METHODOLOGY

For Assessing and Monitoring Rangeland Vegetation in Central Asia

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Introduction

Rangelands Central Asian countries occupy a total area of approximately 260×10^6 hm^2, occupying 65% of the total land area of these five countries (Gintzburger, 2004). These rangelands are considered as the largest contiguous area of grazed land in the world (Mirzabaev et al., 2016). Central Asia rangelands are characterized by spatiotemporal heterogeneity that is associated with climate, floristic biodiversity, topographic variability as well as anthropogenic disturbances. They are the main forage source for livestock that supports the livelihood of resources-poor pastoral and agro-pastoral communities (Larbi et al., 2008).

Rangeland cover mapping has become a widely used and an important resource for characterizing rangeland structure and function. With recent technological advances in image access and image analysis software, it might be possible to develop new methods for measuring vegetation that are more precise and more cost-effective than the techniques currently in use (Chandrashekhar et al., 2015; Louhaichi et al., 2013). Near earth as well as satellite remote sensing can be an effective tool for characterizing and monitoring rangeland condition and trend.

Our objective is to develop a toolkit for monitoring and assessing rangeland vegetation that could be rapidly implemented while retaining accuracy. We wanted to retain the following qualities in our technique: speed and efficiency, a quantifiable level of accuracy, verifiable results, statistical robustness, and easily interpreted results. The methodology should be flexible enough to be deplyed in similar rangeland ecosystems in the dry areas.

Field experimental design

We selected 2 sites which are distinctive in terms of environmental condition (climate, soil, topogrophy and vegetation structure). The first action site represents typical sandy rangelands of Kyzylkum desert in Karakalpakstan in West Uzbekistan, whereas the second site is located in Kurama mountain ranges in North Tajikistan. The current rangeland vegetation in each site represent the dominated type which is highly shaped by livestock grazing. The dominant native species in the Kyzylkum desert in Karakalpakstan is white saxaoul (*Haloxylon persicum* Bunge ex Boiss. & Buhse) while the *Ferulafoetida* (Bunge) Regel is widely expanded in areas with high load of livestock grazing.

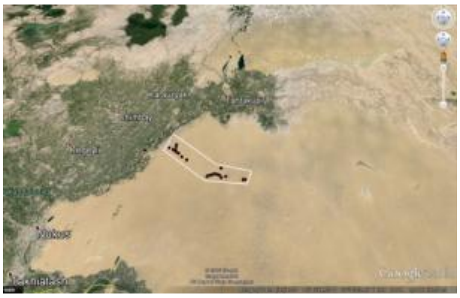
Characteristics of dominant species

Growth of *Ferula foetida*		
		
Seedlings of *Ferula foetida* at an early stage		
		
Mature plant with green leaves	Mature plant with yellow leaves	Dead Ferula (> 8 years) old

Dominant native plant species		
		
Haloxylon persicum	*Artemisia diffusa*	*Carex physodes* (perennial)

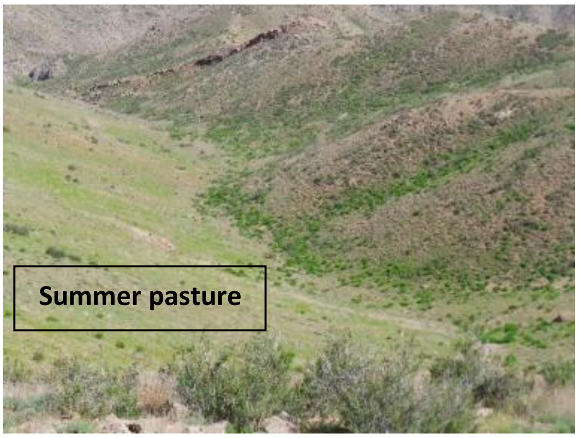
Sandy desert rangelands

We used a grazing gradient approach as a main tool to detect fine-scale changes of vegetation composition and its structure. Three monitoring sites with different level of livestock grazing were selected for conducting the vegetation surveys: rangeland areas around 2 watering wells and one rangeland area with no/limited livestock grazing. The rangeland vegetation around 2 watering wells is surveyed as a distance away from the watering well. Three transects radiating in 3 directions from the center of the well were allocated at each 120 degrees apart from North. The length of each transects ranges between 3.0-3.5 km from the center of the well. Along each transect as a distance away from the well 3 stops were selected to detect vegetation changes caused by different level of livestock grazing. In total 9 stops were monitored around each watering well.

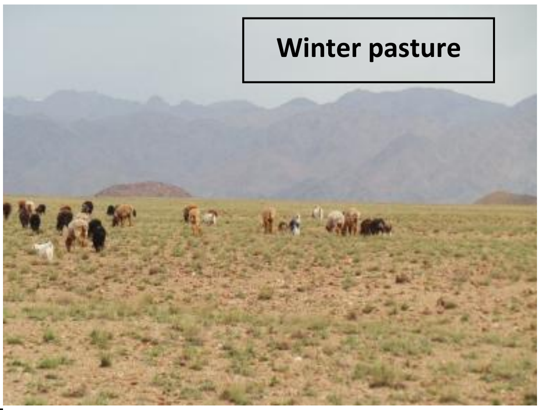


Mountain rangelands

In this action site, we have selected North versus South facing slopes since the aspect (denotes the compass direction in which the slope of a mountain faces) has great influence on long term vegetation formation and its current condition. Selected North versus South facing slopes are also characterized by different level of grazing intensity.



The slopes with different grazing intensity were separately selected in winter and summer pastures. Vegetation surveys were done on North and South aspects in each selected V-shape slope as a distance away from the livestock flock (up to 2.5-3.0 km). In addition, the vegetation of other types of landscapes as gently rolling flat hills in winter pastures, rocky mountains and flat rangelands in a proximity of mountains were covered during vegetation surveys.



Sampling of plant community data using traditional techniques

Vegetation data of spring season were collected during 01-05 May in Karakalpakstan and 15-20 May in Tajikistan. The vegetation measurements basically included biomass, cover and density of perennial plants, biomass of annuals.

Variable quadrat size for biomass estimation

Description of the plant community was done using 50 x 2 m quadrate in scarce vegetation of sand rangelands whereas mountain vegetation was described using 10 x 2 m quadrate due to its high species richness.





The total numbers of shrubs of each species were counted and separated into 3 size categories (big, medium, small). For each species within every size category, 3 representative plants were clipped for determination of annual green biomass using the reference technique.


Biomass production of ephemerals and ephemeroids was identified within 1 x 1 m frame quadrates, randomly distributed with 3 replications.



Line intercept for cover estimation

The cover of shrub species was determined along a line intercept (100 m long) as shown below.


Monitoring rangeland vegetation dynamics using geo-informatics

Digital Vegetation Charting Technique (DVCT)

High-resolution digital images has also proven useful for vegetation classification and quantification. Digital classification methods strive for increased accuracy compared to traditional evaluation procedures.

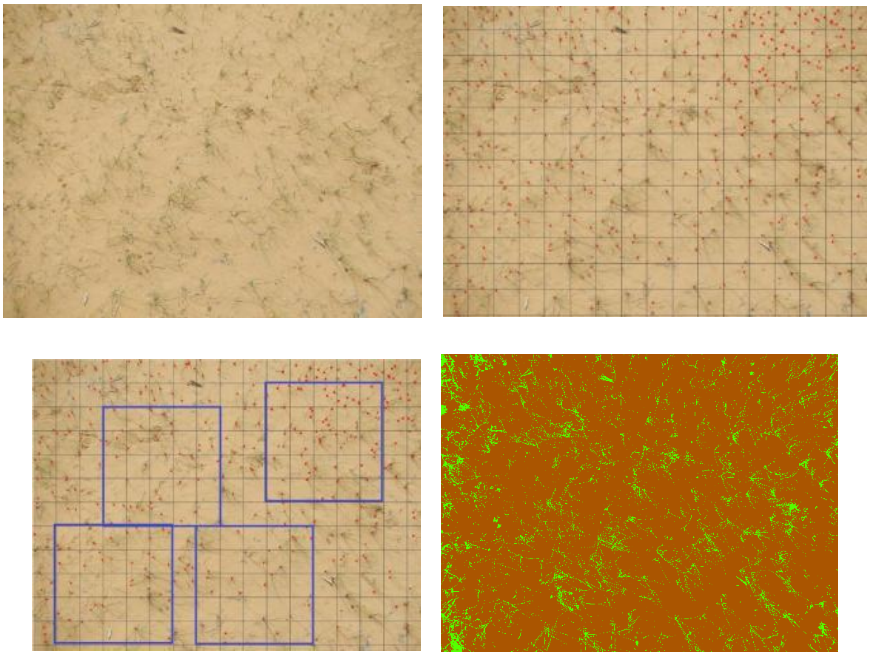
We used GPS-enabled digital cameras with a 16 mega-pixel resolution and a high quality lens. For most of the surveys, we used a Nikon Cool Pix AW 110 camera with a built-in GPS, mounted on a staff or pole that held the camera at a height of 1.5-3 meters above the ground (Booth et al., 2004). The embedded GPS is an autonomous unit that can be used to sync the camera time with GPS time, so that both are in agreement (our camera actually logs time from the camera clock, rather than from the GPS signal). We activate GPS tagging of the images so that each image has the latitude and longitude of the location of each photograph. Attached to the staff or pole is a platform with a bubble level, so the camera can be pointed vertically downward. Also on the platform is a magnetic compass, so that the top of the camera can be pointed southward when images are taken. During the photographic sampling, we maintain the camera in an upright position so the GPS fixes are of the highest quality possible. GPS locations are logged internally in a latitude/longitude format using the WGS 84 system. This information is automatically written into the header file of all photographs taken.

In the office process the images taked per site are stored in a separate folder that is labeled with the site name and/or number. We then process these with VegMeasure Image Positioning Tool software, which uses the sensor size on the camera and focal length to scale the image and then rotates the image so that it is positioned correctly on the landscape. The output from this program generates a kml file for each photograph, which georegisters it with the correct latitude/longitude (WGS 84). The program also creates a GeoDatabase, which is a comma delineated file with the latitude/longitude, image name, date, time, and image path. As soon as the kml file is created, the images can be opened in any GIS program and will be positioned correctly on the landscape (within the limits of the original GPS accuracy – usually less than 5 m).

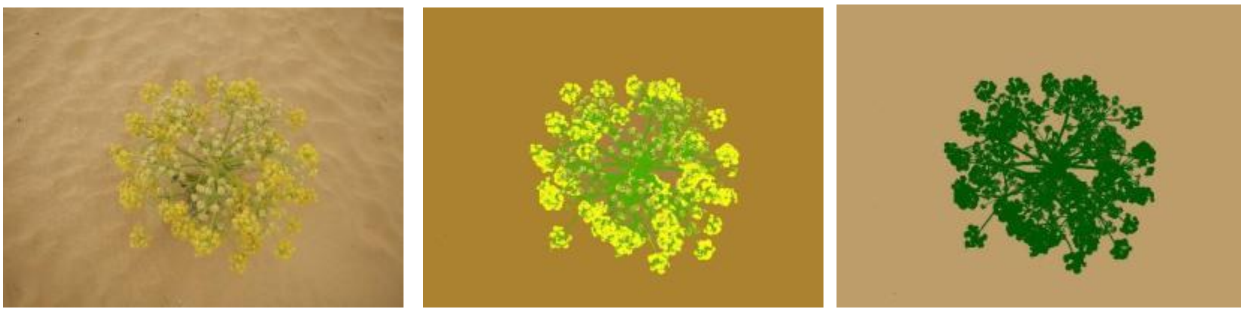
Once the geodatabase is created, we use VegMeasure is a Digital Vegetative Charting Technique (DVCT) that measures vegetation on the ground in a non-destructive manner (Louhaichi et al., 2010; 2015).
This program is able to measure the percent cover of foliage, litter and bare ground, as well as other parameters of interest in quadrats. In addition data collected with DVCT will be used also as a training site for supervised classification of satellite RS. The software enables hue extraction, calibrating a threshold, K-means classification, brightness algorithms, and green leaf algorithms. With appropriate sampling methods large scale maps can be made and vegetative change can be measured over time. As this method creates a permanent record the results can be revisited through time.

Density estimation of Carex (annual species) using DVCT

Carex physodes is an ephemeroid sedge, 15–35 cm tall. It reproduces both asexually by underground rhizomes and sexually by seeds. The aboveground parts of this species die in summer, and the underground parts produce new individuals from underground buds when the snow melts during the next spring. C. physodes can be used to fix and stabilize sand as illustrated below. It has a small vegetative growth and it would be very tedious and time consuming to count the density of this species under field condition.



Canopy cover estimation using DVCT



Developing allometric equations to estimate rangeland vegetation biomass using cover, hight and dimameter as surrogate

Since plant biomass is usually positively correlated with canopy cover. Measurements of canopy cover can be easily and precisely made through image processing of high-resolution digital photography. In previous studies, the DVCT was used to estimate the canopy cover of three plant species: *Artemisia herba-alba* Asso., *Rhanterium suaveolens* Desf. and *Stipa tenacissima* L. Biomass of the selected species was also determined to develop regression models and correlation equations with the relative canopy cover (Tarhouni et al., 2016; Louhaichi et al., in press).

Linking near earth RS to satellite RS

Grassland degradation and desertification in the Central Asia has been accelerated over the past few decades due to increasing livestock grazing intensity and climate variability. To restore, maintain, and enhance grassland condition and productivity in the Central Asia is the goal of many research and development projects in the region. However, these efforts have been hampered by the lack of (1) updated and accurate information on grassland dynamics, conditions, and productivity; and (2) the capacity to generate such information in timely manner. The need for improved assessment tools that can inform strategic planners on how best to utilize increasingly scarce resources such as feed and water across the landscape scales.

Satellite imaging is a powerful assessment tool that can assess and track grassland resources that are necessary inputs to sustainable livestock production systems. The time-series analysis of the satellite remote sensing has been playing an increasing role in characterization and monitoring of grassland condition and productivity. Most studies have used Normalized Difference Vegetation Index (NDVI) data from optical images to evaluate grassland condition and productivity in the context of land degradation and desertification. We have used addtional indices such as Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) along with indices derived from the land surface temperture (LST) to assess the dynamics of the grassland condition and productivity.

The individual spectral bands in each of the 8-day composite surface reflectance MOD09A1 datasets were used to calculate four spectral indices: (1) Normalized Difference Vegetation Index (NDVI), (2) Enhanced Vegetation Index (EVI), (3) Land Surface Water Index (LSWI), and (4) Normalized Difference Snow Index (NDSI) (see Equations 1 - 3):

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \quad (1)$$

$$LSWI = \frac{\rho_{nir} - \rho_{swir}}{\rho_{nir} + \rho_{swir}} \quad (2)$$

$$EVI = 2.5 \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + 6 \times \rho_{red} - 7.5 \times \rho_{blue} + 1} \quad (3)$$

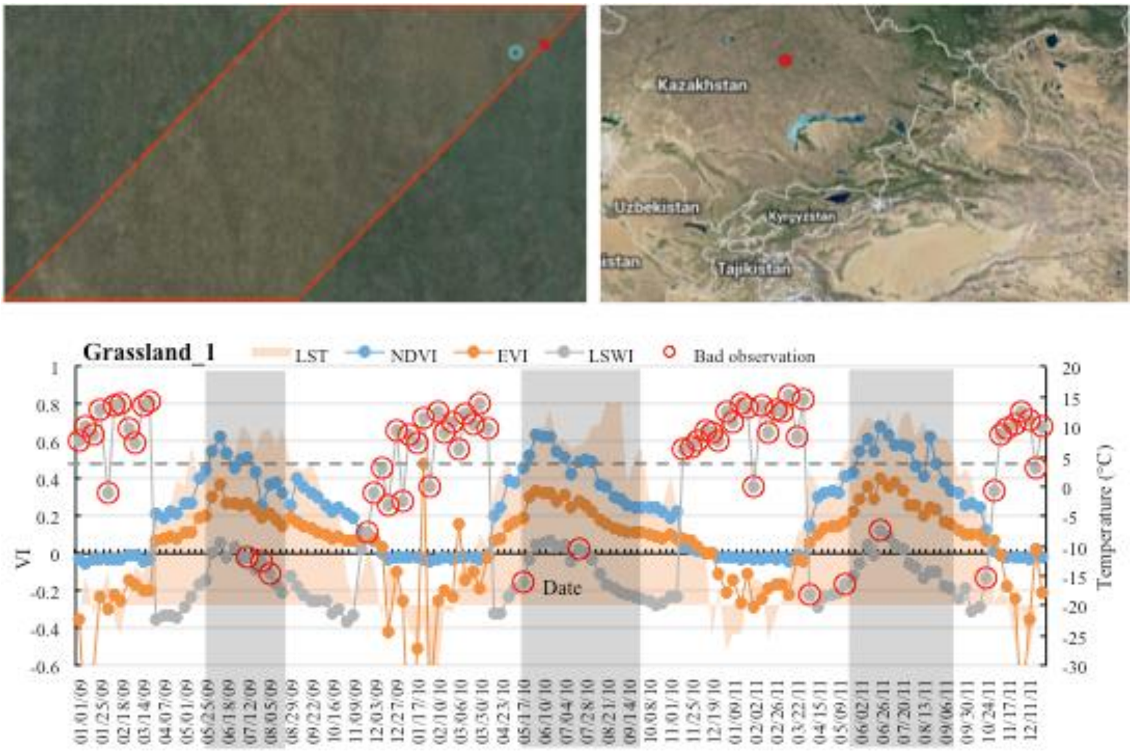


Figure 3. Seasonal dynamics of NDVI, EVI, LSWI and NDVI for a grassland pixel.

Dryland vegetation can be characterized in a number of ways, and here we developed a simple and robust way to delineating desert vegetation to understand the dynamics of the grazing lands. The single pixel assessment of the production dynamics using MODIS satellite data shows trends of the vegetation changes at a 8-days interval to depict inter and intra annual dynamics. Similar assessment can be done but with higher spatial resolution from less than a meter to 30m. As observed from the in-situ data, there is lot of the back scattered reflectance from the land surface due to desert or very sparse vegetation often less than 15% canopy cover which may hinders picking up of the vegetation cover which can be overcome by using high resolution data to segregate mixed pixels. The vegetation condition measured at the ground level plots (or transects) such as vegetation condition, spatial matrix/arrangements, density, biomass and species composition (e.g., palatable, non-palatable, C3, C4) can be link to individual pixel to establish the relationship between the ground and space borne imaging to quantify to map and monitor the dynamics of the livestock feedstock across the scales. In this pilot study, we analyzed seasonal dynamics of three vegetation indices (NDVI, EVI and LSWI) in the study area to understand the spatio-temporal dynamics of the grasslands. The resultant maps and methodology need to be further evaluated through systematic and stratified sampling of the in-situ data collected across the spatial and temporal scales to represent the varying degree of the grasslands/rangelands which help us quantify and characterize the grassing lands for sustainable livestock management in the region.

Perspective

The steps decribed above have to be repeated again during the fall to capture the seasonal variations (temperal resolution). This frequencuy is needed to document the status of rangeland vegeatation (productivity and quality) before and after grazing.

The obtained ground truth vegetation data and key findings in both action sites will be overlayed to environmental and management conditions. The results then will be incorporated into GIS and RS technologies to characterize spatial and temporal dynamics of rangeland vegetation. Satellite remote sensing data will be incorporated at different spectral and spatial resolutions. The most cost effective approach and tools will be outscaled. The results may lay on the basis of development of operative methods in assessing rangeland condition of different ecological zones.

Note: The dense vegetation in the sandy rangelands of Kyzylkum desert in Karakalpakstan makes difficult for coarse RS data collected in 2015 to assess rangeland value (species composition, palatability, etc.). The site is invaded by Ferula. Although the species is unpalatable when it is green. However, its seeds are well grazed by sheep and camels at the end of vegetative period and when dry during winter season the leaves can be eaten by livestock., *Ferula assa-foetida* L. is used as spice, as aphrodisiac and as herbal remedy. It was used since ancient times. It is an oleo gum resin which exudes out of the rhizomes. Normally it is used as an antiflatulent, digestive aid. Pharmacologically used as antimicrobial, antiasthmatic, antiepileptic and also reported to have contraceptive/abortifacient activity.
The strong smell is inherent and characteristic of the oleogum resin.

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