Conservation of Arctic Flora and Fauna

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An International Arctic Vegetation Database
A foundation for panarctic biodiversity studies

CONCEPT PAPER

Acknowledgements

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- Directorate for Nature Management, Trondheim, Norway
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- Aleut International Association (AIA)
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Back cover photo: Black biological soil crust communities covering marine-alluvial sands, Hayes Island, Franz Josef Land/ Skip Walker

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Conservation of Arctic Flora and Fauna

CAFF Designated Area

Summary

This paper proposes an International Arctic Vegetation Database (IAVD), an essential first step in developing a panarctic ecological information system for use in research, nature conservation, education and policy making. This would be the first vegetation database to encompass an entire global biome. This is achievable because the Arctic is the only biome that has its entire list of known plants, including about 2870 vascular plants, 900 mosses and 1600 lichens, documented in up-to-date flora checklists developed by taxonomists within the CAFF Flora Group. The IAVD would provide a solid foundation for vegetation analysis and a wide variety of circumpolar conservation and biodiversity studies. Driving motivations for the IAVD include 1) development of an international approach to address pressing science questions that have been spurred by the rapid climate and land-use changes occurring in the Arctic, 2) harmonization of the North American and European approaches for archiving and classifying Arctic vegetation, and 3) archiving legacy vegetation data sets that are in danger of being lost. A large body of international experience in other biomes will help to make the task feasible. Here we present the history of the project, a brief background in vegetation classification, how the project fits within the CAFF conservation mandates, a conceptual framework for the database, how it will be made, some of the potential products, a brief statement of expected funding requirements, and a preliminary inventory of the existing Arctic vegetation data sets.

Moss polster community, Hayes Island, Franz Josef Land /Photo: Ina Timling

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Sedge, prostrate shrub, moss, lichen plant community, Nuuk, Greenland /Photo: Skip Walker

Introduction: The nature of vegetation data

An estimated 260,000 known vascular-plant species, 13,000 lichens, and 16,000 bryophytes occur on Earth (Raven et al. 2006). These are distributed in a myriad of plant communities, which differ in composition and spatial structure depending on past and present environmental conditions. The vegetation of a region refers to the plant communities, whereas the regional flora refers to the plant species. Plant communities and their constituent species have tremendous value to humanity because they provide food, medicine, clothing and shelter to the world's population; they help to regulate the Earth's climate and control essential nutrients and resources, including water and the composition of the air that we breathe. Because vegetation provides the primary production and structure of the food web, it also controls the distribution of other biota such as mammals, birds and fish. Furthermore, plant communities have important cultural and spiritual values. Because of plant communities' extraordinary complexity and their essential importance to mankind, vegetation scientists have devoted a great deal of energy to describing, classifying and analyzing the vegetation of the Earth (e.g., Walter 1976, Whittaker 1978, Ellenberg 1988, De Cáceres 2011).

Vegetation sampling

Developing a comprehensive and consistent Arctic Vegetation Classification and a checklist of plant-community types will first require organizing the large amount of independently collected plant-community data from around the Arctic into a database. The most useful information for this are vegetation data collected according to standard protocols that have been used in many parts of the Arctic for developing vegetation classifications, such as those used in the Braun-Blanquet classification approach (Westhoff and van der Maarel 1978) and the U.S. National Vegetation Classification (Jennings et al. 2009). Vegetation data are collected from plant communities in typical habitats that repeatedly occur across broad landscapes. In the Arctic, these include such examples as zonal habitats, dry gravelly habitats, wet fens and bogs, snowbeds, saline coastal habitats, sandy dune habitats, riparian and floodplain habitats, springs, talus slopes, calcareous loess habitats, and moist rich meadows. Many vegetation scientists around the world use an approach whereby data are recorded from small plots (e.g., 5 m x 5 m). These plots are floristically and structurally homogeneous areas that are representative of plant communities that repeatedly recur in similar habitats within a region. Within each sample plot, a full list of all the plant species is made, including an estimate of the percentage cover of each species. Often characteristics of the site are also recorded, such as elevation, slope and aspect, landform, bedrock, parent material, soil pH, snow regime, animal use of the site, disturbances, and active-layer depth. Other vegetation information might include horizontal and vertical structure of the plant community and plant biomass. This information is usually organized into *two data matrices: one containing the plant-species-cover data, and one containing the other environmental and vegetation information*. These data matrices can then be used to describe, classify, and analyze plant species and plant communities in relationship to environmental characteristics. The information in these data matrices is the principal data that are used in classifying plant communities and characterizing land surfaces for vegetation mapping.

Other approaches to sampling vegetation, such as point-intercept methods, belt transects, or repeated measures of biomass, leaf-area and spectral reflectance, are useful for monitoring vegetation changes, but the data collected by these methods require separate database approaches. These data will be archived in the proposed project but would not be included in the standardized vegetation database.

Vegetation generally integrates the ecological processes acting on a site or landscape more measurably than any other factor or set of factors and is often chosen as the basis for the classification and mapping of terrestrial ecosystems. Patterns of co-occurring plant species have received more attention than those of other components, such as fauna, because they are attached to the soil and immobile, thus relatively easy to measure and map. An additional benefit is that vegetation is often used to infer soil and climate patterns. Vegetation data are important for the analysis and description of ecological patterns and processes and have been collected using standardized methods from much of the Arctic (see insert panel).

The need for a panarctic vegetation database

Many Arctic environmental problems are no longer national or regional in character and must be addressed in a global context. Political boundaries seldom coincide with biogeographic boundaries. Thus, management strategies for long-term maintenance of biodiversity may be better focused on the characteristic biota of much larger regions (Noss 1983). Vegetation characteristics are often used in environmental inventories, land-use planning, environmental management, and conservation evaluations because the vegetation acts as an integrator of many of the physical and biological attributes of ecosystems (Specht 1975, Austin 1991). Several countries have developed or are developing vegetation databases and classifications as instruments for ecological research, nature conservation and policy making (Schaminée et al. 2011). An Arctic-wide approach to vegetation data management, classification and analysis is particularly important at this moment in history because global climate change has intensified efforts to inventory, classify and map the vegetation of the Arctic in much more detail than has been done previously (Callaghan et al 2005). An international approach of describing, naming and analyzing plant communities is needed for a wide variety of purposes related to anticipated global changes, resource development, land-use planning, studies of biota and biodiversity, education, and human social-ecological interactions. Vegetation scientists have made the first steps from local vegetation analyses to pan-Arctic analyses.

Salix glauca riparian shrubland, Nuuk, Greenland /Photo: Skip Walker

Some history

The concept of an International Arctic Vegetation Database and classification was proposed at the First International Arctic Vegetation Classification Workshop in 1992 at Boulder, CO, USA (M.D. Walker et al. 1994). This meeting strongly stimulated international interest in Arctic plant-community research. The idea was revived at the Second International Workshop on Circumpolar Vegetation Classification and Mapping, Tromsø, Norway 2004 (Daniëls et al. 2005) and recently received a favorable response from the Conservation of Arctic Flora and Fauna (CAFF) Flora Group at the 4th International CAFF Workshop in Tórshavn, Faroe Islands (Talbot 2008, Kuss and Walker 2008). The proposed database will be the next step toward the ultimate goal of creating a classification and Prodromus (comprehensive list of plant communities) of Arctic vegetation that is accessible through the worldwide web.

The Circumpolar Arctic Vegetation Map was a major step toward fulfilling the ideas from the Boulder

Workshop (CAVM Team 2003, Walker et al. 2005) (Figure 1). During the process of making the map, much of the circumpolar arctic plant-community information was reviewed and updated (Daniëls et al. 2005; Walker et al. 2005). Although the Arctic is a relatively under-sampled region of the Earth, a great deal of high-quality plot-level vegetation information has been collected, and a unified classification framework for the vegetation of the biome is an achievable goal.

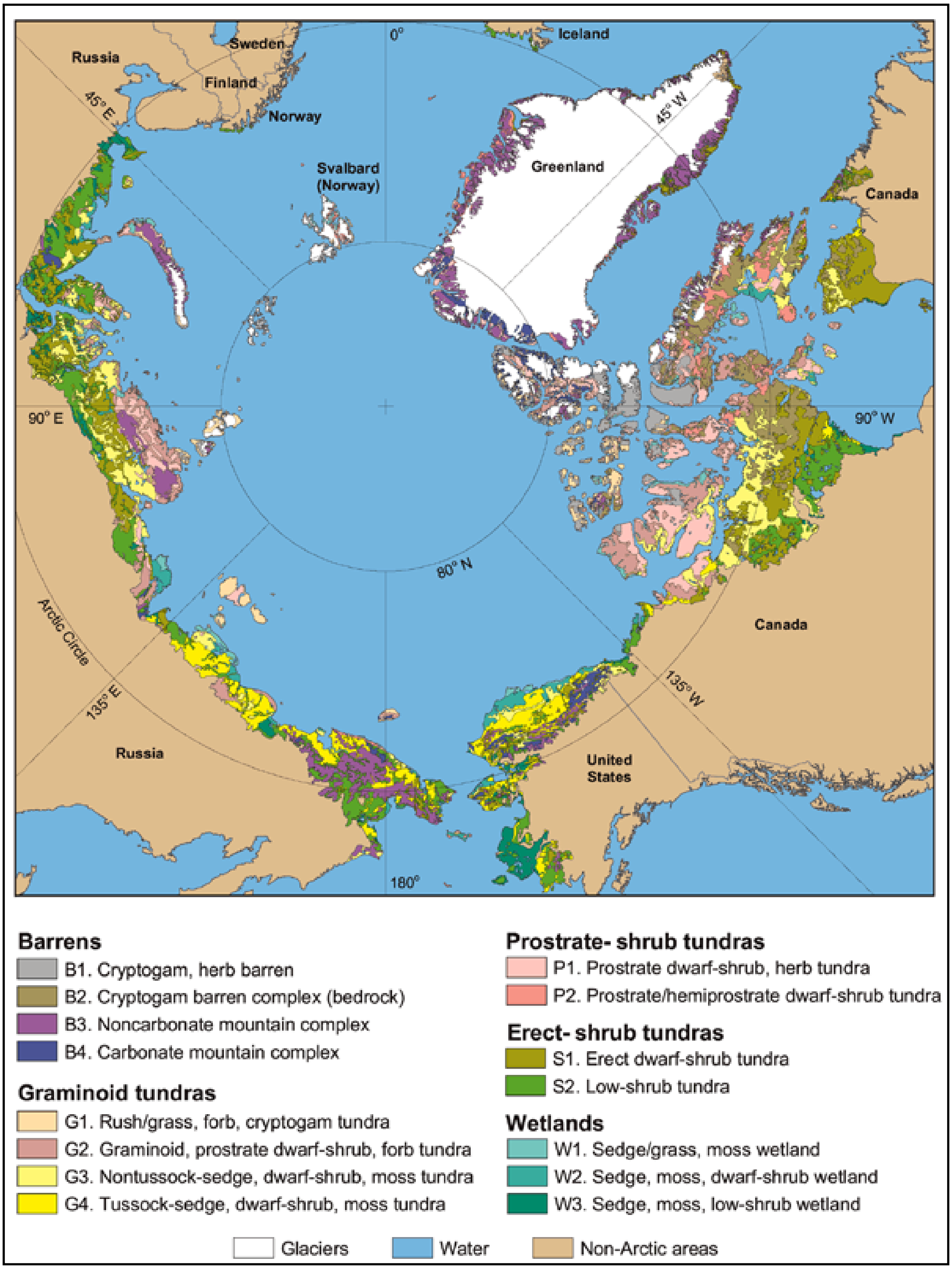

Figure 1. Circumpolar Arctic Vegetation Map shows the extent of the Arctic, define by the northern treeline, and the dominant physiognomic vegetation types.

Two main approaches to vegetation classification in the Arctic

One of the principal products that would eventually be derived from the International Arctic Vegetation Database would be a panarctic vegetation classification. In Arctic regions, two approaches to vegetation classification are prevalent: the European or Braun-Blanquet (Br-Bl.) approach and the American approach.

The European approach: The tradition developed by Josias Braun-Blanquet (1928, 1964; Westhoff & van der Maarel 1978) is the basis for numerous comprehensive textbooks and treatments of the vegetation of Europe and other parts of the world (e.g., Ellenberg 1988, Dierschke 1994, Dierssen 1996, Klötzli et al. 2010). The approach is considered a floristic-based approach: That is, all levels of the classification hierarchy are based primarily on species composition. A review of vegetation studies for the Circumpolar Arctic Vegetation Map showed that the Br.-Bl. approach is the most widely used method of vegetation study in the Arctic, with many studies in Europe, Svalbard, Greenland, Russia, Canada and Alaska (e.g. Barrett 1972, Böcher 1963, Bültmann 2005, Thannheiser 1988, Daniëls 1994, Daniëls et al. 2004, Drees & Daniëls 2009, Dierssen 1992, Dierssen & Dierssen 2005, Elvebakk 1994, 2005, Fredskild 1998, Kholod 2007, Kade et al. 2005, Kucherov & Daniëls 2005, Matveyeva 1998, 2002, 2006, Möller 2000, Razzhivin 1994, Schickhoff et al. 2002, Sieg & Daniëls 2005, Sieg et al. 2005, 2006, 2009, Sekretareva 2003, Talbot et al. 2005, Vonlanthen et al. 2008, Walker et al. 1994, Zanokha 2001, 2003). The Br.-Bl. method, however, has not gained wide acceptance in North America, although there have been scattered attempts to apply it in, for example, in the Colorado alpine (Komárková 1979), the North American boreal forests (Rivas-Martínez et al. 1999), the eastern deciduous forests (Miyawaki et al. 1994), and principally in the Arctic (references cited above). The best sources for learning the method are in German (e.g., Braun-Blanquet 1964, Dierschke 1994, Dierssen 1996, Wilmanns 1998), and several texts in English have provided overviews (e.g. Shimwell 1971, Mueller-Dombois & Ellenberg 1974; Westhoff and van der Maarel 1978, Kent & Coker 1992).

The American approach: The Nature Conservancy started the approach about 35 years ago, which eventually evolved into the U.S. National Vegetation Classification (USNVC) (Grossman et al. 1998, Jennings et al. 2009) and the Canada National Vegetation Classification (CNVC) (Ponomarenko & Alvo 2001). The American approach uses floristic criteria similar to the Br.-Bl. approach at the lowest level (association level) of classification and a variety of other criteria for higher-level units including vegetation physiognomy (general outward appearance) and biogeographic criteria (Faber-Langendoen et al. 2009). In 2001, The Nature Conservancy transferred the development of the approach to NatureServe http://www.natureserve.org/aboutUs/index.jsp, which is under subcontract to the U.S. Forest Service to manage the classification database and oversee changes in content. The Ecological Society of America (ESA) and the National Biological Information Infrastructure (NBII) Program in the U.S. Geological Survey are also playing supervisory and peer review roles for the USNVC. The approach has gained wide recognition and acceptance among government agencies in the U.S., and several countries in the western hemisphere are using it to guide their national vegetation classifications, including Bolivia, Canada, Mexico and Venezuela (Faber-Langendoen et al. 2009). The CNVC approach is being used to include the U.S. and Canadian Arctic in the Canadian vegetation classification.

The need for a harmonized approach: The American and Br.-Bl. approaches are similar at the lowest level (plant-association level) of the hierarchies, but the details of the hierarchic approaches make it difficult to make the systems totally compatible. Plant associations described according to the Br.-Bl. approach can be included in the U.S. and Canadian vegetation classification systems; whereas, the reverse is not easily accomplished without considerable additional attention to the naming and publication of the plant communities according to international protocols (Weber et al. 2000). There is need, especially in the Arctic, for harmonizing the Br.-Bl. and American approaches because so much of the world is heavily invested in one or the other method (DeCaceras & Wiser 2011). The Arctic vegetation database would be constructed so that the data could be incorporated into either approach.

Oxyria digyna, Hayes Island, Franz Josef Land / Ina Timling

Is the Arctic an appropriate region for such a database?

Of all the global biomes, the Arctic Tundra Biome best lends itself to a unified international approach for managing its vegetation information. Because of its proximity to the Arctic Ocean with its relatively homogeneous maritime climate, a relatively small flora and mainly young landscapes, the Arctic is floristically and vegetatively the most homogeneous of all the global biomes. It is also the only biome that has its entire list of known plants, including about 2200 vascular plants, 900 bryophytes and 1700 lichens, documented in up-to-date flora checklists (Meltofte 2011 in prep., Afonina & Czernyadjeva 1995, Elvebakk & Prestrud 1996, Sekretareva 1999, Afonina 2004, Kristinsson et al. 2011, Elven et al. 2011). The Arctic Tundra Biome is already mapped at the global scale according to physiognomic categories (CAVM Team 2003), and it is the best described of all biomes. If successfully applied here, it would be a good model for application to other global biomes such as the boreal forest biome (Spribille & Chytrý 2002) and the CAFF Circum-Boreal Forest Mapping effort (http://caff.arcticportal.org/index.php?option=com_content&view=frontpage&Itemid=191).

Red *Bryum rutilans* community, Hayes Island, Franz Josef Land / Skip Walker

How the International Arctic Vegetation Database fits within the CAFF mandate

The Conservation of Arctic Flora and Fauna (CAFF) is the Biodiversity working group of the Arctic Council. Its mandate is to address the conservation of Arctic and boreal biodiversity, and communicate findings to the governments and residents of the North, helping to promote practices that ensure the sustainability of northern resources. The mandate also includes working towards regulations and practices for flora and vegetation, fauna, habitat management, utilization, and conservation. To help fulfill this role, CAFF produces a range of strategies and plans for directly conserving species and plant communities and also provides a framework that facilitates more effective conservation measures. These strategies provide scientific and conservation recommendations on how to implement and ensure the most effective management response. They are developed via intensive international cooperation between countries and scientists across the Arctic region.

Within CAFF are three expert groups (Flora (CFG); Seabirds (CBird); and Protected Areas (CPAN)) that are related to key activities of CAFF and serve to synthesize, coordinate and publish research within these areas of activities. The Arctic Vegetation Database is a project of the CFG. The CFG was created in 2004 to ensure that scientists, conservationists, and managers interested in arctic and boreal flora and vegetation would have a forum to promote, facilitate, and coordinate conservation, management, and research activities of mutual concern. The CFG promotes the following activities:

- International opportunities to support the conservation needs of the biodiversity of arctic flora and vegetation;
- Conservation partnerships within the Arctic and neighboring areas;
- Research and education for conservation partnerships;
- Exchange of published information and unpublished data concerning arctic flora and vegetation; and
- Development of cooperative botanical activities for the CAFF annual work plan.

Aconitum delphiniifolium ssp. delphiniifolium / Martha Raynolds

Conceptual framework of the International Arctic Vegetation Database

The International Arctic Vegetation Database is a project undertaken by members of the CAFF Flora Group. The plant-community data of the IAVD will be intimately linked to the plant species lists contained in the Panarctic Flora database (Figure 2) the output of both databases will be made available to researchers and the general public through the Circumpolar Biodiversity Monitoring Programme's (CBMP) Data Portal.

Plant Species Lists

A standard list of accepted plant species names is an essential first step toward making the IAVD. Taxonomists within the CAFF Flora Group of the Arctic are developing Panarctic lists of vascular plants, bryophytes and lichens. A standard vascular list has already been created (*The PanArctic Flora*, PAF), and was made available on the web in 2011 (Elven et al. 2011). The list of arctic lichens has also been published and is available on the CAFF web site (Kristinsson et al. 2011). The lists will be compiled in a database format that can include plant descriptions, photographs, and information on genetics, ecology, habitat, and geographic distribution. Sources of information will be listed in a reference bibliography. Red List plants will be highlighted, so that inventories and descriptions of rare and endangered plants can be easily generated. Specialists from the CAFF Flora Working

If I knew all there is to know about a golden Arctic poppy growing on a rocky ledge in the Far North, I would know the whole story of evolution and creation.

–Sigurd F. Olson. Reflections from the North Country, 1976

Photo: Skip Walker

Group will keep the database current using password access via the internet. These lists will be combined into a single list for the vegetation database. Many Arctic vegetation surveys have used nomenclature in other lists of species (e.g. Hultén 1968, Böcher et al. 1968, Porsild & Cody 1980, Rebristaya et al. 1995, Afonina & Czernyadjeva 1995, Elvebakk & Prestrud 1996, Sekretareva 1999, Afonina 2004, Elven et al. 2011, Cody 2000, Kristinsson 2001, Petrovskiy et al. 1996, Aiken et al. 1999 onwards, Talbot et al. 1999, Brodo 2001, Alsos et al. 2005-2010, Lid & Lid 2005, University of Alaska Museum of the North 2001-2010). Synonymous names from these and other lists will be included, following protocols developed for the SynBioSys vegetation information system of the European Vegetation Survey, http://www.synbiosys.alterra.nl/synbiosyseu/.

Sorting voucher collections and biomass aboard the M. Somov, 2010/ Skip Walker

Plant Community Data

The Arctic Vegetation Database will contain the detailed species-cover information collected from sites in the Arctic and associated environmental information if available. These data will come from published studies of plant communities. The Plant Community Database will lay the foundation for an analysis of arctic plant communities and an annotated list (Prodromus) of all described plant communities in the Arctic. The Plant Community Data will be compiled using the Plant Species List to ensure consistent species nomenclature.

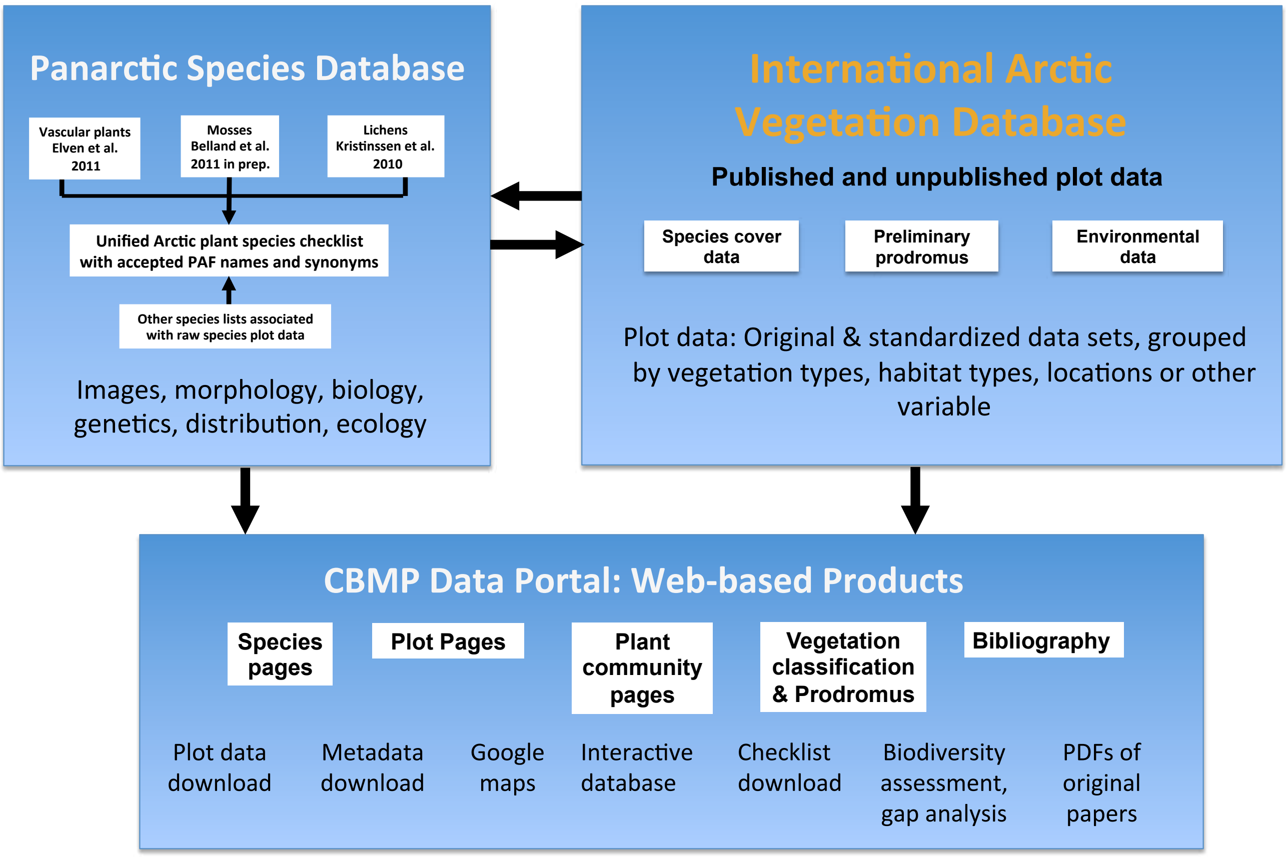

Figure 2. Conceptual diagram of the International Arctic Vegetation Database.

How will the International Arctic Vegetation Database be created?

This project will assemble the available raw plant-community information into a common database (Fig. 3). The vegetation database will contain the detailed species-cover and supporting environmental information from the studies of plant communities in the Arctic. The database will be created using the software application Turboveg (http://www.synbiosys.alterra.nl/turboveg; Hennekens & Schaminée 2001). The justification for using Turboveg is that it is the most widely used vegetation database tool and lends itself well to other software packages developed in Europe for vegetation classification and analysis, such as JUICE (Tichy 2002) and MULVA-5 (Wildi and Orlóci 1996). Turboveg is an application for front-end management of vegetation data. Eventually the data will be stored in a client server database such as the open source database object-relational system PostgreSQL http://www.postgresql.org/. An important first step in developing the database will be incorporating the standardized Arctic species list into Turboveg. We will use the pan-Arctic checklists (Elven et al. 2011, Kristinsson 2011, Afonina 2004, Belland 2012 in progress) and cross-reference all others names as synonyms. The information from Turboveg can be readily imported into VegBank, the database used for the US National Vegetation Classification and IBIS, the database used by many Russian vegetation scientists (Solomeshch & Mirkin 1999).

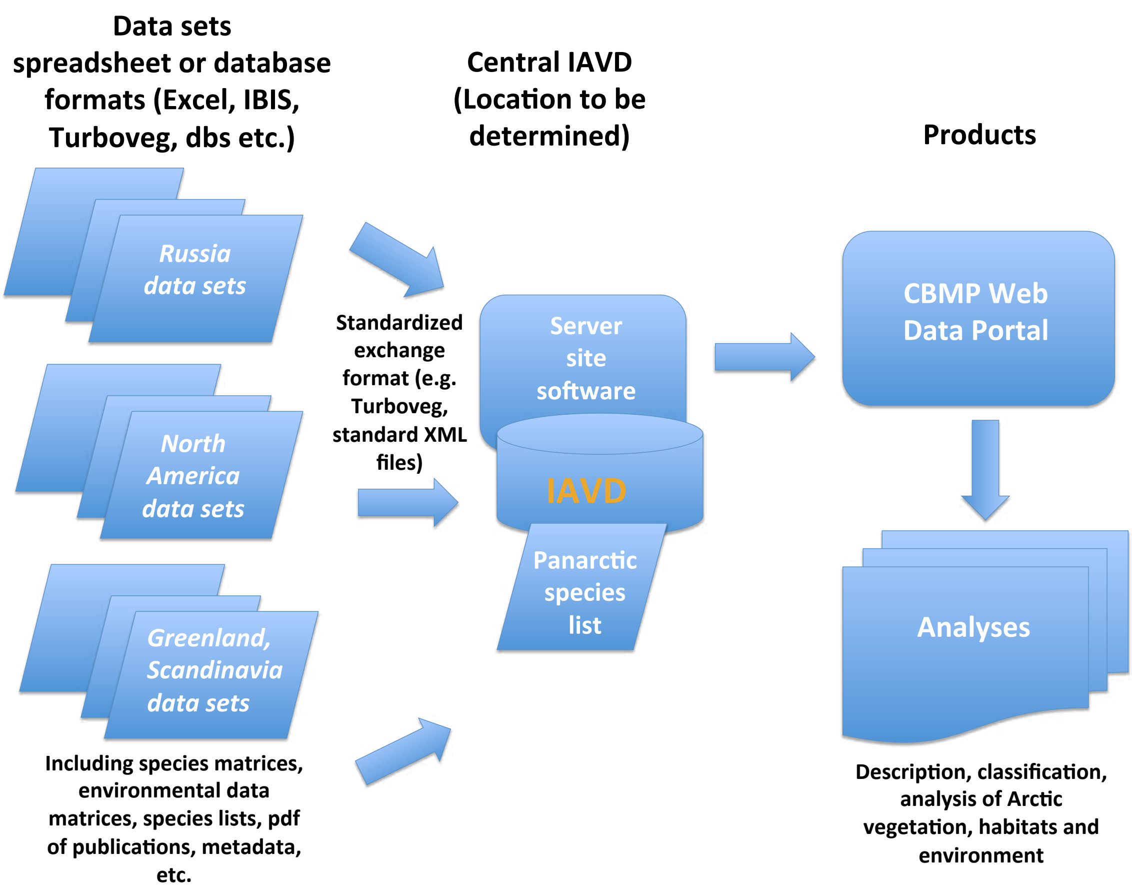

Figure 3. Data flow for the International Arctic Vegetation Database. The Circumpolar Biodiversity Monitoring Programme's Data Portal will be the host server for the database.

Development of a standardized set of environmental variables will also be needed. The list of environmental variables for most plots will be short and include such things as geographic coordinates, elevation, and site moisture status. For some plots extensive soil and environmental information is available and will be included. Part of the goals of the project will be to develop recommendations for future collection of plot-level environmental data to complement vegetation information.

During the first year, a workshop that is tentatively planned to be held in Wageningen, the Netherlands, will lay the foundation for the database and assemble a list of the key datasets that will be included. A training session in the latest version of Turboveg is also planned. We will invite scientists with an interest or focus on Arctic vegetation science to participate and comment on this collaborative circumarctic project. We will draw on the experience of colleagues at Wageningen University, the Netherlands, and Masaryk University, Czech Republic, who have long experience in building large vegetation databases (Schaminée et al. 2009). We will also solicit the cooperation and help of Canadians who are building an Arctic vegetation database in Canada (de Groot et al. 2010) and the developers of VegBank for the US National Vegetation Classification. Our long-term goal is a classification is compatible with the American and European systems.

The project will likely require the full-time attention of three post-doctoral students and an assistant to enter data from sets of known vegetation information for the Arctic. We will prioritize the data entry to first include the best published digital data sets with complete vascular and nonvascular plant species lists collected according to Br.-Bl. protocols (see Appendix 1 for preliminary list of datasets). As time permits we will enter data from unpublished and non-digital sources. A special effort will be made to retrieve critical legacy data sets that are in danger of being lost or whose authors have died. Data collected with incomplete species lists or by non-experts will have low priority. Key investigators will work at their home institutions to prepare their data for inclusion in the database. Two additional workshops are planned to help coordinate the effort. A bibliography of vegetation surveys in the Arctic will accompany the database. The International Arctic Vegetation Database will be accessible through the web. We will create download options such that checklists and plant community information can be customized and retrieved, for example for specified geographic areas.

In the first year of the project, a prototype database will be created using the most readily available Arctic vegetation data sets. This prototype will be draw on the protocols, methods, and experience used for the SynBioSys information system of the European Vegetation Survey, headquartered in Wageningen, the Netherlands, and Vegetation Database of the Czech Republic (Chytrý 2010).

Cushion-forb, lichen community, Hayes Island, Franz Josef Land / Skip Walker

Web-based products

Figure 4. Example species web page.

Once the International Arctic Vegetation Database has been created, it can be used for a wide variety of applications. The original plot data that were used to populate the database can be exported in their original condition or with consistent species nomenclature. The species data or environmental data can be exported for subsets of the database, selected for example on the basis on geographical location, or community type, or researcher. Lists of species occurrence can be created for specific areas or communities, for comparative analysis or biodiversity assessment. Geographical distribution of plot data can be used for gap analysis, to determine areas that are poorly sampled. Lists of known species can be created for geographic areas, a valuable resource for both experts looking for rare or overlooked plants, and researchers not familiar with the flora of an area.

The IAVD and the plant species lists will be accessible via the CAFF Circumpolar Biodiversity Monitoring Program's Data Management Portal. Web pages for individual plant species and plant communities will be automatically generated from the database, showing photographs and descriptions of the plant communities and their habitat (Figure 4). The web portal will have a geographic component, so that distribution maps can be created. Plant species checklists can be generated for specific areas. Summary statistics derived from the database will be a key resource for providing up-to-date biodiversity assessments and identifying knowledge gaps. One of the first uses of the completed Database will be to conduct a community analysis. The analysis will use the plot data to identify consistent recurring groups of species that form identifiable communities. These communities form the basis for vegetation mapping and habitat descriptions. A list of these communities, the Arctic Prodomus, will be a valuable resource for researchers and managers.

Funding for the International Arctic Vegetation Database

We will request funds, likely from a variety of international agencies, for an anticipated 5-year project that may include the following scope of items that will be modified after consultation among the participants and reviewers of the proposal:

1. Three workshops for key investigators (approximately 10-15 people) to meet and discuss the requirements and progress of the project.
2. 3 full-time 3-yr post-doc experts in Arctic vegetation and database management to assemble the International Arctic Vegetation Database. This could be split between experts in Russia, North America, and Greenland/Scandinavia.
3. 1 half-time student assistant to help with data entry.
4. Consulting to help to design the Turboveg and PostgreSQL databases.
5. 6-month salary for a web-site developer to make a web site where all the information will be available.
6. 6-month salary for student assistants at the 6 institutions that have the key Arctic vegetation data sets (University of Münster, Komarov Botanical Institute, University of Alaska, USFWS Anchorage, Tromso, Yukon Government in Whitehorse) to help the key investigators prepare their data for inclusion in the database and write the necessary metadata.

Cassiope tetragona, North Slope, Alaska/ Martha Raynolds

Timeline

Year 1: Organizing workshop, Wageningen, the Netherlands. Complete IAVD prototype. Obtain funding.
Year 2-4: Assemble data from literature sources at three main centers UAF (North America), Münster (Greenland and Scandinavia), and St. Petersburg (Russia). Build server site software. Build pages for CBMP data portal.
Year 5: Test and release the database.

International partners

A large number of people have been involved with making this concept paper and a large group of other Arctic vegetation scientists will be involved once the project begins. Those most actively involved to this point include:

Ken Baldwin, Canadian Forest Service, Natural Resources Canada
Tom Barry, CAFF, Akureyri, Iceland
Steffi Ickert-Bond, University of Alaska Fairbanks
Amy Breen, University of Alaska Fairbanks
Helga Bultmann, University of Münster, Germany
Milan Chytrý, Masayrk University, Brno, Czech Republic
Fred Daniëls, University of Münster, Germany
Stephan Hennekens, Wageningen University, the Netherlands
Catherine Kennedy, Yukon Government, Canada
Patrick Kuss, University of Bern, Switzerland
Nadyezhda Matveyeva, Komarov Botanical Institute, St. Petersburg, Russia
Robert Peet, University of North Carolina, USA
Martha Raynolds, University of Alaska Fairbanks, USA
Valodya Razzhivin, Komarov Botanical Institute, St. Petersburg, Russia
Stephen Talbot, US Fish and Wildlife Service, Anchorage, AK, USA
Lubomir Tichý, Masayrk University, Brno, Czech Republic
D.A. (Skip) Walker, University of Alaska Fairbanks, USA
Marilyn Walker, University of Colorado, USA

Research team during 2010 Expedition to Hayes Island/ Skip Walker

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Appendix A. Preliminary survey of Arctic relevés

Country	Source (author, date, location, journal)	Published Relevés	Other
Canada	Babb & Bliss 1974, QE Islands, J. Applied Ecology	8	
	Barrett 1972, Devon I., UBC PhD		72
	Bergeron 1988, Sverdrup Pass, Ellesmere I., U Toronto MSc		65
	Bliss 1977, Truelove Lowlands, Devon I, U Alberta Press	2	
	Bliss & Svoboda 1984, QE Islands, Holarctic Ecology	41	
	Bliss et al. 1994, Devon & Ellesmere I. , Arctic & Alpine Research	19	
	Breen & Levesque 2006, Sverdrup Pass, Ellesmere I., Can J Botany	20	
	Brigland 1986, Cape Herschell, Ellesmere I., UNStJ MSc		70
	Cordes et al. 1984, Mackenzie Delta, report for BC Hydro		48
	Duclos et al. 2006, Bylot and Baffin I., Parks Canada		541
	Forbes 1993, mostly disturbed sites	246	
	Forbes 1994, mostly disturbed sites	180	
	Gill 1971, Mackenzie Delta, UBC PhD		64
	Gonzalez et al. 2000, CAVM Canada expedition AGC data report		108
	Gould, A.J., 1985, Lake Hazen, Ellesmere I., U Toronto MSc		50
	Hastings 1983, Mackenzie Delta, U. Alberta MSc		34
	Hernandez 1972, Tuktoyuktuk Peninsual, U. Alberta MSc		38
	Levesque 1997, Ellesmere I, U. Toronto PhD		41
	MacHutchon 2000, Vuntut Park, Parks Canada		89
	Nams & Freedman 1987, Alexandra Fiord, Ellesmere, Holarctic Ecology	8	
	Rowe et al. 1977, Rankin Inlet, Muskox	13	
	Smith et al. 1989, Herschel I., Ag. Canada		538
	Vonlanthen et al. 2008, Isachsen, Mould B., Green Cab., Phytocoenologia	75	
	Canada approx. total	**612**	**1758**
Alaska	*Alaska Geobotany Center*		
	Breen 2012?, North Slope poplars, Phytocoenologia	25	
	Edwards et al. 2002, North Slope	15	
	Jorgenson 2009, NPS, Arctic Network relevés	763	
	Kade et al. 2005, North Slope Frost boils, Phytocoenologia	117	
	Schikhoff et al. 2001, N. AK, Willow comm., Phytocoenologia	85	
	Walker 1981, 1985, Prudhoe Bay, Ph.D. thesis and CRREL report	93	
	Walker et al. 1984, Imnavait Crk. data report, M.D. Walker et al. 1994 (JVS),	81	
	Walker and Barry 1991, Toolik Lake data report, M.D. Walker et al. 1994 (JVS),	72	

Alaska cont´d	Walker M.D., 1990, Pingos of N. Alaska, published thesis	293	
	Edwards et al., 2000,, ATLAS data report		12
	Elias et al. 1996, Barrow, Barter I. Legacy data report		61
	Walker et al. 1997, Happy Valley Data report		55
	AGC Subtotal	756	181
	Churchill 1955, Umiat, Ecology	51	
	Cooper 1986, Arrigetch Mtns, Phytocoenologia	372	
	Ebersole 1985, Oumalik, unpublished thesis		85
	S. Talbot:		
	Talbot et al. 2005, alders of SW AK, Phytocoenologia	128	
	Talbot & Talbot 2008, Chisik I., (Daniëls Festschrift vol.)	38	
	Talbot et al. 2010, Unalaska (Botany)	65	
	Talbot & Talbot 1994, Attu Island	79	
	Webber, IBP studies at Barrow, summary table in Tieszen 1978		33
	Alaska approx. total	**2274**	**299**
Greenland	De Molenaar 1974, MoG	61	
	De Molenaar 1976, MoG	305	
	Daniels 1982, MoGBiosci	269	
	Sieg et al 2006, Phytocoenologia	394	
	Sieg & Daniels 2005, Phytocoenologia	49	
	Lünterbusch & Daniels 2004, Phytocoenologia	49	
	Sieg et al 2009, Phytocoenologia	55	
	Drees & Daniels 2009, Phytocoenologia	149	
	Lepping & Daniels 2007, Polarforschung	57	
	Lünterbusch et al 1997, Polarforschung	50	
	Böcher 1963, MoG	450	
	Div MoG Danish researchers, MoG	200	
	Dierssen div.	50	
	Stumbock 1993, Diss. Bot	214	
	Lünterbusch Dissertation Münster		236
	Ferwerda, MSc Thesis Utrecht		150
	GBU-Berichte Copenhagen		150
	Herk and Knaapen, MSc Thesis, Utrecht		70
	Daniels 1992 Disko, still to be published		105
	Daniels NW Greenland 1993, still to be published		100
	Daniels 1998 NW Greenland, still to be published		100
	Daniels North Greenland 1995, still to be published		75
	Daniels West Greenland 2001-2003, still to be published		72
	Daniels SE Greenland 1995, still to be published		13
	Daniels 2009 S Greenland, still to be published		15
	Lepping 1998 NW Greenland, still to be published		60
	Dierssen & Dierssen W Greenland1981, still to be published		500
	Greenland approx. total	**2352**	**1646**

Svalbard (Arve Elvebakk)	Syntaxa are reviewed in Elvebakk (1994, JVS) without association tables.		
	19 habitat types in 17 alliances, Several hundred relevés are in unpublished theses. eg. I. Möller 2000, NW Svalbard (479), Current total for Svalbard 479		
Russia	V.D. Alexandrova, 1983, Franz Jozef Land	61	
	Forbes (1995, 1996, 1997, Forbes & Sumina 1999) Yamal mostly disturbed	419	
	O. and I. Lavrinenko:		
	2010, marshes in Malozemelskaya tundra	100	
	2010 in prep, Dryas comm. in European Russia Arctic		60
	2010 in prep, Barents Sea coastal communities		50
	Others already in Excel		380
	subtotal	100	490
	S. Kholod 2007, Wrangel Island	691	400
	N. Koroleva 1994, Kola Peninsula, JVS	250	
	N. Koroleva, unpublished from Barents Sea coast		400
	E.E. Kylygina, 2008, Pechora R. sandy outcrops	121	
	N. Matveyeva:		
	1979, Taimyr, Cape Cheluskin	5	
	1979, Maria Pronchitscheva Bay	4	
	1994, Taimyr Peninsula, 5 Ass.	180	
	1998, Taimyr Pen., 4 Ass.	90	
	2003, Plato Putorana alpine belt	31	
	2006, Bolshevik I.	250	
	Unpublished in field books		500
	Matveyeva subtotal	560	500
	Raynolds 2004, Kolyma R., ATLAS study		25
	Razzhivin 1994, Chukotka snowbeds, summary Table in JVS		261
	Sekretareva (1991, 1992, 1995, 1999, 2001,2003), Willows of E. Russ. Arctic,	235	164
	O. Sumina 1994, Disturbed sites, Chukotka	181	
	Walker et al. 2009, Yamal data report		66
	L.L. Zanokha (1993, 1995, 2001, 2003, 5 ass. From Taimyr (?) region	182	
	LL Zanokha, unpublished from Taimyr, Labytnangi, Plateau Putorana		600
	Russia approx. total	**2381**	**2906**
ARCTIC APROX. TOTAL		**11622**	**5626**

Appendix A References

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Appendix B. Glossary

Arctic: The high-latitude region that has no trees on most surfaces (although small inclusions may occur around extrazonal areas, such as hot springs, or small areas on warm south-facing slopes). In a bioclimatic sense, the Arctic region has tundra vegetation, an Arctic flora and an Arctic climate with cool summers and very cold winters.

Belt-transect method: A method of sampling vegetation whereby a long narrow strip of vegetation, usually only a few centimeters or meters wide, is defined and the constituent plants are recorded, measured, etc.

Biomass: The mass of biotic material per unit area (e.g., g m^{-2}). Plant biomass (phytomass) is often divided into living and dead material, aboveground and belowground components, and further subdivided according to species, plant growth forms or plant functional groups.

Bryophyte: A collective term that includes land plants that do not have true vascular tissues (i.e., non-vascular plants), including the mosses (Bryophyta), liverworts (Marchantiophyta), and hornworts (Anthocerotophyta).

Canopy cover: The proportion of ground area covered by the vertical projection of the canopy — often expressed as a percent of the area.

Flora: (1) A list of all the plant species living in a defined area at a particular time. (2) A book describing all the plant species in a specific area. (3) A collective term for all the plant species in an area, in the same way that "vegetation" is a collective term for all the plant communities.

Lichen: A symbiotic organism composed of a fungus (the mycobiont) with a photosynthetic partner (the phycobiont), usually a green alga (e.g., *Trebouxia*) and / or cyanobacterium (e.g., *Nostoc*).

Moss: A non-vascular plant in the division Bryophyta. Mostly small soft plants with a distinct stem and simple ribbed leaves. The reproductive part (sporophyte) usually consists of a spore-bearing capsule situated on a stalk (seta).

Ordination: A multivariate method of vegetation analysis that orders species and/or sample units along known environmental gradients (direct ordination), such as a soil moisture or snow gradient or according to their floristic and/or environmental similarity (indirect ordination).

Phytosociology: The branch of vegetation science that deals with plant communities, their description and classification, their composition and structure, environmental relationships, succession and geographical distribution.

Plant community: An assemblage of plants living together and interacting among themselves in a specific location in nature.

Plant community type: An abstract plant community that is defined by species composition, structure and habitat.

Point-intercept method: A group of techniques for measuring plant cover. A typical technique consists of lowering many regularly placed pins into the plant canopy and recording the "hits" on various species. Another method consists of sighting into the plant canopy with a telescope device with cross hairs to determine the points and the species intercepting the point. The cover of each species is the percentage of hits of that species divided by the total number of sample points.

Prodromus: A checklist of syntaxa (see syntaxon).

Relevé: (Derived from Fr. meaning a statement or summary or a list). A sample of vegetation collected from a plot of defined size according the European Braun-Blanquet approach. It usually includes a complete list of plant species, estimates of the cover-abundance of each species, and information on the site characteristics (environmental information), soil, and layers in the plant community.

Syntaxon (pl. syntaxa): Syntaxa are classified vegetation units of the hierarchical classification system of the Braun-Blanquet approach. They are characterized by species and can refer to vegetation units at any level in the hierarchy (e.g. sub-association, association, alliance, order, class).

Tundra: The vegetation beyond the northern and altitudinal limit of trees, where low shrubs and dwarf shrubs, herbaceous plants (grasses, sedges, forbs), mosses and lichens predominate.

Vascular plant: A term that refers to plants with an internal system of lignified vascular tissue for the transport of water and nutrients (via xylem) and photosynthetic products (via phloem). Includes club mosses, horsetails (*Equisetum*), ferns, gymnosperms (including conifers), and flowering plants (Angiosperms).

Vegetation: (1) A collective term for the mosaic of plant communities in the landscape of a specific area. (2) A system of largely spontaneous growing plants in coherence with their sites.

Vegetation classification: The process of defining vegetation types consisting of similar assemblages of plants often for mapping or analyses. Various approaches for vegetation classification are used at different scales and by different national traditions. At the lowest level of classification most approaches define vegetation types based on repeating assemblages of co-occurring plant species.

Vegetation composition: The plant species, plant functional types, life forms and/or growth forms within plant communities, often recorded as a list of species.

Vegetation structure: The horizontal and vertical distribution of plants within plant communities. It refers to the cover and height of species, layers and plant functional types.

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