Using of MODIS NDVI Time Series for Grassland Habitat Classification and Assessment

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1. Introduction

Satellite images with high spatial resolution are widely used for habitat assessment and surveillance. Their low temporal resolution however, limits their ability for regular monitoring of habitats in adequate time span. Recently, after the launch of the Terra and Aqua satellites with the MODIS (Moderate Resolution Imaging Spectroradiometer) on board, new approaches started to be more frequently used for habitat classification and monitoring. One of the most widespread approaches use time series analysis of vegetation indices (e.g. NDVI – Normalized Difference Vegetation Index) that reflects the temporal profile of vegetation greenness on the land surface.

Semi-natural grasslands in agricultural landscape bear high biodiversity values and there is still lack of precise information on their spatial extent and status at pan European scale. One of the main criteria for good status of the semi-natural grasslands is their extensive usage, e.g. regular cutting and/or grazing. In order to get such information, detection of site management is needed for longer periods (e.g. 10 years) in order to reveal trends for possible abandonment or intensification.

Because of gradual availability of time series products from sensors such as MODIS and under a great expectation of upcoming Sentinel3 mission, we analyzed here suitability of MODIS NDVI time series at 250m spatial resolution for classification and assessment of grassland habitats in Slovak heterogeneous landscape. Particularly, we focused on detection of cutting practices, overgrowing, flooding, overgrazing, which are all considered as important determinants of grassland habitat quality.

1.1 NDVI time series for grassland classification and assessment

Grasslands with similar physiognomy may have different temporal pattern of NDVI affected by a broad range of natural or human driven factors. Multitemporal analysis of NDVI time series iteratively explores the main determinants of seasonality and uses this information for the subsequent classification of grasslands to determine their vegetation type, status and functioning. Grassland classification may include both full coverage classification of grassland areas or exploration and classification of main grassland types based on sampled areas. For example Aragon and Oesterheld (2008) used a combined approach using information of spatial arrangement (from single date HR Landsat TM image) and information on functional properties (NDVI dynamics derived from multitemporal MODIS 250m NDVI series) to map grassland vegetation communities in Argentinean flooded Pampa grasslands. The authors successfully classified 5 grassland vegetation types with an overall accuracy of 76% and documented that grassland vegetation communities significantly differ in their seasonal and interseasonal pattern of NDVI. Hill et al. (1999) classified a pastoral landscape in eastern Australia resulted into 8 broad categories: sown perennial pastures, sown perennial pastures with woodland, sown annual pastures, mixed pasture and cropping, native pastures, native pastures with woodland, degraded or revegetated areas and forest. Paruelo et al. (2001) used NDVI dynamics as a descriptor of ecosystem functioning and widely applied this approach for mapping and classifying ecosystem functional types. They used three measures calculated from the seasonal curve of NDVI: annual integral of NDVI as an estimate of primary production, relative annual range of NDVI and date of maximum NDVI both of which were used to capture the seasonality of primary production

In this context we explored different approaches (including data pre-processing, classification strategies, training and validation data sets) in order to assessed the added value of multitemporal analysis of MODIS 250m NDVI time series for the assessment of grasslands in heterogeneous landscape in Slovakia.

2. Data and processing

Two grassland datasets were used for the analyses (Table 1).

Table 1. Data sets used for this case study.

		Grassland types	NDVI data	Temporal coverage	Source
1	Slovakia	All grasslands on agricultural land (excluding alpine meadows)	16 day; 8 day	2003-2012	National dataset
2	Hungarian lowlands	N2000 grasslands	8 day	2003-2012	EEA

We used homogenous grassland sites derived from Slovak national land parcel information system (LPIS) that were visually inspected on Google Earth in order to omit heterogeneous MODIS pixels. Totally 3758 pure pixels were included in this dataset. Natura 2000 grassland sites across the Hungarian lowlands were extracted from EEA dataset. Only those Natura 2000 sites that contained more than 80 % of grassland habitats were included in data set. Finally, 2800 pixels were randomly selected for the analysis.

We used MOD13Q1 (16 day NDVI with 250 m spatial resolution) and combined MOD13Q1 and MYD13Q1 (8 day NDVI with 250 m spatial resolution) products downloaded from LP DAAC distribution centre for the area covered by Modis tile grid h19v4. Usefulness index and quality assurance layers of the products were utilized in order to minimize negative effects of clouds, cloud shadows, aerosols, sun-sensor geometries and snow. Missing data were interpolated and smoothed using Savitsky – Golay filter within the TimeSat software in order to get complete NDVI time series from 2003 to 2012. As the first step we used PCA of the 2009 annual series (16 days and 8 days time span) in order to explored main season-driven variability in grasslands. The extracted components were later used to produce a broad classification of grasslands based on their seasonality. Finally, we explored several specific multitemporal indexes (e.g. variability in peak season, spring negative anomaly, etc.) to test the potential for detecting specific characteristics of grassland status (e.g. cut management, flooding regime, etc).

3. Results and conclusion

The PCA of 16 day 2009 NDVI time series of Slovak grasslands (data set 1) extracted 5 components with a total explained variance of 91 % (Figure 1). This demonstrates that the seasonal NDVI pattern of grasslands varies substantially. Factor loadings show that it is mainly the different timing of peak season, cutting and different greenness in spring and autumn what determines seasonal variability in Slovak grasslands.

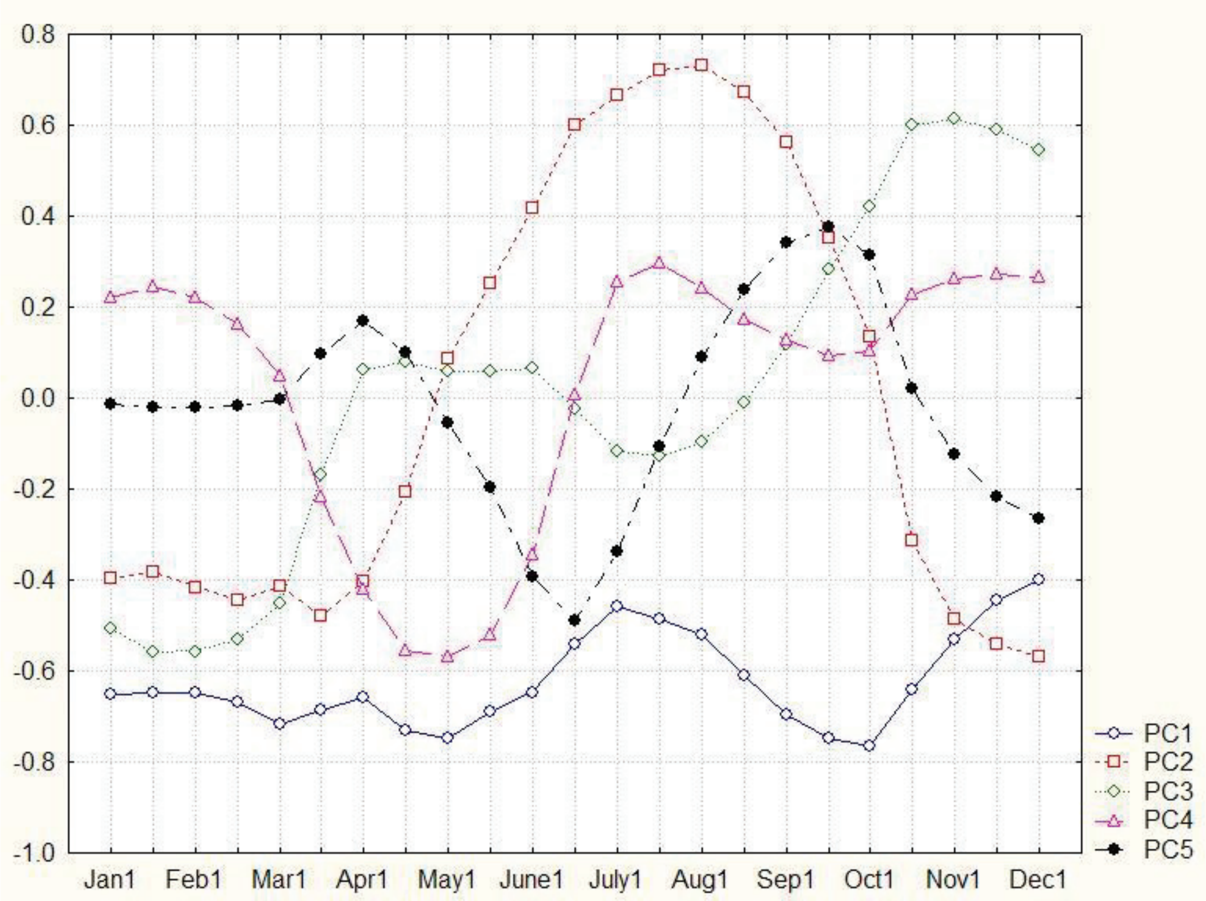

Figure 1: Factor loadings resulted from PCA of 16 day 2009 NDVI composite of Slovak grasslands.

Classification of these 5 components using k-means clustering resulted in 5 main types of grasslands with specific temporal profile of NDVI (Figure 2). It is visible that mainly productivity (blue and purple clusters), different management (red and black clusters) described main differences in managed grasslands. A special case represents green cluster that can be attributed to mountainous grasslands typical with shorter vegetation season and delayed vegetation peak.

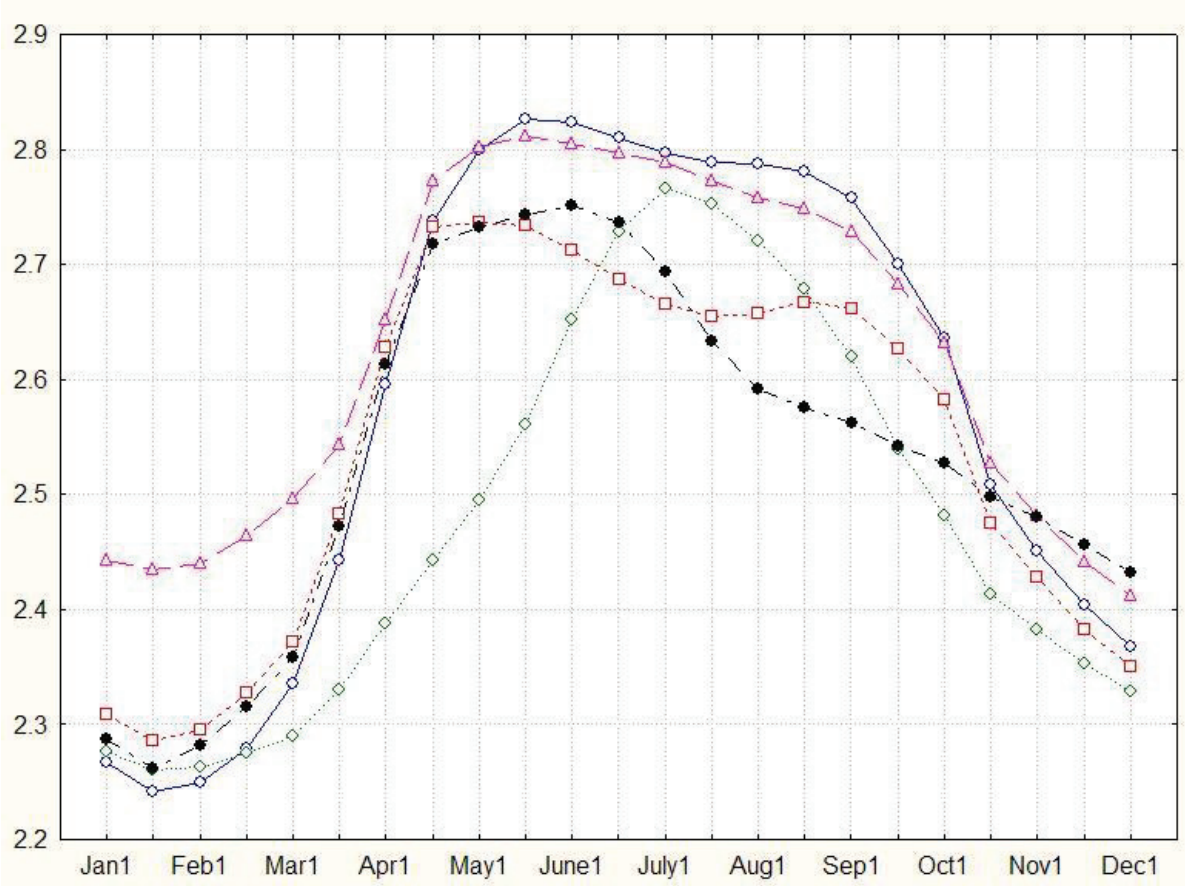

Figure 2: Average temporal profile of NDVI of resulted clusters (16 day NDVI composite of 2009) (original scale of NDVI -1/+1 rescaled to 1/3).

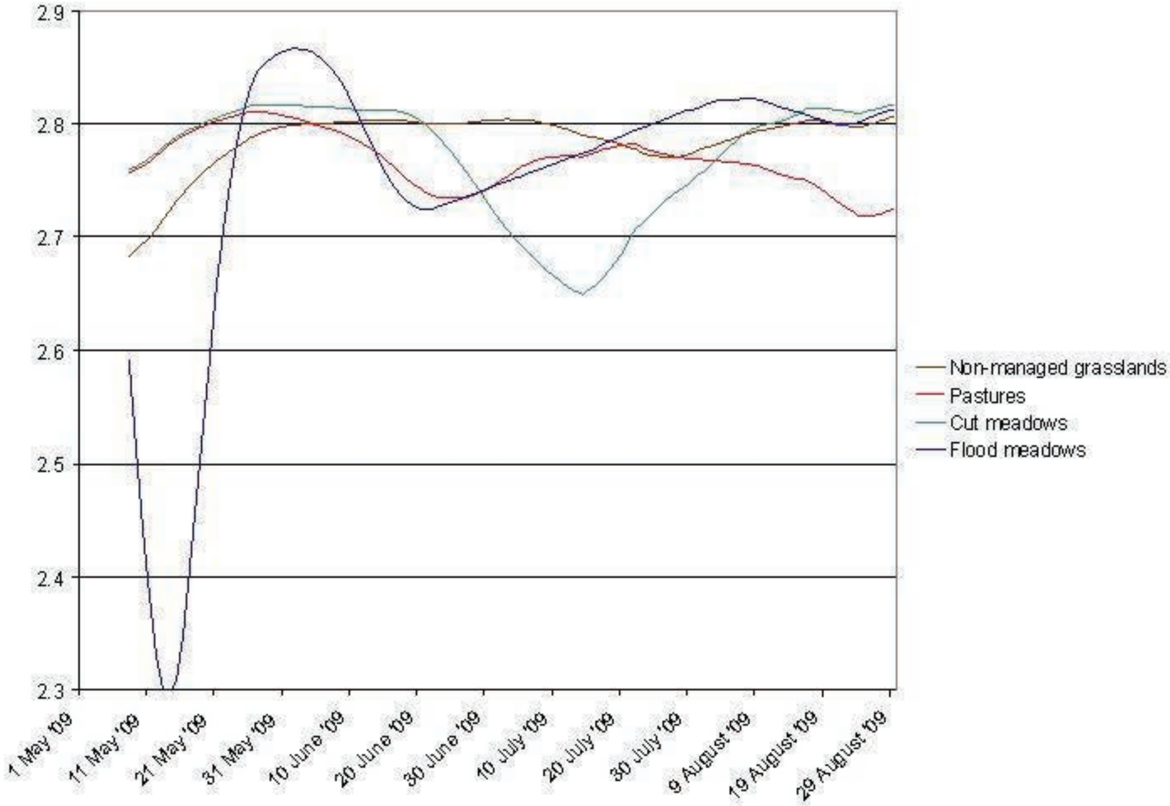

Figure 3: Classification of grasslands using 8 day NDVI composite of vegetation growth period in 2009 (original scale of NDVI -1/+1 rescaled to 1/3)

When we used the same approach with increased temporal resolution (8 day) of NDVI composite data within vegetation growth period (May-September) we obtained slightly different results (Figure 3) with better distinction of flooded grasslands, pastures and cut grasslands. The same approach and data were used for assessment of Hungarian grasslands in N2000 areas (Figure 4). These grassland types exhibit distinct seasonal variability that was later reflected in the following classification: wetland and salt marshes, cut meadows, pastures and non-managed natural grasslands.

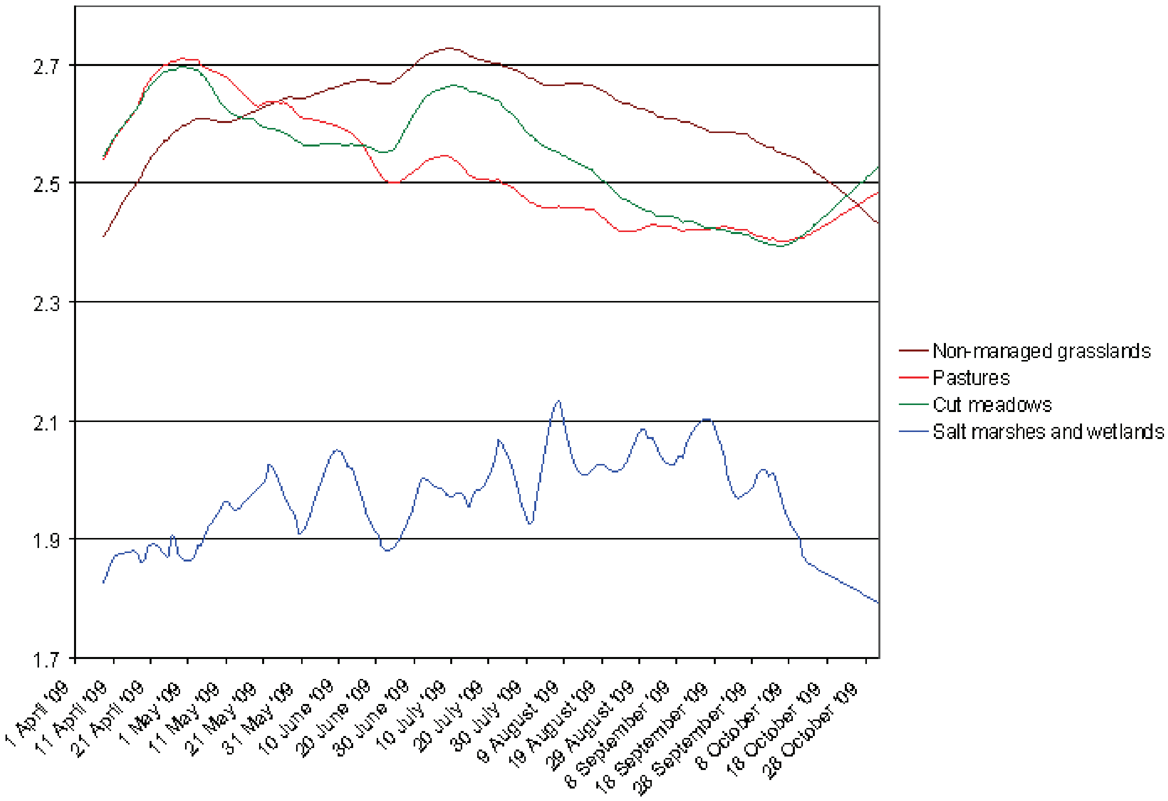

Figure 4: Classification of Hungarian grasslands in Natura 2000 areas using 8 day NDVI composite of vegetation growth period in 2009 (original scale of NDVI -1/+1 rescaled to 1/3).

Grassland seasonal pattern of NDVI varied substantially and reflects not only different vegetation type but also land use, management practices or site hydrology. To conclude, indicators of grassland habitat status can be relatively successfully identified in cases when they represent relatively large compact homogenous areas of similar grassland types or when a regional adaptive approach benefits from a-priori knowledge of the distinct seasonality of the respective grassland habitat type. We demonstrated that when some knowledge on grassland occurrence exists (e.g. from EEA), classification based on temporal NDVI profile brings valuable information on grassland habitat status. In general, productivity (which relate to amplitude of NDVI curve) and seasonality (variance within season) represent main distinctive characteristics of grasslands. Especially, timing of NDVI peak, rate of increase of NDVI in spring, bimodal shape of NDVI, or negative anomaly in spring can be used for distinguishing of extensive meadows, pastures, flooded meadows and abandon overgrown grasslands. However, more regional specific knowledge from grassland experts needs to be used in order to derive consistent algorithms for broader scale habitat assessment and classification.

Acknowledgements

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