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Original Articles

Assessment of vegetation degradation in mountainous pastures of the Western Tien-Shan, Kyrgyzstan, using eMODIS NDVI

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ABSTRACT

The detection and assessment of vegetation degradation of mountain pastures is of high interest given the increasing number of reports on degradation as well as the importance of pastures as a source of livelihood for many mountain communities globally. Due to its synoptic perspective, remote sensing is an attractive instrument to rapidly assess and diagnose degradation prevalence and status. While it is relatively straight-forward to assess degradation leading to a change in vegetation cover by remote sensing, it is more challenging to study changes in vegetation composition, i.e. vegetation degradation. Therefore, our aim was to investigate the use of the seasonal variation (phenophases) of zonal-specific pastures varying in vegetation degradation using the normalized difference vegetation index (NDVI). For ground-truthing, quantitative and qualitative relevé data were collected during field surveys 2008–2015 during the growing season, and have been used to validate the classification of vegetation degradation based on eMODIS NDVI composite data for selected normal and dry years. Using a 500 m buffer zone, vegetation features have been extracted and correlated with satellite reflectance spectra for classifying the remote sensing imagery. We found a significant difference in compositional structure among degradation classes for all ecozones. Since qualitative changes in vegetation cover were caused by a replacement of dominant grasses and forbs with unpalatable forbs or shrubs with different reflectance patterns, our results indicate that excluding the alpine zone, vegetation degraded pastures differed from non-degraded ones by higher NDVI values at each phenology phase, although this was not always significant. As vegetation degradation led to an earlier greenup and later senescence, i.e. an observed extension of the growing season in terms of NDVI data, shifts in species composition could also be driving effects that have so far mostly been interpreted as signs of climatic changes. The procedures of this study and the developed conditional inference classification trees enable cost-effective screenings of large areas to detect vegetation degraded pastures and to assess seasonal grazing impact from remote sensing based interpretation. We conclude that the procedures developed here using eMODIS NDVI composite datasets are well suited for vegetation degradation assessments. This can improve monitoring of vegetation degradation as well as land-use planning.

1. Introduction

Pasture degradation is a complex phenomenon driven by many factors. Pasture degradation includes changes in vegetation productivity, native vegetation cover and phenology, which have already changed in temperate regions in response to climate change and management practices (Gong et al., 2015). Vegetation degradation is widespread in Central Asia, affecting 59% of the total area, as a consequence of long-term impacts of inappropriate management practices and ongoing environmental changes (Kharin, 2002). Here, we define vegetation degradation as changes in compositional structure of a sward while the total vegetation cover remains without change (Kharin, 2002). From a grassland use perspective, we especially consider the replacement of palatable species with unpalatable species, weeds or

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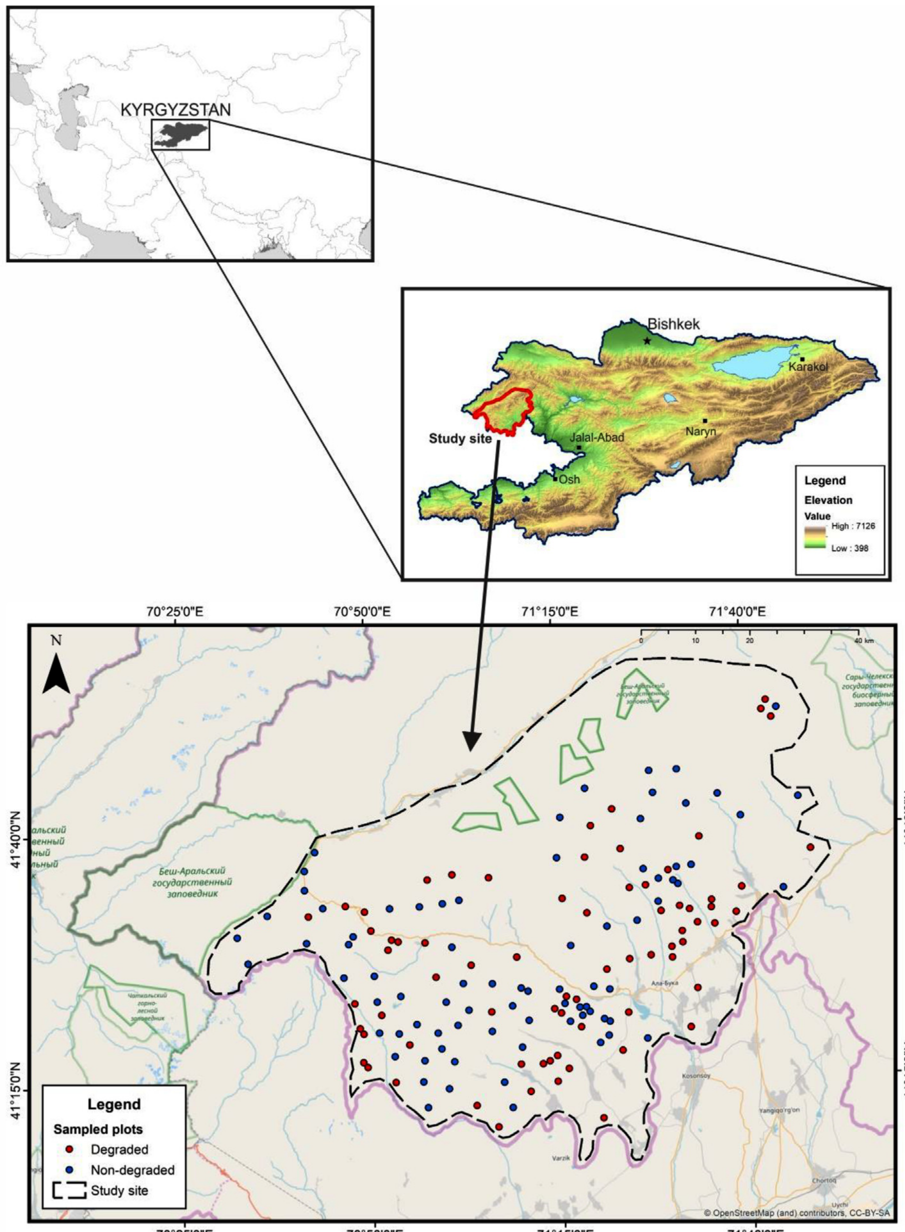

Fig. 1. Map of the study site with sampled pasture plots. Areas with green borders are protected areas of the Besh Aral nature reserve. (Map by Evgenii Shibkov). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

shrubs. This form of vegetation degradation has been of particular concern for pasture users that need to evaluate the extent and magnitude of degradation to adept pasture use planning.

In Kyrgyzstan, the total 9.1 million ha pasture area is characterized by a complex mountain topography that led to a highly heterogeneous composition of soils and vegetation communities blending into each other (Mamytov, 1982; Vyhodtsev, 1956). Vegetation degradation has been a concern since the 1970's; more than 36% of different zonal pastures have been severely invaded by unpalatable species and shrubs (Popova, 1970; Shihotov, 1976). By 2012, these degraded areas extended to 49% (Adenov et al., 2012). By 2014, the climax vegetation in 14% of the total pasture area (1.3 million ha) has changed in its species composition and reached a nearly irreversible degradation status (Pasture Deparment, 2014). Most of the affected pastures have been found in mountain steppe and subalpine meadow-steppe zonal pastures in the Northern, Central and West Tien-Shan mountain ranges, where vegetation cover changes are ongoing (Nuralieva and Bekirova, 2015). Even though vegetation degradation has been reported, existing vegetation maps dating back to the soviet period do not differentiate between vegetation cover and compositional vegetation degradation, and it is difficult to track the extent and severity of compositional vegetation degradation back in time.

Vegetation degradation is commonly measured on the ground, which is laborious and costly, especially at large scales or in mountainous areas. There is a wealth of studies showing that remote sensing can be used to analyze quantitative changes in vegetation cover, as one aspect of degradation (e.g. Xie and Sha, 2012). However, less effort has been spent on degradation concerning qualitative changes in vegetation cover. Some studies suggested that remote sensing might be a powerful tool for detecting invasive species in pastures at the landscape level. Nevertheless, they highlighted the difficulties related to species discrimination due to the diversity of native vegetation and the similarity of spectral reflectance patterns (Bestelmeyer et al., 2006; Brown and Bestelmeyer, 2012; Ding et al., 2013; Gang et al., 2014; Geerken and