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The Map of the Natural Vegetation of Europe and its application in the Caucasus Ecoregion

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ABSTRACT. The Map of the Natural Vegetation of Europe was compiled and produced by an international team of leading geobotanists from 31 European countries over the period 1979 – 2003. The final results are available in printed and digital form, especially on an interactive CD-ROM with German and English texts. They include vegetation maps at the scales of 1: 2.5 and 1: 10 million, a hierarchically structured overall legend, a comprehensive explanatory text, and standardized digital data sheets with detailed information on 699 mapping units.

The digital database on CD-ROM facilitates a multitude of analyses and uses in the fields of research, teaching, information, and planning. Selected examples give a brief overview of the present application of the European map data. Thus the European vegetation map is very important for the development of a protected areas network in the Caucasus Ecoregion. *© 2007 Bull. Georg. Natl. Acad. Sci.*

Key words: *Map of potential natural vegetation, Europe, concept, published results, interactive CD-ROM, overall legend, digital data sheets, examples of application.*

1. Aims, Concept, and Substance of the European Vegetation Map Project

The objective of this international project was to prepare a map of the (potential) natural vegetation of Europe that is based both on a unified concept and the current state of knowledge. This was to be achieved through close co-operation between leading geobotanists from almost every country in Europe. In this undertaking, however, a major problem was to unite the different methods of recording, classifying and depiction of vegetation practised by the various phytosociological schools of Europe into a single concept that could be accepted and used by all participants in the project. Therefore a unified definition of the natural vegetation and its units, a unified means for processing and designating the mapping units as well as a systematic overall legend for their classification had to be developed.

As a result the experts proposed a hierarchic classification system that combines the principles of different schools of vegetation science. It takes into account vegetation-specific criteria at different levels based on

- structure and physiognomy of the plant cover (main formations and formation complexes) at the highest level, and
- dominant species and characteristic species combination as well as further floristic differentiation at lower levels.

The highest position is occupied by climatically or edaphically-based zonal and vertical, as well as azonal, primary formations. At the next level the vegetation is subdivided into (sub)zonal or geographically separate formations or supra-ordinate vegetation types with domi-

nant species or specific species combinations in the main layer (usually the tree layer). In the following levels, further differentiation is based on sub-zones (e.g. northern, central, southern boreal), altitudinal belts (e.g. lowland, colline, montane) as well as trophy levels and other soil-related differences (acidophilous, oligotrophic, hygrophilous etc.).

The purpose of mapping the potential natural vegetation is to reproduce the **current natural site potential** based on vegetation types. This is the result and expression of what might grow on its own accord as determined by the indigenous plant species, as well as by the climatic (temperature, precipitation and their seasonal distribution) and edaphic conditions (structure and texture, water balance, nutrient supply of soils) that prevail in the different areas of Europe.

The effects of direct human intervention and utilisation, as well as large-scale changes in the environmental conditions caused by air and water pollution and recent climatic changes, are not taken into consideration. The map of the natural vegetation of Europe therefore displays the potential distribution of the dominant natural plant communities consistent with the current climatic and edaphic conditions.

The determination of the structure and composition of the potential natural vegetation is principally based on surviving remnants of natural and near-natural ecosystems and their correlation with site-specific conditions (climate, soil, temperature, nutrient and water balance) and the distribution of characteristic and differential plant species.

2. Implementation of the Mapping Project

The initiative steps were taken by Paul Ozenda, Grenoble, Werner Trautmann, Bonn, and Eugenij M. Lavrenko, Leningrad, during the XIIth International Botanical Congress in Leningrad in 1975. Afterwards P. Ozenda, W. Trautmann and R. Neuhäusl were sending invitations for pan-European cooperation to prominent geobotanists of Europe.

After publishing the preceding 1st edition of the Vegetation Map of the European Council Member States at the scale 1 : 3 million [1], the first common and decisive meeting with predominance of east European scientists took place in Czechoslovakia 1979 [2]. Since that time numerous international meetings and workshops were held until 2001.

The three main coordination centres for the Project implementation were:

• the **Komarov Botanical Institute** of the **Russian Academy of Sciences**, Department for Vegetation Geography and Cartography, in St. Petersburg for the USSR area (S. A. Gribova, Z. V. Karamyševa, T. K. Jurkovskaja, and collaborators),

• the **Botanical Institute** of the **Czech Academy of Sciences** in Pruhonice near Prague (R. Neuhäusl, Z. Neuhäuslová, and collaborators) and

• the **Federal Agency for Nature Conservation** (formerly: Federal Research Center for Nature Conservation and Landscape Ecology) in Bonn (W. Trautmann, U. Bohn, and collaborators). U. Bohn was principal coordinator of the Project since 1991, succeeding the late R. Neuhäusl, who was successful principal coordinator 1979–2001.

The **mapping area** (see Figure 1) is comprising the entire territory of Europe, including Iceland, Jan Mayen, Svalbard, Franz Josef Land and Novaya Zemlya, the Ural Mountains, Ural river and Caspian Sea marking the eastern boundaries, including the Caucasian states Georgia, Armenia and Azerbaijan. The Atlantic islands Azores, Madeira and the Canary Islands are excluded.

3. Final Results of the Mapping Project

The final results of the Pan-European Mapping Project – after 25 years of intensive international co-operation – are now available in printed and digital form. They can be manifold used for information, research, teaching, evaluation and planning [3]. They include:

The Map of the Natural Vegetation of Europe at the scale of 1 : 2.5 million (consisting of 9 map sheets, 1 legend sheet with German and English text)

The General Map at the scale of 1 : 10 million with 77 aggregated map units (this is the reduced and generalized version of the 1 : 2.5 million map; see Figure 1)

The overall Legend with 699 mapping units in German and English (hierarchical classification into 19 main formations and formation complexes as well as further sub-classification at various levels)

Detailed Explanations for each mapping unit in the form of standardized data sheets on CD-ROM (with information on distribution, structure and floristic composition of the natural vegetation, syntaxonomy, site conditions, conservation status and representative stands of near-natural vegetation, land use, current substitute vegetation, most important references, etc.)

A comprehensive Explanatory Text, with information on

– The Project history,

– Basic material for the European vegetation map (vegetation maps and other baseline data of the participating countries),

– Concept of the vegetation map (content and mapping principles),

– Physiographical, climatic and phytogeographical classification of Europe,

– Late- and post-glacial vegetation history of Europe,

– Characterization and classification of the natural vegetation formations as main part (14 zonal and 5 azonal formations and their further subdivision down to the level of mapping units),

– Additional overview maps on distribution and classification of the individual main formations,

– List of the mentioned plant taxa (on CD-ROM),

– Detailed list of contributors,

– Glossary of technical terms,

– Literature.

An **Interactive CD-ROM** of the Map of the Natural Vegetation of Europe providing digital access to all the maps and textual information, both in German and English version [4]. The interactive digital data availability on CD-ROM offers the possibility of analysing the map content in a variety of ways by linking the digital map data with those of the overall legend, the data sheets, the references, the list of plant taxa, the explanatory text, and other information or external GIS data.

Proceedings of the Vilm workshop 2001 with international contributions and examples on the application and analysis of the European Vegetation Map [5].

These comprehensive complete works provide a unified vegetation and ecological database for the whole of Europe for the first time. (All publications can be ordered from the German Landwirtschaftsverlag in Münster)

4. Structure of the Overall Legend

The fundamental units of the vegetation map, that are characterized by a specific species combination of the dominant plant community and/or by a region- and site-specific community mosaic, are linked into a hierarchically structured classification system within the framework of the overall legend.

The main groups of this system form 19 physiognomic-structurally and ecologically characterised **formations** and **formation complexes**, of which 14 (A to O) represent the macroclimatic zones in a sequence from the north to the south and south-east of Europe, as well as the corresponding altitudinal belts in the mountain ranges. Their differentiation and spatial sequence is determined primarily by the temperature gradient: from cold and humid to warm and dry climates. The last 5 formations (P to U) are listed as azonal vegetation types characterized by predominantly edaphic site factors, such as the presence of saline or wet soils, and are modified only secondarily by macroclimatic factors. The individual main formations are labelled in abbreviated form (as a code for the vegetation map) with capital letters in alphabetical order (see key of Figure 1). In this way each mapping unit can be assigned rapidly and unambiguously to the respective main formation in the map.

Corresponding vegetation types with similar structure and species composition, such as polar deserts and subnival vegetation of high mountains or tundras and alpine vegetation, are combined in one formation group because of their close structural, floristic and climatic relations.

List of main formations

Classification according to physiognomy and environmental conditions

Zonal and extra zonal vegetation (depending primarily on climate)

A Polar deserts and subnival-nival vegetation of high mountains (6 units)

B Arctic tundras and alpine vegetation (59 units)

C Subarctic, boreal and nemoral-montane open woodlands, as well as subalpine and oro-Mediterranean vegetation (47 units)

D Mesophytic and hygromesophytic coniferous and mixed broad-leaved-coniferous forests (64 units)

E Atlantic dwarf shrub heaths (14 units)

F Mesophytic deciduous broad-leaved and mixed coniferous-broad-leaved forests (172 units)

G Thermophilous mixed deciduous broad-leaved forests (77 units)

H Hygro-thermophilous mixed deciduous broad-leaved forests (3 units)

J Mediterranean sclerophyllous forests and scrub (53 units)

K Xerophytic coniferous forests and scrub (33 units)

L Forest steppes (meadow steppes alternating with deciduous broad-leaved forests) and dry grassland with xerophytic scrub (17 units)

M Steppes (21 units)

N Oroxerophytic vegetation (thorn-cushion communities, tomillares, mountain steppes, partly scrub) (8 units)

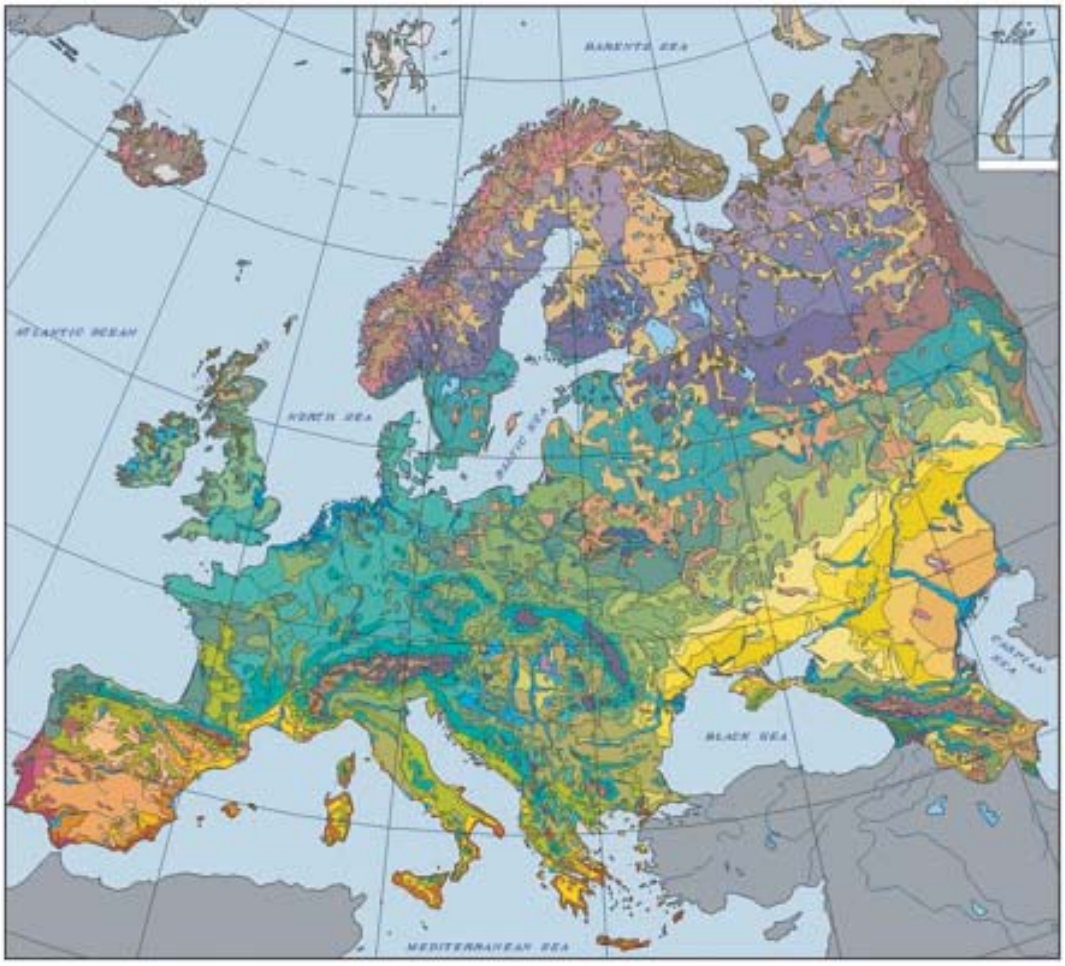
O Deserts (10 units)

Azonal vegetation (determined by specific soil properties and hydrological conditions)

P Coastal vegetation and inland halophytic vegetation (36 units)

R Tall reed vegetation and tall sedge swamps, aquatic vegetation (4 units)

General Map of the potential natural vegetation of Europe



Based on: BOHN/NEUHÄUSL et al (2000)
(scaled-down version of the generalized map at a scale of 1:10,000,000)

Source: Federal Agency for Nature Conservation (BfN), 2002

A1	D2	E	G4	K2	O2
A2	D3	a b F1	H	K3	P1
B1	D4	F2	a b J1	K4	P2
B2	D5	F3	a b J2	a b L1	R
B3	D6	a b F4	J3	L2	S1
B4	D7	a b F5	J4	a b M1	S2
B5	a b D8	F6	J5	a b M2	S3
C1	D9	F7	J6	M3	T
C2	D10	G1	J7	M4	U1
C3	a b D11	G2	J8	N	U2
D1	a b D12	G3	K1	O1	

Fig. 1. Reduced General Map of the Natural Vegetation of Europe (1:10 million) with main formations and sub-formations (source: BfN 2002).

Key to the General Map of the Potential Natural Vegetation of Europe (Figure 1)

A1, A2	**Polar deserts and subnival-nival vegetation of high mountains**
B	**Arctic tundras and alpine vegetation**
B1-B4	Arctic tundras
B5	Alpine vegetation in the boreal, nemoral and Mediterranean zones
C	**Subarctic, boreal and nemoral-montane open forests, as well as subalpine and oro-Mediterranean vegetation**
C1, C2	Boreal (open) forests and nemoral-montane birch forests, partly with pine forests
C3	Subalpine and oro-Mediterranean vegetation
D	**Mesophytic and hygromesophytic coniferous and mixed broadleaved-coniferous forests**
D1-D3	Western boreal spruce forests
D4-D7	Eastern boreal pine-spruce and fir-spruce forests
D8	Hemiboreal spruce and fir-spruce forests with broadleaved trees
D9	Montane to altimontane fir and spruce forests in the nemoral zone
D10-D12	Boreal, hemiboreal and nemoral pine forests
E	**Atlantic dwarf shrub heaths**
F	**Mesophytic deciduous broadleaved and mixed coniferous-broadleaved forests**
F1	Acidophilous oak and mixed oak forests, poor in species
F2	Mixed oak-ash forests
F3	Mixed oak-hornbeam forests
F4	Lime-oak forests
F5	Beech and mixed beech forests
F6	Oriental beech forests
F7	Caucasian mixed hornbeam-oak forests
G	**Thermophilous mixed deciduous broadleaved forests**
G1, G2	Subcontinental and sub-Mediterranean-subcontinental thermophilous (mixed) oak forests
G3, G4	Sub-Mediterranean and meso-supra-Mediterranean mixed oak forests
H	**Hygro-thermophilous mixed deciduous broadleaved forests**
J	**Mediterranean sclerophyllous forests and scrub**
J1-J4	Meso- and supra Mediterranean, as well as relict sclerophyllous forests
J5-J8	Thermo-Mediterranean sclerophyllous forests and xerophytic scrub
K1-K4	**Xerophytic coniferous forests and scrub**
L1, L2	**Forest steppes (meadow steppes or dry grasslands alternating with deciduous broadleaved forests or xerophytic scrub)**
M	**Steppes**
M1-M3	Herb-rich and pure feather grass steppes
M4	Desert steppes
N	**Oroxerophytic vegetation (thorn cushion communities, tommilares, mountain steppes, partly scrub)**
O1, O2	**Dwarf semishrub deserts**
P1, P2	**Coastal dune and (inland) halophytic vegetation**
R	**Tall reed and tall sedge swamps, aquatic vegetation**
S1-S3	**Mires**
T	**Fen and swamp forests**
U1, U2	**Vegetation of floodplains, estuaries and freshwater polders**

S Mires (25 units)
T Fen and swamp forests (7 units)
U Vegetation of flood-plains, estuaries and fresh water polders and other moist or wet sites (42 units)

The formations are divided into subgroups according to their species composition, the finer climatic differences and larger-scale site conditions. The subzones are arranged from north to south and south-east, oceanity or continentality classes from west to east. These in turn are subdivided according to nutrient supply, altitudinal belts, water balance and geographical location (see key of Figure 1).

The approximately **700 mapping units** form the basic elements of the vegetation map. Because of the small scale, we are always dealing with characteristic, area- or habitat- specific complexes of various (potential) natural plant communities. Of these, usually one particular community is dominant, and this gives the unit its name. The **name of a mapping unit** reflects in general its (bio)geographic distribution, physiognomy (e.g. tundra, grassland, heath, forest, mire) and the characteristic, as well as the dominant plant species of the main vegetation types.

5. Examples of Using the European Vegetation Map Data

As soon as the data of the Vegetation Map of Europe became available in digital form there were numerous requests to make it available for analyses and appli-

cation on a European, national or regional level.

The European Topic Centre on Nature Conservation (ETC/NC) in Paris was the first to use the map for an ecological classification of Europe combining vegetation and climatic data [6]. Further analysis and evaluation of the map for an ecological classification of Europe for nature conservation purposes and reporting on forest resources was undertaken in collaboration with the WWF-US, WWF-International and FAO. In this context the map was used to develop maps of "Terrestrial Ecoregions of the World" [7] and a "Global Ecological Zones Map" within the scope of the "Forest Resources Assessment Programme 2000" of the FAO [8]. Here, the broad division of the vegetation map into climate-zonal and regional (phytogeographical) super-units was employed to obtain a global overview.

Furthermore, the digital data of the 1:10 million and 1:2.5 million maps have served as a reference for determining gaps and deficiencies in the European network of protected areas for natural vegetation types and ecosystems (biosphere reserves, national parks, strict nature reserves, Natura 2000 sites). The World Conservation Monitoring Centre (WCMC) in Cambridge, UK, used the digital map data in collaboration with WWF-International for a "Gap Analysis of Protected Forest Areas in Europe" [9].

6. Examples of Application in the Caucasus Ecoregion

The Caucasus is distinguished both by the uniqueness and the high level of its biodiversity (Table 1). At the same time, the unique biodiversity of the Caucasus region is subjected to strong human impacts, which pose a threat not only to individual species but also to the balance of ecosystems. The Caucasus has been identified as one of the Earth's 25 biologically richest and most endangered terrestrial ecoregions, along with the Tropical Andes, Brazil's Atlantic Forest, Madagascar, the Mediterranean Basin, the Philippines and New Zealand.

Table 1.

Main formations of the Caucasus Ecoregion (according to the Natural Vegetation of Europe)

A. Subnival-nival vegetation (2900-3000 and 3600-3700

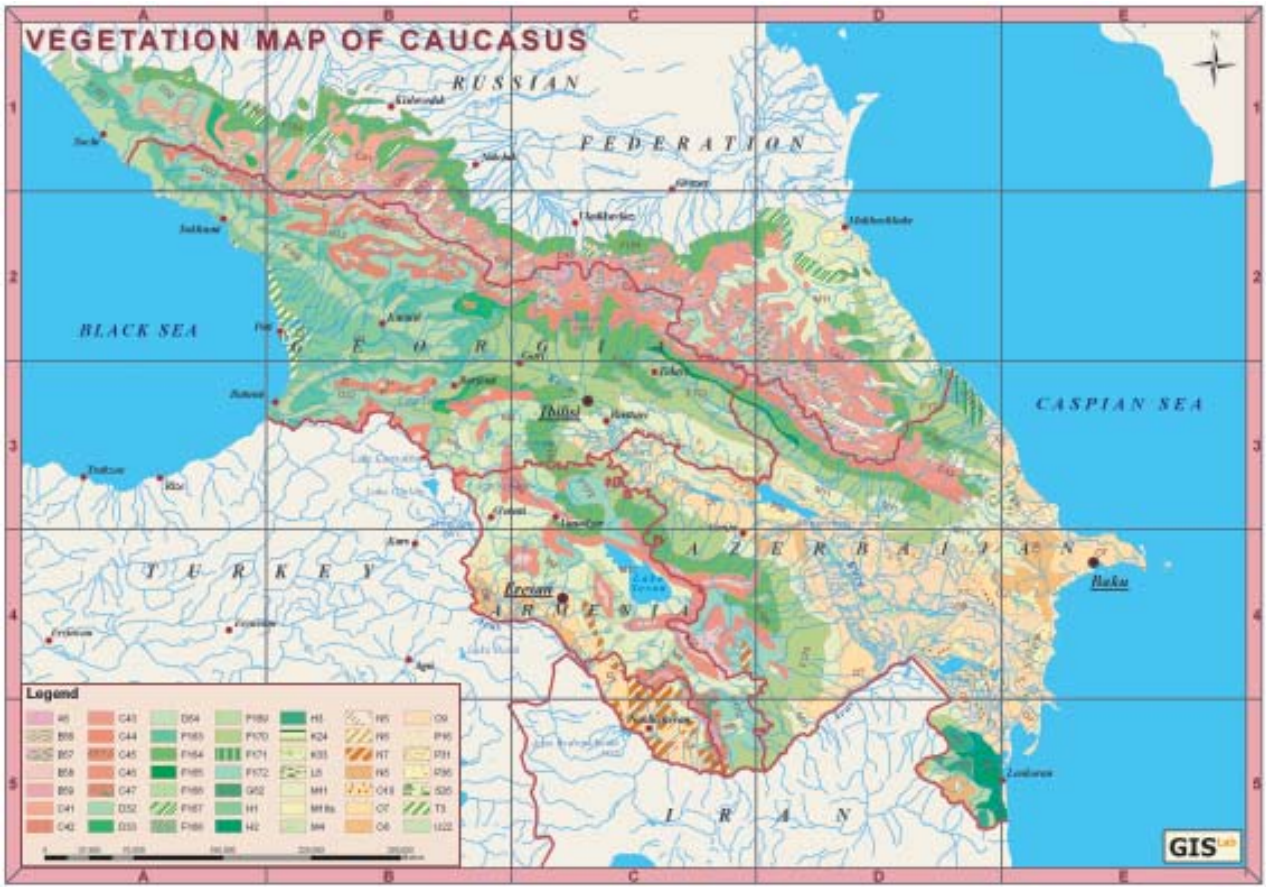


Fig. 2.

m) is quite pronounced in the Caucasus. The number of species amounts to 300, although the number of typical subnival plants is much less (70-80 species). The most noteworthy are monotypic endemic genera: *Pseudovesicaria, Symphyoloma, Pseudobetckea, Trigonocaryum,* a Minor Asian-Caucasian monotypic genus *Vavilovia,* a Caucasian-Asian genus *Didymophysa.* Endemic and Minor Asian-Caucasian taxa occur in every part of the Caucasus.

B. Alpine vegetation on carbonate and silicate strata (2400-2900 m). The Caucasian alpine vegetation consists of alpine tussock meadows, carpet-type phytocenoses and prostrate shrubbery (*Rhododendron caucasicum*). In the south-eastern part of the Caucasus, where the influence of Iranian-Minor Asian continental climate is evident and the precipitation is lower than 1000 mm, no carpet vegetation can be found and meadow steppes predominate.

C. Caucasian crooked and open woodlands (C41-C47). The subalpine belt of the Caucasus stretches from 1800 (2000) to 2400 (2700) m. Mesophilous vegetation such as crooked forests, shrubbery of *Rhododendron caucasicum,* tall herbaceous vegetation and grasslands are spread there.

D. Mesophytic and hydromesophytic coniferous and mixed forests made up of *Abies nordmanniana, Picea orientalis, Taxus baccata, Pinus kochiana, Populus tremula.*

F. F6. Caucasian oriental beech and oriental beech-hornbeam forests. This group includes mountain summer-green deciduous forests distributed between the Black and Caspian Seas. The forests are spread in the middle and upper mountain belts between 1000-1600 (1900) m. Evergreen shrubs (*Prunus laurocerasus, Rhododendron ponticum* etc.) grow in beech forest understorey in strongly humid conditions of Colchis.

F7. Hornbeam-oak mixed forests of the Caucasus. All the mesophilous, thermophilous and xerophilous hornbeam-oak mixed forests of Crimea/Caucasus pertain to this formation.

G Thermophilous mixed deciduous broad-leaved forests made up of *Quercus pedunculiflora, Q. petraea, Carpinus orientalis.*

H. Hygro-thermophilous mixed deciduous broad-leaved forests. This vegetation is spread in two different regions: the Colchic lowland at the Black Sea (Georgia) (*Quercus imeretina, Q. hartwissiana, Daphne pontica, Rhododendron ponticum, Prunus laurocerasus* etc.) and Talysh mountains on the south-western side of the Caspian Sea (Azerbaijan) (*Quercus castaneifolia, Parrotia persica, Albizzia julibrissin* etc.). *Zelkova carpinifolia, Carpinus caucasicus, Fagus orientalis* etc. occur in both regions. The forests are specifically diverse and rich in endemic taxa and relicts of the Tertiary.

M. Steppes in the Caucasus are spread north of the Black Sea, on the Caspian lowland, in East Georgia and mountainous regions in a form of islets. The main constituents are: from grasses – *Stipa pulcherrima, Festuca valesiaca,* etc.; from forbs – species of *Dianthus, Salvia, Onobrychis, Astragalus*; from tuberous and bulbous plants – species of *Tulipa, Crocus, Gagea, Iris,* etc.

N. Oreoxerophytic vegetation is characterized by high ecological and biomorphological specialization of species. These plants are adapted to winter cold, summer dryness, high solar radiation. The main constituents are: *Astragalus caucasicus, A. microcephalus, A. denudatus, Onobrychis cornuta, Acantholimon spp.,* etc.

O. Deserts in the Caucasus are spread in the Caspian depression, valleys of the rivers Kura and Arax and also in a form of small fragments in various regions of the South Caucasus including southern and eastern parts of Georgia. Species of *Artemisia* (*A. lerchiana, A. pauciflora, A. splendens*), representatives of Chenopodiaceae (species of *Anabasis, Salsola*), *Astragalus, Atraphaxis, Haloxylon, Calligonum* predominate in the desert. Ephemers and ephemeroids are distinguished by high coverage.

Humans have inhabited the Caucasus for thousands of years, impacting natural systems in many ways. During the last decade the countries of the Caucasus Ecoregion have been catapulted into severe economic crises, resulting in the expansion of illegal logging and trade in timber and other resources, the increasing dependence of local communities on firewood for fuel, and uncontrolled hunting. These pressures, coupled with oil and gas exploitation and transport, agriculture, and overgrazing, have led to degradation of biodiversity in the Caucasus Ecoregion, leaving less than 12 percent of the region's natural habitats in their original state.

Within the frame of this article, the Caucasus Ecoregion denotes a total area of 440,000 km² including the territories of Armenia, Azerbaijan, and Georgia, in addition to the North Caucasus portion of the Russian Federation.

The establishment of a system of protected areas in the Caucasus Ecoregion is considered below. There is a long tradition of nature conservation in the Caucasus. The first strict nature reserve in the region was created in 1912 in Lagodekhi Gorge on the south-eastern slopes of

the Great Caucasus Range in Georgia. Today, there are 40 strict nature reserves and 6 national parks conserving the biodiversity in the Caucasus Ecoregion. According to the data for January 2002. This system of nature reserves covers a total land area of 13,122 km² or three percent of the Caucasus. An additional 2,116 km² area of marine and lake habitats is included in strictly protected reserves in the Ecoregion. If multi use sanctuaries and protected forests (IUCN categories IV to VI) are added, then more than 12 percent of the Ecoregion is formally afforded some form of protection. Nevertheless, most of the reserves are too small and isolated to guarantee long-term biodiversity conservation, or their status of protection is insufficient to preserve the ecosystems within. Furthermore, violations of protected area regimes, such as poaching and grazing, are on the rise due to the economic crisis.

Management for biodiversity conservation is however only really effective in strict nature reserves and national parks, and sometimes in sanctuaries. Outside these reserves, the safety of natural ecosystems is more related to their inaccessibility (e.g., narrow gorges with steep slopes) and the level of infrastructure (e.g., absence of roads) than with their protection regimes. Generally, in these areas the protection regimes are insufficient to preserve the ecosystems within. Even most strict nature reserves and national parks are too small to guarantee long-term biodiversity conservation, and the protection regime is not always properly enforced.

Furthermore, the existing protected areas network is not entirely representative of the full range of biodiversity in the Ecoregion. Saving the unique ecosystems and endangered species of the Caucasus Ecoregion requires linking the protected areas through a system of corridors and stepping stones, and creating new protected areas where gaps exist. Most of the countries in the Caucasus Ecoregion have plans to set aside new territories for protection, but an Ecoregion approach is important for determining conservation needs and how to connect the existing territories on à larger scale. A strategically planned network of protected areas (Econet) for the Caucasus should incorporate strict nature reserves, national parks, and other areas of high conservation value (IUCN categories 1 and II) as large core areas or nodes, and use sanctuaries, protected forests, and other multiple use areas (IUCN categories IV VI) as stepping zones and corridors between the nodes.

The Map of Natural Vegetation of Europe [3] depicts the basic ecosystem diversity of the Caucasus region (see Figure 2). A preliminary small-scale spatial analysis of the vegetation formations, sub-formations and mapping units (as integrated components of the main ecosystems) in connection with distribution of the existing protected areas sets the stage for strategic planning of a regional Econet.

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1979-2003 წლებში ევროპის 31 ქვეყნის წამყვანი გეობოტანიკოსების ჯგუფმა შეადგინა და გამოსცა „ევროპის ბუნებრივი მცენარეულობის რუკა“. სამუშაოს საბოლოო შედეგები არსებობს ბეჭდვითი და ელექტრონული სახით, კერძოდ, ინტერაქტიური CD-ROM-ის სახით გერმანული და ინგლისური ტექსტებით. შედეგები მოიცავს მცენარეულობის რუკებს მასშტაბით 1:2.5 მლნ-დან 1:10 მლნ-მდე, იერარქიული სტრუქტურის მქონე საერთო ლეგენდას, ამომწურავ ახსნა-განმარტებით ტექსტსა და მონაცემთა სტანდარტიზებულ ელექტრონულ ფურცლებს დეტალური ინფორმაციით რუკის 699 ერთეულის შესახებ. CD-ROM-ზე არსებული ელექტრონული მონაცემთა ბაზა აიოლებს მონაცემთა მრავალგვარ ანალიზს და გამოყენებას პოვებს კვლევის, განათლების, საინფორმაციო და დაგეგმარების დარგებში. კავკასიის ეკორეგიონში ევროპის რუკის თანამედროვე გამოყენება ილუსტრირებულია რჩეული მაგალითებით. ამ რუკას დიდი მნიშვნელობა აქვს კავკასიის ეკორეგიონში დაცული ტერიტორიების განვითარებისათვის.

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