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Ecological Changes in Semi-Arid Central and West Asia: Drivers and Trajectories

Statement of the Problem

Conventional regional assessments of vegetative resources in semi-arid areas 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 dryland degradation, as well as the successful identification of mutual influences and causal relationships between vegetation change and possible drivers like human, climate and hydrology.

Project Hypothesis

Successfully classifying dryland vegetation by both dominant vegetation type and level of coverage will significantly improve our understanding of the sustainability, vulnerability and resilience of these dryland systems, and how they affect hydrologic processes.

How the project will advance towards the NEWS challenge

Natural Vegetation Covers

The focus of our investigations will be the natural vegetation covers and the agricultural areas of semi-arid Central and West Asia. One of the challenges we pose is to regionally classify natural vegetation covers according to dominant vegetation type and absolute coverage. The attributes associated with these parameters, will allow the monitoring of ecological changes rather than less meaningful green biomass changes. Our particular interest will focus on the discrimination between palatable and unpalatable vegetation types, between degraded and not-degraded vegetation types, and between annual grasses and perennial shrubs. On the basis of aforementioned vegetation types, sound assessments of grazing potentials, of vulnerabilities, of degradation degrees, or changes in these can be made.

This will be achieved by using the Fourier Filtered Cycle Similarity (FFCS) method that we developed during our South-West Asia project (SWAP). The FFCS approach takes advantage of diagnostic differences in the plants' phenological cycle (NDVI-cycle), where class assignment is based on a shape similarity measure. The FFCS method meets special requirements for region-scale dryland monitoring like elimination of background influences, identification of vegetation type independent from its coverage, invariance to phenological shifts as caused by climate gradients, and independence from scene statistics. Further advantages include an ecologically meaningful class description and a realistic view of natural spatial coverage variations.

The spatial temporal variations differentiated by vegetation type and coverage will be the key to the understanding of vegetation dynamics and their mutual interaction with parameters like climate, evapotranspiration, surface runoff, infiltration, soil-moisture, and human activities.

Ecological changes that occurred during the past 10 to 15 years will be studied based on a comparison of FFCS classifications from MODIS and from 1-km AVHRR data available for the year 92/93. Lower resolving 8km AVHRR data we consider as too coarse to resolve the spatial pattern of vegetation types. 8km AVHRR will be used instead to study the seasonal/interannual variability of classified vegetation types. A special focus will be the investigation of each vegetation type's sensitivity to parameters like precipitation, temperature, soil moisture, and human influence. Based on a statistical approach we will separate the signal of each driver and independently study its influence on the vegetation cover. The approach has originally been developed to discriminate between climate (precipitation) driven and human induced degradation processes in the Middle East and will be modified to allow the assessment of additional drivers, in particular temperature and soil moisture. To support or to correct the conclusions from the statistical analyses, we will employ a physical approach using a hydrologic model (see below).

Agricultural Environments

The strongly continental climate of Central Asia contrasts with that of Southwest Asia in limiting the growing period and the seasonality of crop growth. The comparison of the two different climates and the agricultural practices they support will give hints to possible changes in land use practices under certain climate change scenarios. Cropping intensity and cropping patterns including their spatial-temporal changes will be studied using trend analyses and Discrete Fourier Analysis (DFT) applied to NDVI time-series (AVHRR, MODIS). These techniques proved to be especially suited to monitor spatial-temporal changes in cropping intensity and in cropping patterns, i.e., winter- or summer crops or double cropping, and how these are influenced by hydro-meteorological parameters. Of particular interest will be the study of the relationship between climate parameters and timing of crop growth. E.g., cold and extended winter times will delay germination and push crop growth towards the irrigation intensive summer time or vice versa. Found relationships will be used to draw future climate change scenarios and their possible implications like required adaptations in cultivation practices, and possible changes in irrigation water demands. The study of irrigated and rain-fed agriculture is aimed at addressing several questions that will establish a baseline of conditions: What have been the impacts of past and current agricultural land use or their abandonment and how have these changed, e.g., soil erosion, soil fertility, salt deposition, fragmentation of steppe vegetation, desert encroachment, water use, etc.? How have changes in agricultural practices changed water requirements?

Hydrologic Modeling

The hydrologic modeling component is aimed at addressing the following questions: What are the seasonal and interannual natural variations? What is the water consumption of current land use activities and how has it changed? How do current water resource use activities respond to naturally occurring changes in river flow? What are the impacts of changes in natural vegetation cover on hydro-meteorological parameters? What are likely impacts of the continuation of current trends in land use on water resources?

To learn about the interaction between hydrologic parameters and land cover/land use changes we will perform model runs over the past 25 years at a temporal resolution that matches AVHRR/MODIS compositing periods at a spatial resolution of 1km. For the results to be useful for field activities modeling outputs need to reflect the individual hydrologic characteristics of each area (pixel) rather than watershed characteristics. 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.

Modeling of snow accumulation and of snow melt will be implemented and be tested against remotely sensed snow products to describe river flow, which forms the main source for irrigation water in the low lands.

Identify NASA ESE system components to be engaged

To achieve proposed project goals our study focuses on the analyses of data from temporally high resolving sensor systems like MODIS on TERRA/AQUA (NDVI time-series, snow products, temperature data) and on NDVI time-series from the 8/1-km resolving AVHRR sensor. Other data that we can currently foresee include precipitation data from TRMM, various Landsat data sets, especially to verify results obtained from lower spatial resolution data sets, and SRTM topographic data. For modeling hydrologic processes we will employ GSFC's grid based Land Information System (LIS).

A brief description of the current work on the topic of the proposal

The development of statistical approaches and of physical models, usable on a regional scale to describe environmental changes in semi-arid South-West Asia, have been the subject of our recently expired NASA IDS grant. Special interest was dedicated to the results' usability to elaborate managing strategies and for making field level decisions, as needed by our local partners.

Specifically, we developed and field tested a new remote sensing approach (Fourier Filtered Cycle Similarity classification) that identifies vegetation characteristics as they are used in field-based degradation assessments. Discriminating between the contribution of individual drivers like human or climate to rangeland degradation was another research focus. An in-house regional hydrologic model was developed to study 20 years of seasonal and interannual variations/trends of hydro-meteorological parameters and their influence on land cover/land use. In this context we also acquired a tremendous number of sampling points, and carried out long-term field experiments that we consider a valuable contribution to the new project and to the further verification of NASA ESE components.

Expected outcomes

1. Synopsis of rangeland resources (vegetation, soil, water), apparent trends and triggering causes that will serve as a basis for managing grazing activities, for initiating preventive measures and for elaborating sustainable rehabilitation strategies.
2. 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.

3. 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.
4. 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.
5. Further validation of our Fourier Filtered Cycle Similarity Classification with the overall goal to do a global classification of arid and semi-arid areas. Such product also holds great potential for assessing the drylands' role and dynamics in carbon sequestration.
6. Knowledge transfer to collaborating Centers in the region (ACSAD, ICARDA). Both maintain remote sensing facilities of their own and have a focus on semi-arid areas. This includes data processing techniques, data use, interpretation of results, and integration of results into a management strategy.

A rough total project budget and brief explanation

	1st Year	2nd Year	3rd Year	Total
Personnel	110000.00	110000.00	110000.00	330000.00
Equipment	4000.00	2500.00	2500.00	9000.00
Supplies	4000.00	4000.00	4000.00	12000.00
Travel	12000.00	10000.00	10000.00	32000.00
Other	4000.00	6000.00	4000.00	14000.00
Indirect Costs	53600.00	53000.00	52200.00	158800.00
Total	**187600.00**	**185500.00**	**182700.00**	**555800.00**

Costs for personnel include 1-month summer salary for the PI, full-time employment of a senior scientist and part time employment of 2 undergraduate students to support data analyses. Under supplies we foresee expenditures for GPS units, small computer hardware and software, storage media, and field supplies. Equipment covers a RAID disk and associated upgrades. Travel costs include attendance of science meetings and trips to Central-West Asia for field surveys and for discussions with regional collaborators. Other costs cover the purchase of satellite data and publications in peer-review journals.

Anticipated cooperators investigators, organizations, agencies and companies

The International Center for Agricultural Research in Dry Areas (ICARDA) is a Research Center of the Consultative Group on International Agricultural Research (CGIAR) with a mandate area that covers Central-West Asia and North Africa. Analysing degradation processes and agro-ecological in collaboration with national Ministries with a special focus on Central Asian countries. (Dr. Eddy DePauw)

The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) is an organization of the Arab League with a mandate for Arab states, but expanding its activities also into non-Arab countries. Among others, ACSAD has valuable experience in water issues in arid and semi-arid areas and in the various aspects of rangeland management and rehabilitation with ongoing field projects in various countries. (Dr. Hassan Habib)

The Department of Atmospheric and Climate Studies of the Eidgenoessische Technische Hochschule (Zuerich). (Dr. Christoph Schaer)

The Remote Sensing Division of the GeoResearch Center/Potsdam. (Dr. Hermann Kaufmann)