Tuexenia 38: 385–404. Göttingen 2018.
doi: 10.14471/2018.38.012, available online at www.zobodat.at

Ecosystem condition assessment of semi-natural grasslands outside the Natura 2000 network in Bulgaria, using vegetation data

Eine Bewertung des Ökosystemzustands des halbnatürlichen Graslands in Bulgarien außerhalb von Natura 2000-Gebieten auf Grundlage von Vegetationsdaten

Desislava Sopotlieva[1,*], Nikolay Velev[1], Nadya Tsvetkova[2, 3], Vassil Vassilev[2, 3] & Iva Apostolova[1]

[1]*Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, 1113, Bulgaria;*
[2]*Remote Sensing Application Center – ReSAC, Sofia, 1463, Bulgaria;*
[3]*Geo Polymorphic Cloud, Sofia, 1111, Bulgaria;*
[*]*Corresponding author, e-mail: Desislava.Sopotlieva@iber.bas.bg*

Abstract

Action 5 of the EU Biodiversity Strategy 2020 calls EU Member States to map and assess ecosystem conditions and services. In line with the Millennium Ecosystem Assessment (MA) and the Reports of the Working Group on Mapping and Assessment on Ecosystems and their Services (MAES), Bulgaria developed a National Methodological Framework and Methodology for grassland assessment and mapping. We used this methodology to broadly assess the ecosystem condition of semi-natural grasslands that are located outside the Natura 2000 network in Bulgaria. Given the important role of vegetation in natural ecosystems, we focused on five indicators of ecosystem structure and processes: plant species richness, vegetation cover, number of red list plant species and invasive alien plants and plant biomass. The assessment of these indicators was applied to polygons that represent distinct grassland ecosystems. Polygons were mapped using aerophoto images with a minimum mapping unit of 0.25 ha. Whenever possible, we matched polygons to vegetation data, extracted from phytosociological databases. Additional field sampling was conducted in 2016. We filled data gaps for polygons through geospatial and statistical modelling. A total of 123,152 grassland polygons (sum of area: 634,518.23 ha), representing dry, mesic, wet and seasonally wet, alpine and subalpine grasslands and inland salt steppes were mapped and assessed. Our results show that 32% of the grassland polygons outside Natura 2000 were in ‘very good’ condition regarding ‘plant species richness’, with another 49% being in ‘good’ condition. Polygons with ‘bad’ and ‘very bad’ scores were located in close proximity to large agricultural systems and heavily populated areas. Alpine and subalpine grasslands and inland salt steppes were usually in ‘good’ and ‘very good’ condition mostly due to a low degree of agricultural use. Wet and seasonally wet grasslands might be the most fragile of the assessed grassland ecosystems;10% of their polygons were found to be in ‘bad’ condition regarding ‘plant species richness’. Biomass analysis revealed that more than 75% of the assessed polygons were in ‘good’ and ‘very good’ condition, which indicates high fodder value for grazing animals. We conclude that grasslands outside the Natura 2000 network represent good examples of semi-natural ecosystems. These areas are still in relatively ‘good’ condition and have the capacity to provide valuable ecosystem services. Our results could serve as a solid foundation for regional planning and policy development.

Manuscript received 06 November 2017, accepted 09 April 2018
Co-ordinating Editor: Viktoria Wagner

Keywords: biomass, ecosystem assessment, ecosystem services, GIS, grassland mapping, invasive alien plants, phytosociological database, plant diversity, red list plant species

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Since the beginning of the 21st century, ecosystem services and their role for human well-being have become a major area of interest in applied ecology. Ecosystem services are defined as the conditions and processes through which natural ecosystems sustain human life and deliver goods to the economy (DAILY 1997). Humanity is vitally dependent on the continuous supply of many ecosystem services such as food, clean water and air (TEEB 2010). As these services are consistently undervalued, the irresponsible exploitation of natural resources results in biodiversity loss and decline of ecosystem conditions (UK NATIONAL ECOSYSTEM ASSESSMENT 2011), the latter defined as 'the capacity of ecosystems to yield services' (MAES et al. 2014).

Biodiversity is positively related to ecosystem conditions (MACE et al. 2012) and to the provision of ecosystem services (DÍAZ et al. 2006). Global ecosystem assessment reports, such as the Millennium Ecosystem Assessment (MA 2005) and the Economics of Ecosystems and Biodiversity (TEEB 2010), have emphasized the negative effect of biodiversity loss on human well-being. These documents reinforce exploring the role of biodiversity, ecosystem function and their benefits in enhancing human well-being. A step forward in this regard is the fulfilment of Action 5 of the EU Biodiversity Strategy 2020, which recommends Member States to map and assess the state (condition) of ecosystems and their services (MAES et al. 2013). For this purpose, a common typology was set up including all major ecosystems (MAES et al. 2013). To date, five countries (Portugal, United Kingdom, Spain, Norway and Belgium) have compiled ecosystem condition assessments at the national scale (SCHRÖTER et al. 2016).

Following earlier studies and the documents of the Working Group on Mapping and Assessment of Ecosystems and their Services (MAES) (e.g., BURKHARD et al. 2009, MAES et al. 2012, 2013, 2014, ERHARD et al. 2016), Bulgaria developed a National Methodological Framework. As part of this effort, APOSTOLOVA et al. (2017) prepared a methodology for mapping and assessing grassland condition and services in Bulgaria. This methodology consists of three parts: 1) definition of grassland ecosystems (typology), and the assessment of their 2) conditions, and 3) services. In the period 2015–2017, several assessment and mapping projects of nine defined major ecosystem types at the national level were conducted in Bulgaria. One of these projects targeted grasslands.

In Europe, meadows and pastures are often semi-natural and have high plant diversity (ROLEČEK et al. 2014, DENGLER et al. 2016). They have attracted the attention of phytosociologists and hence, are well-represented habitats in vegetation plot databases. The large amount of existing vegetation plot data has the potential to provide valuable information not only for vegetation classification but also for conservation, monitoring vegetation change as well as other practical applications (e.g., CHYTRÝ et al. 2016) such as the assessment of ecosystem condition.

According to national statistics, grasslands cover approximately 10% of Bulgaria's territory (GERGINOVA et al. 2016). Nearly half of their area remains outside the Natura 2000 network. To date, no comprehensive assessment has been compiled on Bulgaria's grasslands outside the Natura 2000 network. As a result, we addressed the following main question:

‘What is the ecosystem condition of Bulgaria’s semi-natural grasslands that are located outside the Natura 2000 network?’. We aimed to close this knowledge gap by (1) identifying grassland polygons outside Natura 2000 network in Bulgaria, (2) assessing their ecosystem conditions based on vegetation indicators, and (3) visualizing results on a national map.

2. Material and Methods

2.1 Study region

The study was conducted across the entire territory of Bulgaria and encompassed areas falling outside the Natura 2000 network. The country’s climate is influenced by both temperate and Mediterranean climates (VELEV 2002). Bulgaria’s potential natural vegetation is dominated by deciduous forests but local orographic and climatic differences create conditions that support a high diversity of plant community types. Three phytogeographic regions are present in Bulgaria: European deciduous forests, Euro-Asiatic steppe and forest steppe, and Mediterranean sclerophylous forests (BONDEV 2002). Grasslands in Bulgaria are mostly of secondary origin, a result of long-lasting human land-use (VELCHEV 2002a). According to VELCHEV (2002b), dry and mesic grasslands are widespread in the country, with dry grasslands being the most species-rich.

2.2 Mapping of grasslands

For the current assessment, we considered grasslands as areas with at least 30% herbaceous ground cover that occasionally include shrubs (less than 20% coverage) or single trees. Applied grassland typology follows the general guidelines of the MAES technical reports reflected in the EUNIS classification at level 2: E1. Dry grasslands, E2. Mesic grasslands, E3. Seasonally wet and wet grasslands, E4. Alpine and subalpine grasslands and E6. Inland salt steppes. All respective subordinate subtypes present on the territory of Bulgaria were considered. Woodland fringes (E5), chasmophytic, psammophytic, mire and bog vegetation were omitted; sparsely wooded grasslands (E7) were also excluded as they do not occur in Bulgaria.

We used GIS layers (Corine Land Cover, National map of habitat types, Land Parcel Identification System) and aerophoto images (50 cm spatial resolution) for manual delineation of polygon boundaries. We considered using NDVI data for distinguishing different grassland types but found them to be too insensitive for our purposes. Minimum mapping units were set at 0.25 ha following the methodology of APOSTOLOVA et al. (2017). Our mapped polygons varied in size with 32% of them being ≤ 1 ha.

2.3 Definition of ecosystem condition indicators

Vegetation is a basic ecosystem component. It forms the base of the food chain and serves as habitat for many organisms. We assessed ecosystem conditions based on five plant diversity indicators: 1) plant species richness, 2) vegetation cover, 3) number of red list plant species, 4) number of invasive alien plants and 5) plant biomass. All indicators are in accordance with the proposals of the MAES working group and reflect the main drivers and pressures that grasslands are exposed to, including habitat change, abandonment, overexploitation and species invasions (as proposed by ERHARD et al. 2016). Some of these measures are also among the essential indicators proposed in the second MAES report - e.g., ‘Species richness’ and ‘Red List Index for European species’ (MAES et al. 2014). Table 1 includes definitions and measurement units of the applied indicators, as well as their indicative significance for assessing the condition of grassland ecosystems.

Given that assessment is defined as ‘assembling, summarizing, organizing, interpreting, and possibly reconciling pieces of existing knowledge and communicating them so that they are relevant and helpful to an intelligent but inexpert decision-maker’ (MAES et al. 2014), the actual values for each

Table 1. Indicators for the assessment of grassland ecosystem conditions, including definitions, measurement units, and type of condition they indicate.

Tabelle 1. Indikatoren für die Bewertung des Zustandes von Graslandökosystemen, inkl. Definitionen, Messeinheiten, und den Zustandstyp, den sie anzeigen.

Indicator type	Indicator group	Indicator	Definition	Units	Indication of
Ecosystem structure	Biotic diversity	Plant species richness	Number of taxa registered in sample plot of an ecosystem	Number of species per sample plot area	Ability of the ecosystem to resist and maintain functionality
		Vegetation cover	Total vegetation cover estimated visually within the sampling plot	Percent	Spatial structure and disturbance rate
		Red list plant species	Number of plant taxa with conservation significance	Number of species per sample plot or per 10×10 km grid unit	High nature value
		Invasive alien plant species	Number of non-native species with ability for spreading and threaten native ecosystems	Number of species per sample plot or per 10×10 kmgrid unit	Pressure on native grassland species
Ecosystem processes	Matter budget	Plant biomass	Aboveground matter produced by plants	t/ha (air dry aboveground biomass)	Forage yield

indicator need to be transformed into an easy-to-use scoring system. We used the five-grade 'best expert's knowledge' scoring system of APOSTOLOVA et al. (2017), which we adapted for grassland subtypes (Table 2).

2.4 Data sources

Vegetation plots sampled in grassland communities were extracted from all available phytosociological databases including national sampling: the Bulgarian Vegetation Database (GIVD ID EU-BG-001, APOSTOLOVA et al. 2012), the Balkan Dry Grassland Database (GIVD ID EU-00-013, VASSILEV et al. 2012) and the Balkan Vegetation Database (GIVD ID EU-00-019, VASSILEV et al. 2016). Subsequently, only plots with precise geographical coordinates were selected, which resulted in 3445 square-shaped plots extracted from these data sources. The size distribution of the selected plots was as follows: 93% – 16 m^2, 5% – 100 m^2, 1% – between 1 and 15 m^2, less than 1% – between 16 and 100 m^2. In addition, we included data from 2244 previously mapped polygons from the National Grasslands Inventory Project (MESHINEV et al. 2005) with 100 m^2 vegetation plots into each polygon. In 2016, we conducted field sampling in areas previously lacking data. This work resulted in the addition of 343 16 m^2 vegetation plots. Thus, the final dataset included a total of 6032 vegetation plots.

Aboveground plant biomass data were newly collected in 191 grassland polygons. Each sample represented the air-dried weight of the total aboveground phytomass in a 0.25 m^2 plot. For ease of comparison among polygons, the values we obtained were transformed to tons per hectare.

The list of invasive alien plants follows PETROVA et al. (2013). Red list plant species are in accordance with PETROVA & VLADIMIROV (2009) and PEEV et al. (2015); only the categories Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) were taken into account in this study.

Table 2. Overview of the assessment scale used to evaluate ecosystem conditions in grasslands of Bulgaria. The scale specifies the numeric values for the five indicator scores and five grassland subtypes. The assessment scale was adapted from APOSTOLOVA et al. (2017).

Tabelle 2. Übersicht über die Erfassungskala, die verwendet wurde um den Zustand von Graslandökosystemen in Bulgarien zu bewerten. Die Skala gibt numerische Werte für die fünf Bewertungsnoten ('Score') und Grasland Subtypen an. Die Erfassungskala wurde übernommen von APOSTOLOVA et al. (2017).

Indicator	Grassland subtype	Assessment scale				
		Score 1 (very bad)	Score 2 (bad)	Score 3 (moderate)	Score 4 (good)	Score 5 (very good)
Plant species richness	Dry	≤4	5-20	21-30	31-40	≥41
	Mesic	≤6	7-20	21-30	31-40	≥41
	Wet and seasonally wet	≤6	7-18	19-27	28-40	≥41
	Alpine and subalpine	≤4	5-10	11-20	21-25	≥26
	Inland salt steppes	≤2	3-4	5-8	9-15	≥16
Vegetation cover	Dry	≤30	31-40	41-60	61-80	≥81
	Mesic	≤60	61-70	71-80	81-89	≥90
	Wet and seasonally wet	≤60	61-70	71-80	81-89	≥90
	Alpine and subalpine	≤50	51-60	61-80	81-89	≥90
	Inland salt steppes	≤10	11-20	21-40	41-60	≥61
Red list plant species	Dry	0	1	2-4	5-9	≥10
	Mesic	0	1	2	3-4	≥5
	Wet and seasonally wet	0	1	2	3	≥4
	Alpine and subalpine	0	1	2-4	5-8	≥9
	Inland salt steppes	0	1	2	3	≥4
Invasive alien plant species	Dry	≥5	3-4	2	1	0
	Mesic	≥5	3-4	2	1	0
	Wet and seasonally wet	≥5	3-4	2	1	0
	Alpine and subalpine	≥5	3-4	2	1	0
	Inland salt steppes	≥5	3-4	2	1	0
Plant biomass	Dry	≤0.500	0.501-1.000	1.001-2.500	2.501-3.500	≥3.501
	Mesic	≤0.500	0.501-1.000	1.001-2.500	2.501-3.500	≥3.501
	Wet and seasonally wet	≤0.500	0.501-1.000	1.001-2.500	2.501-3.500	≥3.501
	Alpine and subalpine	≤0.500	0.501-1.000	1.001-2.500	2.501-3.500	≥3.501
	Inland salt steppes	≤0.500	0.501-1.000	1.001-2.500	2.501-3.500	≥3.501

2.5 Applying ecosystem condition indicators

As our polygons were relatively homogeneous, we assumed that a sample plot represented the vegetation properties of the entire polygon. In cases where we had more than a single indicator source per polygon, priority was given as follows: 1) the latest field data; 2) information from phytosociological databases; and 3) the Grassland Inventory Project database. Due to the different locality accuracies of our data sources (e.g., point data from the phytosociological databases and polygon data from the

Grassland Inventory Project database), we used a buffer equalization, i.e., target grassland polygons located up to 50 m from the nearest available sampling data (point or polygon) were assign the same values for condition indicators.

2.5.1 Indicators 'plant species richness' and 'vegetation cover'

For those target grassland polygons that intercepted (including buffer) a sampling plot, we attributed the plot's total number of plant species and its percentage of vegetation cover to the polygon. For all remaining polygons, we made the assumption that phytogeographic regions, as defined by BONDEV (2002), share common ecological and vegetation characteristics. Therefore, we calculated an average species richness and vegetation cover value for each grassland subtype. This procedure involved all available vegetation plots (including those within Natura 2000) located within each phytogeographic region. The obtained indicator values were attributed to all polygons with missing data in the respective grassland subtype within a region.

2.5.2 Indicator 'red list plant species'

For those polygons that intercepted (including buffer) a sampling plot, we attributed values for the number of red list plants as registered in the sampling plot to the polygon. For the rest of the polygons we applied the following procedure: the red list was refined and only taxa with grassland habitat preferences were selected. Plant species with other type of habitat preferences (e.g., forest or aquatic plants) were excluded from the assessment. Subsequently, the grassland specialists were grouped by ecosystem subtype (see Supplement E1). GIS vector layers with presence of red list species, according to their distribution in a 10 × 10 km UTM-grid square (PEEV et al. 2015), were prepared for every grassland subtype. The obtained indicator values were attributed to all polygons with missing data of the respective subtype within the frame of one UTM grid cell. If a grassland polygon was intersected by two or more UTM-grid squares, the highest obtained value of red list plants was assigned to it.

2.5.3 Indicator 'invasive alien plant species'

For those polygons that intercepted (including buffer) a sampling plot, we attributed the number of invasive alien plant species as those registered in the sampling plot to the polygon. For the rest of the polygons, we first selected only invasive alien taxa with grassland habitat preferences and then grouped them by grassland ecosystem subtype (Supplement E2). GIS vector layers, with presence of invasive alien species per UTM-grid square, were prepared for each grassland subtype according to their distribution reported by PETROVA et al. (2013). Further procedures matched those applied to the 'red list plant species' indicator.

2.5.4 Indicator 'plant biomass'

Values for aboveground biomass (tons per hectare) were assigned directly to all sampled polygons. We used a regression model for all polygons with missing data. As the relationship between grassland aboveground biomass and cover is generally positive and linear (AXMANOVÁ et al. 2012, JIANG et al. 2017), we used our data to model plant biomass as a response variable of plant coverage (linear regression, $R^2 = 0.145$, $p < 0.001$). We used the equation '$y = 0.0967x - 5.7432$' (y-biomass, x-vegetation cover) to calculate all missing biomass values.

2.6 Statistical analyses, GIS database and software

We compiled a summary of descriptive statistics for each ecosystem condition indicator in each grassland subtype for two datasets: 1) polygons receiving values from available data sources (hereinafter referred to as 'polygons linked to field data') and 2) all polygons falling outside the Natura 2000 network. Descriptive statistics and regression analyses were performed with STATISTICA 13 (DELL INC. 2016).

We created a GIS database that included information on all actual ecosystem condition indicator values for each grassland polygon, the source or procedure by which they were obtained, and their respective ecosystem condition scores (from 'very bad' to 'very good', according to Table 2). ArcGIS Desktop ver. 10.x (ESRI 2011) was used to set up and analyze the GIS database and to create ecosystem condition maps.

3. Results

3.1 Data availability and general patterns of ecosystem condition indicator values

We identified a total of 123,152 distinct grassland polygons (sum of area: 63,4518.23 ha) outside the boundaries of the Natura 2000 network for our study. Of these, 9796 polygons intercepted with the available data and received values for at least one of the selected indicators: plant species richness, n = 8627 polygons; vegetation cover, n = 9664; invasive alien plant species, n = 9695; red list species, n = 9787; and plant biomass, n = 191 (see left part of Table 3). Data availability differed among grassland subtypes, with plenty of information for dry grassland polygons but few data for alpine and subalpine grasslands (Table 3).

In general, dry, mesic, and wet grasslands exhibited similar values of average plant species richness per plot, whereas inland salt steppes, alpine and subalpine grasslands were relatively species poor (Table 3). Vegetation cover was high across all grassland subtypes (means plot cover > 80% both for 'polygons linked to field data' set and for 'all polygons' data set) with the exception of some dry grasslands (which had a minimum plot cover of 40%; Table 3). Inland salt steppes exhibited the highest average vegetation cover, had the lowest standard deviation, and showed the smallest range between lower and upper quartiles in the 'all polygons' data set (Table 3). Red list plant species were infrequent across all grassland subtypes. Among the polygons that were linked to field data, dry grasslands had the highest average value for this indicator. When considering all polygons, the highest average number of red list plants was found in alpine and subalpine grasslands (Table 3). Dry grasslands contained the highest diversity of invasive alien species (Table 3). However, most polygons lacked invasive alien plants, regardless of the grassland subtype. Alpine and subalpine ecosystems had no records of invasive alien plants. The 'plant biomass' indicator revealed that grasslands produced commensurable amounts of aboveground plant biomass. Lowest absolute values for both measured and interpolated biomass were found in dry grasslands (Table 3).

3.2 Ecosystem conditions of grassland polygons

According to the 'plant species richness' indicator, approximately half of all grassland polygons were in a 'good' and nearly a third in a 'very good' condition (Table 4, Fig. 1a). Dry and mesic grassland subtypes exhibited the highest scores for this indicator. The polygons with 'good' and 'very good' plant species richness scores were spread throughout the country but were predominantly concentrated in the mountainous regions and in proximity to Natura 2000 sites (Fig. 1a). A general trend of relatively low plant diversity, and hence less favorable ecosystem condition, was observed in lowland areas with intensive agriculture and in areas close to human settlements (Fig. 1a). Although inland salt steppes are located in lowland areas, they were assessed as being in a 'very good' condition. Across all grassland

Table 3. Statistical summary of the ecosystem condition assessment. Measures were calculated for the numeric values of the assessment scale for every indicator and across all grasslands and the individual grassland subtypes, respectively. The left part represents the results for polygons linked to field-collected data sources, incl. those obtained through field sampling and from phytosociological databases ('Polygons linked to field data'). The right part shows the results for all polygons, incl. those linked to interpolated values ('All polygons').

Tabelle 3. Statistischer Überblick über die Erfassung des Ökosystemzustandes. Angaben beruhen auf Berechungen der numerischen Werte der Erfassungsskala für jeden Indikator, und für das gesamte Grasland und einzelne Grasland Subtypen. Der linke Teil stellt die Ergebnisse für die Polygone dar, die mit Felddaten verknüpft wurden, inkl. der Daten, die im Feld gesammelt und pflanzensoziologischen Datenbanken entnommen wurden ('Polygons linked to field data'). Im rechten Teil sind Ergebnisse für alle Polygone aufgeführt, inkl. derer, bei denen Polygone mit interpolierten Werten verknüpft wurden ('All polygons').

Indicator	Grassland subtype	Polygons linked to field data								All polygons							
		Number of polygons	Mean	Min	Max	Lower quartile	Upper quartile	S.D.	Coef. Var.	Number of polygons	Mean	Min	Max	Lower quartile	Upper quartile	S.D.	Coef. Var.
Plant species richness	All grasslands	8627	50.0	1.0	100.0	32.0	65.0	21.6	43.3	123152	38.3	1.0	100.0	33.0	42.0	10.9	28.4
	Dry	4823	51.9	12.0	100.0	33.0	67.0	21.7	41.2	72972	39.4	12.0	100.0	35.0	42.0	9.8	25.0
	Mesic	2608	49.4	11.0	100.0	33.0	62.5	21.1	42.6	35270	37.7	11.0	100.0	30.0	45.0	11.7	31.1
	Wet and seasonally wet	957	48.0	1.0	100.0	32.0	60.0	21.3	44.4	14174	34.8	1.0	100.0	26.0	40.0	12.4	35.6
	Alpine and subalpine	0	–	–	–	–	–	–	–	128	26.9	22.0	50.0	22.0	24.0	10.3	38.3
	Inland salt steppes	239	26.7	7.0	70.0	20.0	33.0	9.5	35.4	608	26.4	7.0	70.0	21.0	29.0	10.9	41.1
Vegetation cover	All grasslands	9664	90.2	40.0	100.0	85.0	98.0	10.1	11.2	123152	89.0	40.0	100.0	86.0	94.0	7.8	8.8
	Dry	5579	89.1	40.0	100.0	85.0	97.0	10.5	11.8	72972	87.5	40.0	100.0	84.0	93.0	8.2	9.4
	Mesic	2811	91.3	60.0	100.0	90.0	100.0	9.7	10.6	35270	90.8	60.0	100.0	86.0	95.0	6.9	7.6
	Wet and seasonally wet	1028	92.3	60.0	100.0	90.0	100.0	8.2	8.9	14174	91.5	60.0	100.0	89.0	95.0	5.5	6.1
	Alpine and subalpine	5	94.2	80.0	100.0	95.0	98.0	8.1	8.6	128	84.6	73.0	100.0	73.0	93.0	10.5	12.4
	Inland salt steppes	239	92.4	70.0	100.0	90.0	100.0	7.6	8.3	608	92.6	70.0	100.0	92.0	95.0	5.0	5.4

Indicator	Grassland subtype	Polygons linked to field data								All polygons							
		Number of polygons	Mean	Min	Max	Lower quartile	Upper quartile	S.D.	Coef. Var.	Number of polygons	Mean	Min	Max	Lower quartile	Upper quartile	S.D.	Coef. Var.
Red list plant species	All grasslands	9787	0.4	0.0	4.0	0.0	1.0	0.8	174.5	123152	0.4	0.0	15.0	0.0	0.0	0.9	256.4
	Dry	5661	0.5	0.0	4.0	0.0	1.0	0.8	162.2	72972	0.5	0.0	15.0	0.0	1.0	1.1	205.8
	Mesic	2851	0.4	0.0	4.0	0.0	1.0	0.8	190.7	35270	0.1	0.0	5.0	0.0	0.0	0.4	422.6
	Wet and seasonally wet	1034	0.3	0.0	3.0	0.0	0.0	0.6	199.8	14174	0.1	0.0	5.0	0.0	0.0	0.4	391.3
	Alpine and subalpine	0	–	–	–	–	–	–	–	128	2.5	0.0	8.0	1.0	3.0	2.4	93.9
	Inland salt steppes	239	0.2	0.0	2.0	0.0	0.0	0.5	208.6	608	0.4	0.0	4.0	0.0	0.0	1.0	260.1
Invasive alien plant species	All grasslands	9695	0.1	0.0	4.0	0.0	0.0	0.3	382.4	123152	1.8	0.0	5.0	0.0	3.0	1.6	89.8
	Dry	5603	0.1	0.0	4.0	0.0	0.0	0.3	374.1	72972	2.9	0.0	5.0	3.0	3.0	1.0	33.6
	Mesic	2818	0.1	0.0	3.0	0.0	0.0	0.3	401.0	35270	0.1	0.0	4.0	0.0	0.0	0.3	291.8
	Wet and seasonally wet	1027	0.1	0.0	3.0	0.0	0.0	0.4	368.7	14174	0.1	0.0	2.0	0.0	0.0	0.3	335.4
	Alpine and subalpine	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	128	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Saline	239	0.1	0.0	1.0	0.0	0.0	0.2	417.8	608	<0.1	0.0	1.0	0.0	0.0	0.2	447.2
Plant biomass	All grasslands	191	3.4	0.4	9.0	2.0	4.5	1.8	51.9	123152	2.9	<0.1	9.0	2.6	3.4	0.8	26.7
	Dry	95	2.9	0.4	7.6	1.5	3.9	1.7	59.7	72972	2.7	<0.1	7.6	2.4	3.3	0.8	29.6
	Mesic	84	3.9	1.3	9.0	2.7	5.0	1.6	41.8	35270	3.0	<0.1	9.0	2.6	3.5	0.7	22.4
	Wet and seasonally wet	3	4.0	3.2	4.6	3.2	4.6	0.8	18.6	14174	3.1	<0.1	4.6	2.9	3.5	0.5	17.4
	Alpine and subalpine	6	3.4	1.2	8.0	2.0	4.5	2.5	73.1	128	2.4	1.2	8.0	1.3	3.3	1.1	46.1
	Inland salt steppes	3	2.8	2.4	3.1	2.4	3.1	0.3	12.1	608	3.2	1.0	3.9	3.2	3.5	0.5	15.0

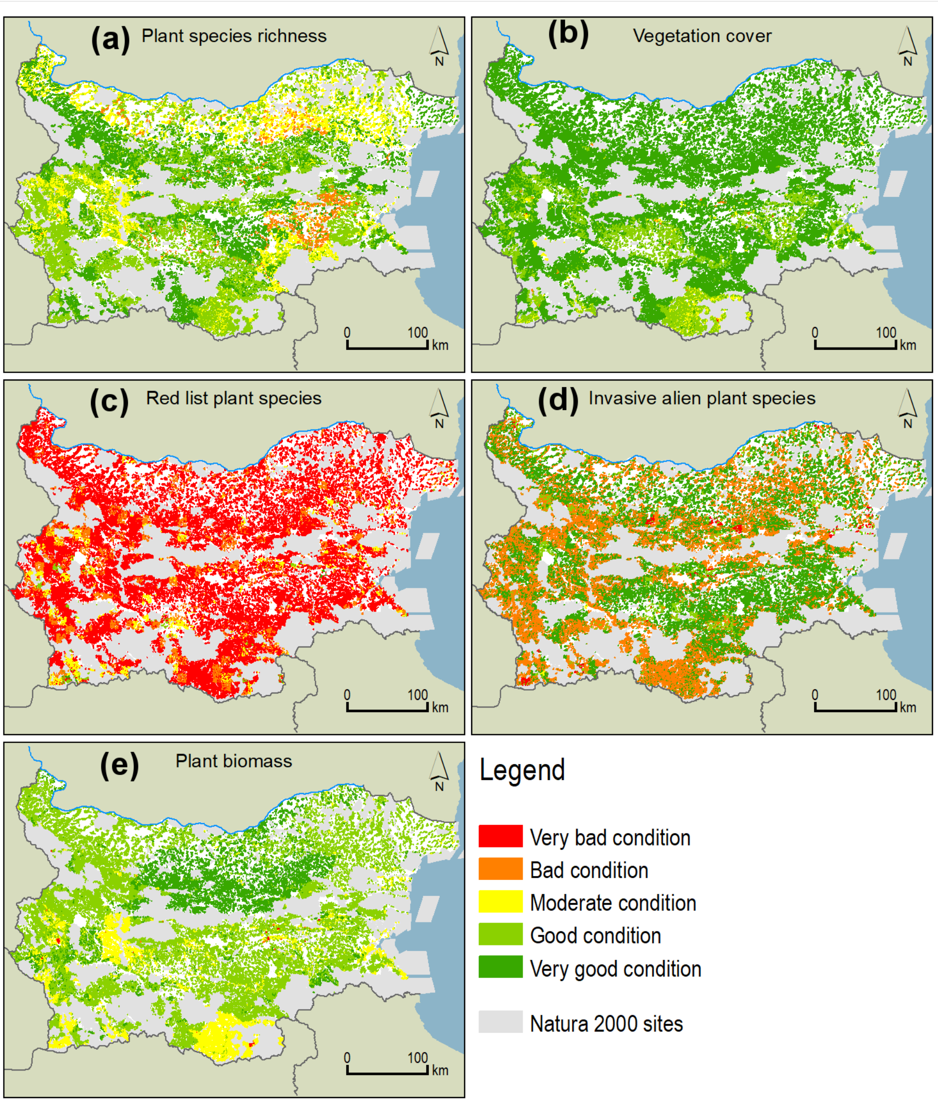

Fig. 1. Spatial distribution of grassland polygons outside the Natura 2000 network in Bulgaria and their ecosystem condition scores (in colour, ranging from dark green - 'very good' to red - 'very bad') for the studied indicators. White places pixels represent areas without grassland polygons. Grey pixels indicate the terrestrial and marine Natura 2000 areas in Bulgaria.

Abb. 1. Räumliche Verteilung der Graslandpolygone außerhalb des Natura 2000 Netzwerkes in Bulgarien und deren Zustandsbewertung (farbig markiert, mit Werten zwischen dunkel grün – ‚very good'/‚sehr gut' und rot – ‚very bad'/‚sehr schlecht') für die erfassten Indikatoren. Weiße Pixel stellen Gebiete ohne Graslandpolygone dar. Graue Pixel repräsentieren die terrestrischen und marinen Natura 2000 Gebiete in Bulgarien.

subtypes, very few polygons were in a 'very bad' condition, i.e., exhibited below average plant species richness. One exception was wet and seasonally wet grasslands since approximately 10% of their polygons were found to have a 'bad' score for this indicator (Table 4).

Most polygons were in 'good' and 'very good' condition with respect to the 'vegetation cover' indicator (Table 4). Throughout the country, this indicator changed very little across polygons, except for the most southern region (Fig. 1b), where more open dry grasslands occur. A small number of mesic, wet and seasonally wet grasslands were found to have a 'bad' and 'very bad' condition according to vegetation cover (Table 4). This is rather worrisome as these plant communities have naturally a dense plant cover.

According to the 'red list plants' indicator, more than 78% of all grassland polygons were in a 'very bad' condition. Relative 'hot-spots' of red list plants were found in the north-eastern and in the western/southwestern part of Bulgaria - areas that are influenced by steppe and Mediterranean floristic elements (Table 4, Fig. 1c).

Nearly half of the grassland polygons had three or more invasive alien plants species and were thus in a 'bad' ecosystem condition according to this indicator. Dry grassland polygons had the worst scores in this respect (Table 4, Fig. 1d). Rather surprisingly, some regions with grasslands containing invasive alien plants were simultaneously identified as 'hot-spots' for red listed plants (compare Fig 1c, d).

According to the 'plant biomass' indicator, most studied grassland polygon, irrespective of the grassland subtype, were found to be in 'good' condition (Table 4). The most productive grasslands were found in the foothills of the northern Balkan Range (Fig. 1e).

4. Discussion

According to MAES et al. (2014), an ecosystem in a 'healthy state (condition)' may provide a sustained flow and more services compared to an ecosystem managed to provide the maximum amount of a single service. In Europe, many natural and semi-natural ecosystems are currently under severe human pressure and in an 'unhealthy' state (RAPPORT et al. 1998). Our study suggests that in Bulgaria, grasslands outside the Natura 2000 network are in a relatively good condition and have the potential to deliver a variety of different services.

Species richness (diversity) is positively related to ecosystem stability and resilience and has been pointed out as one of the most easy-to-measure indicators of ecosystem health (COSTANZA 1992). We found our studied grassland to be relatively species-rich even when compared to other species-rich grasslands in Europe (e.g., TURTUREANU et al. 2014). Polygons with the highest plant species richness were located in mountainous areas, often adjacent to Natura 2000 sites. This supports the buffer zone effect around the Natura 2000 sites mentioned by VAN DER SLUIS et al. (2016). Our mean values for 'plant species richness' were higher than those reported for certain grasslands and regions in Bulgaria. For example, dry grasslands in southeastern Bulgaria showed plant species richness values between 15.3±4 and 31.4±5.6 (mean±SD) per 16 m^2 (SOPOTLIEVA & APOSTOLOVA 2014), while those in western Bulgaria had mean species richness of 27.16–33.95 per 16 m^2 (VELEV & VASSILEV 2014). PALPURINA et al. (2015) found species richness of 52.2±17.6 (mean±SD, per 100m^2) in dry lowland grasslands in Bulgaria and Romanian Dobrudzha. This value corresponds well with our 'field data' set calculation of 51.92±21.7 (mean±SD, Table 3). Mesic grasslands in the central part of western Bulgaria showed an average of 35.6 to 38.9 plant species per 16 m^2 (VELEV & VASSILEV 2014). These values are similar to the value we obtained

Table 4. Distribution of polygons across ecosystem condition indicators and assessment scores. Values are listed for all grasslands and every grassland subtype. They encompass the total number of polygons, percentage share from all polygons and from the polygons of the relevant grassland subtype, respectively.

Tabelle 4. Verteilung der Polygone nach Indikatoren für Ökosystemzustände und Bewertungsnoten. Die Werte sind aufgelistet für das gesamte Grasland und für einzelne Grassland Subtypen. Sie umfassen die gesamte Anzahl der Polygone, den prozentuellen Anteil über alle Polygone und über Polygone der einzelnen Grassland Subtypen hinweg.

Indicator	Grassland subtype	Total number of polygons	Assessment scale														
			Score 1 (very bad)			Score 2 (bad)			Score 3 (moderate)			Score 4 (good)			Score 5 (very good)		
			Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]
Plant species richness	All grasslands	123152	2	<0.1	–	3406	2.8	–	18801	15.3	–	61050	49.6	–	39893	32.4	–
	Dry	72972	0	0.0	0.0	86	0.1	0.1	8320	6.8	11.4	40370	32.8	55.3	24196	19.6	33.2
	Mesic	35270	0	0.0	0.0	1808	1.5	5.1	7280	5.9	20.6	14606	11.9	41.4	11576	9.4	32.8
	Wet and seasonally wet	14174	2	<0.1	<0.1	1512	1.2	10.7	3200	2.6	22.6	5916	4.8	41.8	3544	2.9	25.0
	Alpine and subalpine	128	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	96	0.1	75.0	32	<0.1	25.0
	Inland salt steppes	608	0	0.0	0.0	0	0.0	0.0	1	<0.1	0.2	62	0.1	10.2	545	0.4	89.6
Vegetation cover	All grasslands	123152	65	0.1	–	303	0.3	–	3763	3.1	–	27000	21.9	–	92028	74.7	–
	Dry	72972	0	0.0	0.0	2	<0.1	<0.1	156	0.1	0.2	16175	13.1	22.2	56639	46.0	77.6
	Mesic	35270	55	<0.1	0.2	213	0.2	0.6	3090	2.5	8.8	7784	6.3	22.1	24128	19.6	68.4
	Wet and seasonally wet	14174	10	<0.1	0.1	88	0.1	0.6	452	0.4	3.2	3041	2.5	21.5	10583	8.6	74.7
	Alpine and subalpine	128	0	0.0	0.0	0	0.0	0.0	65	0.1	50.8	0	0.0	0.0	63	0.1	49.2
	Inland salt steppes	608	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	608	0.5	100.0

Indicator	Grassland subtype	Total number of polygons	Score 1 (very bad)			Score 2 (bad)			Score 3 (moderate)			Score 4 (good)			Score 5 (very good)		
			Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]	Polygons [number]	Share from all polygons [%]	Share from relevant subtype [%]
Red list plant species	All grasslands	123152	96659	78.5	–	17206	14.0	–	8110	6.6	–	1002	0.8	–	175	0.1	–
	Dry	72972	50030	40.6	68.6	14562	11.8	20.0	7421	6.0	10.2	834	0.7	1.1	125	0.1	0.2
	Mesic	35270	32960	26.8	93.5	1732	1.4	4.9	456	0.4	1.3	106	0.1	0.3	16	<0.1	0.1
	Wet and seasonally wet	14174	13148	10.7	92.8	825	0.7	5.8	165	0.1	1.2	31	<0.1	0.2	5	<0.1	<0.1
	Alpine and subalpine	128	22	<0.1	17.2	28	<0.1	21.9	57	<0.1	44.5	21	<0.1	16.4	0	0.0	0.0
	Inland salt steppes	608	499	0.4	82.1	59	<0.1	9.7	11	<0.1	1.8	10	<0.1	1.6	29	<0.1	4.8
Invasive alien plant species	All grasslands	123152	1120	0.9	–	65510	53.2	–	102	0.1	–	5226	4.2	–	51194	41.6	–
	Dry	72972	1120	0.9	1.5	65503	53.2	89.8	79	0.1	0.1	304	0.2	0.4	5966	4.8	8.2
	Mesic	35270	0	0.0	0.0	7	<0.1	<0.1	13	<0.1	0.0	3736	3.0	10.6	31514	25.6	89.4
	Wet and seasonally wet	14174	0	0.0	0.0	0	0.0	0.0	10	<0.1	0.1	1157	0.9	8.2	13007	10.6	91.8
	Alpine and subalpine	128	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	128	0.1	100.0
	Inland salt steppes	608	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	29	<0.1	4.8	579	0.5	95.2
Plant biomass	All grasslands	123152	226	0.2	–	57	0.1	–	27579	22.4	–	74603	60.6	–	20687	16.8	–
	Dry	72972	161	0.1	0.2	41	<0.1	0.1	20530	16.7	28.1	42925	34.9	58.8	9315	7.6	12.8
	Mesic	35270	55	<0.1	0.2	12	<0.1	<0.1	5236	4.3	14.9	21582	17.5	61.2	8385	6.8	23.8
	Wet and seasonally wet	14174	10	<0.1	0.1	4	0.0	<0.1	1692	1.4	11.9	9630	7.8	67.9	2838	2.3	20.0
	Alpine and subalpine	128	0	0.0	0.0	0	0.0	0.0	67	0.1	52.3	44	<0.1	34.4	17	<0.1	13.3
	Inland salt steppes	608	0	0.0	0.0	0	0.0	0.0	54	<0.1	8.9	422	0.3	69.4	132	0.1	21.7

from the ‘all polygons’ set (37.7, Table 3) for the respective grassland type. Inland salt steppes are typically considered species poor (MOLNÁR & BORHIDI 2003), a finding also confirmed by our study.

Most grassland polygons in our study exhibited a vegetation cover of > 60% (see Table 3), which is in line with previous studies in Bulgaria (e.g., TZONEV et al. 2008, VELEV et al. 2010, PEDASHENKO et al. 2013, SOPOTLIEVA & APOSTOLOVA 2014). In our study, we also used vegetation cover to calculate aboveground plant biomass. We collected our field data for this interpolation at sites representative of each grassland subtype, to reflect the current state of the vegetation in these semi-natural areas. However, this could have overestimated vegetation cover (and biomass) and underestimated the presence of disturbed patches. In the future, studies on vegetation cover should also take into account sites more heavily impacted by anthropogenic disturbances in order to determine the strength of the human influence and the relationship between vegetation cover, disturbance, and ecosystem services (VANACKER et al. 2014).

Red list plants were rare across all studied grassland subtypes. In fact, most polygons did not contain any red list species. This is not surprising, as the majority of areas with a high concentration of red list plants (see map in PEEV et al. 2015) are currently included in protected areas, which largely overlap with the Natura 2000 network (see VAN DER SLUIS et al. 2016 for a similar conclusion at the European scale). However, we found that some grassland polygons outside the Natura 2000 network still held a significant concentration of red list plants (see Fig. 1c) and thus could provide cultural services, such as plant watching. In our study, some dry grasslands reached the highest number of red plant species as compared to all other grassland subtypes. This finding is not surprising given that many dry grasslands are found on limestone and host many Balkan endemics. Subalpine and alpine grasslands represent another group markedly rich in rare plants, due to the richness of the mountain flora and especially that of relict and endemic plants.

Subalpine and alpine grasslands were also in ‘very good’ condition regarding the ‘invasive alien plant species’ indicator. These results reflect the general trend of low invasion levels at high altitudes (CHYTRÝ et al. 2009, ALEXANDER et al. 2011). Similarly to some Central European semi-natural grasslands (cf. CHYTRÝ et al. 2005), Bulgaria’s dry grasslands were among the most affected by invasive alien plants. For this indicator, half of their polygons were in a ‘bad’ ecosystem condition. As previously noted by many authors, the open structure of these dry grasslands has the potential to facilitate species invasions (for a review see JAUNI et al. 2015). Interestingly, we found polygons with both rare and invasive alien plants, such as in southwestern Bulgaria. This finding needs to be addressed by a more detailed study but the pattern could be linked to the region's enhanced transboundary traffic with neighboring Greece. The international highways were mentioned as one of the main ways for the introduction of invasive alien plants in Bulgaria (PETROVA et al. 2012).

Knowledge of biomass production across different grassland subtypes is crucial for land-use planning and management. Unfortunately, only few studies have explored biomass production across different vegetation types in Bulgaria (e.g., KOCHEV & TZEROVSKA 1994, APOSTOLOVA & MESHINEV 2001). In line with our results for vegetation cover, we obtained very high results for the ‘biomass’ indicator across grassland subtypes and polygons (calculated yields between 2.5 and 3.5 t/ha for 60% of the grassland polygons). The hay yield in Bulgaria differs between years and regions, but the average hay yield for the period 2010-2014 was 2.876 t/ha (calculations based on data from the latest Agrostatistical Reference Book, GERGINOVA et al. 2016). This value is lower than the mean value obtained for the ‘field data’ set, but very close to the mean value obtained for the ‘all polygons’ set - 3.387 t/ha and 2.865 t/ha, respectively (Table 3). In combination with forage quality, these results can be used in calculating animal food availability - one of the most important ecosystem service provided by grasslands.

The calculated indicator values for mean, lower and upper quartiles for the ‘all polygons’ set (Table 3) correspond well to the known grassland vegetation characteristics in Bulgaria and support the objectivity of the proposed scoring system (Table 2). The values for lower and upper quartiles correlate with the thresholds for ‘good’ ecosystem condition, especially for the ‘plant species richness’, ‘vegetation cover’ and ‘plant biomass’ indicators. The relatively high standard deviation (SD) and coefficient of variation (CV) of these indicators show differences between the polygons. This could be explained by the vegetation diversity (different syntaxa included) in each grassland subtype.

5. Conclusion and outlook

The results presented in this work are the first step towards the assessment of grassland ecosystem conditions in Bulgaria. Land-use planners can use our map and scoring results to maintain and improve ecosystem services provided by grasslands falling outside the Nature 2000 network. As long as each polygon has a separate assessment score for each indicator, regional planners can select polygons that are best for, among other things, forage supply, ecotourism, or combined ecosystem services. Given that we linked our study MAES, it will be possible to compare ecosystem condition in Bulgarian grasslands to those found in other parts of the European Union.

Our ecosystem assessment relied on up to date, accurate, and spatially associated vegetation data. Vegetation databases were a valuable resource for our project given their detailed information on the presence and abundance of plants, vegetation structure and environmental characteristics. Unfortunately not all polygons intersected with a vegetation plot, which forced us to use alternative data sources. By using this approach, we included data on the distribution of red list plants and invasive plants alongside with phytocoenological sampling data even though the former information was available at a rather large scale (10 × 10 km grid square). This could have overestimated the presence of red listed and invasive aline species. Given the rich information that vegetation database archive, it is important to foster vegetation studies across Bulgaria. In addition, future studies should explore unpublished sources for ‘hidden’ information on plant species records. This requires additional efforts to digitize herbarium collections and to build a contemporary information system with precise georeferenced data in Bulgaria.

For our assessment, we calculated only the number of invasive alien plants. Future studies, however, could benefit from the calculation of species abundance or coverage. After all, the dense cover of a single species can potentially be more threatening than the presence of a few individuals of several plant species.

In the future, special attention should be directed to the ‘plant biomass’ indicator given its high significance to grassland ecosystem services. Given the framework of our study, we were able to sample relatively few data points across the country and had to interpolate values based on vegetation cover. Future studies could improve the assessment of ecosystem condition in Bulgarian grasslands by sampling more on the ground data points and taking fodder quality into consideration.

Our results suggest that it is difficult to characterize Bulgaria's grasslands based on a single set of scores given that they encompass different subtypes and differ in their condition, depending on what indicator is considered. We believe that the application of a more specific scoring system has the potential to produce a more precise assessment. Therefore, the newly developed scoring system was refined for all individual subtypes.

In the near future, we intend to apply this methodology to assess the grassland ecosystem condition of areas within the Natura 2000 network and account for grassland ecosystem services at the national level.

Erweiterte deutsche Zusammenfassung

Einleitung – Die fünfte Fassung der EU-Biodiversitätsstrategie empfiehlt den teilnehmenden Mitgliedsstaaten die Erfassung und Bewertung des Zustands und der Leistungen von Ökosystemen. Bulgarien hat daher auf Grundlage der Empfehlungen der *Working Group on Mapping and Assessment of Ecosystems and their Services* (MAES) einen nationalen methodischen Rahmen zur Bewertung von Graslandökosystemen erarbeitet (APOSTOLOVA et al. 2017). Ziel der vorliegenden Studie war die Bewertung des Zustands des halbnatürlichen Graslands außerhalb von Natura 2000-Gebieten in Bulgarien auf Grundlage von Vegetationsdaten. Die dabei verwendete große Menge vorhandener Vegetationsaufnahmen besitzt also nicht nur ein Potential zur Vegetationsklassifikation sondern auch für praktische Anwendungen, wie die hier durchgeführte Bewertung zeigt (vgl. CHYTRÝ et al. 2016). Dazu wurden Graslandpolygone in der Landschaft identifiziert und hinsichtlich ihres Zustands mittels Indikatoren bewertet. Anschließend wurden die Ergebnisse in Karten visualisiert.

Material und Methoden – In Anlehnung an die EUNIS-Level 2-Klassifikation wurden fünf Graslandtypen unterschieden: Trockenrasen, mesophiles Grünland, Nasswiesen und saisonale Nasswiesen, alpines und subalpines Grasland sowie Binnensalzsteppe. Diese Graslandtypen wurden auf Grundlage von fünf Indikatoren bewertet: Pflanzenartenreichtum, Vegetationsdeckung, Pflanzenarten der Roten Liste, invasive (gebietsfremde) Arten und Phytomasse (s. Tab. 1). Dazu wurde das Grasland nach Typen in (einheitliche) Polygone von mindestens 0,25 ha Größe zerlegt. Zur Bemessung der ersten vier Indikatoren diente ein Datensatz von 6032 Vegetationsaufnahmen, während die Phytomasse auf Grundlage von 191 Messungen bemessen wurde. Diese Daten wurden mit Angaben zum Vorkommen von Rote Liste-Arten (PEEV et al. 2015) und gebietsfremden (invasiven) Pflanzenarten (PETROVA et al. 2013) in einem 10 × 10 km UTM-Raster ergänzt. Datenlücken wurden durch räumliche und statistische Modellierung gefüllt. Für jeden Indikator wurden die Werte in ein einfach zu handhabendes fünfstufiges System überführt, welches auf Experteneinschätzung beruhte (Tab. 2).

Ergebnisse – Insgesamt wurden 123.152 Graslandpolygone mit einer Gesamtfläche von 634.518,23 ha erfasst. In etwa der Hälfte der Polygone war das Grasland hinsichtlich des Pflanzenartenreichtums in einem guten Zustand und in etwa einem Drittel der Polygone in einem sehr guten Zustand (Tab. 4). Es gab sehr wenige Polygone, in denen das Grasland in einem sehr schlechten Zustand war; dies galt für alle fünf Graslandtypen. Die Polygone mit den höchsten Werten für Artenreichtum befanden sich in Bergregionen, häufig in der Nähe von Natura 2000-Gebieten. Dieses Ergebnis zeigt, dass um viele bestehende Natura 2000-Gebiete offenbar ein Puffer aus artenreichem Grasland existiert (VAN DER SLUIS et al. 2016). Polygone mit hinsichtlich des Artenreichtums weniger gutem Ökosystemzustand befanden sich dagegen im Tiefland, d. h. in Gebieten mit intensiver Landwirtschaft sowie in der Nähe zu menschlichen Siedlungen (Abb. 1a). Bezüglich der Vegetationsdeckung waren alle Polygone in einem guten oder sehr guten Zustand, d. h. die Grasnarbe war relativ dicht ausgebildet (Tab 4). Landesweit schwankten die Werte dieses Indikators kaum. Eine Ausnahme bildeten die südlichsten Landesteile, in denen vermehrt offene Trockenrasen existieren (Abb. 1b). Arten der Roten Liste waren nach unserer Auswertung insgesamt relativ selten; 78,5 % der Polygone wiesen gar keine Arten der Roten Liste auf. Polygone mit relativ vielen Arten der Roten Liste befanden sich v. a. im Nordosten und Westen sowie im Südwesten des Landes (Abb. 1c). In diesen Gebieten kommen vermehrt seltene Steppen- und mediterrane Florenelemente vor, was den höheren Anteil gefährdeter Arten erklärt. Fast die Hälfte der Graslandpolygone wiesen drei oder mehr gebietsfremde Pflanzenarten auf und waren diesbezüglich in einem schlechten Zustand. Dabei schnitten die Polygone mit Trockenrasen am schlechtesten ab (Abb. 1d). Polygone mit subalpinem und alpinem Grasland waren dagegen hinsichtlich des Vorkommens gebietsfremder Pflanzenarten in einem insgesamt sehr guten Zustand. Die Datenverfügbarkeit für Phytomasse schwankte zwischen den einzelnen Graslandtypen und Polygonen stark. 60 % der Polygone zeigten einen berechneten Wert von 2,5–3,5 t Phytomasse pro Hektar. Das produktivste Grasland befand sich in den Ausläufern des nördlichen Balkangebirges (Abb. 1e).

Diskussion – Die Ergebnisse unserer Studie stellen einen ersten Schritt in Richtung einer Gesamtbewertung des Ökosystemzustands des bulgarischen Graslands dar. Sie zeigen, dass sich das bulgarische Grasland außerhalb von Natura 2000-Gebieten in einem relativ guten Zustand befindet und potentiell eine Reihe verschiedener Ökosystemleistungen erbringen kann. Unsere Ergebnisse ermöglichen es Landschaftsplanern und Naturschützern, die Ökosystemleistungen des Graslands einer Region zu erkennen, zu nutzen und zu verbessern. Da jedes Polygon für jeden Indikator eine eigene Note aufweist, können Planer diejenigen Gebiete auswählen, die eine bestimmte Ökosystemleistung am besten erfüllen, z. B. Gebiete mit hoher Futterproduktion für Nutztiere (über die Phytomasse) oder Gebiete mit hoher Attraktivität für den Ökotourismus (über den Artenreichtum). Da unsere Studie an das MAES-Evaluierungssystem geknüpft war, wird es in Zukunft möglich sein, das bulgarische Grasland hinsichtlich seines Ökosystemzustands mit dem Grasland anderer Regionen der Europäischen Union zu vergleichen. Unsere Ökosystembewertung war auf zeitnah erhobene Vegetationsdaten mit geographischen Koordinaten angewiesen. Vegetationsdatenbanken waren in dieser Hinsicht eine wichtige Datenquelle für unser Projekt. Sie lieferten detaillierte Informationen über die Anwesenheit und die Abundanz von Pflanzenarten, sowie über die Vegetationsstruktur und Umweltparameter. Bedauerlicherweise waren nicht für alle Polygone Vegetationsdaten verfügbar. Daher mussten wir auch alternative Datenquellen nutzen; für einige Polygone mussten wir z. B. auf Verbreitungsdaten von Rote Liste-Arten und gebietsfremden Arten zurückgreifen. Zukünftige Studien dieser Art könnten die Güte der Ökosystembewertung noch weiter verbessern, indem sie noch mehr Felddaten nutzen, die zukünftig zu erheben sind.

Acknowledgements

This work is a part of the project “Assessment and mapping of GRASSLAND ecosystems condition and their services in Bulgaria” (D-33-90/03.09.2015) funded by the program BG03 Biodiversity and ecosystem services, Financial mechanism of the European Economic Area (EEA) 2009-2014. (http://grasslands-ecoservices-bg.eu/index.php/en/). We thank Vladimir Vladimirov for the selection of grassland invasive alien plant species and Dr. Boris Assyov for his help on the rare plants list precision. We are grateful to two anonymous referees, the editor (Dr. Viktoria Wagner) for their constructive comments on an earlier version of this manuscript and to Dr. Kaloyan Ivanov (Virginia Museum of Natural History, USA) who did the linguistic editing.

Supplements

Additional supporting information may be found in the online version of this article.

Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.

Supplement E1. Red list plants of Bulgaria with a preference for grassland habitats (selected from PETROVA & VLADIMIROV [2009]).

Anhang E1. Rote Liste Arten in Bulgarien, die eine Präferenz für Grasland-Habitate aufweisen (ausgewählt aus PETROVA & VLADIMIROV [2009]).

Supplement E2. Invasive alien plant species in Bulgaria with a preference for grassland habitats (selected from PETROVA et al. [2013]).

Anhang E2. Invasive gebietsfremde Arten in Bulgarien, die eine Präferenz für Grasland-Habitate aufweisen (ausgewählt aus PETROVA et al. [2013]).

References

ALEXANDER, J.M., KUEFFER, C., DAEHLER, C.C., EDWARDS, P.J., PAUCHARD, A., SEIPEL, T. & MIREN CONSORTIUM (2011): Assembly of nonnative floras along elevational gradients explained by directional filtering. – PNAS 108: 656–661.

APOSTOLOVA, I. & MESHINEV, T. (2001): Economic productivity of major high-mountain pasture types on the territory of the Central Balkan National Park. – Phytol. Balcan. 7: 65–73.

APOSTOLOVA, I., SOPOTLIEVA, D., PEDASHENKO, H., VELEV, N. & VASILEV, K. (2012): Bulgarian Vegetation Database: historic background, current status and future prospects. – Biodiv. Ecol. 4: 141–148.

APOSTOLOVA, I., SOPOTLIEVA, D., VELEV, N., VASSILEV, V., BRATANOVA-DONCHEVA, S. & GOCHEVA, K. (2017): Methodology for assessment and mapping of grassland ecosystems condition and their services in Bulgaria. – Clorind, Sofia: 55pp. – URL: http://www.iber.bas.bg/sites/default/files/2018/MAES_2018/B3%20GRASSLAND_ENG%20PRINT.pdf.

AXMANOVÁ, I., TICHÝ, L., FAJMONOVÁ, Z. et al. (2012): Estimation of herbaceous biomass from species composition and cover. – Appl. Veg. Sci. 15: 580–589.

BONDEV, I. (2002): Geobotanichesko rayonirane (Geobotanical regions). – In: KOPRALEV, I. (Ed.): Geografiya na Bulgariya. Fizicheska i socialno-ikonomicheska geografia (Geography of Bulgaria. Physical and Socio-Economic geography) [in Bulgarian]: 336–352. Publ. House ForCom, Sofia.

BURKHARD, B., KROLL, F., MÜLLER, F. & WINDHORST, W. (2009): Landscapes‘ capacities to provide ecosystem services – a concept for land-cover based assessments. – Landsc. Online 15: 1–22.

CHYTRÝ, M., HENNEKENS, S.M., JIMÉNEZ-ALFARO, B. et al. (2016): European Vegetation Archive (EVA): an integrated database of European vegetation plots. – Appl. Veg. Sci. 19: 173–180.

CHYTRÝ, M., PYŠEK, P., TICHÝ, L., KNOLLOVÁ, I. & DANIHELKA, J. (2005): Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. – Preslia 77: 339–354.

CHYTRÝ, M., PYŠEK, P., WILD, J., PINO, J., MASKELL, L.C. & VILÀ, M. (2009): European map of alien plant invasions based on the quantitative assessment across habitats. – Divers. Distrib. 15: 98–107.

COSTANZA, R. (1992): Toward an operational definition of ecosystem health. – In: COSTANZA, R., NORTON, B.G. & HASKELL, B.D. (Eds): Ecosystem health: New goals for environmental management. – Island Press, Washington: 239–256.

DAILY, G.C. (Ed.) (1997): Nature's services. Societal dependence on natural ecosystems. – Island Press, Washington, DC: 392 pp.

DELL INC. (2016): Dell Statistica (data analysis software system), ver. 13. – URL: software.dell.com.

DENGLER, J., BIURRUN, I., APOSTOLOVA, I. et al. (2016): Scale-dependent plant diversity in Palaearctic grasslands: a comparative overview. – Bull. EDGG 31: 12–26.

DÍAZ, S., FARGIONE, J., CHAPIN III, F.S. & TILMAN, D. (2006): Biodiversity loss threatens human well-being. – PLoS Biol. 4: 1300–1305.

ERHARD, M., TELLER, A., MAES, J. et al. (2016): Mapping and assessment of ecosystems and their services – 3rd Report. Mapping and assessing the condition of Europe’s ecosystems: Progress and challenges. – European Environment Agency: 179 pp.

ESRI (2011): ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Redlands.

GERGINOVA, A., ARSHINKOVA, A., GALABOVA, V. et al. (2016): Agrostatistical Reference Book. – Ministry of Agriculture and Food, Sofia: 234pp. – URL: http://www.mzh.government.bg/MZH/Libraries/%D0%A1%D0%BF%D0%B8%D1%81%D1%8A%D0%BA_%D0%BD%D0%B0_%D0%BE%D0%B4%D0%BE%D0%B1%D1%80_%D1%80%D0%B0%D0%B7%D0%B2%D1%8A%D0%B4%D0%BD%D0%B8_%D0%BE%D1%80%D0%B3/AgrostatisticalReferenceBookMAF-2000-2015.sflb.ashx [accessed 2018-02-22].

JAUNI, M., GRIPENBERG, S. & RAMULA, S. (2015): Non-native plant species benefit from disturbance: a meta-analysis. – Oikos 124: 122–129.

JIANG, Y., ZHANG, Y., WU, Y., HU, R., ZHU, J., TAO, J., & ZHANG, T. (2017): Relationships between aboveground biomass and plant cover at two spatial scales and their determinants in northern Tibetan grasslands. – Ecol. Evol. 7: 7954–7964.

KOCHEV, H & TZEROVSKA, L. (1994): Parvichna biologichna produkciya na dve asociacii ot Vitosha planina (Primary biological production of two associations on Vitosha Mountain) [in Bulgarian]. – Ecologija 26: 26–36.

MA (Millennium Ecosystem Assessment) (2005): Ecosystems and human well-being: Synthesis. – Island Press, Washington D.C.: 138 pp.

MACE, G., NORRIS, K. & FITTER, A. (2012): Biodiversity and ecosystem services: a multilayered relationship. – Trends Ecol. Evol. 27: 19–26.

MAES, J., EGOH, B., WILLEMEN, L. et al. (2012): Mapping ecosystem services for policy support and decision making in the European Union. – Ecosyst. Serv. 1: 31–39.

MAES, J., TELLER, A., ERHARD, M. et al. (2013): Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem assessments under Action 5 of the EU biodiversity strategy to 2020. – Publications office of the European Union, Luxembourg: 57 pp.

MAES, J., TELLER, A., ERHARD, M. et al. (2014): Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. – Publications office of the European Union, Luxembourg: 80 pp.

MESHINEV, T., APOSTOLOVA, I., GEORGIEV, V., DIMITROV, V., PETROVA, A. & VEEN, P. (2005): Grasslands of Bulgaria. Final report on the National Grasslands Inventory Project – Bulgaria, 2001–2004. – Dragon 2003 Ltd. Publishers, Sofia: 104 pp.

MOLNÁR, Z. & BORHIDI, A. (2003): Hungarian alkali vegetation: Origins, landscape history, syntaxonomy, conservation. – Phytocoenologia 33: 377–408.

PALPURINA, S., CHYTRÝ, M., TZONEV, R., DANIHELKA, J., AXMANOVÁ, I., MERUNKOVÁ, K., DUCHOŇ, M. & KARAKIEV, T. (2015): Patterns of fine-scale plant species richness in dry grasslands across the eastern Balkan Peninsula. – Acta Oecol. 63: 36–46.

PEDASHENKO, H., APOSTOLOVA, I., BOCH, S. et al. (2013): Dry grasslands of NW Bulgarian mountains: first insights into diversity, ecology and syntaxonomy. – Tuexenia 33: 309–346.

PEEV, D., PETROVA, A., ANCHEV, M., TEMNISKOVA, D., DENCHEV, C. M., GANEVA, A., GUSSEV, C. & VLADIMIROV, V. (Eds.) (2015): Red data book of the Republic of Bulgaria. Vol. 1. Plants and fungi. – Bulgarian Academy of Sciences & Ministry of Environment and Water, Sofia: 881 pp.

PETROVA, A. & VLADIMIROV V. (Eds.) (2009): Red List of Bulgarian vascular plants. – Phytol. Balcan. 15: 63–94.

PETROVA, A., VLADIMIROV, V. & GEORGIEV, V. (2012): Razprostranenie na chuzhdi i invazivni vidove rasteniya, saobshteni za Bulgariya prez poslednite 20 godini (1991–2011) (Distribution of alien and invasive plant species, reported for Bulgaria during the past 20 years (1991–2011)) [in Bulgarian]. – In: PETROVA A. (Ed.): Proceedings of the VII. National Conference of Botany, 29-30.09.2011, Sofia: 339–348. Bulgarian Botanical Society, Sofia.

PETROVA, A., VLADIMIROV, V. & GEORGIEV, V. (2013): Invasive alien species in Bulgaria. – Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia: 320 pp.

RAPPORT, D.J., COSTANZA, R. & MCMICHAEL, A.J. (1998): Assessing ecosystem health. – Trends Ecol. Evol. 13: 397–402.

ROLEČEK, J., ČORNEJ, I.I. & TOKARJUK, A.I. (2014): Understanding the extreme species richness of semi-dry grasslands in east-central Europe: A comparative approach. – Preslia 86: 13–34.

SCHRÖTER, M., ALBERT, C., MARQUES, A., TOBON, W., LAVOREL, S., MAES, J., BROWN, C., KLOTZ, S. & BONN, A. (2016): National ecosystem assessments in Europe: A review. – BioScience 66: 813–828.

SOPOTLIEVA, D. & APOSTOLOVA, I. (2014): Dry grassland vegetation in the transition zone between two biogeographic regions. – Hacquetia 13: 79–120.

TEEB (The Economics of Ecosystems and Biodiversity) (2010): Mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB. – Progress Press, Malta: 36 pp.

TURTUREANU, P.D., PALPURINA, S., BECKER, T., DOLNIK, C., RUPRECHT, E., SUTCLIFFE, L.M., SZABÓ, A. & DENGLER, J. (2014): Scale-and taxon-dependent biodiversity patterns of dry grassland vegetation in Transylvania. – Agr. Ecosyst. Environ. 182: 15–24.

TZONEV, R., LYSENKO, T., GUSSEV, C. & ZHELEV, P. (2008): The halophytic vegetation in south-east Bulgaria and along the Black Sea coast. – Hacquetia 7: 95–121.

UK NATIONAL ECOSYSTEM ASSESSMENT (2011): The UK National Ecosystem Assessment: Synthesis of the Key Findings. – UNEP-WCMC, Cambridge: 86 pp.

VAN DER SLUIS, T., FOPPEN, R., GILLINGS, S. et al. (2016): How much Biodiversity is in Natura 2000? The “Umbrella Effect” of the European Natura 2000 protected area network. – Alterra Wageningen UR (University & Research centre), Wageningen: 147 pp.

VANACKER, V., BELLIN, N., MOLINA, A. & KUBIK, P.W. (2014): Erosion regulation as a function of human disturbances to vegetation cover: a conceptual model. – Landsc. Ecol. 29: 293–309.

VASSILEV, K., STEVANOVIĆ DAJIĆ, Z., CUŠTERESVSKA, R., BERGMEIER, E. & APOSTOLOVA, I. (2012): Balkan Dry Grasslands Database. – Biodiv. Ecol. 4: 330.

VASSILEV, K., PEDASHENKO, H., ALEXANDROVA, A. et al. (2016): Balkan Vegetation Database: historical background, current status and future perspectives. – Phytocoenologia 46: 89–95.

VELCHEV, V. (2002a): Izpolzvane, sastoyanie i problemi na stopanisvane i opazvane na rastitelnostta (Utilization and qualitative characteristics of vegetation and problems of its management and protection). – In: KOPRALEV, I. (Ed.): Geografiya na Bulgariya. Fizicheska i socialno-ikonomicheska geografia (Geography of Bulgaria. Physical and Socio-Economic geography) [in Bulgarian]: 352–355. Publ. House ForCom, Sofia.

VELCHEV, V. (2002b): Osnovni cherti i zakonomernosti na razprostranenieto na savremennata rastitelnost (Characteristic features and regularities on the distribution of the present-day vegetation). – In: KOPRALEV, I. (Ed.): Geografiya na Bulgariya. Fizicheska i socialno-ikonomicheska geografia (Geography of Bulgaria. Physical and Socio-Economic geography) [in Bulgarian]: 321–324. Publ. House ForCom, Sofia.

VELEV, S. (2002): Klimatichno rayonirane (Climatic zoning). – In: KOPRALEV, I. (Ed.): Geografiya na Bulgariya. Fizicheska i socialno-ikonomicheska geografia (Geography of Bulgaria. Physical and Socio-Economic geography) [in Bulgarian]: 155–156. Publ. House ForCom, Sofia.

VELEV, N. & VASSILEV, K. (2014): Management regimes within syntaxa of semi-natural grasslands in West Bulgaria. – Hacquetia 13: 191–204.

VELEV, N., APOSTOLOVA, I., ROZBROJOVÁ, Z. & HÁJKOVÁ, P. (2010): The alliances *Arrhenatherion*, *Cynosurion* and *Trifolion medii* in western Bulgaria – environmental gradients and ecological limitations. – Hacquetia 9: 207–220.

Sopotlieva et al.: Ecosystem condition assessment of semi-natural grasslands outside the Natura 2000 network in Bulgaria, using vegetation data

Supplement E1. Red list plants of Bulgaria with a preference for grassland habitats (selected from PETROVA & VLADIMIROV [2009]). The list is divided by grassland subtype. Nomenclature follows PETROVA & VLADIMIROV (2009) and PEEV et al. (2015).

Anhang E1. Rote Liste Arten in Bulgarien, die eine Präferenz für Grasland-Habitate aufweisen (ausgewählt aus PETROVA & VLADIMIROV [2009]). Die Liste ist gegliedert nach Grassland-Subtypen. Die Nomenklatur folgt PETROVA & VLADIMIROV (2009) und PEEV et al. (2015).

Dry grasslands: *Achillea thracica*; *Adonis volgensis*; *Aegilops comosa*; *Aegilops dichasians*; *Aegilops speltoides*; *Alkanna jordanovii*; *Alkanna stojanovii*; *Alkanna tinctoria*; *Allium cupani*; *Anacamptis pyramidalis*; *Anchusa macedonica*; *Anchusa stylosa*; *Anthemis virescens*; *Anthyllis aurea*; *Aristolochia rotunda*; *Artemisia chamaemelifolia*; *Asterolinon linum-stellatum*; *Astragalus dasyanthus*; *Astragalus exscapus*; *Astragalus glaucus*; *Astragalus physocalyx*; *Astragalus ponticus*; *Astragalus sesameus*; *Astragalus wilmottianus*; *Bellevalia ciliata*; *Bromus lanceolatus*; *Buglossoides glandulosa*; *Buglossoides sibthorpiana*; *Bunium ferulaceum*; *Capsella thracica*; *Carduus adpressus*; *Carduus thracicus*; *Centaurea arenaria*; *Centaurea bovina*; *Centaurea gracilenta*; *Centaurea inermis*; *Centaurea rumelica*; *Cirsium alatum*; *Cirsium bulgaricum*; *Cirsium stojanovii*; *Cleistogenes bulgarica*; *Colchicum bivonae*; *Colchicum davidovii*; *Colchicum doerfleri*; *Corynephorus divaricatus*; *Crassula tillaea*; *Crucianella latifolia*; *Delphinium balcanicum*; *Delphinium peregrinum*; *Delphinium albiflorum*; *Dianthus pallidiflorus*; *Dianthus stribrnyi*; *Dracunculus vulgaris*; *Echinophora sibthorpiana*; *Edraianthus serbicus*; *Erysimum bulgaricum*; *Erysimum cheiranthoides*; *Erysimum comatum*; *Erysimum quandrangulum*; *Festuca xanthina*; *Gaudinia fragilis*; *Geranium macrostylum*; *Geranium tuberosum*; *Glycyrrhiza glabra*; *Goniolimon besseranum*; *Goniolimon collinum*; *Goniolimon dalmaticum*; *Goniolimon tataricum*; *Gypsophila tekirae*; *Haplophyllum balcanicum*; *Haplophyllum thesioides*; *Hedysarum grandiflorum*; *Hedysarum tauricum*; *Hieracium virosum*; *Himantoglossum caprinum*; *Hippocrepis unisiliquosa*; *Huetia cynapioides*; *Hymenocarpus circinatus*; *Hypericum thasium*; *Jurinea ledebourii*; *Jurinea tzar-ferdinandii*; *Knautia byzantine*; *Knautia degenii*; *Lathyrus saxatilis*; *Legousia pentagonia*; *Lens ervoides*; *Leontodon saxatilis*; *Leontodon tuberosus*; *Lotononis genistoides*; *Marrubium frivaldskyanum*; *Medicago bondevii*; *Medicago constricta*; *Medicago coronata*; *Medicago rhodopea*; *Merendera attica*; *Nepeta ucranica*; *Nigella orientalis*; *Nonnea obtusifolia*; *Onosma rhodopea*; *Ophrys apifera*; *Ophrys cornuta*; *Ophrys insectifera*; *Ophrys mammosa*; *Ophrys reinholdii*; *Orchis papilionacea*; *Paeonia tenuifolia*; *Parvotrisetum myrianthum*; *Phalaris aquatic*; *Prangos ferulacea*; *Reichardia picroides*; *Romulea bulbocodium*; *Romulea linaresi*; *Salvia pinnata*; *Salvia scabiosifolia*; *Scabiosa atropurpurea*; *Scorpiurus subvillosus*; *Serapias vomeracea*; *Serratula bulgarica*; *Sideritis lanata*; *Silene cretica*; *Silene graeca*; *Silene lydia*; *Spiranthes spiralis*; *Stachys balcanica*; *Stachys leucoglossa*; *Stachys serbica*; *Stefanoffia daucoides*; *Stipa lessingiana*; *Trifolium globosum*; *Trifolium ligusticum*; *Trifolium physodes*; *Trifolium spumosum*; *Trifolium squamosum*; *Trifolium squarrosum*; *Tulipa aureolina*; *Tulipa thracica*; *Tulipa urumoffii*; *Verbascum adrianopolitanum*; *Verbascum anisophyllum*; *Verbascum bugulifolium*; *Verbascum dieckianum*; *Verbascum nobile*; *Verbascum pseudonobile*; *Verbascum urumoffii*; *Veronica multifida*; *Vicia amphicarpa*; *Vulpia unilateralis*.

Mesic grasslands: *Arctostaphylos uva-ursi*; *Arenaria pirinica*; *Asperula suberosa*; *Aubrieta columnae*; *Aubrieta gracilis*; *Fritillaria meleagroides*; *Gladiolus palustris*; *Ononis repens*; *Orchis ustulata*; *Traunsteinera globosa*; *Viola pumila*.

Wet and seasonally wet grasslands: *Caltha cornuta*; *Caltha polypetala*; *Cardamine penzesii*; *Dactylorhiza incarnata*; *Dactylorhiza kalopissii*; *Epipactis palustris*; *Herminium monorchis*; *Lathyrus palustris*; *Leucojum aestivum*; *Ligularia glauca*; *Ligularia sibirica*; *Oenanthe lachenalii*; *Oenanthe tenuifolia*; *Orchis laxiflora*; *Pedicularis palustris*; *Potentilla palustris*; *Ranunculus fontanus*; *Ranunculus lingua*; *Ranunculus stojanovii*; *Rhynchocorys elephas*; *Tozzia carpathica*.

Alpine and subalpine grasslands: *Achillea chrysocoma*; *Achillea urumoffii*; *Alchemilla achtarowii*; *Alchemilla asteroantha*; *Alchemilla bandericensis*; *Alchemilla bulgarica*; *Alchemilla catachnoa*; *Alchemilla erythropoda*; *Alchemilla fissa*; *Alchemilla heterophylla*; *Alchemilla indivisa*; *Alchemilla jumrukczalica*; *Alchemilla mollis*; *Alchemilla straminea*; *Alchemilla viridiflora*; *Anchusa davidovii*; *Brassica nivalis ssp. jordanoffii*; *Bromus parilicus*; *Campanula transsilvanica*; *Campanula trojanensis*; *Carex riloensis*; *Cerastium moesiacum*; *Chondrilla urumoffii*; *Colchicum borisii*; *Danthoniastrum compactum*; *Festucopsis sancta*; *Galium boreale*; *Gentiana acaulis*; *Gentiana frigida*; *Gentiana lutea*; *Gentiana nivalis*; *Gentiana punctata*; *Gentianella amarella*; *Gentianella crispata*; *Gentianella engadinensis*; *Geranium coeruleatum*; *Hieracium villosum*; *Knautia dinarica*; *Lathyrus alpestris*; *Lathyrus filiformis*; *Lathyrus linifolius*; *Lathyrus pancicii*; *Leontopodium alpinum*; *Leucorchis albida*; *Lilium albanicum*; *Lilium rhodopaeum*; *Nigritella nigra*; *Orchis ustulata*; *Oxytropis urumovii*; *Pedicularis oederi*; *Phyteuma confusum*; *Poa jordanovii*; *Poa pirinica*; *Polygala alpestris*; *Polygala amarella*; *Sedum kostovii*; *Sedum stefco*; *Stachys bulgarica*; *Swertia perennis*; *Thlaspi bellidifolium*; *Thymus perinicus*; *Thymus stojanovii*; *Veronica rhodopaea*; *Viola gracilis*; *Viola orphanidis*; *Viola speciosa*; *Viola stojanowii*.

Inland salt steppes: *Bassia hirsuta*; *Hymenolobus procumbens*; *Limonium asterotrichum*; *Limonium bulgaricum*; *Limonium gmelinii*; *Limonium latifolium*; *Limonium meyeri*; *Limonium vulgare*; *Plantago cornuti*; *Plantago tenuiflora*; *Polycnemum heuffelii*; *Scorzonera parviflora*; *Suaeda heterophylla*; *Taraxacum bessarabicum*; *Triglochin maritima*.

Sopotlieva et al.: Ecosystem condition assessment of semi-natural grasslands outside the Natura 2000 network in Bulgaria, using vegetation data

Supplement E2. Invasive alien plant species in Bulgaria with a preference for grassland habitats (selected from PETROVA et al. [2013]). Nomenclature follows Petrova et al. 2013. Abbreviations: dry – Dry grasslands, mesic – Mesic grasslands, wet – Wet and seasonally wet grasslands, saline – Inland salt steppes.

Anhang E2. Invasive gebietsfremde Arten in Bulgarien, die eine Präferenz für Grasland-Habitate aufweisen (ausgewählt aus PETROVA et al. [2013]). Die Nomeklatur folgt PETROVA et al. (2013). Abkürzungen: dry – Trockenrasen, mesic – mesophiles Grünland, wet – Nasswiesen und saisonale Nasswiesen, saline – Binnensalzsteppe.

Ailanthus altissima (dry); *Ambrosia artemisiifolia* (dry-only pastures near settlements); *Amorpha fruticosa* (mesic-rarely, wet-rarely); *Asclepias syriaca* (dry-rarely, mesic-rarely); *Bidens frondosus* (wet-rarely); *Cuscuta campestris* (dry-rarely); *Datura stramonium* (dry- rarely in intensively used pastures near settlements); *Elaeagnus angustifolia* (dry); *Erigeron annuus* (dry, mesic, saline-rarely); *Erigeron bonariensis* (dry-rarely); *Erigeron canadensis* (dry-rarely, saline-rarely); *Erigeron sumatrensis* (dry-rarely); *Euphorbia maculata* (dry- pastures near settlements, roads); *Fallopia ×bohemica* (mesic-rarely); *Gleditsia triacanthos* (dry-rarely, mesic-rarely); *Helianthus tuberosus* (mesic-rarely, only if by arable land; by road margins, by rivers); *Impatiens glandulifera* (mesic-rarely, wet-rarely); *Juncus tenuis* (mesic-rarely); *Koelreuteria paniculata* (dry-rarely); *Lycium barbarum* (dry-rarely); *Oenothera biennis* (mesic-rarely); *Opuntia humifusa* (dry); *Robinia pseudoacacia* (dry); *Senecio inaequidens* (dry-rarely); *Solidago gigantea* (mesic-rarely); *Symphyotrichum novi-belgii* agg. (mesic-rarely); *Xanthium spinosum* (dry).