syr-Darya watershed, the Amu Darya watershed and some of the watersheds that discharge into the Caspian Sea.



Examples of annual NDVI-cycles from different vegetation covers, demonstrating the diversity of phenological cycles. The image is a color composite of the first three Fourier magnitudes calculated from a one year NDVI time-series covering the Syr-Darya watershed. In general, variations in hue are indicative for different vegetation types or cropping patterns, variations in intensity indicate variations in vegetation coverage (dark colors representing low, bright colors high coverage). Original NDVI-cycles are shown in red, Fourier-filtered cycles (first 5 harmonics) in blue.

Functional Vegetation Groups and Vegetation Coverage

Understanding vegetation growing cycles and the functional characteristics that can be derived thereof are the key to a more meaningful, regional assessment of degradation (rehabilitation) processes as well as to a better parametrization of hydro-meteorological parameters.

Various hydro-meteorological parameters are closely linked to the phenological cycle of a plant and to its coverage. This includes parameters like water infiltration, surface run-off, evapotranspiration, or soil water uptake. Being able to map temporal-spatial variations in term of these parameters will significantly improve our ability to monitor the status of ecosystems and to model interaction and feedbacks between vegetation and hydrology.

To overcome limitations typically associated with conventional classifications of remotely sensed NDVI time series, we developed alternative Fourier based cluster algorithms that are sensitive to characteristics associated with the plants phenology. To further verify our approach and to create a data base of characteristic growing cycles, part of the field work will concentrate on the identification and the on-site monitoring of reference vegetation types.

Literature:

Geerken, R., Batikha, N., Celis, D., Depauw, E., 2005, Differentiation of rangeland vegetation and assessment of its status: field investigations and MODIS and SPOT VEGETATION data analyses. Int. J. Remote Sens., Vol.26, 20, 4499-4526.

Geerken, R., Zaitchik, B., Evans, J. P., 2005, Classifying rangeland vegetation type and coverage from NDVI time series using Fourier Filtered Cycle Similarity. Int. J. Remote Sens., Vol.26, 24, 5535-5554.

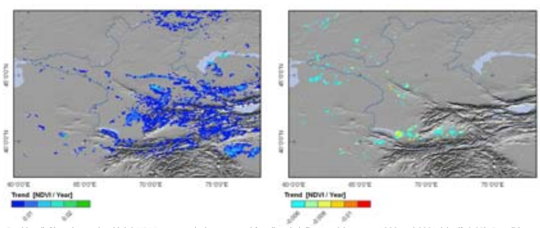
Evans, J.P. and R. Geerken, 2006, Classifying rangeland vegetation type and coverage using a Fourier component based similarity measure. Remote Sensing of Environment (in review).

Rangelands

Inter-annual climate fluctuations typically cause variations in rangeland vegetation covers that exceed those imposed by most human activities by a multiple. To reveal the subtle human induced vegetation changes - originating e.g. from overgrazing, fuel-wood cutting or rehabilitation - the contribution of the climate signal to the vegetation cycle has to be removed.

Using a technique that has been developed at our Center we will identify human induced changes in the rangelands of Central Asia. Some of the questions we want to answer include:

- Which areas have undergone change?
- What are the main drivers for change?
- What vegetation types do we find in areas undergoing change? Or
- Are there regional differences in change patterns and what is causing them?



Positive (left) and negative (right) NDVImax trends (uncorrected for climatic influences) between 1982 and 2001 (signif. 0.05). Possible explanations: Decreasing length of period of snow-cover in the mountains, intensification of agriculture along the river Chu and at Lake Balkash (drop in lake level?), recovery of rangelands at Lake Aydarkul, salinization of irrigated fields east of Lake Aydarkul.

Irrigated and Rainfed Agriculture

The study of irrigated and rain-fed agriculture is primarily intended to create a baseline of information that will address the following questions:

- What are the dynamics in rain-fed and in irrigated agriculture in terms of spatial extent, cropping practices (single – double crops and spring – summer crops), field patterns (providing hints to well- or canal irrigation), crop types, and productivity?
- How does climate influence, crop timing and agricultural productivity?
- What is the impact of abandoned fields (soil erosion, time it takes for re-growth of natural vegetation)?
- What are the impacts of aeolian sediments, salinization, desert encroachment or industrial pollution on agricultural productivity and its spatial distribution?
- To what extent has governmental policy influenced changes in agriculture.

With the snow melt being particularly important for water availability in rivers, snow accumulation in adjacent mountains must be considered when assessing water resources and proper water use. Using the results from hydrologic modeling we will address further questions:

- What are the changes in irrigation water use over time and how is this related to the water resources and in particular to their inter-annual variability?
- What are the options to make water use more efficient - crop type, water distribution, cropping cycles?
- What might be the impact of climate change on agricultural strategies and water use?

Hydrologic Modeling

Water availability and water withdrawal is strongly related to winter precipitation and summer temperature. With sometimes up to 80% of river water derived from snow-fall (Syr-Darya), adjacent mountain areas are of particular importance for water availability in the rivers. Locally available soil-moisture and surface run-off define the rangelands suitability for grazing. Accordingly, the hydrologic watershed modeling component of this project is aimed at addressing the following questions:

- What is the natural flow regime of the river systems?
- What are the seasonal and inter-annual variations in snow cover, snow-melt, river discharge, soil moisture, run-off which occur naturally?
- How do current water resource use activities respond to naturally occurring changes in river flow and reservoir storage?
- How does the natural vegetation cover respond to variations in inter-annual availability of soil moisture?
- What are the likely impacts of the continuation of current trends in land use/land cover on water resources?
- What will be the impact of future climate change on the water resources given future land use change scenarios?

To achieve this , we will use our FFCS classifications, in addition to other image parameters like albedo, for the definition of some critical hydrologic variables that strongly depend on vegetation type and coverage, i.e., roughness, surface runoff, infiltration, evapotranspiration, soil-moisture. Temporal analyses of the response pattern of NDVI-cycles to the soil-moisture cycle will give further hints to the kind of vegetation changes.

Data that would be helpful:

- Field data on land use and land cover describing vegetation type (species) and vegetation coverage, that can be used as reference sites in high temporal resolution data sets (Modis, SPOT Veg.).
- Daily climate data (mostly temperature and precipitation) and the whole range of parameters for Penman PET calculation.
- River discharge data for the Syr-Darya, Chu, Amu Darya, Kuer rivers.
- Data on water withdrawal from rivers.

Data that will be acquired

- Time series of hyperspectral field measurements on different crops and vegetation covers to monitor temporal spectral characteristics.
- Irrigation water use measured at different test sites (irrigated crops) to assess water use efficiency.
- Land use and land cover mapping (mostly in Uzbekistan, Kasachstan).

Products / Outcome

- Map of functional vegetation groups for Central Asia including their coverage (absolute or relative to reference sites depending on field data availability).
- Current trends and projected changes in hydrologic parameters, in terms of their temporal occurrence, and their period and amount of availability, under the assumption of continuing trends and various climate change scenarios.
- Future potentials and vulnerabilities of the semi-arid areas, arising from climate change and human pressure and their implications for agricultural productivity and grazing capacities.
- Possibilities to respond to current and projected changes such as the use of other crop types or cropping patterns, alternative areas/resources or more efficient methods of resource use, e.g., irrigation techniques, water distribution.
- Knowledge transfer to collaborating Centers in the region (ICDC, IWMI, ICARDA).

Collaborating Institutes / Organizations:

- International Water Management Institute (IWMI)
- The International Center for Agricultural Research in Dry Areas (ICARDA)
- Institute for Atmospheric and Climate Science ETH Zuerich

Funding Agency

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Contact information:

Roland Geerken: roland.geerken@yale.edu
Ronald Smith: ronald.smith@yale.edu

Project website: http://www.yale.edu/emcwa