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GrassPlot – a database of multi-scale plant diversity in Palaearctic grasslands

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Abstract

GrassPlot is a collaborative vegetation-plot database organised by the Eurasian Dry Grassland Group (EDGG) and listed in the Global Index of Vegetation-Plot Databases (GIVD ID EU-00-003). GrassPlot collects plot records (relevés) from grasslands and other open habitats of the Palaearctic biogeographic realm. It focuses on precisely delimited plots of eight standard grain sizes (0.0001; 0.001; ... 1,000 m²) and on nested-plot series with at least four different grain sizes. The usage of GrassPlot is regulated through Bylaws that intend to balance the interests of data contributors and data users. The current version (v. 1.00) contains data for approximately 170,000 plots of different sizes and 2,800 nested-plot series. The key components are richness data and metadata. However, most included datasets also encompass compositional data. About 14,000 plots have near-complete records of terricolous bryophytes and lichens in addition to vascular plants. At present, GrassPlot contains data from 36 countries throughout the Palaearctic, spread across elevational gradients and major grassland

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types. GrassPlot with its multi-scale and multi-taxon focus complements the larger international vegetation-plot databases, such as the European Vegetation Archive (EVA) and the global database “sPlot”. Its main aim is to facilitate studies on the scale- and taxon-dependency of biodiversity patterns and drivers along macroecological gradients. GrassPlot is a dynamic database and will expand through new data collection coordinated by the elected Governing Board. We invite researchers with suitable data to join GrassPlot. Researchers with project ideas addressable with GrassPlot data are welcome to submit proposals to the Governing Board.

Keywords: biodiversity; European Vegetation Archive (EVA); Eurasian Dry Grassland Group (EDGG); grassland vegetation; GrassPlot; macroecology; multi-taxon; nested plot, scale-dependence; species-area relationship (SAR); sPlot; vegetation-plot database.

Abbreviations: EDGG = Eurasian Dry Grassland Group; EVA = European Vegetation Archive; GrassPlot = Database of Scale-Dependent Phytodiversity Patterns in Palaearctic Grasslands; SAR = species-area relationship.

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Co-ordinating Editor: Florian Jansen

GIVD Fact Sheet

GIVD Database ID: EU-00-003			**Last update:** 2018-03-20
Database of Scale-Dependent Phytodiversity Patterns in Palaearctic Grasslands (GrassPlot)		**Web address:** https://www.bayceer.uni-bayreuth.de/ecoinformatics/en/forschung/gru/html.php?id_obj=139267	
Database manager(s): Jürgen Dengler (juergen.dengler@uni-bayreuth.de); Idoia Biurrun (idoia.biurrun@ehu.es)			
Owner: GrassPlot Consortium			
Scope: The database was formerly named "Database Species-Area Relationships in Palaearctic Grasslands" and started as a repository for the data collected at the EDGG Research Expeditions/Field Workshops and similar multi-scale sampling schemes. In 2017 it was re-launched as a collaborative database associated with the Eurasian Dry Grassland Group (EDGG). GrassPlot collects vegetation-plot data of grasslands in the widest sense (i.e. everything except forests, tall shrublands, aquatic and segetal communities) from the Palaearctic biogeographic realm (i.e. Europe, North Africa, West, Central, North and Northeast Asia). With respect to sampling methodology, GrassPlot is more restrictive than typical vegetation-plot databases. It only includes data of plots with one of our eight standard grain sizes: 0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1,000 m². However, we also allow deviations up to 10% from these grain sizes, e.g. 9 m² instead of 10 m². Nested-plot series with at least four different grain sizes are also included; for the latter, any grain size is allowed. Plots must have been precisely delimited in the field (e.g. with a tape around the perimeter or with frames for smaller sizes) and thoroughly been sampled at least for vascular plants, but preferentially also for terricolous bryophytes and lichens. GrassPlot accepts (i) pure richness data (together with the required metadata) or (ii) complete vegetation plots (compositional data), i.e. species identities with presence-absence, cover, abundance or any other measure of dominance.			
Availability: according to a specific agreement		**Online upload:** no	**Online search:** no
Database format(s): Excel, R long table format		**Export format(s):** Excel, CSV file	
Plot type(s): normal plots, nested plots		**Plot-size range:** 0.0001 to 1024	
Non-overlapping plots: 18702	**Estimate of existing plots:** 50000	**Completeness:** 37%	**Status:** ongoing capture
Total no. of plot observations: 168997	**Number of sources (biblioreferences, data collectors):** 130		**Valid taxa:** NA
Countries (%): ES: 32.31; SE: 15.47; IT: 8.84; AT: 7.75; IR: 7.69; NO: 7.52; DE: 4.33; HU: 2.16; GB: 1.71; PL: 1.64; CH: 1.37; UA: 1.12; IL: 1.06; RU: 1.03; FR: 0.97; EE: 0.93; CZ: 0.66; CN: 0.61; RO: 0.61; BG: 0.34; RS: 0.29; MN: 0.28; JP: 0.25; SK: 0.24; NL: 0.21; LV: 0.15; GR: 0.11; HR: 0.06; DK: 0.05; SI: 0.02; MA: 0.02; TR: 0.02; AM: 0.01; BY: 0.01; FI: 0.01			
Formations: Forest: 0% = Terrestrial: 0% // Non Forest: 100% = Aquatic: 0% (Fresh water: 0%); Semi-aquatic: 20% (Haline water: 17%; Fresh water: 2%); Terrestrial: 80% (Arctic-alpin: 14%; Non arctic-alpin: 66% [Natural: 7%; Semi-natural: 59%; Anthropogenic: 1%])			
Guilds: all vascular plants: 100%; bryophytes (terricolous or aquatic): 8%; lichens (terricolous or aquatic): 8%; algae (terricolous or aquatic): 8%			
Environmental data (%): altitude: 98.2; slope aspect: 52.4; slope inclination: 57.9; microrelief: 1.6; surface cover other than plants (open soil, litter, bare rock etc.): 4.6; other soil attributes: 2.4; soil pH: 1.4; land use categories: 89.1; soil depth: 2.4; other attributes: loss at ignition; C/R ratio; calcium carbonate content; texture class			
Performance measure(s): presence/absence only: 79.9%; cover: 18.5%; number of individuals: 0.5%			
Geographic localisation: GPS coordinates (precision 25 m or less): 23.6%; point coordinates less precise than GPS, up to 1 km: 59.6%; small grid (not coarser than 10 km): 0.6%; political units or only on a coarser scale (above 10 km): 0.1%			
Sampling periods: 1940-1949: 0.04%; 1960-1969: 0.02%; 1980-1989: 2.41%; 1990-1999: 2.41%; 2000-2009: 79.05%; 2010-2019: 15.74%; unknown: 0.64%			
Information as of 2018-03-23 further details and future updates available from http://www.givd.info/ID/EU-00-003			

Introduction

The Palaearctic is the largest biogeographic realm of the world (Olson et al. 2001). It contains large areas of grasslands (9.7 million km² or 22% of the Palaearctic realm), of both natural and secondary origin (Török & Dengler 2018). These grasslands harbour a high diversity of many taxonomic groups and encompass contrasting local diversity. While some grassland types contain the majority of global vascular plant diversity records surveyed at small scales (Wilson et al. 2012), others can be very species poor (Dengler et al. 2016a). The high variation in local diversity and wide environmental gradients occupied (different biomes, elevational zones from the sea level to the alpine, diverse soil types, etc.) make Palaearctic grasslands an ideal study object for understanding patterns and drivers of local plant diversity. Moreover, since many Palaearctic grasslands contain significant numbers of bryophytes and lichens, they allow testing of biodiversity patterns across taxa with contrasting biological traits (e.g. Löbel et al. 2006).

Plant community ecology is aimed at describing and understanding patterns of species composition and diversity recorded in small plots ("relevés" in phytosociology) in order to infer patterns and processes at local or regional scales. Macroecology, by contrast, analyses and explains patterns of diversity and its components across large regions, such as continents or the planet. The latter so far has typically relied on single species distribution data derived from sources such as the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/) and gridded to coarse spatial grains, such as cells of 10,000 km² (Beck et al. 2012). This is far from the grain sizes at which relevant processes as the interaction among species and with their abiotic environment occur (Beck et al. 2012). In Europe, local studies on plant community composition, typically using the phytosociological method (Dengler et al. 2008; Guarino et al. 2018), surged in the last century (Schaminée et al. 2009). However, their grain sizes (e.g. Chytrý & Otýpková 2003) are still significantly larger than those at which some local processes, such as biotic interactions and edaphic filters (Siefert et al. 2012; Turtureanu et al. 2014), might act, which could be distances of centimetres or decimetres. Moreover, local studies have been criticized as being idiosyncratic and failing to derive general trends across regions (Chiarucci 2007; Dengler et al. 2011; Beck et al. 2012). A way to overcome this shortcoming, and to link community ecology to macroecology, is to unite individual vegetation-plot datasets into big databases that cover large geographic areas (Dengler et al. 2011; Wiser 2016).

The European Vegetation Archive (EVA; Chytrý et al. 2016) and the global vegetation-plot database "sPlot" (Dengler & sPlot Core Team 2014), each with more than one million plots, are examples for recently assembled large vegetation-plot databases (Appendix 1). The first pilot biodiversity studies of fine-grain plot data across large biogeographic extents (e.g. Wagner et al. 2017) demonstrated the opportunities of large vegetation-plot databases. However, analyses based on large databases face methodological difficulties. First, plot sizes can vary considerably among different schools, regions, decades and vegetation types (Chytrý & Otýpková 2003). In some phytosociological schools, plots might not even be delimited in the field, have rather vague boundaries or irregular shapes to ensure so-called "floristic homogeneity" (e.g. Géhu 2010). Second, the degree of completeness of the species list recorded within each plot can vary due to sampling effort or taxonomic skills. Moreover, in certain phytosociological traditions, species or even whole life forms that were perceived as not belonging to an "ideal" community were (and sometimes still are) not recorded even when present in the plot (e.g. Géhu 1980).

While it is generally accepted that patterns and drivers of biodiversity are scale-dependent, this idea is based largely on theoretical considerations (Shmida & Wilson 1985) and insights from meta-analyses (Field et al. 2009; Siefert et al. 2012). By contrast, this hypothesis was rarely investigated in the field, using nested multi-scale data from the same location and plant community (e.g. Podani et al. 1993; Reed et al. 1993; Turtureanu et al. 2014). Moreover, notwithstanding that terrestrial vegetation is made up of taxa with contrasting biological traits, including vascular plants, bryophytes and lichens, large vegetation databases to date have been focusing on vascular plants (see Appendix 1).

The outlined aspects inspired us to set up GrassPlot, the "Database of Scale-Dependent Phytodiversity Patterns in Palaearctic Grasslands". The aim was to complement EVA and sPlot with a specialised and selective database of multi-scale (and often multi-taxon) data from Palaearctic grasslands exhaustively sampled on precisely delimited plots. We use this Long Database Report to introduce GrassPlot to the scientific community, summarise its current content and demonstrate arising opportunities in the concert of existing databases.

History and governance of GrassPlot

The interest of some co-authors in small-scale species-area relationships (SARs) (Dengler 2009a; Wilson et al. 2012) motivated several regional studies in various dry grasslands in Europe (Dengler et al. 2004; Dengler & Boch 2008) and led then to the launch of the annual Research Expeditions (now: Field Workshops) of the European Dry Grassland Group (EDGG; now: Eurasian Dry Grassland Group; Vrahnakis et al. 2013; http://www.edgg.org). The first expedition took place in 2009 in Transylvania, Romania. It revealed grasslands that scored several global records of small-scale vascular plant diversity (Wilson et al. 2012). With the aim of facilitating overarching studies of SARs, Dengler et al. (2012) compiled available data in the "Database Species-Area Relationships in Palaearctic Grasslands" with 727 nested-plot series comprising a total of 7,202 individual plot observations. The EDGG Field Workshops continued to record standardised multi-scale vegetation data of grasslands across the Palaearctic, from Spain to Siberia (Vrahnakis et al. 2013). This effort resulted in several regional analyses of biodiversity patterns (e.g. Turtureanu et al. 2014; Polyakova et al. 2016). By 2016, the accumulation of data from the EDGG Field Workshops and from other researchers who had started to adopt the EDGG sampling methodology (Madari & Tănase 2016; Cancellieri et al. 2017) prompted the EDGG to create a comprehensive database. Initial steps included the compilation of an overview of existing datasets (Dengler et al. 2016a) and a description of the sampling approach (Dengler et al. 2016b), based on earlier suggestions by Dengler (2009b).

During an international workshop in Bayreuth in March 2017, the database was formally established with the name "GrassPlot" as a collaborative initiative within the EDGG (see http://bit.ly/2BIHmnq; logo in Fig. 1). The Data Property and Governance Rules (Bylaws) of GrassPlot (Supplement S1) have been set up to balance the interests of data providers and data users in a fair and transparent manner. In particular, data contributors remain owners of their data, are informed about any plans to use their data and can opt-in as active co-authors of papers. Depending on the size and complexity, a dataset in GrassPlot can have one or several owners. The GrassPlot Consortium is made up of these data owners and the 17 participants of the initial GrassPlot workshop. The Consortium elects the Governing Board every two years. The current Governing Board consists of J. Dengler (as Custodian), I. Biurrun (as Deputy Custodian) as well as T. Conradi, I. Dembicz, R. Guarino and A. Naqinezhad (as other members). It is responsible for managing GrassPlot and for handling data requests as well as offering co-authorship under the Bylaws. Paper proposals can be submitted only by members of the GrassPlot Consortium or by author teams at least comprising one Consortium member.

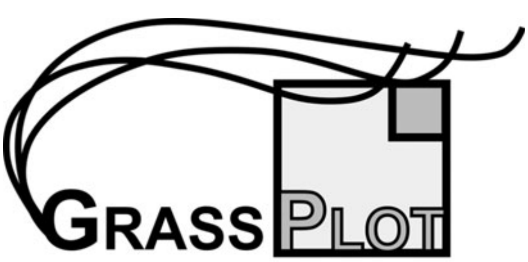

Fig. 1. GrassPlot logo developed by Iwona Dembicz. It links the *Stipa* awns (reminiscent of the EDGG logo) to the multi-scale sampling approach of precisely delimited plots.

GrassPlot is registered in the Global Index of Vegetation-Plot Databases (GIVD; http://www.givd.info/; Dengler et al. 2011) under the ID EU-00-003 and has its own website with regularly updated information on the current content (http://bit.ly/2qKTQt2). Moreover, the Governing Board actively approached researchers worldwide whose publications were based on data that potentially met the GrassPlot criteria. This has maintained a constant inflow of datasets, accompanied by a substantial growth of the Consortium to currently 198 members from 35 countries.

Technical implementation

Since GrassPlot focuses on species richness and species-area relationships, its header data are stored in a single large spread sheet, with every row representing a (sub-) plot and containing information on species richness, the locality, vegetation structure and ecological parameters, plus an indication of nesting within larger plots. We adopted this solution because the nested nature of many plots is something that could not be easily accustomed in the common software for vegetation management (Turboveg 2; Hennekens & Schaminée 2001). Two additional spreadsheets list the metadata for the correspondent datasets and contact information of the Consortium members. As such, GrassPlot is organised differently from EVA and its contributing databases (Chytrý et al. 2016; see Appendix 1).

Compositional data, i.e. species composition and cover values, were not the original focus of GrassPlot and are not required parameters for new data (see Appendix 1). However, since they were widely available for most individual datasets, they were also incorporated. GrassPlot stores these data in long format .txt files. The latter were created semi-automatically based on the original, wide-format tables, provided by the data owners. Species names are taxonomically and nomenclaturally harmonized by a series of documented and repeatable R scripts (R Core Team 2017), similar to those used in sPlot (Purschke 2017). By this circumstance we are not able to resolve identical names that refer to different taxonomic concepts (Jansen & Dengler 2010; see Appendix 1). This way, the data do not lend themselves for syntaxonomic analyses but they are a solid ground to analyse local diversity patterns and assembly rules.

The simple structure of the richness- and metadata in GrassPlot allows updates with little delay when new data are submitted. By contrast, compositional data are usually integrated with a time lag as they can come in many different formats, and the harmonisation of their taxonomies is challenging. GrassPlot data are stored in the .xlsx and .txt formats, which can be directly fed into different analytical software. While GrassPlot is updated continuously, each version is numbered and stored, enabling analyses with older versions.

Content of GrassPlot v. 1.00

GrassPlot collects vegetation-plot data of grasslands in the widest sense (i.e. everything except forests, tall shrublands, aquatic and segetal communities) from the Palaearctic biogeographic realm (i.e. Europe, North Africa, West, Central, North and Northeast Asia). With respect to sampling methodology, GrassPlot is more restrictive than typical vegetation-plot databases. It only includes data of plots with one of our eight standard grain sizes: 0.0001, 0.001, 0.01, 0.1, 1, 10 100, 1,000 m². However, we also allow deviations up to 10% from these grain sizes, e.g. 9 m² instead of 10 m². Nested-plot series with at least four different grain sizes are also included; for the latter, any grain size is allowed. Plots must have been precisely delimited in the field (e.g. with a tape around the perimeter or with frames for smaller sizes) and thoroughly been sampled at least for vascular plants, but preferentially also for terricolous bryophytes and lichens. GrassPlot accepts (i) pure richness data (together with the required metadata) or (ii) complete vegetation plots (compositional data), i.e. species identities with presence-absence, cover, abundance or any other measure of dominance.

The first publicly released GrassPlot version 1.00 of 14 January 2018 contains data from 126 contributing datasets (Supplements S2 and S3). In total, the database comprises 168,997 plots of different grain sizes and 2,797 nested-plot series with at least four grain sizes (often consisting of several subseries). Most contributors have assigned their plots to the "semi-restricted access" regime, few in "restricted access" and currently none in "free access" (Table 1). For the majority of plots (98%), the owners also provided compositional data although these are not fully integrated yet (Table 1).

Geographically, the plots range from Morocco in the west (9.2° W) to Japan in the east (161.6° E) and from Tibet (China) in the south (28.6° N) to Svalbard (Norway) in the north (77.9° N). The highest density of plots was recorded in temperate Europe (Fig. 2). In total, the plots originate from 36 countries, with Spain having the highest number (54,608 plots) and Austria the highest density (15.62 plots per 100 km²) of plots (Table 2). However, GrassPlot also contains relatively high densities of plots in countries that were hitherto only poorly represented in EVA (Chytrý et al. 2016) and sPlot (Dengler & sPlot Core Team 2014), namely Iran, Israel, Norway and Sweden. Plot elevation ranges from sea level (0 m a.s.l.) to 5,197 m a.s.l., with the largest fraction encompassing 2001–3000 m a.s.l. (Table 1). In total, data were sampled during the period of 1948 to 2017, with 79% of all plots surveyed in the decade of 2000–2009 (Table 1). Currently, 74% of all plots are syntaxonomically assigned to a class or a more precise level (Table 3). The temperate dry grasslands of the *Festuco-Brometea* (21%) and the Oromediterranean *Festucetea indigestae* (18%) are the best represented classes.

Table 1. Overview of some key parameters of GrassPlot v. 1.00 in terms of access regime, quality of the data, methodological aspects as well as temporal and elevational distribution. The column "NA" indicates the fraction of plots in GrassPlot for which the respective field is currently not filled.

Parameter	NA	Frequency distribution of parameter values
Availability of data		
– Access regime	–	1 – restricted access (1.7%); 2 – semi-restricted access (98.3%); 3 – free access (0.0%)
– Availability of compositional data	–	Yes (97.7%); to be provided later (0.2%); no (2.1%)
Methodological aspects		
– Recording method	<0.3%	Shoot presence (87%); rooted presence (12.7%)
– Plot shape	–	Squares (75.3%); rectangles 1:2 (22.5%); rectangles 1:1.6 (0.5%); rectangles more elongated than 1:2 (< 0.1%); circles (1.6%)
– Accuracy of coordinates	0.4%	≤ 1 m (3.4%); 1.1–10 m (30.1%); 11–100 m (6.2%); 101–1,000 m (59.1%); > 1,000 m (0.7%)
Distribution of plots		
– Year of recording	–	Before 1980 (< 0.1%); 1980–1989 (2.4%); 1990–1999 (2.7%); 2000–2009 (79.1%); 2010 and later (15.7%)
– Elevation	3.9%	≤ 10 m a.s.l. (8.4%); 11–100 m a.s.l. (17.2%); 101–1,000 m a.s.l. (12.1%); 1,001–2,000 m a.s.l. (12.0%); 2,001–3,000 m a.s.l. (34.2%); 3,001–4,000 m a.s.l. (16.0%); > 4,000 m a.s.l. (< 0.1%)

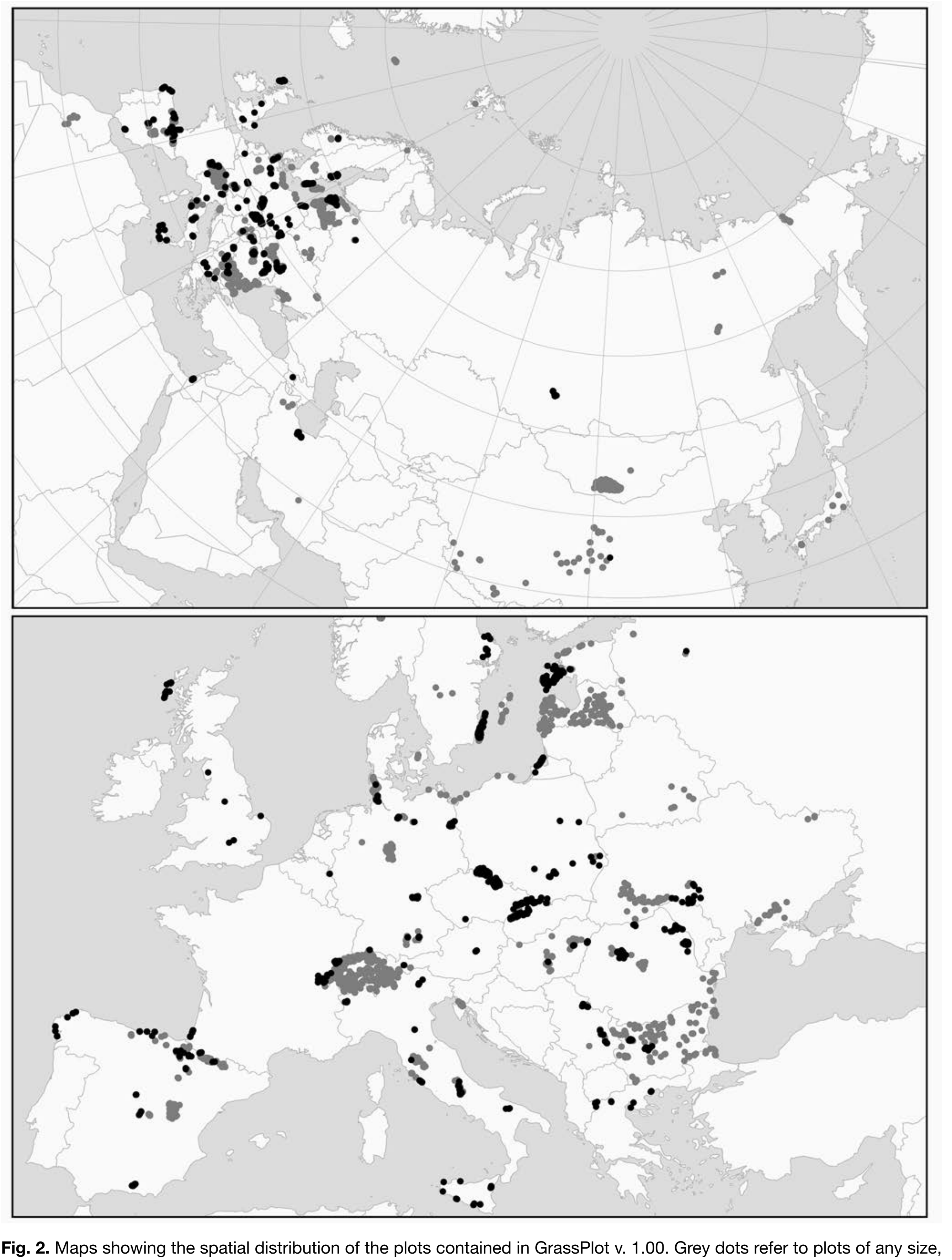

Fig. 2. Maps showing the spatial distribution of the plots contained in GrassPlot v. 1.00. Grey dots refer to plots of any size, while black dots indicate nested-plot series with at least four different grain sizes.

Table 2. Numbers (*N*) and densities of plots per country (or dependent territory), sorted by decreasing density of plots per 100 km². The twenty countries with the highest densities are given in the table. The remaining 16 countries can be found in the GIVD Fact Sheet. Area [km²] refers to the size of the respective territory.

Code	Country	Area [km²]	*N*	*N*/100 km²
AT	Austria	83,855	13,099	15.62
ES	Spain	504,790	54,608	10.82
IL	Israel	20,724	1,795	8.66
SE	Sweden	440,940	26,149	5.93
CH	Switzerland	41,285	2,307	5.59
IT	Italy	301,245	14,943	4.96
NO	Norway	323,758	12,717	3.93
HU	Hungary	93,030	3,648	3.92
EE	Estonia	45,100	1,578	3.50
DE	Germany	356,840	7,311	2.05
CZ	Czech Republic	78,864	1,111	1.41
UK	United Kingdom	244,587	2,886	1.18
PL	Poland	312,685	2,778	0.89
NL	Netherlands	41,160	354	0.86
SK	Slovakia	49,035	405	0.83
IR	Iran	1,648,000	12,992	0.79
RS	Serbia	77,453	493	0.64
BG	Bulgaria	110,910	572	0.52
SJ	Svalbard and Jan Mayen	61,397	280	0.46
RO	Romania	237,500	1,025	0.43

Table 3. The ten most represented phytosociological classes (according to Mucina et al. 2016) in GrassPlot 1.00, based on the numbers (*N*) and percentages of plots (%) in the total dataset.

Class	Group	*N*	%
Festuco-Brometea	Temperate dry grasslands	36,242	21.4%
Festucetea indigestae	Alpine grasslands	31,086	18.4%
Juncetea trifidi	Alpine grasslands	13,947	8.3%
Carici rupestris-Kobresietea bellardii	Alpine grasslands	10,958	6.5%
Stipo-Trachynietea distachyae	Mediterranean grasslands	6,697	4.0%
Molinio-Arrhenatheretea	Temperate mesic and wet grasslands	6,206	3.7%
Koelerio-Corynephoretea canescentis	Temperate dry grasslands	3,874	2.3%
Ammophiletea	Coastal grasslands	3,550	2.1%
Juncetea maritimi	Coastal grasslands	3,347	2.0%
Helichryso-Crucianelletea maritimae	Coastal grasslands	3,259	1.9%
Other classes		7,283	4.3%
Not yet assigned to a class		42,548	25.2%

Table 4. Number of plots (*N*) and the mean (S_{mean}) and maximum (S_{max}) richness in GrassPlot (v. 1.00) across different plot sizes, and for vascular plants and the complete terricolous vegetation (vascular plants, bryophytes and lichens), respectively. Non-standard plot sizes include all other plot sizes (which are collected only in case of nested-plot series). Note that due to different samples, maxima of bigger plot sizes could sometimes be lower than for smaller plot sizes or that maxima for complete terricolous vegetation could sometimes be lower than for vascular plants only. Information on plot size pairs, such as 10 m² and 9 m², is combined in one line because based on species-area relationships with typical *z*-values between 0.15 and 0.30, the relative difference in richness would only be about 1.6–3.2%, i.e. negligible given the overall variability of the data.

	Vascular plants			Complete terricolous vegetation		
Plot size	***N***	S_{mean}	S_{max}	***N***	S_{mean}	S_{max}
0.0001 m²	2,206	1.9	11	1,540	2.0	10
0.001 or 0.0009 m²	3,344	3.3	19	1,481	3.3	19
0.01 m²	66,011	3.8	24	2,524	6.5	29
0.1 or 0.09 m²	3,747	11.7	43	1,496	10.3	46
1 m²	17,216	13.8	79	2,008	18.2	82
10 or 9 m²	5,520	31.0	98	2,016	34.1	101
100 m²	2,565	31.9	127	824	46.8	134
1,000 or 900 or 1,024 m²	181	47.2	134	45	59.1	123
Non-standard plot sizes	68,207			2,490		
Total	168,997			14,424		

The most frequent standard plot sizes are 0.01 m², followed by 1 m² and 9–10 m² (Table 4). Data for the complete terricolous vegetation (vascular plants, terricolous bryophytes and lichens) are available for 14,424 of all plots (8.5%) (Table 4, Fig. 2). Methodologically, the majority of contributors used shoot sampling rather than rooted sampling (Table 1), which can make a big difference for the assessment of vascular plant richness at small spatial grains (Dengler 2008; Güler et al. 2016; Cancellieri et al. 2017). Among plot shapes, squares were most frequently employed (75%), followed by rectangles with 1:2 edge length ratio (23%). Circles are the most compact shape, but difficult to delimit (see Güler et al. 2016), and were used in less than 2% of the records. The geographic coordinates stored in GrassPlot are nearly always more accurate than 1 km and in 3.4% of plots have an accuracy of 1 m or less (Table 1). Many structural (e.g. cover and height of vegetation layers; biomass) and ecological (e.g. topography, soil, land use) parameters are stored by GrassPlot in header data fields with harmonized terminology and units of measurement (see Supplement S4).

GrassPlot in the context of other large vegetation-plot databases

With EVA (Chytrý et al. 2016) and sPlot (Dengler & sPlot Core Team 2014) providing huge amounts of vegetation-plot data of any vegetation type across Europe and the world (see Appendix 1), respectively, the need of an additional supra-national database like GrassPlot could be questioned. Actually, EVA and sPlot are unprecedented in spatial coverage (see Appendix 1). Being set up as all-purpose databases, however, they are not always suited optimally for certain specific questions. For this reason, specialised smaller databases have emerged e.g. with special focus on provision of plots with extensive and standardised soil data measured in the plot (e.g. Wamelink et al. 2012), for comparison of ecological impacts (e.g. PREDICTS, not only vegetation: Hudson et al. 2014) or for time-series in permanent plots (e.g. GLORIA: Pauli et al. 2012; forestREplot: Verheyen et al. 2017).

GrassPlot was set up with the aim to assemble data from Palaearctic grasslands by focusing on a multi-scale and multi-taxon approach. Multi-scale data are either not covered by the other large international vegetation-plot databases such as EVA (Chytrý et al. 2016) and sPlot (Dengler & sPlot Core Team 2014) or, if covered, not clearly labelled as such, reducing accessibility (see Appendix 1). While one might think that alternatively one could just use the huge amount of plots of different sizes found in "normal" vegetation-plot databases, tests have shown that with this approach not even the most simple scaling law in ecology, the species-area relationship (SAR), is realistically depicted (see Chytrý 2001; Dengler et al. 2006). Therefore, GrassPlot complements the existing databases by specifically filling the gap of multi-scale plot data. This enables analyses of scale-dependent patterns and processes across distant regions, which so far have been impossible. By contrast, EVA and sPlot are better suited for any type of analyses that requires high spatial coverage (see Appendix 1). GrassPlot is not suited for purposes of vegetation classification due to the low spatial coverage/high spatial autocorrelation and the fact that plant names are only matched by synonymy but not by concepts (taxonyms) (see Appendix 1). Certain types of analyses could benefit from conducting them parallel in EVA/sPlot and in GrassPlot. For example, patterns of plot-scale species richness in European grasslands could be captured with high spatial resolution through the data contained in EVA, but the results might be considerably biased by regional differences in the sampling methodology (e.g. the completeness of species records). The same study done with GrassPlot would suffer much less from differences in sampling quality, but hardly could produce an alpha-richness map of Europe, simply because the available data are much sparser (see Fig. 2). A combination of both data sources might thus allow taking advantage of both "approaches".

While the majority of plots either are suited for EVA/sPlot or for GrassPlot, a rather small fraction is meeting the requirements of both (see Appendix 1): These are Palaearctic grassland plots on precisely delimited areas of 1, 9, 10 or 100 m² with thoroughly sampled species composition, including "importance values" (i.e. cover, abundance, biomass, ...). It makes sense to include this limited amount of data in both EVA/sPlot and GrassPlot because they are stored in different formats that are readily prepared for different analyses. Good coordination between GrassPlot, EVA and sPlot is ensured because J. Dengler and I. Biurrun from the GrassPlot Governing Board are also involved in the EVA Coordinating Board and J. Dengler additionally in the sPlot Steering Committee. That way, redundant work is reduced and the effective inclusion of data whose qualities meet the criteria of several of these huge supranational databases in all of these is ensured (if data providers agree). Moreover, GrassPlot is also accepting small, local datasets that are in number of plots far below the thresholds of EVA/sPlot. Several such small datasets together could then be provided to EVA or sPlot.

Resumé and outlook

Despite being relatively small for an international vegetation-plot database, we believe that GrassPlot can become a valuable tool in "community macroecology". While the big databases EVA and sPlot are better suited for the majority of purposes, GrassPlot can be advantageous for specific questions that require highly standardised data. Potential users are advised to select the most suitable database for a certain purpose based on the particular characteristics of these three (Appendix 1) and other databases.

Beyond that we hope that GrassPlot with its focus on methodological aspects of sampling and the prevalence for a few "standard" plot sizes, will encourage many vegetation scientists to consider these issues and thus promote the collection of highly comparable data sets. Noteworthy, the same plot sizes (or a subset of these), each separated from the next by one order of magnitude, had previously been proposed in various frameworks (Shmida 1984; Peet et al. 1998; Chiarucci et al. 2001; Dengler 2009b).

GrassPlot is a dynamic database that will continue to integrate suitable datasets in the future. Researchers in possession of data that meet the GrassPlot specification and who wish to join our Consortium are welcome to contact our database manager (I. Biurrun). We particularly seek data from underrepresented regions (most of Asia, North Africa and some parts of Europe; see Fig. 2) and vegetation types (e.g. mesic, wet and Mediterranean grasslands; see Table 3) as well as generally plots with recording of bryophytes and lichens. Readers who wish to address a research idea with GrassPlot data are welcome to submit a project proposal jointly with a Consortium member of their choice to the Governing Board.

Author contributions

J.D. managed the predecessor databases of GrassPlot, while I.B. served as database manager from the start of GrassPlot onwards and V.W. handled the compositional data. J.D. led the writing of this report, with major contributions from V.W. as well as I.B., S.B., A.C., T.C., I.D., G.F., I.G.-M., R.G., M.J., A.N. and M.J.S. The figures were prepared by I.D. and the supplements by J.D., A.N. and I.G.-M. All other authors contributed data to GrassPlot, checked and approved the manuscript.

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Supplement S1: GrassPlot Bylaws.
Supplement S2: Overview of the datasets in GrassPlot 1.00.
Supplement S3: Bibliographic references to the datasets contained in GrassPlot 1.00.
Supplement S4: Overview of the content of the header data fields other than those in Tables 1–4.

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Appendix 1. Comparison of the three large supra-national databases of vegetation-plot data: EVA, sPlot and GrassPlot, indicating their similarities and differences (information as of 14 January 2018).

Aspect	EVA	sPlot	GrassPlot
Scope			
Geographic scope	Europe (+ Canary Islands, Turkey, Caucasus countries)	World	Palaearctic biogeographic realm
Vegetation types included	All	All	Grasslands and other open habitats
Plot sizes	Any in the range 1–1,000 m² and also plots without reported size	Any in the range 1–10,000 m²	Eight standard grain sizes from 0.0001 to 1,000 m² (other sizes only if part of nested plot series)
Nested plots	Not supported	Not supported	Specialised in nested plots; information on hierarchy of nesting is stored
Delimitation of plots and comprehensiveness of sampling	No requirements	No requirements; even plots are included where only dominant species have been sampled (but this information is available)	Only plots that have been precisely delimited in the field and sampled comprehensively
Data types and formats			
Information contained in the database	Plots with compositional data	Plots with compositional data	Plots with compositional data or just richness data + metadata
Format in which the data are stored and provided	Turboveg 2 databases combined in a Turboveg 3 database	Turboveg 2 databases combined in a Turboveg 3 database; data provision as R Data.table with harmonized information	Spread sheet for richness, methodological and environmental data; long table format in R for compositional data
Matching with plant trait and phylogenetic data available	No (but in the future possible via collaboration with sPlot/TRY)	Yes	No
Available information per plot			
Recording of non-vascular plants	Rare and if available often not comprehensive; plots with comprehensive data cannot be extracted	Rare and if available often not comprehensive; plots with comprehensive data cannot be extracted	Often included and then comprehensive
Importance values of species	Normally required (Br.-Bl., % or similar)	Multitude of quantitative scales, but also presence-absence	Importance values (often %) or just presence-absence
Precision of plot coordinates	High to very low; field often not filled	High to very low	Mostly high
Environmental data measured in the plot	Not standardised	Not standardised	Standardised and thus directly usable
Names of plants provided	Standardised to an internal taxonomic backbone for Europe (SynBioSys Taxon Database), also taking into account different meanings of the same name in different floras	Harmonized with online tools, taking into account synonymy, but not different meanings of the same name in different floras	Harmonized with online tools, taking into account synonymy, but not different meanings of the same name in different floras

Appendix 1. cont.

Aspect	EVA	sPlot	GrassPlot
Current content			
Plot number	1,474,590	1,121,244	168,997
Countries covered	57	160	36
Spatial density of available plots	High	High in Europe, medium in parts of North America and Australia, sparse elsewhere	Relatively sparse
Overlap with the other databases in the table	The majority of EVA plots are also in sPlot	sPlot accepts European plots only via EVA	Overlap with EVA and sPlot is small and documented; it is recommended that plots that are suitable for EVA/sPlot and GrassPlot should be contributed twice
Responsible working groups and their rules			
Affiliated with	European Vegetation Survey (EVS)	German Centre for Integrative Biodiversity Research (iDiv)	Eurasian Dry Grassland Group (EDGG)
Website	http://euroveg.org/eva-database	https://www.idiv.de/splot	http://bit.ly/2qKTQt2
Governed by	7-head Coordinating Board	5-head Steering Committee	7-head Governing Board
Members	72 supranational, national and regional databases	110 supranational, national and regional databases, 2 continental data aggregators	192 owners of 126 regional datasets
Required offers of opt-in authorships for analytical papers	No requirement, usually one co-author for each database that contributed at least (5%) 10% of the final dataset	One opt-in co-author for each database used in the study	One opt-in co-author for each dataset that contributed at least 2% of the final dataset