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Research Paper

Contributions to "E-Taxonomy" – A virtual approach to the flora of Mongolia (FloraGREIF)

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Summary

FloraGreif has been developed to be a fast, searchable information system about the flora of Mongolia, uniting components of an e-Flora and a digital herbarium. It contains basic botanical, ecological and geographic data for the approximately 2800 Mongolian vascular plants. Specimen records are documented by location descriptions and additional image data (scans of herbarium specimens, photos of living plants) which can be used for taxonomic revision and chorological analysis.

Currently, 2871 species of vascular plants are known to occur in Mongolia. For nearly all species, the distribution in Mongolia, habitat requirements, and red-list status are given. More than 800 species have been treated comparatively with a short description. 1151 species are represented by at least one record (location description, herbarium specimen, and/or images of living plants). At the moment (January 2013), 1220 species are represented by at least one scan of a herbarium specimen, 1427 species are represented by records, and 725 species by photos of living plants.

Specific search algorithms and navigation structures allow a targeted search for individual species or the output of species lists for particular regions or habitats. The open-source approach of the web portal makes it possible to transfer the system to other re-

Zusammenfassung

Mit FloraGREIF ist ein schnelles, durchsuchbares Informationssystem zur Flora der Mongolei entstanden, das zwischen einer e-Flora und einem digitalen Herbarium angesiedelt ist. Es enthält botanische, ökologische und geographische Basisdaten für die mehr als 2800 Gefäßpflanzen der mongolischen Flora. Artnachweise werden durch Fundortangaben und zusätzliche Bilddaten (gescannter Herbarbeleg, Lebendaufnahmen) dokumentiert, die für taxonomische Revisionen und chorologische Auswertungen nutzbar sind.

Aktuell sind für die Mongolei 2871 Arten nachgewiesen. Für nahezu alle Arten gibt es Informationen zur Verbreitung in der Mongolei, den Habitatansprüchen und zum Rote-Liste-Status. Mehr als 800 Arten sind vergleichend bearbeitet und mit einer kurzen Beschreibung versehen. 1151 Arten sind mit mindestens einem „record" (Nachweis einer Art an einem Punkt durch Fundortangabe, Herbarbeleg oder Foto) belegt. Derzeit (Feb 2013) sind 975 Arten mit mindestens einem Scan eines Herbarbeleges, 731 Arten mit Lebendaufnahmen (Habitus-, Detail- oder Makroaufnahmen), 509 Arten mit beidem sowie 340 Arten mit Habitataufnahmen repräsentiert.

Spezielle Suchalgorithmen und Navigationsstrukturen erlauben eine gezielte Suche nach einzelnen Arten oder die Ausgabe von Artenlisten für ein-

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gions of the world. The virtual approach to the Flora of Mongolia also provides access to extensive herbarium collections, enabling their use for future research.

zelne Regionen bzw. Habitate. Der virtuelle Zugang zur Flora der Mongolei zeigt den aktuellen floristischen Bestand und erschließt die reichen botanischen Sammlungen aus der Mongolei, so dass sie für zukünftige Forschungen leicht nutzbar sind. Der open-source Ansatz des Webportals ermöglicht es, das System auf andere Regionen zu übertragen.

Introduction

In the extremely continental climate of Mongolia, the north is dominated by circumboreal and Eurasian flora elements, while the south is dominated by desert and semidesert vegetation elements. Vegetation zones from taiga to desert can be found here, with numerous rivers, closed-drainage basins, and rock formations as special environments. The country is little industrialized, and possesses large, non-regulated rivers as well as extensive fresh- and salt-water lakes. It is sparsely settled, with only 2.9 million inhabitants; 30% of the population live as nomads or semi-nomads. Great expanses of the steppe zone suffer from intensive grazing. Furthermore, it is expected that due to global climate change, chiefly the sensitive desert and semi-desert regions will change. The country's flora and fauna are relatively well-researched; numerous publications exist, the older of which are often in Russian (GUBANOV & HILBIG 1993, DOROFEJUK & GUNIN 2000).

In the field of phytosociology, close cooperation in research existed between the German Democratic Republic (GDR; former East Germany) and Mongolia. This resulted in comprehensive collections in Ulaanbataar, Khovd, and Germany (Table 1). In Germany, the collections are chiefly concentrated in the herbaria in Halle (HAL), Gatersleben (GAT), Osnabrück (OSBU), and Greifswald (GFW) (HILBIG 2006). In processing the collected material, many specialists from various countries were involved (HILBIG 1984).

Scientific results were regularly published in the series "Erforschung biologischer Ressourcen der Mongolischen Volksrepublik" [Research on the biological resources of the People's Republic of Mongolia], including the fundamental works by HILBIG (1990, 1995) on the vegetation of Mongolia. NATHO (2005) honored the long-term research work in Mongolia, with special reference to the large proportion of publications on the vegetation of Mongolia in "Feddes Repertorium".

Recently, the first two volumes of the Mongolian Flora Project have been published: the Cyperaceae and Apiaceae (NYAMBAYAR 2009; URGAMAL 2009). In addition, recent bilingual, illustrated floras by HAUCK & SOLONGO (2010) and Jamsran (2012) are available. PYAK et al. (2008) compiled the endemics of the Mongolian Altai, and BEKET (2009) has written a comprehensive flora of the Altai.

The web portal FloraGREIF http://greif.uni-greifswald.de/floragreif can close the gap between "conventionally" published information and the new options offered by IT. It has been accessible on the Internet since March, 2009, and enables students and others interested to quickly become familiar with the flora of Mongolia. In addition, digitized materials from botanical collections provide experts with a database for further study of Mongolian plant life. Written in English for international use, the system is described below. The design as well as technical details of its Internet presentation and how the system functions are given in RILKE & NAJMI (2011).

Materials and methods

With two basic hierarchy levels – data on the species (taxon level) and pecies records (record level) – the system makes it easier to use the extensive botanical collections from Mongolia and employ them as comparative data for research purposes. It links the species-oriented data with the collection data, and is available to users with defined access rights (Fig. 1). Fundamentally, anyone who uses the website is a "passive" user, but with authorization, "active" users can enter data of their own.

Species-oriented data include a short description which is essentially based on differential characters, habitat demands, distribution in Mongolia, and growth form. As further species-oriented information, the red-list status according to SHIIREVDAMBA

Table 1
Collections on the Flora of Mongolia (2012)

	Herbarium	No. Records online	Total Stock	% records of total stock	No. Scans	% scans of total stock
remarkable collections	HAL	921	15000	6.1	302	32.79
	GAT	196	10000	1.9	53	27.04
	GFW	2259	5000	45.1	570	25.23
	JE	39	1500	2.6	6	15.38
	OSBU	668	1710	39.0	–	
	LE	180	?	–	–	
further collections	B	308	?	–	216	
	KAS	4	0	–	–	
	MHA	1			–	
	MO	1			–	
	Müritzeum	45	45		3	6.67
	MW	16			–	
	NS	5			–	
	NY	1			–	
	TK	2			–	
	US	4			1	
private collections	K.F. GÜNTHER	270	?		85	31.48
	M. KRETSCHMER	63			8	12.70
	G. & S. MIEHE	24			–	
	S. RILKE	371	371		159	42.86
	H. v. WEHRDEN	68	in preparation		4	
	K. WESCHE	210	in preparation		8	

et al. (1997) is available on the Internet. Comments by DULAMSUREN et al. (2005) were taken into consideration. The current Red List of Mongolia according to the categories of the IUCN (NYAMBAYAR et al. 2011, see http://iucnredlist.org) above all includes rare species in Mongolia, many of which are outliers from other vegetation zones, for example, *Vaccinum myrtillus;* however, the status of these has yet to be evaluated further.

All collection data are records of a species at a particular location. These can be herbarium sheets, digital photos, literature references which can be viewed online, scanned herbarium specimens, detailed images (close-ups) of the plant or habitat photos.

A record thus at the very least contains information on the occurrence of the species at a particular location; the corresponding habitat data have been compiled in a database and can be downloaded. However, the majority of the species records contain additional information, often a high-resolution scan of the herbarium sheet. The most definitive records are those in which the living plant was photographed before it was collected. Other records consist exclusively of photos of the living plant (often with an overview image and detailed images of a specimen).

For each record, there are mandatory data fields which contain information on the contributor (e.g., collector or photographer) and location with coordinates and habitat. A herbarium sheet additionally includes the date of collection, collection number, name of the person who identified and/or revised the plant specimen, flowering status, remarks on the plant, and name of the herbarium. Plant photos are divided into four groups: scan of herbarium sheet, overview image of living plant, detailed image of living plant, and habitat photo.

Further material and photographic collections are continually entered. In this respect, we are already cooperating with the Osnabrück herbarium (OSBU, B. NEUFFER) and the Wesche private herbarium (Görlitz).

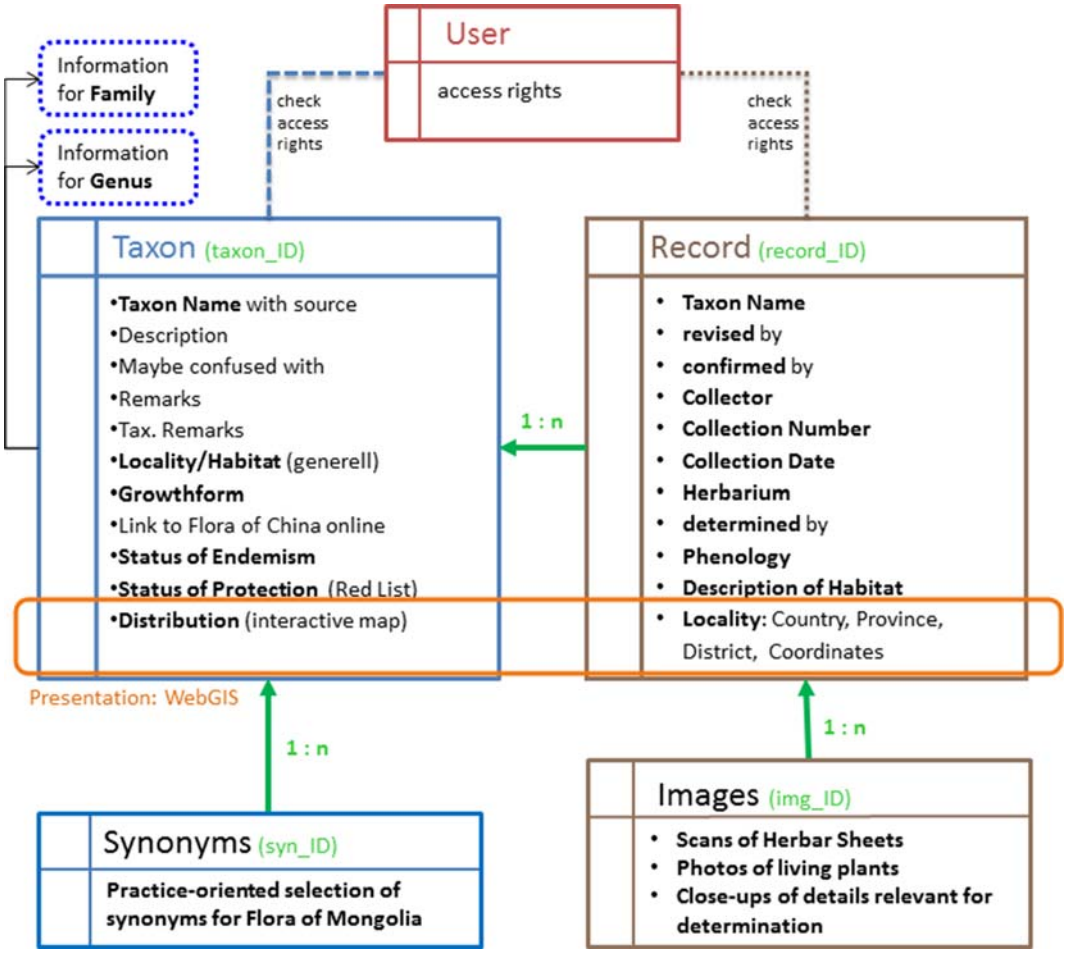

Fig. 1
Overview of the available data on species and records belonging to it (taxon data and record data). Green lines indicate relational links between database entities

Herbarium scans, species photos and macros

Initially, the high-resolution, high-quality herbarium scans (600 dpi, ca. 7200 × 10 400 pixel) were done at the BGBM (Botanic Garden and Botanic Museum) in Berlin. Current digitalization (300 dpi) is being performed at the Botanical Institute of Greifswald University with an A3-HerbScan device (Royal Botanic Gardens Kew) (Fig. 2).

As a supplement to herbarium scans, a modified microscope body and bellows are used to take macrophotographs (close-ups) of individual plant parts in order to show characters relevant for identification (e.g., fruit form in chenopods, utricles in sedges, or hermaphroditic and purely female flowers in the genus *Artemisia*). This can be done in the field (Fig. 6) or from a herbarium sheet.

Selection of the analyzed families

The species chosen for analysis were those which fulfilled one of the following criteria (Fig. 3, Table 1):

a) From families that are hard to identify, whose diagnostic characters required in the flora are hardly visible to the naked eye or are not yet formed at the usual collecting season (e.g., Asteraceae, Chenopodiaceae, Poaceae, Polygonaceae, Tamaricaceae).

Fig. 2
The HerbScan device in GFW, operated by Susanne STARKE (left); an example of a high-resolution scan of a herbarium sheet, which makes helpful comparisons possible thanks to exact depiction of details (here, the ligula) [*Eragrostis minor* ssp. *mimica* H. SCHOLZ, leg. M. SCHNITTLER, 16. 08. 2003] (right)

Fig. 3
Examples of species according to the selection criteria. Left (a): difficult to identify; middle (b): species-rich genus; right (c): dominant species of a vegetation unit

b) Species-rich genera and those with very similar species pairs (*Allium*, *Artemisia*, *Astragalus*, *Carex*, *Stipa*).
c) Species or genera with great importance for the formation of a vegetational unit (dominant species, numerous Poaceae, Asteraceae, Chenopodiaceae).
d) Monotypic families.

The families or genera were analyzed in the following three "qualitative" steps:

1. Overview analysis: species available in GFW were analyzed, usually without material borrowed from other herbaria
2. Comparative floristic analysis: all species from the herbaria (HAL and GFW, in part alos from GAT, JE) were included
3. Monographic analysis: As many species occurring in Mongolia as possible with records and characters relevant for identification were included. In addition, records were always borrowed from other herbaria (HAL, GAT, JE, various private herbaria, LE). Details relevant for identification were shown in overviews and close-ups.

E-Taxonomy

Virtual floras and information systems

Increasingly, printed floras are also being offered online as virtual floras; the most prominent example is the Flora of China (XINQI & TURLAND 2000). Virtual herbaria, e.g., the C.V. STARR Virtual Herbarium of the New York Botanical Garden [http://sciweb.nybg.org/science2/VirtualHerbarium.asp] or the Virtual Herbarium of BGBM Berlin-Dahlem [http://ww2.bgbm.org/Herbarium/default.cfm] provide access to digitized herbarium sheets on the Internet. Projects such as Visual Plants online [http://www.visualplants.de/] offer both identification keys as well as digitized herbarium specimens and numerous photos for identifying a plant. "Virtual collecting" is more and more often done as photos of plants.

Current floras or floristic works of Mongolia have to date not been available on the Internet. Even images of definitely identified, live plants in their natural habitats are seldom found online, despite rapid progress in digital photography. The information system **FloraGREIF** opens an application-oriented, virtual access to the flora of Mongolia, while simultaneously fulfilling the demands of a repository for research data. Hence, it is positioned between a virtual flora and a digital herbarium.

Multi-access key

Today, numerous users world-wide are already using the information system FloraGREIF, in order to access precisely taxonomic data, specimen data and images for species, genera, and families. Given the concise description of characteristics, definitively identified herbarium specimens and images, users can check the identification of the plant before them. The application-oriented selection of synonyms especially for the flora of Mongolia and a list of the respective, easily confused species facilitate this process.

In the current project (2012–2014), we are developing a computer-aided multi-access (random-access) key to make the database systematically usable for the identification of plants. The goal is to enable the user to identify an unknown plant at least down to family or genus.

In contrast to dichotomous keys, this key will not follow the taxonomic hierarchy; rather, based on a character database, it will request charactes and traits currently available to the user (for an example, see GÖTZ, 2001).

The database of characters currently contains 53 features categorized into:

- fruit (6 characters)
- flower (18 characters)
- leaf (16 characters)
- shoot (4 characters)
- root (3 characters)
- inflorescence (3 characters)
- habit (3 characters)

The character selection is essentially based on the works of GRUBOV (1982), HEYWOOD (2007), and KUBITZKI (1990). The precision with which the details of the characters is described depends on the experience of the botanical editor. It is important to find a balance between simplifying technical terms for the user's sake while still guaranteeing professional accuracy. All characters are grouped according to flowering status (vegetative, flowering, flowering to fruiting). The selection of characters in the keying process is adapted to this phenological status. Because certain characters

only develop during certain stages of maturity, definitive identification is often possible only when the plant is flowering or bearing fruit.

In addition, the characters are assigned to categories: easy to recognize, not self-explanatory, prior knowledge required and visible to the naked eye, visible but hand lens helpful, visible only with manipulation. Depending on the knowledge of the user or recognizability in the field, the selection of potential characters is set.

This should enable both experts and less experienced persons to use the key. The sequence in which the characters are shown by category is determined by the user. During the identification process, characters or groups of characters can be omitted, which usually leads to a greater number of results.

Ideally, the digital key can make identification down to species possible. During the timespan of the project, this will probably first be achieved for monotypic families. In most cases, the number of likely species will be limited to a manageable scope. Then, this number can be further reduced by comparing photos and/or using external sources. Especially the species-rich families such as Cyperaceae, Asteraceae, Chenopodiaceae, and Apiaceae will need special keys that are already online or in print or are the focus of further research.

The character database and the characters are assigned to the taxonomic units (order, family, subfamily, tribe, genus, section, species) via the user interface of the web portal FloraGREIF. In this way, the successful cooperation with experts on individual families and genera can be continued for entering the characters.

Results – Flora of Mongolia

On the project homepage, 2871 species are currently listed for Mongolia (January 2013). This species catalogue includes both evaluations from the literature (e.g., GUBANOV 1999; DULAMSUREN 2004, see also RILKE & NAJMI 2011) and taxonomic revisions.

The species list is founded on the work of GUBANOV (1996), which comprises 2823 taxa in 662 genera and 128 families; the fundamental compilation by GRUBOV (1982/2001) was revised in terms of nomenclature and expanded by 600 taxa.

For all species and synonyms, the source (usually a flora or floristic literature) is given. In addition, the synonyms necessary for practical botanical work in Mongolia are included. Names are used in accordance with NCU standards (GREUTER et al. 1993). In dubious cases, the names were compared against the recent floras (GRUBOV 1999–2006; MALYSHEV et al. 1988–2003; WU & RAVEN 1994+), CZEREPANOV (1995) and IPNI (2004+).

The distribution in Mongolia is presented over 16 phytogeographic regions (GRUBOV 1955, based on GRUBOV & YUNATOV 1952). The cartographic representation of these zones in WebGIS visualizes the range and allows simple comparison between related species, thus making distribution patterns recognizable (Fig. 4). GUBANOV (1996) provides the basis of data on the occurrence of a species in a particular region. Where necessary, his information is adapted during processing/revision of the families.

The plant database can be searched in two ways: as an overview grouped by families or as a targeted search using numerous parameters (Fig. 5). This enables effective photo comparisons, and plants encountered can be compared with already definitively identified material and assigned to a family or genus (possibly even also a species).

Through the increasing use of internet-enabled mobile devices (e.g., smartphones), users can also access the saved information "on location" and thus enjoy a simple identification aid on the flora of Mongolia which can be used anywhere that has Internet access.

Floristic contents

In the first phase of the project, approximately 1/3 of the species recorded for Mongolia were processed. The emphasis lay on species that are hard to identify or dominate a vegetation unit (Chenopodiaceae 93% processed, Poaceae 47% and Cyperaceae 45% processed). In contrast, several highly visible and large-flowered representatives of the families Campanulaceae, Lamiaceae, and Scrophulariaceae are as yet under-represented. Chenopodiaceae, Ephedraceae, Papaveraceae and 26 small or monotypic families have already been completed (Table 2).

At the end of the first project (May 2012), 6380 records for 1249 species had been entered. Of these, approximately 2/3 had been comparatively analyzed (step 2, above): 595

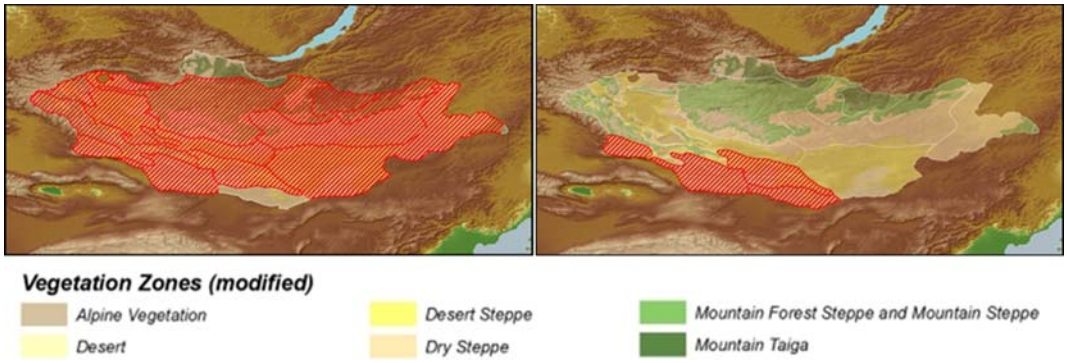

Fig. 4
Comparison of the distribution of *Salsola collina* (left) and *S. arbuscula* (right): *Salsola collina* has a Eurasian distribution and forms dense stands where it occurs in Mongolia, although this is its eastern range limit. *Salsola arbuscula* is a Central Asia element and colonizes southwest Mongolia

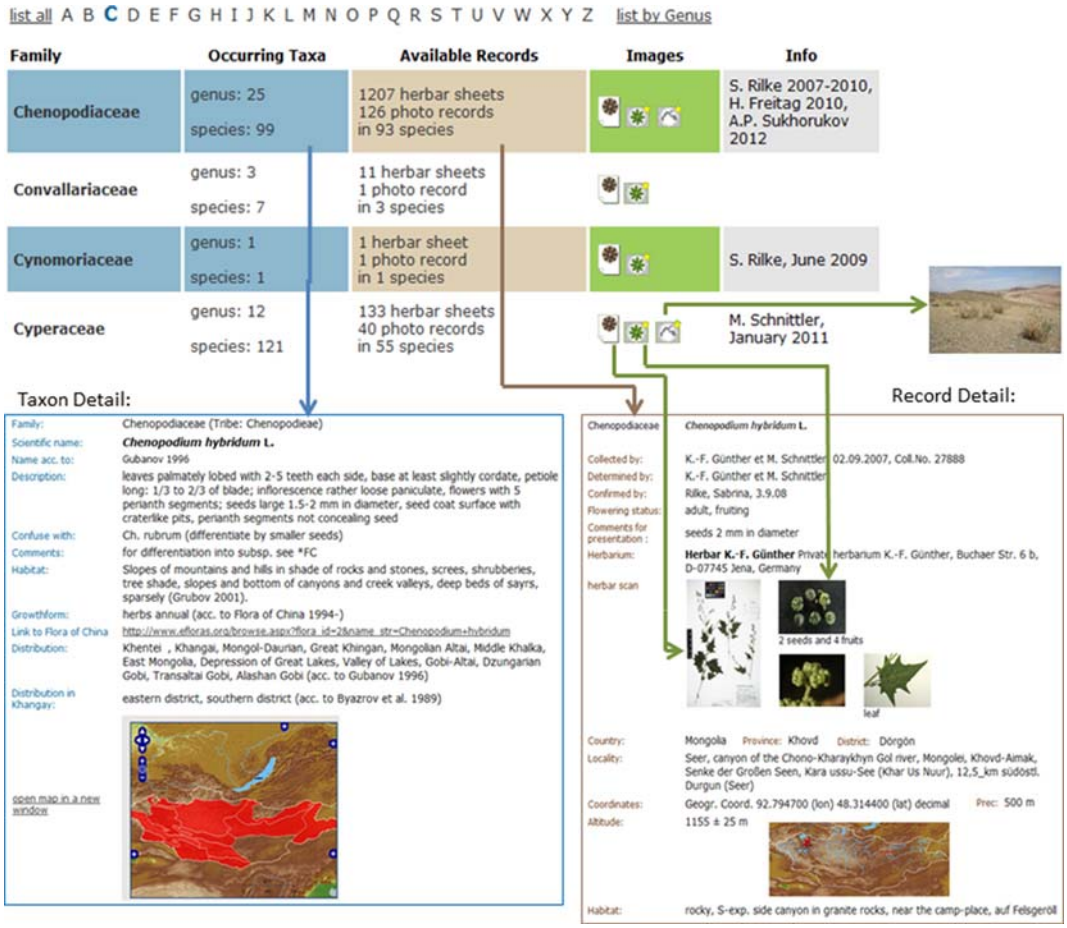

Fig. 5
Search options for species, herbarium specimens, plant photos or scans

Table 2
Families with more than 50 Species

Family	Genera	Species	criteria	"qualitative" steps	No. Herbarium Specimens	% completed species for family	No. revised specimens	No. confirmed specimens
Asteraceae	80	399	b	1, 3	940	40	75	376
Fabaceae	26	317	b	1, 3	306	28	24	98
Poaceae	62	232	a, c	2	589	47	58	318
Rosaceae	28	142	a	2	135	24	1	16
Brassicaceae	58	142	–	–	103	23	0	25
Cyperaceae	12	121	a, b	2	173	45	24	50
Ranunculaceae	22	119	b	2	420	63	48	273
Chenopodiaceae	25	99	a, b, c	3	1342	94	156	845
Caryophyllaceae	23	88	–		116	30	1	32
Lamiaceae	23	81	–	–	132	41	3	19
Polygonaceae	14	69	a, c	2	189	70	19	112
Apiaceae	34	67	a	1	139	57	18	56
Boraginaceae	22	54	a	1	123	63	4	43
Alliaceae	1	51	a, b	2	171	65	28	56
Total	430	1981	–	–	4878	49	459	2319

herbarium sheets had been revised, and the identification of 3040 herbarium sheets had been confirmed. Of the processed specimens, an average of 47.6% have been confirmed and 9.3% have been revised. Particularly high proportions of revised records are found for instance in Ephedraceae (51%, 94 of 183 sheets revised), Alliaceae (16%, 28 of 171), Apiaceae (12%, 18 of 139), Chenopodiaceae (12%, 156 of 1342), Grossulariaceae (16%, 7 of 43), Poaceae (10%, 58 of 589), Polygonaceae (10%, 19 of 189), Tamaricaceae (10%, 6 of 60) and Papaveraceae (9%, 8 of 90). These do not include the records which were identified for the first time by the botanical editor. To date, species records for 43% of all Mongolian plant species from 110 families can be accessed.

In the past 4 years, the following experts have participated in the identification and revision of genera or families: H. FREITAG and M. MAIER-STOLTE (Kassel: *Ephedra*), H. FREITAG (Kassel: Chenopodiaceae, *Suaeda)*, N. FRIESEN (Osnabrück: *Allium*), P. HANELT (Gatersleben: *Papaver*), D. PODLECH (Munich: *Astragalus*), N. KILIAN (Berlin: Liguliflorae/ Cichorioideae), R. WISSKIRCHEN (Bonn: Polygonaceae), H. SCHOLZ (Berlin: *Eragrostis*), E. RAAB-STRAUBE (Berlin: *Saussurea*), P. KUSS (Bern: *Pedicularis*), K.F. GÜNTHER (Jena: Apiaceae).

For 634 species, distinguishing characters for identification have been determined, which are based on the identification key by GRUBOV (1982/2001) and the short descriptions focusing on characters relevant for identification given there; this was supplemented with our own observations and information from "The Flora of China" (XINQI & TURLAND 2000) as well as from "The Flora of Siberia" (MALYSHEV et al. 1988–2003). Grubov's work (1999–2006) was also used in monographed species (step 3, Table 2).

Thanks to the comparatively processed material, reliably identified herbarium sheets are available which form a solid basis for further studies. Because further vegetation ecology projects strongly depend on the quality of identification, the system described here provides a special advantage over just digitizing herbarium sheets.

For the following 18 families, currently only data on distribution and habitat are available: Araceae, Asphodelaceae, Aspidiaceae, Aspleniaceae, Botrychiaceae, Capparaceae, Celastraceae, Cryptogrammaceae, Droseraceae, Monotropaceae, Oxalidaceae, Polypodiaceae,

Fig. 6
Close-up images with details relevant for identification: Infructescence of *Anabasis brevifolia* C.A. MEY (top), habit (bottom) leg.: K.F. GÜNTHER & M. SCHNITTLER 27895. The different color of the fruit's wing-like perianth is noteworthy, but it is not a distinguishing characteristic for identification

Scheuchzeriaceae, Selaginellaceae, Sparganiaceae, Thelypteridaceae and Trilliaceae. 1622 species could not be recorded, either by collections or with photos. Of 127 endemics, 33 species are presented, and of 154 subendemics, 88 species are presented. In some cases, plants rare to Mongolia have been recorded from neighboring regions where they occur more frequently (e.g., the Russian Altai, which borders on Mongolia).

Species records from 16 herbaria and 7 private collections were processed for Flora-GREIF (Table 1). In addition, data from several phytosociologically oriented works – chiefly from western Mongolia (C. KNOPF & G. WERHAHN, Rostock 2004; M. KRETSCHMER, Greifswald 2004; A. STRAUSS, Greifswald 2004) – as well as doctoral theses (H. VON WEHRDEN, Halle 2009; Ch. DULAMSUREN, Göttingen 2004; A. ZEMMRICH, Greifswald 2007) and the post-doctoral thesis by K. WESCHE (Halle 2007) were incorporated into the system.

Furthermore, the system contains 6052 photos by 11 photographers (Table 3). 850 habitat photos provide an overview of typical habitats and cover 340 species primarily from western Mongolia.

With 15,000 sheets, the herbarium of the University of Halle possesses the largest Mongolian collection outside Russia (LE) and Mongolia (UBA, UBU). It exists as an independent collection. Important collectors include K. HELMECKE, W. HILBIG, E. J. JÄGER, H. D. KNAPP, H. V. WEHRDEN & K. WESCHE. The second-largest collection – 10,000 sheets from Mongolia – is located in the herbarium at Gatersleben (GAT), to which P. HANELT, J. KRUSE & K. PISTRICK contributed substantially. Greifswald (GFW) has approximately 5000 herbarium sheets of definitively identi-

Table 3
Images

Photograph	No. Fotos	No. Records	Average No. Fotos per Record
SCHNITTLER, M.	4301	654	6,5
KRETSCHMER, M.	1250	956	1,3
STUBBE, A. & M.	235	20	11,7
ZEMMRICH, A.	127	86	1,4
JOLY, F.	77	49	1,5
HAUCK, M.	22	7	3,1
RILKE, S.	21	15	1,4
VESPER, M.	7	3	2,3
FREITAG, H.	7	7	1
WEISS, Th.	4	1	4
BRECKLE, S.	1	1	1

fied plant material, including collections by K. KLOSS and H. D. KNAPP, and recent material by S. RILKE, M. SCHNITTLER, A. ZEMMRICH, as well as specimens collected by students. The digitized herbarium sheets by M. SCHNITTLER (GFW) and K. F. GÜNTHER (JE) are supplemented by detailed close-ups of the collected plants when they were alive, which makes the collection particularly valuable. In contrast, specimens collected by students and records originating from phytosociological research often only consist of plant fragments that were collected for comparative purposes. At the herbarium of the University of Osnabrück (OSBU), there are approximately 1700 herbarium sheets, which were collected starting in 2001 during three field excursions (NEUFFER et al. 2003).

Many joint Mongolian-German research projects have concentrated on the west and south of the country. Thanks to the results of the project "Weideökosysteme in der westlichen Mongolei im Wandel" [Changes in pasture ecosystems in western Mongolia] (http://www.geowiss.uni-hamburg.de/i-geogr/biogeographie/mongolia/welcome.html) in the Great Lake Basin (near Khovd), the western part of the country is much better represented with herbarium sheets in FloraGREIF than is the eastern part. Especially taxa of the Siberian flora, which extend into northern Mongolia, Manchurian species of the small deciduous forest area in the east, and numerous subendemic species of the Gobi Desert are not yet adequately represented.

Additional botanical information

Under the menu item **Information,** one can find an overview of field excursions to Mongolia organized by the University of Greifswald (2003, 2003 & 2007) (**Travelogues**), all **Presentations** held up to now on the project, **Publications**, selected **Images** from the field excursions as well as links to **Virtual Herbaria and Plant Images Online**.
Under the menu item **Technical Terms/Botany,** the following additional information can be found:

- links to internet **Sources,** such as IPNI, digitized reference works for nomenclature, digitized botanical literature, sources for valid names and further e-floras.
- links to herbaria in which the plant collections presented in FloraGREIF are kept **(Index Herbariorum)**.
- List of collectors and botanists whose identifications or private herbaria are incorporated in the project **(Collectors' List)**. These names can be used as search parameters in targeted searches.
- A list of species which could occur in Mongolia (according to Gubanov, 1996) but for which concrete location data and herbarium specimens are still lacking **(Species with references to Mongolia without specific location data, cited in Gubanov 1996)**.

WebGIS

The spatial analysis functions (WebGIS) implemented to date enable the display of a spe-

cies distribution (as occurring in phytogeographic regions and/or site-distribution maps of the existing species records) on various topographical and thematic maps. For further information, see ZEMMRICH et al. (2012).

Because for every record, be it a herbarium sheet or a photo, the coordinates must also be cited, it will be possible to issue site-distribution maps. These will be all the more informative the more species records are present in the system. For older records (specimens collected before 1990), coordinates can be reconstructed as long as the location is adequately documented.

An expansion is planned, e.g., the comparative presentation of selected species. The combination of the distribution map with the various map layers allows interesting phytosociological evaluations.

Discussion – Goals and Future Plans

In the first project phase, FloraGREIF was supported by the German Research Society (Deutsche Forschungsgemeinschaft; DFG) for three years (2007–2010). In the current phase (2011–2014), the project is expanded to include an interactive synoptic key. Complementary to the strictly systematically-designed keys of conventional identification works, this key will lead the user to a genus or a group of similar species, which can then be identified by direct comparison.

In addition, further species records are entered continually; however, priority is given to species that are not yet represented by photographic material. The most important goal of this quantitative expansion is to include the database of the herbarium UB of the Botanical Institute of the Academy of Sciences, as well as to compare our results with the results of the project on the Mongolian flora (URGAMAL 2009; NYAMBAYAR 2009). The implementation of the WebGIS application makes it possible to create updated distribution maps, which provides a platform for the floristic mapping of the country.

The species-related information of the taxon level is predominantly expanded by distinguishing characters for identification. Steps toward an expert system are planned, for instance, with data on plants with medicinal uses, the plant parts employed, and chemical composition (LIGAA et al. 2009).

Through the open-source approach, the system can be transferred to other regions and/or expanded beyond Mongolia by adapting the corresponding species lists. Such follow-up applications are desired and have already been frequently requested (for Kasachstan, Azerbaijan, Afghanistan and Inner Mongolia).

The University of Greifswald is responsible for the constant maintenance and supervision (hardware and software, backup) of this information system on the flora of Mongolia.

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