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EDITORIAL | CLASSIFICATION OF OPEN HABITATS IN THE PALAEARCTIC

Classification of grasslands and other open vegetation types in the Palaearctic – Introduction to the Special Collection

Arkadiusz Nowak[1,2], Idoia Biurrun[3], Monika Janišová[4], Jürgen Dengler[5,6]

1 *Institute of Biology, University of Opole, Opole, Poland*
2 *Polish Academy of Sciences Botanical Garden – Center for Biological Diversity Conservation in Powsin, Warsaw, Poland*
3 *Plant Biology and Ecology, Faculty of Science and Technology, University of the Basque Country UPV/EHU, Bilbao, Spain*
4 *Plant Science and Biodiversity Centre, Institute of Botany, Slovak Academy of Sciences, Banská Bystrica, Slovakia*
5 *Vegetation Ecology Research Group, Institute of Natural Resource Sciences (IUNR), Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland*
6 *Plant Ecology, Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Bayreuth, Germany*

Corresponding author: Jürgen Dengler (dr.juergen.dengler@gmail.com)

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Abstract

With this editorial, we introduce the Special Collection "Classification of grasslands and other open vegetation types in the Palaearctic". In searching the Web of Science for classification papers on Palaearctic grasslands, we found 207 studies from 1972–2021, including 106 typical classification works. These studies originated mainly from Europe, with only few from Asia and only one from Northern Africa. While Europe in the 20th century already had a strong tradition in regional classification studies, the launch of a common plot database (European Vegetation Archive, EVA) and a continental syntaxonomic reference list (EuroVegChecklist) have spurred the developments there in recent years. We then introduce the seven articles of the Special Collection. Four of them present regional studies of certain vegetation types, namely spring vegetation (*Montio-Cardaminetea*) in Grisons, Switzerland, dry grasslands (*Festuco-Brometea*) of the inneralpine valleys of Austria, montane to subalpine tall-herb vegetation (*Mulgedio-Aconitetea*) in the Sudetes Mts., Poland, and steppe depressions (*Festuco-Brometea* and *Molinio-Arrhentatheretea*) in Southern Ukraine. A new synthesis of the grassland vegetation of Navarre in Spain (all classes, focus on *Festuco-Brometea*), started with an unsupervised classification and translated it into a hierarchical expert system, while another study provided the first synthesis of the tall-herb vegetation (mainly *Ulopteretea prangae*) of Tajikistan. Finally, a study based on the GrassPlot database compared fine-grain beta-diversities across open vegetation types of the Palaearctic.

Abbreviations: EDGG = Eurasian Dry Grassland Group, EVA = European Vegetation Archive, IAVS = International Association for Vegetation Science, WoS = Web of Science.

Keywords

Africa, Asia, beta diversity, grassland, open vegetation, Palaearctic, phytosociology, spring vegetation, syntaxonomy, tall-herb vegetation, vegetation classification, vegetation-plot database

Introduction

The Palaearctic biogeographic realm extends over vast areas of Europe, northern Africa and Asia north of the Himalaya (Olson et al. 2001). Within this realm, the steppe biome covers ca. 10.5 million km² and is one of the largest continuous ecosystems on earth (Wesche et al. 2016). Grasslands of the Palaearctic can be divided into

four major categories (Dengler et al. 2014, 2020a; Wesche et al. 2016): (i) zonal steppes, (ii) arctic-alpine grasslands, (iii) azonal and extrazonal grasslands, and (iv) secondary grasslands. Some related vegetation types also have a considerable share of graminoids, such as tall-forb communities, halophytic vegetation, semi-deserts, mires and springs, reed beds and forest-steppes.

To better understand the extraordinary diversity of Palaearctic grasslands and related habitats, we need to improve the survey techniques and broaden the scope of sampling to accomplish a consistent system of vegetation classification. This will strengthen communication among vegetation scientists from different regions and provide the scientific foundation for international nature conservation initiatives and formulation of the best management practices. However, a comprehensive and consistent classification system is still far from being fully realised, particularly in the Asian and African parts of the Palaearctic.

With this editorial, we introduce and summarize a Special Collection on "Classification of grasslands and other open vegetation types in the Palaearctic" in "Vegetation Classification and Survey", aimed at filling some of the knowledge gaps. It was initiated by the IAVS Working Group EDGG (Eurasian Dry Grassland Group; https://edgg.org/; see Dengler et al. 2021), as a follow-up to two previous such initiatives in "Applied Vegetation Science" (Dengler et al. 2013) and "Phytocoenologia" (Janišová et al. 2016). We begin with a bibliographic analysis of publication activities on the topic, followed by an outline of the state of knowledge and current advancements in the three continents that are part of the Palaearctic. We subsequently summarize the articles in the Special Collection before we conclude with an outlook.

Status of classification studies on grasslands and other open habitats in the Palaearctic

Bibliometric analysis of grassland classification studies

In order to assess the progress of research on grassland classification in recent decades, we conducted a search in the Web of Science Core Collection database (WoS) on 22 December 2021 (i.e. five years after Janišová et al. 2016), using the search terms "classification" and "grassland", and additionally "classification" and "steppe" (Figure 1). We excluded studies from outside the Palaearctic. We found a total of 207 studies from the time span of 1972–2021. Most of these studies could be classified into three approaches. The first approach was plot-based classification, appearing in 106 studies. These studies primarily concerned Europe or European regions (98 works). Only seven studies took place in the Asian part of Russia, and even fewer in Middle Asia (4), Iran (3) and northern Africa (1). These classification studies, mostly following the phytosociological method, were mainly published in a handful of journals, such as "Phytocoenologia" (22), "Tuexenia" (19), "Applied

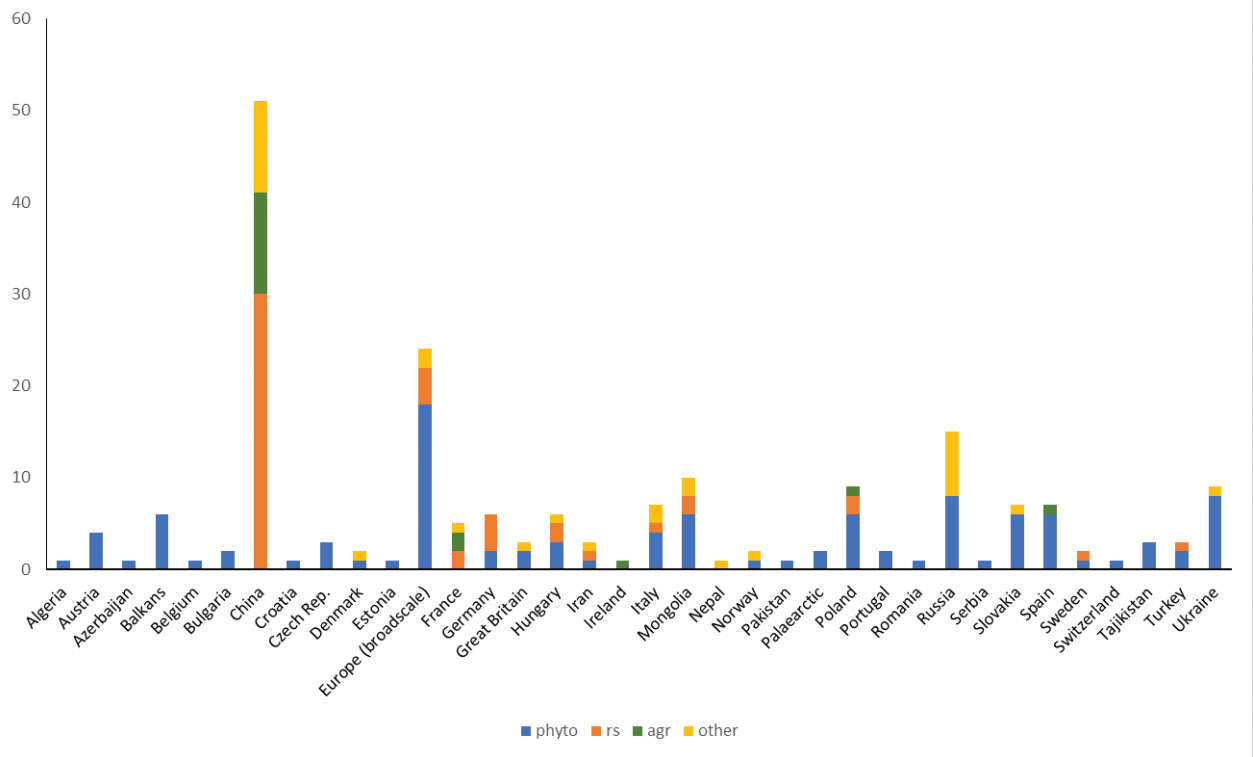

Figure 1. Geographical coverage and types of contributions among classification studies of Palaearctic grasslands published in Web of Science journals 1972–2021. phyto: typical phytosociological, rs: remote sensing, agr: agricultural and other: other approaches for classification.

Vegetation Science" (15), "Preslia" (7), "Plant Biosystems" (6), "Annali di Botanica" (4), "Journal of Vegetation Science" (4) and "Acta Societatis Botanicorum Poloniae" (4). A second approach for classification was based on remote sensing and was well represented in the literature search (50 papers). Although classifications using this method are not based on high-quality phytodiversity data sampled in plots, they can serve as a valuable tool in higher-level classification of extended areas of Asia or Africa and help to identify gaps for further detailed field surveys. Such remote sensing studies mainly originated from China. The third approach is a practical, agricultural approach to classify grasslands based on their value as pasture for livestock (17 studies). Finally, 32 classification studies could not be assigned to one of the previous three approaches.

The number of publications focused on grasslands and related habitats in recent years was stable to slightly increasing. There was a downward trend in the number of typical phytosociological studies, which may be related to the completion of many projects in already well-researched areas and may also be due to the publication of studies outside of journals covered by the WoS. Studies on classification by remote sensing have increased in numbers in the last decade and recently stabilized (Figure 2). These observed trends may offer only a limited picture of developments in vegetation classification science, given that only a small number of relevant journals are included in the WoS. For example, the journals "Hacquetia", "Plant Sociology", "Vegetation of Russia", "Annali di Botanica", "Acta Musei Silesiae - Scientiae Naturales", "Thaiszia", "Braun-Blanquetia", "Collectanea Botanica", "Acta Botanica Malacitana"," Silva Lusitana"," Documents Phytosociologiques"," Acta Botanica Gallica" and "Vegetation Classification and Survey" are not yet included in the WoS statistics. Moreover, monographs devoted to vegetation classification are also not included in the WoS Core Collection.

Situation in the European part of the Palaearctic

In Europe, there is a long tradition of vegetation classification save for some regions in the East and in the North. However, even in countries without a phytosociological tradition, such as Bulgaria, Ukraine and European Russia, there have been intensive attempts to inventarise the vegetation types phytosociologically during the last 30 years. In consequence, there are thousands of local and regional classification studies of grasslands and other open habitats in Europe, and new papers are still being published.

Subsequently, comprehensive overviews of the vegetation types in whole countries or other larger regions were published. Traditionally, these were based solely on literature reviews (e.g. Austria: Mucina et al. 1993; Iberia: Loidi 2017) or on literature reviews supplemented by presentation of synoptic tables (e.g. Southern Germany: Oberdorfer 1992 et seq.; Northern Europe: Dierßen and Dierßen 1996). With the advent of national vegetation-plot databases (see Schaminée et al. 2009), more and more national and regional treatises of vegetation types have been based on the statistical analysis of tens of thousands of relevés computerized in a single database, resulting in vegetation typologies that are much more reproducible than in the past (UK: Rodwell 1992; Netherlands: Schaminée et al. 1996; Mecklenburg-Vorpommern, NE Germany: Berg et al. 2004; Czech Republic: Chytrý 2007; Slovakia: Janišová 2007). While the wealth of local, regional and national studies yielded a detailed knowledge of vegetation of the continent, these independent and uncoordinated efforts also led to inconsistent typologies, from which it is hard to extract a general.

Here, the EuroVegChecklist (Mucina et al. 2016), a multi-author enterprise evolving over approximately one decade, offered a new solution to harmonize vegetation classification efforts across Europe. While the

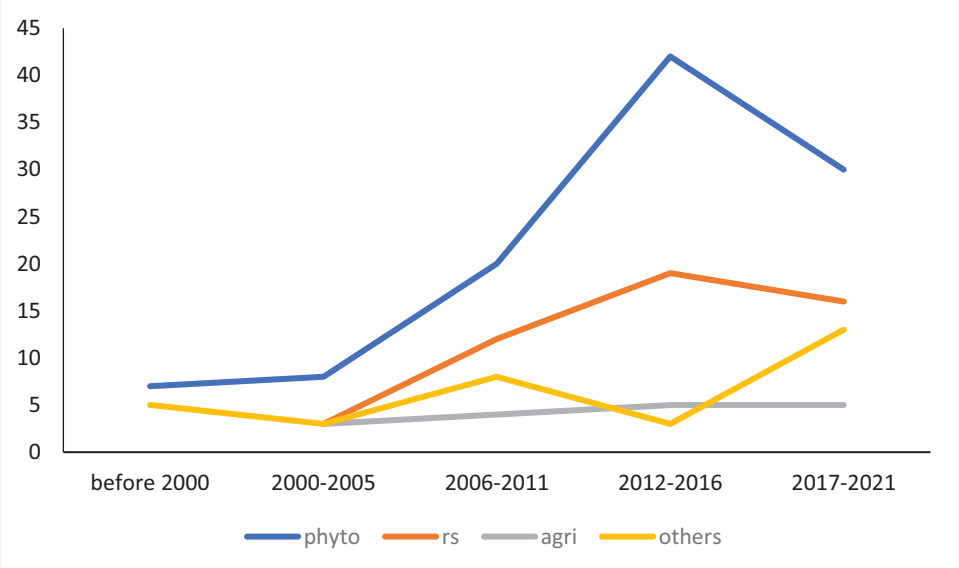

Figure 2. Number of classification studies on Palaearctic grasslands published in Web of Science journals 1972–2021. phyto: typical phytosociological, rs: remote sensing, agr: agricultural and others: other approaches for classification.

EuroVegChecklist is exclusively based on literature reviews and not on the actual analysis of plot data, it is the first consistent and comprehensive overview of all higher-level syntaxa (alliances, orders and classes) in Europe. In parallel, the consortium of the European Vegetation Archive (EVA; Chytrý et al. 2016) started to compile a comprehensive vegetation-plot database of the continent and some adjacent regions, such as Turkey, Cyprus and the Caucasus countries, with meanwhile more than 1.9 million vegetation plots (see http://euroveg.org/eva-database-eva-reports). Before the release of EVA, there have been only very few attempts to classify certain vegetation types at a subcontinental or continental scale, using a common dataset of relevés; one notable exception being the spring vegetation of the class *Montio-Cardaminetea* (Zechmeister and Mucina 1994). Following this development, one could witness an increasing number of such studies of grasslands and other open habitats using the wealth of EVA data and modern statistical methods The following open habitat types were thus classified at a subcontinental scale: the saline communities of Southeast Europe (Eliáš et al. 2013), the wet tall-herb grasslands (García-Madrid et al. 2016) and the acidophilous alpine grasslands (Gavilán et al. 2017) of the Iberian Peninsula, the mesic grasslands in Western and Central Europe (Rodríguez-Rojo et al. 2017), the *Festuco-Brometea* in Central and Eastern Europe (Willner et al. 2017), the central Mediterranean xerothermic cliff vegetation (Terzi et al. 2018) and the *Lygeum spartum* grasslands in the Mediterranean Basin (Marcenò et al. 2019). More recently, the first pan-European EVA-based syntaxonomic studies have been published, mostly focussing on highly specialised and/or relatively rare types of open vegetation, such as *Scheuchzerio-Caricetea* (Peterka et al. 2017), coastal dunes (Del Vecchio et al. 2018; Marcenò et al. 2018), *Phragmito-Magnocaricetea* (Landucci et al. 2020), mountain gravel bars (Kalníková et al. 2021) and *Oxycocco-Sphagnetea* (Jiroušek et al. 2022). By contrast, continental syntheses of the large and diverse grassland classes, such as *Molinio-Arrhenatheretea*, *Festuco-Brometea*, *Koelerio-Corynephoretea* or *Elyno-Seslerietea* are still missing, probably due to the huge effort required for preparing the datasets with tens of thousands of plots and thousands of species and analysing them in all their heterogeneity. While bottom-up, unsupervised classifications are still to be done for larger parts of the European open vegetation, of late there is a top-down, supervised classification available for all vegetation types, including those of open habitats, which can be seen as a good first approximation (Chytrý et al. 2020), a preliminary version of which was used for the European Red List of habitats (Janssen et al. 2016).

Situation in the Asian part of the Palaearctic

In the Palaearctic parts of Asia, due to the vast area and different methodological approaches and traditions of vegetation classification, the situation is quite different to that of Europe. Most striking is the lack of consistent continental syntheses dedicated to a particular type of vegetation.

However, it should be noticed that the vegetation survey in the Asian part of Russia has accelerated in recent years. During the period of 2001–2010, in "Vegetation of Russia" alone 13 classification papers have been published on *Molinio-Arrhenatheretea*, 10 on *Festuco-Brometea*, five on *Festuco-Puccinellietea*, two on *Carici rupestris-Kobresietea bellardii*, two on *Juncetea trifidi*, one on *Cleistogenetea squarrosae*, one on *Calamagrostietea langsdorffii*, one on *Scorzonero-Juncetea gerardii*, one on *Arundinello anomalae-Agrostietea trinii*, one on *Koelerio-Corynephoretea*, one on *Artemisietea lerchianae*, one on *Agropyretea repentis* and one on *Mulgedio-Aconitetea* (Mirkin and Naumova 2011). The vegetation classification program of the Russian part of Asia is still in progress, with the main goal of publishing a multi-volume work summarizing the vegetation diversity of the country in 2027 (Plugatar et al. 2020). The Presidium of the Russian Academy of Sciences in 2019 approved a resolution on the need of a modern vegetation classification. The program is set to accomplish the survey of tundra deserts and alpine vegetation by 2025, steppe and meadow vegetation by 2026 and halophytic vegetation by 2027. Promising and important publications have appeared from the program in recent years, including phytosociological research on steppes in the Rostov region (Demina et al. 2016), western Chukotka (Dokuchayeva and Sinelnikova 2015), Orenburg region (Dulepova et al. 2018), West Siberian Plane (Korolyuk 2014), Buryatia (Korolyuk 2017b), Eastern Transbaikalia (Korolyuk 2019), Middle (Teptina et al. 2018) and South Ural (Yamalov et al. 2011), steppe meadows of the eastern Altai-Sayan (Makunina and Parshutina 2017), forest-steppes of Central Altai (Makunina 2013), coastal grasslands of the Russian Pacific (Dudov 2018), psammophytic vegetation of Buryatia (Dulepova and Korolyuk 2021), meadows of the Russian Far East (Ermakov and Krestov 2009), northern Altai (Makunina and Maltseva 2012), the Tobol and Irtysh watersheds (Tishchenko et al. 2015), the Kulunda and Kasmala region (Tishchenko and Korolyuk 2018) and South Ural (Yamalov et al. 2013), alpine meadows of Western Altai (Zibzeev and Nedovesova 2015) and arctic tundra (Sumina 2020). However, vast areas of arctic tundra in Yakutia, Chukotka, Taymyria, Kolyma and Yamal, alpine grasslands in Stanovoy Mts., Chersky Mts. and Verkhoyansk Mts., and meadows and tall forb communities in the Khabarovsk and Amur region (Primore) and the Central Siberian Plateau have not yet been classified.

Following the seminal work of Zohary (1973) on the vegetation of the Middle East, several regional phytosociological studies have been published on grasslands and other open vegetation types, mainly of Turkey and Iran (e.g., Quézel 1973; Klein 1982, 1987; Akman et al. 1984, 1996; Kürschner 1986; Kürschner et al. 1998; Parolly 2004; Noroozi et al. 2010, 2014, 2017; Kürschner and Parolly 2012; Al-Aklabi et al. 2016; Ghorbanalizadeh et al. 2020). Recently, Naqinezhad et al. (2021) presented a

plot-based supranational synthesis of the mire vegetation of the Irano-Turanian region. However, while the phytosociological overview in these two countries is still far from complete, many other countries of Southwest Asia (Caucasus countries, Israel, Jordan, Lebanon, Syria, Iraq, and the whole Arab Peninsula) are, to our knowledge, still void of in-depth phytosociological studies with the use of modern approaches.

In Middle Asia, there are recent treatments of the Steppes of central (Rachkovskaya 2016) and northern Kazakhstan (Korolyuk 2017a). Relatively well studied are the various grassland and other open habitat types of Tajikistan and Kyrgyzstan (Cheng et al. 2008; Wagner 2009; Borchardt et al. 2011; Nowak et al. 2016, 2018, 2021; Świerszcz et al. 2020). By contrast, hardly anything is known on the typology of grasslands in Turkmenistan, Uzbekistan and Afghanistan.

In China, there have been few phytosociological classification studies by foreigners, e.g. on the Tibetan Highlands (Miehe et al. 2011). Relatively recently, China has started an attempt to classify the vegetation of the whole country (Guo et al. 2018). However, since the classification is done with an idiosyncratic approach and the results so far are published only in Chinese, the outcomes are hardly usable for a pan-Palaearctic overview. However, very recently, a comprehensive, plot-based classification of all *Stipa*-dominated steppes across China has been published internationally (Liu et al. 2022). Based on more than thousand relevés, the authors developed a classification system on two hierarchical levels and present it with comprehensive synoptic tables, thus allowing comparison with phytosociological studies in neighbouring countries despite following the approach of the "International Vegetation Classification" rather than a phytosociological approach. For the Himalayas and adjacent high-mountain habitats, several classification works have been published from northern Pakistan (Peer 2000; Peer et al. 2007), alpine meadows and steppes of Central Karakorum (Hartmann 1968) and eastern Ladakh (Dvorský et al. 2011) or semi-deserts and alpine swards of Ladakh (Hartmann 1995, 1997).

Finally, in East Asia, Japan has a strong phytosociological tradition, with most of the works dating from the previous century and in Japanese (Miyawaki 1980–1989; Fujiwara 1996), and only few papers in international journals, but also predating modern phytosociological methods (e.g. Itow 1974; Ohba 1974). In the two Koreas, there are only few classification studies on open vegetation (e.g. Blažková 1993; Kolbek and Jarolímek 2013).

Situation in the African part of the Palaearctic

For Northern Africa, up to now there are only relatively few and geographically restricted classification studies, e.g., on deserts and salt marshes in Egypt (Bornkamm and Kehl 1990; Hatim et al. 2021) or mountain vegetation in Algeria (Benhouhou et al. 2003). There are some recent syntheses on Mediterranean grassland types that also included North African data (Galán de Mera et al. 2000; Marcenò et al. 2018, 2019).

Content of the Special Collection

This Special Collection contains seven research articles, involving 46 authors from twenty countries. The studies come from across the Palaearctic. There are four regional studies of a specific vegetation type, two broader-scale syntheses and one study that used existing vegetation typologies as a reference system for analysing biodiversity patterns. We introduce the studies as follows:

Świerkosz and Raczyńska (2021) classified montane to subalpine tall forb vegetation (*Mulgedio-Aconitetea*) in the Sudetes Mts., Poland. Due to a large discrepancy between the Polish national classification and supraregional classifications, the authors analysed the variability of this type of vegetation in the study region, resulting in nine association-level units, belonging to four alliances (*Petasition officinalis*, *Rumicion alpini*, *Calamagrostion villosae* and *Adenostylion alliariae*). Based on this analysis using 399 relevés, there is now a classification system of the class for western Poland that matches the EuroVegChecklist (Mucina et al. 2016).

Nowak et al. (2021) addressed a similar vegetation type and conducted a comprehensive study on tall-forb vegetation of Tajikistan and Kyrgyzstan, Middle Asia. In the close vicinity of steppes and pseudosteppes, in the mountainous landscape of Middle Asia, tall-forb vegetation prevails on slopes and screes. This is the first study of this highly diverse and species rich vegetation type in the region. Based on 244 relevés, the authors distinguished 13 associations and five communities at association level, assigned to the class *Prangetea ulopterae*.

Seiler et al. (2021) analysed small springs, which are often neglected despite their high ecological and conservation value. Following Zechmeister and Mucina (1994), little work had taken place on the syntaxonomy of the class *Montio-Cardaminetea* in Europe. The classification was often considered as challenging due to the paucity of species. Through careful sampling of vascular plants and bryophytes in springs of Park Ela in Grisons, Switzerland, the authors could now show that his habitat is anything but species poor. The unshaded springs were included in broadly defined *Cratoneurion* and springs in forested sites were referred provisionally to *Caricion remotae* and *Lycopodo europaei-Cratoneurion commutati*. This work is an important contribution for the planned revisions of the *Montio-Cardaminetea* in Europe.

García-Mijangos et al. (2021) revised the grasslands classification in northern Spain (Navarre) based on a consistent dataset of 839 relevés. The authors started with an unsupervised TWINSPAN classification, which they slightly modified to maximise separation by diagnostic

species, and then derived an electronic expert system from the classification system. They did this at four hierarchical levels, from class down to association, which will allow the unambiguous classification of future relevés. The authors recognized only five floristically and ecologically clearly separated classes (*Lygeo-Stipetea*, *Festuco-Brometea*, *Molinio-Arrhenatheretea*, *Nardetea strictae* and *Elyno-Seslerietea*), that is, significantly fewer than in previous syntaxonomic overviews. Within the dry grasslands of the *Festuco-Brometea*, the authors continued the classification down to eight associations in four alliances and two orders. While the distinguished associations largely corresponded with previous knowledge, this study suggests significant modifications at higher syntaxonomic levels, which call for verification in larger-scale studies. Moreover, the authors have proven that particularly in Mediterranean grasslands bryophytes and lichens are core elements with high diagnostic value.

Magnes et al. (2021) studied the inneralpine dry grasslands of Austria, following the trails of the seminal work by Braun-Blanquet (1961). After the latter publication, only few and local studies dealt with this enigmatic vegetation type of the Alps, while outside the Alpine arch, the classification systems steadily evolved due to the increasing availability of large multinational datasets. For the *Festuco-Brometea* of eastern Central and Eastern Europe, Willner et al. (2017) could establish the existence of three floristically and ecologically clearly differentiated orders of meso-xeric, xeric and rocky grasslands. This is different from the concept of Braun-Blanquet (1961), which was adopted by many subsequent works, of a western order *Brometalia erecti* and an eastern order *Festucetalia valesiacae*. The study published here shows that also the inneralpine dry grasslands of Austria are better described by the three orders of Willner et al. (2017). Furthermore, the authors identified hotspots of biodiversity in a cultural landscape of the inner-alpine valleys of Austria.

Shapoval and Kuzemko (2021) studied an unusual habitat type within the steppe biome in south-eastern Ukraine. Based on 641 relevés, the authors present nine vegetation types that inhabit a unique habitat in land depressions (so called *pody*). Two of the vegetation types were assigned to the suballiance *Galio ruthenici-Caricenion praecocis* (*Festuco-Brometea*). A further three associations were included in *Molinio-Arrhenatheretea*, two in the alliance *Myosuro-Beckmannion eruciformis* (*Isoeto-Nanojuncetea*). Moreover, one community of *Rumex ucranicus* and *Puccinellia distans* was presented. Thanks to this work, the placement of steppe depression vegetation in the syntaxonomic system of Europe was clarified and eight syntaxa on alliance, suballiance and associations rank were validated. Two associations and two subassociations were described as new to science.

Lastly, Dembicz et al. (2021b) studied the variability in one important aspect of vegetation diversity. Based on the nested-plot data from the GrassPlot database (Dengler et al. 2018; Biurrun et al. 2019), they used the *z*-value of the power-law species-area relationship as a measure of fine-grain (within-plot) beta diversity (see Dengler et al. 2020b; Dembicz et al. 2021a). While the variability of *z*-values was large within phytosociological classes, ecological-physiognomic vegetation types and biomes, the large dataset allowed the detection of significant differences. In particular, Alpine and Mediterranean vegetation types had above-average *z*-values, while managed grasslands with benign soil and climate conditions and saline communities were characterised by particularly low *z*-values.

Conclusions and outlook

The systematic classification and inventory of plant communities provide an important reference system for studying and forecasting the ongoing processes in the biosphere, which are driven, in part, by climate change and land use change. Vegetation classification conducted with modern approaches (Dengler et al. 2008; De Cáceres et al. 2015) leads to classification systems that can serve as a common language, enabling professionals in various fields of science to communicate and interact with each other in the process of studying and formulating practical ecosystem-related management decisions.

As vegetation scientists, we have inherited a deep need for peregrination from Alexander von Humboldt (von Humboldt and Bonpland 1807). We carry out research expeditions, no matter the scale. Faced with this tremendous task of completing the work of classification, mapping, and effective preservation of the diversity of the Palaearctic open vegetation, we hope that the works presented in this Special Collection make an important contribution of bringing us closer to this goal.

Our systematic literature review revealed that the number of publications on the classification of Palaearctic grassland vegetation in international journals was growing in recent years, albeit still on a low level and restricted to very few journals that are willing to accept such topics. Therefore, we hope and assume that with the recent launch of "Vegetation Classification and Survey" as a journal exclusively devoted to vegetation classification (Jansen et al. 2020), the situation will improve in the future.

We also found that the state of knowledge and progress is quite divergent among the three continents contributing to the Palaearctic biogeographic realm. Due to the activities of the European Vegetation Survey (EVS; http://euroveg.org/) and the availability of its comprehensive vegetation-plot database European Vegetation Archive (EVA; http://euroveg.org/eva-database; see Chytrý et al. 2016), Europe is spearheading the attempts for comprehensive and consistent classification systems of grasslands and other open habitat types. With the EuroVegChecklist (Mucina et al. 2016) a continental checklist of the higher syntaxonomic units is available, which is the basis for future improvements by an established committee (http://euroveg.org/evc-committee). A continent-wide supervised classification has recently become available that allows the automatic assignment

of vegetation plots to broad habitat types, mostly corresponding to phytosociological orders (Chytrý et al. 2020). This tool does a reasonably good job, albeit a significant fraction of plots remains unclassified. Moreover, distributions maps of all vegetation alliances present in Europe have been recently published (Preislerová et al. 2022). These ideas, together with continent-wide unsupervised and semi-supervised classification attempts based on EVA data, make it likely that in the future we will have an electronic expert system for automatic assignment of nearly any plot to phytosociological classes, orders and alliances.

For the Asian and African parts of the Palaearctic, the development is much more heterogeneous and lagging. As reviewed above, there are strong ongoing attempts of modern phytosociological classification of open habitats, at regional to country level, in some countries (mainly Russia, Tajikistan and Iran). For other countries, such as Japan and the francophone countries of North Africa, a strong phytosociological tradition is known, but we are not aware of any recent publications on that topic in international journals. China, on the other hand, has started a major effort to classify all vegetation of this vast country, but using different approaches from phytosociology (Guo et al. 2018). Lastly, there are many countries where there are currently no internationally recognized attempts to classify their grassland vegetation. We hope that this editorial can stimulate the development of classification systems that are consistent across broad scales. The recent foundation of African and Asian Regional Sections of IAVS are very promising developments in this respect. Furthermore, the GrassPlot database (Dengler et al. 2018) is collecting high-quality plot data of grasslands and other open habitats throughout the Palaearctic, often from otherwise underrepresented regions, and plans to contribute these data to the European (EVA; Chytrý et al. 2016) and global vegetation-plot database (sPlot; Bruelheide et al. 2019). Recently, the GrassPlot Consortium has started an attempt to compile a comprehensive list of phytosociological classes (and potentially orders) of open habitats throughout the Palaearctic and develop a crosswalk to GrassPlot's ecological-physiognomic habitat typology (Biurrun et al. 2019). Last but not least, while this editorial signifies the completion of this Special Collection, a follow-up Special Collection on the classification of grasslands of Asia is on the way (https://vcs.pensoft.net/collection/317/).

Author contributions

A.K. planned and drafted this editorial with major inputs by J.D., while all authors improved and approved the manuscript.

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E-mail and ORCID

Arkadiusz Nowak (anowak@uni.opole.pl), ORCID: https://orcid.org/0000-0001-8638-0208
Idoia Biurrun (idoia.biurrun@ehu.eus), ORCID: https://orcid.org/0000-0002-1454-0433
Monika Janišová (monika.janisova@gmail.com), ORCID: https://orcid.org/0000-0002-6445-0823
Jürgen Dengler (Corresponding author, dr.juergen.dengler@gmail.com), ORCID: https://orcid.org/0000-0003-3221-660X