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CURRENT RESEARCH AND TEACHING

Toward a new arctic vegetation map: a review of existing maps

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Introduction

A circumpolar arctic vegetation map and series of derived products are needed for a variety of current issues, including resource development, studies of arctic biota and biodiversity, arctic land-atmosphere, ice, ocean and human interactions, land-use planning, and education. A new map would provide a common legend and language for the ecosystems of the arctic region. It would also be a key component of circumpolar geographic information systems (GIS). At the Circumpolar Arctic Vegetation Mapping Workshop held in St. Peterburg, Russia, 21-25 March 1994, 51 participants from all the circumpolar countries reviewed the status of mapping north of the arctic treeline, and developed an approach to formatting a series of new maps. 15 papers by regional experts described the status of arctic vegetation mapping in each of the circumpolar countries (Walker & Markon in press).

Status of vegetation mapping

Alaska (S.S. Talbot)

A comprehensive bibliography concerning maps of arctic Alaska has recently been prepared (Talbot in press). At present, only one map covers all of arctic Alaska (Spetzman 1963; scale 1:2 500 000). There have been numerous variations derived from this map at similar scales (e.g. Ktichler 1966; Anon. 1973). Until the late 1970s there were relatively few maps at larger scales. In response to increasing resource development, planning mandates, and wildlife-habitat studies, federal and state agencies sought efficient vegetation mapping methods to inventory regions within the Arctic at higher resolution.

Conventional photo-interpretation was used in western Alaska for 1:60 000-scale range surveys of Hage-meister Island (Swanson & Laplant 1987), Nunivak Island (Swanson et al. 1986) and the Seward Peninsula (Swanson et al. 1985) and habitat analysis in the Hazen Bay, Yukon Delta National Wildlife Refuge (Tande & Jennings 1986) and northwest Alaska (Becia 1987). Concurrently, satellite, multispectral-scanner (MSS) data became available, influencing the direction of research by providing a new tool to inventory large areas of public lands. Vast Arctic landscapes were mapped using satellite images at intermediate scales (mainly 1:250 000). Consequently, maps covering the greatest portions of Arctic Alaska are at 1:250 000 scale.

Visually-interpreted Landsat maps were prepared for several national parks: Kobuk Valley (Racine 1976), Chukchi-Imuruk area (Racine & Anderson 1979), and Katmai Western Extension (Young & Racine 1978). Computer classification of satellite digital data was done in several portions of western Alaska, including the Alaska Peninsula and Bristol Bay area (Wibbenmeyer et al. 1982), the Dillingham Quadrangle (Anon. 1987), Togiak (M.D. Fleming & S.S.Talbot, unpubl. 1982), and the Yukon Delta National Wildlife Refuge (S.S. Talbot et al. unpubl. 1986). Northwestern Alaska has been mapped by Craighead et al. (1988) and Nodler et al. (1978), with smaller areas mapped at Anvik/ Bonasila (D.D. Osborne et al., unpubl. 1986), Buckland area (Adams & Connery 1983), Cape Krusenstem (Faeo 1993), Gates of the Arctic National Park (Wesser in prep.), Nulato Hills (Meyer & Spencer 1983), Kobuk Valley (Wesser 1994), and Selawik National Wildlife Refuge (Markon 1988). In northern Alaska, major mapping projects have occurred in the Arctic National Wildlife Refuge (Walker et al. 1982; Markon 1989; Jorgenson et al. 1993); the National Petroleum Reserve - Alaska (Morrissey & Ennis 1981; Spencer & Krebs 1982); and the Prudhoe Bay region (Walker & Acevedo 1987).

Large-scale studies of rather small areas are scattered throughout Arctic Alaska. For the Aleutian Islands, vegetation maps exist for Bogoslof I. (Byrd et al. 1980), Buldir I. (Byrd 1984), Amchitka I. (Amundsen 1972), Atka I. (Friedman 1984), and Simeonofl. (S.S. Talbot et al. unpubl. 1984). Other maps of western Alaska include St. Paul Island and Pribilof Is. (G.V. Byrd & N. Norvell, unpubl. 1988). In northern Alaska, large-scale maps include Atkasuk (Meade River, Komarkova & Webber 1980), Prudhoe Bay (Walker et al. 1980), Barrow (Walker 1977; Webber 1978); Markon 1992), Imnavait Creek (Walker et al. 1989; Walker in press), Mirth-Mancha (Mouton & Spindler 1980), and Okpilak River delta (Spindler 1978).

Most of the intermediate scale maps and many of the large-scale maps reflect the structure of the vegetation and are sometimes supplemented with ecological information. A statewide vegetation classification (Viereck et al. 1992) has been developed, but has not been consistently applied in tundra regions, and there is an un-evenness in coverage and mapping scale. Despite these shortcomings, it should be possible to use intermediate scale maps of large areas, and large scale maps of small areas, as guides to interpret Advanced Very High Resolution Radiometer (AVHRR) (1.1-km pixel resolution) digital data from the NOAA (National Oceanic and Atmospheric Administration) satellites.

Canada (S.C. Zoltai)

Vegetation of arctic Canada has not been mapped on a systematic basis This may be due to the fact that no single government agency is responsible for inventorying the natural vegetation. This resulted in a large number of botanical or floristic studies in small areas scattered throughout the arctic without an effort to synthesize them into vegetation maps of large regions, except on a very broad, general level (Anon. 1966, 1971). Broad-scale generalizations were based on such regional studies (e.g. Bliss 1979; Ediund 1983).

In the absence of a systematic effort, vegetation mapping has been opportunistic. Botanists attached to the Geological Survey of Canada have produced a number of vegetation maps (Bamett et al. 1975; Ediund 1982a,b,c, 1990; Tarnocai et al. 1976; Thomas et al. 1979; Vincent & Ediund 1978; Woo & Zoltai 1977). A landscape-vegetation map of Labrador, including its arctic-alpine part, was prepared by the Lands Directorate (Lopoukhine et al. 1977). Environment Canada also instituted a program of landscape and vegetation mapping (Anon. 1980), but this initiative was not pursued. Additionally, as a first step in evaluating areas for potential national parks, vegetation maps were prepared for Parks Canada, mainly as unpublished reports (J.P. Kelsall et al. in 1970; V. Woo & C.S. Zoltai in 1977, C.S. Zoltai et al. in 1979, 1980a,b, 1981 and 1983), but also as publications by the Canada Wildlife Service (Zoltai et al. 1987; Zoltai et al. 1992). Other mapping projects were carried out by universities resulting in the mapping of small areas (Arkay 1972; Beschel 1970; Muc & Bliss 1977; Muller 1963; Ritchie 1962). During the 1970s and 1980s, proposed pipeline developments initiated a number of vegetation studies, but these did not result in mapping projects. In addition to the mapped areas, there are dozens of small areas where the vegetation was analyzed and classified. Such information, along with the already mapped areas, could be used for ground reference information for satellite-derived classifications.

As most of the vegetation maps were created to describe specific areas, there was little effort made to develop a common vegetation mapping system for all of arctic Canada. The detail of the vegetation units was dictated by the scale of mapping; most units combined vegetation morphology and common species into their legend. Such terms as high shrubs, low shrubs, dwarf (prostrate) shrubs, graminoids, wet meadows, etc., were commonly used in combination with species. The amount of bare soil, when created by cryoturbation or desert processes, was often indicated.

Greenland (C. Bay)

Only a few research institutions in Denmark have dealt with vegetation mapping in Greenland, mainly the Greenland Botanical Survey (GBS), Greenland Environmental Research Institute (GERI), and the Geographical Institute, University of Copenhagen. No strategy for mapping the vegetation of all Greenland exists. However, in the last decades, regional vegetation mapping has been carried out in different parts of Greenland as part of biological projects that had objectives other than vegetation mapping, such as environmental monitoring of oil exploration, impacts of sheep farming, and studies of foraging dynamics of herbivores. Different techniques have been used, and both biologists and geographers have been involved, resulting in maps of different scale and size. Only a small part of the vegetated areas of Greenland is mapped in any detail.

In Northeast Greenland, the Ministry for Greenland initiated environmental investigations in the early 1980s in connection with a planned oil exploration on Jameson Land. This project included mapping of the largest lowland in High-Arctic Greenland. Totally, 265 detailed maps at 1:25 000 scale, each covering 25 km^2, were produced using aerial photograph interpretation (Bay & Holt 1986). This was the largest and most detailed mapping project ever carried out in Greenland. SPOT-1 and Landsat TM (Thematic Mapper-based vegetation maps of selected areas in Jameson Land were later produced in order to compare methods (Mosbech & Hansen 1994). The conclusion was that satellite-based vegetation mapping was inadequate for mapping of vegetation classes covering less than a few hundred m^2. However, it was possible to distinguish 10 vegetation classes using the satellite data compared to 14 classes using aerial photos. In 1988-1990, a privately sponsored 3-yr mapping project was carried out in the National Park in North and Northeast Greenland, using a NOAA-satellite-based approach (Bay 1992; Bay & Fredskild 1990; Hansen & S0gaard unpubl.). This gave information on distribution of important biological areas, such as vegetated areas with large populations of terrestrial herbivores. In addition, ground reference data were obtained for a SPOT-satellite-based vegetation classification (Bay & Fredskild 1991). The vegetation index distinguished seven categories, but since the vegetation is very patchy and mosaic-like, the interpretation was difficult. False-color aerial photographs at 1:86 000 scale from most North and Northeast Greenland are available for future mapping projects.

In North Greenland, false-color aerial photographs magnified to a scale of 1:20 500 were interpreted as part of an environmental reconnaissance (Aastrup et al. 1986).

In West Greenland, three areas have been mapped using aerial photographs or SPOT data as part of a management plan for a local community and for projects concerning distribution of caribou and muskoxen habitats. A vegetation mapping project covering most of southern West Greenland is under preparation in connection with monitoring caribou and muskoxen habitats. Initially, it will be based on NOAA data, and for more detailed vegetation maps, SPOT satellite data will be used.

In South Greenland, the vegetation of the protected Qingua-Valley has been mapped based on both aerial photos and Landsat MSS data, and a comparison of the methods has been performed (Feilberg & Folving 1990). Aerial photos and analysis of satellite data have aiso been used in minor areas in South Greenland in connection with monitoring the impact of sheep farming.

F.J.A. Daniels (in Walker & Markon in press) recently proposed a framework for mapping all of Greenland at small scales using six broad units based on the occurrence of classes of vegetation derived according to the Braun-Blanquet approach (Westhoff & van der Maarel 1978).

Iceland (E. Einarsson)

Vegetation mapping in Iceland started relatively late, but it is one of the few circumpolar countries to develop a map scheme for all its lands. In 1955, the Department of Agriculture of the University Research Institute, now the Agricultural Research Institute, started the field work for a l:40000-scale map of the actual vegetation of the grazing land Gnupverkaarettur in South Iceland, most of it found at an altitude above 300 m (Johannesson & Thorsteinsson 1957). The purpose was to provide information about the plant communities, determine the carrying capacity of the lands, evaluate their quality for agricultural use, and to provide a basis for wise planning and use of the land. The legend units, defined by S. Steindorsson, consisted of two complexes: dryland vegetation and wetland vegetation, with each complex divided into several sociations based on growth forms and dominant species in the upper layers of the vegetation without much regard to mosses and lichens.

In 1961, a plan was developed to extend the mapping to the entire country, using the same legend and scale, which would result in a total of 289 maps. This ambitious work continued for 20 yr under the direction of Thorsteinsson and Steindorsson in the Agricultural Research Institute (Steindorsson 1981; Thorsteinsson 1981) At the beginning, the emphasis was on mapping the central highlands, which have for centuries been used for sheep grazing, but too often overgrazed, resulting in serious and extensive vegetation damages and soil erosion. From 1968, vegetation mapping was carried out in the lowlands as well, for the same purpose as earlier and for comparison of the highland and lowland areas. The mapping in the lowlands required extending the legends to include six main vegetation complexes: dryland vegetation, half bogs, bogs, fens, aquatic vegetation and land without vegetation. Land with mosaics of vegetation is classified as complex vegetation. The main vegetation complexes are divided into 15 orders and 91 sociations. This work resulted in maps of most of the uninhabited central highlands and some parts of the inhabited lowlands, but during the 1980s funding gradually declined. A total of 64 maps, mainly in the central highlands, have been published at a scale of 1:40 000 by either the Icelandic Survey Department or the Cultural Fund (Gudbergsson 1981; Steindorsson 1981; Thorsteinsson 1981). Another 32 maps at the same scale have been completed, but funds for publication are lacking. These maps were made with the help of a computer and the data reside in a digital database. Additionally, 28 maps, mainly of lowland areas, have been published at 1:25 000 scale, eight at 1:20 000 scale and a few at 1:10 000 scale. A total of about 60 % of Iceland is thus covered by vegetation maps in various stages of publication.

From 1991 to 1993, a group of specialists worked on a program to set up a geographic information system in Iceland (Thorsteinsson et al. 1993). Part of the group was devoted to vegetation mapping and is currently producing two experimental vegetation maps of part of South Iceland at 1:25 000 scale. The group recommended that the vegetation mapping of the country should be continued and completed within the next 10 yr by the Icelandic Museum of Natural History, as the Agricultural Research Institute is no longer interested in continuing the project.

So far, no vegetation map for all of Iceland has been made. The Icelandic Museum of Natural History has decided to make one in the near future, probably at 1:500 000 scale. This map will show the potential natural vegetation of the country, rather than the actual vegetation. A recently published satellite image of Iceland at 1:600 000 scale may be of a great help. Iceland is also found on the *Vegetation Map of the Council of Europe Member States* at 1:3000000 scale, and the *Council of Ministers Map of Physical Geographic Regions.* These maps are mainly based on natural vegetation.

Svalbard and Scandinavia (A. Elvebakk & B.E. Johansen)

The classification presently used in Norway is that of the *Vegetation Region Map of Norway* made by botanists from four universities of Norway (1:1 500 000; Dahl et al. 1986). A simplified version was published by Moen (1987). A similar vegetation zone map was also produced for Svalbard (Brattbakk 1986), where the 'High Arctic' is defined as composed of a *Papaver dahlianum* zone and a *Salixpolaris* zone, and the 'Mid Arctic' with *SiDryas octopetala* zone and a *Cassiope tetragona* zone.

Such vegetation zone maps do not show the spatial distribution of vegetation types, but instead areas with characteristic sets of vegetation types thought to reflect climatic conditions. Many areas are defined on the basis of species occurrences, as the distribution of species is better known than the distribution of vegetation types. Thus, it would be appropriate to use the terminology 'climatic-phytogeographical maps' as usedbyTuhkanen (1984). The classic study ofFennoscandia by Ahti et al. (1968) includes the northern, middle, and southern boreal zones, a transitory hemiboreal zone, and the temperate zone. All alpine areas are called oroarctic. The circumboreal maps ofTuhkanen(1984) follow the same system, but include also a hemiarctic zone north of the boreal area.

Elvebakk (1985) mapped the zones of Greenland, Svalbard and adjacent part of Arctic Russia on a very coarse scale. The nomenclature adopted the major division of the Arctic in polar desert and arctic tundra as used by Aleksandrova (1980), and combined it with a subdivision of the arctic tundra in three parts parallel to the Fennoscandian division of boreal areas. Later Elvebakk (1989) made a more detailed zone map of Svalbard based on phytogeography, including a subdivision of the middle arctic tundra zone. The nomenclature is the same as in Elvebakk (1985), and this system was adopted by the standard Norwegian flora (Lid & Lid 1994) and by the Flora Nordica project - except that the hemiboreal zone will be renamed the arctoboreal zone.

Only minor parts of Svalbard have been mapped using satellite data. 0ritsland et al. (1980) tested the use ofLandsat MSS data in the Isfjorden area, and Spjelkavik & Elvebakk (1989) used Landsat TM data to detect reindeer winter grazing areas on mountain plateaus in the Gipsdalen area, and Elven et al. (1990) presented a vegetation map of Btinsow Land, also in central Spitsbergen. This study also included a hierarchical classification key for satellite data interpretation. Spjelkavik (1994) compared satellite based mapping with traditional methods based on aerial photographs. Finnmark in northernmost mainland Norway has been more extensively mapped by use of remote sensing data. Today the whole Finnmark county and the northernmost parts of Troms0 are mapped based on Landsat TM data (Johansen in Walker & Markon in press).

More detailed large-scale maps were produced during the Norwegian MAB (Man and the Biosphere) project. Five areas on Svalbard (Reinsdyrflya and

Lapponiahal0ya in the north, Br0ggerhalv0ya and Lagdalsflya in the west, and Adventdalen in the central part) were mapped based on traditional use of aerial photographs and phytosociological principles (Brattbakk 1981, 1984, 1985a,b,c). The map scales range from 1:10000 to 1:50000. Thannheiser (1992) mapped areas in the north at 1:100 000 scale. In mainland Norway, the Norwegian Institute of Land Inventory keeps an updated list of all vegetation and land-use maps, and in the area defined as arctic there is only a series of three agricultural land-use maps.

Russia (S. Kholod &. B.A. Yurtsev)

The St. Petersburg workshop was the first time since the 1975 International Botanical Congress in Leningrad that western scientists have had the opportunity to view all the major maps produced for the Russian Arctic. Some maps were previously classified for military reasons (e.g. maps of the Taimyr Peninsula; Shchelkunova 1975), and others have only recently been finished, including, northern Yakutia (Andreev & Shcherbakov 1989), and the Chukotsk peninsula (A.N. Polezhayev, unpubl. 1993). Unlike large regions of the Arctic in the western hemisphere, all of Arctic Russia has now been mapped at a relatively fine level of detail.

Vegetation mapping in Russia has old traditions connected with the names of V.B. Sochava and E.M. Lavrenko. The major centers of the vegetation mapping are the Komarov Botanical Institute (St. Petersburg), Institute of Geography of Siberia and the Far East (Irkutsk) and Moscow State University. Small-scale vegetation maps, created in these institutions, reflect all the vegetation north of the polar treeline, most notably the *Map of Vegetation of the European part of the USSR* (Scale 1:2500000; Isachenko & Lavrenko 1979), *Map of Vegetation of the West Siberian Plain* (Scale 1:1000000; Ilyina et al. 1976), *Geobotanical Map of the Nonchernozem Zone of the Russian Soviet Federative Socialistic Republic* (Isachenko et al. 1976), and the *Vegetation Map of the USSR for the Higher School* (scale 1:4000000; Belov et al. 1990). Most small-scale maps, covering the northern territories of Russia and created in the last 20 yr, were compiled according to a unified methodology. For example, on all of the above maps, the tundra zone, which is south of the polar desert or the high-arctic tundra subzone *(sensu* Yurtsev et al. 1978; Yurtsev 1994, in Walker & Markon in press), is subdivided into three subzones: arctic tundra, northern (typical) tundra, and southern tundra, and within each of them the regional variants are distinguished (e.g. Kola, East-European, Ural, West Siberian, etc.). A number of vegetation maps were created for separate parts of the Russian Arctic, such as: Kanin-Timan and Malozemelsk region (scale 1:1000000; Gribova et al. 1975), Novaya Zemlya (scale 1:7000000; Gribova 1975), the West Siberian Arctic (scale 1:1 000 000; L.I. Meltzer in Walker & Markon in press, and Yakutia (scale 1:5000000;

Andreev & Shcherbakov 1989). The modem status of knowledge on the arctic vegetation of the European Russia is mirrored in the *Vegetation Map of Europe* (scale 1:2 500 000) being created now under the aegis of International Union of Biological Sciences (IUBS) and European Economic Community (EEC) (Neuhausl et al. 1990).

Of special interest are the correlated ecology-phytocoenology map of Asian Russia (scale 1:7 500 000;

Buks et al. 1977), where the mapped vegetation units are correlated with the duration of vegetative period and the total sum of active positive temperatures (> +10 °C);

and the *Landscape Map of Northern Siberia* (scale 1:1 000000; Melnikov & Moskalenko 1991) where the interconnections between the basic vegetation units and the geological, geomorphic and permafrost conditions are shown.

Middle-scale maps include the following: *Map of Vegetation and Forages of the Taimyr National Circuit* (scale 1:500000; Shchelkunova 1975), *Map of Vegetation and Pastures of the Chukotka Autonomous Circuit* (scale 1:200000; Polezhayev 1993, manuscript map), *Map of the Vegetation of the Northern Areas of Yakutia* (scale 1:500000; Shchelkunova 1964-1965). The large-scale vegetation map of Chukotka was generalized up to scales 1:1000 000 and 1:2 500 000 (Polezhayev unpubl.), displaying various meso-, macro- and megacombinations of plant communities. Similarly, Shelkonova's map of Taimyr vegetation, with formations as basic vegetation units (Shchelkunova 1975) was the product of the generalization of the original map, scale 1:1000 000, showing the distribution of plant associations and groups of associations.

For the last two decades, large-scale vegetation maps have been made for many northern areas of Russia. The vegetation of small intensive study plots has been mapped, providing insight to the connections between the vegetation and environmental factors as well as into the features of the horizontal structure of the vegetative cover. Intensive study plots have been mapped in different zonal units of Taimyr (Matveyeva 1978), East European tundras (Katenin 1972), and Chukotka tundra areas (Katenin 1974, 1981, 1988). Recently, large-scale vegetation maps have been made for numerous protected areas (e.g. Wrangel State Reserve: Kholod 1989), where large-scale vegetation mapping is performed using air photographs at 1:25000 to 1:50000 scale.

Russian phytogeographers and geobotanists have been instrumental in defining phytogeographic divided the circumpolar Arctic (and Antarctic) into geobotanical areas. The first vegetation map of the circumpolar Arctic was compiled by S.A.Gribova in the *Russian Atlas of the Arctic* (Treshnikov 1985). Maps of floristic subdivisions and latitudinal phytogeographic zonation of the circumpolar Arctic were created by Yurtsev et al. (1978), Rebristaya & Yurtsev (1985), and Yurtsev (1992, 1994).

The status of vegetation mapping in arctic Russia was reviewed in a series of papers at the workshop (Walker & Markon in press): Western Siberian Arctic (L.I. Meltzer; N.G. Moskalenko; I.S. Ilyina & T.K. Yurkovskaya); Taimyr Peninsula (R.P. Shchelkunova);

Arctic Yakutia (V.O. Perfilieva & K.A. Volotovskyi);

Lena River delta vicinity (K.A. Volotovskyi); and Chukotka (A.N. Poleshayev; A.E. Katenin).

The mapping methods employed on most of the Russian maps follow those used by the Geography and Cartography Department at the Komarov Botanical Institute and may lend themselves to standardization across other parts of the Arctic. The recently completed vegetation map of Europe, which was compiled at the Komarov, serves as a model of the type of map that could be created for the circumpolar Arctic (Neuhausl et al. 1990).

Two new major Russian initiatives are compiling and editing Russian arctic vegetation maps: (1) *The Ecological Atlas of the Russian Arctic* organized by the Research Institute for Protection of Nature of the Arctic and the North will consist of over 400 maps and involves over 60 institutions (I. Safronova in Walker & Markon in press). The vegetation portion of the atlas will consist of 15 maps to be produced by the Komarov Institute. (2) The Arctic Environmental Database project is organized by Moscow State University, the World Conservation Monitoring Centre, and the Scott Polar Research Institute, Cambridge (A.P. Kapitsa et al. in Walker & Markon in press); O.A. Novoselova in Walker & Markon in press; C. Smith in Walker & Markon in press). The project will describe the biodiversity resources and the threats to their conservation, as well as other environmental phenomena that reflect the links of arctic ecosystems to global and regional ecological processes. The data base will be compiled and made available through a GIS facility established at Moscow State University.

Approach to making a new arctic vegetation map

The participants at the St. Petersburg workshop agreed that a new map should be derived from an electronic map data base that contains the latest state of knowledge and could be updated as new information comes available. Currently there is a need for two types of vegetation maps, one that displays the circumpolar distribution of biomass, and a second depicting regions with characteristic sets of vegetation types based on plant physiognomy and floristic composition. The first is important for numerous studies related to global carbon budgets and climate change and can be derived relatively quickly using remote-sensing technology. The second map requires the synthesis of existing vegetation information contained in many maps plus mapping of previously unmapped regions of the Arctic.

A proposed method was developed for the synthesis map at a small scale (compiled at about 1:5000000 scale and reduced to 1:7500000 scale). Regional experts would manually interpret regions with similar assemblages of vegetation. This would be done from combinations of aerial photographs and satellite images. Map-polygon boundaries would be interpreted from existing vegetation maps and guided by landscape units as they appear on false-color AVHRR images. The map would be based on the best information available and no field effort would be involved. Separate teams of scientists would work on vegetation maps for each of the circumpolar countries. Frequent communication between representatives from each country would be necessary to ensure uniformity of the maps. The separate maps would be assembled and recast into a single map with some simplification where necessary. Remote sensing and GIS technology now make map creation a dynamic process. The raw data can be continually updated and maps modified based on new information.

A framework for a three-level hierarchic legend was proposed for the map following a combined floristic -physiognomic-ecological approach (Sochava 1962). A derivative of Yurtsev' s (1994) north-south floristic zones would form the highest level of the hierarchy. The second level of the hierarchy would be derived from Yurtsev's east-west floristic sectors. The lowest level of the mapping would be based on physiographic, geo-morphic, and geologic boundaries that enclose areas with similar vegetation assemblages. The maps would employ matrices of supplemental information to characterize each map unit in terms of dominant phytosocio-logical units, dominant and differential plant species, characteristic parent material, and geomorphic situation.

Conclusion

The large amount of vegetation mapping done in all of the circumpolar countries is a valuable base for reinterpreting and synthesizing the vegetation of the circumpolar region into a single map. Russia, which covers the largest portion of the arctic region, also has the most complete coverage at useful scales. On the other hand, the Canadian Arctic still has large regions that have not been mapped. Presently, there is a confusion of terminology, legends, scales, mapping methods, and uneven distribution of mapping effort across the Arctic. The heritage of vegetation mapping and the legends developed at the Komarov Institute may serve as useful models for a unified approach to a circumpolar map. The first challenge will be to develop a legend and map terminology that all the circumpolar countries can agree on. This is no easy task because many of the terms commonly used in Russia have very different interpretations in the West. Toward this goal, the attendees agreed to meet again in Arendal, Norway in 1995 to discuss the issue of the unified vegetation legend. The attendees, who had primarily arctic tundra expertise, agreed that they would focus on the region north of tree line. A similar project is needed for the boreal forest region.

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