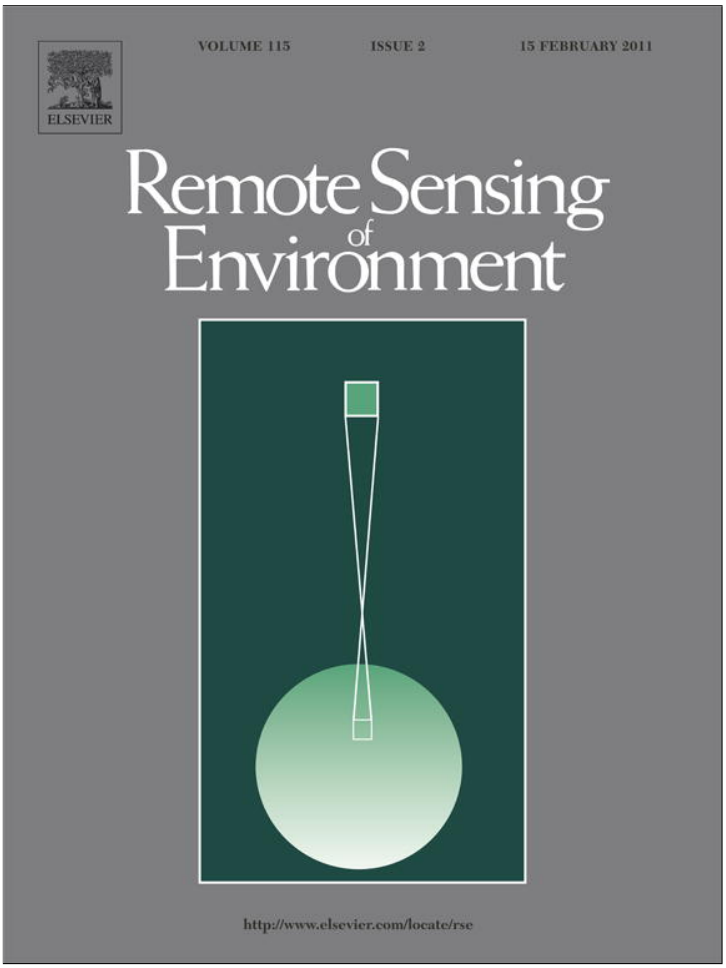

Remote Sensing of Environment 115 (2011) 465–474

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Quantification of aboveground rangeland productivity and anthropogenic degradation on the Arabian Peninsula using Landsat imagery and field inventory data

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ARTICLE INFO

Article history:
Received 21 March 2010
Received in revised form 18 September 2010
Accepted 21 September 2010

Keywords:
Al Jabal al Akhdar
Allometric equations
ANPP modelling
NDVI trend analysis
Oman
Residual method
Semi-arid woodlands

ABSTRACT

The productivity of semi-arid rangelands on the Arabian Peninsula is spatially and temporally highly variable, and increasing grazing pressure as well as the likely effects of climatic change further threatens vegetation resources. Using the Al Jabal al Akhdar mountains in northern Oman as an example, our objectives were to analyse the availability and spatial distribution of aboveground net primary production (ANPP) and the extent and causes of vegetation changes during the last decades with a remote sensing approach. A combination of destructive and non-destructive biomass measurements by life-form specific allometric equations was used to identify the ANPP of the ground vegetation (<50 cm) and the leaf and twig biomass of phanerophytes. The ANPP differed significantly among the life forms and the different plant communities, and the biomass of the sparsely vegetated ground was more than 50 times lower (mean = 0.22 t DM ha^{-1}) than the biomass of phanerophytes (mean = 12.3 t DM ha^{-1}). Among the different vegetation indices calculated NDVI proved to be the best predictor for rangeland biomass.

Temporal trend analysis of Landsat satellite images from 1986 to 2009 was conducted using a pixel-based least square regression with the annual maximum Normalized Differenced Vegetation Index ($NDVI_{max}$) as a dependent variable. Additionally, linear relationships of $NDVI_{max}$ and annual rainfall along the time series were calculated. The extent of human-induced changes was analysed using the residual trends method. A strongly significant negative biomass trend detected for 83% of the study area reflected a decrease in annual rainfall but even without clear evidence of deforestation of trees and shrubs, human-induced vegetation degradation due to settlement activities were also important.

1. Introduction

In arid and semi-arid areas, rangelands play a vital role in the provision of forage for native and domestic herbivore animals, but they exhibit great temporal and spatial variation in aboveground net primary production (ANPP), reflecting differences in water availability and vegetation dynamics (Huenneke et al., 2002; McNaughton et al., 1989). Precipitation is one of the major driving forces for biomass availability in dry areas and is therefore highly correlated with vegetation cover, making semi-arid rangelands a sensitive indicator of climate change (Bai et al., 2004). In combination with increasing population and livestock pressure, climatic changes with a decline of precipitation can lead to land degradation, which is an increasing environmental problem on the Arabian Peninsula (Abahussain et al., 2002). For the Hajar Mountains of northern Oman, which provide important habitats for wildlife and endemic plant communities (Patzelt, in press), recent studies have shown that pasture areas near settlements are suffering from particularly strong degradation (Brinkmann et al., 2009; Patzelt, in press), whereby the amount and quality of fodder available for village-managed goat herds is diminishing (Schlecht et al., 2009). However, statistics on recent trends and the extent of land degradation on the Arabian Peninsula are still scarce (Abahussain et al., 2002) and monitoring tools are urgently needed to analyse the status and changes of rangeland vegetation. Since degradation is associated with a long-term decline in production, monitoring ANPP of rangeland vegetation is regarded as a valuable tool to indicate land degradation at different spatial and temporal scales (Diouf and Lambin, 2001; Prince et al., 1998; Tucker et al., 1991).

Different methods have been developed to estimate ANPP depending on the rate of biomass turnover of the ecosystem (Catchpole and Wheeler, 1992). As an alternative to labour and time intensive harvesting techniques, the 'double sampling procedure' uses a regression relationship of biomass to predictive variables, such as vegetation cover, plant height, leaf area or vegetation density (Cochran, 1977; Sala and Austin, 2000). Besides field measurements, applications based on satellite images for ANPP mapping and temporal change assessment

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0034-4257/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.rse.2010.09.016