Forestry Department
Food and Agriculture Organization of the United Nations

FRA 2000

GLOBAL ECOLOGICAL ZONING FOR THE GLOBAL FOREST RESOURCES ASSESSMENT 2000

FINAL REPORT

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The Forest Resources Assessment Programme

Forests are crucial for the well-being of humanity. They provide foundations for life on earth through ecological functions, by regulating the climate and water resources and by serving as habitats for plants and animals. Forests also furnish a wide range of essential goods such as wood, food, fodder and medicines, in addition to opportunities for recreation, spiritual renewal and other services.

Today, forests are under pressure from expanding human populations, which frequently leads to the conversion or degradation of forests into unsustainable forms of land use. When forests are lost or severely degraded, their capacity to function as regulators of the environment is also lost, increasing flood and erosion hazards, reducing soil fertility and contributing to the loss of plant and animal life. As a result, the sustainable provision of goods and services from forests is jeopardized.

FAO, at the request of the member nations and the world community, regularly monitors the world's forests through the Forest Resources Assessment Programme. The next report, the Global Forest Resources Assessment 2000 (FRA 2000), will review the forest situation by the end of the millennium. FRA 2000 will include country-level information based on existing forest inventory data, regional investigations of land-cover change processes and a number of global studies focusing on the interaction between people and forests. The FRA 2000 report will be made public and distributed on the World Wide Web in the year 2000.

The Forest Resources Assessment Programme is organized under the Forest Resources Division (FOR) at FAO headquarters in Rome. Contact persons are:

Robert Davis	FRA Programme Coordinator	robert.davis@fao.org
Peter Holmgren	FRA Project Director	peter.holmgren@fao.org

or use the e-mail address: fra@fao.org

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Paper drafted by: Henk Simons, FAO-FRA Programme
Editorial production by: Patrizia Pugliese, FAO-FRA Programme

Abbreviations

CEC	Commission for Environmental Cooperation (Canada, USA, Mexico)
DEM	Digital Elevation Model
EDC	Eros Data Center of the United States Geological Survey
EFZ	Ecofloristic Zone
EZ	Ecological Zone or Zoning
FAO	Food and Agricultural Organization of the United Nations
FRA	Forest Resources Assessment (Programme)
FRA 2000	Global Forest Resources Assessment 2000
GEZ	Global Ecological Zone (or Zoning)
GIS	Geographic Information System
IIASA	International Institute for Applied System Analysis
IRSA	Institute for Remote Sensing Applications, Chinese Academy of Sciences
LET	Laboratoire d'Ecologie Terrestre
LUT	Look-up Table
WCMC	World Conservation Monitoring Centre
WWF	World Wide Fund for Nature

Definitions

Domain

Broadest entity or level in classification, equivalent to the five thermic Köppen - Trewartha climatic groups and including the tropical, subtropical, temperate, boreal and polar domain.

Ecological Zone

Defined as a zone or area with broad yet relatively homogeneous natural vegetation formations, similar (not necessarily identical) in physiognomy. Boundaries of the Ecological Zones approximately coincide with Köppen- Trewartha climatic types, which are based on temperature and rainfall. An exception to this definition are "mountain systems", classified as one separate Ecological Zone in each domain and characterized by a high variation in both vegetation formations and climatic conditions.

Mountain systems

Mountain systems are defined as zones/areas that have a distinctly different vegetation (and climate) than the surrounding lowlands at a given latitude. Mountain vegetation is usually lower and the floristic composition is different (with generally fewer species). Additional components to define mountain systems are altitude and steepness of slopes. It is difficult to select specific altitudinal thresholds for defining mountain systems also as the changes in vegetation are often gradual, however they are usually at around 1000 - 1200 meter in the tropics and decrease with higher latitudes.

Physiognomy

Covers all aspects of the structure of vegetation, such as height, (tree) density, thorniness, deciduousness, life forms, etc.

Abstract

A global ecological zoning (GEZ) map and database has been developed for the "Global Forest Resources Assessment 2000" (FRA 2000) conducted by the United Nations Food and Agriculture Organization. The underlying strategy for FRA's ecological zoning closely reflects both the thematic and technical requirements of the map and the many operational constraints for implementation. Characteristics and components of the FAO EZ classification include the use of the Köppen-Trewartha system (1968), with some modifications, in combination with vegetation characteristics as a basis for the delineation of zones. A key event in the development of the map was the Cambridge expert consultation, July 1999, where the concepts and proposed classification system were discussed, amendments made and a final classification system adopted. The GEZ classification system has a hierarchic structure: at the broadest level 5 domains are distinguished and at the second level 20 global Ecological Zones. The mapping work was carried out principally using regional or national "potential vegetation" maps to define boundaries of Ecological Zones at the global level. Regional experts and scientists provided support and advice. Although using a variety of map inputs inevitably provoked methodological problems such as edge matching across adjacent maps, a protocol for correcting such problems was successfully developed and implemented. In addition to the global EZ map regional descriptions were prepared on vegetation, climate and physiography of the Ecological Zones. The report is divided into three sections:

- Part I presents the GEZ classification framework;
- Part II explains how the map was developed; and
- Part III contains the descriptions of the GEZ for each region.

PART I: CLASSIFICATION FRAMEWORK

1 Introduction

The United Nations Food and Agriculture Organization regularly reports on the world's forest resources through the Forest Resources Assessment Programme (FRA), which is now actively facilitating the execution of the Global Forest Resources Assessment 2000 (FRA 2000)[1]. Along with the core information on the state and changes in forests, FRA 2000 will report on various ecological aspects of forests. In doing so, the assessment will provide new information on forests by ecological zones and contribute to understanding the implications of forest change on biological diversity, sustainable forest management, protection and carbon-cycling processes.

While the FRA 2000 EZ map is unique in its global character, a similar map was developed by FAO in 1990 for the ecological zoning of the tropics. The map was used to report forest state and change statistics by ecological zone and for stratification in deforestation modelling and the remote sensing survey. The EZ work for FRA 2000 is seen as a logical continuation and expansion of the tropical ecological zoning done for the previous assessment. Because of the limited geographic coverage and increased resolution, FRA 1990 was able to delineate detailed *ecofloristic zones*[2], as well as at the more general *ecological zones* applicable at regional and global levels. To ensure compatibility of the 1990 EZ map with the 2000 global exercise, FAO in co-operation with the Laboratoire d'Ecologie Terrestre (LET) in France, has updated the tropical *ecological zones*, producing a fully compatible ecological zoning map for the tropics based on the 2000 criteria. At the same time, FAO and LET have also revised the more detailed *ecofloristic zones* for the tropics using new maps and information available since 1990.

[1] Experts in forest resources from member countries, international and national organisations, NGO's and individuals contributed to planning FRA 2000. During 1996, the international forestry community provided important recommendations to the planning of FRA 2000 through a number of meetings, culminating with the "Expert Consultation on Global Forest Resources Assessment 2000" held in Kotka, Finland during June 1996. This meeting, referred to as *Kotka III*, considered the reporting of forest information by Ecological Zones as a high priority and advised FAO to develop the ecological zoning map required for the task. Following Kotka III, in 1997, the Fourth Session of the UN Intergovernmental Panel on Forests (IPF IV) expressed strong support for FRA 2000, the Kotka III recommendations and FAO's role as facilitator for the execution of FRA 2000. In March 1997, FAO's Committee on Forestry (COFO 1997) and FAO's member countries endorsed Forest Resources Assessment as one of FAO Forestry's highest priorities.

[2] The term *ecofloristic zone* utilised by the FRA 1990 map identifies the most detailed ecological units where floristic composition played a major role in their identification and delineation. In contrast, the term *Ecological Zone* denotes the more generalised units for the 1990 map correlating well with climatic and physiography. As the global zoning is conducted at a more generalized level, the term *Ecological Zone* has been retained to describe the mapping units contained within the FRA 2000 global ecological map.

2 FAO Requirements

Many environmental problems are no longer national or regional in character and must be addressed in a global context. Aggregating information on forest resources by ecological zones organises reporting according to the natural characteristics of the vegetation, rather than along national boundaries, which frequently cut across natural ecosystems. Through reporting by ecological zones, valuable insight is obtained regarding characteristics of forest resources, which may serve to identify and resolve issues of importance to many countries, entire regions or even the planet as a whole.

To achieve meaningful reporting, classes in a global ecological framework must identify and accurately group broad yet relatively homogenous natural formations of forest vegetation. The global classification cannot be overly detailed, which would likely confuse reporting by fragmenting major global ecosystems and risk creating an incomprehensible number of classes. Conversely, an overly simplistic scheme could degrade the utility of the map by representing too few classes of forests and aggregating too wide a variety of forests within the same zone.

While most countries have nationally appropriate means of compiling information according to ecologically meaningful units, the practical tools needed to aggregate and compile forest information by these units at the global level do not presently exist. This is due in part to the fact that, in the past few applications have required analysis and reporting by ecological zones at the global scale. However, global applications of ecological zoning are expected to gain prominence as a result of increases in information needs relating to climate change (Kyoto Protocol) and biodiversity conservation, as well as for FAO's global assessments.

According to the Kotka III meeting, FRA 2000 was asked to deliver specific information to the world community by ecological zones at the global level, including:

- Area of forest and other wooded lands (year 2000)
- Change in forest and other wooded lands (1990 – 2000)
- Number, area and status of protected areas
- Forest volume and biomass
- Forest fires

In order to fulfil the information requirements for FRA 2000, a spatial ecological zoning database, which is geographically registered and sufficiently reliable at the global scale, is needed. Such a database should also be the product of an international effort carried out under FAO's guidance, due to the need for broad acceptance of the approach by many countries.

3 Concept and classification

3.1 Approach and principles of the FAO Ecological Zoning

The underlying strategy for FAO-FRA ecological zoning reflects both the thematic and technical needs of the map as well as the many operational constraints that were expected in its development. In terms of ecosystem principles, the map requirements are such that zones or classes are defined and mapped using a holistic approach. That is, both biotic and abiotic components of ecosystems are considered in the zoning scheme. Beyond the thematic content and zoning, practical aspects of digital cartographic production, such as data availability, currency, scale and associated reliability of the map inputs were taken into account.

To identify specific alternatives and constraints in the development of a global EZ map appropriate for FRA2000 purposes, FAO conducted two preliminary studies (Zhu, 1997 and Preto, 1998). Findings from these studies, experience in the development of the tropical EZ map for FRA 1990 and recommendations from other parties consulted in the process indicated that the development of an *entirely new* global ecological zoning map by FAO could not be completed by the year 2000, due to time constraints and the large amount of scientific, organisational and financial resources required. With this in mind, follow-up investigation focused on identifying an existing scheme that might be used or adapted to FAO's needs.

Due to the enormity of conducting the work on a global scale, the most appropriate classification scheme had to meet FAO's thematic requirements, be practical to construct with available resource and meet the scrutiny of a diverse group of users from all parts of the world. A survey of existing schemes revealed several possibilities. Each of the existing schemes were developed for specific purposes according to various environmental criteria, with macroclimate as an element being used by most (Preto 1998 and WCMC 1992). This is logical, as the macroclimate, that is temperature and precipitation, correlates well with the potential vegetation associated with a particular locale. In this respect, macroclimate was considered a logical basis for the FRA ecological zoning as well.

For the choice of climatic parameters to be used in the FRA 2000 map a number of global systems were surveyed including Köppen modified by Trewartha (Köppen, 1931, Trewartha, 1968), Thorntwaite (1933) and Holdridge (1947). Out of these possibilities, initial work indicated Köppen-Trewartha was a good candidate for the FRA 2000 work due to the number of classes that corresponded well to FRA 2000 needs. Moreover, further study showed that while Köppen-Trewartha is based on climate there is a demonstrated good correspondence between its subzones or climatic types and the natural climax vegetation types and soils within them (Bailey 1996)[3]. These factors were seen as major advantages in favour of using the Köppen-Trewartha system for the backbone of the FRA 2000 zoning.

[3] This is largely because Köppen derived his climate classes from observations on the distribution of natural vegetation types on various continents (Köppen 1931).

One good precedent for using Köppen in global ecological zoning was carried out by Robert Bailey, who used the Köppen-Trewartha system in toto for development of his ecoregion scheme for North America and the rest of the world (1989, 1995, 1998). He noted that although ecological zones can be mapped by reference to a single feature (such as climate), they must always be checked to ensure that the boundaries have ecological significance. At the same time, a climatic map showing such key features as temperature and precipitation is not necessarily an ecological map until the boundaries are shown to correspond to significant biological boundaries. Likewise maps of landform types (derived from digital elevation data) are not necessary ecological maps until it has been shown that the types co-vary with other components of the ecosystem, such as vegetation (Bailey, personal communication 1998).

To further the development of the work, FAO in cooperation with EDC and WCMC developed a prototype zoning scheme for FRA 2000 based on Köppen-Trewartha. The zoning was made hierarchical using Köppen-Trewartha's climatic groups and - types as FAO Ecological Zone levels 1 and 2. A third level was also tested during the pilot project and represents the differentiation within the first two levels according to landform. Mountains with altitudinal zonation were distinguished from lowland plains.

In practical terms, delineation of EZ level 2 adapting Köppen-Trewartha's climatic types was proposed as the working level for definition and mapping of Global classes. This will be accomplished by using both macroclimatic data[4] and existing climax or potential vegetation maps. Use of vegetation maps will assure a more precise delineation of the Ecological Zones[5]. Using generalised climate maps alone might result in a final product where the zones actually mapped could probably correspond poorly to boundaries of homogenous vegetation transitions.

3.2 Cambridge expert consultation

The proposed approach and classification scheme briefly outlined above was presented and discussed at an expert consultation in Cambridge from 28 - 30 July 1999, organized by WCMC (FAO, 2000). The participants were mostly regional experts in ecological zoning and forest / vegetation mapping. Case studies on North-America and South America were

[4] Among the existing climate classification systems, the one by Köppen-Trewartha is found to be the least demanding on data, which is primarily based on precipitation and temperature — an important consideration from the production standpoint and may account for its wide use. As meteorological stations around the world routinely collect values for these attributes and the information is generally available in existing maps, this was seen as an additional advantage from the perspective of producing the map and database, which would require a relatively consistent global distribution of input data. Other global climate classification systems, for example, Thornwaite (1931) and Holdridge (1966), call for evapo-transpiration data, which is not uniformly available at the global level.

[5] The FAO Ecological Zone maps developed during Forest Resources Assessment 1990 for the tropics used a similar approach. A hierarchal system was adopted, using climatic and physiographic factors for identifying the regional classes or Ecological Zones. These zones were defined by aggregation of more detailed ecofloristic zones (EFZ). The classification criteria for EFZ included physiognomy, phenology, floristics and vegetation dynamics of vegetation (FAO, 1989). The dominant or characteristic species of the natural flora were used as indicators. Boundaries of ecofloristc zones were delineated with the help of existing potential, mostly national, vegetation maps and brought to a common classification and scale. Class boundaries were delineated using standardised vegetation maps of the tropical regions.

presented as well, illustrating the overall concept, methods and utility of the map in an operational context. The workshop adopted, with some modifications, the proposed classification system based on Köppen-Trewartha climatic types in combination with potential vegetation as a sound basis for global ecological zoning. The workshop results indicated that the proposed system could be implemented in all regions, both in scientific - and practical terms. Source input maps were identified for all regions, most of them available in digital format. It was noted that the Köppen-Trewartha system might not match well with potential vegetation in specific regions, for instance Australia. Some modifications to the proposed classification were made to better reflect the vegetation zonation and they include:
a) the inclusion of a mountain systems zone at level 2 in four broad climatic domains: tropical, subtropical, temperate, boreal (not applied in polar domain)
b) the subdivision of the boreal zone into a more northerly (poleward) tundra woodland and a southerly coniferous forest zone (approximately corresponding with the Taiga in former USSR)
c) the division of the tropical seasonally dry climate type (Aw) into two: one with a short dry season, roughly corresponding with moist deciduous forest and one with a long dry season, corresponding with dry deciduous forest and woodlands.

3.3 FAO Global Ecological Zone classification system

FAO's global Ecological Zone classification relies on a combination of climate and (potential) vegetation. The following summarizes the classification criteria and principles of the system:

- The Köppen-Trewartha climatic groups and climatic types, with modifications adopted at the Cambridge workshop, are the first two levels of a hierarchical FAO global Ecological Zone classification system (Table 1, 30). At the broadest level, equivalent to Köppen-Trewartha's climatic groups, five domains are distinguished based on temperature: Tropical, Subtropical, Temperate, Boreal, Polar.

- At the second level, 20 classes or Ecological Zones are distinguished using precipitation as additional criterion. Within each domain a zone of mountain systems is distinguished at level 2. The Ecological Zones reflect broad zones of relatively homogeneous vegetation, such as tropical rainforest, tropical dry forest, boreal coniferous forest, etc. Typical azonal vegetation types, for instance mangroves, heath and swamps are not separately classified and mapped. Mountain systems usually contain a variety of vegetation types and include forests, alpine shrubs, meadows and bare rock. The current global framework cannot address the high, mostly small-scale diversity of mountain habitats. The polar domain is not further subdivided, as it is treeless and only very sparse shrub or grass vegetation occurs locally. Here the second level is equivalent to the first.

- The second level, of 20 classes, is the reference or working level for the global Ecological Zone mapping[6]. The names of the global Ecological Zones reflect the dominant zonal vegetation.

[6] A more detailed regional classification system similar to that carried out for FRA1990 may be conducted for regions. Concept and principles for more detailed schemes that use elevation and other parameters will be discussed during the Cambridge Expert meeting, July 1999.

A main principle in delineating the global Ecological Zones involves aggregating or matching regional ecological or potential vegetation maps into the global framework. The following steps can be distinguished (the practical implementation is described in Part II):

1. Identification of Köppen-Trewartha climatic types and mountains occurring in a region; which will approximate the level 2 Ecological Zone class of the FAO scheme.

2. Establishment of correspondence between regional/national potential vegetation types and the global Ecological Zones.

3. Final definition and delineation of the global Ecological Zones, using the maps and source data consulted in steps 1 and 2[7].

4. Edgematching between adjacent maps.

5. Validation.

[7] For this part of the work, FAO has relied heavily on the advice of regional experts specializing in ecological zoning and mapping.

3.4 Characteristics of global Ecological Zones

3.4.1 Tropical domain

Mean temperature of all months over 18°C. Approximate location between the Tropic of Cancer 23° N and the Tropic of Capricorn 23° S. Lowland zones are up to 1000 - 1500 meter.

Name	Tropical rain forest
Code	Tar
Climatic criteria	Uniformly high temperatures and heavy annual precipitation (at least 1500 mm, often > 2000 mm) distributed throughout the year. Either no dry season or at most 3 months during winter.
Vegetation	Tropical evergreen and semi-evergreen rainforest. The vegetation is lush, with tall, closely set trees that often form a continuous multi-layered canopy and emergent trees reaching a height of 50 to 60 meters. Most diverse terrestrial ecosystem, with a large number of tree species.
Distribution	Astride the equator and extending 5 to 10 degrees on either side. Main locations: Amazon basin, South America; Congo basin, Africa; Insular South East Asia.

Figure 1 Lowland dipterocarp forest, Peninsular Malaysia

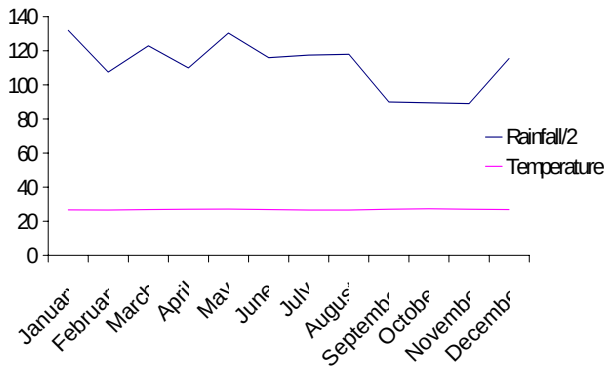

Figure 2 Climate diagram TAr Balikpapan – Indonesia (12°7 S 116°9 E; Alt 3; R 2367)

Name	Tropical moist deciduous forest
Code	Tawa
Climatic criteria	Tropical climate with summer rain and a dry period of 3 to 5 months. Annual rainfall is generally in the range of 1000 to 2000 mm.
Vegetation	Moist semi-deciduous and deciduous forest types. Examples: monsoon forest in Asia, cerrado in South America and wet Miombo woodlands in Africa.
Distribution	Both north and southward of equator, approximately between 5 and 15 degrees. Most extensive areas are found in South America (cerrado) and Africa.

Figure 3 Wetter type Miombo woodland, North Zambia

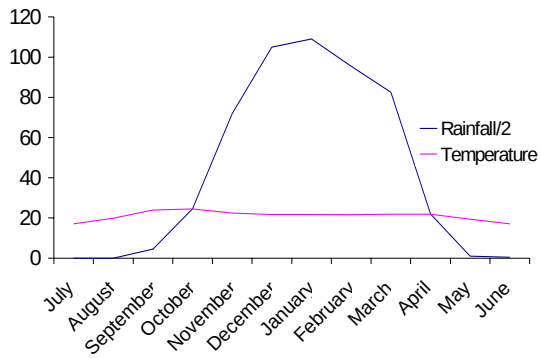

Figure 4 Climate diagram Tawa Zambezi - Zambia (13°53 S 23°12 N; Alt 1078; R 1033)

Climate diagrams (after Walter 1973)

In a climate diagram the months of the year are represented along the horizontal axis, from January to December for the Northern Hemisphere and from July to June for the Southern Hemisphere, so that the summer is always in the middle of the diagram. The curves give the mean monthly values of temperature (t) and rainfall (N). By choosing a scale at which 10°C is made to correspond to 20 mm of rainfall, a relatively dry season (N-curve lies below the t-curve) can be depicted. Geographic coordinates, altitude (Alt, in m above sea level) and mean annual rainfall (R, in mm) of the climate station are presented as well. Climate diagrams give information concerning the mean temperature and rainfall at a particular location over the course of the year. They also show the occurrence, length and intensity of relatively humid and relatively arid seasons and the duration and severity of a cold winter. This information provides invaluable insight in the ecological conditions of a location and helps to verify the ecological zoning.

Name	Tropical dry forest
Code	TAwb
Climatic criteria	Tropical climate, with summer rains and a dry period of 5 to 8 months. Annual rainfall ranges from 500 to 1500 mm.
Vegetation	Dry tropical forest and woodland, including drier type of Miombo and Sudanian woodlands, savana (Africa), caatinga and chaco (South America), dry deciduous dipterocarp forest and woodlands (Asia).
Distribution	At both sides of equator, approximately between 15 and 20 degrees. This zone is most extensive in Africa.

Figure 5 Dry woodland, Malawi

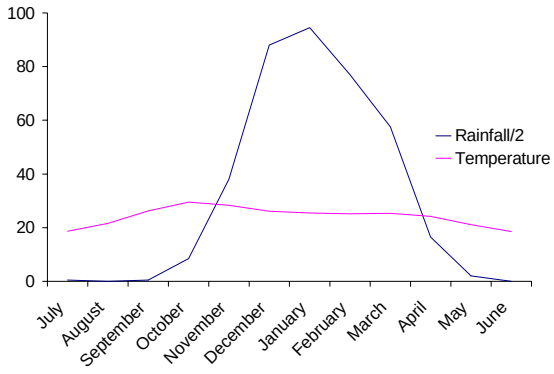

Figure 6 Climate diagram TAwb
Kariba - Zimbabwe
(16°52 S 28°88 E; Alt 518; R 766)

Name	Tropical shrubland
Code	TBSh
Climatic criteria	Tropical temperature regime and evaporation > precipitation. Annual rainfall ranges between 200 and 500 mm.
Vegetation	Shrubs, xeromorphic woodlands, dry savana, thornbush.
Distribution	Most extensive in Africa and South Asia, where they form the equatorward margins of the tropical deserts.

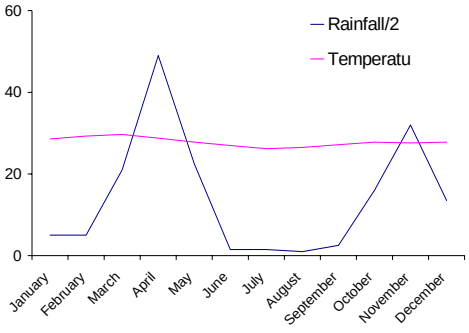

Figure 7 Climate diagram TBSh
Wajir - Kenya
(1°75 N 40°07 S; Alt 244; R 341)

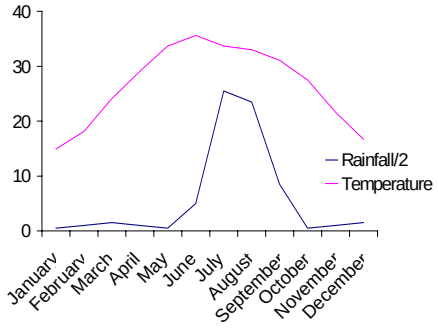

Figure 8 Climate diagram TBWh
Nawabshah - Pakistan
(26°25 N 68°37 E; Alt 38; R 140)

Name	Tropical desert
Code	TBWh
Climatic criteria	Tropical regime and all months dry.
Vegetation	Very sparse (dwarf) shrubs or no vegetation cover.
Distribution	The heart of the tropical deserts lies in the vicinity of latitudes 20 or 25 north and south. Main tropical deserts are Sahara and Namibian deserts in Africa, the west coast of South America and deserts of Western India and Pakistan.

Name	Tropical mountain systems
Code	TM
Climatic criteria	High variety of climatic conditions, varying with altitude.
Vegetation	Due to the variation in climatic conditions and altitude, there is a high variety of vegetation types along altitudinal belts, ranging from evergreen submontane rainforest, cloud forest up to alpine grassland.
Distribution	Main tropical mountain systems are the Andes in South America, mountains of the Rift Valley system in Eastern Africa and the Eastern Himalayas in Asia.

Figure 9 Evergreen mountain forest at around 2000 meter altitude, Thailand

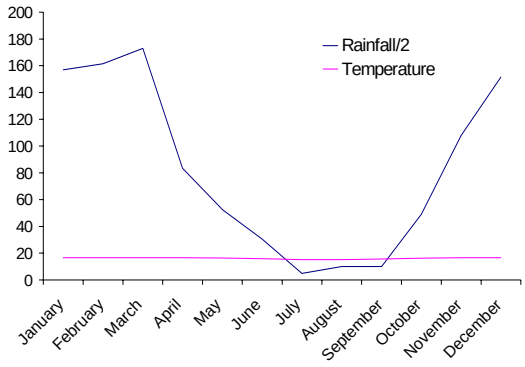

Figure 10 Climate diagram TM
Tosari (Java) - Indonesia
(7°88 S 112°92 E; Alt 1735; R 1985)

3.4.2 Subtropical domain

At least 8 months above 10°C. The location is from about 25 to 40 degrees, both at northern and southern latitudes. This domain comprises the subtropical arid and semi-arid zones just poleward of the tropical domain, the typical Mediterranean zone and a humid zone. In other climate systems only the arid and semi-arid zones are referred to as subtropical, the other two are considered “warm temperate”. Lowland zones are from sea level up to approximately 1000 meters.

Name	Subtropical humid forest
Code	SCf
Climatic criteria	Subtropical humid: precipitation is distributed throughout the year and all months are humid. Annual rainfall usually more than 1000 mm.
Vegetation	Evergreen broadleaved forest, evergreen coniferous forest and winter deciduous forest. Examples: Eucalyptus-Nothofagus forests of Southeastern Australia and Tasmania, *Castanopsis* forest in Southeast China, *Aracauria* forest in Brazil, Longleaf-Slash pine forest in Southeast USA.
Distribution	At eastern side of continents: Southeast USA, Southern Brazil, Southeastern tip of Africa, Southeast Australia and Southeast China.

Figure 11 Slash pine forest, Southeast USA

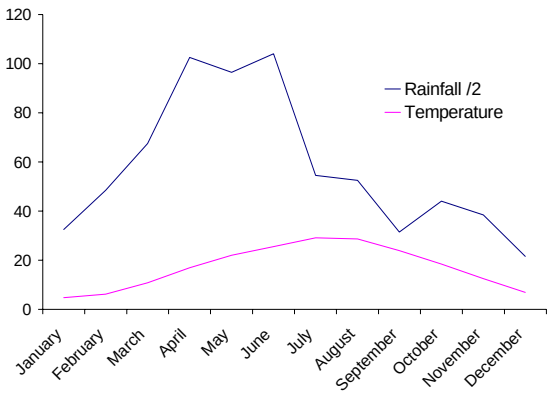

Figure 12 Climate diagram SCf Changsha - China (28°1 N 113°8 E; Alt 46; R 1388)

Name	Subtropical dry forest
Code	SCs
Climatic criteria	Mediterranean climate, characterized by dry hot summers and humid, mild winters. Annual rainfall is in the range of 400 to 900 mm.
Vegetation	Sclerophyllous evergreen forest, woodland and shrub. Maquis dominated by *Quercus ilex* in the Mediterranean region; chaparral in California, Chilean Matorral, Fynbos in the Cape Region and Eucalyptus forest in Southwest Australia. Fire is a regular feature.
Distribution	Occuring along the western sides of the continents at the poleward margins of the subtropical deserts, in five distinct regions: the Mediterranean basin, central and coastal California, Central Chile, the Cape region of South Africa and southwest and south Australia.

Figure 13 Mediterranean Maquis, Italy

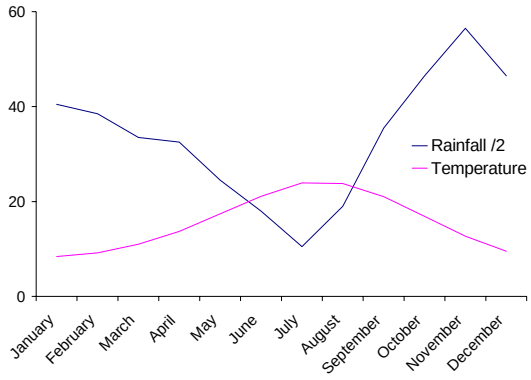

Figure 14 Climate diagram SCs
Rome - Italy
(41°78 N 12°58 E; Alt 105; R 804)

Name	Subtropical steppe
Code	SBSh
Climatic criteria	Evaporation > precipitation.
Vegetation	Steppe vegetation, with xerophytic shrubs dominating. Example: wormwood steppe in the Middle East with *Artemisia* species.
Distribution	Forming the poleward boundary of tropical/subtropical deserts and mostly fringing the Mediterranean climates. Main distribution in North America, Middle East and Australia.

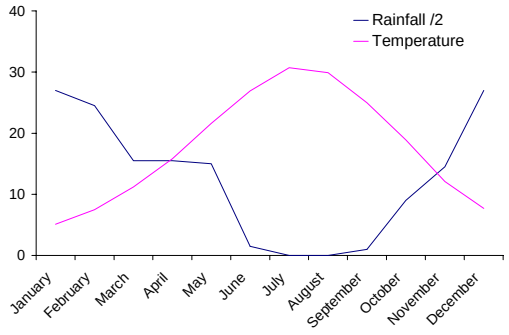

Figure 15 Climate diagram SBSh
Tel Abiad - Syria
(36°7 N 38°95 E; Alt 349; R 301)

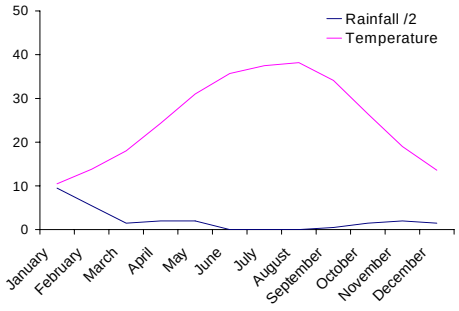

Figure 16 Climate diagram SBWh
Nukaib - Iraq
(32°03 N 42°25 E; Alt 305; R 52)

Subtropical deserts, SBWh (Figure 16), are immediately bordering the tropical deserts in poleward direction and form actually often one entity, for instance the Sahara. Main difference is the higher range of the annual temperature in the subtropical desert.

Name	Subtropical mountain systems
Code	SM
Climatic criteria	Varies with altitude.
Vegetation	High variation in vegetation, related to altitude, exposure and humidity. For instance montane rainforest in western Himalayas, grass steppe on mountains of Iran.
Distribution	Main subtropical mountain systems are parts of the Andes, mountains in the Middle East and western part of the Himalayas.

Figure 17 Mediterranean mountain vegetation with cedar and oak (at around 2000 m altitude), Hosh Eden, Libanon

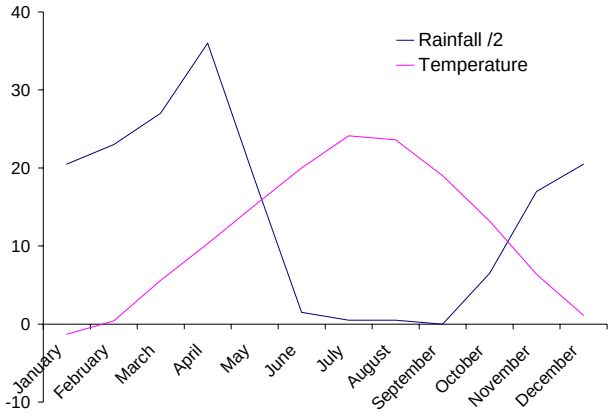

Figure 18 Climate diagram SM
Iran - Nowjeh
(35°2 N 48°68 E; Alt 1979; R 343)

3.4.3 Temperate domain

The temperate domain occupies a medial position within the middle latitudes - usually between the subtropical domain equatorwards and the boreal domain polewards. The boundaries with the subtropical - and boreal domain are 8 months and 4 months, respectively, with average temperatures of 10°C or above. Its main distribution is in the northern hemisphere.

Name	Temperate oceanic forest
Code	TeDo
Climatic criteria	This is the milder climate type and the boundary with the continental climate is the 0°C isotherm for the coldest month. Average monthly temperature is always above 0°C. The zone is humid with adequate rainfall at all seasons. The total amount of rainfall, however, varies greatly from region to region and ranges from 400-800 mm where lowlands predominate up to 2000-3000 mm on windward lower coastal mountain slopes.
Vegetation	Deciduous broadleaved forest, i.e. beech forest, in Western Europe; Mixed forest and coniferous forest in Western USA: main coniferous tree species here are western redcedar, western hemlock and Douglas-fir.
Distribution	Typically found on the western or windward side of the continents: western Europe, western part of North America, Southern Chile, New Zealand.

Figure 19 Temperate broadleaved forest, USA

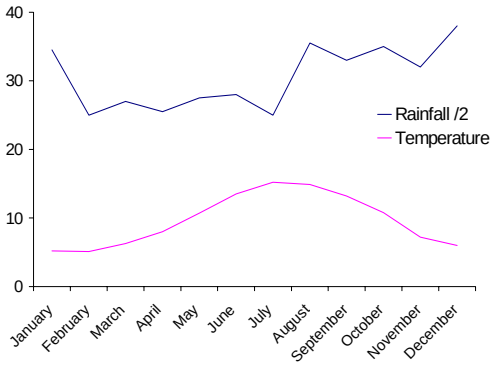

Figure 20 Climate diagram TeDo Dublin - Ireland (53°43 N 6°25 W; Alt 85; R 732)

Name	Temperate continental forest
Code	TeDc
Climatic criteria	In winter, at least one month has an average temperature below zero. Colder and snowier winters, shorter frost-free seasons and larger annual ranges of temperature differentiate the more severe continental climate from the temperate oceanic type. Rainfall decreases from the seaward margins toward the interiors and usually from the lower toward the higher latitudes as well.
Vegetation	Deciduous broadleaved forest, for instance oak-hornbeam in Central Europe and mixed forest. In Eurasia, the forest-steppe zone, a mozaic of deciduous forest stands and meadow steppe is included.
Distribution	This zone occupies interior and leeward (eastern) areas of the continents. As it is associated with large continents in middle latitudes, the zone is confined to the Northern hemisphere (Eurasia and North America).

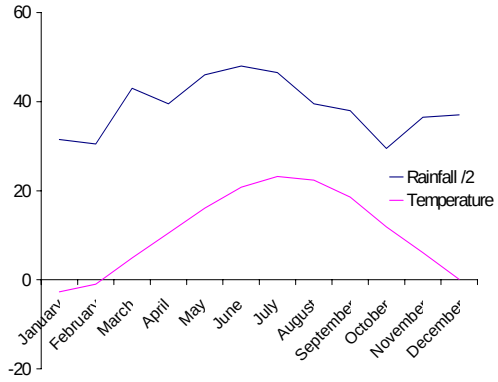

Figure 21 Climate diagram TeDc
Pittsburgh - USA
(40°5 N 80°22 W; Alt 373; R 931)

Name	Temperate steppe
Code	TeBSk
Climatic criteria	Characterised by a period of severe cold. Evaporation > precipitation and annual rainfall ranges from approximately 200 to 400 mm.
Vegetation	Steppe vegetation dominated by grass, sometimes in combination with low shrubs. Prairie in North America.
Distribution	Found in the deep interiors of North America and Eurasia, most extensive in the latter.

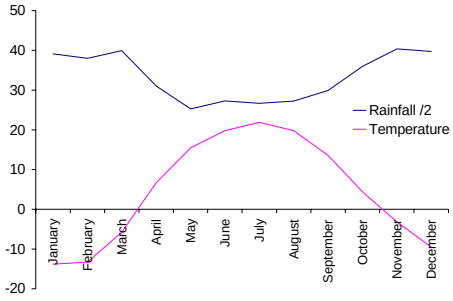

Figure 22 Climate diagram TeBSk
Orenburg - Russian Federation
(51°75 N 55°1 E; Alt 109; R 370)

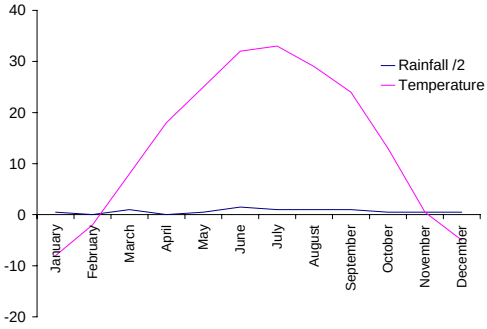

Figure 23 Climate diagram TeBWk
Turpan - China
(42°93 N 89°2 E; Alt 37; R 16)

Name	Temperate desert
Code	TeBWk
Climatic criteria	All months dry, severe cold period.
Vegetation	Bare rock, sand, with spare grass or shrubs.
Distribution	Interior of North America and Eurasia (for instance Gobi desert).

Name	Temperate mountain systems
Code	TeM
Climatic criteria	Boreal characteristics, snow covered for large part of the year.
Vegetation	Pine forest is dominating on temperate mountains.
Distribution	Main temperate mountains are the Rocky mountains in North America, the Alps and Pyrenees in Europe and large parts of China.

Figure 24 Mountain spruce forest, Apalache Mountains, Eastern USA

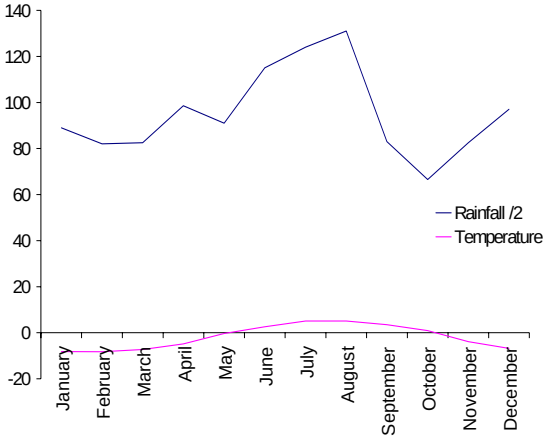

Figure 25 Climate diagram TeM Saentis - Switzerland (47°25 N 9°35 E; Alt 2500; R 2284)

3.4.4 Boreal domain

The Boreal, or subarctic, domain is found only in the higher latitudes of the Northern Hemisphere between 50-55 to 65-70 degrees. It has at least one and up to 4 month with an average temperature above 10^{o} C. Another feature is the large annual range of temperature. Rainfall is low, generally below 500 mm. The northern boundary, approximately the isotherm of 10^{o}C for the warmest month (usually July), coincides rather well with the poleward limit of tree growth. The Russians have given the name *taiga* to the subarctic lands of Eurasia with their extensive coniferous forests and this term is also applied to the comparable region in North America.

Name	Boreal coniferous forest
Code	Ba
Climatic criteria	At the most 3 month with an average temperature above 10^{o} C. Long cold winters and short, relatively warm summers.
Vegetation	Dense coniferous forest. Spruce and fir dominate the forests of North America, northern Europe and western Siberia, while larch is common in the forests of central and eastern Siberia.
Distribution	Northern part of North America and Eurasia.

Figure 26 Taiga coniferous forest, Komi Republic World Heritage site, Russian Federation

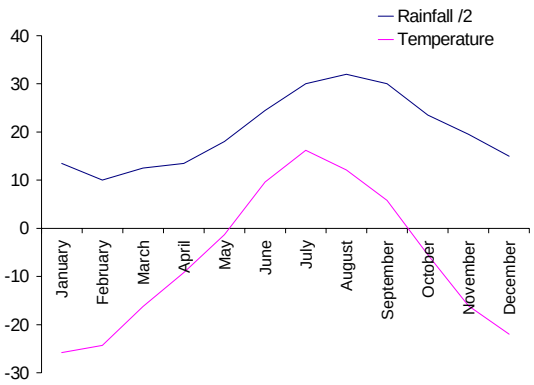

Figure 27 Climate diagram Ba
Tarko Sale - Russian Federation
(64^{o}92 N 77^{o}82 E; Alt 27; R 484)

Name	Boreal tundra woodland
Code	Bb
Climatic criteria	Similar to Ba, but generally colder and more extreme, in particular very low winter temperatures. Permafrost throughout the zone.
Vegetation	Open woodland and - forest. In the Russian Federation monoculture of larch; in North America with black spruce and tamarack. The vegetation characteristics are the defining criteria to distinguish the zone from Ba, where closed coniferous forest is the predominant vegetation.
Distribution	Forming the northern fringe of the boreal domain. More extensive in Canada than in Eurasia.

Figure 28 Open deciduous larch forest, Yakutia, Northeast Russian Federation

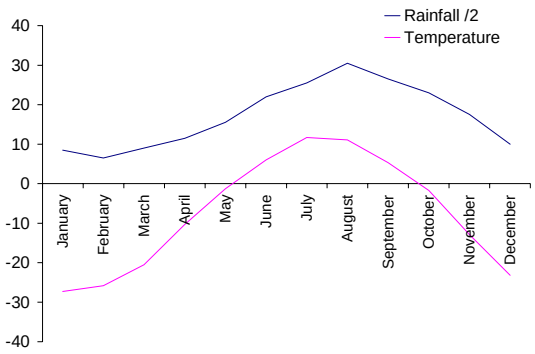

Figure 29 Climate diagram Bb Churchill Man. - Canada (58°73 N 94°07 W; Alt 29; R 412)

Name	Boreal mountain systems
Code	BM
Climatic criteria	Generally very extreme and cold, continuous permafrost.
Vegetation	Open woodlands, shrub.
Distribution	Eastern Russian Federation, Western Canada.

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Table 1. FAO global ecological zoning framework.

EZ Level 1 – Domain		EZ Level 2 – Global Ecological Zone		
Name	Criteria (Equivalent to Köppen-Trewartha Climatic groups)	Name (reflecting dominant zonal[a] vegetation)	Code	Criteria (approximate equivalent of Köppen – Trewartha Climatic types, in combination with vegetation physiognomy and one orographic zone within each domain)
Tropical	All months without frost: in marine areas over 18°C	Tropical rain forest	TAr	Wet: 0 – 3 months dry[b]. When dry period, during winter
		Tropical moist deciduous forest	TAwa	Wet/dry: 3 – 5 months dry, during winter
		Tropical dry forest	TAwb	Dry/wet: 5 – 8 months dry, during winter
		Tropical shrubland	TBSh	Semi-Arid: Evaporation > Precipitation
		Tropical desert	TBWh	Arid: All months dry
		Tropical mountain systems	TM	Approximate > 1000 m altitude (local variations)
Subtropical	Eight months or more over 10°C	Subtropical humid forest	SCf	Humid: No dry season
		Subtropical dry forest	SCs	Seasonally Dry: Winter rains, dry summer
		Subtropical steppe	SBSh	Semi-Arid: Evaporation > Precipitation
		Subtropical desert	SBWh	Arid All months dry
		Subtropical mountain systems	SM	Approximate > 800-1000 m altitude
Temperate	Four to eight months Over 10°C	Temperate oceanic forest	TeDo	Oceanic climate: coldest month over 0°C
		Temperate continental forest	TeDc	Continental climate: coldest month under 0°C
		Temperate steppe	TeBSk	Semi-Arid: Evaporation > Precipitation
		Temperate desert	TeBWk	Arid: All months dry
		Temperate mountain systems	TM	Approximate > 800 m altitude
Boreal	Up to 3 months over 10°C	Boreal coniferous forest	Ba	Vegetation physiognomy: coniferous dense forest dominant
		Boreal tundra woodland	Bb	Vegetation physiognomy: woodland and sparse forest dominant
		Boreal mountain systems	BM	Approximate > 600 m altitude
Polar	All months below 10°C	Polar	P	Same as domain level

Notes:

[a] Zonal vegetation: resulting from the variation in environmental, i.e. climatic, conditions in a north south direction.

[b] A dry month is defined as the month in which the total of precipitation P expressed in millimeters is equal to or less than twice the mean Temperature in degrees Centigrade.

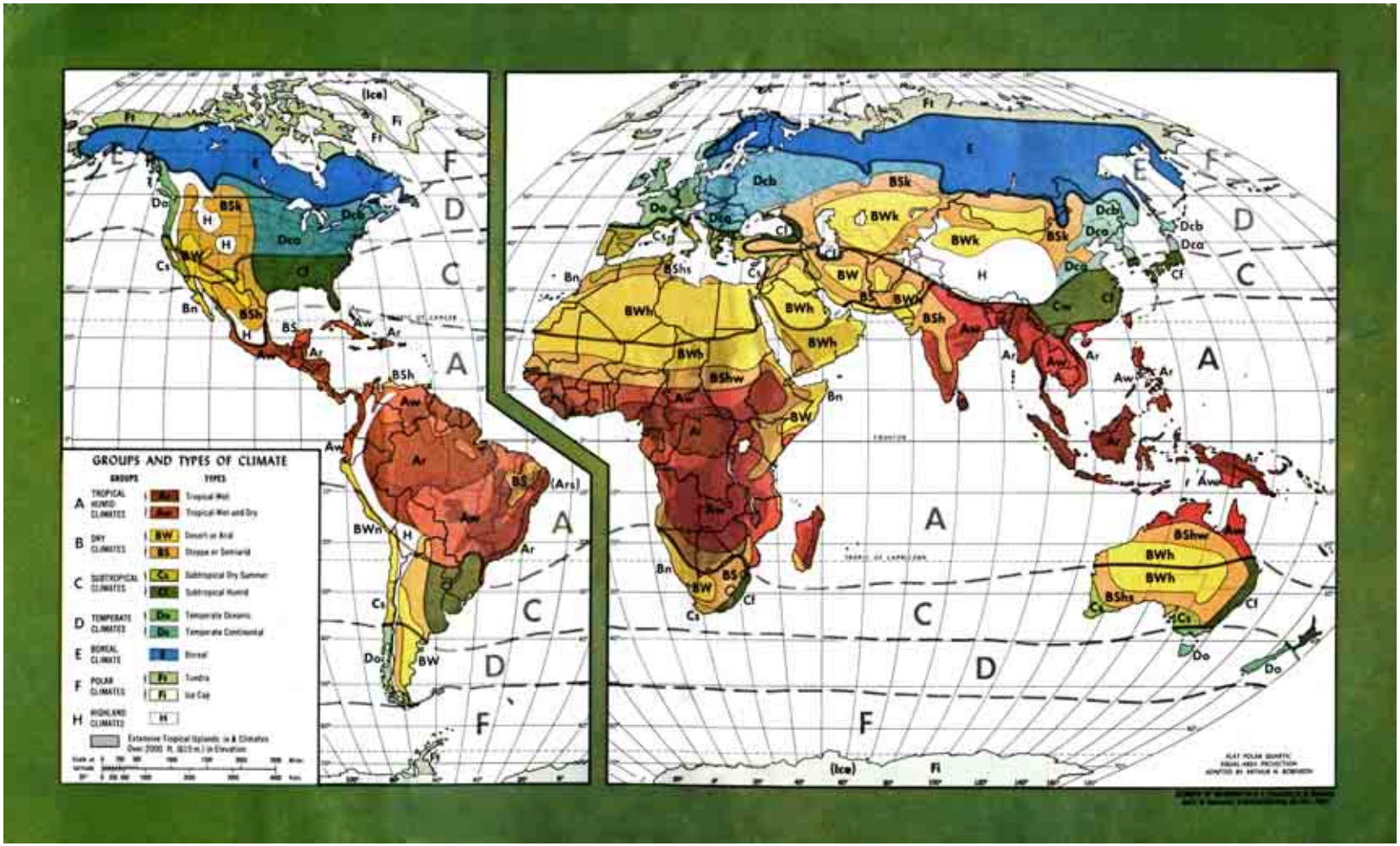

Figure 30. Global distribution of Köppen-Trewartha climatic groups and types (from Trewartha 1968)

PART II : DEVELOPMENT OF THE MAP AND RESULTS

1 Methodology

1.1 Use of regional source maps and expertise

To ensure the best use of regional knowledge and information, existing regional/national maps on vegetation, biogeography, ecology and climate were used to generate the GEZ map. In some cases, such as the USA, the classification is based on the Köppen-Trewartha climate system and translation to the FAO GEZ is straightforward. In other cases, a more thorough study of mapping criteria, including physiognomy, phenology, floristics and dynamics of vegetation types, was needed to establish the correspondence. An additional benefit of using the existing country/regional maps is that they could form the basis or provide supporting information for more detailed regional ecological zoning beyond FRA 2000.

The country/regional vegetation maps also helped in harmonisation of Ecological Zone boundaries across countries or regions. The experts attending the Cambridge expert consultation contributed in a major way to define Ecological Zones of their respective regions as well as in edge matching between adjoining geographic regions.

The following steps were applied to define and map the FAO global Ecological Zones region by region. They are divided in conceptual, thematic issues and technical production steps.

1.2 Conceptual and thematic issues

Collection and study of relevant maps and information: suitable regional/national maps of climate, potential vegetation or ecoregions were searched and studied. The ideal maps show distribution and zonation of (potential) natural vegetation and have supporting documentation with details on classification system and criteria. Other important (map) attributes are floristic information, climate and landform or physiography. Depending on regions, the scale of maps was usually smaller than 1 million and both paper and digital versions of the maps were obtained. A first step in the selection of source map(s) was to identify and delineate the Köppen-Trewartha climate types occurring in the country or region (see Figure 30 and Table 1), which are the approximate boundaries of FAO GEZ Level 2. This was followed by an in-depth study of the ecological – and /or vegetation maps, focusing on classification principles and - criteria used, to select the input map(s) for generating the global EZ map. Consultation with regional experts, i.e. authors of maps and publications, was vital in this process. A reference list was made of all source data used.

Matching or aggregating national/regional classes into the FAO GEZ. Based on the in-depth study the relation between national/regional source classes, vegetation types, ecoregions etc.

and the Level 2 global Ecological Zones was established. This usually involved aggregation of a number of regional classes into one GEZ. Then an “equivalence “ or look-up table for the region was produced, showing the correspondence between the regional classes and the global Ecological Zones Level 1 and 2, together with documentation and explanation of the matching for review and evaluation purposes. This includes the description and definition of the regional vegetation types or – ecosystems.

1.3 Map production and technical Issues

Both the existing FRA1990 ecofloristic zone maps and several existing regional maps have been produced using ESRI Arc/Info GIS software system. Thus, it was convenient for the rest of the work to be conducted on Arc/Info, or at least Arc/Info importable. After study of the digital map in the Arc/Info coverage environment and making sure the digital version has appropriate attributes for the polygons, the coverage was edited and attributes for each FAO GEZ levels (1 and 2) were added.

Regarding polygon edge-matching problems along country and regional boundaries, two related causes occurred. One was due to mismatch of polygon definition translations between polygons of both sides, as stated earlier. This problem was generally easy to solve by going back to the original maps and making sure the translation is correct. The other cause is due to offset of lines of the polygons on both sides, even though they may have the same labels. For this problem, we edited manually the coverage and change locations of the lines. This sometimes required more ancillary data and maps such as: composite of NOAA AVHRR spectral bands, classified continental-scale land cover (such as the USGS global land cover database) and digital elevation model (DEM) data.

The resulting output from a regional GEZ production includes the following: Arc/Info coverage of EZ map with attributes of each EZ levels, graphics (e.g. GIF images) of the two levels of EZ, a table containing the levels of EZ and corresponding labels or codes of the input regional maps. For these output materials, see the results by region.

From the perspective of GEZ production, there were some obstacles that affected the progress of producing regional and ultimately global GEZ.

Availability of suitable regional/national maps. For some regions or countries, maps may not exist that have suitable scale, information content, or quality. It is also possible that some regions have paper maps but not their digital version. One solution was to use as an alternative the few available global-scale maps, such as the Terrestrial Ecoregions of the World map (WWF 2000) in combination with a climate map based on Köppen.

Edge matching of cross-boundary polygons. Two sticking points that had to be solved: 1) it was more complicated when different classification principles had been used for the two bordering maps and 2) manual editing was sometimes necessary and is not elegant.

1.4 Implementation

Following the classification and guidelines outlined above, the global map was compiled through a region by region approach. The case studies on North America and South America

provided useful experiences and guidelines for GEZ mapping in other regions. In the implementation of the work, regional experts actively participated or were consulted. EDC was responsible for producing the EZ maps for the temperate and boreal regions and jointly with FAO compiled the global map and database, while LET, Toulouse produced the EZ maps for the tropical regions, i.e. South America, Africa and Asia. FAO - FRA2000 provided overall technical and conceptual guidance. After the Cambridge meeting, July 1999, it took one year to produce a draft global map. The draft EZ map was reviewed at a meeting in Salt Lake City (5-7 July 2000) and the final map and database were completed by October 2000.

Regional division and collaborating institutions in the work were as follows:

Region	**Main partners and collaborators**
North - and Central America	US Forest Service, USA
	Canadian Forest Service, Canada
	Institute of Geography, University of Mexico, Mexico
	Tropical Science Center, Costa Rica
Europe	Federal Agency for Nature Conservation, Germany
Former USSR	IIASA, Austria
	Biogeography Department, Moscow State University, Russian Federation
China	IRSA, Chinese Academy of Sciences, China
Middle East	Damascus University, Syria
Australia	Bureau of Rural Sciences, Australia
Tropics	LET, France

2 Results

Presentation of the results roughly follows the FAO regional division: North and Central America, Europe and Northern Asia, Asia, South America, Africa and Oceania.

For Asia, quite a number of different subregional and national source maps had to be used to compile the GEZ map: Tropical Asia, Middle East, China, Korea's, Mongolia, Japan. The regions South America, Africa and Tropical Asia are presented together, as the same type of source maps, the eco-floristic zone maps produced by LET, were used to compile the GEZ map. For each region we present a) the source maps that were used, together with classification criteria; and b) look-up tables giving the correspondence between the source classes and the FAO Ecological Zones with comments/explanations. Appendix II-1 presents the source maps that were used to delineate the global Ecological Zones.

In the look-up tables (further abbreviated as LUT) only the codes of the Global Ecological Zone are given (Table 2). More details on the zones, such as names, climatic criteria, vegetation, are presented in Table 1 and paragraph 3.4 of Part I of this report.

Table 2. Codes and names of FAO Global Ecological Zones.

Domain	**Global Ecological Zone (GEZ)**	
	Code	**Name**
Tropical	TAr	Tropical rain forest
	TAwa	Tropical moist deciduous forest
	TAwb	Tropical dry forest
	TBSh	Tropical shrubland
	TBWh	Tropical desert
	TM	Tropical mountain systems
Subtropical	SCf	Subtropical humid forest
	SCs	Subtropical dry forest
	SBSh	Subtropical steppe
	SBWh	Subtropical desert
	SM	Subtropical mountain systems
Temperate	TeDo	Temperate oceanic forest
	TeDc	Temperate continental forest
	TeBSk	Temperate steppe
	TeBWk	Temperate desert
	TeM	Temperate mountain systems
Boreal	Ba	Boreal coniferous forest
	Bb	Boreal tundra woodland
	BM	Boreal mountain systems
Polar	P	Polar

2.1 North and Central America

The zoning of this region was based on maps and inputs from five countries / subregions, from North to South: Canada, the United States, Mexico, Central America and the Caribbean.

2.1.1 Canada

The source for the GEZ of Canada is the map "Ecological Regions of North America" (CEC, 1997). The map was developed by the Commission for Environmental Cooperation (CEC) whose members are Canada, Mexico and the United States.

The CEC map is applying a holistic ecosystem or landscape classification, based on various components or parameters such as climate, soils, landform, vegetation and also land use. Three levels of ecological regions are distinguished and at the broadest level North America is divided into 15 Level I regions. Nested within the Level I regions, 52 Level II ecological regions have been mapped. The scale of presentation of Level II is at approximately 1:30 million.

Table 3. LUT Canada.

FAO system		**Corresponding source class: Ecological region Level II**
Domain	**GEZ**	
Temperate	TeDc	5.2 Mixed wood Shield 5.3 Atlantic Highlands 8.1 Mixed wood Plains 8.2 Central USA Plains
	TeBSk	9.2 Temperate Prairies 9.3 West-Central Semi-Arid Plains
	TeM	6.2 Western Cordillera 7.1 Marine West Coast Forests
Boreal	Ba	5.1 Softwood shield 9.1 Boreal Plains
	Bb	3.1 Alaska Boreal Interior 3.3 Taiga Plains 3.4 Taiga Shield 4.1 Hudson Plain
	BM	6.1 Boreal Cordillera 3.2 Taiga Cordillera
Polar	P	1.1 Arctic Cordillera 2.1 Northern Arctic 2.2 Alaska Tundra 2.3 Brooks Range 2.4 Southern Arctic

Source: Ecological Regions of North America (CEC, 1997)

Level II was considered the most appropriate scale and detail of source classes to use for compiling the FAO GEZ map. The correspondence between source classes, Level II ecological regions and the GEZ was established by studying the criteria and descriptions of

the ecological regions. For example region '5.1 Softwood Shield' corresponds to FAO EZ class 'Ba-Boreal Coniferous forest', based on the description (CEC, 1997) that the ecological region has a mean annual temperature of –2 to -6^{o}C, a mean annual precipitation of 550-1500 mm, a vegetation of primarily conifers, lichens and shrubs and that landform is hilly with some plains.

Mountain systems are in the CEC classification placed under the "Cordillera" and "Sierra" ecological regions. Landform is a dominant criterion in defining these regions, rather than an altitudinal threshold. As a result, the CEC mountain ecological regions are broad and diverse systems, including mountains, plateaus and valleys.

2.1.2 USA

The source for the GEZ of USA is the map Ecoregions of the United States (Bailey, 1994). The classification of ecoregions is based on the Köppen-Trewartha climate system distinguishing broad domains equivalent to climate groups and within these domains, divisions approximately equivalent to climate types. The presence of mountains is an additional criterion in the classification and within each division a lowland and a mountain class are distinguished. An essential feature of mountainous regions is the altitudinal differentiation or zonation of vegetation and climate.

As the FAO GEZ classification makes use of the same Köppen-Trewartha climate system, delineation of GEZ for USA was therefore simple. However, a few differences occur between Bailey's US ecoregions and FAO's GEZ classification:

a) The definition, delimitation by Bailey of a Prairie Division (250), a transition zone between steppe (310, 330) to the west and subtropical (220) and warm-hot continental (210, 220) forest Divisions to the east. This Prairie Division is subdivided into a northern temperate Province and a southern subtropical Province. According to Dr Bailey (pers. communication), this Division has more affinity with FAO's steppe zones than with the forest zones. Therefore, the northern, temperate Province (251) has been classified as FAO's temperate steppe (TeBSk) while the southern, subtropical Province has been classified as subtropical steppe (SBSh).

b) Difference in mountain classification: FAO distinguishes only one zone of mountain systems within each domain, while Bailey subdivides each Division into a lowland ecoregion and a mountain ecoregion. However, the two systems are easily comparable, as the grouping of various mountain ecoregions into one FAO mountain zone is straightforward (Table 4).

Table 4. LUT United States.

FAO system		Corresponding source class: Ecoregion – Division
Domain	**GEZ**	
Tropical	TAwa	410 Savannah Division, (Everglades)
Subtropical	SCf	230 Subtropical Division
	SCs	260 Mediterranean Division
	SBSh	250 Prairie Division 255 Prairie Parkland (Subtropical) Province 310 Subtropical steppe
	SBWh	320 Subtropical Desert Division
	SM	M230 Subtropical Regime Mountains M260 Mediterranean Regime Mountains M310 Subtropical Steppe Regime Mountains
Temperate	TeDo	240 Marine Division
	TeDc	210 Warm continental Division 220 Hot continental Division
	TeBSk	250 Prairie Division: 251 Prairie Parkland (Temperate) Province 330 Temperate steppe Division
	TeBWk	340 Temperate desert Division
	TeM	M210 Warm Continental Division M220 Hot Continental Regime Mountains M240 Marine Regime Mountains M330 Temperate Steppe Regime Mountains M340 Temperate Desert Regime Mountains
Boreal	Bb	130 Subarctic Division
	BM	M130 Subarctic Regime Mountains
Polar	P	120 Tundra Division M120 Tundra Regime Mountains

Source: Ecoregions of the United States (Bailey, 1994)

2.1.3 Mexico

The same source map was used as for Canada, the CEC ecological regions of North America (CEC, 1997). In addition, climatic data were studied to verify the approximate delineation of the FAO GEZ. This was particularly needed to determine the reclassification of the CEC Level II ecological regions under Tropical Wet and Tropical dry forests. The greater part of the Tropical Wet forests correspond to FAO GEZ moist deciduous forest (TAwa), while most of the Tropical Dry Forests ecological regions are part of GEZ tropical dry forest (TAwb).

Table 5. LUT Mexico.

FAO system		Corresponding source class: Ecological region Level II
Domain	**GEZ**	
Tropical	TAr	15.1 (part) Humid Gulf of Mexico coastal plains and hills 15.3 Sierra Los Tuxtlas
	TAwa	15.1 (part) Humid Gulf of Mexico coastal plains and hills 15.2 Plain and hills of the Yucatan Peninsula 15.5 Western Pacific plain and hills 15.6 Coastal plain and hills of Soconusco 14.1 Dry Gulf of Mexico coastal plains and hills 14.5 (part) Southern Pacific coastal plain and hills
	TAwb	14.2 Northwestern plain of the Yucatan Peninsula 14.3 Western Pacific coastal plain, hills and canyons 14.4 Interior depressions 14.5 (part) Southern Pacific coastal plain and hills 14.6 Sierra and plains of El Cabo
	TM	13.3 Eastern Sierra Madre 13.4 Transversal neo-volcanic system 13.5 Southern Sierra Madre 13.6 Central American Sierra Madre and Chiapas highlands
Subtropical	SBSh	9.5 Texas-Louisiana coastal plain 9.6 Tamaulipas-Texas semi-arid plain 12.1Western Sierra Madre piedmont 12.2 Mexican high plateau
	SBWh	10.2 Sonoran and Mohave deserts 10.3 Baja Californian desert 10.4 Chihuahuan desert
	SM	13.2 Western Sierra Madre

Source: Ecological regions of North America (CEC, 1997)

2.1.4 Central America

National Holdridge Life Zone maps were used to compile the GEZ map for Central America. Such maps are available for all countries (see references).

The Holdridge Life Zone classification system is a predictive scheme for identifying and delimiting potential vegetation or Life Zones based generally upon the effects of temperature, rainfall and evapotranspiration and also taking into account elevation (Holdridge, 1967).

Since the FAO GEZ system is more general than the Holdridge Life Zone system, several life zones needed to be aggregated into a single GEZ. To start with, applying the temperature criteria of the FAO system, the whole of Central America is within the tropical domain. (According to Holdridge biotemperature criteria, portions are subtropical). The Tropical and Premontane belts of the Holdridge Life Zone system correspond with GEZ Tropical lowland zones, while the Lower Montane, Montane and Sub-Alpine belts are aggregated into GEZ Tropical mountain systems (TM). The Tropical and Subtropical lowland and premontane Life Zones were than classified according to the range of ecological parameters, primarily amount and distribution of rainfall or length of the dry season. There is a good correspondence between the Holdridge life zone humidity provinces and GEZ. For example, all life zones indicated “wet” or “rain” belong to GEZ tropical rain forest (TAr); the “moist” Life zones,

except two, correspond with Tropical moist deciduous forest (TAwa); and the "Dry" ones belong to tropical dry forest (TAwb).

Table 6. LUT Central America.

FAO system		**Corresponding source class: Holdridge Life zone**
Domain	**GEZ**	
Tropical	TAr	Tropical wet forest Tropical moist forest (marine association) Premontane wet forest (hot transition) Premontane rain forest Subtropical wet forest Subtropical rain forest
	TAwa	Tropical moist forest Tropical moist forest (monsoonal association) Premontane moist forest (hot transition) Subtropical moist forest
	TAwb	Tropical dry forest Subtropical dry forest Premontane moist forest (fc)
	TBSh	Tropical very dry forest Subtropical thorn woodland
	TM	Lower Montane moist forest Lower Montane wet forest Lower Montane rain forest Montane moist forest Montane wet forest Montane rain forest SubAlpine rain paramo

Sources: various national Holdridge Life zones maps and Holdridge (1967)

2.1.5 Caribbean Islands

Source map for the Caribbean GEZ is the Terrestrial Ecoregions of the World map (WWF, 2000). Ecoregions are defined on the basis of shared ecological features, climate and plant and animal communities. A driving principle in the mapping is to present the best available national-regional information, rather than applying a common global classification framework. As a result, the scale of zoning and mapping is generally more detailed than the FAO GEZ system, which is clearly reflected in the LUT.

In addition to the above source map, climatic data and DEM data were used to establish the correspondence. Based on rainfall data (annual amount, length of dry season), it appeared that the moist forest ecoregions correspond generally with GEZ Tropical rain forest (TAr), the dry forest ecoregions with GEZ Tropical moist deciduous forest (TAwa) and the scrub ecoregions with Tropical dry forest (TAwb).

Table 7. LUT Caribbean.

FAO system		Corresponding source class: Ecoregion
Domain	**GEZ**	
Tropical	Tar	Cuban Moist Forest Hispaniolan Moist Forest Jamaican Moist Forest Leeward Islands Moist Forest Puerto Rican Moist Forest Windward Islands Moist Forest
	TAwa	Bahamian Dry Forest Cayman Islands Dry Forest Cuban Dry Forest Hispaniolan Dry Forest Jamaican Dry Forest Leeward Islands Dry Forest Puerto Rican Dry Forest Windward Islands Dry Forest Cuban Wetland Enriquillo Wetland Bahamian Mangroves Greater Antilles Mangroves Lesser Antilles Mangroves
	TAwb	Cuban Cactus Scrub Leeward Islands Xeric Scrub Windward Islands Xeric Scrub
	TM	Bahamian Pine Forest Cuban Pine Forest Hispaniolan Pine Forest

Source: Terrestrial Ecoregions of the world (WWF, 2000)

2.2 Europe

The eastern boundary of Europe is defined by the Urals down to the western shores of the Caspian Sea.

The source map to compile the GEZ for Europe is the General Map of the Natural Vegetation of Europe (Bohn et al., 2000). The map shows the distribution of dominant potential natural plant communities corresponding to the actual climate and edaphic conditions. Further, it shows the regular natural distribution of the vegetation in correlation with longitude, latitude and altitude as well as the distribution and structure of the most important azonal vegetation types. The classification is organized in a hierarchic structure. At the highest level, 19 vegetation formations and formation complexes are distinguished, based on physiognomic-ecological features of the natural plant cover. They are designated by capital letters A to U (see Appendix II-2). 14 of these main units (A-O) represent the predominant zonal formations characterized by the prevailing life forms. They correspond to the main macroclimatic zones and belts in a sequence following the gradient from a cold and wet (north-northwest, high altitude) to a warm and dry (south-southeast) climate. The azonal formations P-U are partly characterized by heterogeneous physiognomy dependent on varied site conditions, especially coastal, mire and flood plain units. At the next level, each formation is subdivided into subgroups according to its most important features such as prevailing life forms, dominant

species and species groups. For instance, within the mesophytic deciduous broadleaved and mixed coniferous-broadleaved forests (F), 7 subgroups (F1- F7) have been distinguished which are characterized by the dominance of different tree species. They reflect different edaphic, climatic and phytogeographical conditions. The third level, not shown in Appendix II-2, represents the basic mapping units and comprises altogether some 650 units.

The correspondence between the Europe Natural Vegetation map and the FAO GEZ is presented in table 8. The vegetation types in bold occur only in that particular GEZ (one to one) and as can be seen, quite a number of source classes correspond to more than one GEZ. The source classes are approximately sorted by area extension. The following comments serve to further clarify the correspondence:

a. The whole Mediterranean region, in the European system classified as an entity separate from the subtropics, is part of the subtropical domain in the FAO GEZ. The zonal formation “Mediterranean sclerophyllous forests and scrub vegetation (J)”, characterizes the GEZ subtropical dry forests (SCs). In addition some sub-Mediterranean vegetation types (G) and Xerophytic coniferous forests (K) are part of the zone.

b. The temperate domain is largely dominated by the “Mesophytic deciduous broadleaved and mixed broadleaved-coniferous forests (F)” and the boundary between the oceanic zone (TeDo) and the continental zone (TeDc) roughly coincides with the boundary between F5a, forests dominated by beech and F3 to the east. The latter are mixed oak-hornbeam forests and presence of hornbeam replacing beech indicates a continental climate. Besides F3, type D8 “mixed forest dominated by conifers” is a major vegetation of TeDc and the northern limit forms the boundary with the Boreal coniferous forests (Ba) to the north.

c. The forest-steppe formation (L), a transition zone between continental forest and steppe, has been classified as GEZ Temperate continental forest (TeDc). According to regional experts (Udo Bohn, Anatoly Shvidenko), the formation has more affinity with forest than with steppe.

d. A number of vegetation types correspond with a lowland GEZ and as well with a mountain GEZ. The latter is usually located in a domain at lower latitude (for example type G3 corresponds both with TeDo and SM). These general regularities were helpful in delineation of mountain systems. The altitudinal threshold is on average around 800 m.

Table 8. LUT Europe.

FAO system		Corresponding source class: Vegetation formation
Domain	**GEZ**	
Subtropical	SCf	Hygro-thermophilous mixed deciduous broad-leaved forests (H) Swamp and fen forests (alder, birch) (T) Caucasian mixed hornbeam-oak forests (F7)
	SCs	Mediterranean sclerophyllous forests and scrub (all types: J1 – J8) Mediterranean mixed deciduous broadleaved forests (G3, G2, G4) Mediterranean pine forests (K2, K1) Azonal vegetation (U1, P1, P2)
	SM	Mediterranean mixed deciduous broadleaved forests (G4, G3, G2) Montane beech and mixed beech forests (F5b) Xerophytic coniferous forests and scrub (K4, K3, K1) Subalpine and oro-Mediterranean vegetation (C3) Supra-Mediterranean oak forests (J1b) Oroxerophytic vegetation (N)
Temperate	TeDo	Mesophytic deciduous broadleaved and mixed broadleaved-coniferous forests (F5a, F1a, F2, F3) Sub-Mediterranean broadleaved, oak dominated forests (G3) Hemiboreal coniferous forests with broadleaved trees (D8a, D12a) Azonal vegetation (U1, U2, S1, T, P1)
	TeDc	Mesophytic deciduous broadleaved and mixed broadleaved-coniferous forests (F3, F4a, F1a, F5a, F7) Hemiboreal coniferous forests with broadleaved trees (D8a, D12a, D11a) Forest steppes (L1a, L2, L1b) Broadleaved, oak dominated forests (G2, G1, G3) Steppes (M2b) Azonal vegetation (U1, T, S3, S1, P2, R)
	TeBSk	Steppes (M2a, M1a, M3, M4) Azonal vegetation (U1, R, P2, P1) Pine forests, partly with broad-leaved trees (D12a)
	TeBWk	Deserts (O1, O2) Azonal vegetation (U1, P2, R, P1) Oroxerophytic vegetation (N)
	TeM	Mesophytic deciduous broadleaved and mixed broadleaved-coniferous forests (F5b, F6, F4b, F1b) Montane coniferous forests, partly with broadleaved trees (D9, D8b, D12b) Subalpine vegetation (C3) Alpine vegetation (B5) Montane steppes (M2b, M1b) Nemoral, sub-and oro-Mediterranean pine forests (K1) Oroxerophytic vegetation (N)
Boreal	Ba	Boreal coniferous forests (D1 – D6, D10, D11b, D8a) Azonal vegetation, mostly mires (S1, S2, U1) Southern arctic and shrub tundras – Iceland (B3) Western boreal and montane birch forests, with pine – Iceland (C2)
	Bb	Eastern boreal woodlands (C1) Azonal vegetation: mires (S2, S3)
	BM	Western boreal and montane birch forests, with pine (C2) Alpine vegetation (B5, B4) Montane (Ural) coniferous forests (D7, D5) Subnival-nival vegetation of high mountains (A2) Atlantic dwarf shrub heaths (E) Azonal vegetation: ombrotrophic mires (S1)
Polar	P	Arctic tundras (B3, B1, B2) Arctic-subarctic ombro-minerotrophic mires (S2) Arctic polar deserts (A1)

Source: General Map of the Natural Vegetation of Europe (1:10 million) coordinated by U. Bohn et al.. (2000).

2.3 Northern Asia (Asian part of the former Soviet Union)

The map of vegetation of the USSR (Isachenko et al., 1990) has been used as the main source for the delineation of the GEZ in territories of the former Soviet Union The recently published map of vegetation of Russia and some neighbouring countries (Ogureeva et al., 1999) has been used for cross-checking and verification of certain boundaries.

The vegetation map of the USSR, scale 1: 4 million, represents 133 vegetation classes which are combined in 13 aggregated categories of vegetation. The "restored" or natural vegetation that existed before the transformation of land is indicated on areas currently under agriculture. The map presents major regularities of latitudinal (due to change of solar and thermal regimes) and regional (due to level of "oceanality-continentality" of climate) differentiation of vegetation at the continental scale; altitudinal types of vegetation communities in mountains; specifics of azonal and intrazonal vegetation; some features of natural and anthropogenic dynamics of vegetation cover; other information. Altogether, the basic map legend comprises more than 350 different units of vegetation / land cover.

The map "Zones and altitudinal zonality types of vegetation of Russia and adjacent territories" (Ogureeva et al., 1999), scale 1: 8 million, presents general regularities of spatial distribution of natural vegetation in plains and mountains. For the zonal lowland vegetation, the system uses three classification levels: zones, subzones and for each sub-zone, due to change of "oceanality-continentality" of climate, geographical variants. For mountain regions, the major unit of the classification used for vegetation differentiation in mountains is an altitudinal vegetation belt; systems, types and geographical variants of altitudinal zonality are major classifying categories.

The LUT shows the correspondence between the GEZ and the two source maps and indicates that the two source maps are very compatible in classification and terminology.

Delineation of mountain systems is based on the definition of mountain forests according to Russian forest inventory manuals (FFSR, 1995): “All forests (including areas covered by dwarf pine, shrubbery birch, etc.) are accounted for as mountain forests, when they grow in mountain systems or in separate mountain massifs with the change of relative heights of the territory more than 100 m and average slope from the foot of mountains to watersheds of mountain ranges, or to the altitudinal tree line is more 5^{o} (independently upon some parts have slope less 5^{o}), as well as all forests of mountain plateau and uplands, independently upon slope of terrain”.

To be consistent with the reclassification for Europe, the forest-steppe in Northern Asia has been classified as GEZ Temperate continental forest (TeDc). On the same grounds, the sub-Taiga, a transitional belt at the southern limits of the Taiga and occupied by mixed coniferous-broadleaved forests, has been also included in the same GEZ (TeDc). The former belt constitutes the southern limit of this GEZ, the latter the northern limit.

Table 9. LUT Northern Eurasia.

FAO system		**Corresponding source class**	
Domain	**GEZ**	**Isachenko map** [1]	**MGU/BI map**[2,3]
Polar	P	1000 Polar Desert (1) 2110 Arctic Plain Tundra (1) 2200 Mountain (3) Tundra 2120 Northern Tundra (4) 2130 Southern Tundra (2)	A.1. Polar Desert (2) A.2. Arctic Tundra (4) A.3. Typical Tundra (5) A.4. Southern Tundra (5) 1-3. (Mountain) arctic types (3) 4-9. (Mountain) Tundra (6)
Boreal	Bb	1100 Shrub communities 4111 Pre-tundra Sparse Forests (3)	Б.1. Forest tundra (6) 10-22 Hypoarctic (Mountain) Types (13) [4]
	Ba	4112 Northern Taiga Forests (4) 4113 Middle Taiga Forests (5) 4114 Southern Taiga Forests (4)	Б.2. Northern Taiga (6) Б.3. Middle Taiga (8) Б.4. Southern Taiga (5)
	BM	4211 Sub-alpine Sparse Forests (2) 4212 Mountain Taiga Forests (7)	23-49. Boreal (Taiga) Types (27)
Temperate	TeDc	4115 Sub-Taiga (Plain) Forests (4) 5100 Broad-leaved (Plain) Forests (6) 4120 Forest Steppe Forests (2)	Б.5. Sub-Taiga (7) B.1. Subzone of Broad-Leaved Forests (4) B.2. Subzone of Forest Steppe (7)
	TeBSk	6100 Plain Steppe (7)	Г. Steppe Zone (12)
	TeBWk	7100 Plain Desert (11)	D. Desert Zone (8)
	TeM	7200 Mountain Desert (7) 7300 Sub-Alpine Desert (1) 6200 Mountain Steppe (8) 6300 Sub-alpine Mountain Steppe (3) 8000 Savannoides (mountain) (4) 9000 Phryganoides (4) 4220 Mountain Temperate Dark Coniferous Forests (4) 5200 Broad-leaved (Mountain) Forests (6) Mountain Sparse Forests and Shrub 3000 Sub-alpine Sparse Forests (1)	52-72. Nemoral Mountain (Broad-Leaved Forests) (23) 73-77. Subarid (5) Mountain

Note: [1] Table contains aggregated classification units of the original maps. Number of initial classes presented in Isachenko map is indicated in brackets. Azonal (e.g., bogs) and intrazonal classes of plains are included in zonal aggregations. [2,3] Number of geographical variants by Ogureeva et al. (1999) is presented in brackets. [4] The territories are distributed between Bb and BM.

2.4 Other non-tropical Asia

2.4.1 China

The ecological zoning for China was mainly based on the map and manuscript "Geographic Distribution of China's Main Forests" (Zheng de Zhu, 1992). In addition, the Vegetation map of China (Hou Xue-Yu, 1983) and a paper by Zheng Du (FAO, 2000) on the eco-geographic regionalisation of China provided valuable information. Zheng Du also advised on the final delineation and classification of the GEZ for China.

The map of the Geographic Distribution of China's Main Forests has a hierarchic structure with three levels (Appendix II-3). At the highest level China is divided into two main regions: the Monsoon moist region, roughly the eastern half of China and the Interior dry region to the west. The boundary between the two regions is approximately following the 500 mm isohyet. At the second level, the primary factor for classification is temperature; the Monsoon moist region, where China's forest is concentrated, is subdivided in 8 zones, ranging from cold-temperate in the north to "quasi-tropical" in the south. The third, Division level is classified with consideration of distribution of forest types and dominant species. As the classification system is focused on forests, non-forested areas such as arid rangelands, deserts and grasslands are not categorized at the division level. Additional factors used in the classification are topography and landform. Both at the second and third level, mountain classes are distinguished.

The correspondence between the source map and the FAO GEZ was established by comparing climatic criteria of both systems. The reclassification of Divisions of the eastern Monsoon Moist region is as follows, from north to south:

- cold temperate zone corresponds with GEZ boreal coniferous forest (Ba);
- divisions of the central temperate and eastern warm temperate zone correspond with GEZ temperate continental forest (TeDc), except for mountain divisions which are part of TeM;
- all divisions (no. 8 – 12) of the Western Medium to High Mountain Temperate Zone are classified as Temperate Mountain systems (TeM);
- divisions of the Northern - , Middle – and Southern Subtropical zone are part of GEZ subtropical humid forest (SCf), except for mountain divisions;
- quasi-tropical divisions correspond with the Tropical domain. 21 and 22 belong to GEZ TAwa and 23 to TM.

The interior dry region comprises vast mountain systems, including the Tibetan plateau and temperate deserts and steppe. Delineation of mountain systems was done with help of DEM data and the 1000 m contour was taken as threshold.

Table 10. LUT China.

FAO system		Corresponding source class: Geographic divisions of China's main forests
Domain	**GEZ**	
Tropical	TAwa	(21) Leizhou Peninsula Division (22) Hainan Island Division
	TM	(23) Southern Yunnan Division
Subtropical	SCf	(13) Middle-to-Lower Changjiang Alluvial Plain Division (15) South of Changjiang Low Mountain Division (16) Sichuan Basin Division (18) Taiwan Division (19) South China Hilly Division
	SM	(14) Qinling Range and Dabashan Mountain Division (17) Yunnan Plateau Division (20) Western Guangxi and Central-Southern Yunnan Division Parts of Central Temperate zone, Interior dry Region
Temperate	TeDc	(2) Eastern Mountain Division (4) Liaodong Peninsula and Shandong Peninsula Division (5) Huanghuaihai Coastal Plain Division
	TeBSk	(3) Western Plain Division Parts of Central Temperate zone, Interior dry Region
	TeBWk	Parts of Central Temperate zone, Interior dry Region
	TeM	(6) North China Middle-to-Low Mountain Division (7) The Loess Plateau Division (8) Southern Gansu and Northern Sichuan Division (9) Eastern Kangding Division (10) Western Kangding Division (11) Southern Sichuan and Northwestern Yunnan Division (12) Southeastern Tibet Division (24) Altai Mountain Division (25) Tianshan Mountain Division (26) Qilianshan Mountain Division Parts of Central Temperate zone, Interior dry Region
Boreal	Ba	(1) Daxinganling Division

Source: Geographic Distribution of China's Main Forests (Zheng de Zhu, 1992).

2.4.2 Mongolia, Japan and Korea Peninsula

For these countries the map of Terrestrial Ecoregions of the world (WWF, 2000) was used as source. The following primary sources were used to delineate the Ecoregions: Mongolia's wild heritage (Mongolia Ministry for Nature and Environment, 1996), Distribution of forest vegetation and climate in the Korean peninsula (Yim, 1977) and the Potential Natural Vegetation map of Japan (Miyawaki, 1975).

Table 11. LUT Mongolia.

FAO system		Corresponding source class: Ecoregion
Domain	**GEZ**	
Temperate	TeBSk	Dagurian Forest Steppe Mongolian-Manchurian Grassland
	TeBWk	Alashan Plateau Semi-Desert Eastern Gobi Desert Steppe Gobi Lakes Valley Desert Steppe Great Lakes Basin Desert Steppe Junggar Basin Semi-Desert Taklimakan Desert
	TeM	Altai Alpine Meadow and Tundra Altai Montane Forest and Forest Steppe Khangai Mountains Alpine Meadow Khangai Mountains Conifer Forest Selenge-Orkhon Forest Steppe
Boreal	BM	Sayan Alpine Meadow and Tundra Sayan Intermontane Steppe Sayan Montane Conifer Forest Trans-Baikal Conifer Forest

Source: Terrestrial Ecoregions of the world (WWF, 2000)

Table 12. LUT Korea Peninsula.

FAO system		Corresponding source class: Ecoregion
Domain	**GEZ**	
Subtropical	SCf	Southern Korea Evergreen Forest
Temperate	TeDc	Central Korean Deciduous Forest Manchurian Mixed Forest Changbai Mountains Mixed Forest

Source: Terrestrial Ecoregions of the world (WWF, 2000)

Table 13. LUT Japan.

FAO system		Corresponding source class: Ecoregion
Domain	**GEZ**	
Subtropical	SCf	Nihonkai Evergreen Forest Taiheiyo Evergreen Forest
	SM	Taiheiyo Montane Deciduous Forest
Temperate	TeDc	Hokkaido Deciduous Forest South Sokhalin-Kurile Mixed Forest
	TeM	Hokkaido Montane Conifer Forest Honshu Alpine Conifer Forest Nihonkai Montane Deciduous Forest

Source: Terrestrial Ecoregions of the world (WWF, 2000)

2.4.3 Middle East

The Middle East is the geographic region bordering Europe, former USSR, Tropical Asia and Africa and comprises the following countries: Afghanistan, Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.

The main sources that were consulted for producing the Ecological Zone map for the region were the Vegetation map (UNESCO-FAO, 1970) and the bioclimatic map of the Mediterranean zone (UNESCO-FAO, 1963). Zohary (1973), Quezel (1977) and Barkoudah (1998) provide good background information on vegetation and bioclimate of the Middle East.

After a study of the maps and consultation with the regional expert, Youssef Barkoudah, the two UNESCO-FAO maps were found to be most suitable sources for the EZ mapping, in particular the vegetation map. They are presenting the two main features or set of criteria that form the basis for the FAO global Ecological Zone classification, i.e. climate and potential vegetation. Although the climatic criteria used in the UNESCO-FAO bioclimatic map differ from Köppen-Trewartha, there is a good general correspondence between the two systems. The UNESCO-FAO vegetation map was used for the delineation of the Ecological Zones. This map depicts the potential vegetation formations in relation to climate. The various formations are distinguished on basis of physiognomy.

Characteristic for the region is the large extent of dry Ecological Zones, both desert and sub-desert, with no - or sparse vegetation. Mountains are also extensive and most forests in the region are confined to mountains, in particular the wetter submontane zones. Steppe vegetation, dominated by grass and shrubs, cover the drier mountain zones.

Table 14. LUT Middle East.

FAO system		Corresponding source class: Vegetation formations
Domain	**GEZ**	
Tropical	TBWh	**14** Tropical biased formations. **15** Transitional formations . **16** Perennial formations with or without ephemerophytes in accentuated desert climates. **17** Ephemerophyte-dominated formations **18** Sparse ephemerophyte formations or no vegetation.
	TM	**4** Mountain forest – *Junicepera procera.* **6** Upland formation (1000 – 2000 m) with *Junicepera procera* and *Podocaropus gracilior*. **12** Mountain thorny scrub and thickets.
Subtropical	SCf	**28** Formations of the sub-humid Mediterranean stage. **50** Formations of the sub-Mediterranean submountain stage.
	SCs	**26** Formations of the western Mediterranean evergreen oak stage. **27** Formations of the eastern Mediterranean evergreen oak stage.
	SBSh	**11** Shrub or tree pseudosteppe and savannah, thickets and open forest. **12** Bush shrub and tree pseudosteppe and savannah and thickets. **19** Arbuscular shrub pseudosteppe in warm temperate climates. **20** Arbuscular shrub pseudosteppe in temperate climate. **21** Lowland. **23** Shrub or tree pseudosteppe in less dry climate. **25** Steppe with or without trees or shrubs.
	SBWh	**16** Perennial formations with or without ephemerophytes in accentuated desert climates. **18** Sparse ephemerophyte formations or no vegetation. **13** Mediterranen biased formations. **15** Transitional formations.
	SM	**21** Upland steppe, with or without shrubs. **22** Shrub or tree pseudosteppe in very dry climate. **24** Temperate and cold temperate climates with shrub pseudosteppe or pistachio-almond tree pseudosteppe. **25** Mainly high steppe with or without trees or shrubs. **30** High mountain steppe and grassland. **31** Plateau and submontane steppe. **33** Steppes or tree steppes with pistachio, almond and Juniper. **34** Steppe or tree steppes with juniper. **35** Oak and juniper forest stage formations. **36** Formations of the deciduous and semi deciduous forest stage; **37** Formations of the western sub-Mediterranean oak and pine stage; **38** Formations of the eastern sub-Mediterranean oak and pine stage; **39** Formations of the fir and cedar stage; **40 – 46**: Mountain formations (Temperate and cold axeric climates).
Temperate	TeDc	**47** Formations of the western humid submountain stage. **48** Formations of the western dry submountain stage.
	TeBSk	**32** Lowland steppes.
	TeBWk	**51** Steppe and desert formations.

Source: Vegetation map of the Mediterranean zone (UNESCO – FAO, 1970)

2.5 South America, Africa and Tropical Asia

These three regions are presented together, as the source maps are all of the same type, i.e. the ecofloristic zone (EFZ) maps. These EFZ maps were developed during FRA1990 to report forest resources information by Ecological Zone. The work was carried out by ICIV, now the Laboratoire d' Ecologie Terrestre (LET), Toulouse, France. As part of the FRA2000 ecological zoning LET has updated and amended the EFZ maps. This involved the development of a consistent classification and coding for the three continents and refinement

of the EFZ delineation by using more recent (potential) vegetation maps and digital elevation model (DEM) data.
The EFZ classification has two levels (Appendix II-4). At the broadest level 28 groups of ecofloristic zones, indicated with Roman numerals, are defined, based on climate, vegetation physiognomy and physiography, i.e. altitude. The ecofloristic zone identifies the most detailed ecological units where floristic composition together with geographic location played a major role in their identification and delineation (LET, 2000).

A case study on South America was carried out prior to the Cambridge meeting, mainly to test the compatibility between the EFZ classification for the tropics and the proposed global framework based on Köppen-Trewartha. The results of this study indicated a good overall correspondence between the systems, with a significant amendment to divide the Köppen-Trewartha tropical Aw, the seasonally dry zone, into a wetter (3 to 5 dry months) and drier (5 to 8 dry months) zone. This division better reflects the vegetation zonation in the tropics: moist deciduous forest followed by dry forest and woodlands further away from the equator.

After completing the GEZ for South America, the correspondence was established for Africa and Asia and one common LUT prepared (Table 15). The altitudinal threshold between lowland and mountains is generally taken at 1000 meter, with some local variations. In certain regions in Asia, for instance western Ghats, India and the mountain range of Sumatra, Indonesia, the threshold is as high as 1500 - 1800 meter. The threshold is based on a clear change in physiognomy and species composition of the forest.

Table 15. LUT South America, Africa and Tropical Asia.

FAO system		**Corresponding source class: Ecofloristic zone (Group)**	
Domain	**GEZ**		
Tropical	TAr	I-II	Tropical lowland, wet and very wet
	TAwa	III	Tropical lowland, subhumid with dry season
	TAwb	IV	Tropical lowland, dry with pronounced dry season
	TBSh	V-VI	Tropical lowland, very dry and semi-arid
	TBWh	VII	Tropical lowland, arid
	TM	VIII	Tropical medium elevation wet
		IX	Tropical medium elevation subhumid
		X	Tropical medium elevation dry
		XI	Tropical medium elevation semi-arid
		XII	Tropical montane moist
		XIII	Tropical montane subhumid
		XIV	Tropical montane dry
		XV	Tropical montane semi-arid
		XVI	Tropical high elevation
Subtropical	SCf	XVII	Subtropical lowland humid and subhumid
	SCs	XVIII	Subtropical lowland seasonally dry
	SBSh	XIX	Subtropical lowland semi-arid
	SM	XX	Subtropical medium elevation humid
		XXI	Subtropical medium elevation seasonally dry
		XXII	Subtropical medium elevation semi-arid
		XXIII	Subtropical montane humid
		XXIV	Subtropical montane seasonally dry
		XXV	Subtropical high elevation
Temperate	TeDo	XXVI	Temperate lowland oceanic
	TeBSk	XXVII	Temperate lowland semi-arid
	TeM	XXVIII	Temperate mountain

Source: Ecofloristic zone maps (LET, 2000)

2.6 Oceania

2.6.1 Australia

The main source for the GEZ of Australia is the Interim Biogeographic Regionalisation for Australia (Thackway et al., 1995). Additional sources that were consulted are a Climate map of Australia (Dick, 1975), which follows the Köppen classification and Australia's State of the Forests Report (BRS, 1998). The latter report presents maps on current forest distribution by forest type, crown cover density and other attributes.

The Interim Biogeographic Regionalisation for Australia (IBRA) defines so called IBRA regions or biogeographic regions for Australia to serve as a national framework for the conservation of biodiversity. The major attributes used to define and delineate the IBRA regions are: climate, lithology/geology, landform, vegetation, flora and fauna and land use. A total of 80 IBRA regions have been identified and mapped.

The global ecological zoning for Australia, carried out by Australia's Bureau of Rural Sciences (BRS), was complicated for the following reasons:

a. For Australia the correlation between vegetation physiognomy and climate is less distinct or different as in other regions. The use of Köppen-Trewartha climate types as a basis for ecological zoning is therefore less valid and more complicated to implement. For instance, in most tropical semi-arid regions (TBSh) the dominant vegetation is shrubland, however, woodlands dominate this zone in Australia. In the Australian deserts, vegetation is generally better developed compared to other deserts.

b. Difference in terminology / classification between the commonly applied climate system in Australia and the FAO GEZ system. For instance, the southwest and most of southeastern Australia are generally referred to as (warm) temperate or Mediterranean in the Australian system. In the FAO GEZ system these regions are part of the subtropical domain.

The correspondence between the Australia sources and the GEZ was established by first identifying and delineating the approximate Köppen-Trewartha climate types and then correlate the boundaries with the IBRA regions and distribution of natural vegetation. The resulting LUT is presented in Table 16. As an intermediate level between the source units, the IBRA regions and the FAO GEZ, BRS distinguishes 14 ecozones with relatively uniform climate and vegetation. The relationship between these ecozones and the further aggregated GEZ level is shown in the LUT and explained below:

- The subtropical dry forest zone (SCs) is divided into a typical Mediterranean zone (ecozone 12) with a warm and dry summer in the southwest of Australia and ecozone 11 in the central south characterized by a cool summer and a less distinct seasonality of rainfall.

- The subtropical steppe zone (SBSh) consists of 2 northern ecozones (no. 5 and 6) with typical subtropical characteristics (even rainfall, slightly higher during summer), while rainfall in the southern ecozone 13 is concentrated in winter. Also vegetation is distinctly

different between the zones. For instance, ecozone 6 is defined based on dominance of low *Acacia aneura* woodlands and shrublands commonly known as "Mulga".

- The Australian deserts (SBWh) are divided into deserts dominated by (sparse) shrubs (ecozone 7) and grassland deserts (ecozone 8).

- The temperate mountain systems (TeM) comprises a zone of medium altitude (ecozone 10) and the high altitude Australian Alps (ecozone 14).

Table 16. LUT Australia.

FAO system		**Corresponding source class: Biogeographic region (IBRA)**	
Domain	**GEZ**		
Tropical	TAr		Ecozone 1
		CMC	Central Mackay Coast
		WT	Wet Tropics
	TAwb		Ecozone 2
		CYP	Cape York Peninsula
		NK	North Kimberley
		VB	Victoria Bonaparte
		TEC	Top End Coastal
		PCA	Pine Creek- Arnhem
		CA	Central Arnhem
		DAB	Daly Basin
	TBSh		Ecozone 3
		GUP	Gulf Plains
		EIU	Einasleigh Uplands
		OVP	Ord-Victoria Plains
		GFU	Gulf Fall Uplands
		BBN	Brigalow Belt North
		STU	Sturt Plateau
		DL	Dampierland
		CK	Central Kimberley
		DEU	Desert Uplands
		GUC	Gulf Coastal
Subtropical	SCf		Ecozone 4
		SEQ	South East Queensland
		NNC	NSW North Coast
		SB	Sydney Basin
	SCs		Ecozone 11 (cool summer)
		NCP	Naracoorte Coastal Plain
		LB	Lofty Block
		WAR	Warren
			Ecozone 12 (summer dry)
		JF	Jarrah Forest
		SWA	Swan Coastal Plain

Table 16. continued

Domain	GEZ	Corresponding source class: Biogeographic region (IBRA)
Subtropical	SBSh	Ecozone 5 (northern subtropical)
		BBS Brigalow Belt South
		DRP Darling Riverine Plain
		NSS NSW South West Slopes
		CP Cobar Peneplain
		NAN Nandewar
		Ecozone 6 (northern subtropical, drier than 5)
		ML Mulga Lands
		Ecozone 13 (southern warm temperate)
		MDD Murray - Darling Depression
		RIV Riverina
		AW Avon Wheatbelt
		MAL Mallee
		EYB Eyre and Yorke Block
		VM Victorian Midlands
		ESP Esperance Plains
		GS Geraldton Sandplains
	SBWh	Shrub-sand deserts (22 regions) – Ecozone 7
		Grass-sand deserts (3 regions) – Ecozone 8
Temperate	TeDo	Ecozone 9
		SEC South East Corner
		VVP Victorian Volcanic Plain
		WSW West and South West
		SCP South East Coastal Plain
		WOO Woolnorth
		BEN Ben Lomond
		FRE Freycinet
		DE D'Entrecasteaux
		FUR Furneaux
	TeM	Ecozone 10 (> 800 m)
		SEH South Eastern Highlands
		NET New England Tableland
		CH Central Highlands
		TM Tasmanian Midlands
		Ecozone 14 (> 1200 m)
		AA Australian Alps

Source: Bureau of Rural Sciences, Australia (based on Thackway et al., 1995)

2.6.2 New Zealand

For the GEZ of New Zealand, the Terrestrial Ecoregions of the world map (WWF, 2000) was used as source. The primary source for delineation of Terrestrial Ecoregions is "Ecological regions and districts of New Zealand" (New Zealand Department of Conservation. 1987).

The correspondence was established by correlating the source map with the distribution of Köppen-Trewartha climate types (Figure 30). North Island is part of the subtropical domain, while South Island belongs to the temperate domain.

Table 17. LUT New Zealand.

FAO system		Corresponding source class: Ecoregion
Domain	**GEZ**	
Subtropical	SCf	Northland Temperate Kauri Forest Northland Temperate Forest
Temperate	TeDo	Southland Temperate Forest Westland Temperate Forest Richmond Temperate forest Cantebury-Otago Tussock Grassland Rakiura Island Temperate Forest Nelson Coast Temperate Forest
	TeM	Fiordland Temperate Forest Southland Montane Grassland

Source: Terrestrial Ecoregions of the world (WWF, 2000)

2.6.3 Pacific Islands

The GEZ of the Pacific Islands is based on the WWF Terrestrial Ecoregion map (WWF 2000) and study of climatic data. The whole region corresponds to GEZ Tropical rain forest (TAr).

2.7 Compilation of the global GEZ map

After producing the regional GEZ maps the global GEZ map was composed out of all the regional tiles. The process involved first the thematic aspect of edge-matching. This was particularly an issue for the vast area of Europe and Asia, where a number of different tiles had to be brought together with large bordering areas. The delineation of GEZ between the Europe part and the former USSR matched well, only little adjustments were needed. The same applies to the GEZ boundaries between Europe and the Middle East. Most attention needed the matching of the tiles Tropical Asia, China and the former USSR, complicated by the presence of extensive mountain systems on the border areas. In addition, there is considerable difference in detail of GEZ delineation between Tropical Asia and China. After solving the edge problems the GEZ regional tiles were transformed to a global base map: ESRI's Digital Chart of the World (DCW), edition 1 December 1994. The base scale of the DCW is 1: 1 million. The end result, the GEZ map of the world, is presented on the next page. The GEZ map, together with other global maps produced by FRA2000, is also presented on the FAO Forestry-FRA website: www.fao.org/forestry/fo/fra/index.jsp under global maps.

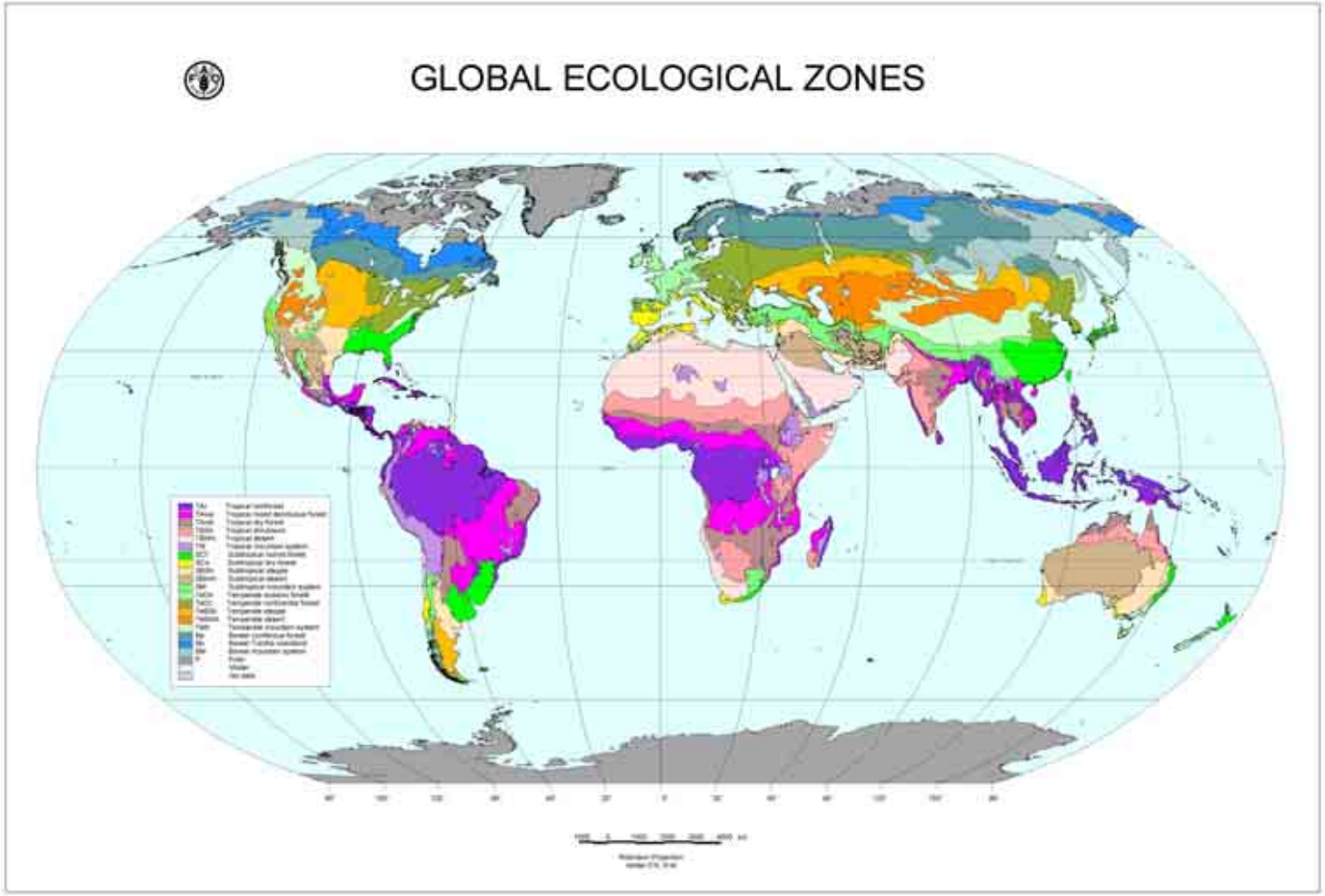

Figure 31. Global Ecological Map of the world

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Appendix II-1: Source maps used for the delineation of FAO GEZ

Region	Name of map	Scale	Projection	Thematic information / classification criteria
Canada and Mexico	Ecological regions of North America (CEC 1997)	1: 10 million	Lambert Azimuthal Equal Area	Holistic classification system based on climate, soils, landform, vegetation and also land use. Hierarchic system: 15 Level I ecological regions and 52 Level II regions.
USA	Ecoregions of the USA (Bailey 1994)	1: 7.5 million	Lambert Azimuthal Equal Area	Classification based on Köppen climate system: broad domains equivalent to climate groups, subdivided into divisions approximately equivalent to climate types.
Central America	National Holdridge Life zone maps, transformed to a regional base map	Various scales Base map at 1: 1.5 million		Holdrige Life Zones are defined using the parameters (bio)temperature, rainfall and evapotranspiration.
South America, Africa, Tropical Asia	Ecofloristic zones maps (LET 2000)	1: 5 million	Lat-Long	28 groups of ecofloristic zones are defined, based on climate, vegetation physiognomy and physiography, i.e. altitude. The EFZ identifies the most detailed ecological units, based on the additional criteria of flora and geographic location.
Middle East	Vegetation map of the Mediterranean zone (UNESCO – FAO, 1969)	1: 5 million		Distribution of potential vegetation formations in relation to climate. The various formations are distinguished mainly on basis of physiognomy.
Europe	General Map of the Natural Vegetation of Europe. (Bohn et al., 2000)	1: 10 million	Equidistant_Conic	Distribution of potential natural plant communities corresponding to the actual climate and edaphic conditions. At broadest level 19 vegetation formations defined, of which 14 zonal and 5 azonal formations.
Former Soviet Union	Vegetation map of the USSR (Isachenko et al., 1990)	1: 4 million	Lambert Azimuthal Equal Area	Distribution of broad vegetation formations related to climate, altitude and also current land use. 133 vegetation classes are aggregated into 13 categories of vegetation
China	Geographic Distribution of China's Main Forests (Zheng de Zhu, 1992)			Main aim to identify and map China's forest vegetation A hierarchic classification is used based on climate and distribution of forest types and tree species. 27 Forest Divisions are mapped.
Australia	Interim Biogeographic Regionalisation for Australia (Thackway et al., 1995)	1: 15 million	Albers Equal Area	Major attributes to define biogeographic regions are: climate, lithology/geology, landform, vegetation, flora and fauna and land use. A total of 80 IBRA regions have been mapped.
Caribbean, Mongolia, Korea's, Japan, New Zealand, Pacific Isl.	Terrestrial Ecoregions of the World (WWF 2000)		Lat-Long	Ecoregions are defined by shared ecological features, climate and plant and animal communities. Main use is for biodiversity conservation.

Appendix II-2: Legend of the General Map of the Natural Vegetation of Europe

I ZONAL FORMATIONS

A Polar deserts and subnival-nival vegetation of high mountains
A1 Arctic polar deserts
A2 Subnival vegetation of high mountains in the boreal and and nemoral zone
B Arctic tundras and alpine vegetation
B1 Northern arctic tundras
B2 Middle arctic tundras
B3 Southern arctic and shrub tundras
B4 Mountain tundras and sparse mountain vegetation
B5 Alpine vegetation in boreal, nemoral and Mediterranean zone
C Subarctic, boreal and nemoral montane open woodlands, as well as subalpine and oro-Mediterranean vegetation
C1 Eastern boreal woodlands
C2 Western boreal and nemoral-montane birch forests, partly with pine forests
C3 Subalpine and oro-Mediterranean vegetation (forests, scrub and dwarf shrub communities in combination with grasslands and tall forb communities)
D Mesophytic and hygromesophytic coniferous and mixed broadleaved–coniferous forests
Western boreal spruce forests, partly with pine, birch, alder
Northern boreal types
D1 Middle boreal types
D2 Southern boreal types
D3 Eastern boreal pine-spruce and fir-spruce forests, partly with birch, larch
Northern boreal types
D4 Middle boreal types
D5 Southern boreal types
D6 Montane (Ural) types
D7 Hemiboreal spruce and fir-spruce forests with broad-leaved trees: a) lowland-colline, partly submontane
D8 types, b) montane (Ural) types
Montane to altimontane, partly submontane fir and spruce forests in the nemoral zone
D9 Boreal and hemiboreal pine forests, partly with birch, spruce
Northern boreal pine forests
D10 Middle and southern to hemiboreal pine forests: a) lowland-colline types, b) montane types
D11 Hemiboreal and nemoral pine forests, partly with broad-leaved trees: a) lowland (to submontane) types,
D12 b) montane to altimontane types
E Atlantic dwarf shrub heaths
F Mesophytic deciduous broad-leaved and mixed coniferous-broadleaved forests
F1 Acidophilous oak and mixed oak forests, poor in species. a) lowland to submontane types,
b) montane to altimontane types
F2 Mixed oak-ash forests
F3 Mixed oak-hornbeam forests
F4 Lime-oak forests: a) lowland colline types, b) submontane-montane types
F5 Beech and mixed beech forests: a) lowland to submontane types b) montane to altimontane types, partly with fir and spruce
F6 Oriental beech and hornbeam-Oriental beech forests
F7 Caucasian mixed hornbeam-oak forests
G Thermophilous mixed deciduous broadleaved forests
G1 Subcontinental thermophilous (mixed) pedunculate oak and sessile oak forests
G2 Sub-Mediterranean-subcontinental thermophilous bitter oak forests, as well as mixed forests
G3 Sub-Mediterranean and meso-supra-Mediterranean downy oak forests, as well as mixed forests
G4 Mediterranean oak forest
H Hygro-thermophyllous mixed deciduous broadleaved forest

J Mediterranean sclerophyllous forests and scrub
Meso- and supra Mediterranean, as well as relict sclerophyllous forests
J1 Quercus ilex subsp. rotundifolia forests: a) Meso-Mediterranean types, b) Supra-Mediterranean and relict types
J2 Holm oak forests: a) Meso-Mediterranean types, b) Supra-Mediterranean and relict types
J3 Cork oak forests
J4 Kermes oak forests and scrub
Thermo-Mediterranean sclerophyllous forests and xerophytic scrub
J5 Thermo-Mediterranean cork oak forests
J6 Thermo-Mediterranean Quercus ilex subsp. rotundifolia forests
J7 Wild olive-locust tree forests
J8 Thermo-Mediterranean xerophytic scrub
K Xerophytic coniferous forests and scrub
K1 Nemoral, sub-and oro-Mediterranean pine forests
K2 Meso- to thermo-Mediterranean pine forests
K3 Meso- and supra-Mediterranean fir forests
K4 Juniper and cypress woodlands and scrub
L Forest steppes (meadow steppes or dry grasslands alternating with deciduous broadleaved forests or xerophytic scrub)
L1 Subcontinental meadow steppes and dry grassland alternating with oak forests or scrub:
a) Lowland colline types, b) submontane to montane types
L2 Sub-Mediterranean-subcontinental lowland to montane herb-grass steppes, partly meadow steppes, alternating with oak forests with Acer tataricum
M Steppes
M1 Herb-rich grass steppe: a) lowland colline types, b) montane type
M2 Herb-grass steppe: a) lowland colline types, b) montane type
M3 Grass steppes
M4 Desert steppes
N Oroxerophytic vegetation (thorn cushion communities, tommilares, mountain steppes, partly scrub)
O Deserts
O1 Northern lowland dwarf semishrub deserts
O2 Southern lowland-colline dwarf semishrub deserts with ephemeroids

II AZONAL FORMATIONS

P Coastal vegetation and inland halophytic vegetation
P1 Vegetation of costal sand dunes and sea shores, often in combination with halophytic vegetation, partly with vegetation of rocky sea shores
P2 Coastal and inland halophytic vegetation
R Tall reed and tall sedge swamps, aquatic vegetation
S Mires
S1 Ombrotrophic mires
S2 Arctic-subarctic ombro-minerotrophic mires
S3 Minerotrophic mires
T Fen and swamp forests
U Vegetation of flood plains, estuaries and freshwater polders
U1 Flood-plain vegetation and moist lowland forests
U2 Vegetation of estuaries and freshwater polders

Appendix II-3: Geographic divisions of China's main forests

(Zheng-de Zhu, 1992)

I. MONSOON MOIST REGION

1. Cold Temperate Zone
    (1) Daxinganling Division
2. Central Temperate Zone
    (2) Eastern Mountain Division
    (3) Western Plain Division
3. Eastern Warm Temperate Zone
    (4) Liaodong Peninsula and Shandong Peninsula Division
    (5) Huanghuaihai Coastal Plain Division
    (6) North China Middle-to-Low Mountain Division
    (7) The Loess Plateau
4. Western Medium to High Mountain Temperate Zone
    (8) Southern Gansu and Northern Sichuan Division
    (9) Eastern Kangding Division
    (10) Western Kangding Division
    (11) Southern Sichuan and Northwestern Yunnan Division
    (12) Southeastern Tibet Division
5. Northern Subtropical Zone
    (13) Middle-to-Lower Changjiang Alluvial Plain Division
    (14) Qinling Range and Dabashan Mountain Division
6. Middle Subtropical Zone
    (15) South of Changjiang Low Mountain Division
    (16) Sichuan Basin Divi—ion
    (17) Yunnan Plateau Division
7. Southern Subtropical Zone
    (18) Taiwan Division
    (19) South China Hilly Division
    (20) Western Guangxi and Central-Southern Yunnan Division
8. Quasi-tropical Zone
    (21) Leizhou Peninsula Division
    (22) Hainan Island Division
    (23) Southern Yunnan Division

II. INTERIOR DRY REGION

9. Cold Temperate Zone
    (24) Altai Mountain Division
10. Central Temperate Zone
    (25) Tianshan Mountain Division
    (26) Qilianshan Mountain Division

Appendix II-4: Ecofloristic zone classification framework (LET, 2000)

Group of EFZ	Name *Climax zonal vegetation*	Criteria (climate and altitude)	Ecofloristic zone		
			South America	**Africa**	**Asia**
I	Tropical lowland wet *Dense (semi)evergreen ombrophilous forest*	P>2000mm, 0 d.m., Alt.0-1000m in S.America tm>15°, P>1500, 0-4 d.m., Alt. 0-300m in Africa, 0-700m in Asia	Ia Extremely wet Ib Very wet	Ia-IIa Equatorial Africa Ib-IIb Madagascar Ic Western Africa Ombrophilous forest Id-IId Drier semi-evergreen rainforest Ie-IIe Sambirano (Mada.) If East Africa	Ia-IIa Malaya west of Wallace's Line Ib-IIb Malaya east of Wallace's Line Ic-IIc SE Asia Id-IId India, Myanmar Ie Sri Lanka If-IIf Nepal
II	Tropical lowland wet *Evergreen seasonal forest*	P>1500mm, 0-4 d.m., Alt.0-1000m in S.America, 300-1000m in Africa 700 to 1000-1500 in Asia	IIa Amazon Basin IIb Atlantic coast IIc Iguaçu-Parana Valleys		
III	Tropical lowland moist with pronounced dry season *Moist deciduous forests*	P=1000-2000mm, 3-6d.m., tm>15° Alt. 0 to 800-1500m	IIIa Cerrados IIIb Semi-deciduous forests IIIc Llanos IIId Pantanal IIIe Paraguay-Parana vall.	IIIa W Africa IIIb Savanna woodland with *Isoberlinia* IIIc Madagascar IIId Wetter Miombo IIIe E Africa IIIf Transition f. (S Hem.)	IIIa Philippines IIIb Indonesia IIIc Papua-New-Guinea IIId S and SE Asia
IV	Tropical lowland dry with pronounced dry season *Dry forests and woodlands*	P=400-1500mm, 5-9d.m., tm>15° Alt. 0 to 1000-1500m	IVa Caatinga IVb Carib and Guayaquil IVc Chaco	IVa S Sudanian Domain IVb Accra IVc Cabinda IVd Drier miombo	Iva Papua-New-Guinea IVb SE Asia Ivc India, Sri Lanka
V	Tropical lowland very dry *Thorn bush, dry savannas*	P=300-1000mm, 7-11d.m., tm>15° Alt. 0-1000m	V Xeromorphic woodlands (Guajira and Guayaquil)	Va N Sudanian Domain Vb E Africa Vc Madagascar Vd S Africa	Va Indonesia Vb Viet Nam Vc India, Myanmar
VI	Tropical lowland semi-arid *Pseudo-steppe*	P=200-500mm, 9-11d.m., tm>15° Alt. 0 to 1000-1800m		VIa Sahel VIb E Africa VIc Madagascar VId S Africa	VI Low discontinuous thorny thicket (Rajasthan, Ph.9, p.188)
VII	Tropical lowland arid *Desert*	P<150-200mm, 10-12d.m., tm=10-15° Alt. 0-1500m	VII Coastal desert	VIIa Sahara desert VIIb East African desert VIIc Karoo desert	VII Rajasthan desert

Appendix II-4. Continued

Group of EFZ	**Name** *Climax zonal vegetation*	**Criteria (climate and altitude)**	**Ecofloristic zone**		
			South America	**Africa**	**Asia**
VIII	Tropical medium elevation wet –*Dense moist (semi-evergreen forest)*	P=1000-2000mm, 0-3d.m., tm<18° Alt. 800-2000m	VIIIa Very wet VIIIb Wet	VIIIa Continental Africa VIIIb Madagascar	VIII Dense moist (semi)evergreen forest (Himalaya foothill)
IX	Tropical medium elevation subhumid – *Seasonal and sclerophyllous forests*	P=700-2000mm, 2-6d.m., tm>13° Alt. 800-2000m	IX Seasonal submontane forest	IXa W Africa IXb Madagascar (Ph.10) IXc E Africa	
X	Tropical medium elevation dry – *Shrublands and thickets*	P<1000mm, 6-11d.m., tm=15° Alt. 1500-2000m		Xa E Africa Xb Windhoek M. (S Africa)	
XI	Tropical medium elevation semi-arid –*Thorn woodlands and shrub pseudo-steppes*	P=200-1000mm, 2-12 d.m., tm<15° Alt. 900-2000m	XI Thorn woodlands and xeromorphic thickets	XI Shrub pseudo-steppe (Sahara)	
XII	Tropical montane moist *Ombrophilous montane forest*	P=1500-2500mm, 0-4d.m., tm<15° Alt. 1800-3500m	XIIa Very wet XIIb Wet	XIIa Continental Africa XIIb Madagascar	XIIa Malaya Archip. XIIb New-Guinea XIIc SE Asia XIId S India, Sri Lanka XIIe E Himalaya foothill XIIf Subalpine Indonesia XIIg Subalpine New-G.
XIII	Tropical montane subhumid *Low seasonal montane forest*	P=900-1500mm, 1-5d.m., tm<15°, Alt. 2000-3500m	XIII Low seasonal montane forest (Andes)		
XIV	Tropical montane dry *Low dry montane forest*	P<1300mm, 6-10d.m., tm<15° Alt. 2000-3000m		XIV *Juniperus procera* forest (E Africa)	
XV	Tropical montane semi-arid *Shrub pseudo-steppe*	P=200-800mm, 3-12d.m., tm<15°, Alt. 1800-3000m	XV Shrub with *Cactaceae* (Andes)	XV Bush pseudo-steppe (Sahara)	
XVI	Tropical high elevation - *Alpine scrub*	Alt. > 3000m	XVIa *Paramo* XVIb P*una*	XVI Alpine scrub	XVI *Ericaceae* belt
XVII	Subtropical lowland humid(a)and subhumid (b) *Evergreen forests and thickets*	a. P=1000-2500 mm, 0-4d.m., tm<20°, alt.0-1300m ; b. P=600-1000mm	XVIIa *Araucaria angustifolia* forest XVIIb Pampa	XVIIa Evergreen forest XVIIb Coastal thicket (S Africa)	
XVIII	Subtropical lowland seasonally dry *Sclerophyllous forests*	P=400-1500mm, 3-7d.m., tm>7°	XVIII *Nothofagus* forest	XVIIIa N Africa (moist) (Ph.11) XVIIIb S Africa XVIIIc N Africa (contin.)	

Appendix II-4. Continued

XIX	Subtropical lowland semi-arid *Xeromorphic woodlands and pseudo-steppes*	P=200-1000mm,6-11d.m.,tm=6-17°	XIXa Tropical regime XIXb Mediterranean	XIXa Pseudo-st./ *Acacia* XIXb Pseudo-steppe/ *Pistacia*	
XX	Subtropical medium elevation humid *Mixed forest*	P=800-1000mm, 0-3d.m., tm<12° Alt.900-1600m		XXa Northern Africa (Ph. 12, p.188) XXb Southern Africa	
XXI	Subtropical medium elevation seasonally dry *Submontane mixed or coniferous forest*	P=500-2000mm, 2-8d.m., tm>7° Alt. 900-1600m		XXIa N Africa XXIb S Africa (*Trans. For*.) XXIc Highveld	XXIa W Himalaya XXIb Kashmir
XXII	Subtropical medium elevation semi-arid *Shrub pseudo-steppe*	P<300mm, 8-12d.m., tm>7° Alt. 1500-2000m		XXII Shrub pseudo-steppe	
XXIII	Subtropical montane humid *Evergreen mixed forest*	P=600-1100mm, 0-4d.m., tm<7° Alt.1500-2900m		XXIIIa N Africa XXIIIb S Africa	
XXIV	Subtropical montane seasonally dry *Evergreen montane forest*	P=500-1500mm, 2-6d.m., tm<7° Alt.1500-3000m		XXIVa N Africa XXIVb S Africa	XXIVa W Himalaya (bixeric regime) XXIVb NW Himalaya (Medit.)
XXV	Subtropical high elevation *Mixed forests and shrubs*	Alt. > 3000m	XXV Steppe (Andes)	XXVa N Africa XXVb S Africa	XXVa Himalaya (*Mixed forest)* XXVb NW Himalaya *(Mixed for. and shrub)* XXVc Himalaya (above 4000m)
XXVI	Temperate lowland oceanic *Evergreen forest and "tundra"*	P=500-3500mm, 0 d.m tm=5-11°	XXVIa *Valdivian forest* XXVIb *Subpolar forest* XXVIc *Cold temperate steppe* XXVId *"Tundra"*		
XXVII	Temperate lowland semi-arid *Deciduous thicket and steppe*	P=100-300mm, tm=6-13°	XXVIIa *Deciduous thicket* XXVIIb *Steppe*		
XXVIII	Temperate mountain *Coniferous forest and steppes*	P=(a)1000-2500mm, (b)100-400mm, tm<10° Alt. > 1000m	XXVIIIa *Araucaria araucana forest* XXVIIIb *Andean steppe*		XXVIII Steppic Tibetan zone

Note: Explanation of abbreviations. P: Annual rainfall; d.m.: dry month; tm: mean temperature of coldest month; Alt.: Altitude

PART III: REGIONAL DESCRIPTIONS

1 Introduction

This section describes for each geographic region (Figure 32) the global Ecological Zones in terms of climate, physiography and vegetation. Vegetation descriptions focus on natural or potential vegetation, with information on physiognomy and (tree) flora. Few details are provided on current land use. Maps and tables show the distribution of the Ecological Zones by region and the area statistics are summarized in Appendix III-1.

Various regional scientists/experts compiled or contributed to the GEZ descriptions:

- North and Central America: Harry Hirvonen of the Canadian Forest Service, Luis Morales of the National University of Mexico, Vicente Watson of the Tropical Science Center, Costa Rica.
- South America, Africa and Tropical Asia: Marie-France Bellan of LET, France
- China: Zhiliang Zhu of EDC, United States.
- Europe: Christoph Hettwer of the Federal Agency for Nature Conservation, Germany.
- Former Soviet Union: Anatoly Shvidenko of IIASA, Austria.
- Australia: Phlip Tickle of BRS, Australia

The GEZ descriptions were complemented and edited by the author.

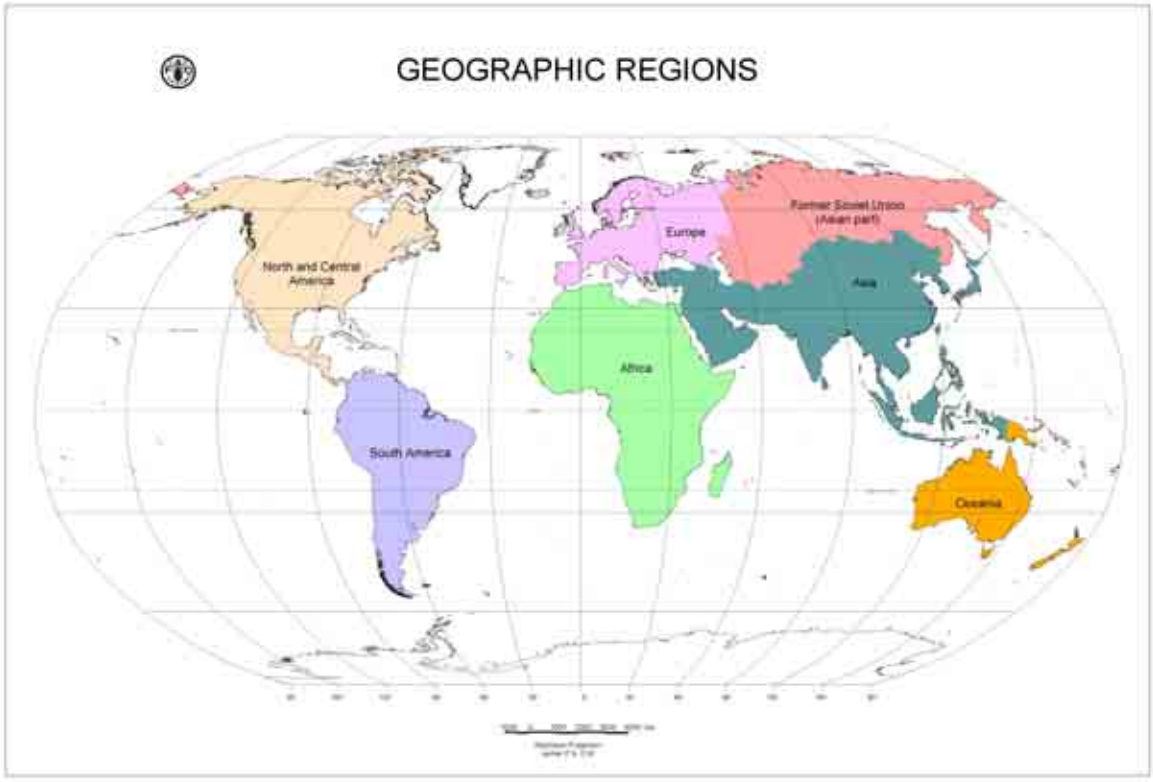

Figure 32. Geographic regions of the world

2 North – and Central America

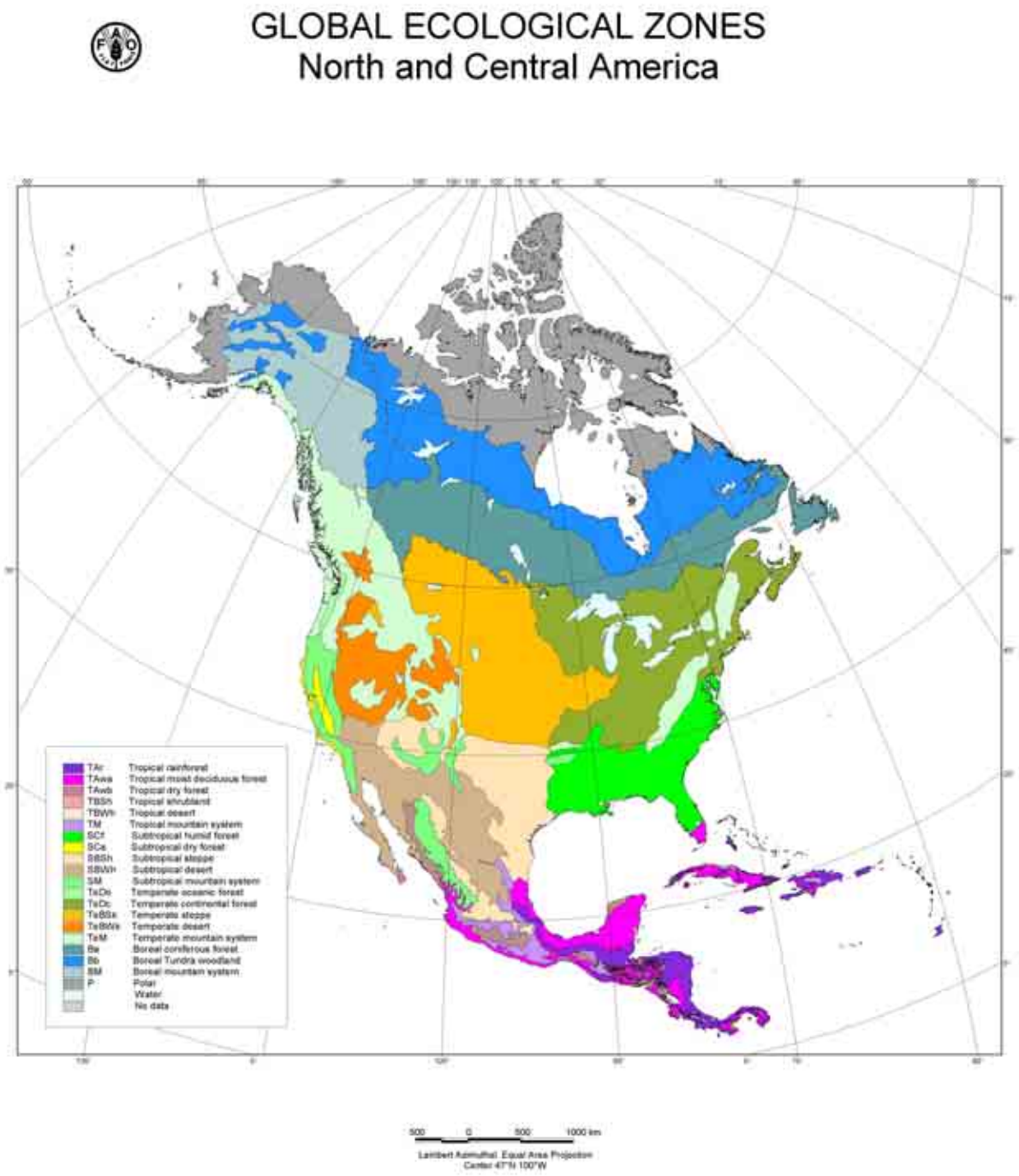

Figure 33. GEZ map of North and Central America.

Table 18. Global Ecological Zones of North and Central America.

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Tropical rain forest	440 880	2.0	3.0
Tropical moist deciduous forest	678 048	3.1	6.1
Tropical dry forest	226 004	1.0	3.0
Tropical shrubland	2 147	0.1	0.0
Tropical desert	0	0	0
Tropical mountain systems	259 112	1.2	5.7
Subtropical humid forest	1 068 503	4.9	22.8
Subtropical dry forest	87 039	0.4	5.5
Subtropical steppe	1 167 280	5.4	23.8
Subtropical desert	1 083 874	5.0	16.3
Subtropical mountain systems	592 297	2.7	12.2
Temperate oceanic forest	40 123	0.2	2.2
Temperate continental forest	2 023 770	9.3	29.1
Temperate steppe	2 121 768	9.8	36.0
Temperate desert	742 929	3.4	13.8
Temperate mountain systems	1 976 781	9.1	27.4
Boreal coniferous forest	2 186 972	10.0	25.8
Boreal tundra woodland	2 566 393	11.8	65.0
Boreal mountain systems	1 182 345	5.5	18.8
Polar	3 220 372	14.9	60.0
Total land area	21 666 637	99.8	

2.1 POLAR DOMAIN (P)

The polar domain of North America occupies northern Alaska, northern Yukon, the Arctic islands of Canada, northern Labrador, portions of the Northwest Territories and northern Quebec.

Climate

This Ecological Zone experiences long, cold winters and short, cool summers. The climate is most extreme in the Arctic Cordillera. Mean annual temperature ranges from around –20^{o}C in the most northern part to -7^{o}C in the south; summer mean temperatures range from –6^o to +6 ^{o}C; winter mean temperatures from as low as –35^{o}C in the mountains of Ellesmere Island to -17.5^{o}C in northern Quebec. The annual precipitation varies from 100 mm to 600 mm. Snow may fall any month of the year and usually persists on the ground for at least 10 months (September to June). Permafrost is continuous and may extend to a depth of several hundred meters.

Physiography

Two rather distinct regions may be distinguished: the Arctic Cordillera, occupying the northeastern fringes of the continent and the large tundra region. The former is a vast mountain chain of deeply dissected Precambrian crystalline rocks. Elevations range from sea level to over 2000 m above sea level. Massive ice caps and valley glaciers mask many of the rugged mountains. Most of the rugged landscape is ice or exposed bedrock. The tundra region consists largely of broadly rolling uplands and lowlands, mostly underlain by Precambrian granite bedrock with some areas of flat-lying Paleozoic and Mesozoic sedimentary bedrock. The undulating landscape is studded with innumerable lakes and wetlands. Soils are frozen, with a shallow and wet layer in summer.

Vegetation

In the most northern fringes of the zone, vegetation only grows in sheltered valleys and along coastal margins and consists of herbaceous and shrub-type communities. Further south, the tundra vegetation is dominated by dwarf shrubs. Major river valleys support scattered clumps of stunted spruce trees. Typical shrubs include dwarf birch (*Betula* spp.), willows (*Salix* spp.) and heath species commonly mixed with various herbs and lichens. Wetlands are common in the low-lying areas, mainly supporting sedge and moss covers.

2.2 BOREAL DOMAIN

2.2.1 Boreal tundra woodland (Bb)

Climate

Climate is characterized by short, cool summers and long, cold winters. Cold arctic air influences the zone for most of the year. Mean annual temperature ranges between -10^{o}C in the Mackenzie Delta to 0^{o}C in parts of Labrador. From north to south, the mean summer temperature varies from 6^{o} to 14^{o}C. The mean winter temperature ranges between –26^{o} and -16^{o}C. Snow and freshwater ice persist for six to eight months of the year. The mean annual precipitation is low in the west ranging 200-500 mm. Higher mean levels are reached in the east where the average varies between 500-800 mm and portions of Labrador reaching 1000 mm.

Physiography

This Ecological Zone is segmented by a huge lowland plain, the Hudson Plain. This region is underlain by flat-lying Paleozoic and Proterozoic sedimentary rock. Elevations rarely exceed 500 m above sea level. Extensive wetlands with subdued glacial features and a belt of raised sandy beach strands characterize the surface. Coastal marshes and tidal flats are extensive along the shores of Hudson Bay and James Bay within this zone. The relief of this lowland has been significantly affected by post-glacial marine submergence and rebounding of its surface. Due to poor drainage, organic cryosolic and mesisolic soils predominate. Regosals are common along the coast. Permafrost is continuous in the north and patchy in the south.

The western portion of this zone consists of subdued broad lowlands and plateaus incised by major rivers. It is largely underlain by limestone, shale and sandstone. Surface deposits are largely glacial till with areas of lacustrine. Alluvium is common within the river valleys. A large portion of the area is underlain by permafrost. Patterned ground features are common.

Vegetation

The Hudson Bay lowlands of this Ecological Zone contain the largest extensive area of wetlands in the world. Vegetation associations consist of arctic tundra and some boreal forest transition types. The poorly drained areas support dense sedge-moss-lichen covers and the better-drained sites support open woodlands of black spruce (*Picea mariana*), tamarack (*Larix laricina*) and some white spruce (*P. glauca*). The raised beaches present a striking pattern of successive black spruce ridges alternating with bogs and fens. The predominant shrub layer consists of dwarf birches, willows and Labrador tea (*Ledum groenlandicum*). Balsam poplar (*Populus balsamea*), white spruce and white - or paper birch *(Betula papyrifera*) are common along rivers.

East of the Hudson Bay lowlands, there are large tracts of open stands of black spruce woodland with an understorey of lichen and feather moss. Generally, much of the wind-swept plateau lands is dominated by open stands of stunted black spruce and tamarack with Labrador tea and sphagnum moss. White spruce is also present. There are large areas of treeless bogs and fens except for dwarf black spruce and tamarack. Alder (*Alnus incana*) thickets are common along river banks and other drainage areas. Other species occurring sporadically include trembling or quaking aspen (*Populus tremuloides*) and balsam fir (*Abies balsamea*). Limited treed vegetation occurs along the exposed headlands of the Atlantic Coast and within the interior most wind-swept barrens.

In the central portion of this zone, west of Hudson Bay, open stands of black and white spruce and tamarack dominate. Sometimes these open forests comprise jack pine (*Pinus banksiana*) as well. Low shrub tundra-like vegetation is common, characterized by willow and birch shrubs. Bare rock outcrops and wetlands are also common.

The western limits of this Ecological Zone are characterized by open, generally slow-growing, black spruce. Upland and foothill areas and southerly locales tend to be better drained and are warmer than that typical for the zone. In these areas, mixed wood forests characterized by white and black spruce, lodgepole pine (*Pinus contorta*), tamarack, white birch, trembling aspen and balsam poplar are common. Along nutrient-rich alluvial flats, white spruce and balsam poplar grow to sizes comparable to the largest in the boreal forest to the south.

2.2.2 Boreal coniferous forest (Ba)

Climate

Climate is generally continental with long, cold winters and short, warm summers. Continental effects of climate are modified in the east with proximity to the Atlantic Ocean. The mean annual temperature ranges between -4^{o}C in central Canada to 5.5^{o}C in the boreal regions of the Island of Newfoundland. Mean summer temperatures vary between 11^{o} and 15^{o}C with mean winter temperatures occurring between -20.5^{o} C in the west to -1^{o}C in the east. Mean annual precipitation varies between 100 and 625 mm with the exception of boreal Newfoundland where precipitation averages are higher, being in the range of 900 - 1600 mm.

Physiography

A broadly rolling mosaic of uplands and associated wetlands dominates this Ecological Zone. Except in the west, Precambrian granitic rock outcrops are interspersed with ridged to hummocky deposits of glacial till, fluvioglacial materials (including numerous eskers) and colluvium. Soils are acidic and range from humo-ferric podzols in the south to brunisols in the north. Luvisols have limited distribution where silts and clays dominate. Peatlands with organic soils are common. In the west, cretaceous shales dominate. The topography is generally gently rolling consisting of hummocky to kettled glacial deposits and lacustrine deposits. Surface materials are generally deep with luvisols and brunisols being the dominant soils. Permafrost is frequent within the peatlands.

Vegetation

Much of the Ecological Zone is distinguished by closed stands of conifers, largely white (*Picea glauca*) and black spruce (*P. mariana*), balsam fir (*Abies balsamea*) and tamarack (*Larix laricina*). Common deciduous species include white birch (*Populus papyrifera*), trembling aspen (*P. tremuloides*) and balsam poplar (*P. balsamea*). In the southern boreal, conifers such as eastern white (*Pinus strobus*), red (*P. resinosa*) and jack pine (*P. banksiana*) are evident. At the transition with southern forests, species such as sugar maple (*Acer saccharum*), black ash (*Fraxinus nigra*) and eastern white cedar (*Thuja occidentalis*) are found.

To the western boundary of the boreal, lodgepole pine (*Pinus contorta*) begins to make an appearance. In general the vegetation is medium to tall, closed stands of trembling aspen, balsam poplar and jack pine with white and black spruce occurring in late successional stages. Lodgepole pine may dominate in some of the upland areas along with white spruce and balsam fir. The poorly drained valleys tend to be concentrated with black spruce. The western boreal transition to the south is often characterized by trembling aspen and balsam poplar. White spruce and balsam fir are the climax species but are not widespread due the frequent occurrence of fire. Poorly drained bogs and fens are characterized by tamarack, black spruce, several ericaceous shrubs and mosses.

The eastern boreal forest is characterized by both open and closed black spruce and balsam fir forests with a ground cover of mosses and ericaceous shrubs. White birch and trembling aspen are typical of disturbed sites. White spruce is generally more tolerant of ocean spray and is thus more prevalent than black spruce or tamarack in areas exposed to the ocean. Kalmia (*Kalmia angustifolia, K. latifolia*) are very common shrubs. Wetlands are extensive and are comprised by a cover of stunted black spruce, tamarack or shrubs such as kalmia or Labrador tea (*Ledum groenlandicum*).

The northern boreal Ecological Zone is transitional to the boreal tundra. Drier sites are characterized by pure stands of jack pine or mixed stands of jack pine, white birch and trembling aspen. Wet sites are dominated by black spruce and balsam fir. Treed fens and bogs are dominated, as well, by stunted black spruce and tamarack.

Precambrian granitic bedrock dominates the central and eastern portions of the zone. This is overlain by coarse till deposits interspersed with marine and lacustrine deposits. Long, sinuous esker formations are common. Thousands of lakes and wetlands dot the landscape and lowlands are often covered with peatlands. Permafrost is discontinuous but widespread.

Brunisolic and humo-ferric podzolic soils are dominant in the south. Cryosols are widespread in northern regions and, within wetlands, gleysols and organic croyosols are present.

2.2.3 Boreal mountain systems (BM)

Climate

The climate ranges from cold, subhumid to semiarid. It is marked by long, cold winters and short, warm summers. Mean annual temperatures range from -10^{o} in the north to 5^{o}C in the south. Mean summer ranges are 6.5^{o} to 11.5^{o}C and mean winter temperatures range between -13^{o} and -25^{o}C. Mean annual precipitation is lowest in valleys in the rain shadow of the Coast Ranges (less than 300 mm) and increases in the interior ranges where up to 1500 mm of precipitation is received at higher elevations.

Physiography

This Ecological Zone is characterized by mountain ranges that contain numerous high peaks and extensive plateaus which are separated by wide valleys and lowlands. Bedrock is largely sedimentary and igneous. Surface features have been modified because of glaciation, erosion, solifluction and aeolian and volcanic deposition. A small portion of the northwest was unglaciated. Permafrost is widespread. Cryosols dominate with warmer, lower elevations having brunisols, podzols and luvisols. Abundant permafrost features such as peat hummocks, palsas and peat plateaus are common.

Vegetation

To the north, natural vegetation ranges from arctic and alpine tundra associations of dwarf shrubs, mosses and lichen at higher elevations to open woodland of white spruce *(Picea glauca*) and white birch (*Betula papyrifera*) mixed with dwarf birches and willows. The unglaciated Old Crow Basin comprises stunted stands of black spruce and tamarack with some white spruce. Wetlands are common as well.

To the south, there are grasslands on south-facing slopes with boreal vegetation on north-facing slopes. In general, vegetative cover ranges from closed to open forest over much of the plateaus and valleys. White and black spruce, subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamea*) and white birch occur. Lodgepole pine and subalpine fir tend to disappear rapidly northwards. At higher elevations, extensive areas of rolling alpine tundra characterized by sedge meadows and rock are predominant.

2.3 TEMPERATE DOMAIN

2.3.1 Temperate oceanic forest (TeDo)

Climate

The nearness of the Pacific Ocean profoundly moderates the climate and annual temperatures averages 9^{o} to 13^{o}C. The moderate rainfall reaches its maximum in winter; summer has a slight moisture deficit. Average rainfall ranges from around 400 to 1500 mm, but in much of

the area, the range is from 750 to 1150 mm. Coastal mountains are responsible for the drier and less muted climate. Fog partially compensates for the summer drought.

Physiography

This relatively small Ecological Zone occupies a north-south depression between the Pacific Coast range and the Cascade Mountains. Elevation ranges from sea level to around 500 meters. Landform is characterized by level to gently sloping floodplains bordered by dissected high terraces and hills. Isolated hills and low mountains do also occur. The predominant soils are solenetz, brunisols and podzols.

Vegetation

Before cultivation, dense coniferous forest dominated the vegetation. The temperate coastal forests are composed of mixtures of western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*). In interior valleys of Washington and Oregon, the coniferous forest is less dense than along the coast and often contains deciduous trees, such as big-leaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*) to the south and black cottonwood (*Populus trichocarpa*). There are woodlands that support open stands of oaks or are broken by groves of Douglas fir and other trees; principal indicator species are Garry or Oregon white oak (*Quercus garryana*) and Arbutus or Pacific madrone (*Arbutus menziesii*). Poorly drained sites with swamp or bog communities are abundant.

2.3.2 Temperate continental forest (TeDc)

Climate

Much of the continental portion of this Ecological Zone is marked by warm summers and cool winters. The weather is highly changeable as the Zone falls along one of the major storm tracks of North America. Mean annual temperatures range from 2^{o} to 10^{o} C. The mean summer temperature ranges from 16^{o} to 18^{o} C with mean winter temperatures ranging from -2.5^{o} to -7^{o} C. Mean annual precipitation over much of the Ecological Zone ranges 720-1000 mm.

The proximity of the Atlantic Ocean moderates the climate of eastern portion of this Ecological Zone. It creates a cool, moist, maritime climate and moderate temperatures occur. Mean annual temperatures range from 3.5^{o} to 6.5^{o} C. Annual summer means fall between 13^{o} and 15.5^{o} C. Mean winter temperatures are spread between -8^{o} to -2^{o} C, the warmer temperatures occurring along the Atlantic Coast. Mean annual precipitation varies from 900 to over 1500 mm near the coast.

Physiography

The interior of the Ecological Zone is underlain by carbonate-rich Paleozoic bedrock. Topography is a combination of level plains and gently rolling hills consisting of deep morainal, lacustrine and marine/estuarine deposits. Fine-textured luvisols, along with more coarse-textured brunisols and poorly drained gleysols are the predominant soils. Along the northern fringe, adjoining the Boreal Ecological Zones, podzols and brunisols are prevalent on coarse textured soils. The Zone contains the most productive agricultural soils in Canada.

The lower parts of the Appalachian Uplands and the Northumberland Coastal Plains comprise the eastern portion of the unit. The uplands are composed of granite, gneiss and other hard crystalline rocks. This upland terrain is covered by glacial till and coarse-textured humo-ferric podzols are the dominant soils. In the coastal lowland areas, deeper, more fertile luvisolic soils exist. These fine to moderate textured soils are underlain by sedimentary bedrock.

Vegetation

At one time the entire Ecological Zone was heavily forested, supporting more species of trees than any other part of Canada. However, most of the forests of the area around the Great Lakes and the northeastern United States have succumbed to urbanization and conversion to agricultural activity. Where forest cover exists, it varies from the mixed-coniferous/deciduous stands of white and red pine *(Pinus strobus, P. resinosa*), eastern hemlock (*Tsuga canadensis*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*) and white birch (*Betula papyrifera*) in the northern portions to the rich diversity of the deciduous Carolinian forest and in the southwest.

Historically, the Great Lakes Lowlands and large parts of the North-eastern United States were covered by deciduous forest, dominated by tall broadleaf trees that provide a dense, continuous canopy in summer and shed leaves completely in winter. Lower layers of small trees and shrubs develop weakly. In spring, a luxuriant cover of herbs quickly develops, but is greatly reduced after trees reach full foliage and shade the ground. The mixed mesophytic association, the deciduous forest with the greatest diversity, occupies well-drained sites. Widespread dominants include sugar maple, American beech (*Fagus grandifolia*), white elm (*Ulmus americana*), basswood (*Tilia americana*), red and white oak (*Quercus rubra, Q. alba*), walnut (*Juglans nigra, J. cinerea*), hickory (*Carya ovata, C. cordiformis*), buckeye (*Aesculus* spp.) and eastern hemlock (*Tsuga canadensis*), in addition to 20-25 other species. Some of the rarest trees in Canada, such as the sassafras (*Sassafras albidum*), tulip tree (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*) and cucumber-tree *(Magnolia acuminata*), were native to the southern part of this Zone. An oak association, with white oak and northern red oak as dominant species, occurs east of the Appalachian Mountains. American chestnut (*Castanea dentata*) formerly was abundant, but a blight has destroyed much of this species.

Further inland, where precipitation is lower, the drought resistant oak-hickory association is the dominant vegetation, which has both species in abundance. The oak-hickory forest is medium-tall to tall, becoming savannah-like in its western reaches, where it gradually turns into prairie. It sometimes forms a mosaic pattern with prairie. Widespread dominants are white oak, red oak, black oak (*Quercus velutina*), bitternut hickory (*Carya cordiformis*) and shagbark hickory (*Carya ovata*). The understorey is usually well developed, often with flowering dogwood. The shrub layer is distinct, with some evergreens. Many wildflower species occur. Wetter sites typically feature an abundance of American or white elm, tuliptree (*Liriodendron tulipifera*) and sweetgum (*Liquidambar styraciflua*). Northern reaches of this association contain increasing numbers of maple, beech and basswood (*Tilia americana*).

Much more forest exists in the northeastern portion of this Ecological Zone. Here, forests are generally composed of mixed stands of conifers and deciduous species characterized by red spruce (*Picea rubens)*, balsam fir (*Abies balsamea*), yellow birch (*Betula alleghaniensis*) and sugar maple. Red and white pine and eastern hemlock occur to a lesser but significant degree. Some boreal species are present, including black (*Picea mariana*) and white spruce (*P.*

glauca) balsam poplar (*Populus balsamifera*) and white birch. Jack pine (*Pinus banksiana*) is prominent on sandy soils. A pine-oak forest occupies dry sandy soils along the northern Coastal Plain of the US that are frequently exposed to naturally occurring fires. There is a thick shrub layer beneath the pines. Eastern white cedar (*Thuja occidentalis*) occur on mesic sites.

2.3.3 Temperate steppe (TeBSk)

Climate

The climate of this North American Ecological Zone is greatly influenced by its location in the heart of the continent. The Rocky Mountains to the West impede easy access of moisture-bearing winds from the Pacific Ocean. This results in the Ecological Zone having a continental climate that is subhumid to semiarid with short, hot summers and long, cold winters. Generally, the zone is characterized by low precipitation and high evaporation. Mean annual temperatures range from 1.5^{o} to 3.5^{o}C. Mean winter temperatures range from -12.5^{o} to -8^{o} C and mean summer temperatures from 14^{o} to 16^{o}C.

Mean annual precipitation is variable covering a range between 250 mm in the arid grasslands to near 700 mm in the higher elevation wooded portions (elevations that reach to 200 m above surrounding plains). Much of the Zone receives around 300-400 mm of rain annually and a water deficit situation is characteristic of this Ecological Zone.

Physiography

Cretaceous shales and flat-lying Paleozoic limestone underlie the Zone. The surface is a nearly level or rolling plain consisting of hummocky glacial, calcareous moraine or gently undulating lacustrine deposits. Scattered glaciofluvial deposits occur. The inherent soils are Black, Dark Gray and Dark Brown Chernozems. These soils have a high moisture-holding capacity and are naturally fertile, both characteristics conducive to agricultural production. The southern portions of the Zone have large areas of Solonetzic soils. The upper elevation forested soils are dominated by luvisols. Depending on rainfall, there are millions of small wetlands in the form of sloughs, ponds and marshes.

Vegetation

Aspen parkland constitutes the northern edge of this Ecological Zone, a transition zone to the boreal forest to the North. It is associated with groves of trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*) and intermittent grasslands. The aspen parkland has expanded southward considerably since the prairie fires were effectively stopped by settlement. Much of the Zone however, was historically natural steppe grassland dominated by spear grass (*Poa annua*), wheat grass (*Agropyron* spp.) and blue grama grass (*Bouteloua* spp.). Sagebrush *(Artemisia tridentata*) was and remains abundant. Yellow cactus and prickly pear (*Opuntia spp*.) are found on dry sites. Along with the encroachment of aspen, agricultural activity has substantially reduced the area of natural grassland. Today, native vegetation is relegated to non-arable pasture lands dominated by spear grass and wheat grass and a variety of shrubs. Patches of scrubby aspen (*Populus*), willow *(Salix*), cottonwood (*Populus*) and box-elder (*Acer negundo*) occur on shaded slopes of valleys and river terraces. To the East, the Zone consists of a mosaic of trembling aspen, bur oak (*Quercus macrocarpa*) and grasslands (e.g. *Andropogen gerardii, Panicum virgatum, Sorghastrum nutans*). Further

south, oak and hickory become the dominant tree species in the prairie-parkland transition zone with the eastern broadleaf forests.

2.3.4 Temperate desert (TeBWk)

Climate

The aridity of this Ecological Zone is the result of the rain shadow of the Sierra Nevada and Cascade Mountains ranges as they intercept the wet winter air masses brought by the westerly and easterly winds. Summers are hot and winters are cold, with stronger seasonal temperature extremes on the higher plateaus. The average annual temperature ranges from 4^{o} to 13^{o}C. Spring comes early, except at higher elevations. Annual precipitation averages about 130 to 400 mm. Almost no rain falls during the summer months. Part of the winter precipitation falls as snow.

Physiography

The zone covers the physiographic region called the Great Basin, the northern Colorado Plateau in Utah and the plains and tablelands of the Columbia-Snake River Plateaus and Wyoming Basin. Much of the southern part of this zone is made up of separate interior basins; only a small part of it drains to the sea. The lower parts of many basins have heavy accumulations of alkaline and saline salts. The northern plateaus include most of the Northwest's lava fields. Lying at about 900 m, the plateaus are surrounded by lavas that have been folded or faulted into ridges. Aridisols dominate all basin and lowland areas, while extensive alluvial deposits, Entisols, are found in stream floodplains and in fans at the foot of mountains. In the southern part of this Ecological Zone, salt flats and playas without soils are extensive in the lower parts of basins with interior drainage.

Vegetation

The chief vegetation, sometimes called sagebrush steppe, is made up of sagebrush *(Artemisia tridentata*) mixed with short grasses. Other important plants are antelope bitterbrush (*Purshia tridentata*), shadscale (*Atriplex confertifolia*), fourwing saltbush (*Atriplex* sp.), rubber rabbitbrush (*Chrysothamnus nauseosus*), spiny hopsage (*Grayia spinosa*), horsebrush (*Tetradymia* spp.) and short-statured Gambel oak (*Quercus gambelii*). All these shrubs tolerate alkali to varying degrees, essential to their survival on poorly drained soils. Moist alkaline flats support alkali-tolerant greasewood (*Sarcobatus vermiculatus*). Along streams in and near the mountains where the water is good, valley bottoms are lined with willows and sedges. Above the sagebrush belt lies a woodland zone dominated by pinyon pine (*Pinus edulis*) and juniper (*Juniperus* spp.).

2.3.5 Temperate mountain systems (TeM)

Climate

The climate of this Ecological Zone is extremely varied. Along the Pacific Coast, it ranges from a relatively humid maritime climate at low elevations to cold, arctic conditions above tree line. Along the coast the mean annual temperature ranges from 4.5^{o}C in the north to 9^{o}C in the south. Summer means vary between 10^{o} and 15.5^{o}C with winter means between -0.5^{o}

and 3.5°C. Average annual precipitation is extremely variable being 600 mm in the Gulf Islands and ranging up to 4000 mm to the north.

The interior portion of the zone is as variable. The Coastal Ranges and Rocky Mountains create rain shadow areas of mean annual precipitation of 250- 400 mm. This rises to 1500 mm in the mountains. Temperatures in the dry lowlands average 7.5°C annually with a summer mean of 16.5°C and winter mean of -1.5°C. Winter means can reach –15°C and colder with increasing elevation reaching to the ice fields beyond tree line.

The climate of the Appalachian Highlands is temperate, with distinct summer and winter and all areas are subject to frost. Average annual temperatures range from below 10°C in the north to about 18°C at the south end of the highlands. Average annual precipitation varies from 900 mm in the valleys to 2000 mm on the highest peaks, the highest in the eastern United States. A considerable amount falls as snow.

Physiography

This Ecological Zone includes the Coast Mountains, the Rocky Mountains with the highest peaks reaching 3600 m above sea level and the Appalachian Mountains reaching to around 2000 m. Amongst the mountain ranges there are interior plains along with the major intervening valleys. The plains are most extensive in the north. Most of these plains are covered by glacial moraine and some lacustrine and fluvial deposits. Mountains are largely colluvium and rock outcrops. Luvisols and brunisols are the common soils of the interior plateaus and lower slopes. In the wetter mountainous areas, humo-ferric and ferro-humic podzols dominate. Soils of the dry lower valley floors are characterized by chernozems supporting grasslands. The highest elevations consist of alpine glaciers and rock.

Vegetation

This mountainous unit is extremely diverse in terms of major vegetation associations: coastal western hemlock, coastal Douglas-fir, mountain hemlock, interior Douglas-fir, interior cedar-hemlock, montane spruce, englemann spruce-subalpine fir, sub-boreal pine-spruce, sub-boreal spruce, ponderosa pine, bunchgrass and alpine.

The Pacific Coast Mountains comprise the temperate rain forests of the coastal western hemlock zone. These forests are among the most productive in North America and contain some of the world's largest and long-lived trees. This vegetation association exists at low elevations along the coast and is dominated by western hemlock (*Tsuga heterophylla*) and amabilis – or Pacific silver fir *(Abies amabilis*) as climax species although several other species are common. Big-leaf maple (*Acer macrophylum*) reaches its northern extension in the southern portion of this zone. It is generally found along creek beds and other alluvial areas along with red alder (*Alnus rubra*) and black cottonwood (*Populus trichocarpa*). At high elevations, up to 2000 m, mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*) and amabilis fir assume prominence along with yellow or Pacific cedar (*Chamaecyparis nootkatensis*). Closed stands become open and stunted with higher elevations as sedge and heather communities begin to dominate. Alpine conditions are too severe for the growth of most woody plants except for some dwarf shrubs (*Salix* spp., *Betula* spp.) herbs, mosses and lichens.

Amabilis fir, lodgepole pine (*Pinus contorta*) and sitka spruce (*Picea sitchensis*) are common in the north. At lower northern elevations, western hemlock and western red cedar (*Thuja plicata*), dominate with red alder pioneering on disturbed sites. The coastal Douglas-fir association is found in the lee of the coastal mountains. Douglas-fir (*Pseudotsuga menziesii*) dominates. Western red cedar (*Thuja plicata*) is typical on wetter sites and Garry oak (*Quercus garryana*) and arbutus (*Arbutus menzeisii*) are abundant on drier sites. Salal (*Gaultheria shallon*) and Oregon grape (*Mahonia repens*) are common understorey vegetation.

In the rain shadow of the Coast and other mountain ranges of this Ecological Zone, the interior Douglas-fir associations dominate. Fires have resulted in even-aged lodgepole pine stands at higher elevations while ponderosa pine (*Pinus ponderosa*) is the common seral tree at lower elevations. The very driest portions are dominated by bunchgrasses. The driest associations are the bunchgrass zone which is confined to lower elevations of the hottest valleys. Bluebunch wheatgrass (*Elymus spicatum*), fescue (*Festuca* spp.) among others and sage brush (*Artemisia tridentata*) dominate with some ponderosa pine and Douglas-fir occurring in wet swales. Areas dominated by ponderosa pine represent the warmest and driest forest regions of this diverse Ecological Zone.

The montane spruce association dominates much of the interior plateau regions. Here, at mid elevations, closed stands of englemann spruce (*Picea englemanii*) and subalpine fir are common. Lodgepole pine, western white pine (*Pinus monticola*), Douglas-fir and trembling aspen reflect areas of past fire history. At higher elevations the Englemann spruce- subalpine fir begin to dominate. The forest often has an open parkland appearance with trees clumped interspersed with heath and grassland meadows. Under drier conditions extensive lodgepole pine and whitebark pine (*Pinus albicaulis*) are common. Wetter areas may be dominated by mountain hemlock (*Tsuga mertensiana*).

The interior wet belt of this Ecological Zone is characterized by a western red-cedar -western hemlock forest. It has the widest variety of conifer trees of all the major forest types within the zone. Along with the two dominant species other common trees include white spruce (*Picea glauca*), englemann spruce (including hybrids) and subalpine fir. Douglas-fir and lodgepole pine occur in the drier portions of this wet belt. Skunk cabbage (*Symplocarpus foetidus*) and devil's club (*Oplopanax horridus*) characterize the ground vegetation.

In the sub-boreal plateau areas, south of true boreal forest associations, englemann-white spruce and subalpine fir dominate. Even-aged lodgepole pine and trembling aspen *(Populus tremuloides*) cover extensive areas of previously burned sites. Wetlands are also extensive and common. An extensive tundra alpine belt occurs at high elevations. Moist meadows with low-lying shrubs, grasses, sedges and mosses are common. At the highest elevations rock and glaciers dominate.

In the Appalachian Highlands, a vertical zonation prevails, with the lower limits of each forest belt rising toward the south. The valleys of the southern parts support a mixed oak-pine. Above this zone lies the Appalachian oak forest, dominated by a dozen species each in the white oak and black oak groups. Above this zone lies the northeastern hardwood forest, composed of birch, American beech (*Fagus americana*), maple, elm, red oak (*Quercus rubra*) and basswood (*Tilia americana*), with an admixture of eastern hemlock (*Tsuga canadensis*) and white pine. Spruce-fir forest and meadows are found of the highest peaks of the Allegheny and Great Smoky Mountains. Mixed mesophytic forest extends into narrow

valleys of the southern Appalachians, where oak vegetation predominates. The northern reaches, composed of the Adirondack and New Highlands, are located in the transition zone between the boreal spruce-fir forest to the north and the deciduous forest to the south. Growth form and species are very similar to those found to the north, but red spruce (*Picea rubens*) tends to replace white spruce. Here, the valleys contain a hardwood forest, dominated by sugar maple, yellow birch (*Betula alleghaniensis*) and beech. Low mountain slopes are covered with a mixed forest of spruce, fir, maple, beech and birch. Above the mixed-forest zone lie pure stands of balsam fir (*Abies balsamea*) and red spruce, which devolve into krummholz at higher elevations. Above the timberline appears alpine meadow.

2.4 SUBTROPICAL DOMAIN

2.4.1 Subtropical humid forest (SCf)

Climate

Mild winters and hot, humid summers characterize the climate of this Ecological Zone. Average annual temperature is 15^{o} to 21^{o}C. Annual precipitation ranges from around 1000 to 1500 mm and is relatively evenly distributed throughout the year, with most areas having either a summer or spring maximum.

Physiography

This Ecological Zone comprises the Atlantic and Gulf Coastal plains and the piedmont. The flat coastal plains have gentle slopes and local relief of less than 100 m, while the piedmont reaches to about 300 m altitude. Most of the numerous streams in the zone are sluggish; marshes, swamps and lakes are abundant. Ultisols dominate throughout the zone on the higher areas, with Entisols and Inceptisols in alluvial bottomland and floodplains of the major streams. Locally, Vertisols are formed from marls or soft limestones. The soils are derived mainly from coastal plain sediments ranging from heavy clay to gravel, with sandy materials predominant. Silty soils occur mainly on level expenses.

Vegetation

On the coastal plains, temperate rain forest, also called temperate evergreen rain forest or laurel forest, is the dominant natural vegetation. Subtropical rain forest has fewer tree species than its tropical counterpart; trees are not as tall here, leaves are usually smaller and more leathery and the leaf canopy less dense. Common species include evergreen oaks (*Quercus myrtifolia, Q. virginiana, Q.laurifolia*) and species of laurel and magnolia (*Magnolia grandiflora, M. virginiana*). There is usually a well-developed lower stratum of lower vegetation that may variously include tree ferns, small palms, shrubs and herbaceous plants. Further inland, the climax vegetation is medium-tall to tall forests of broadleaf deciduous and needleleaf evergreen trees. Loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*) and other southern yellow pine species dominate the stands, singly or in combination. Common associates include oak (*Quercus* spp.), hickory (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), red maple (*Acer rubrum*) and winged elm (*Ulmus alata*). The main grasses are bluestem, panicums and longleaf uniola. Dogwood (*Cornus* spp.), viburnum, hawthorn (*Crataegus* sp.), blueberry (*Vaccinium* spp.), American

beautyberry (*Callicarpa americana*), yaupon (*Ilex vomitoria*) and numerous woody vines are common.

Along the Mississippi river, small patches of riverine deciduous forests still occur, with an abundance of green ash (*Fraxinus pennsylvanica*), Carolina poplar (*Populus deltoides*), elm, cottonwood, sugarberry (*Celtis laevigata*), sweetgum and water tupelo (*Nyssa aquatica*), as well as oak and baldcypress (*Taxodium distichum*). Pecan (*Carya illinoensis*) is also present, associated with American sycamore (*Platanus occidentalis*), American elm (*Ulmus americana*) and roughleaf dogwood (*Cornus drummondii*). Vines are prolific along watercourses. Along the Atlantic coast and Gulf coast, extensive coastal marshes and interior swamps are dominated by gum and cypress.

Today, needleleaf evergreen forests of loblolly and slash pine (*Pinus taeda, P. elliottii*) are widespread in this Ecological Zone, predominantly as second-growth forest following fire and deforestation.

2.4.2 Subtropical dry forest (SCs)

This Ecological Zone is situated on the Pacific Coast between approximately 30^{o} and 45^{o}N.

Climate

The climate is typically Mediterranean, characterized by hot, dry summers and mild winters, with precipitation associated with winter frontal storms from the Pacific Ocean. Annual temperatures average about 10^{o} to 18^{o}C, with average summer temperature above 18^{o}C and average winter temperatures above 0^{o}C. Annual rainfall ranges from 200 to 1000 mm, depending on latitude and altitude, always with a pronounced summer drought. There is a great annual variability of total precipitation and extreme droughts are not uncommon. Coastal fog is common, particularly from May through July.

Physiography

This zone includes the Pacific Coast, comprising discontinuous coastal plains, low mountains and interior valleys and the Central Valley of California – a flat alluvial plain between the Sierra Nevada and the Coast Ranges. The latter area has broad, nearly level valleys bordered by sloping alluvial fans, slightly dissected terraces and the lower foothills of the surrounding uplands. Large undrained basins lie in the south. Elevations range from sea level to 700 – 1000 m. The soils of this zone include Alfisols, Entisols and Mollisols. They are high in bases and quite fertile when moisture is adequate. In the northern Coastal plains, the dominant soils are Ultisols (under forest).

Vegetation

A number of distinct vegetation types are present. The redwood (*Sequoia sempervirens*) is characteristic of the fog belt on seaward slopes of coastal northwestern California. Associated with it are Douglas-fir (*Pseudotsuga menziesii*) and other conifers such as western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*). The redwood forest is a hygrophyllic type of warm-temperate forest. Redwoods can attain a height of 100 m, but trunks remain relatively slender. Redwood forests typically have a well-developed understorey, usually dominated by large and colourful Pacific rhododendrons and western

azaleas (*Rhododendron* spp.). Other shrubs, especially salal (*Gaultheria shallon*) and California huckleberry (*Vaccinium ovatum*) are usually present. Many ferns and flowering plants grow in the cool shade, such as western sword fern and redwood sorrel. Along the coast in a narrow, patchy belt lies pine-cypress forest. Inland, the southfacing mountain slopes are covered by mixed forest, including tanoak (*Lithocarpus densiflorus*), live oak (*Quercus* spp.), madrone (*Arbutus menziesii*) and Douglas-fir.

The central and southern coastal areas are covered by chaparral, a mostly evergreen shrub vegetation. Several tree species are endemic to this region, including the Monterey cypress (*Cypressus macrocarpa*), Torrey pine (*Pinus torreyana*), Monterey pine (*P. radiata*) and Bishop pine (*P. muricata*). Chaparral has a thickened, hardened foliage resistant to water loss and forms a cover a closely spaced shrubs 1 to 4 m tall. Common shrubs include chamise (*Adenostoma fasciculatum*), buckbrush or ceanothus (*Ceanothus* spp.) and manzanita (*Arctostaphylos* spp.). Coastal sage scrub, summer-deciduous plants that tolerate more dry conditions than the evergreen chaparral, are found at lower elevations. Patches of live oak (*Quercus* spp., mostly *agrifolia*) or valley oak (*Quercus lobata*) woodland are found on the hills and lower mountains.

A blue oak (*Quercus douglasii*)-foothill pine (*Pinus sabiniana*) woodland community forms a ring around the Central Valley of California, which itself once had extensive grasslands and riparian forests.

Most of the coastal plains and interior valleys have been converted to urban use or irrigated agriculture. Citrus, grapes, avocados, nuts (such as almonds and walnuts) and deciduous fruits are grown extensively. Irrigated alluvial soils are also highly productive of vegetable crops.

2.4.3 Subtropical steppe (SBSh)

Climate

The climate of this Ecological Zone is semiarid-subtropical. Summers are long and hot and winters are generally short and mild. Annual temperatures average 14^{o} to 21^{o}C. Annual precipitation varies considerably within this Ecological Zone, from about 250 mm in the drier (mostly western) regions, to about 1000 mm in the northeastern Prairie Parkland region, which forms a transition to the subtropical humid forest. In the southern steppe, precipitation falls mostly during the growing season, while it is more evenly distributed throughout the year in the northern parts. High winds of cyclonic origin are an important climatic factor in this Ecological Zone. It is also subject to periodic, intense droughts and frosts.

Physiography

This Ecological Zone is dominated by flat to rolling plains and plateaus. Sizable portions in the United States are hilly or classified as tablelands with moderate relief, 100 to around 1000 m. The Mexican landscape alternates flat areas and low hills. Surface geology of this Ecological Zone is varied; major portions are aeolian, others are stream deposits and much of the zone is comprised of thin residual sediments. The Mexican portion is underlain by Cenozoic sedimentary rocks with recent continental deposits, mainly n the coast. Soils are commonly Mollisols and Aridisols, containing some humus.

Vegetation

A variety of natural vegetation is found in this zone. Grasslands in which shrubs and trees grow singly or in bunches, typical for the steppe or prairie, are predominant. On the plains of the southern US and Mexico, xerophytic grasses (blue grama and buffalo grass) are the characteristic vegetation. However, in much of these areas, mesquite (*Prosopis* sp.) grows in open stands of prickly shrubs. Other shrub species include acacia (*Acacia* sp.), paloverde (*Cercidium* sp.), silverleaf (*Leucophyllum* sp.), hackberry (*Celtis occidentalis*), Texas olive (*Cordia boissieri*), barreta (*Helietta parvifolia*), corbagallina and ocotillo. Over much of the plateaus, the characteristic vegetation is also grass, especially prairie three-awn (needlegrass); trees and shrubs occur only in very open stands. Locally, oak and juniper are mixed with grasses and mesquite and on steep rocky slopes these trees may form closed stands. Due to low rainfall they rarely grow higher than 5-7 m. The most characteristic tree is Ashe juniper. On slopes down to the Rio Grande, the ceniza shrub dominates. Live oak (*Quercus virginiana*) forest is found along the Gulf Coast. A unique semiarid forest consisting of small trees and shrubs occupies the Rio Grande delta. The endangered sabal palm (*Sabal palmetto*) is native here. In the northeastern part of the Ecological Zone, oak savanna, dominated by post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*), forms a transition with the more humid subtropical forest zone.

The generally higher Colorado Plateau has a distinct vegetation. Woodland is the most extensive vegetation type, dominated by open stands of two-needle pinyon pine and several species of juniper (*Juniperus*), often termed pygmy forest. In the lowest areas there are arid grasslands. Xeric shrubs grow among the grasses and sagebrush is dominant over extensive areas. A profusion of annuals and perennials blooms during the summer rainy season. At low elevations in the south of the Plateau, several kinds of cactus and yucca are common. Cottonwoods and other trees grow along some of the permanent streams.

2.4.4 Subtropical desert (SBWh)

South of the Arizona-New Mexico Mountains in the US are the North-American deserts, extending as far south as the Mezquital and Tehucán Valleys in Mexico.

Climate

This Ecological Zone has a desert and steppe climate: arid to semi-arid, with marked seasonal temperature extremes. Summers are long and hot. Winters are short, but may include brief periods when temperatures fall below zero. The climatic condition in this zone is the result of the rain shadow produced by the Eastern Sierra Madre and the Neovolcanic Ridge. Average annual precipitation ranges from as low as around 50 mm to 500 mm locally. The southern deserts have higher average temperatures and evaporation rates. Some northern areas, such as the Sonoran and Chihuahuan deserts, are dominated by a more episodic summer rainfall pattern.

Physiography

Topography of the North American deserts is characterized by extensive plains, most gently undulating, from which isolated low mountains and buttes rise abruptly. Elevations range from 85m below sea level (Death Valley) to around 1200 m. Basins with no outlets drain into shallow playa lakes that dry up during rainless periods, with alluvial fans and bajadas found

at the margin slopes. Extensive sand dunes occur in some areas. Soils are dry, mostly Aridisols and dry Entisols, are generally lacking humus and distinct soil profiles and are high in calcium carbonate. A dominant pedogenic process is salinization, which produces areas of salt crust.

Vegetation

The desert vegetation comprises of sparse, low growing shrubs and grass. There is however local variation, related to altitude, latitude and landform diversity. Creosote bush is common in the Mojave desert, which is also the area of the distinctive Joshua tree (*Yucca* sp.). The Sonoran desert has greater diversity in its vegetation than the other North American deserts that are dominated by low shrubs. Paloverde-cactus shrub vegetation includes various types of cacti, such as saguaro, cholla (*Opuntia cholla*) and agave (*Agave* sp.). Plants of the Chihuahuan desert shrub are often shorter with sparser foliage than similar plants of the other deserts. Yuccas, tarbush (*Flourensia cernua*) and creosote are dominant shrubs and grasses are intermixed throughout much of the Chihuahuan desert. The bajadas and hills include ocotillo (*Fouquieria splendens*), Joshua tree, lechuguilla (*Agave lechuguilla*) and prickly pear (*Opuntia polyacantha*) and some isolated mountains rise high enough to carry a belt of oak and juniper woodland.

2.4.5 Subtropical mountain systems (SM)

The following mountain ranges comprise the Ecological Zone: southernmost portion of the Cascade Mountains and the Rocky Mountains, Sierra Nevada, the Coast Range and the Western Sierra Madre.

Climate

The climate of this Ecological Zone is extremely diverse, related to latitude, altitude and exposure. The prevailing west winds influence climatic conditions; the east slopes are much drier than the west slopes. Rain falls during winter and the yearly amount increases with elevation, at high altitude mostly as snow.

Physiography

The Coast Range, Sierra Nevada and California Mountains are comprised of a mixture of steeply sloping to precipitous mountains crossed by many valleys wit steep gradients, hills and tablelands. It occupies an area of tectonic instability at the interface of the North American and Pacific tectonic plates and contains a variety of active faults. Altitude ranges from around 600 to more than 4300 m. Much of this region has been glaciated. Soils include ultisols on mountain slopes where air is humid, dry Alfisols at lower elevations and entisols in narrow floodplains and alluvial fans of the valleys.

The southern extent of the Rock Mountains consists mostly of steep foothills and mountains, but includes some deeply dissected high plateaus. Elevations range from 1200 to 3000 m, with some mountain peaks as high as 3900 m.

The western Sierra Madre in Mexico is one of the largest volcanic ranges of the world, being some 1250 km long and ranging from 125 to 300 km wide, with elevations up to 3000 m above sea level. Mountains, canyons and foothills are dominant and the bedrock is of igneous

origin. Major ranges include: Sierra Tarahumara, Papasquiaro Tepehuanes, Sombrerete. Predominant drainage is toward the Pacific Ocean. The Conchos River and the inner basin of Nazas-Aguanaval are also important in the hydrological system

Vegetation

Vegetation zones are well marked, generally in altitudinal belts.

In the Sierra Nevada, southern Cascades and northern Coast Range, the following zonation prevails:
The lower slopes, from about 500 to 1200 m, are covered by coniferous and shrub associations. On higher slopes, foothill pine (*Pinus sabiniana*) and blue oak (*Quercus douglasii*) dominate, forming typical open or woodland stands. Most of the low hills are covered by close-growing evergreen shrubs, or chaparral, in which buckbrush and manzanita (*Arctostaphylos* sp.) predominate. Several oaks are common associates. Above this belt, the montane zone is situated between 600 and 1800 m in the Cascades and between 1500 and 2400 m or more in the south. The most important trees are ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), Douglas-fir (*Pseudotsuga menziesii*), sugar pine (*P. lambertiana*), white fir (*Abies concolor*), red fir (*A. magnifica*) and incense cedar (*Calocedrus decurrens*); but several other conifers are also present. The spectacular giant sequoia (big tree) (*Sequoiadendron giganteum*) grows in a few groves on the western slopes. Dense chaparral communities of manzanita, buckbrush (*Ceanothus cuneatus*) and buckthorn (*Ceanothus* spp.) may appear after fire, sometimes persisting for years. Within the Sierra rain shadow, on the dry eastern slopes, Jeffry pine replaces ponderosa pine. The subalpine zone begins at 1800 – 2500 m and extends upslope for about 300 m. Mountain hemlock (*Tsuga mertensiana*), California red fir (*Abies magnifica*), lodgepole pine (*Pinus contorta*), western white pine (*P. monticola*) and whitebark pine (*P. albicaulis*) are important. The timberline is at about 2100 m in the north to 3000 m in the south

In the drier California Coastal Range further south, the montane vegetation consists of sclerophyll forest and chaparral, in which trees and shrubs with thick, hard evergreen leaves dominate. Chaparral occupies the greater area, found on southfacing slopes and drier sites, while forest appears on northfacing slopes and wetter sites. The most important evergreen trees are California live oak (*Quercus agrifolia*), canyon live oak (*Q. chrysolepis*), interior live oak (*Q. wislizeni*), tanoak (*Lithocarpus densiflorus*), California laurel (*Umbellularia californica*), Pacific madrone (*Arbutus menziesii*), golden chinkapin (*Castanopsis chrysophylla*) and Pacific bayberry (*Myrica californica*). Chaparral includes at least 40 species of evergreen shrubs with varying degrees of dominance and importance. Some are so dense that they practically eliminate understorey vegetation; other types support a highly productive understorey. The most important species are chamise and manzanita. Other common species include Toyon (*Heteromeles arbutifolia*), California scrub oak (*Quercus dumosa*), mountain mahogany (*Cercocarpus* sp.) and many species of ceanothus. At higher elevations and near the ocean, chaparral is often interspersed with coniferous forest. The interior valleys have sagebrush and grassland communities and a riparian forest with many broadleaved species grows along streams.

Vegetation zones in the southern Rocky Mountains resemble those further north (see Temperate Mountain systems), but occur at higher elevations. The foothill zone, reaching as high as 2000 m, is characterized by mixed grasses, chaparral brush, oak-juniper woodland and pinyon-juniper woodland. At about 2000 m, open forests of pondorosa pine are found,

although pinyon and juniper occupy southfacing slopes. In Arizona, the pine forests area strongly infused with Mexican species, including Chihuahuan pine (*Pinus leiophylla* var. *chihuahuana*) and Apache pine and (*Pinus engelmanii*). Pine forest is replaced at about 2400 m by Douglas-fir. Aspen (*Populus tremuloides*) is common in this zone and limber pine (*Pinus flexilis*) grows in places that are rockier and drier. At about 2700 m, the Douglas-fir zone merges into a belt of Engelmann spruce (*Picea engelmanni*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*). Limber pines and bristlecone pines (*Pinus longaeva*) grow in the rockier places. The alpine zone starts from around 3400 m.

Vegetation of the Western Sierra Madre in Mexico can be evergreen or deciduous, primarily being composed of conifers and oaks. They grow from 10 to 30 m, sometimes reaching 50 m. This vegetative cover may comprise from one to three tree layers, one or two shrub layers and a herbaceous stratum. A mountain cloud forest occurs in places. This forest community is characterized by about 3000 vascular plant species, 30 percent of which are endemic to Mexico. Mexican beech is a relict in Mexico. There are about 40 species of pine and more than 150 species of oak in Mexico—more than anywhere else in the world.

2.5 TROPICAL DOMAIN

2.5.1 Tropical rain forest (TAr)

The Ecological Zone encompasses in Mexico parts of the Gulf Coastal Plain, the lowlands of the Chiapas Sierra Madre and in Central America, lowlands along the Caribbean – Atlantic coasts and small areas along the Pacific coast. Parts of the Caribbean Islands are also included in this zone.

Climate

Year-round temperatures are averaging between 20°C and 26°C, with little seasonal variation. The average annual precipitation range is 1500 to 3000 mm and in some areas may attain totals of more than 4000 mm. The number of dry months is less than three and occurs during winter. Hurricanes (Tropical cyclones) are responsible for very heavy regional rains between August and October. They are uncommon or absent south of about 12^{o}S (Costa Rica and Panama).

Physiography

Topographically speaking, there are two distinct units within the tropical rain forest zone. One is the lowland, frequently poorly drained and the other is a very steep area in the lower portions of the central ranges. The lowlands are found in northeast Costa Rica, east of Nicaragua and along the northeast coast of Honduras. Another big portion with these characteristics is located on the Atlantic side of Guatemala, Belize and Mexico. The steep areas are found extensively in Panama and Costa Rica. Other areas include the border region of Nicaragua and Honduras and the northern-exposed middle elevations of Honduras and Guatemala, including the Mayan Mountains. Guatemala has also a section of this type of Ecological Zone in the Pacific southwest region.

Vegetation

The tropical evergreen to semi-evergreen rain forest along the Atlantic coast is a tall and dense forest. There are many species of canopy trees, some being deciduous during the dry season. The forest has a complex and diverse flora and the number of vascular plant species approximates 5000. Canopy trees reach 30 to 40 m high with emergent trees up to 50 m. Trees have round crowns and thick, clean and vigorous stems, some with well-developed buttresses. The subcanopy layer is dense with trees from 5 to 25 m tall, most of them with good-shaped stems and small buttresses. The understorey layers present a great variety of palms and tree ferns. Forest stands are typically of mixed ages with a great abundance of air plants (epiphytes): bromeliads, ferns and orchids among others. Common tree species include: paque or paleto (*Dialium guianense*), allspice tree (*Pimenta dioica*), breadnut (*Brosimum alicastrum*), Manteco (*Ampelocera hottlei*), Masica (*Brosimun alicastrum*), Masaquilla (*Pseudolmedia* cf. *spurea*), Laurel (*Cordia alliodora*, *C. bicolor*) Maria (*Callophyllum brasiliense)*, Hule (*Castilla elastica, C. Tunu),* Cuajada (*Dendropanax arboreus)*, Caobina (*Mauria sessiliflora*), Seliyon (*Pouteria izabslensis)*, Sangre de Pozo (*Pterocarpus offfcinalis*), Varillo (*Zymphonia globulifera*), Caoba (*Swietenia macrophyulla*), Cumbillo or sombrerete (*Terminalia amazonia*), Sangre Real (*Virola koschnyi*) and San Juan or copai-yé wood (*Vochisia hondurensis*).

At infertile locations, for instance on top of hills and slopes, pine grows, alone or in association with oak. In addition, there are abundant “Guamiles” (young secondary forests) in different successional stages, a result of abandoned subsistence agriculture.

The tropical evergreen and semi-evergreen forest in the northern part of the zone (Nicaragua, Honduras, Peten region in Guatemala, Belize) have been historically exploited for mahogany hardwood (*Swietenia macrophylla*). Gum (*Manilkara*) and Palo tinte (*Haematoxilum*) are other important timber species. Also in Mexico, the forests have been widely exploited for precious woods like mahogany and red cedar.

Beside the formations described above, there are also well-developed rain forests in specific places on the Pacific side of Central America, characterized by high biomass levels. There are other forests as tall or taller than this, but the many strata and rapid natural turnover of the forest (probably less that 100 years) make it very special.

In a middle elevation belt approximately between 400 and 1300 m altitude on the wetter (Atlantic) side of the Central America ranges, also known as coffee belt, grows an evergreen forest, intermediate in height, with two or three strata. Canopy trees are mostly 30-40 m tall, with round or umbrella-shaped crowns and straight branches. Buttresses are common but small. The subcanopy is very dense with trees 15-25 m tall, slender trunks often unbranched for most of their length, narrow, round to conical crowns and thin, light or dark-coloured bark. Palms are common at well-drained locations. The understorey is also very dense and may be difficult to distinguish from the subcanopy stratum. Understorey trees are 8-15 m tall, often with leaning, crooked or twisted trunks and relatively long crowns with horizontal branches; many trees have stilt roots. Tree ferns are common in the understorey. The shrub layer is 2-3 m tall and very dense. Dwarf palms are uncommon in the shrub layer. The ground layer consists of a nearly continuous cover of ferns, *Selaginella* and broadleaved herbs, often with bluish leaves. Epiphytes cover practically all surfaces.

2.5.2 Tropical moist deciduous forest (TAwa)

Climate

The climate of this Ecological Zone is drier than in the rain forest zone and the dry season is more pronounced (3 – 5 months). Along the Pacific coast, the amount of precipitation diminishes from Guatemala to El Salvador and Honduras, where locations at the Fonseca Gulf, together with some of the small closed interior valleys in Guatemala and Honduras, are the driest part of the region. Then, precipitation increases from Nicaragua to Costa Rica decreases again in Panama after the Azuero peninsula. Common average annual precipitation is around 1300 mm in El Salvador. It lowers to less than 1000 mm in Honduras and it increases again from Nicaragua to Costa Rica. Most of the Yucatan Peninsula in Mexico receives 1000 – 1500 mm annually.

Physiography

The zone comprises the lower Pacific part of the Central ranges in Central America, the plains and hills of the Yucatan Peninsula, humid parts of the Gulf of Mexico plains and the Everglades.

Vegetation

The predominant vegetation is high deciduous forest with three or four storeys and approximately 100 tree species in the associations on fertile soils. The most typical tree species in this formation are *Cordia alliodora, Carapa guianensis, Guarea, Vitex, Virola, Calophyllum brasiliensis, Terminalia chriquensis, Dialium guianensis, Tabebuia pentaphylla, Ochroma lagopus and Manilkara*. From Nicaragua southwards, the associations are enriched by many South American species such as *Anacardium excelsum, Dipteryx panamensis, Eschweilera calyculata, Lecythis and Prioria copaifera.*

Certain distinct associations include pure stands of cativo (*Prioria copaifera)* on riparian flood lands, palm swamps and the mangrove swamps on the tidal estuaries.

On the drier parts of the coffee belt, from 600 to about 1600 m, grows a two-layer semideciduous, seasonal forest of medium height. Canopy trees are mostly dry season deciduous, about 25 m tall, with characteristically broad, flat or umbrella-shaped crowns and relatively short, stout trunks, often with thick, fissured or flaky bark. Compound leaves are very common. Understorey trees are 10-20 m tall, evergreen, with round to conical crowns and short, twisted or crooked boles with smooth or moderately rough bark. There is a dense shrub layer, 2-3 m tall, of single or multiple-stemmed woody plants, some armed with spines. Ground layer is sparse. Epiphytes are rare, but woody vines are abundant.

2.5.3 Tropical dry forest (TAwb)

Climate

The tropical climate of the zone is characterized by intense episodes of rainfall, especially during summer. Overall, average annual precipitation is between 600 and 1600 mm. The dry season varies from 5 to 8 months.

Physiography

The zone comprises flat narrow lowlands or low hilly areas up to 1000 m altitude, located mainly along the Pacific Coast and also including interior depressions of the Sierra Madre and the northwestern plain of the Yucatan Peninsula in Mexico. Many valleys in the interior of Honduras and some valleys in Guatemala are also classified under this category. Soils are weakly developed, mainly from calcareous, metamorphic and volcanic rocks. They have a variable depth from shallow to deep. Textures are also variable, from clayey to sandy, depending on the nature of the underlying bedrock. Steep relief occurs over large parts of the Ecological Zone. The Pacific Coastal Plain and the Western Sierra Madre emerged in Paleozoic times. The Coastal Plain is a flat region dipping gently to the sea, interrupted by eroded hills surrounded by extended alluvial cones. Detritic material from Pleistocene and recent times cover the surface. A number of rivers traverse the plain as they drain toward the Pacific Ocean.

Vegetation

The dominant vegetation formation of this Ecological Zone is a dry deciduous forest. A diverse flora is present, particularly in the tree and bush layers that are dominant in most of this zone. Low deciduous and semi-deciduous forests predominate. This implies a marked seasonal pattern and a physiognomic difference between dry and humid seasons. The forests are from 4 to 15 m tall and have three distinct strata. Southern floristic elements are prominent, along with numerous endemic genera on the Pacific side. Legumes dominate the tree flora. There are many recognized associations within this formation, determined by the character of the soils or the position of the water table.

In El Salvador and Nicaragua, a *Crescentia* association is common on flats with a hardpan layer. These flats are waterlogged during the rainy season and thoroughly dried out during the dry season. The severe conditions seem to be tolerated by only one tree species, *Crescentia alata.* This tree is also found away from these flats, but then in association with other species.

On very infertile soils, *Curatella americana* and *Byrsonima crassifolia* form a very distinctive association. Since these two species are extremely fire-resistant, they are found not only on originally infertile soils, but also on soils seriously degraded by excessive cropping and burning. In northwestern Costa Rica in the Guanacaste region, a very similar association occurs on soils derived from pumice rock. This association differs in that *Quercus oleoides* accompanies the other two species. Here, *Quercus* drops to elevations close to sea level, clearly indicating the fact that species distribution often depends on lack of competition rather than on specific climatic conditions. This area is so infertile that it has never been utilized for cultivation. Extensive grazing with frequent burning is the rule.

A specific vegetation is found on shallow soils, covering large areas in Eastern Salvador and Southern Honduras. This formation contains many of the trees from the better soils, but is dominated by species such as *Acacia farnesiana, Caesalpinia coriaria and* “carbon”, a very aggressive leguminous tree which is apparently a *Mimosa.*

The two vegetation associations covering the major part of the zone at the Pacific Coast differ little in occurring trees species, but are quite distinct as to the dominant species. The division depends primarily on the extent to which the soil dries out during the dry season. Characteristic species, many of which provide excellent hardwood timber, include *Cedrela mexicana, Swietenia humilis, Entherolobium cyclocarpum, Pithecelobium saman, Hymenaea courbaril andira inermis, Platymiscium, Chlorophora tinctoria, Astronium graveolens, Dalbergia, Sweetia panamensis, Achras zapota and Tabebuia chrysantha.* From Mexico to Honduras *Cybistax donnell-smithii* is another important element, while from Nicaragua south, *Bombacopsis quinatum* is a conspicuous tree. In Mexico, the low deciduous forests contain about 6000 vascular plant species, of which 40 percent are endemic. Here, the Balsas Basin contains a large number of endemic species and it is the most significant region for the family of copales (papelillos), trees that are harvested for commercial and ritualistic uses. Other species of economic importance include parota (*Entherolobium cyclocarpum*), cuéramo, Mexican red cedar (*Cedrela mexicana*), palo de rosa, sabicú (*Lysiloma* sp.), jabin and henequen or false sisal (*Agave fourcroyoides*).

Where the water table is high in fertile soils, such as in river flats, a taller and more luxuriant forest occurs, with occurrence of such species as *Brosimun* sp. and *Anacardium excelsum* more common in tropical moist forest. This association has a much greater tendency towards an evergreen condition than the other dry forest association.

2.5.4 Tropical shrubland (TBSh)

There are two small interior valleys, one in Guatemala and another in Honduras that belong to this category. Mean annual precipitation is around 700 mm and the vegetation is composed of Cacti, small spiny trees and shrubs.

2.5.5 Tropical mountain systems (TM)

Climate

The climate in the mountain areas varies enormously due to different exposure to the wind direction and variation in altitude. Wind exposed areas are normally wet or pluvial while the interior valleys are usually moist or dry. Annual variation in monthly mean temperatures is generally less than 5°C, but mean annual temperatures range from some 12°C at about 1500 m to less than 6°C at 3800 m on summits of the Sierra Madre in Guatemala or in the Talamanca range in Costa Rica. The lower elevation limit for 12 °C mean annual temperature could be as low as 1100 m on the Atlantic slope, but it normally is around 1600 m on the Pacific slope.

Physiography

In Mexico, the Eastern Sierra Madre chain, from 60 to 200 km wide, attains a height of 3900 m above sea level and stretches for 1000 km. It consists of mountains and folded hills, as well as valleys and plains. The most prominent mountains include: Arteaga, Gorda and La Huasteca. The Neovolcanic Belt, stretching from the Pacific Ocean to the Mexican Gulf, is 880 km long and 130 km wide. It includes the highest peaks of Mexico, including Pico de Orizaba, Iztaccíhuatl and Popocatépetl (more than 5000 m high) and contains a number of active volcanoes.

Elevation in highland areas in western Guatemala reaches to as much as 4300 m. Elevation continues to be great through Guatemalan territory to about 2700 m along its eastern border with El Salvador and Honduras. The highland continues unbroken through Honduras, where about 70% of the territory consists of valleys and hills between 1000 and 2000 m in elevation. This continues into northwestern Nicaragua, but drops to the Nicaraguan Lake depression where the elevation is only 32 m except on isolated volcanoes. From there, the continental divide rises to reach almost 1500 m at the Orosi Volcano in Costa Rica. Here, the ranges increase in height to reach 3820 m at the summit of Chirripo Mountain on the Talamanca Range, which continues at high elevation into western Panama. Most of central Panama is divided by a narrow mountain range of about 1000 m in height, broken in the middle by a deep depression through which the Panama Canal passes. Near the border with Colombia, an isolated, higher range rises connecting directly with the western range of the Colombian Andes.

Most of Central America is composed of uplands dissected by deep valleys and plateaus. Both young volcanic and old, worn down crystalline mountains are present. High plateaus and valleys, as well as coastal lowlands derived from their geological erosion, provide favourable climates and soils for intensive agriculture, especially for the production of coffee, sugarcane and horticulture.

Vegetation

The mountain vegetation is described in two sections: one for the northern part from Nicaragua to Mexico and another for Costa Rica and Panama.

Mexico – Guatemala - Nicaragua High Land Area
Broadleaved forests prevail in highland areas of Mexico, Guatemala and Nicaragua but pine forests are also very common. For example, in the mountain areas of Guatemala with less than 1000 mm annual rainfall, the most notable trees are the *Pinus pseudostrobus* and several species of *Quercus*. There are also other genera from the temperate zone, like *Salix, Sambucos, Ostrya and Acer*. On those sites where annual precipitation surpasses 1000 mm, the climax forest consists of a mixed broad-leaved forest, including *Prunus, Cornus*, members of the Lauraceae and Ericaceae families and several other species. Forest here is tall and very dense, with canopy trees generally reaching 30 m in height and a dense shrub layer. Mosses commonly grow on stems and branches of the canopy trees.

Talamanca Costa Rica and Panama Mountains
This high area includes several altitudinal belts with the paramo vegetation appearing above 3500 m altitude. Three main peaks reach this altitude, all of them within Costa Rica: the Cerro de la Muerte, Chirripo and Kamuk mountains. The altitudinal zonation is as follows:

The so-called coffee belt between 600 and 1600 m, an important zone in Central America since most of the population lives there. This belt has been classified as part of the tropical lowland zones and is described in that section. The wettest part was lumped with the TAr zone and the moist part with the TAwa zone (see above).
From 1600 m to approximately 3500 m, the vegetation can be either a very tall oak forest or a mixed Lauraceae-rich forest. The tall oak forest is a high, comparatively open stand, characterized by emergent, large-crowned oaks, *Quercus copeyensis* and *Q. seemanni*,

reaching up to 50 m and a lower stratum of relatively small to medium sized trees with abundant epiphytes. The Lauraceae-rich forest is not as tall as the oak forest but still reaches 30 m in height. This is the kind of forest found in the Monteverde Cloud Forest Reserve in Costa Rica and also in the Cerro Punta area in Panama. The forest is very dense, with multiple strata and frequently a very large amount of epiphytes, especially in the areas with high cloudiness. It is possible to find *Ocotea, Phoebe, Nectandra* and *Persea* trees from the Lauraceae family. These species provide a very good food supply for the Resplendent Quetzal (*Pharomacro muccine*), a very beautiful bird that constitutes one of the main tourist attraction in the region.

From 2800 to 3500 m there are many shrub species, at least in the altered zones; among them are *Escallonia, Weimmannia, Budleia* and a bamboo species. In the primary forest, evergreen oaks, including *Quercus costaricensis,* dominate the tree canopy, which reaches some 25 – 30 m high. The trees are thick and short-trunked and the crowns are formed by heavy, twisted limbs. A shrub layer is an outstanding feature of the forest, often composed of a dense stand of bamboo of several meters high. Epiphytes, including ferns, orchids, Araceae, bromeliads, small ericaceous shrubs and mosses are abundant.

The paramo, the vegetation above 3500 m, is herbaceous and includes a few shrubs but no trees.

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3 South America

Figure 34. GEZ map for South America

Table 19. Global Ecological Zones of South America.

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Tropical rain forest	6 631 240	37.3	45.5
Tropical moist deciduous forest	4 302 306	24.2	38.9
Tropical dry forest	1 681 596	9.5	22.5
Tropical shrubland	103 034	0.6	1.2
Tropical desert	137 638	0.8	1.2
Tropical mountain systems	1 886 495	10.6	41.7
Subtropical humid forest	1 199 948	6.8	25.6
Subtropical dry forest	100 504	0.6	6.3
Subtropical steppe	639 738	3.6	13.0
Subtropical desert	0	0	0
Subtropical mountain systems	238 162	1.3	4.9
Temperate oceanic forest	259 147	1.4	14.4
Temperate continental forest	0	0	0
Temperate steppe	498 298	2.8	8.5
Temperate desert	0	0	0
Temperate mountain systems	76 895	0.4	1.1
Total land area	17 755 001	99.9	

3.1 TROPICAL DOMAIN

3.1.1 Tropical rain forest (TAr)

The tropical rain forest zone of South America extends over the whole Amazonian basin as well as on the Pacific coast of Colombia and Ecuador, crossed by the Equator. It also extends on the Atlantic coast of Brazil and the median valleys of Iguaçu and Parana in Brazil.

Climate

The trade winds blowing from the southeast in the southern hemisphere are responsible of the wet climate of the Atlantic coast. The regime is axeric, with huge amounts of rain in the heart of the Amazonian basin and the western coast (more than 3000 mm, even up to 8000 mm). Everywhere else, rainfall is between 1000 and 3000 mm, with often a short dry period in winter, even up to 4 months in some places. Temperatures are high, especially in the Amazonian region, where mean temperature of the coldest month is always more than 20°C. On the Atlantic coast, it decreases when latitude increases (15°-20°C), as the Ecological Zone extends beyond the Tropic of Capricorn, up to 30°S.

Physiography

The Amazon Basin lies at less than 200 m above sea level and flat or gently rolling lowlands stretch from the eastern slopes of the Andes to the Atlantic coast. There, the Guiana Shield and the Brazilian Shield, to the north and south of the Amazon valley respectively, are

covered with Tertiary continental sediments and Quaternary sands. The soils are mostly ferralsols. Along the proper Amazon depression, many swamps and flooded valleys occur.

The Pacific coastal region is an irregular strip, narrow near Panama, 100 km wide near the border with Ecuador, on the foothill of the Andes.

On the Atlantic coast, behind wide sand beaches, low plateaux with shallow soils lead to the crystalline hills, mostly lower than 1000 m, carved by numerous valleys filled with fertile clayey soils. These hills form a barrier receiving the rains and clouds from the Atlantic Ocean.

Vegetation

The Amazon Basin contains by far the largest area of tropical rain forest in the world. The area of Amazonian and Pacific forests is more than 4 000 000 km^2. In this vast extent, at least 10 to 20 different vegetation types might be distinguished, ranging from several associations of dense humid evergreen forest to edaphic grasslands. Even if deforestation is rather active in the southern border of the Amazonian basin, it is estimated to encroach upon a relatively small portion of the original extent. On the Atlantic coast, dense evergreen forest only remains at the top of the hills. Deforestation began almost as soon as Europeans arrived in Brazil. It was first exploited for timber, then affected by mining, coffee, banana and rubber plantations. In the low fertile valleys, they were converted to agriculture, especially sugar cane. Five ecofloristic zones have been distinguished within this Ecological Zone, according to variation in climate humidity, geographical location and flora. Edaphic vegetation types are represented by riverine ombrophilous (evergreen) forest, swamp ombrophilous forest, mangrove forest and flooded grassland.

The wettest type (annual rainfall > 3000 mm, locally up to 8000 mm) is found in the upper basin of the Amazon River, Amapà and west coast of Colombia. The vegetation is luxuriant evergreen forest, multi-layered, up to 50 m tall, with emergent trees. Buttresses and stilt roots are fairly frequent. The biggest trunks reach 2 meters in diameter. Undergrowth is fairly sparse, but epiphytes are very abundant. It has a very rich flora and presents many local facies. Most important tree families are: Annonaceae, Bombacaceae, Burseraceae, Clusiaceae, Euphorbiaceae, Leguminosae, Moraceae, Sterculiaceae.

The most extensive rain forest is somewhat drier (annual rainfall between 2000 and 3000 mm) and occurs in the Amazon Basin and at the eastern foothills of the Central Andes. It is a multi-layered forest of 40 m tall, with or without emergent trees, mainly evergreen but with marked leaf reduction during the short dry season. The forest floor is rich in shrubs and herbaceous plants. The chief families are Bignoniaceae, Bombacaceae, Euphorbiaceae, Moraceae, Sterculiaceae, etc. In Brazil, Leguminosae are particularly important: *Parkia, Tachiglia, Hymenolobium, Swartzia* and others. In Peru the most common species include *Bombax munguba, Calycophyllum spruceanum, Castilloa ulei, Cedrela odorata* and in Venezuela *Calophyllum brasiliense, Carapa guianensis, Cedrela fissilis, Ceiba pentandra* are among the dominants.

Evergreen swamp forest covers large areas in the Amazon region, particularly in the delta. In Brazil, this flood-forest is known as “igapo”. Characteristic species are *Bombax aquaticum, Calophyllum brasiliense, Macrolobium acaciaefolium, Triplaris surinamensis*, etc. and above all many palms, among others: *Euterpe oleracea, Manicaria saccifera, Mauritiella pacifica, Raphia taedigera*.

Mangrove forests are well established in the big estuaries, especially in the tidal-flow zone. They occur along the Atlantic coast and to a lesser extent along the Pacific coast. The largest mangroves are found in Brazil. Here we find the following zones, moving from the see inland: first a belt of *Rhizophora mangle*, then mangrove of *Avicennia tomentosa* and *A. nitida* and finally on higher ground a vegetation dominated by *Laguncularia racemosa*, often edged on its landward side by a fringe of palms. Stilt roots or pneumatophores are common. Other common trees and shrubs in South American mangroves include *Ardisia granatensis, Avicennia tomentosa, Conocarpus erectus, Conostegia polyantha, Rhizophora brevistyla* and *Rustica occidentalis.*

3.1.2 Tropical moist deciduous forest (TAwa)

Climate

A wide area with rather high rainfall but an always pronounced dry season extends around the wet Amazonian Basin. A rather surprising feature is the occurrence of a large island of this Ecological Zone in the Amazonian area. It corresponds to the western slope of the uplift Guiana Shield, culminating at Mount Roraima (2810 m); this area does not receive in winter the winds blowing from the Atlantic Ocean.

Physiography

This Ecological Zone roughly corresponds with the two main shields forming eastern South America:

The Brazilian Shield, to the southeast, is a rather flat surface where very old rocks are exposed; its altitude is less than 500 m in its northern part and gently rises to 900-1000 m in its southeastern part; the Parnaiba River flows to the Atlantic Ocean through a deep depression filled with more or less ancient sediments.
The Guiana Shield to the north, on which large extents of sandstones are exposed.

Along the Andean Range, the Orinoco River flows in a depression relied with the Amazonian one.

To the south, a wide depression between the Brazilian Shield and the Andes forms the Pantanal. On the other side of the Andes, the deep depression of the Cauca River low valley also belongs to this Ecological Zone.

Vegetation

This large Ecological Zone is mainly covered by “cerrado” in Brazil, i.e. a mosaic of grasslands, tree savannas and woodlands, with patches of semi-deciduous forest. There, grazing is the main activity, but the growing of maize and leguminous soya is increasing in some parts. The prevailing physiognomy is a savanna with woody plants. However, in some areas, a real forest occurs, namely “cerradao”. It is a short semi-deciduous forest, 10 to 15 m tall, of medium density. The trees, more or less twisted, have big crowns, thick bark, broad leathery leaves and deep roots. There are no thorn-trees. In the sufficiently open undergrowth, there is a herbaceous layer. The flora includes forest species such as *Bowdichia, Hymenaea, Piptadenia incurialis, Machaerium,* with also “cerrado” species like *Curatella americana,*

Qualea, Kielmeyera coriacea and others. In northern Argentina, around Salta, a forest very similar to this type grows on the foothills of the Andes. It is a semi-deciduous broad-leaved forest, taller than the "cerradao", where the higher trees are *Aspidosperma peroba, Astronium* sp., *Cedrela fissilis, Gallesia guararema*. The "Campo cerrado" presents several facies: shrub savanna or tree savanna of varying density. Trees and shrubs are short, 3 to 8 m high and twisted with low branches and thick bark. The leaves are persistent or partially deciduous. Flora is rich, with Leguminosae and Myrtaceae very prevalent in the tree and shrub canopies. The most common species are *Caryocar brasiliensis* (Caryocaraceae), *Curatella americana* (Dilleniaceae), *Kielmeyera coriacea* (Guttiferae), *Qualea* (Vochysiaceae). In the herbaceous layer, grasses and composites predominate.

On the edge of the Amazonian Basin and in Andean foothills grows an evergreen seasonal or semi-deciduous forest. In Argentina and Paraguay, this fairly dense forest includes 3 tree canopies, the tallest reaching 30 m. Characteristic trees include *Apuleia leiocarpa, Aspidosperma polyneuron, Balfourodendron riedcianum, Cabralea* spp., *Cedrela* spp. In Bolivia, *Astronium urundeuva, Ateleia guareia, Ficus* spp. and *Hura crepitans* are dominant species.

In Venezuela, the flora and physiognomy of llanos have some similarity with Brazilian "cerrados". Llanos are tall grasslands with evergreen broad-leaved tree synusia where the main trees are *Acacia caven, Celtis spinosa, Prosopis alba, P. nigra*. A deciduous thorn forest occurs in some places, with *Caesalpinia coronaria, Capparis coccolobifolia, Cercidium praecox, Mimosa, Piptadenia flava* and other species in addition to the main llanos species.

To the south, the grasslands of Pantanal and those around the junction of Paraguay and Parana rivers in Argentina, belong to this Ecological Zone.

To the northwest, in Colombia, the low plain of Cauca River is largely cultivated, with palms, banana trees, sugar cane plantations. Patches of the original deciduous forest remain, surrounded by savannas.

3.1.3 Tropical dry forest (TAwb)

Climate

In some areas, sheltered from the humid trade-winds, climate is drier. These regions may be close to the sea, like northeastern Brazil and Caribbean coast, or inland, like the Argentine "chaco". The same ecological conditions are experienced around Guayaquil Gulf. Rainfall varies between 500 and 1000 mm and the long dry season is 5 to 8 months. Just behind the barrier of the Atlantic hills, rainfall may be less than 500 mm and overall extremely variable. Temperatures are always high (mean temperature of the coldest month > 20°C) in the areas close to the Equator; they are lower in Chaco which extends up to 34°S.

Physiography

In northeastern Brazil, this Ecological Zone lies on the eastern Brazilian Shield, formed of Precambrian rocks and raised on its Atlantic border, forming a barrier of uplands at a medium elevation of 1000 m, with some peaks between 2000 and 3000 m. In Argentina, the Chaco extends on the lowlands bordering the eastern side of the Andes. Parts of this Ecological

Zone along the Caribbean coast take place on rather recent sediments forming the coastal plain, whereas on the border of Guayaquil Gulf, the lower slopes of the Andes belong to the same Zone

Vegetation

In Brazil, the typical vegetation of the Ecological Zone is the “caatinga”. This local name designate a wide variety of xerophytic vegetation types, with or without Cactaceae, sometimes dense and almost closed, sometimes very open and pseudo-steppe like. This dry forest, more or less deciduous, has a low tree canopy (5 to 10 m), fairly open, composed of thin-stemmed trees, a shrub layer and a sparse herbaceous layer. Flora is rich, with fairly numerous Leguminosae, specially *Amburana, Caesalpinia, Mimosa*. The palms *Cocos commosa* and *Copernicia cerifera* (Carnauba) assume considerable importance in flood plains. Due to the severe climate as well as very poor soils, often lithosols, this region seems unfavourable to agriculture. However, through a considerable irrigation effort, it has been largely reclaimed and farmed (food crops, cereales, cotton, stock farming).

In Argentina, the Chaco constitutes a wooded region of relative ecological homogeneity, in a transitional zone between the tropical and subtropical ones. The prevailing vegetation of the Chaco is deciduous xerophilous forest with many climatic and, above all, edaphic variations. All these types are characterized by “quebrachos” (*Schinopsis, Aspidosperma*). The most humid forests occur in the east, a drier forest in the west and xerophilous forest on the lower Andean foothills.

In the coastal region of the Caribbean, deciduous forests and woodlands rich in Leguminosae occupied a large part of the plain. Due to increased dryness and overgrazing, these forests have been largely replaced by agriculture or thickets. Today, around population centres and agriculture, Cactaceae formations, with or without thorn trees, form a transition with the real sclerophyllous thorn forest. Similar woodlands with Cactaceae grow along the Guayaquil Gulf in Peru and Ecuador.

3.1.4 Tropical shrubland (TBSh)

Climate

Except the drier parts of Caribbean coast, this Ecological Zone extends along the Pacific coast of South America, from the south of Guayaquil Gulf to the Tropic of Capricorn. This dry climate is dependent on general factors: the large high-pressure area, the trade winds, Humboldt’s Current, the Andean barrier. Rainfall is less than 500 mm, with a long dry season of 8-9 months and high temperatures (always more than 20°C). To the south, in Peru, rainfall is even lower than 100 mm, but a light drizzle maintains high humidity and allows some plants to live.

Physiography

This Ecological Zone is a very narrow belt between the lower slopes of the Andes and the coastal desert. The altitude may reach 1000-1200 m on the Peruvian “lomas”. Soils are poor, often squelettic.
Vegetation

Xeromorphic woodlands are represented by “algarrobo”, found on the southern coast of the Guayaquil Gulf. It is a perennial-leaved woodland dominated by *Prosopis chilensis*. In western Venezuela, a deciduous thorn woodland grows in the same conditions. It is a multi-layered woodland of 8 –15 m high and the canopy is dominated by *Bulnesia arborea, Capparis, Pithecellobium unguiscati, P. saman, Prosopis and Pterocarpus*.

Subdesert deciduous shrubland, with or without succulents, is another main vegetation in this zone. In Guajira, it is a low, open thicket, dominated by deciduous thorn trees and succulents, floristically close to the “caatinga”. In Peru and Chile, the coastal “lomas”, when not degraded, bear a xerophytic thicket with scattered trees. Among the woody plants, the following are important: *Acacia macrantha, Caesalpinia spinosa* (tara), *Capparis pisca, Carica candicans, Prosopis chilensis* and *P. limensis*.

3.1.5 Tropical desert (TBWh)

Climate

This Ecological Zone comprises the Pacific coastal desert, in Peru and Chile, where rainfall is much less than 200 or even 100 mm, without fog. Temperatures are high in the north, cooler in winter to the south (mean temperature of the coldest month < 15°C).

Physiography

This coastal fringe is mainly formed of sands, or sometimes rocks.

Vegetation

It is a true desert, with scattered vegetation of deciduous dwarf shrubs (*Larrea, Caesalpinia, Capparis, Prosopis*) and succulent cacti.

3.1.6 Tropical mountain systems (TM)

Climate

The tropical mountains of South America are mainly the Andean range, extending from northern Colombia and Venezuela to 28-29°S. However, some uplift parts of the ancient shields, in Venezuela and Brazil, experience specific climatic features due to elevation. The common character of these mountain regions is lower temperatures leading to specific vegetation types above 1000 to 1500 m depending on the location. Precipitations greatly vary, but the region is everywhere tropical, with low annual range of temperature. Several altitudinal belts have been distinguished, defining submontane, montane and high elevation Eco-Floristic Zones.

Northern Andes
Although the Andes form a barrier which limits east-west exchanges in the northern Andes (Colombia and Venezuela), the eastern and western faces are well watered. The former receive rains from the east and northeast Atlantic, the latter, rains from the Pacific. In this the Andean forests are comparable. Above 1000 m altitude, precipitations range from 1500 to 5000 mm. Mean temperature of the coldest month is often close to 15°C, but drops down to

10°C or less with increasing elevation. There is generally no dry season, or a very short one. Moreover, in some places, there is a heavy cloud cover and very frequent fog. Frost occurs above 2000 m.

Central Andes
South of Ecuador, there is a contrast between the eastern side of the Andes, very wet, whereas Andean valleys and the western side are drier. On the eastern face, climate is similar to that of the northern Andes. In the inter-Andean valleys, even in Colombia and Venezuela, precipitations are 1000-1500 mm (sometimes less) and the dry season is 2 to 5 months. On the western face, in Peru, precipitations are even lower (less than 500 mm) and the climate becomes very dry or semi-arid. In Venezuela, the uplift southern part of the Guiana Shield reaches 1000 to 3000 m. These uplands close to the Equator receive humidity from the Atlantic Ocean and rainfall is very high. Also rather high rainfall almost all along the year is recorded on the Atlantic slopes of the uplift East-Brazilian Shield, along the Atlantic coast.

Physiography

The ranges of the Andes result of relatively ancient foldings, eroded then raised again in the Tertiary age. Today, frequent earthquakes and numerous active volcanoes manifest recent tectonic activity. The Andes reach maximum width and height in the central portion of Bolivia and Peru, even if the highest peak (Mt Aconcagua, 6959 m) is located in subtropical Chile. In central Peru, more than 10 peaks reach 6000 m or more. Then elevation decreases northwards to about 2000 m in northern Peru. In Ecuador, the Andes split in two separate ranges (Cordillera Occidental and Cordillera Central) and a third (Cordillera Oriental) is added to the east. The eastern Cordillera continues into Venezuela following the Caribbean coast to northern Trinidad. In northern Colombia, the isolated massif of the Sierra Nevada de Santa Marta (5775 m) also belongs to the Andes. A narrow band of trans-Andean lowlands follows the Pacific coast from Chile to northwestern Colombia and here merges broadly with the Caribbean lowlands of Colombia and Venezuela. The rocks are of various origins and composition; volcanic material occurs in many places. The raised parts of the ancient shields are formed of very old rocks. Their altitude may reach 2000 m or more (2810 m at Mt Roraima, in Brazil).

Vegetation

The Andean forests depend on two main factors: precipitation, which determines, from one extreme to the other, hyperhumid forests or dry thorn forests and altitude (or temperature) which allows a distinction to be made between submontane and montane forests.

Northern Andes
In this moister part of the range, ombrophilous evergreen to seasonal forests are everywhere the climax vegetation up to 3200 to 3800 m, which is the timberline.

Between 1000 and 1800-2400 m, one finds submontane or lower montane forest. It is quite similar to lowland rain forest but a large number of species drop out and are replaced by more upland species. This forest tends to be lower than that of the surrounding lowland area, the upper canopy at 25 – 30 m, with fewer woody vines and less-buttressed trees. Epiphytes, lianas and palms are abundant. Many of the lowland taxa still persist in this belt, such as species of *Licania* (Chrysobalanaceae) and *Eschweilera* (Lecythidaceae), but a number of distinctly highland elements also enter the lower montane forest, for example in the

Colombian Andes: *Alchornea bogotensis, Brunellia comocladifolia and Cinchona cuatrecasasii*. The montane or upper montane forest, starting at 1800 to 2400 m, may extend in places up to 3400 m. It is usually less tall than the submontane forest, with a predominance of microphyllous trees. Vascular epiphytes are still common, but woody lianas rarer. An increasing number of typical montane species enter the flora, for example *Brunellia occidentalis, Symplocos pichindensis* and *Weinmannia balbisiana*. In the drier parts, montane forests are evergreen seasonal. Above this zone, subalpine forests may extend up to 3800 m in some places. Few vascular epiphytes and climbers occur, but there are abundant mosses and lichens. The characteristic highland flora includes many species of *Befaria* (Ericaceae), *Brunellia* (Brunelliaceae), *Clusia* (Clusiaceae), *Gynoxys* (Asteraceae), *Miconia* (Melastomataceae), *Rhamnus* (Rhamnaceae) and *Weinmannia* (Cunoniaceae). On the high ridges exposed to the wet winds, there is montane cloud forest, with its characteristic "elfin woodland" physiognomy: low gnarled trees with extremely abundant mosses and lichens. Above the timberline, the "paramo" appears, herbaceous vegetation with a few shrubs but no trees.

A separate unique submontane formation is *Podocarpus* forest, which remains today mainly in the lower montane region in northern Peru. Naturally it occurred scattered along the Andes of Colombia and Peru and in the Coastal Cordillera of Venezuela. The conifer *Podocarpus oleifolius* dominates this forest, where *Drimys winteri, Ocotea architectorum* and *Weinmannia* are also common trees.

Central Andes
In Peru and Bolivia, the wet eastern face of the Andes bears hyperhumid to seasonal submontane and montane forests. Their structure, physiognomy and floristics are similar to these of the northern Andes. In the drier inter-Andean valleys, the forest often becomes deciduous, even xerophilous with thorn trees at the submontane level. As these Andean valleys have been populated for a long time, the forests are often very degraded and transformed into thicket or scrub. On the western slopes of the Andes, under very dry climate, scrub woodland replaces forest. Above the timberline, from central Peru southwards, "paramo" is replaced by drier "puna".

Non-Andean mountains
In non-Andean highlands, the submontane level is mostly present, with ombrophilous rain forest rather similar to the lowland one, but of lower stature and with a slightly distinct flora.

3.2 SUBTROPICAL DOMAIN

3.2.1 Subtropical humid forest (SCf)

This Ecological Zone concerns plateaux and lowlands on the Atlantic side of the continent, south of the Tropic of Capricorn up to 40°S; it lies on southern Brazil, Uruguay and Argentina

Climate

The two main climatic characters are lower temperatures in winter (mean temperature of the coldest month<15°C) and rainfall evenly distributed throughout the year. However, rainfall regularly decreases from the North (1000-2500 mm) to the South (600-1000 mm).

Physiography

The northern part, mainly the States of Parana and Santa Catarina in Brazil, is a gently rolling plateau region whose altitude varies from 300 to 1000 m. The southern part lies on lowlands generally less than 600 m.

Vegetation

The natural vegetation of the wetter northern parts of the zone is evergreen coniferous forest dominated by *Araucaria angustifolia*. These forests once covered sizeable areas, giving these regions a particular geobotanical stamp. In Brazil, this formation has several storeys. The *Aracauria* forest, some 25 m tall, may be almost pure; but more often it dominates a dense forest with a profusion of *Cedrela fissilis, Phoebe porosa, Tabebuia, Parapiptadenia* and the shrub *Ilex paraguayensis*. Today, only residual areas remain, as this forest has been much exploited for timber production. However, reforestation efforts are conspicuous in this part of Brazil. The other important feature of this region is the considerable extension of coffee growing. In Argentina, the *Aracauria* forests are also 25 to 30 m tall and these conifers dominate a canopy of broadleaved species of 20 m tall. The humid forest is rich in tree ferns, lianas and epiphytes. Prevailing species include *Apuleia leiocarpa, Aspidosperma polyneuron, Balfourodendron riedelianum, Cedrela, Nectandra, Ocotea* and *Peltophorum*.

In Rio Grande do Sul as well as on the lowlands of Uruguay and eastern Argentina, grasslands become the main vegetation from the “campos limpos” of southern Brazil to the “pampas” of Uruguay and Argentina. They are short grasslands, 50 cm to 1m tall, more or less dense, becoming graminoid steppe to the south. Main grasses include *Aristida, Bothriochloa lagurioides, Briza, Eragrostis, Poa, Piptochaetium, Stipa*. In Rio Grande do Sul riparian forests are fringing the main rivers.

3.2.2 Subtropical dry forest (SCs)

Climate

The Ecological Zone lies on the central “Mediterranean” part of Chile, between 32° and 38° south. Rainfall regime is of a Mediterranean type, with summer drought (2-7 months) and winter rains. Annual precipitation varies from 500 mm in the northern coastal region to 2000 mm on Andean foothills. Winter temperatures are cool (10-15°C).

Physiography

This GEZ concerns a rather narrow stretch of lowlands, less than 200 km wide, lying between the Andes foothill and the Pacific Ocean. However, the long north-south valley extending just at the foot of the Cordillera is separated from the coastal plain by the Cordillera de la Costa. The latter reaches 2000 m in front of Santiago and further south it is reduced to some tabular segments.

Vegetation

The climax is a sclerophyllous evergreen forest or woodland with xerophytic species such as *Lithraea caustica* (Anacardiaceae), *Quillaja saponaria* (Rosaceae), *Peumus boldus* (Monimiaceae) and the Lauraceae *Cryptocarya* and *Beilschmiedia*. The endemic palm *Jubeae chilensis* grows in a narrow area northeast of Valparaiso; columnar cacti (*Trichocereus*) and the large *Puya* spp. (Bromeliaceae) as well as the thorny *Colletia* and *Prevoa* are found in dry, rocky habitats. Many species of this forest are used as firewood. As a result, the forest is often degraded and replaced by secondary thorny thicket with *Acacia caven*. Moreover, it has been widely reclaimed for agriculture.

Toward the south or in the Andean foothill, where precipitation is higher, the sclerophyllous forest gives way to open deciduous "mesophitic" forest of "roble", dominated by various *Nothofagus* species, *N. obliqua, N. dombeyi, N. procera*, associated with *Aetoxicon punctatum, Araucaria araucana, Drymis winteri, Laurelia serrata* and others.

3.2.3 Subtropical steppe (SBSh)

Two regions belong to this Ecological Zone. One is located to the west of the Andes, covering most of the Chilean "Norte Chico" and forming a transitional area between the previous Mediterranean zone and the Atacama Desert. The other is to the east of the Andes, an extensive region in central Argentina making a transition between the tropical "Chaco", subtropical "pampa" and temperate steppes to the south.

Climate

In this large area sheltered from ocean moisture by the barrier of the Andes or the coast direction, rainfall ranges from 100 to 800 mm, the regime still being more or less tropical. The dry period is very long, up to 9 months. Mean temperature of the coldest month may be less than 10°C. In Chile, rainfall is even lower, from less than 100 to 400 mm, with a Mediterranean regime. Temperatures are warmer than in Argentina, with mean temperature of the coldest month between 13° and 15°C.

Physiography

In Argentina, the Ecological Zone lies on the large depressions area stretching along the Andes, with the exception of some "sierras" around Mendoza. In Chile, the Andean foothills extend forming alluvial cones separated by flat plains. Then the coastal plain is rather wide.

Vegetation

In this GEZ, the densest vegetation type is a deciduous thicket with various species of *Prosopis*, turning into large areas of thorn woodland. In the drier inland plain, it is rather a subdesert shrubland with *Bougainvillea, Cercidium* and various Rhamnaceae. In Chile, *Acacia caven* and *Puya* dominate the subdesert thorn scrub of the "Norte Chico". Nevertheless, extraction of firewood over a long period, followed by agricultural reclamation, has greatly reduced the stands of *Acacia caven*.

3.2.4 Subtropical mountain systems (SM)

Climate

The subtropical Andes roughly lie from 26° to 40°S. From 1000 m to nearly 7000 m altitude, the climate is everywhere cold. The area is bordered to the west by the highest peaks forming a barrier against the winds blowing from the Pacific Ocean. As a result, precipitations are low, generally less than 300 mm. The dry season mainly occurs in spring and summer (October-December). Strong winds make the effects of aridity and cold more pronounced.

Physiography

A range of volcanoes constitutes the boundary between Chile and Argentina. There are some of the highest peaks of the Andes, particularly Mount Aconcagua, which nearly reaches 7000 m. South of the Aconcagua, the Cordillera becomes narrower and its elevation is decreasing to the south, with peaks only reaching 4000 m, then 3000 m. To the east of this volcanoes range, elevation slightly decreases up to the shrubby lowlands of the previous Ecological Zone.

Vegetation

In the lower reaches of the Andes, between 1000 m and 1800 - 2400 m, we find sub-montane beech forest on the wetter slopes. It is a deciduous low forest or woodland containing species such as *Nothofagus dombeyi*, *N. obliqua*, *N. procera*, *Aetoxicon punctatum*, *Araucaria araucana*, *Drymis winteri*, *Laurelia serrata*, *Persea lingue*. Drier slopes are covered with evergreen sclerophyllous shrubs or xerophytic deciduous woodland. Higher up, the vegetation changes gradually into a steppe with caespitose grasses. This steppe replaces the northern dry “puna”: it is slightly moister and denser than the dry “puna”, due to less aridity. Above 4500 m, there is no more vegetation, but only glaciers and snow.

3.3 TEMPERATE DOMAIN

3.3.1 Temperate oceanic forest (TeDo)

Climate

South of 38°S, the western side of the Andes is well watered due to oceanic influences, when drought decreases from north to south, with decreasing temperatures. These conditions also prevail at the very end of South America, as far as Tierra de Fuego. Rainfall ranges from 1000 to 3500 mm, evenly distributed throughout the year. Mean temperature of the coldest month is lower than 10°C in the north and decreases to about 0°C in the south. In eastern Patagonia, rainfall is less than 1000 mm, with mean monthly temperatures always lower than 10°C.

Physiography

In the northern part of the Ecological Zone, from around 38° to about 43°S, the main Chilean physical units can be recognized:

- the coastal plain, with a great extent in Chiloe Island;
- the coastal Cordillera;
- the central plain, with moraines and numerous glacial lakes in Los Lagos region, before being submerged into the sea, south of Puerto Montt;
- the volcanic Andes.

In the southern part, the Patagonian Andes are partially disaggregated, sometimes covered with glaciers, which merge into lakes or into the Ocean.

Vegetation

The northern part of the region harbours the typical Valdivian forest, which is a broadleaved very dense evergreen forest up to 40-45 m tall, with an equally dense undergrowth and many epiphytes. Species of *Nothofagus* dominate the tree canopy, including *Nothofagus obliqua, N. dombeyi, N. procera*, in association with *Aextoxicon punctatum, Drymis winteri, Eucryphia cordifolia*. A slight lowering of temperature accompanying higher altitude or latitude gives rise to a, less species-rich, mixed broadleaved/coniferous forest, with *Nothofagus antarctica, N. dombeyi, N. nitida, Fitzroya cupressoides, Pilgerodendron uvifera, Podocarpus nubigenus*. An even more marked fall in temperatures may result in increasing precipitations (particularly towards the south) giving rise to a more hygrophilous forest, the subpolar evergreen ombrophilous forest, becoming a swamp forest on gley soils. In Tierra de Fuego, this forest gradually gives way to shrub formations, then a sort of tundra.

3.3.2 Temperate steppe (TeBSk)

Climate

In trans-Andean zones, precipitations are lower than in the western side: 500-600 mm, with still low temperatures (mean temperature of the coldest month = 5-7°C). It freezes almost all along the year. In the eastern part, aridity, cold and very strong winds are limiting factors for vegetation.

Physiography

This Patagonian trans-Andean zone is made of the outcrops of Patagonian and Deseado shields in the depression along the Andes.

Vegetation

On the eastern side of the Andes, decreasing precipitations induce cold deciduous forest eastward gradually becoming a thicket or shrub formation transitional to the Patagonian steppe. The eastern lower part of Patagonia is covered with a grassy steppe.

3.3.3 Temperate mountain systems (TeM)

Climate

The central part of Patagonian Andes, up to 52°S, still reaches 2000 to 3000 m elevation. The western upper slopes are wet, whereas the eastern side is drier. The most striking climate features are cold, snow and winds.

Physiography

Volcanoes often form the highest peaks, surrounded by glaciers. There are numerous glacial lakes on both sides.

Vegetation

Subalpine beech forest, dominated by *Nothofagus betuloides* forms the timberline on the wettest slopes and borders the western sides of the Patagonian ice fields on steep slopes. It is found on thin rocky soils. This elfin type has low multi-stemmed trees of a few to 10 m, greatly deformed by the weight of the snow. The shrub layer is poor in stature and species composition. These forests are transitional to the scrub- and grasslands at higher altitudes in which *N. betuloides* occurs scattered among the shrubs *Chiliotrichum diffusum* and *Empetrum rubrum*. On the drier slopes and towards the eastern drier zone, a beech forest of *Nothofagus betuloides* and *N. pumilio* occurs. It is transitional between the purely evergreen lowland forests and the deciduous *N. pumilio* forests which form the timberline on all but the wettest sites. Above the timberline, the prevailing vegetation is an Andean grassy steppe.

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4 Africa

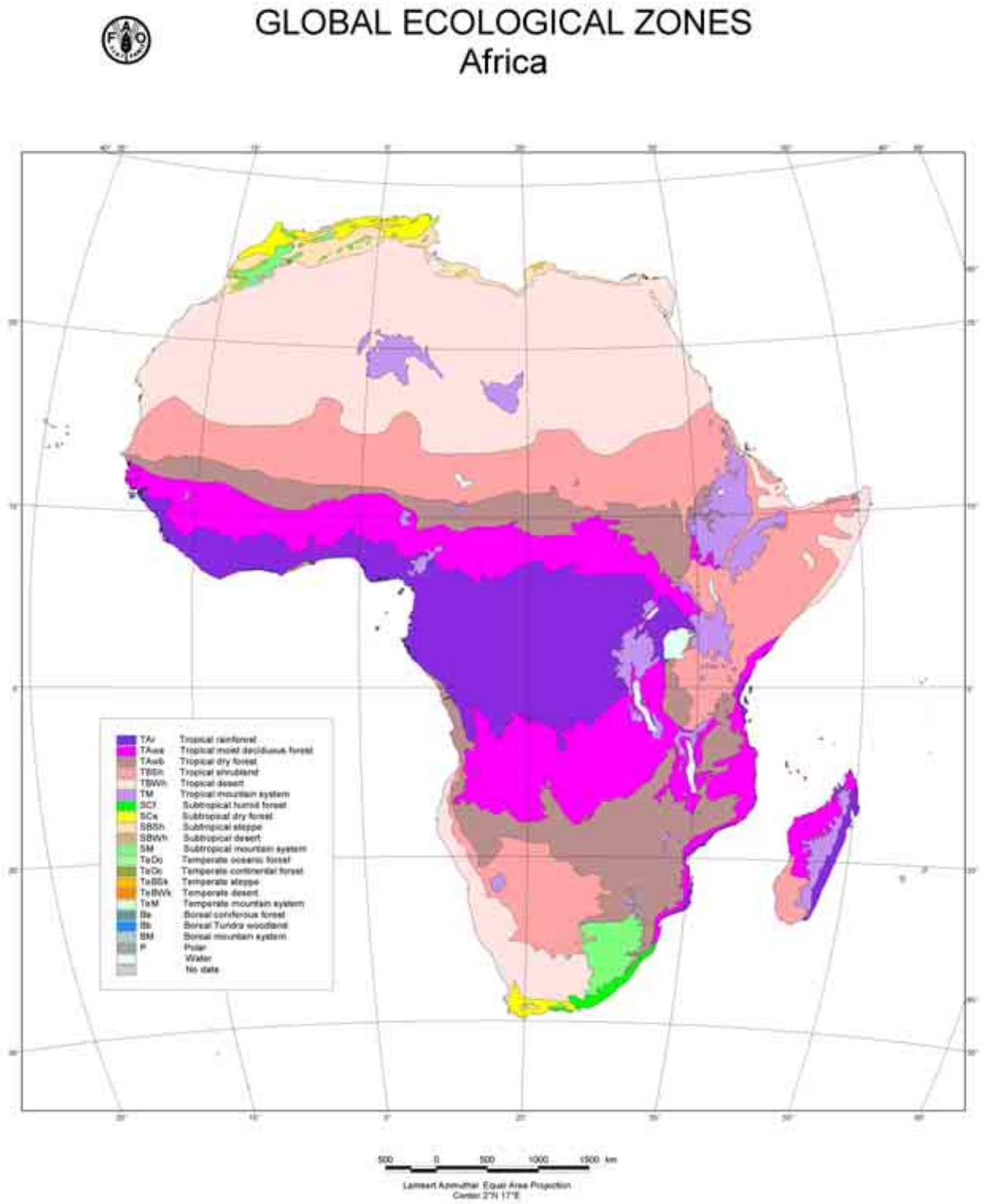

Figure 35. GEZ map of Africa.

Table 20. Global Ecological Zones of Africa.

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Tropical rain forest	4 017 705	13.5	27.6
Tropical moist deciduous forest	4 661 180	15.6	42.2
Tropical dry forest	3 669 529	12.3	49.1
Tropical shrubland	5 977 939	20.0	71.9
Tropical desert	8 737 674	29.3	75.5
Tropical mountain systems	1 473 226	4.9	32.6
Subtropical humid forest	85 099	0.3	1.8
Subtropical dry forest	334 816	1.1	21.0
Subtropical steppe	456 663	1.5	9.3
Subtropical desert	0	0	0
Subtropical mountain systems	412 356	1.4	8.5
Total land area	29 826 187	99.9	

4.1 TROPICAL DOMAIN

4.1.1 Tropical rain forest (TAr)

Climate

This Ecological Zone covers the central part of Africa, on both sides of the Equator, as well as on the southeastern coasts of the continent. High rainfall, ranging from 1000 to more than 2000 mm/year, is due to the permanency of the Inter Tropical Convergence zone (ITC) on the Equator, or to the trade winds blowing from the south-east on the southern hemisphere (eastern coasts of Tanzania, Zimbabwe, Madagascar). The regime is more or less equatorial or tropical. If there is a dry season, it does not exceed 3 to 4 months and always occurs in winter. Temperature is always high in these low latitude areas, generally more than 20°C, except in the mountains, where it is lower, with still a low annual range.

Physiography

The Ecological Zone is underlain by the ancient rocks of the crystalline shield which only outcrop in the Cameroon and Madagascar highlands. Everywhere else, they are buried by younger sedimentary rocks in basins and upland plains mostly between 150 and 600 m above sea level, as well as coastal deposits. The Congo basin, dominating the central part of the zone, has an average altitude of 400 m and gradually rises to the uplands and plateaux which form its rim. In the basin the Precambrian rocks are covered by continental sediments ranging from Paleozoic to recent. Quaternary sediments cover the large alluvial plain in the centre of the basin where there are remnants of former lakes and extensive swamps. Surrounding the Congo basin are the equatorial uplands, a region of dissected plateaux which merge with it. Near the basin the plateaux are mostly composed of slightly metamorphic Upper Precambrian sandstone, quartzite and schist.

Vegetation

The greater part of the Ecological Zone was formerly covered with rain forest on well-drained sites and swamp forests on hydromorphic soils. Today, little undisturbed rain forest remains and secondary grassland and various stages of forest regrowth are extensive. In the mountains, lowland rain forest is replaced by dense ombrophilous low forest and various types of thicket.
In this large area, several Eco-Floristic Zones have been distinguished according to, either a more or less wet climate and with or without a dry season, or a distinctive flora. Regarding the flora, three blocks have to be separated: the Guineo-Congolian region of western and central Africa, with about 80% of endemic taxa; Madagascar (about 80% of endemic species) and the eastern coast of southern Africa. In the latter, linking elements with the two formers can be recorded. Compared to the rain forests of South America and Asia, African forests are relatively poor floristically. The density of tree species in various African lowland evergreen forests is much lower than has been recorded for forests in the other continents.

The most extensive formation is the Guineo-Congolian lowland rain forest, concentrated in the Congo basin: tall dense forest, more than 30 m high with emergents up to 50 – 60 m and several strata. Some canopy species are deciduous, but the forest is evergreen or semi-evergreen. Epiphytes are abundant, particularly in the wetter types. Main large trees include *Entandophragma* spp., *Guarea cedrata, G. thompsonii, Lovoa trichilioides* (all Meliaceae), *Maranthes glabra* (Chrysobalanaceae), *Parkia bicolor* (Leguminosae), *Pericopsis elata* (Leguminosae), *Petersianthus macrocarpus* (Lecythidaceae). Small patches of single dominant moist evergreen and semi-evergreen rain forest occur that are usually dominated by one or more of the following species of Leguminosae: *Brachystegia laurentii, Cynometra alexandri, Gilbertiodendron dewevrei, Julbernardia seretii, Michelsonia microphylla*.

The rain forest of Madagascar is 25-30 m tall, without large emergent trees. The forest is evergreen, with many palms, some bamboos and abundant epiphytes, especially epiphytic ferns and grows up to 800 to 1000 m altitude. This forest is very rich in species. Some of the important families represented in the upper canopy are Euphorbiaceae, Rubiaceae, Araliaceae, Ebenaceae (*Diospyros*), Sapindaceae, Burseraceae (*Canarium*), Anacardiaceae, Elaeocarpaceae (*Echinocarpus*), Lauraceae, Guttiferae, Myrtaceae, Malpighiaceae and the conspicuous giant monocot (*Ravenala madagascariensis*).

In the drier periphery of the zone, we find transitional forest types. These evergreen or semi-evergreen forests may be characterized in West Africa by the following tree species, absent from wetter types: *Afzelia africana, Aningeria altissima, A. robusta, Chrysophyllum perpulchrum, Cola gigantea, Khaya grandifolia, Mansonia altissima*. Other important species include: *Triplochiton scleroxylon, Celtis mildbreadii, Holoptelea grandis, Sterculia* spp., *Trilepisium madagascariense, Chlorophora excelsa*.

Mangroves extend along the muddy, sheltered coasts of the Gulf of Guinea from Angola up to Senegal. They are characterized by the following tree species: *Rhizophora racemosa, R. harrisonii, R. mangle, Avicennia africana, A. nitida, Laguncularia racemosa* and *Acrostychum aureum*.

4.1.2 Tropical moist deciduous forest (TAwa)

Climate

Around the Guineo-Congolian basin, along the south-eastern coast of Africa, as well as in the central part of Madagascar, the wet zone is bordered by an area where the dry season is always pronounced, during up to 6 months. There is a single rainy season, in summer, but there are pronounced regional variations. Annual rainfall varies between 800 and 1500 mm, locally up to 2000 mm.

Physiography

To the south of the Guineo-Congolian basin, this GEZ lies on the Great African Plateau, the altitude of which is mostly 900-1000 m, up to 1500 m. In eastern Angola and Kwango, the Precambrian rocks of the plateau are covered by a thick mantle of Kalahari sands. To the north of the Guineo-Congolian basin, the gently undulating surfaces are nearly everywhere below 750 m altitude, except Jos and Mandara plateaux. Most of the soils are formed from Precambrian rocks. The coastal plain of southeastern Africa is underlain by marine sediments of various ages, from Secondary to recent. In Madagascar, this GEZ extends on the western side of the island up to about 800 m altitude. The greater part of the region is underlain by sediments of Secondary and Tertiary ages covering the crystalline Precambrian.

Vegetation

Several vegetation types exist together in this Ecological Zone. Forests formerly occurred on deep, freely drained soils. Their areas have greatly decreased due to fire and cultivation. Dry evergreen forest, which is a drier, simpler in structure and floristically poorer facies of rain forest, is widely distributed on Kalahari sands, with *Marquesia, Berlinia, Laurea*. Semi-evergreen forest of Guineo-Congolian type is mainly confined to Angola. On the eastern coastal plain, forest is the climax, but it has been largely replaced by wooded grassland and cultivation. The forest, due to change in amount and distribution of rainfall, dry season atmospheric humidity and the availability of soil moisture, changes rapidly in floristic composition and physiognomy. However, it is generally deciduous.

Everywhere else, the most widespread and characteristic vegetation type is woodland, namely Wetter Zambezian miombo woodland to the south, Sudanian woodlands to the north. Wetter miombo are characterized by several species of *Brachystegia (B. floribunda, B. glaberrima, B. taxifolia, B. wangermeeana, B. spiciformis, B. longifolia, B. utilis),* the canopy height being more than 15m, sometimes reaching a height of 30 m. Associate species include *Marquesia macroura* and *Pterocarpus* spp., *Julbernardia, Isoberlinia*. Sudanian woodlands, generally lower, are characterized by several species of *Acacia* and by the Leguminosae *Isoberlinia doka*. Beside the latter species, other characteristic species include *Acacia dudgeonii, A. gourmaensis, Antidesma venosum, Faurea saligna, Lophira lanceolata, Maprounea africana, Maranthes polyandra, Monotes kerstingii, Ochna afzeli, O. schweinfurthiana, Protea madiensis, Terminalia gluacescens* and *Uapaca togoensis*.

In Madagascar, primary vegetation is a dry deciduous forest or thicket, but the most extensive vegetation is secondary grassland. Nevertheless, some areas of dry deciduous forest remain, especially along the coast, with various facies depending on the soil: forest with *Dalbergia* on

lateritic soils, *Tamarindus indica* on sandy soils, *Adansonia, Bathiaea* on calcareaous plateaux.

Mangroves occur along sheltered coasts of the Indian Ocean, dominated by *Rhizophora mucronata, Avicennia marina* and *Sonneratia alba*. Other tree and shrub species include *Ceriops tagal, Bruguiera gymnorrhiza* and *Xylocarpus obovatus*.

4.1.3 Tropical dry forest (TAwb)

Climate

Still further from the Equator and from the wet southeastern coast, rainfall decreases and the dry season is always long, during 6-7 months. Rainfall varies between 500 and 1000 mm. Temperature is always high, with mean temperature of the coldest month≅20°C. These conditions are also found in Ghana (Accra) and on the western coast of Africa (Cabinda): in Ghana, the wet winds blowing from the south-west do not reach the coast of Accra; in Cabinda, the Benguela Current induces low rains in the neighbour coast.

Physiography

To the south, this GEZ is an extension of Zambezian region. The flat surfaces of the Great African Plateau lie at more than 1000-1200 m. They are formed of a great variety of Precambrian rocks. The western limit of the plateau is an escarpment separating it from the coastal plain of Cretaceous and more recent sediments. To the north, it is also an extension of the previous south Sudanian region. This plain formed from Precambrian rocks is covered, on large areas of its eastern part, with recent deposits: consolidated dunes or clays.

Vegetation

In these drier conditions, the predominating vegetation type is woodland. In the Zambezian region: drier miombo, poorer than the wetter one, on the plateau; mopane (*Colophospermum mopane*) woodland or Sudanian woodland in the southern valleys and depressions; scrub woodlands with *Acacia caffra, A. davy, A. luederitzii* in the southern lowlands of the Ecological Zone. Grasslands occur on seasonally waterlogged soils. In the Sudanian region: woodlands with *Acacia albida, A. macrostachya, A. nilotica*; in Sudan, woodlands with *Anogeissus leiocarpus* and various species of *Combretum*. Where cultivation is possible, most of the land is bush fallow. Permanent or semi-permanent cultivation is being practiced around the large towns. Two specific Ecofloristic Zones have been defined in Accra plain and Cabinda. Near Accra, some patches of dry semi-evergreen forest with *Diospyros abyssinica* and *Milletia thorningii* remain and the drier parts are covered by sparse short grassland dotted with thicket clumps. In Cabinda, the prevalent vegetation is wooded grassland with *Adansonia digitata* and many individuals of *Anacardium occidentale* and *Mangifera indica,* two introduced trees. A conspicuous tree of this zone in Africa is the boabab *(Adansonia digitata)* with its bizarre big trunk.

4.1.4 Tropical shrubland (TBSh)

Climate

In these areas close to the tropics, rainfall becomes lower and lower, when temperatures are still high. It is the case of the Sahelian zone and Kalahari, as well as the southwestern part of Madagascar. Rainfall is always less than 1000 mm and scarcely reaches 200 mm in the drier parts. Mean temperature of the coldest month is generally more than 20°C, except in Kalahari where, due to proximity of the sea, temperatures are lower (mean temperature of the coldest month may drop down to 10°C). Somalia is a special case: even if it lies across the Equator and not further than 12°N, the climate is semi-arid or arid. Whereas the trade winds direction is parallel to the coast and does not bring much humidity. Moreover, in winter, the Indian monsoon reaches this part of Africa after crossing large continents. As a result of these phenomena, Somalia is dry, with annual rainfall between 400 and 750 mm and very high temperatures due to low latitude.

Physiography

Most of the Sahel region forms a flat or gently undulating landscape below 600 m. Large areas are covered with Pleistocene clays or sand sheets. The Kalahari basin extends to the south of the Great Escarpment. It is filled with Tertiary sands and lies between 850 and 1000 m. Somalia is a low land extending from the sea level to about 900 m. Its underlying lithology is extremely diverse, with extensive areas of Secondary and lower Tertiary sediments and less extensive areas of tertiary and Pliocene lava flows. In Madagascar also, this GEZ corresponds with a wide plain formed of Secondary and Tertiary sediments.

Vegetation

In these very dry areas, spontaneous vegetation is generally pseudo-steppe, scrub woodland or thicket. In the Sahelian zone, which supports wooded grassland (mainly with *Anogeissus* and *Acacia*) in the south and semi-desert grassland in the north, pastoralism is the main land use. Pastoralism also prevails in Somalia, in predominating deciduous shrubland and thicket with *Acacia* and *Commiphora*.

In the Kalahari, stunted scrub woodland with acacia (*Acacia karroo*) and shrub pseudo-steppe form the landscape.

In Madagascar, even if dry deciduous forest still occurs on the northern part of the GEZ, the most characteristic vegetation type is the deciduous thicket with Didiereaceae. Extensive areas are covered with this thicket in the western part of the region, but the central plateau is mainly covered with dry savanna.

4.1.5 Tropical desert (TBWh)

Climate

This Ecological Zone extends on the desertic African lands: Sahara, Karoo-Namib and the coastal zone of Somalia. There, rainfall is lower than 200 mm and does not allow growth of a continuous vegetation cover.

Physiography

The Sahara consists of several basins filled with Pleistocene deposits: sands or gravels. Between the depressions, Cretaceous and Tertiary deposits form a stone desert. The geology and physiography of the Karoo-Namib region is very diverse. In the interior of the Cape Province, the surface is formed of the Karoo system and is generally even. In the northwest, granite and other primitive rocks are exposed, with igneous intrusions, on the escarpment of the Great Interior Plateau. The Namib Desert lies on a coastal peneplain, extensive areas of which are covered with moving sand of recent origin.

Vegetation

Generally, only pseudo-steppe and shrub pseudo-steppe can be found in these areas, with woody vegetation concentrated along the wadis in Sahara. Large surfaces are true desert.

4.1.6 Tropical mountain systems (TM)

Climate

Above 800 to 1200 m, temperature decreases and vegetation changes. So, we defined submontane, montane and high elevation Ecofloristic Zones within each GEZ. All of them correspond with tropical vegetation types. The main mountains systems of tropical Africa are the Cameroon highlands, the mountains of Kenya, the Kivu ridge and Ethiopian highlands. Some lower and isolated hills occur, such as Fouta Djalon, Jos and Mandara plateaux in West Africa, Hoggar in Sahara or Windhoek Mountain in southern Africa. The central part of Madagascar is formed of a high range separating the western wide lowlands from the narrow eastern coastal plain. The climatic type of each mountain is close to that of the surrounding lowland, with lower temperatures and, often, higher rainfall.

Physiography

The physiography is very diverse. Most of the Ethiopian highlands are formed of basalt, though Precambrian rocks locally outcrop. The Kenya highlands are mostly formed of volcanic post-Miocene deposits; Cherangani Hills are composed of Precambrian metamorphic rocks. The Kivu ridge and contiguous uplands are largely composed of Precambrian rocks. The Cameroon highlands are formed partly of volcanic, partly of ancient crystalline rocks. Mount Cameroun is a still active volcano. In Madagascar, the central highlands are formed of the Basement complex of igneous and metamorphic rocks.

Vegetation

Also the vegetation is extremely diverse and varies with climate. On most mountains the lowermost vegetation is forest. Between the lowland forest and the rather different (in physiognomy and flora) montane forest, there is a submontane transition zone. In many places, however, the vegetation of this transition zone has been destroyed by fire and cultivation. Montane forest, generally above 1500-2000 m, is lower in structure than lowland and submontane forests. At the upper part of the montane level, an Ericaceous belt replaces the forest. Then, mostly above 3000 m, followed by Afro-alpine shrublands and grasslands.

In western Africa, on the Kivu ridge or on the wetter slopes of Ethiopian highlands and East African mountains, the rain forest is similar in structure and physiognomy to the lowland rain forest, but it is floristically different. The trees of the upper stratum are 25 – 45 m tall. Their crowns are raised well above the middle tree stratum and are heavy branched and wide-spreading. The middle tree stratum is 14-30 m tall, the lower tree layer at 6 – 15 m and often mixed with the shrub layer. Characteristic tree species of Afromontane rain forest include *Aningeria adolfi-friedericii, Chrysophyllum gorungosanum, Cola greenwayi, Diospyros abyssinica, Drypetes gerrardii, Olea capensis, Podocarpus latifolius, Prunus africana, Syzigium guineense* subsp. *afromontanum* and *Xylamos monospora*.

Bamboo (*Arundinaria alpina*) forest or thicket occurs on most of the high mountains in East Africa and sporadically on some of the mountains of Cameroon. It is mostly found between 2300 and 3000 m and appears to grow most vigorously and to form continuous stands on deep volcanic soils on gentle slopes where the rainfall exceeds 1250 mm per year.

In Madagascar, the original vegetation in the mountains was forest: moist montane forest with *Tambourissa* and *Weinmannia* and sclerophyllous montane forest with *Dicoryphe* and *Tina* on the eastern slopes, drier "tapia" (*Uapaca bojeri*) forest on the western slopes. Over extensive areas, these forests have been replaced by secondary grassland. Above 2000 m, the characteristic vegetation is montane thicket.

In some parts of western Africa (Jos and Mandara plateaux) as well as in Kenya, Burundi and in southwestern Ethiopian uplands, at medium elevation, bushland or thicket remains, transitional between Sudanian or Zambezian vegetation and montane forest.

In Ethiopia and Kenya, dry mountain vegetation types are extensive: evergreen or semi-evergreen shrubland and thicket (with *Acacia, Carissa*) at medium elevation and *Juniperus procera* forest at montane level in Ethiopia.

The mountains of the Sahara are semi-arid to arid, with little vegetation cover.

4.2 SUBTROPICAL DOMAIN

4.2.1 Subtropical humid forest (SCf)

This Ecological Zone is restricted in Africa to a narrow zone along the east coast of Southern Africa, roughly between 25^{o} and 34^{o}S.

Climate

The coastal regions of the zone have a moderately high and well-distributed rainfall and, except in the extreme south are frost free. Annual rainfall is 800-1200 mm and mean temperature of the coldest month 7° to 15°C. Mean annual temperature diminishes from 22^{o}C in the north to 17^{o}C in the south. Further inland, climate changes rapidly over short distances.

Physiography

This narrow belt along the coast is formed of rocks of the Basement Complex, sandstones and sedimentary strata of the Karoo System. In the northern part, the plain is wider, up to 240 km, composed of Cretaceous and Tertiary marine sediments overlying the Basement.

Vegetation

In most of the Ecological Zone, the natural vegetation is evergreen or semi-evergreen forest, in some parts approaching rain forest in stature and structure. The canopy varies in height from 10 to 30 m or slightly more. The most luxuriant stands approach rain forest in stature and structure. The canopy is evergreen to semi-evergreen. About 120 species occur in the canopy, though normally not more than 30 would be present in any one stand. The flora is from various origins, with some endemic species like *Atalaya natalensis, Anastrabe integerrima, Beilschmiedia natalensis, Brachylaena uniflora, Cola natalensis, Commiphora harveyi, Cordia caffra, Diospyros inhacaensis and Manilkara concolor*. Today, where the original vegetation has not been completely replaced, land cover often consists of a mosaic of forest, scrub forest, bushland and thicket, with secondary grasslands.

Where the rainfall is too low to support forest, the most widespread climax vegetation is evergreen and semi-evergreen bushland and thicket. In the north this type is most extensively developed in the low-lying country between the forests of the coastal plain and the mountainous country inland. Further south it occupies deep valleys. The most widespread bushes, which grow 3-6 m tall, include among others *Azima tetracantha, Bauhinia natalensis, Carissa bispinosa, Diospyros* spp., *Euclea* spp., *Maytenus* spp., *Olea africana, Phyllanthus verrucosus, Schotia* spp. and *Xeromphis rudis*. Arborescent succulent species of *Aloe* and *Euphorbia* occur throughout. In the southern part, the vegetation becomes close to the Cape fynbos, a sclerophyllous shrubland with *Leucadendron* and *Metalasia*.

4.2.2 Subtropical dry forest (SCs)

Climate

This Ecological Zone concerns the Mediterranean climates of North Africa and South Africa. The dry season, more or less pronounced (3 to 6 months), is in summer, most of the rainfall (400-1000 mm/year) occurring in winter. The whole of northern Africa experiences this dry period. In South Africa however, only the Cape region has a typically Mediterranean climate; eastwards, the rains become more evenly distributed throughout the year (Subtropical Humid). The annual range of temperatures is rather high, but mean temperature of the coldest month, in lowlands, is always more than 7°C.

Physiography

In northern Africa, the Mediterranean zone is mostly the region of folded mountains at the northwestern extremity of the continent. The various ranges of the Atlas mountains are separated by plateaux and basins. A coastal lowland belt runs from the Atlantic coast to Egypt. Only the lowlands below 1000 m are included in the Ecological Zone. The lithology is diverse, but the prevalent rocks are Secondary or Tertiary sediments, sometimes metamorphosed.

In South Africa, the landscape is dominated by subparallel folded mountain ranges with an average altitude of 1000-1500 m. In the western part, the foothills and lower slopes are commonly formed of Cape granite. The valleys and parts of the coastal belt are formed from Palaeozoic shales and sandstones. The coastal fringe itself consists of Tertiary to recent sands, conglomerate and limestone.

Vegetation

In northern Africa, the climax vegetation is forest, with *Quercus suber, Q. faginea, Q. ilex, Pinus pinaster* in the most humid parts under marine influence and *Tetraclinis articulata, Quercus ilex, Pinus halepensis* on more continental situations. In many places, due to degradation by overgrazing, these forests are replaced by scrubs with the same species. Crops cover a large extent in this Ecological Zone.

In South Africa, the prevalent vegetation of this Ecological Zone is fynbos, which are sclerophyllous shrublands of 1 to 4 m high, with main shrub species *Protea, Clifortia, Muraltia, Leucospermum, Resio, Erica* and *Serruria*. Although the zone covers a small area, it is extremely rich in plant species of which many are endemic. The shrubs and bushes of fynbos vary greatly in height and density. They are mostly richly branched and have twisted boles. In typical fynbos true trees are virtually absent. The only tree species, silver tree *(Leucadendron argenteum),* is of limited distribution and is confined to the humid slopes of Table Mountain, at altitudes below 500 m. Large extents of cultivation and secondary shrublands with "rhenosterbos" (*Elythropappus rhinocerotis*) often have replaced the original fynbos.

4.2.3 Subtropical steppe (SBSh)

Climate

In northern Africa, a wide and continuous transitional zone separates the previous Ecological Zone from the Sahara desert. Rainfall varies from 200 to 500 mm, with a long dry hot season of 6 to 11 months. Mean temperature of the coldest month is always more than 7°C.

Physiography

This transitional belt lies on the Marrakech and Agadir basins in Morocco and the lower inland plateaux in Algeria and Tunisia. Most of these areas are continental sediments of the upper Tertiary. Along the coast of Libya and Egypt, these sediments are partly overlain by Quaternary deposits.

Vegetation

Vegetation in this Ecological Zone is a tree pseudo-steppe with *Acacia gummifera, Ziziphus lotus, Pistacia atlantica,* often replaced, due to degradation, by pseudo-steppes with *Artemisia herba-alba* and *Stipa tenacissima*. In Morocco (Sous), the typical vegetation type is *Argania* forest.

4.2.4 Subtropical mountain systems (SM)

Climate

In northern Africa, the landscape is dominated by the Atlas Mountains, which extend for over 3000 km from northern Morocco to Tunisia, parallel to the Mediterranean coast. Their altitude reaches 1500 m in Tunisia, 2500 m in Algeria, 4165 m in Morocco. The most septentrional range, the Rif Atlas, experiences a humid climate, due to proximity of the

Atlantic Ocean: rainfall approaches 1000 mm, with a short summer drought tempered by a constantly high air humidity. More inland, the dry season is always pronounced and the climate becomes semi-arid to the south. Temperatures decrease with increasing altitude and 3 levels can be distinguished: submontane, montane and high elevation.

In South Africa, the largest highland area is the Highveld Region, which is more than 1000 m in altitude, bordered by the Drakensberg reaching more than 3000 m. Southward, in the Cape Region, the mountain ranges also belong to this Ecological Zone. In these mountains the climate is humid with a tropical regime, axeric in the extreme south (Outeniekwaberge). Rainfall varies from 500 to 1100 mm, with a short winter dry season, not more than 4 months. Winter temperatures are rather low, but more than 7°C up to 1500 m.

Physiography

In northern Africa, the Atlas mountains raised in the Tertiary, consist of several ranges: Rif Atlas in northern Morocco, becoming Tell Atlas in Algeria; High Atlas extending from the Atlantic coast and becoming Saharan Atlas in Algeria; Middle Atlas diverging from the High Atlas in Morocco; Anti-Atlas in southern Morocco, which is an elevated part of the African shield. The Atlas ranges extend in Tunisia as the Northern Tell, the High Tell and the Low Tell. Most of the rocks are Jurassic or Cretaceous sediments, often limestone, except in the Anti-Atlas.

In southern Africa, the Highveld is a part of the Great Interior Plateau of southern Africa. Its elevation gradually increases up to the southeast, from 1000-1200 m to 2000-3000 m in the Drakensberg. The latter is capped with basaltic lava flows, whereas the adjacent lower parts are overlain by Karoo sediments. In Cape region, most of the ranges are formed of sandstones.

Vegetation

In northern Africa, in the northern Atlas ranges, the lower slopes are covered by mixed forest with deciduous oaks or *Quercus ilex* associated with *Pinus pinaster* or *P. halepensis*; above 1600 m this forest gives way to *Cedrus atlantica* forest. In the southern drier ranges, a shrub pseudo-steppe with *Juniperus phoenicea* is replaced, in montane level, by *Juniperus thurifera* forest.

In southern Africa, Highveld region is covered with grassland, but an evergreen montane forest with *Podocarpus, Apodytes, Halleria* grows on the Drakensberg slopes. In the Cape region, a “temperate forest” with *Podocarpus, Ocotea, Olea capensis* grows on the slopes of the Outeniekwaberge, facing the sea. On drier places, a montane evergreen scrub with *Erica* replaces montane forest.

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5 Asia

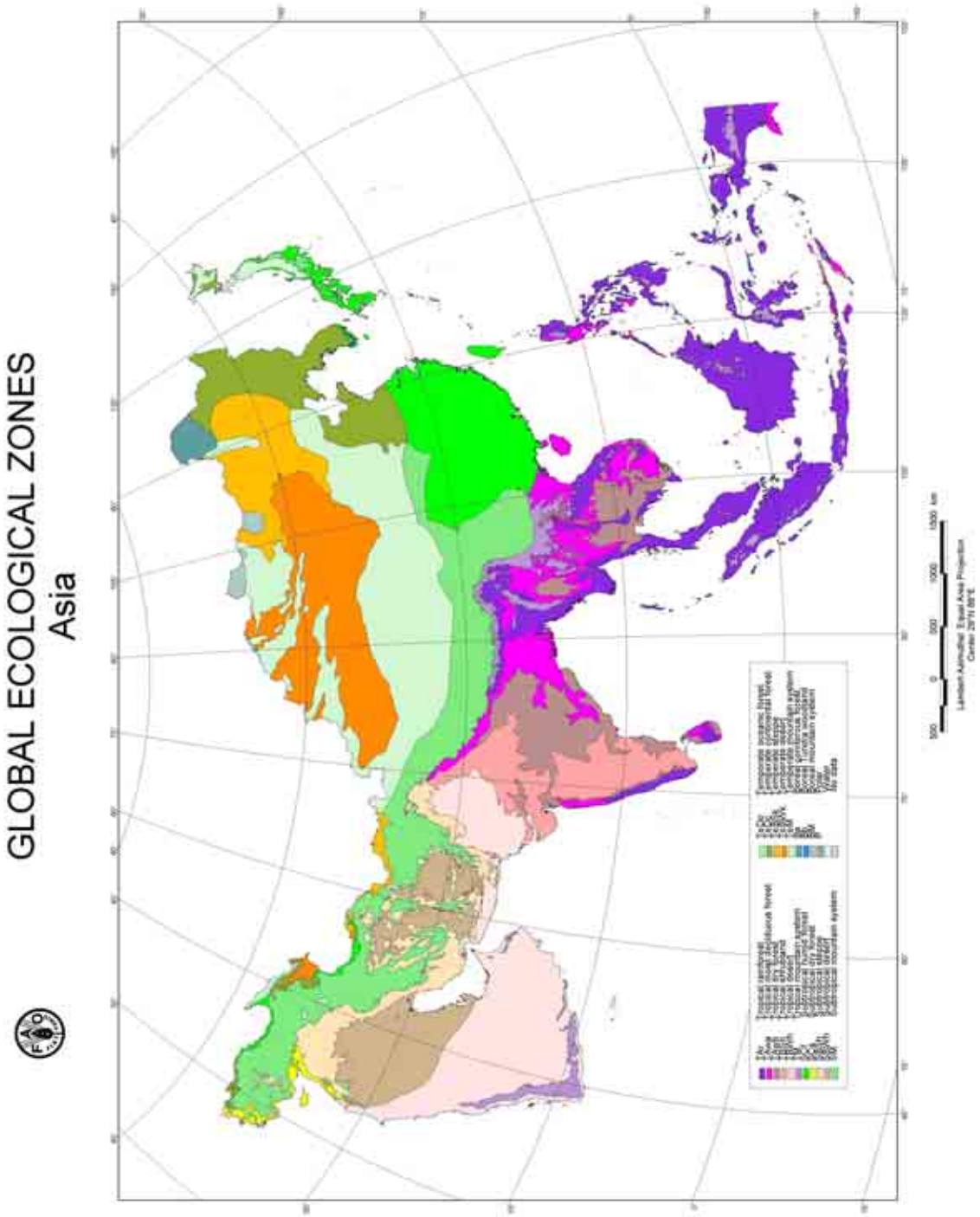

Figure 36. GEZ map of Asia.

Table 21. Global Ecological Zones of Asia.

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Tropical rain forest	3 009 375	11.1	20.6
Tropical moist deciduous forest	1 379 477	5.1	12.5
Tropical dry forest	1 426 603	5.2	19.1
Tropical shrubland	1 167 107	4.3	14.0
Tropical desert	2 704 536	9.9	23.4
Tropical mountain systems	834 931	3.1	18.5
Subtropical humid forest	2 047 862	7.5	43.7
Subtropical dry forest	129 040	0.5	8.1
Subtropical steppe	1 180 330	4.3	2.4
Subtropical desert	1 446 347	5.3	21.7
Subtropical mountain systems	3 459 622	12.7	71.2
Temperate oceanic forest	0	0	0
Temperate continental forest	1 253 135	4.6	18.0
Temperate steppe	1 115 606	4.1	18.9
Temperate desert	2 181 946	8.0	40.4
Temperate mountain systems	3 604 836	13.2	49.9
Boreal coniferous forest	157 450	0.6	1.9
Boreal tundra woodland	0	0	0
Boreal mountain systems	109 168	0.4	1.7
Total land area	27 207 371	99.9	

5.1 TROPICAL DOMAIN

5.1.1 Tropical rain forest (TAr)

This Ecological Zone covers most of the Malay Archipelago stretching across the Equator and parts of Continental Asia.

Climate

The climate of Tropical Asia is under influence of the Intertropical Convergence Zone (ITCZ). The western coasts of the continent are very wet, due to heavy rains brought by the southwest monsoon. These strong winds bring moisture from the Indian Ocean and are interrupted by the Indian Ghâts, the mountains of Sri Lanka, eastern Himalayas and the mountain ranges of Myanmar and Cambodia. Deviating from this general pattern, in Viet Nam and Philippines the eastern coasts are very wet. In winter, the northeast monsoon brings moisture from the Pacific Ocean. Across the zone, annual rainfall is everywhere more than 1000 mm and often more than 2000 mm. In the equatorial regions, there is no dry season. Everywhere else, there is a short dry season of 1 to 4 months, even up to 5 months in some parts of India, Sri Lanka, Bangladesh and Myanmar. Temperatures are always high: mean temperature of the coldest month is often more than 20°C, sometimes lower due to rainfall occurring throughout the year. Within these general conditions, many variations can be distinguished.

Physiography

This extensive Ecological Zone concerns several different regions:

Southwestern coasts of India and Sri Lanka
South India and Sri Lanka are part of the ancient Gondwana continent. These old Precambrian rocks were metamorphosed, eroded and then faulted and uplifted during Tertiary; this resulted in the formation of the Western Ghâts in India and central mountains of Sri Lanka. In southwestern Sri Lanka, the complex of Precambrian shales/gneiss/granites forms successive plains of various elevations from the mountain to the coast. In India, the coastal plain is formed of recent alluvia.

Malaya and the Philippines
Indonesia with Brunei and Sarawak, Timor and Papua-New-Guinea form the main part of the region, with about 3000 islands stretching over more than 6000 km from west to east. On the foothills of the mountains forming the backbone of most of them, lowlands are more or less extensive, depending on the size of the islands. Coastlines have various features: large estuaries and swamps on some parts like in eastern Sumatra, rocky coasts, coral reefs in other parts. Sumatra, Java, the lesser Sundas, Sulawesi, Halmahera are the main islands with active volcanoes; fertile soils cover the ancient lava flows. Borneo, Timor and New-Guinea are mostly constituted from disaggregated ancient rocks, generally leached and poor. The Philippines Archipelago comprises about 7000 islands, 8 major ones, extending roughly in a north-south direction. On Luzon, Mindanao and Mindoro, central mountains reach more than 2000 m altitude, rising above low, often swampy valleys. On the other islands, hills are of lower elevation and the coastal plains are developed in varying degrees. Peninsular Malaysia belongs geologically to the heart of the Asian continent. It is formed of a central granitic mountain stretching from the north to the south, surrounded by sedimentary lowlands. On the western part, some calcareous hills rise above the plain. The western and southern lowlands are often swampy.

Peninsular Thailand, coastal lowlands of Myanmar and eastern Himalayan foothill
Peninsular Thailand prolongs to the north the Malaysian peninsula, with a narrow coastal plain and the Tenasserim range, below 1500 m altitude, formed of Precambrian and granite rocks. To the north, the Tenasserim range gives way to Shan plateau in Myanmar, which elevation is slightly above 1000 m; it is composed of Precambrian and Secondary rocks. It overhangs the central basin formed of Tertiary sediments and irrigated by Irrawady River. The western coast of Myanmar is formed by the Arakan range, made of folded Primary to Tertiary rocks. Its elevation is slightly more than 1000 m. To the north, the arc-shaped assamo-birman ranges reach the eastern Himalayas. Their lower slopes, formed of Tertiary sandstones, clays and marls, merge into the alluvia of Brahmaputra valley and Gangetic plain.

South-east Asia
In central Thailand, a range of hills crosses the country from the north to the south and catches a part of the southwest monsoon. In Cambodia, the zone covers most of the Cardamomes Hills, formed of Cretaceous sandstones. In Laos, most of the lower slopes of the mountains belong to this GEZ. In Viet Nam, it concerns the lower northeastern slopes of the Annamitic range and the southern plateaux of Kontum, Dar Lac, Lang Bian. The Annamitic range is formed of ancient crystalline rocks covered with sandstones and lava flows, rising above the China Sea. The southern plateaux are made of sandstones partially covered with

basalts producing fertile soils. Far to the south, Ca Mau peninsula is the most southern point of the Mekong Delta.

Vegetation

In the wettest parts of this extensive Ecological Zone, the prevailing vegetation type is dense moist evergreeen forest. Floristic variations exist, depending on the location. The most striking difference is the occurrence of Dipterocarpaceae, an important Asian endemic family, to the west of the Wallace's line, whereas they are totally absent to the east of this line. As these forests grow in lowlands, they are under greatest pressure for timber exploitation and conversion to agricultural land. The Sundarbans mangrove forests of the Ganges Delta and those of western New Guinea are by far the most extensive in the world. In the drier parts of the area, mainly in eastern Indonesia and the Himalayas foothill, semi-deciduous or moist deciduous forests occur; especially in the Brahmaputra valley, they are valuable Sal forests (*Shorea robusta*). Due to many climatic and floristic variations, 8 ecofloristic zones have been distinguished within this GEZ.

The lushest and richest rain forests are found in the Malay Archipelago, harbouring a very rich and diverse flora. Over half (220) of the world's flowering plant families are represented, as well as about one-quarter of the genera (2400), of which about 40% are endemic; there are between 25 000 and 30 000 species, of which about one-third are trees more than 10 cm in diameter. Rain forests west of the Wallace line are dominated by Dipterocarpaceae, which are extremely diverse in genera and species. They contribute many (Sumatra, Malaysia), most (Borneo) or all (Philippines) of the top canopy giant trees. The tallest trees occur, not as single emergents about 60 m tall, but as groups, giving the upper forest canopy a rough appearance. The chief genera are *Dipterocarpus, Shorea, Dryobalanops and Hopea*. Other important tree families include Anacardiaceae, Ebenaceae, Leguminosae, Sapindaceae, Euphorbiaceae and Dilleniaceae. *Pometia* (Sapindaceae), *Canarium* (Burseraceae), *Cryptocarya* (Lauraceae), *Terminalia* (Combretaceae), *Syzygium* (Myrtaceae), *Casuarina* (Casuarinaceae), *Araucaria* are among the chief tree genera of the forests east of the Wallace line. The forests may be divided into various formations with distinctive structure and physiognomy. The formations occupy different habitats and species are restricted to one formation to various degrees. Some are endemic to a single formation: for example, ramin (*Gonostylus bancanus*) is confined to peat swamp forest. Lowland evergreen – and semi-evergreen forests (on dry terrain) are the most extensive formations. Important edaphic formations are heath forest (found on podzols), rain forest over limestone, peat swamp forest (along the coasts of East Sumatra, Peninsular Malaysia and Borneo) and fresh-water swamp forest.

The Asian mangroves, most widely distributed in the Indonesian archipelago and the Sundarbans, are richer in species than those anywhere in the world. Mangrove forests can reach heights of 30 – 40 m and are best developed in sheltered bays or in extensive estuaries. Conspicuous species of Asian mangroves are *Avicennia alba, A. officinalis, A. marina, Bruguiera cylindrica, B. gymnorrhiza, Ceriops decandra, Excoecaria agallocha, Rhizophora apiculata, R. mucronata, Sonneratia alba, S. caseolaris and Nipa fruticans.*

5.1.2 Tropical moist deciduous forest (TAwa)

Climate

Where the southwest monsoon influence becomes lighter, rainfall decreases and the winter dry season is more pronounced. In these areas, mostly confined to Continental Asia, rainfall is generally between 1000 and 2000 mm, sometimes more, but there is always a dry season of at least 3-4 months like in Papua-New-Guinea and sometimes more than 6 months like in India. Temperatures are always high, with mean temperature of the coldest month generally more than 20°C, sometimes slightly lower, like in northern India or Myanmar or in the indo-Chinese peninsula.

In China, the southern part of Lezhou and Hainan Island experience a similar climate. Annual mean temperature varies between 22-28^{o}C, January mean 16-20^{o}C, minimum above 0-4^{o}C. Annual rainfall ranges from 1300 to 2800 mm, however many locations only receive 800-900 mm annually. Inter-annual variability is high – a dry year may only receive 1100-1300 mm, while a wet year can get as much as 3000 mm. The rainy season is from May to November, with frequent typhoon and rainstorm visits. The dry season is between December and April.

Physiography

In Sri Lanka, most of the lowlands, to the north and east of the hills, belong to this Ecological Zone. The coast is flat and sandy with lagoons and swamps. Except some coastal alluvia, most of the area lies on the old complex of shales/gneiss/granite. In western India, the coastal plain around Bombay extends on the Deccan traps, giving rise to ferralitic soils due to the still high rainfall (more than 2000 mm). In northern India, the Ecological Zone extends on the eastern ridge of the Deccan plateau and the alluvial plain of the Ganges River. On its border, the Deccan plateau slightly rises in the Eastern Ghâts (1640 m) and the Chota Nagpur plateau (800-1000 m), composed of uplift crystalline peneplains covered with ferralitic soils. Then, some lower plateaux lead to the alluvial plain of the Ganges River, becoming a huge delta in Bangladesh. In Assam, the northern slopes of Shillong plateau (crystalline hill) and the Mikir Hills, rising on the Brahmaputra valley, belong to this GEZ. In Myanmar, the Ecological Zone concerns the hilly Tertiary basin forming most of the country, between the Arakan range and Shan plateau: the elevation ranges from 200 to 1000 m. In Thailand, it is the foothill of the northern and western mountains, between 200 and 800-1000 m. In northern Viet Nam, the Red River valley belongs to this Ecological Zone with the lower foothills of the surrounding mountains and the delta built by the alluvia and spread with calcareous, gneissic or granitic hillocks. In southern Viet Nam, Laos and Cambodia, the GEZ lies on the low plateaux on the western side of the Annamitic range: they are formed of sandstones, sometimes covered with lava flows inducing fertile red soils. In the Philippines, the western foothills of the ranges are included, as well as more or less narrow plains, often swampy. In the small Sunda islands the Ecological Zone lies on the lower mountains slopes, whereas in New-Guinea, the low, flat, often swampy plains of the southern part are included.

China: Granite intrusion-formed mountains occupy central to southern parts of Hainan Island in a radiating pattern, with average altitudes exceeding 1000 m and the main peak, Wuzhishan, reaching at 1867 m. The outer peaks are gradually reduced to low rolling hills under 500 m, with basins and terraces scattered alternately. Lezhou Peninsula is on average 100 m in elevation. Soil distribution is related to altitude: Red soil and latosol under 500 m, mountain Yellow soil between 500 and 1000 m, mountain Yellow-Brown soil above 1000 m.

Drier areas have Red-cinnamon soils, while marine sandy soils and marine saline soils occur along seashores.

Vegetation

Due to the dry season, the natural vegetation is nearly everywhere a deciduous or semi-deciduous forest. This forest type is in Asia commonly known as monsoon forest. Its flora varies according to the region and the actual leafless period varies between species. On average, moist deciduous forests are leafless for at least 8 weeks in February and March. Many dominant trees belong to the Leguminosae, Combretaceae, Meliaceae or Verbenaceae. Dipterocarps are also present, but less conspicuous as in the rain forest. The forest is 20 to 25 m tall and a sparse grass cover is usually present. Teak forests *(Tectona grandis)* in west and north Thailand, Laos, Burma and Peninsular India and sal forests *(Shorea robusta)* in east India and the Ganges valley are of great economic value. Associating trees of the teak forest include *Lagerstroemia, Xylia kerrii, Adina cordifolia, Vitex, Tetrameles nudiflora, Afzelia xylocarpa, Diospyros, Sindora cochinchinensis, Pinus merkusii*, in the sal forests tree species of *Dillenia, Terminalia, Adina, Pterospermum* are co-dominant. Bamboo brakes *(Dendrocalamus strictus)* are common in India and Myanmar, often in secondary stages. Extensive deciduous forests remain on hilly parts of Myanmar and some patches in northern Viet Nam, on the Red River plain. In the remaining part of Indochina, the Ecological Zone is widely covered with deciduous Dipterocarp forest and teak forest. In Papua-New-Guinea, there is a different type of dry evergreen or semi-evergreen deciduous forest, characterized by species such as *Garuga floribunda, Protium macgregorii, Intsia bijuga, Acacia* spp. (Mimosaceae) and presence of Myrtaceae, Proteaceae and Rutaceae.

In China, tropical moist deciduous forest is found below 700 m in basins and river valleys of southern mountains on Hainan Island. The upper canopy is 30-40 m tall, with main species: *Heritiera parvifolia, Amesiodendron chinense, Litchi chinensis, Vatica hainanensis, Diospyros hainanensis, Hopea hainanensis, Lithocarpus fenzelianus, Homalium hainanensis, Podocarpus imbricatus,* etc. The middle layer of the rain forest often includes *Dysoxylum binectariferum, Sindora glabra, Ormosia balansae, Pterospermum heterophyllum, Gironniera subaequalis, Schefflera octophylla, Dillenia turbinata, Hydnocarpus hainanensis*. Understorey is composed of *Ardisia quinquegona, Psychotria rubra, Lasianthus kwangtungensis, Arenga pinnata, Pinaga baviensis, Caryota mitis*. Hill moist forest grows at 700-1200 m altitude and is composed of *Altingia obovata, Manglietia hainanensis, Michelia balansae, Madhuca hainanensis* and species of Fagaceae, Lauraceae, Theaceae and Aquifoliaceae. In the central part of the island, coniferous forests grow on low mountains and hills at altitudes below 800 m. *Pinus latteri* dominates and forms second growth pure forests or mixtures with *Liquidambar formosana, Chukrasia tabularis* and *Engelhardtia roxburghii*. Mangrove forests grow along shorelines around the island except the west coast. Tree species include *Avicennia marina, Rhizophora mucronata, R. apiculata, Bruguiera conjugata, B. cylindrica, Ceriops tagal, Sonneratia acida, Xylocarpus granatum* and others.

5.1.3 Tropical dry forest (TAwb)

Climate

In areas particularly sheltered from the humid winds blowing from the oceans, the climate is dry, with a long winter dry season. It is the case on the eastern ridge of the western Ghâts of India, in the northern and southern coastal plains of Sri Lanka, but also along the eastern

coast of India and in the heart of Myanmar and Thailand. These areas weakly receive, in summer, the southwest monsoon, either due to a mountainous barrier or to a continental location. Whereas in winter, they are influenced by the northeast monsoon: dry cool winds that reach these countries after crossing China and Siberia. In central Cambodia and Viet Nam, the northeast monsoon is dry and warm. Narrow coastal stretches of this climatic type also occur in southern Papua-New-Guinea. Rainfall ranges between 1000 and 1500 mm, with a dry season of 5 to 7 or 8 months. Mean temperature of the coldest month is always more than 15°C, often 20°C.

Physiography

In India and Sri Lanka, the Ecological Zone comprises:
- The coastal plains along the Gulf of Bengal; the very flat plains, generally lower than 300-500 m, are underlain by the ancient granito-gneissic complex and covered, in some parts, by more recent alluvia. Under this dry climate, soils are mostly tropical ferrugineous soils, sometimes lateritic.
- The northeastern part of the Deccan plateau. This plateau generally looks like a peneplain formed of the Precambrian complex eroded, sometimes folded again (Aravalli Hills), partially overlain by Deccan traps. Soils are ferrugineous, locally with black soils on traps.

In Myanmar, this GEZ concerns the Tertiary basin around Mandalay. In Thailand, the Ecological Zone extends on the wide and flat alluvial basin of Chao Phraya River, only broken by some Permian calcareous hillocks. Moreover, the whole Korat plateau, bordered by the Khao Khien mounts and Dangreks on its western and southern ridges and by the Mekong River valley to the north and to the east, belongs to the same Ecological Zone. It is a gently rolling surface with an elevation of 200 to 400 m. It consists of sandstone outcrops, with poor drainage inducing floods during the rainy season and lack of water during the long dry period. In Cambodia, the concerned area is the whole low central plain built by the lower Mekong River and the Tonle Sap. This flat alluvial plain less than 100 m elevation is broken by inselbergs of various origins and by low basaltic plateaux (100-200 m) to the east of the Mekong River. In Viet Nam, the Mekong delta makes part of this zone.

Vegetation

A complex of vegetation types are found in this Ecological Zone. Dry evergreen forest occurs on the dry eastern Coromandel Coast of India and in north Sri Lanka. This very peculiar and vestigial plant community is unknown elsewhere in Asia and is limited to a small area. Today, most of these forests have been cleared for agriculture and locally replaced by *Casuarina equisetifolia* and *Eucalyptus* plantations. The ecologically decisive factors include the rainfall regime with well-marked maxima in October, November or December and a summer of 5 – 7 dry months. This rainfall pattern is uncommon in the tropics. The natural vegetation is a stunted woody formation with a peculiar floristic composition, including *Manilkara hexandra, Chloroxylon swietenia, Albizia amara* and *Capparis zeylanica*. The total flora is poor.

Dry deciduous dipterocarp forests and woodlands are more common and have their main distribution in Viet Nam, Laos, Cambodia and Thailand. The crown density of the woodlands varies from 10 to 40%. The repeated occurrence of fires and the pronounced dry season are certainly determining factors for this open structure. These woodlands are mainly found on acid lithosols and podsols, soils with a low fertility. These conditions determine a quite stable and open formation with a few characteristic dipterocarp species *(Dipterocarpus intricatus, D.*

obtusifolius, D. tuberculatus, Pentacme siamensis, Shorea obtuse), a common *Cycas (C. siamensis)* and a dwarf bamboo *(Arundinaria falcate)* in the undergrowth. In Thailand, some of these woodlands include teak *(Tectona grandis)* and a pine species *(Pinus merkusii)*.

In mixed deciduous woodlands, teak and pine occur with dipterocarps or *Leguminoseae*. They are found in Thailand, Myanmar, Laos and Vietnam. In India, woodlands are common as well but only a few dipterocarps occur, notably *Shorea robusta* and *S. talura*. In southern Papua-New-Guinea, some dry deciduous forests with Myrtaceae and Eucalyptus woodlands occur on a narrow coastal zone.

5.1.4 Tropical shrubland (TBSh)

Climate

This Ecological Zone extends over the main part of Peninsular India, where rainfall varies from 500 to 1000 mm, or even from 200 to 500 mm in its northeastern part, with a long dry season during 7-11 months and warm temperatures (mean temperature of the coldest month>20°C). Similar conditions occur in some small Sunda Islands as well as in a narrow coastal zone of southern Viet Nam.

Physiography

The Deccan plateau is a part of the Indian Shield. Its monotonous rocky surface is formed of the ancient granite-gneissic complex overlain, in its central part, by a thick cover of lava flows. Its mean elevation is 600 to 1000 m. To the northwest, the Indian Shield merges under the Indus alluvia.

Vegetation

In these very dry conditions, only a low open forest can grow, often giving way to woodland, savanna woodland or thickets. Moreover, in densely populated India most of this area is devoted to cultivation and grazing. Stretches of poor degraded savanna or pseudo-steppe intermingle with the crops. The thickets are composed of thorny bushes of *Acacia, Capparis, Maytenus* and *Ziziphus*. In semi-arid Rajasthan, in the northwest of India, Sudano-Deccanian floristic elements prevail. Some thorny thickets and low forest types dominated by *Anogeissus pendula* can be considered as a virtual climax. In these formations, several *Acacia* species *(A. jacquemontii, A. leucophloea)*, *Prosopis*, *Salvadora* and *Capparis* are common shrubs. In southeastern Viet Nam and Indonesia, the low deciduous forest often gives way to a sclerophyllous thicket.

5.1.5 Tropical desert (TBWh)

The main Asian tropical deserts include the Thar Desert on the border of India and Pakistan and the southern half of the Arabian Peninsula.

Climate

In Rajasthan, westwards, rainfall rather suddenly drops down and the border with Pakistan is the Thar Desert. Rainfall is there less than 200 mm, with hazardous rains. Winters are rather cool; mean temperature of the coldest month may be lower than 15°C. The Rann of Kutch, to the south, is also a desert.

In the Arabian Desert, rainfall is very scarce and erratic. Average annual rainfall ranges from 0 to 100 mm, with 25-50 mm for the greater part of the region and rainless years are not uncommon. Temperatures are very high throughout the year, with the mean coldest month always above 10°C. The eastern desert in Yemen is among the hottest places on earth, the absolute maximum reaching more than 40°C and the minimum not much less than 20°C.

Physiography

The Ecological Zone extends on the Thar Desert sands and on the saline soils of the Rann of Kutch. In Arabia, relief is more pronounced, particularly in the western part. Soil development is poor and four major soil types are present: sandy soils in different forms; hammadas ranging from solid rock to soft gypsiferous soil including pebbly and gravely desert ground; loess and similar soils; hydro-saline soils including marshes, sebkhas and the like.

Vegetation

In some places, between the dunes, a pseudo-steppic vegetation may occur. Sandy or rocky deserts are extensive.

The boundery of the Tropical desert in the Arabian Peninsula is based on the presence of tropical plants (south of this line) belonging to the Sudanian Region. The sparse vegetation consists of perennial shrubs, bushes, succulents and grasses. *Acacia* flora is the indicator of the region with plants like *Balanites, Abutilon, Haloxylon, Retametalia, Eremopogon, Trichodesma, Cucumis*, *Cenchrus*, *Cyperus, Tribulus, Maerua*, *Boscia, Tephrosia*, *Rynchosia, Periploca, Pergularia*. Thorny thickets of *Acacia tortilis* and *Maerua crassifolia* characterize the foothills. *Panicum turgidum, Lasiurus hirsutus* are found in sandy plains, Yemen and the Hadramut.

5.1.6 Tropical mountain systems (TM)

The tropical mountain systems of Asia include: a) the eastern Himalayas b) a mountain range stretching from the north of Indochina, Tibet, to the backbone of Malaysian peninsula; it is followed, to the south-east, by the Annamitic range; c) central mountain ranges of the main islands in Indonesia and the Philippines; d) relatively high peaks (more than 2000 m) in India and Sri Lanka and e) mountains in the southwest of the Arabian Peninsula.

Climate

Most tropical mountains of Asia, i.e. those reaching at least 1500 to 2000 m, experience a wet climate. Regarding the Himalayas, they are climatically divided into a subtropical northwestern part and a tropical wet southeastern part. Nepal is a transitional region between these two units. In all tropical mountains, from 1000-1500 m to 4000 m, annual precipitation is more than 1000 mm, sometimes more than 2000 mm. There is a pronounced dry season of

3 to 5 months on the submontane zone of eastern Himalayas, with mean temperature of the coldest month more than 15°C. Everywhere else, the dry season, if it occurs, is very short (less than 3 months). Mean temperature of the coldest month rapidly becomes lower than 15°C with increasing elevation. Above 4500 to 5000 m, eternal snow is found.

The mountains in the southwest of the Arabian Peninsula have a drier climate. Annual rainfall ranges from 400 mm at the lower foothills to 800 mm on the higher escarpments and there are two rainy seasons: in March-April and from July to September.

Physiography

Himalayas
The eastern part of the Himalayas, first oriented west-east in eastern Nepal, Sikkim and Bhutan, takes then a northeast direction. It is composed of two parallel ranges with contracted folds: Low Himalayas, reaching 2000 to 3400 m and Great Himalayas to the north, reaching more than 6000 m. It is interrupted in its eastern end by the high Brahmaputra valley. The highest peaks, reaching more than 8000 m, are located in Nepal.

Northern Indochina, Myanmar and Thailand
This important mountain block, south of Tibet, is formed of north-south folds with steep slopes. It is prolonged by the Arakan range, of which the Secondary and Tertiary rocks follow the Bay of Bengal. On the bordering region between India and Myanmar, the range reaches 2000 to 3000 m. In Malaya, the central mountains consist of crystalline blocks and rarely exceed 2000 m. In northern Thailand, some calcareous crests are more than 1500 m and the Doi Inthanon reaches 2580 m. In northern Laos and Viet Nam, the Annamitic range may be divided into the crystalline block of Phou Houat (2400 m) to the north and the proper Annamitic Cordillera going further to the south, dotted with high granitic blocks (up to 2800 m).

Indonesia and Philippines
In Sumatra, Java, the small Sunda islands, Sulawesi and Halmahera, active volcanoes form the highest peaks (above 3000 m). In Borneo, Timor, New Guinea, the mountains are crystalline blocks; the highest one, in Irian Jaya, is the Gunung Jaya (5030 m)

Arabian Peninsula
The higher peaks in the southwest reach an altitude of 3800 m. The terrain is composed of plateaux, basins hills and slopes. Soils are shallow, rocky or stony, only on cultivated terraces soils are developed. Valleys and wadis with sedimentary soils are rare.

Vegetation

Himalayas
Forests generally cover the Himalayas slopes up to 4000 m. In the lower reaches, these forests are often degraded by shifting cultivation and admixed with thickets. In the widest valleys crops are being cultivated, mostly rice and maize. Around Darjeeling, important tea plantations extend. In this part of the Himalayas we find the following sequence of vegetation formations: at around 1000 m, tropical lowland forest is replaced by an evergreen forest, with *Castanopsis, Schima, Engelhardtia, Lithocarpus and* locally Himalayan chir pine forest (*Pinus roxburghii*). From 2000 to 3000 m is a belt of evergreen oak forest, followed higher-

up by coniferous forest (*Abies, Tsuga*) and then giant Rhododendrons up to 4000-4500 m. Above this altitude, dwarf shrubs and grassland occurs up to 5000-5500 m.

South-east Asia
In Myanmar and Thailand, evergreen oak forests are found above 1500 m with pine forest, followed by Rhododendrons. In Laos and Viet Nam, an evergreen forest with Lauraceae and Fagaceae grows from 1500 to 2000 m and a mixed broad-leaved/conifers forest takes over above this elevation. Woodlands with oaks and pines also occur at high altitude. In Thailand, northern Laos and Viet Nam, these forests are largely affected by shifting cultivation. Nowadays, mozaics of forests and thickets predominate the lower montane zones.

Malaya Archipelago
In Malaysia, as well as in Indonesia and the Philippines, the montane (evergreen) rain forest still covers relatively larger areas as logging mostly affected lowland forests. This forest is best developed between 1400 and 2400 m altitude and is characterized by Fagaceae (*Castanopsis, Lithocarpus, Nothofagus* in New Guinea), Lauraceae, Junglandaceae (*Engelhardtia*), Magnoliaceae (*Casuarina junghuniana*), conifers (*Podocarpus, Pinus* in Sumatra), *Dacrydium, Aracauria, Libocedrus, Phylocladus* and others. Montane rainforest is often affected by shifting cultivation. In the subalpine zone, between 2400 and 4000 m, we find dense or discontinuous montane thickets with Ericaceae (*Rhododendron, Gaulteria*), Vacciniaceae and Myrsinaceae. Pine forest of *Aracauria, Podocarpus* and/or *Libocedrus* often occurs in this belt. The Alpine zone extends above 4000 m altitude and the main vegetation is grassland and discontinuous low scrubs.

Arabian Peninsula
Mountains are the only locations in the Peninsula where forests grow. A number of distinct vegetation zones can be distinguished, related to altitude:
- from around 1000 to 1500-1800 m: *Acacia-Commiphora* deciduous scrub or savanna, with species such as *Acacia asak, Acacia mellifera, Grewia* spp.. *Commiphora* spp. are also abundant with *Anisotes trisulcus*. In the south, succulents like *Euphorbia cactus* and *Euphorbia inarticulate* appear, while in wadis we find *Zizyphus spina-christi*.
- 1500-1800 to 2000 m: evergreen woodland or forest with *Oleeta africana, Podocarpeta, Olea chrysophylla, Trochonanhus comphoratus and* other species.
- 2000 to 3000 m: coniferous forest of *Juniperus procera*.

5.2 SUBTROPICAL DOMAIN

5.2.1 Subtropical humid forest (SCf)

This Ecological Zone has its main distribution in East Asia, i.e. southeast China south of the Yangtze River, the southern tip of South Korea and the southern half of Japan. There are two distinct small geographic units in the Middle East: the western part comprises the Colchis, humid forests at the mountain foot of the Caucasus, extending further westward along the Black Sea and also referred to as Euxinian forest, while the eastern area, or belongs to the foothills of the Talysh mountains at the Caspian Sea.

Climate

East Asia
Winters are mild to warm and summers are hot and wet. Generally, winter temperatures are heavily influenced by northerly cold fronts from Siberia. In summer the Pacific monsoon brings large amounts of precipitation to the region.

China and Korea Peninsula: annual mean temperatures range from 15-17^{o}C in the northern part of the zone to around 21^{o}C in the south and southeast. Inland low mountains and hills are slightly cooler than coastal plains. Annual precipitation varies between 800 and 1300 mm throughout the northern region, while further south it becomes wetter, up to 1800 mm and sometimes 2500 mm in low mountains. Annual rainfall diminishes going west, away from the coast. In the northern and middle parts of the zone rainfall is evenly distributed over the year. In the south the climate is under influence of Indian Ocean monsoons and most of the rain falls during the rainy season between May and October. A dry season of November to April is distinctive, during which hardly any rainfall is expected. The island of Taiwan is also under strong influence of the maritime monsoon climate. Annual mean temperature here ranges from 21^{o} in the north to 25^{o}C in the south. Annual rainfall is between 1500 and 2000 mm.

Japan: the climate is influenced greatly by the monsoon. In winter, there is a prevailing cold and dry northwest wind. Warm and moist southeast winds prevail during summer. Generally speaking, the summers are very hot and the winters rather cold with snow and frosts. Mean annual temperature is around 14^{o} – 17^{o}C. Mean temperatures of the coldest month (January) range from 3^{o} to 7^{o} and those of the warmest month between 26^{o} and 28^{o}C. The yearly precipitation over most of Japan is much greater than that over the continent. Mean annual precipitation ranges from around 1200 mm to locally more than 2500 mm, with two peak rainy seasons: “Baiu” (June-July) and “Shurin” (autumn rain).

Middle East
The climate of the coastal plains and lowlands bordering the south of the Black Sea and the Caspian Sea is warm-temperate with an annual average temperature around 14-15°C. High amounts of precipitation throughout the whole year are characteristic (mean yearly precipitation around 1500-2000 mm, locally up to 4000 mm). This high humidity results from the upward gradient rains of water-saturated air at foot of the High and Low Caucasus. In the Colchis the climate is mild due to the influence of the Black Sea (yearly amplitude of the monthly average temperatures 15-19°C), with mild winters (average temperature of the coldest month 5-6 °C). The winter snow coverage protects the vegetation against the occasional frosts and enables the occurrence of thermophytic forests even at higher altitudes.

Physiography

China: the zone is flat in the northeastern coastal plains and hilly in western as well as southern parts. Sichuan Province in the northwest of the zone concerns a large basin formed by eastern rim of the Tibetan Plateau to its west, Yungui Plateau to its south, Qinling Range to its north and hilly southwestern part of the zone to its east. In northeastern area of the zone is The Yangtze River Delta, in the northeast, encompasses parts of Jiangsu, Anhui, Zhejiang, Hunan, Jiangxi and Shanghai City. Numerous low mountains and hills predominate southeastern China and their altitudes are usually below 1,000 m. A few mountains exceeding 1400 m are Tianmushan (1506 m), Baishanzhu (1800 m) and Huangshan (the Yellow Mountain, 1860 m). Yellow brown soils and mountain yellow soils are common in mountain areas, yellow cinnamon soil prevails in basins and plains. The Yungui Plateau averages above

1500-2500 m, higher towards its northwest corner (4000 m), but descending gradually to 500 m in the south. On the plateau surface, red earth is most common, yellow soils, yellowish brown soils and brown forest soils predominate in mountain areas, while humic carbonat soils and terra rossa are distributed over limestone regions. Taiwan is dominated by uplands and mountains occupy 70 percent of the total area. Western slopes of the Alishan become gradually level and connect to low hills and alluvial plains. Latosols cover large areas below 500 m, mountain red soils and mountain yellow soils are distributed between 500 and 1500 m.

The topography of Japan is very complicated and mountainous; there are many valleys and small plains among the mountain ranges. Volcanoes and tectonic lines are common. Many kinds of rocks belonging to various groups, systems and series can be found. In southwestern "subtropical" Japan, strata of Palaeozoic and Mesozoic origin predominate. Brown forest soils are the most common soils. Other important soil types are black soils of volcanic origin and red and yellow soils.

The coastal plains of the Black Sea and Caspian Sea were produced by the retreat of these seas. Altitude ranges from the lowlands up to 600 m, but particular forest stands still occur around 900 m. The lowland is essentially formed by fluvial accumulative deposits. Red-soils and different types of yellow soils are characteristic for the Ecological Zone. Red-soils (partly fossil) are restricted to the damp Colchis climate. On sites in the foothills also yellow-brown soils and some types of montane brown forest soils are found. Alternating with these soil types humus carbonate soil (rendzina) and alluvial soils occur.

Vegetation

China
Two types of woody vegetation prevail south of Yangtze River in eastern China: pine forest and deciduous forest mixed with evergreen species. The dominant conifer here is *Pinus massoniana*, which grows extensively on slopes of low mountains and hills. The mixed deciduous evergreen forests, dominated by deciduous trees, are a unique subtropical vegetation type in China. Species of this formation include: *Quercus acutissima, Q. variabilis, Q. dentata, Q. glandulifera, Q. fabri, Liquidambar formosana, Pistacia chinensis, Ulmus parvifolia, Zelkova schneideriana, Celtis sinensis, Dalbergia hupeana, Albizia macrophylla, Tilia miqueliana, Cyclobalanopsis glauca, C. myrsinaefolia, Castanopsis sclerophylla, C. carlesii, Lithocarpus glaber, Phoebe sheareri, Cinnamomum chekiangense, Machilus thunbergii* and *Ilex purpurea*. Bamboo stands are very well cultivated in the region, with more than 20 species in *Phyllostachys* of which *P. edulis* is most common.

Western mid-latitude mountains feature small conifer forests of warm-climate, dominated by spruce-fir such as *Abies chensiensis, A. fargesii, A. ernestii, Picea complanata, P. neoveitchii,* as well as *Pinus armandi, P. henryi* and *Platycladus orientalis*. *Pinus tabulaeformis* and *P. bungeana* forests are distributed over western portions of the Qinling range. Deciduous broadleaved forests contain more than 300 woody species, the major trees including *Quercus acutissima, Q. variabilis, Q. liaotungensis, Q. aliena* var. *acuteserrata, Q. dentata, Q. glandulifera, Betula albo-sinensis, Toxicodendron vernicifluum*, etc.

In the southeastern low mountain and hill region as well as the Sichuan Basin, the vegetation is typically represented by evergreen broadleaved forests as well as coniferous forests. Consistently distributed in the entire region is evergreen broadleaved laurel forest of *Cyclobalanopsis glauca*. Then there are *Castanopsis eyrei* and *C. fargesii* in the central to

northern parts of the area, *C. hystrix* and *C. lamontii* from west to east sides of the Nanling mountains. Conifer forests are primarily those of *Pinus massoniana, P. taiwanensis* and *Cunninghamia lanceolata*. *Pinus massoniana* occupies slopes with acid soils, mostly below 800 m. In the western part of the division it may occur up to 1000 m. This species is highly capable of natural regeneration and is tolerant to dry, poor site conditions. The distribution of *P. taiwanensis* displays a discrete island pattern and is common on acid base rocks with average elevations above 800 m and upper limit to 2000 m. *Cunninghamia lanceolata* is also widely distributed, primarily on acid soil slopes below 1200 m altitude. The region is one of the most important bamboo regions in China. There are two million hectares of *Phyllostachys edulis* in the area. Several other species from the same genus also occupy a broad range: *Ph. bambusoides, Ph. nidularis, Ph. mannii, Ph. nigra* var. *henonis* and *Ph. heteroclada*.

On Yungui Plateau in south and southwest China, regional evergreen broadleaved laurel forests are similar to those of eastern areas, consisting of same genera, *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis*, *Cinnamomum* and *Phoebe*, but often with different species. The conifer forest here is dominated by *Pinus yunnanensis*, which grows widely on the plateau surface and mountainous fields at 1000-3100 m in elevation, pure stands usually at 1600-2800 m.

Taiwan's forests are distributed along a distinct gradient from the coastal region to high mountains. Mangrove forests primarily occur along shallow shorelines. Southern subtropical rain forest covers low hills (below 500 m) in northern Taiwan. Major upper storey species include *Cyclobalanopsis glauca, Castanopsis carlesii, C. kusanoi, Ficus microcarpa, Cryptocarya chinensis, Acer oblonga, Elaeocarpu japonica, Illex rotunda* and *Engelhardtia roxburghiana*. Many middle and under story species occur, along with tree ferns up to 10 m tall scattered within the forests. Many of the rain forests have been cleared for citrus orchards, eucalyptus forests and *Phyllostachys edulis* or *Ph. makinoi* plantations. Evergreen broadleaved forests extend on 500-1800 m slopes and comprise *Castanopsis kawakamii, C. fargesii, C. uraiana, Lithocarpus brevicaudatus, L. ternaticupula, L. amygdalifolius, Cinnamomon camphora*, etc.

Japan

The predominant natural vegetation is evergreen broadleaved forest, showing several forest types. The major tree species of the overstorey are *Machilus thunbergii* and *Castanopsis cuspidata* in coastal areas and *Cyclobalanopsis gluaca, C. gilva. C. salicina, C. myrsnaefolia* and *C. acuta* (evergreen oaks) in inland areas. Conifers, such as *Podocarpus macrophyllus, P. nagi* and *Torreya nucifera* occur also in these forests. At higher elevations *Tsuga sieboldii* and *Abies firma* grow in mixture with the broadleaved evergreen species. The medium to lower strata contain small trees and shrubs of such broadleaved evergreen species as *Aucuba japonica, Damnacanthus indicus* and *Neolitsea sericea*. The ground vegetation contains small shrubs, vines, ferns and herbs. Epiphytes are present, as well as many lianas. The natural vegetation including climax forests and other minor communities in this Ecological Zone has been largely altered since rice cultivation was introduced in Japan about two thousand years ago. Secondary forests of *Pinus densiflora, Quercus serrata and Quercus acutissima* now prevail over large areas on foot-hills and lower mountains. Natural stands of *Pinus densiflora* are restricted to extreme habitats such as narrow ridges, steep slopes and lava flows with little soils or exposed bedrocks and peripheries of fens and swamps.

Middle East: Hyrcinian forest and Euxinian forest

Although of relatively small extent, these forests are highly significant as they present the most diverse and productive forests in the Middle East. Both forests are dense broadleaved summer-green types.

The vegetation consists of hygro-thermophilous mixed deciduous broad-leaved forests with varying floristic composition and structure, sometimes with an evergreen understorey. Due to the climatic conditions and biogeographic history these forests are rich in endemic and tertiary relict species. The canopy of the forests is build up by different oak species (in the west *Quercus imeretina, Q. hartwissiana,* in the east *Q. castaneifolia*), also *Castanea sativa, Pterocarya pterocarpa, Diospyros lotus* and *Fagus sylvatica* subsp. *orientalis*. In the subcanopy layer *Zelkova carpinifolia*, *Carpinus betulus* and some *Acer* species are characteristic. The shrub layer is dense and species-rich. Additionally lianas and epiphytes occur. The herb layer consists of different ferns, grasses and herb species.

At higher altitudes the hygro-thermophilous vegetation is replaced by Caucasian mixed hornbeam-oak forests (*Quercus iberica, Carpinus orientalis, Fagus sylvatica* subsp. *orientalis, Castanea sativa*).

Small areas in the lowland, along riversides and the estuaries, are covered by swamp and fen forests (*Alnus barbata, A. subcordata, Pterocarya pterocarpa*).

5.2.2 Subtropical dry forest (SCs)

In Asia, this Ecological Zone is confined to the Middle East and occupies a relatively narrow belt along the Mediterranean Sea.

Climate

The zone has a typical Mediterranean climate, with mild humid winters and dry, moderately hot summers. Annual rainfall ranges from around 400 to 800 mm and is decreasing from north to south.

Physiography

This zone comprises the coastal plain along the Mediterranean Sea and low hills running parallel to the coast. The northern part of the Jordan-Arava Rift Valley is also included in this zone. The coastal plain is a lowland of varying width. It is a zone of light soils, mobile sand dunes and most fertile alluvial ground. The Mediterranean coastline of Turkey is very complex, consisting of many islands, estuaries and small horsts. Intermountain valleys of the Aegan – and Taurus ranges are also part of the zone.

Vegetation

The typical Mediterranean woody vegetation that dominates this zone is maquis, an evergreen sclerophyllous woodland or shrub up to around 5 m high and often dominated by oak. *Ceratonia – Pistacia lentiscus* maquis dominates the coastal plains up to around 200 m, while *Quercus calliprinos – Pistacia palaestina* maquis is the chief vegetation from 200 to 1000-1200 m. Important tree species of the maquis, which has local variants, include *Quercus ithaburensis, Q. infectoria, Q. ithaburensis, Q. coccifera, Laurus nobilis, Arbutus andrachna, Cercis siliquastrum, Juniperus phoenica, Myrtus communis, Olea europea, Phillyrea* spp.,

Pinus halepensis, P. brutia and others. Climbers are also present, for instance *Tamus communis, Rubia tenuifolia, Smilax aspera, Lonicera etrusca, Clementis*. Maquis, when unaffected by man, may under certain conditions develop into a type of forest, dominated by *Quercus calliprinos.*

Various types of pine forest occur, with either Aleppo pine (*Pinus halepensis*), *P. brutia* or *P. pinea* as dominant species. *Pinus pinea*, partly introduced by man, grows mainly on sandstone formations, while *P. halepensis* is confined to rendzina or other chalky soils. The undergrowth is often made up of other maquis components.

5.2.3 Subtropical steppe (SBSh)

This Ecological Zone is confined to western Asia, mainly located in the Middle East.

Climate

The climate of the subtropical steppe is semi-arid. Annual rainfall ranges from about 200 to 500 mm and falls during winter in the Middle East. The subtropical steppes in East Afghanistan and Pakistan are under the influence of the Indian monsoon and receive most of the rainfall from June to September. Although differences in temperature between seasons are relatively high, winters are not severe.

Physiography

As many different geographic regions are part of the zone, physiography is extremely varied. The western part of the zone comprises undulating (piedmont) plains and lower foothills of the Kurdistan and Zagros Mountains, drained by the rivers Euphrates and Tigris. The plains are built mainly of chalks and marls covered by sand and loess. On the lower hills and medium-altitude plateaus, fertile brown soils predominate. In Iran, Afghanistan and Pakistan, all mountainous countries, the steppe zone often forms the transition between low-lying coastal or inland deserts and mountains, comprising the lower foothills.

Vegetation

The dominant steppe vegetation consists of low shrubs and grasses, interspersed with sparse trees particularly at wetter locations. In the Middle East, dominant shrubs include *Artemisia* spp., *Anabasis aphylla, Sarcopoterium spinoasa, Gundelia tournefortii, Haloxylon articulatum, Asphodelus microcarpus* and *Ominus natrix.* At higher, more humid locations a forest-steppe can be found with trees such as *Amygdalus korsuhinskii, A. arabica, Acer monspessulanum, Pistacia atlantica, Pyrus bovei, Rhamnus palaestina* and *Crateagus aronia.* Due to a very long human activity, the original vegetation has been considerably altered. In Pakistan, the woody steppe vegetation consists of shrubs and small trees. Main species are *Acacia modesta* and *Olea cuspidate,* accompanied by *Ziziphu jujuba, Dodonea viscosa* and others.

5.2.4 Subtropical desert (SBWh)

Subtropical deserts in Asia consist of the northern part of the Arabian Peninsula and arid lowlands or inland plateaux in Iran, Afghanistan and Pakistan.

Climate

The climate of the zone is characterized by very low rainfall, > 200 mm annually. Summers are very hot with average temperature of the warmest month ranging from 35 to 40^{o}C and cool winters (mean temperature of the coldest month around 10^{o} - 15^{o}C). The Dasht-e-Kavir depression in Iran, with higher altitudes and further to the north, has a typical continental desert climate, reminiscent of that of Central Asian deserts in moisture deficiency and extreme winter temperatures. Here, the mean annual temperatures vary between 15^{o} and 18^{o}C with extreme maximum temperatures reaching around 40^{o}C and winter extremes well below zero.

Physiography

The Nafud and Syrian deserts are the subtropical deserts of the Arabian Peninsula. Large stretches of the former are covered with layers of Nubian sandstone, which has greatly influenced the nature of the landscape in being the source of sand dunes, sand flats and sand onblows. In addition to the sandstone plateaux, often broken up by lava masses and extinct volcanoes there are also large stretches sand dunes in the Nafud and sand onblows covering the limestone strata. Sheets of gravel are widespread, as well as saline basins. The Syrian Desert is a vast Eocene and Miocene calcareous plateau. The large deserts of Iran are located on the Central Plateau, a vast plateau at 400 – 800 m altitude almost completely enclosed by high mountain systems. It is built up primarily of highly saline ground. Apart from salines this plateau is also partly covered with takirs and sand dunes.

Vegetation

Vegetation in this zone is dominated by low, thorny shrubs with a sparse coverage. Large parts consist of sand without any vegetation. Compared to the tropical desert, floristic composition is different. In the northern part of the Arabian Peninsula we find a steppe with *Artemisia herba-alba, Anabasis articulata, Stipa tortilis, Thymelaea hirsute and Poa sinaica.* In the depressions, formations with *Zygophyllum dumosum, Salsola tetranda* and *Chenolea arabica* occur. In subtropical deserts of Iran and Afghanistan, sparse shrub vegetation, with a ground coverage between only 1 and 10 percent, predominates. Two types can be distinguished: a) Zygophyllum shrubland with *Zygphyllum atriplicoides, Z. eurypterum* and b) Haloxylon shrubland with small shrubs and dwarf shrubs like *Haloxylon salicornicum, H. ammodendrum, H. articulatum and Seidlitzia rosmarinus*. Accompanying species include *Anabasis haussknechti, A. setifera, Calligonum* spp., *Ephedra scoparia and Salsola* spp.

In Iran deserts one finds perennial formations with several species of *Andropogon, Aristida plumose, Bromus, Cymbopogon laniger, Pennisetum orientale* and *Chrysopogon ciliotatus. Artemisia* and thorny *Convolvulus* are abundant; shrubs and bushes of *Acacia horrida, Populus euphratica, Pistacia khinjuk* and *Amygdalus scoparia* are also present.

5.2.5 Subtropical mountain systems (SM)

Subtropical mountain systems cover extensive areas in Asia, in a nearly continuous west-east belt, from the mountains and highlands of Turkey to the eastern reaches of the Himalayas in South China.

Climate

The climate of the Middle Eastern mountain systems is extremely diverse both in temperature and rainfall. Winter rainfall is predominant in the area and only some small portions enjoy light or heavy summer rains. Compared to lowlands in the region, mountains are generally more humid. A typical highland forest-steppe climate (Kurdistan Mts.) has the following characteristics: annual precipitation, in the form of snow and rain, ranges from 500 to 1400 mm; the rainy season is from around September to May-June, the rest of the summer is dry and hot. Another characteristic is that four or more months of the winter have mean minimum temperatures below 0^{o}C.

All along the Himalayan ranges, the rainfall increases from west to east and the climatic regime changes gradually from Mediterranean to typical monsoon types. The rain decreases also from the outer to the inner parts of the ranges. On this basis, the subtropical part of the Himalayas comprises:

- North-west Himalayas (Afghanistan and Pakistan);
- Kashmir;
- Western Himalayas (Himachal Pradesh, Garwal, Kumaon, Nepal) up to Katmandu.

Kashmir still experiences a typical Mediterranean regime, whereas in western Himalayas, a transitional regime is characterized by a bixeric tendency, even if the monsoon reaches these regions. In the submontane and montane levels, rainfall ranges from less than 1000 to 1500 mm, with at least 1 or 2 dry months, up to 7 or 8. Mean temperature of the coldest month varies from around 15°C in the submontane zone, to less than 10°C above 2000 m. Above 3000 m, snow occurs, with frequent winter frost. Precipitations are 500 to 1000 mm. In Kashmir, high plateaux between 2500 and 5000 m have a subdesert cold climate that might be considered either as subtropical or temperate. Rainfall is less than 400 mm, with high annual temperatures amplitude.

China's subtropical mountains comprise mainly the central interior highlands and southwestern high mountains. The region has a harsh climate at high elevations and experiences warmer, moist conditions in medium to low mountains. Annual mean temperature range from 8^{o} to18^{o}C in eastern areas, with January mean above 0^{o}C, extreme low at -20^{o}C; annual rainfall at 800-1200 mm, up to 3000 mm locally. Towards western higher mountain areas, a dryer and colder climate prevails: annual average temperatures at 3^{o}-8^{o}C, January average from -2^{o} to -8^{o}C, extreme low at -27^{o}C, summer average under 14^{o}C; annual rainfall 440-750 mm, decreasing toward the west. In southern Tibet, mean annual temperatures in mountains are 6-8^{o}C, average in winter 2-4^{o}C and in summer around 15^{o}C. Annual precipitation ranges from 300 to 700 mm. River basins in the south at 500 m elevation are relatively warm and moist, with annual rainfall more than 1200 mm and a distinct dry-rainy seasonal change as the result of impact from the Indian Ocean monsoon.

Physiography

Mountains in the Middle East are mostly part of the Irano-Anatolian folded zone. This zone comprises the Pontus, Taurus, Elburz and Zagros mountain systems and the presumably younger and secondary East Mediterranean system of the Aegan and Syro-Palestine ranges. Volcanic features are widespread. Turkey and Iran are mountainous countries, with highest peaks reaching 4000 – 5000 m.

In western Himalayas, the two main ranges are separated by rather wide valleys. Moreover, from Sikkim to the western end of the Himalayas, the low range of the Siwalik (1000 m) stretches on the southern lowland. The highest peaks are located in Nepal and Kumaon, all higher than 7000 m. Glaciers are more numerous than in the eastern part. In Kumaon, erosion is still very active. In Kashmir, the whole mountain becomes lower, but another parallel range, to the north, is the Karakoram, with about 30 peaks higher than 7000 m. South of this high range is the Indus River valley followed, eastwards, by the Ladakh. Southwards lie: the Zascar range, the Kashmir valley at a mean elevation of 1600 m and the subhimalayan region formed of calcareous and rocky ranges reaching 3000 m.

The rugged topography of the zone in China is characterized by high mountains and deep river valleys. The average height of the mountains is around 3000-4000 m, in the eastern part decreasing to 1000 m. The Gonggershan, also known as the Greater Snow Mountain, in eastern part of the region goes up to 7759 m and is covered by many glaciers. In southern Tibet, the physiography comprises highlands and four major river systems, i.e., Yalongjiang, Jingshajiang, Lancangjiang and Nujiang, which run nearly parallel southward. Relatively flat terrain in the north evolves gradually into a plateau. The rugged topography in the south, averaging 4000-5000 m in altitude, is dominated by deep-cutting river valleys which often descend to 2500 m and high mountains masked with mountain glaciers that rise up to 5000 to 6000 m. The soil altitudinal zonation, from low to upper elevations, features mountain yellow earth which supports subtropical evergreen broadleaved forests, mountain yellow-brown earth which supports conifer and broadleaved mixed forests and mountain gray-brown soil which supports alpine conifer forests.

Vegetation

Middle East
Mediterranean mountain vegetation is diverse and includes dense humid forests, shrubland, forest-steppe and treeless grass steppe. The forests can be either deciduous broadleaved or coniferous. In the east Mediterranean, i.e. Lebanon and Syria, a summergreen oak forest is found between 1000 and 1600 m altitude. The forest climax is dominated by *Quercus cerris*, accompanied by *Quercus boissieri* and fragments of *Quercus libani.* This formation has been largely affected by human activities. In western Turkey, black pine (*Pinus nigra*) dominates this belt. From 1500 to 2000-2200 m, we find a subalpine coniferous forest with cedar (*Cedrus libani*), fir (*Abies cilicica*) and juniper (*Juniperus excelsea*). Juniper forest occupies the drier areas. Above 2200 m, alpine dwarf shrubs and meadows occur.

Forest-steppe and steppe vegetation occupy major parts of the central highlands and plateaus of Turkey and Iran. On humid locations grows deciduous oak forest dominated by *Quercus persica* or other oak species and often in combination with juniper (*Juniperus*). In the valleys one finds *Fraxinus oxycarpa, Platanus orientalis, Ulmus campestris,* varieties of *Populus, Salix, Tamarix,* etc. Tree steppe with pistachio, almond and juniper occur at sub-dry locations.

In dry areas, enjoying a yearly rainfall of 250 – 400 mm, the woody vegetation is restricted to shrubs dominated by *Artemisia* and *Stipa* species. The grass layer consists of *Festuca, Poa* and *Bromus* species.

Well-developed forest grows on the higher slopes of the mountains bordering the Black Sea and Caspian Sea. These communities are part of respectively the Euxinian - and Hyrcanian forest complexes. Average yearly rainfall is high, more than 1500 mm locally. At both locations we find summer-green dense forest between approximately 800 and 2000 m altitude. The Hyrcanian montane forest is the deciduous Fagetea hyrcanica with *Fagus orientalis,* accompanied by *Carpinus betulus, Acer insigne and Quercus castaneifolia.* The Euxinian montane forest is composed of deciduous broadleaved trees and conifers, with species of oak, fir and pine. It is characterized by a large number of endemic species of trees, shrubs and herbs.

Northwestern and Western Himalayas
Mountain vegetation here is extremely diverse, due to a wide variety in altitude and climate. In south Afghanistan, open deciduous woodland is the dominant vegetation at medium high altitudes. From around 1100 to 1800-2000 m, where annual precipitation averages 250-400 mm, *Pistacia atlantica* woodland of 4-6 meters high occurs, with a ground cover of 15-20 percent. A denser shrub layer consists of different *Amygdalus* species, *Convolvulus leiocalycinus, Astragalus* spp. and *Ephedra* spp. Between 2000 and 2800 m, with mean annual precipitation more than 400 mm, *Amygdalus* communities prevail. Tree ground cover is up to 30 percent and dominant tree species include *Amygdalus* cf *communis, A. kuramica and Fraxinus xanthoxyloides.*

In east Afghanistan and Pakistan, different types of west Himalayan evergreen sclerophyllous forests and woodlands occur. They resemble the vegetation of the Mediterranean not only in physiognomy and ecology, but also floristically. Woodland of *Quercus baloot* is most extensive and occurs at an altitude of around 1300 to 2000 m. Depending on the water supply, they are either open woodlands with stunted trees of 3-6 m high, or true forests with trees of 15 m or more in height. Climbers are also present. *Quercus dilatata* and *Quercus semecarpifolia* communities are confined to the higher parts of wet mountains. The first dominates between 1900 and 2400 m, the latter from 2400 to 2900 m. Both oak species form rich, mesophylous forests of 8-20 m in height.

Coniferous forest are the most extensive mountain forests. Chir pine forests dominate the lower mountain slopes from 900 m up to 1700-2000 m altitude. The principal species is chir pine (*Pinus roxburghii*), accompanied by some oaks (*Quercus dilatata*) and other broadleaved species. Chir pine occurs almost in pure form in the top canopy, which is moderately dense and reaches a height of 25 to 35 m. The undergrowth is usually dense. The “high level conifers”, ranging from around 1700 to 3000 m altitude, comprises various formations. West of the Indus, *Pinus gerardiana* forest is found between 2000 and 2500 m. Tree cover is about 50-70 percent, with a height of 5 to 12 meters. Xeromorphic dwarf shrubs of *Artemisia, Astragalus, Acontholimon* etc. form the undergrowth. A dense forest of *Cedrus deodara* is found between 2500 and 3100 m in areas with 450 to 650 mm annual rainfall. Other trees of this forest are *Picea morinda, Pinus excelsea* and *Abies webbiana.* With decreasing rainfall *Juniperus seravschanica* gradually replaces the cedar. East of the Indus, influenced by the monsoon rains, better water supply favours blue pine (*Pinus wallichiana*). A dense, mixed forest dominated by *Picea smithiana* and *Abies webbiana* grows in high rainfall areas (> 800 mm per year) between 2900 and 3200 m. In areas with winter rains,

Juniperus woodlands dominate at altitudes ranging from 1500 to 3000 m. Further eastward, under the monsoon influenced climate, *Juniperus* woodland occurs above 3000 m.

Typical subalpine woody vegetation, ranging between 3000 and 4000 m altitude, is a mixture of conifers and broadleaved low trees or shrubs. Main species are *Abies webbiana, Abies spectabilis, Betula utilis* and *Rhododendron campanulatum*. To the drier west we found so called cushion shrublands, with species of *Onobrochis, Astragalus, Acantholimon, Cousinia, Artemisia and Ephedra*. Alpine meadows and dwarf shrubs are confined to mountain ranges with high summer rainfall and occur between 4000 and 5000 m. Dwarf shrubs are dominated by *Rhododendron and Juniperus*.

In Kashmir, from 1500 to 3000 m, coniferous forests occur with *Pinus excelsa* and *Cedrus deodara*, mixed with thickets and grasslands. Above 3000 m, they give way to mixed forests and woodlands with *Betula* and *Abies*. To the east, from Himachal Pradesh to central Nepal, the submontane level from 1000 to 2000 m is also characterized by open woodlands with *Pinus roxburghii*. Above 2000 m, dense evergreen forests occur, with oaks or conifers (*Cedrus deodara, Picea, Pinus excelsa*), then *Abies-Quercus* forests above 3000 m. Above 4000 m, only shrub grasslands are found, with *Rhododendron* and *Juniperus*. Steppic transhimalayan zones, very dry and cold, are covered with open shrub grasslands and steppes.

China
The alpine conifer forests of the Ecological Zone are dominated by *Abies faberi* and *Picea complanata*, which are distributed at 2000-3000 m. The species are often associated with *Tsuga chinensis*, *Picea complanata*, *Acer*, *Tilia* and *Betula albo-sinensis* in the lower reaches, while they form usually pure stands at higher altitudes, up to 4000 m. Among the conifer forests that grow on low and medium altitude mountains are *Pinus massoniana*, *P. yunnanensis*, *Cunninghamia lanceolata*, *Cupressus funebris* in pure stands. Further west and at higher elevation, we see alpine conifer forests of highly cold-tolerant species dominated by *Picea balfouriana* and *Abies squamata*, which often form pure stands on north-facing slopes from 3000 to 4000 m.

Southern Tibet alpine conifer forests are dominated by *Abies spectabilis* and *Picea linzhiensis*. The former species, also called Himalayan fir, establishes pure stands or associates with *Abies georgei* and *Picea likiangensis* in the southern part of the division at 3100-4000 m on north-facing slopes. *P. linzhiensis* forms pure stands in the southeast of the division on 2900-3900 m slopes. Conifer forests at medium elevations are dominated by *Pinus griffithii*. Several types of montane broadleaved forests can be distinguished in the region. The southern subtropical monsoon rain forest occurs at Moto on valley lands under 500 m and is composed of *Shorea robusta*, *Terminalia catappa*, *Terameles nudiflora* and *Dillenia pentagyna*.

In central Taiwan, coniferous and broadleaved mixed forests occupy mountain slopes from 1800 m up to 3000 m altitude. Major species include *Chamaecyparis obtusa* var. *formosana* and *Ch. formosensis*. Broadleaved components include upper-layer species *Cyclobalanopsis stenophylloides*, *Trochodendron aralioides*, *Acer formosanum*, *Sassafras randaiense*, as well as lower-layer species from genera of *Eurya*, *Illex*, *Symplocos* and *Hydrangea*. Alpine conifer forests occur in the Yushan and Bishan mountains at elevations generally above 3000 m with *Abies kawakamii* as major species.

5.3 TEMPERATE DOMAIN

5.3.1 Temperate continental forest (TeC)

Climate

In China, the annual mean temperature varies greatly, from 2°C in the north of the Ecological Zone to 14°C in the south. Climate is distinctly seasonal; winter is relatively long (4-7 months) and spring short (1-3 months). In the northern part, mean coldest month is below -10°C and extreme low at -30°C. Warm summers have monthly average above 20°C in the warmest month and a growing season lasting 100-150 days. Annual precipitation is between 400 and 800 mm for most of the area and 1000 mm over the southeastern part of the Ecological Zone. In the southern part, mean temperature in the coldest months gets below 0°C. Warm summers bring average temperature up to 24°C in the warmest month over most of the area except in mountains. Growing season lasts 200 days. Annual precipitation of 600-1000 mm is unevenly distributed over the year: frequent rainstorms in the summer and droughts in the winter and spring. Coastal areas experience higher rainfall, 1000 to 1400 mm per year. Similar climatic conditions prevail on the Korea peninsula and in Northern Japan.

Physiography

The eastern part of Northeast China features rolling hills and mountains with altitudes averaging 400 to 1000 m and the highest peaks at 1150 m above sea level. Changbaishan, in southern part of the area near the Korean border, has a complex topography, with average heights of 500-1000 m. Its main peak, Baitoushan, is the highest in Northeast China, reaching 2744 m in altitude. Major soil types include gray forest soil, podzolic soil, dark brown soil and meadow soil or phaeozem on terrace of river bands. The rest of the Ecological Zone consists mostly of plains and low hills, with elevations mostly under 800 m, including two peninsulas (the Liaodong Peninsula and Shangdong Peninsula) with dense industrial and population occupation. Two of China's most important rivers, the Liaohe and the Huaihe, wind their way through the region before reaching the Pacific Ocean and deposited a flat, fertile alluvial plain with elevation less than 100 m.

Vegetation

Northern part of the Ecological Zone (in Northeast China) features well-stocked *P. koraiensis* mixed forests on low mountains of 400-600 m. Associated species include *Picea jezoensis* var. *microsperma*, *Picea koraiensis*, *Abies nephrolepis*, *Betula platyphylla*, *B. costata*, *B. davurica*, *Populus davidiana*, *Quercus mongolica*, *Tilia amurensis*, *Acer mono*, *A. ukurunduense*, *A. tegmentosum*, *Ulmus davidiana* var. *japonica*, *Fraxinus mandshurica*, *Juglans mandshurica*, etc. Once disturbed, the mixed forests usually degrade into *Populus davidiana* and *Betual platyphylla* second-growth forests. Further south in Changbaishan mountains near Korean border, about 300 tree and shrub species can be found, where rainfall and temperature conditions are more favourable than those of the northern hills. *Pinus koraiensis* mixed forest in Changbaishan has a similar composition but more species, adding *Abies holophylla*, *Pinus sylvestriformis*, *P. densiflora*, *Taxus cuspidata*, *Thuja koraiensis*, *Fraxinus rhynchophylla* and several maple and linden species.

In contrast with generally forested eastern Northeast China, the rest of the Ecological Zone is under high population pressure and has experienced a long history of human settlement and cultivation. As a result, most of the area has no tree cover left. Pockets of natural

second-growth forests exist, represented by *Pinus densiflora, P. tabulaeformis and* several deciduous oaks. The deciduous oak species include *Quercus acutissima, Q. variabilis, Q. dentata, Q. aliena, Q. serrata, Q. liaotungensis* and *Q. mongolica*. *Q. acutissima* is traditionally used by local farmers to raise silkworms. Temperate fruit trees are widely cultivated in the area, among which are *Malus pumila, Pyrus bretschneideri, Crataegus pinnatifida* and *Castanea mollissima*. Planted species in countryside are mostly *Populus, Salix, Ulmus, Sophora japonica, Ginkgo biloba, Platycladus orientalis, Sabina chinensis, Paulownia fortunei, Catalpa bungei, Castanea mollissima, Diospyros kaki, Zizyphus jujuba, Toona sinensis, Ailanthus altissima* and *Robinia pseudoacacia*. Cultivated bamboo stands are scattered in plains, mostly *Phyllostachys glauca, Ph. vivax, Ph. bambusoides* and *Ph. propinqua*. The region also has reported some successful agro-forestry experiments, using fast-growing timber species, for instance *Populus, Paulownia* and cultivation of improved fruit species such as apple, pear, *Diospyros kaki* and *Zizyphus jujuba*.

The temperate forests of Japan are deciduous, summergreen broadleaved forests dominated by beech. Main trees are *Fagus crenata, Kalopanax septemlobus, Tilia japonica, Quercus mongolica* var. *grosseserrata, Acer mono* etc. Different types of beech forests can be distinguished related to habitat. Moist habitats in valley bottoms and on alluvial fans support *Pterocarya rhoifolia* forests. Common trees of these forests are *Ulmus laciniata, Athyrium pycnosorum, Acer mono, Dryopteris crassirhizoma* and others. Habitats with a high water table in lowlands of northern Honshu and Hokkaido support *Alnus japonica* forest. It is developed on the periphery of fen and reed swamps and on flood deposits along the lower watercourses.

5.3.2 Temperate steppe (TeBSk)

The Ecological Zone comprises vast steppes of Central Asia, occupying the Eastern part of Inner Mongolia in China and central and eastern Mongolia.

Climate

The climate of the Ecological Zone is characterized by a long and cold winter and a short but warm summer. Annual average temperatures vary between 2^{o} and 10^{o}C, with mean temperatures of the coldest month (January) ranging from -10^{o} to -20^{o}C. Mean temperature reaches to 24^{o}C in the warmest month in summer. Growing season lasts 100-175 days. Annual rainfall ranges from 200 to 400 mm, locally up to 600 mm and the maximum is observed during the second half of summer. Spring, as a rule, is dry and with strong winds.

Physiography

In China, the Ecological Zone comprises several northeast -southwest oriented mountains and highlands and plains. Elevation ranges from 1000 to 2000 m, altitudes of main peaks from 2000 to 3000 m. Granite, gneiss, quartzite and schist are the basic rock types in northern mountains, whereas limestone is frequent in southern mountains. Soil zonation from low to high elevations features leached cinnamon soil, mountain brown soil, mountain podzolic soil and meadow soil, sometimes interspersed with a loess layer.

In Mongolia, the Ecological Zone includes the lower reaches of the Uldza River, east and central Mongolian Plains. The landscape is dominated by weakly undulating plains at heights

between 800 – 1500 m. There are numerous valley-like depressions with saline soils and low knoll masses.

Vegetation

Natural vegetation in this Ecological Zone is dominated by grass and shrub steppe. The northeastern plain in Mongolia is covered by forb – grass tansy steppes, while at the lower reaches of the Uldza River, one finds forb – fescue – tall grass meadows and forest- meadow-swamp complexes. Further south, Mongolian steppes are dominated by small sod grasses and *Aneurolepidium-Stipa* associations, often in association with dwarf shrubs such as pea shrubs (*Caragana* spp.), sagebrushes (*Artemisia* spp.) and wormwood (*Cleistogenes squarrosa*). Low knoll stony habitats are covered by petrophyte steppe varieties plus forbs and shrubs. Here one can find *Spiraea*, sometimes Mongolian almond (*Amygdalus mongolica*), elm (*Ulmus* spp.) etc.

In some areas, pockets of woodland can be encountered. Tree species in the Ecological Zone are represented by *Pinus tabulaeformis*, *P. bungeana*, *Picea wilsonii*, *P. meyeri* and *Larix principis-rupprechtii*, individually forming pure stands or sometimes admixed with *Abies nephrolepis*. *Populus davidiana* and *Betula platyphylla* come in from the northeast to form second-growth pure or mixed stands when spruce forests are disturbed, while *Populus cathayana* is common in valleys and lowlands.

This Ecological Zone is facing serious threat from desertification. Large areas in the region have degraded into sandy wasteland. Very little natural vegetation can be found near the Loess Plateau. Only recently, grass species are being planted on the plateau where croplands have failed and serious erosion problems remain. Economic cash species are traditionally planted in the region, including *Juglans regia*, *Zizyphus jujuba*, *Pyrus bretschneideri*, *Armeniana vulgaris* and *Vitis vinifera*.

5.3.3 Temperate desert (TeBWk)

The Ecological Zone comprises the vast desert territories of Central Asia. The Ecological Zone may be described in two distinctive subzones: an eastern part covering the Gobi, Ala-Shan and Bei Shan deserts and a western part covering mainly Takla Makan desert and the Junggar basin.

Climate

The low precipitation in combination with a very high evapotranspiration leads to one of the earth's most prohibiting landscapes. Climate is very arid and continental, with hot summers and cold winters. It is also characterized by high daily fluctuations and strong regional differences. The last traces of the Chinese monsoons coming from the East are still noticeable in the Ecological Zone, which explains why rains fall in summer and rainfall diminishes from around 200 mm in the east to less than 20 mm in the west (Lop-Nor depression, 11 mm). Winter and spring are dry. Mean annual temperatures range from approximately -5^{o} to $+15^{o}$C; January mean temperatures between -20^{o} to -5^{o}C; July mean temperatures from 15^{o} to 25^{o}C.

Physiography

The Gobi is a rocky highland desert averaging 1000-1500 meters in elevation. Rugged terrain intersperses with flat, gravel lands in this large region. Nowhere in the entire western Gobi does groundwater come to the surface. There are some oases in the east. The Ala-shan desert consists largely of sandy wastes, also with elevations between 1000 and 1500 m. Bei-Shan is an ancient elevated block rising locally above 2500 m. Further westward, in the XingJiang Autonomous Region of China, are two major sandy basin deserts: Junggar Basin and Tarim Basin, surrounded by three major high mountain systems: Altai in north, Tianshan in the middle and Kunlun in south. The elevation of the two closed basins ranges from below sea level to above 1,000 meters. The difference in elevation between the basins and the surrounding mountains is a major factor leading to a permanent arid climate.

Vegetation

Vast expanses in these deserts are devoid of vegetation. Low desert shrub and grassland cover areas of Gobi and Ala-shan where local moisture availability is high, such as on low slopes or near small creeks. Woody species are few, including saxaul (*Haloxylon ammodendron*) and occur infrequently. Along large rivers, there are stands of *Populus euphratica* woodland in the region.

In the west of the Ecological Zone, deciduous broadleaved forests are scattered throughout the Yili River basin wherever local climatic conditions are favourable. At elevations of 500-1000 m, there is river-side woodland of *Malus sieversii, Armeniana vulgaris, Crataegus songorica*, *Cerasus tianshanensis*, *Populus euphratica* and *Juglans regia*. The river basin is essentially an important resource preservation area for temperate fruit species. In addition, other important forest resources also exist in the region. Plain areas along edges of the Tarim Basin, southern foothills of the Tianshan and northern foothills of the Kuenlun, support cultivated lands as they receive irrigation from melted alpine snow water.

5.3.4 Temperate mountain systems (TeM)

This Ecological Zone comprises vast mountain systems of Central Asia, including the Tibetan Plateau in China and the Altai and Khangai mountain systems of Mongolia. In addition, mountains of Japan are also part of the zone.

Climate

In lower mountains of north-central China, mean annual temperature decreases from 14 ^{o}C in warmer eastern low hills to 8^{o}C in cooler western highlands. Difference of July mean temperature is 20 versus 26 between east and west, whereas January varies between 0 and –10^{o}C. Similar patterns between eastern low hills and western highlands can be observed for distribution of precipitation. Mean annual precipitation for the temperate mountains typically averages 800 to 300 mm between east and west, most of which falls during summer. Still, this transitional region between the eastern plains and western highlands is seasonally moist to support monsoon vegetation.

On Tibetan Plateau, temperature distribution generally follows elevation contour lines. Mean annual temperature goes from 6-10^{o}C around 3000 m range to 3-7^{o}C above 4000 m and below –2^{o}C above 5000 m and July mean temperature is 16, 10 and 8^{o}C respectively. Annual

mean precipitation follows an east-west gradient from 800 mm in the east rim of the plateau to less than 50 mm in the west near Pakistan and Afghanistan border.

Climate of the Mongolian mountain systems is characterized by high contrasts in temperatures, both over the year and during the day. Annual precipitation ranges from approximately 200 to 600 mm and most of it falls during second half of summer.

Physiography

In China, the temperate mountain zone comprises the towering Tibetan Plateau—the roof of the world and the relatively lower mountains and hills transition region towards central and northern China. The transition region, averaging 1000-2000 meters in elevation, has rugged terrain with steep gullies, plateaus, ridges and the Yellow Loess Plateau, a unique and the largest wind-deposited clay plateau in northern China. The Yellow River, the second longest river of China, winds up and down through the Yellow Loess Plateau, washing away large amount of soil from the region,

The Tibetan Plateau has an average elevation of 4000 m. Most of the world's tallest mountains (> 7000 m) rise up from the region, including the tallest peak of the world Mount Everest at 8848 m. As the world's highest lake region, the Tibetan Plateau is rich with many large glacier lakes and wetlands. China's two most important rivers, the Yangtze and the Yellow, originate in the highlands and begin their journeys eastward towards the Pacific.

The Mongolian Altai is the most extensive and largest mountain range of Mongolia, with highest peaks of more than 4000 m. Traces of ancient glaciation are found in addition to contemporary small glaciers and perennial snow patches. Mongolian Altai is dissected by broad longitudinal valleys that separate several parallel mountain chains that, by erosion valleys and saddles, then are divided into separate ridges and peaks. Another major mountain region is formed by the Khangai uplands with the Khankhukhiin ridge. The heights of most ridges range between 2000 – 3500 m. An alternation between alpine relief and plateau-like summits is characteristic for this region.

Vegetation

China
The transitional region in the east of the Ecological Zone, including the Yellow Loess Plateau, has a long history of economic development and resources exploitation, resulting in only limited natural vegetation existing in the region. Natural forests exist in high, inaccessible mountains. In eastern mountains, these forests are characterized by *Pinus tabulaeformis*, *P. bungeana*, *Picea wilsonii*, *P. meyeri* and *Larix principis-rupprechtii*, individually forming their own pure stands or sometimes mixed by a small number of *Abies nephrolepis*. On the Yellow Loess Plateau and the surrounding areas, local, residual woodlands are scattered, with similar species as *Pinus tabulaeformis*, but also *P. armandi*, *Platycladus orientalis*, *Sabina chinensis*, *Quercus liaotungensis*, *Q. baronii*, *Populus davidiana*, *Betula platyphylla*, *Fraxinus chinensis*, *Toxicodendron vernicifluum*, *Zelkova sinica*, *Acer* and *Tilia* spp.

Natural forests are better preserved in western, higher mountains in the provinces of Gansu, Shanxi and Sichuan. Both conifer and broadleaf forests are present in these mountains. *Abies faxoniana* and *Picea asperata* dominate alpine conifer forests at 2500-3800 m. Conifer species that prefer warmer environment, such as *Picea wilsonii*, *P. brachytyla*, *P. complanata*,

Tsuga chinensis and *T. dumosa*, occupy lower elevations of 2000-3000 m, or sometimes at 3400 m, forming pure stands. Among the medium elevation conifer forests are *Pinus tabulaeformis* and *Cupressus chengii* in pure stands. They grow from around 1300-1400 m to 2100 m. *Pinus armandi* forests can extend up to 2,700 m altitude. Deciduous broadleaved forests are less prominent. *Betula platyphylla, B. albo-sinensis, B. utilis* and *Populus davidiana* are the most common species distributed at 2600-3500 m slopes, associated with *Tilia chinensis, Acer, Dipteronia sinensis, Populus cathayana, P. purdomii* in mixed forests.

Mongolia
There is a great diversity of mountain vegetation in Mongolia. The highlands and mountains of Altai and Khangai have up to six altitude belts: glacial, tundra, mountain-meadow, forest, forest steppe and steppe or desert (part of lowland). The forest belt mainly contains larch forests sometimes mixed with Siberian cedar or - stone pine (*Pinus sibirica*) and spruce or fir. On sandy sediments at the lower slopes pine stands dominate and, together with larch, they form the forest-steppe belt. In Mongolian-Altai the forest belt is often absent. Here the meadow steppes are well developed, with cushion plant formations in combination with *Kobresia* and *Carex* formations. The forest belt of Khangai mountains is in the range of 1800 to 2300 m and formed by of larch stands, yernik-mosses and fescue-mosses sometimes with *Kobresia* spp. and *Potentilla fruticosa*. Broad river valleys are covered by thickets of *Salix* spp. and *Potentilla fruticosa* with occasional larch.

Japan
In Japan, the lower mountain zone is covered with deciduous beech forest, dominated by *Fagus crenata* and *Quercus crispula*. The subalpine belt supports coniferous forests dominated by *Abies mariesii* and/or *A.veitchii*. The altitudinal lower limit of the coniferous forests become gradually southwards, ranging from 700 m in northern Honshu to 1500 m in central Honshu. Mixed forest of *Thuja standishii* and *Tsuga diversifolia* is developed on ridges with shallow soils in the subalpine region of Honshu. *Betula ermanii* and *Alnus maximowiczii* are deciduous tress found in the subalpine and alpine regions. Mixed or pure stands are developed on boulders and shallow soils along snow valleys and on subalpine volcanic habitats. Prevailing coniferous forests on Hokkaido are dominated by *Picea jezoensis* and *Abies sachalinensis*, sometimes accompanied with *Picea glehni*. The alpine region, above the timberline, is characterised by *Pinus pumila* thickets, also including *Vaccinum vitis-ideaea, V. axillare, Empetrum nigrum* var. *japonicum, Gaultheria miqueliana, Cornus canadensis, Rhododendron aureum* etc. Alpine heathlands are found on ridges with little snow accumulation that are subjected to severe winds in winter. The heathland communities are composed of such dwarf scrubs as *Arctous alpinus* var. *japonicus, Arcterica nana, Loiseloeuria procumbens, Vaccinium uliginosum, Empetrum, Diapensia*, etc.

5.4 BOREAL DOMAIN

5.4.1 Boreal coniferous forest (Ba)

The Ecological Zone is confined to the northern part of northeast China.

Climate

The Ecological Zone experiences a rigid climate with a cold and long winter. Mean annual temperatures range between -1^{o} and -6^{o}C, mean minimum of the coldest month below -25^{o}C, extreme low below -45^{o}C. Rivers remain frozen for one half of a year; soils are either permafrost or frozen for most part of a year. Relatively warm summers bring about a monthly mean temperature at 15^{o}C in the warmest months and a growing season of 90 days. Most of its annual mean precipitation of 500 mm falls during summer season, while winter and spring seasons are usually dry and cold with limited precipitation.

Physiography

The Ecological Zone is essentially Daxinganling (the Greater Xingan Range), a medium altitude plateau in a wedge shape, wider in north and narrower in south. Elevation ranges from 1000 m in average, 1400 m in southern mountains, 1700 m in the highest peaks, to 500 m in the northern section. Topography is gently undulating. Soil types, which are mostly shallow with gravel, poor in nutrient and highly podzolized, include podzolic soils, mountain podzolic soils and mountain frost desert soils.

Vegetation

Forests in this Ecological Zone are mostly simple, natural stands of three types. First, *Larix gmelini*, a slow growing species, spreads widely on 300-1100 m slopes and occupys about 70 percent of the total forest area in the Ecological Zone. It forms large pure stands as well as mixed stands with *Betula platyphylla*, *Populus davidiana* and *Quercus mongolica*. Second, *Pinus sylvestris* var. *mongolica* forests are mostly distributed in the north between 300-900 m, on slopes with dry, unproductive soil and also on sand and gravel dunes. It mostly forms small pure stands. Third, *Pinus pumila* dominates on mountain tops or ridges of 1100-1400 m, forming low stands of 3-4 m tall or shrubby clusters, with *Sabina davurica* as main understorey. Besides the three major coniferous forest types, *Pinus sibirica* forest is confined to the northwestern portion of the Daxinganling. Among deciduous broadleaved forests, *Betula platyphylla* and *Populus davidiana* grow as natural second-growth forests following disturbance of *Larix gmelini*, either in pure stands or in mixtures. *Quercus mongolica* forests are found in the south on dry, south-facing slopes below 600 m and have low stand density and crooked tree forms. Deciduous broadleaved mixed forests, composed of *Populus suaveolens*, *Chosenia arbutifolia*, *Ulmus davidiana* var. *japonica* and *Salix* spp., are scattered along the Heilongjiang River and its tributaries.

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6 Europe

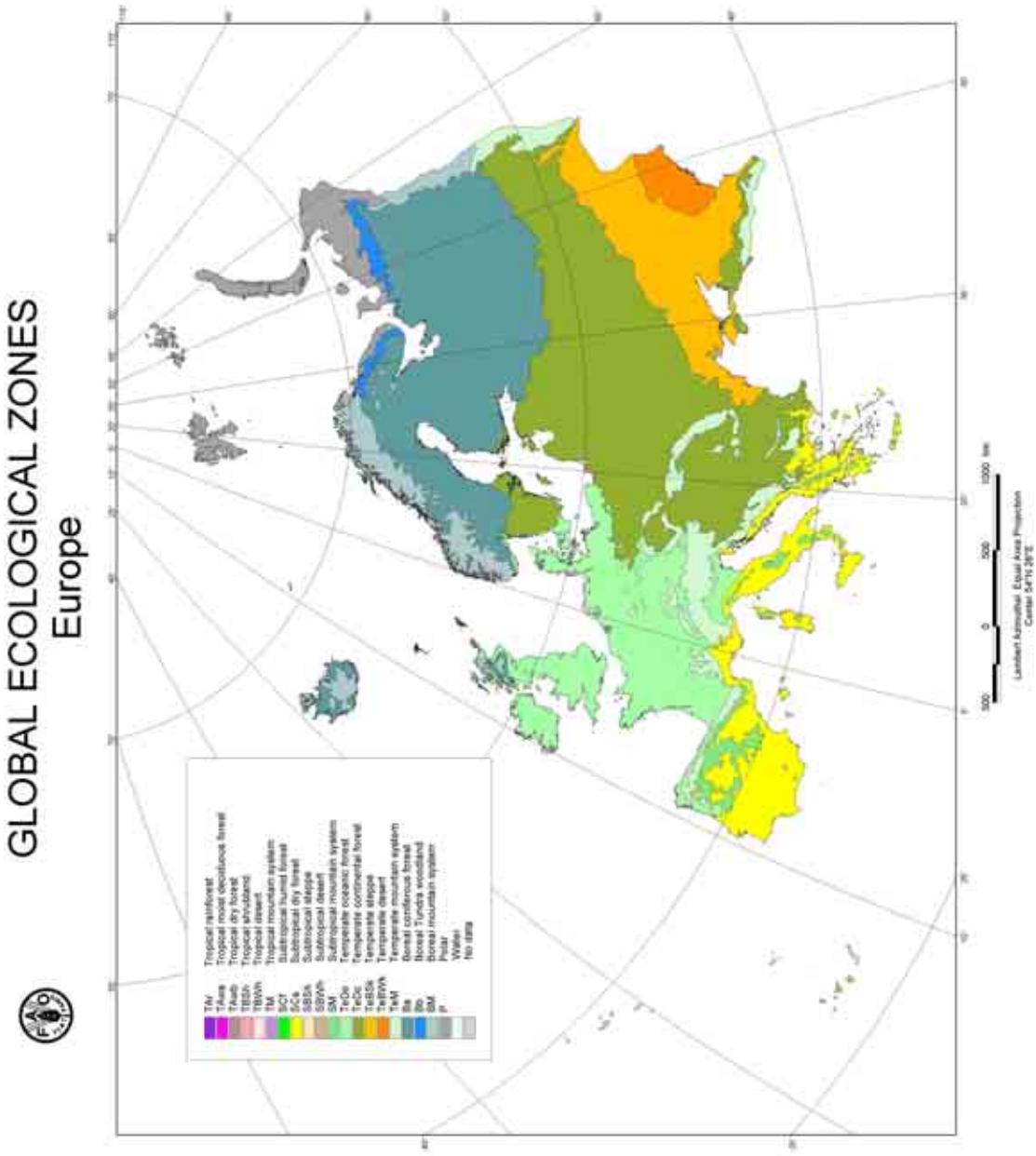

Figure 37. GEZ map of Europe.

Table 22. Global Ecological Zones of Europe.

Global Ecological Zone	Surface area		
	Km²	**% of total land area Region**	**% of GEZ worldtotal**
Subtropical dry forest	816 400	8.1	51.3
Subtropical steppe	5 008	0.0	0.1
Subtropical desert	0	0	0
Subtropical mountain systems	149 240	1.5	3.1
Temperate oceanic forest	1 287 121	12.8	71.3
Temperate continental forest	2 906 694	29.0	41.9
Temperate steppe	955 497	9.5	16.2
Temperate desert	150 343	1.5	2.8
Temperate mountain systems	605 384	6.0	8.4
Boreal coniferous forest	2 195 688	21.9	25.9
Boreal tundra woodland	87 788	0.9	2.2
Boreal mountain systems	457 623	4.6	7.3
Polar	422 632	4.2	7.8
Total land area	10 039 418	100	

6.1 SUBTROPICAL DOMAIN

6.1.1 Subtropical dry forest (SCs)

The subtropical dry forest zone roughly comprises the Iberian peninsula (except the northern part), Rhone basin, Apennines peninsula, Dalmacija and Greece, as well as all European Islands of the Mediterranean Sea. The higher parts of this area, above approximately 800 m, are excluded and belong to subtropical mountain systems.

The Ecological Zone, encompassing the Mediterranean region, forms an intermediate zone between the tropical and the temperate zone. Its limitation is roughly defined by the distribution area of *Olea europaea* and *Quercus ilex*. The subtropical dry forest zone in Europe can be divided into two main latitudinal sub-zones: Mediterranean and a northern sub-Mediterranean zone. The latter forms the transition to the temperate zone.

Climate

Subtropical dry or seasonally dry forests grow in areas with a pronounced Mediterranean winter rain climate, thus with dry warm summers and cool moist winters. Severe frosts are lacking and thermo-Mediterranean areas are generally frost-free. Precipitation maxima are normally in November/December and in February/March. The summer months bring little or no precipitation. Pronounced relief structure provides luv and lee effects for substantial mesoclimatic differentiation. Average annual precipitation is between 400 and 900 mm, rarely over 1200 mm (e.g. Kerkira) or below 400 mm (south-east Spain, south-east Crete). Eastwards the amount of precipitation is slightly decreasing. Average temperatures of the warmest month are between 25° and 28°C, those of the coldest month between 6° and 13°C. Toward the north, in the sub-Mediterranean zone, summer drought is still characteristic but less distinct. Additionally, frosts are more common here and winter temperature is lower.

Evergreen sclerophyllous tree species become replaced by relatively drought resistant deciduous tree species.

Physiography

Most of the Ecological Zone is folded in the Alpidic period, while large areas of the Iberian peninsula have their origins in the Variscian period. The geology is diverse, but the prevailing bedrock is Mesozoic or Tertiary, locally volcanic. The relief of this zone is quite varied and is expressed in a small-scale segregated landscape. Erosion processes are common and occur especially at the beginning of the rainy season after the summer drought. The erosion is enhanced by shallow or marly soils with the consequence of rapidly draining water. Due to the high sediment load, several rivers discharge into extensive deltas. Fossil Terra rossa (chromic luvisols) dominates on lime while Mediterranean cambisols have developed on siliceous bedrock. Degraded soils result mainly from anthropogenic impact and they are widespread.

According to altitude, the Mediterranean zone is generally subdivided into four belts: thermo-Mediterranean, meso-Mediterranean, supra-Mediterranean and oro-Mediterranean. Thermo- and meso-Mediterranean correspond to the conventional definition of Mediterranean. The thermo-Mediterranean belt comprises the warmest regions in the southern coastal strip with species like *Ceratonia siliqua*, *Olea europaea* subsp. *oleaster*, *Pistacia* spp. Colline altitudes, up to 800 m, in Mediterranean mountains are characterized as supra-Mediterranean.

Vegetation

The original zonal vegetation was evergreen sclerophyllous forest. Since some of the world's most ancient civilisations originated in the Mediterranean region, the natural vegetation has been impacted considerably and over large areas has given way to cultivation. The tree species composition of Mediterranean sclerophyllous forests is usually rather monotonous. Only one species dominates the canopy, often one of the evergreen oak species. *Quercus ilex* competed most successfully at humid-subhumid sites; it is represented on the Iberian peninsula outside of Cantabrica and Catalonia by *Q. ilex* subsp. *rotundifolia*, in the rest of the Mediterranean area by *Q. ilex* subsp. *ilex*. The tree layer is 15 to 18 m tall with a closed canopy; the shrub layer is usually 3-5 m tall with species such as *Buxus sempervirens, Viburnum tinus, Phillyrea media, P. angustifolia, Pistacia lentiscus, P. terebinthus, Rhamnus alaternus, Rosa sempervirens*, etc. Lianas are present and the herb layer is sparse. In drier and winter-colder areas *Q. ilex* is replaced by *Q. coccifera*. *Quercus coccifera* is particularly forest forming in the east, while in the west it hardly becomes higher than 2 m. In meso-Mediterranean areas, particularly in the transition belt to sub-Mediterranean zone, deciduous tree species can be more strongly involved. Anthropogenic oak forests and maquis with small proportion of oak species have often a close evergreen bush layer, which is usually formed by *Erica arborea, Arbutus unedo* or *A. andrachne*. At particular humid sites *Laurus nobilis* and *Myrtus communis* are frequent. Especially in the west *Quercus suber* forms distinct forest types.

In thermo-Mediterranean areas oaks are limited to special sites or climatically moderated mountain areas; here *Pinus halepensis* is often the prevailing tree species on light soils in coastal regions and on calcareous rock (in the Aegean and in the east-Mediterranean *P. brutia*). By their resistant bark and the high regeneration potential by seed germinating, *Pinus*

halepensis and *P. brutia* tolerate fire better than other tree species and profit in such a way from forest fires.

The most common type of shrub species of the thermo-Mediterranean is *Pistacia lentiscus*, usually a shrub less than 2 m high, rarely as a tree of up to 6 m. It often grows together with the wild form of the olive tree (*Olea europaea* subsp. *oleaster*) and *Ceratonia siliqua*. Further important stand forming and widespread woody species are *Juniperus phoenicea* and *J. oxycedrus* subsp. *macrocarpa*. The herb layer is species poor. Particularly shadow-tolerantly and widespread fern-like species occur (*Asplenium onopteris, Selaginella denticulata*), evergreen, partly climbing half-shrubs and lianas (*Ruscus aculeatus, Asparagus acutifolius, A. aphyllus, Smilax aspera, Rubia peregrina, R. tenuifolia*) as well as geophytes (*Cylamen* species, *Arisarum vulgare* and other *Araceae*). Furthermore, grasses, such as *Piptatherum miliaceum, P. coerulescens* and *Ampelodesmos mauritanica*, grow in the protection of low sclerophyllous shrubs.

Particularly in the Apennines and in sub-Mediterranean regions, at cooler and better water-supplied sites, mixed deciduous oak forests replace sclerophyllous forest; in the west-Mediterranean represented by *Quercus pyrenaica, Q. faginea*, eastward by *Quercus pubescens* and in the middle and east-Mediterranean by *Quercus cerris* forests. Most of these forests are mixed ones with various tree admixtures.

6.1.2 Subtropical mountain systems (SM)

This Ecological Zone comprises the Iberian mountains (Cordillera Cantabrica, Sistema Central, Sistema Berico, Penibética, Pyrenees), the Apennines, the Greek mountains (Pindus, Olympus, Peleponnesus, Crete), as well as the mountains of Corsica and Sardinia.

Climate

The mountain region of the (sub-)Mediterranean zone is characterised by higher precipitation and a shorter summer drought period than the adjacent lowland region. Due to higher altitudes the annual temperature totals are less, too. Accordingly the frequency of frosts increases.

Physiography

The mountain zone starts at about 800 m, partly from 600 m upward and exceeds up to 2000, locally to 3500 m. It is classified as oro-Mediterranean belt (montane to subalpine) within the Mediterranean region. Due to large relief energy and extensive erosion shallow soils are common. They vary corresponding to the bedrock from rendzina to leptosols. In addition, calcisols (calcic cambisols) and other cambisols occur. The dominant bedrock is Mesozoic or Tertiary, locally volcanic. Folded in the Alpidic period, volcanism is a recent feature in this region.

Vegetation

In contrast to the Mediterranean sclerophyllous forests the vegetation of the subtropical mountain belt is indicated by mainly deciduous oak species (*Quercus pyrenaica, Q. faginea, Q. petraea, Q. frainetto, Q. pubescens*). These forests are usually quite close and shady. On the Iberian peninsula *Quercus pyrenaica* forests dominate on siliceous bedrock, while *Q.*

faginea occupies base-rich sites. In the Pyrenees and eastward *Quercus pubescens* becomes more important in addition to the other oak species. In the subcanopy tree species like *Fraxinus ornus, Ostrya carpinifolia* and *Carpinus orientalis* are widespread. Within the sequence of altitudinal belts the deciduous oak forests are replaced higher up by closed and shady *Fagus sylvatica* forests, partly with *Abies alba, Picea abies*, locally with *Betula pubescens*. In the Apennines, beech forests with *Abies alba* in the tree layer and *Geranium nodosum* in the herb layer characterize the vegetation of this belt. Southward, *Geranium versicolor* becomes an important species. Additionally *Quercus cerris* forests, partly with *Q. frainetto*, are constituent of this region. In the Greek Pindus mountains *Abies borisii-regis* replaces *Abies alba* and dominates the mixed beech-fir forests. At higher altitudes the oak and beech forests are replaced by juniper and cypress woodland (*Juniperus thurifera, J. excelsa, J. foetidissima, J. polycarpos, Cupressus sempervirens*) or by pine (*Pinus nigra* agg.), as well as fir forests (*Abies pinsapo* on the Iberian peninsula, *A. cephalonica* in Greece). Oroxerophytic vegetation of thorn-cushion types with various *Astragalus* species grows in the highest areas of the mountains above the woodline.

6.2 TEMPERATE DOMAIN

6.2.1Temperate oceanic forest (TeDo)

The temperate oceanic forest zone combines spatially separated areas and comprises the Portugal-Spain coastline (Galicia, Asturia, Cantabrica, Euskal), the British Isles except the Scottish Highlands and the mountainous regions, France apart from the south-east mountainous and Mediterranean parts, Central Europe west of a rough line Danzig-Erfurt-Vienna and south of the Alps including the Po plain. In Scandinavia all of Denmark, southernmost Sweden and a narrow strip along the coast of Norway are included. Additionally some climatically sheltered fjords up to the 64° north belong to the temperate oceanic region.

Climate

The climate of the Ecological Zone is influenced by the Gulf Stream and moderated by the proximity to the ocean. The influence decreases however land inward and is replaced in the Po plain by a different climatic parameter with similar effects. The average annual temperature ranges from 7° to 13°C and annual rainfall varies from 600 to 1700 mm. While in coastal areas the temperature of the coldest month does not fall below 0°C, in the inland mean temperature is locally below 0°C.

Physiography

Mesozoic geological formations dominate this region. To the west, Precambrian and Palaeozoic bedrock predominate, while in the east Tertiary and Quaternary material are widespread. Cambisols are the most extensive soils in the Ecological Zone. Podzoluvisols and podzols occur in the northern and eastern parts and locally leptosols have developed on acidic or alkaline rocks. At the coastline of the Northsea fluvisols cover large areas; further inland they locally occur along bigger rivers and streams.

Vegetation

The vegetation is dominated by various types of beech forests and mixed beech forests (*Fagus sylvatica*). They are most extensive in Germany and neighbouring countries. Pure beech forests are relatively dense. In oceanic parts *Ilex aquifolium* is a characteristic species of the shrub layer. The herb layer may vary from poor to rich in species. Beech forests can be classified by nutrient and water supply. On nutrient poor, acidic soils beech is partly mixed with *Quercus robur* and *Quercus petraea* in the canopy. These stands are poor in species. Typical representatives of the herb layer are *Deschampsia flexuosa*, *Pteridium aquilinum* and *Vaccinium myrtillus*. On high-nutrient or base rich sites the number of plant species increases considerably and in spring many of these beech forests are covered by a luxurious geophytes carpet. Today, natural beech forests have been extensively converted into farmland. If they remained as forests they are often transformed into mixed oak-hornbeam forests. Large areas have been reforested with spruce- and Douglas fir.

On very poor, mostly sandy and acidic soils, species-poor oak forests (*Quercus robur*, *Q. petraea*) are dominating the landscape. They are accompanied by birch (*Betula pubescens*) on wetter sites. After clearing and pastoral use, dwarf shrub heath and acidic dry grassland develop. Agricultural use involves potato and grain cultivation.

Outside the distribution area of beech, oak-ash forests (*Quercus robur*, *Fraxinus excelsior*) with *Corylus avellana* and a relatively rich herb layer occupy base-rich, often calcareous soils. Oak-hornbeam forests (*Carpinus betulus, Quercus petraea*) dominate periodically moist soils. They often have a distinct vertical structure with a canopy and subcanopy. South of the Alps *Quercus cerris*, a thermophilous component may occur together with oak and hornbeam. In the southwest of the zone *Quercus pubescens* forests occupy areas under the influence of the milder climate.

Azonal vegetation types include flood plain and alluvial forests with *Quercus robur, Ulmus laevis, U. minor, Fraxinus excelsior*, in combination with willow and poplar alluvial forests (*Salix alba, S. fragilis, Populus nigra, P. alba*). Mires and, concentrated in oceanic parts, blanket bogs may occur as well as swamp and fen forests (*Alnus glutinosa*, *Betula pubescens*). They are locally of significant importance. Large-scale oak-ash forest and elm-ash forests (*Quercus robur, Fraxinus excelsior, Ulmus glabra*), occurring in the marshlands, are characteristic for the Ecological Zone. Early cultivation made these forests disappear and large areas of the original deciduous forests have been cleared. Therefore, the current area of forest and woodland for example in Denmark aggregates to around 12 % of the total land area. In addition, many deciduous stands have been replaced by coniferous forests.

6.2.2 Temperate continental forest (TeDc)

The continental temperate zone is adjacent to the oceanic region within the temperate domain. Roughly it has a triangular shape with the corners in Oslo, Sofia and Ufa. South Sweden, Eastern Europe south of the line Helsinki, Novgorod, Perm and north of the line Bucuresti, Charkov, Ufa belong to the continental temperate region. Additionally, most of the Balkan Peninsula is part of this Ecological Zone, as well as the foothills of the Crimean and Caucasus mountains.

Climate

Due to the smaller influence of the Gulf Stream, annual rainfall in the continental temperate forest zone gradually decreases from the west (c. 700 mm) to the east (c. 400 mm). Much of this region is marked by warm summers and cold winters. Mean annual temperature is about 6°-13°C in the west and decreases to 3°-9°C in the east. Accordingly the temperature of the coldest month ranges from below 0°C in Scandinavia and around 0°C at the Balkan to below - 10°C in the Ural mountains. In the northern parts of the continental Ecological Zone more than two months of the year have a mean temperature below 0°C. Additionally precipitation diminishes from northwest (> 700 mm) to southeast (400 mm). Locally in the foothills of the Caucasus rainfall is very high.

Physiography

The northern parts of the Ecological Zone are largely impacted by the glacial period and were covered by the ice sheet during the maximum extent of the ice. In this region podzols are the most important soil type. Locally, on more nutrient-rich bedrock, luvisols and rendzinas occur. In the western parts and in the south cambisols, leached brown forests soils and chernozems have been established under periglacial conditions.

Vegetation

The prevalent vegetation of the temperate continental Ecological Zone comprises various forest types, distributed along local and regional gradients in climate and nutrient availability. In the northern parts mixed coniferous-broadleaved forests form a belt parallel to the circle of latitude. Spruce forests (*Picea abies*) cover most of the area. To the east *Picea obovata* may occur. In these hemiboreal coniferous forests broad-leaved trees like *Quercus robur, Tilia cordata, Ulmus glabra, Acer platanoides* play an important role in the canopy. The shrub layer is rather poorly developed while herb layer may be rich. On highly acidic, sandy, dry to moderately moist/ partly periodically wet soils pine forests replace spruce. Natural forest stands are dominated by *Pinus sylvestris*, partly with *Picea abies* in the northeast, intermixed with *Quercus robur, Tilia cordata* in the southeast. The canopy of conifers is open to dense. A sparse shrub layer with *Juniperus communis, Sorbus aucuparia, Frangula alnus* may occur while the herb layer can be poor or rich. Typical ground vegetation are dwarf shrubs (*Vaccinium myrtillus, V. vitis-idaea, Calluna vulgaris*) and grasses (*Deschampsia flexuosa, Koeleria glauca* (in the east)). Additional types with abundant moss and/or lichen carpets occur. Soils do not produce good agricultural yields and land is therefore mainly used for forestry (pine) and in some cases as extensive pasture (sheep, goats) or farmland (rye, barley, potatoes).

Further south, deciduous broad-leaved forests are represented by mixed oak-hornbeam and mixed lime-oak forests. Mixed oak-hornbeam forests are predominant on fresh to moist, often hydromorphic soils. The trees forming these stands include *Quercus robur, Quercus petraea, Carpinus betulus* and *Tilia cordata*. Associating species like *Fraxinus excelsior* and *Acer campestre* are also important. The shrub layer alternates between luxuriant and poorly developed, while the herb layer is generally rich in species. Mixed lime-oak forests are found east of the distribution boundary of mixed oak-hornbeam forests continuing the belt of broad-leaved forests eastwards. The tree layer is dominated by *Quercus robur* and *Tilia cordata*. Depending on nutrient level, the shrub and herb layer are often sparse. Land clearing has massively decimated this type of forest.

Most of the subcontinental-sub-Mediterranean thermophilous mixed sessile oak, bitter oak and Balkan oak forests are distributed in the sub-Mediterranean and pannonic area. They occur mainly in the southeast of Europe and the Balkans (Romania, Bulgaria, Yugoslavia). Species-rich, more open, mixed forests dominated by *Quercus cerris* and *Quercus frainetto* occupy the central part of the Balkan peninsula. They consist of a well-developed shrub layer and many thermophilous species in the herb layer. Today, dense canopy forests are strongly reduced and isolated after long exploitation for coppice with standards system, meadow and pasture cultivation, agricultural use as well as woodland pasture.

The subcontinental forest steppe zone extends from southwest to northeast and forms a broad belt of deciduous forests intermixed with hemiboreal coniferous woods and true steppes on chernozem. Ratio between woodland and open land depends on relief and exposure; treeless patches on south-exposures were probably extended by human impact. *Quercus robur* dominates the tree layer, interspersed with *Acer tataricum*, *Acer campestre*, *Carpinus betulus* (only in the West) and *Tilia cordata*. The herb layer is very rich in species with meadow steppes including species of *Stipa*, *Festuca*, *Bromus*, *Carex*, *Agrostis*, *Trifolium*, *Salvia* and *Centaurea*. Original forests have been cleared to a large extent and transformed mostly into intensive farmland (wheat cultivation), rarely still into traditional meadow- and pasture cultivation.

Swamp and fen woods occur in small patches across the entire Ecological Zone. Extensive areas of this vegetation still exist in the lowlands of Poland (Biebrza-Narew lowland, Sandomierer lowland) and Belarus (pripet lowland). On permanently wet peat or peaty gley soils with permanent high groundwater level the dominant tree species is *Alnus glutinosa*, in the Northeast with *Picea abies*. The shrub layer is weakly developed. The ground layer consists of sedges, grasses and tall herbs.

Flood-plain vegetation is prominent along the middle section and lower course of the large rivers Rhine, Elbe, Oder, Vistula, Pripet, Desna, Volga, Save and Danube, on mostly rich, loamy to clayey and regularly flooded alluvial soils. Due to long-term inundation willow and poplar alluvial forests (*Populus nigra*, *Populus alba*, *Salix alba*, *Salix fragilis*) are rather poor in species. Hardwood flood-plain vegetation is highly varied in structure with *Quercus robur*, *Fraxinus excelsior*, *Ulmus minor*, *Ulmus laevis* and *Fraxinus angustifolia* (in south east Europe). Shrub layer consists of *Corylus avellana*, *Sambucus nigra*, *Crataegus laevigata*, *Euonymus europaea* and *Cornus sanguinea*. In spring, appearance of geophytic vegetation in the herb layer (*Anemone nemorosa*, *Ranunculus ficaria*, *Gagea lutea*, *Corydalis cava*) is a characteristic feature, while in summer nitrophilous herbs (*Aegopodium podagraria*, *Urtica dioica*, *Anthriscus sylvestris*) appear. River regulation and embankment have resulted in a strong decline of (near-)natural habitat and nowadays only fragments of original flood-plain forests remain.

6.2.3 Temperate steppe (TeBSk)

This Ecological Zone occupies the area south of the line between Bucuresti and Ufa excluding the Caspian plain. To the south the zone is delineated by a line from the Crimean peninsula to the mouth of the Terek River.

Climate

The climate varies with geographic location. Towards the east, the aridity is increasing as a result of decreasing precipitation, higher maximum temperatures and a stronger continentality. In the western parts, long cold frosty winters occur with temperature declining to -30°C and less. Winters are even colder and more severe in the east. In the Pontic lowlands and in the Azov plain the moderating influence of the Black Sea and the Azov Sea is notable. The mean July temperature reaches 20°-22°C in the west, in the east 25°C. Due to the low annual precipitation (in the west from 300 mm to 450-500 mm, in the east from 250 mm to 350-400 mm) and the high summer temperatures there are often dry, wind-rich periods. This phenomenon causes partial draining of the herb layer and forces the plants into a resting stage. A water deficit situation is characteristic for this Ecological Zone.

Physiography

Relief of the steppe zone is quite diverse, with various exposures and uplands forming the landscape of this semiarid region. Bedrock is characterised by types of alluvial and aeolic deposits. Since evaporation exceeds precipitation, no soil leaching but accumulation of easily soluble salts occur. Due to this feature large areas in the south of the steppe are build up of chernozems. Additionally solonetz-kastanozems occur, which often form complexes with solonetz soils. At the boundary to the deserts solonchaks occur.

Vegetation

Steppes, the main vegetation of the semi-arid region, are characterised by perennial xerophilous and often xeromorphic grasses (*Stipa, Festuca, Koeleria, Cleistogenes, Agropyron, Poa* and *Helictotrichon* spp.) and herbs (e.g. *Galatella, Tanacetum* spp.). The portion of herbs decreases towards the southeast. Additional components of the vegetation in the steppe zone are ephemeroids and geophytes as well as shrubs (e.g. *Spiraea, Rosa, Chamaecytisus, Prunus, Amygdalus, Caragana* spp.). Tomillares, *Thymus* steppes and petrophytic predominantly dwarf semishrub and dwarf shrub communities on rocky habitats are frequent. The presence of hemihalophyts and halophyts is typical for the steppe zone, particularly the southern part. Accompanying forests (mainly *Quercus robur*) are confined to sites with sufficient water supply: at slopes and in hollows, depressions and on tidal terraces.

6.2.4 Temperate desert (TeBWk)

The temperate desert zone corresponds geographically with the Caspian plain. Additionally the Transcaucasian lowland, the Kura plain, the area of Baku and the borderland of Armenia to Iran belong to this Ecological Zone.

Climate

The climate of the deserts in the temperate zone is characterised by a pronounced aridity and continentality: very low amounts of precipitation (50-250 mm); high evaporation, which exceeds the yearly precipitation to tenfold; distinct dryness during the vegetation period; high summer temperatures (July mean temperature 24°-27°C); and a cold winter (January mean temperature around -10°C) with thin snow cover.

Physiography

The harsh desert climate lead to the development of a typical desert relief with pronounced erosion and aeolic processes. In the Turanic deserts two soil types dominate: brown desert soils in the north and grey-brown desert soils in the central and south region. In the Caspian lowland light soils dominate (loamy sands and sands). Large surfaces in the desert area are formed by solonetz, solonchak and takyrs (= bare, even pan like clay soils).

Vegetation

Desert vegetation clearly reflects the physical soil characteristics. Dwarf semishrub deserts on clayey soils are poor in species. Only one perennial species dominates accompanied by 1-3 other species. Annuals are always present (e.g., *Allium, Eremurus, Ferula, Rheum, Tulipa, Carex, Poa* species) and their abundance depends on the actual weather conditions.

Hemipsammophytic vegetation on loamy-sandy soils is richer in species. They differ by specific grasses (on non- and weakly salty soils) or by dwarf semishrub communities (on soils with higher salinity). Sandy soils are characterized by psammophytic vegetation (with dwarf semishrub, semishrub, shrub, *Stipa* spp., *Agropyron fragile, Carex physodes* and specific herbs of sandy soils (annual or perennial). Dwarf semishrubs like *Artemisia* spp. are quite common as well as *Anabasis*-, *Salsola*-species. Species poor vegetation with 10-15 species is most prominent. On sandy, stony soils species number increases up to 30-40.

6.2.5 Temperate mountain systems (TeM)

The temperate mountain systems include all mountainous parts of the temperate domain. More particularly the Cantabrican mountains, Pyrenees, Massif Central, Jura, Alps, the highest sites of the British Isles mountains, the Central European uplands, Carpathians, Dinaric Alps, Balkan mountains, Rhodope mountains, the High and the Low Caucasus, the foothills of the Talysh mountains as well as the southern Ural.

Climate

As highest altitudinal belt of the temperate domain the mountain region is characterised by generally higher precipitation and lower temperature. Climate of this Ecological Zone is extremely varied. According to Luv and Lee effects at particular sites precipitation varies from over 3000 mm to <500 mm (Vale d´Aosta, Erivan). The average annual temperature ranges from -4° to 8°C (locally 12°C), the average January temperature of highest altitudes fluctuates between -10° and -4°C.

Physiography

The mountains reach around 1000 m in the northern parts up to >5600 m in the Caucasus. They are mostly folded in the Alpidic period and only the northern mountains, for instance on the British Isles and the German hilly country, are formed before. Most of the region was covered by ice in the glacial period. Glacial features are obvious and widespread. Still some glaciers exist in the Alps and in the Caucasus. Due to the varied climatic and geological conditions different soil types occur, from young shallow lithosols to deeply developed cambisols.

Vegetation

Beech forests and particularly mixed beech forests with *Abies alba, Picea abies, Acer pseudoplatanus, Fraxinus excelsior* and *Ulmus glabra* characterise the vegetation of the lower belt in this region. Similar to the oceanic region pure beech forests of higher altitudes are relatively dense. Different types of beech forests can be classified related to nutrient and water supply. With higher altitudes other tree species become more prominent. To the east *Fagus sylvatica* (subsp. *sylvatica*) is replaced by *Fagus sylvatica* subsp. *moesiaca* and further eastward by *F. sylvatica* subsp. *orientalis*. An evergreen understorey may occur.

At higher altitudes fir and spruce forests (*Abies alba, A. borisii-regis, A. nordmanniana, Picea abies, P. orientalis, P. omorika*) replace the beech forests. *Abies* and *Picea* dominate with alternating portions. *Pinus sylvestris, Fagus sylvatica*, partly *Quercus robur* and pioneer species like *Sorbus aucuparia, Populus tremula, Betula pendula* play a minor role. The shrub layer, when present, consists of *Sambucus racemosa, Frangula alnus, Rubus fruticosus* agg. Dwarf shrubs, grasses and herbs such as *Vaccinium myrtillus, Deschampsia flexuosa, Maianthemum bifolium, Oxalis acetosella, Hieracium murorum* and various acidophilous mosses (*Polytrichum formosum, Dicranum scoparium, Bazzania trilobata*) are characteristic for the ground layer.

Around the timberline pine scrub (*Pinus mugo*) partly alternating with *Rhododendron* spp. may occur. This scrub and krummholz grades at higher altitudes into alpine grasslands, various dwarf shrub vegetation and rock and scree vegetation of the alpine to nival belt.

In western parts of the Iberian peninsula oak forests (*Quercus robur, Q. pyrenaica, Q. petraea*) with *Betula pubescens* subsp. *celtiberica*, ericoides and other acidophilous species cover the top of the mountains.

In the Ural the altitudinal zonation starts with lime-oak forests (*Quercus robur, Tilia cordata*), followed by herb-rich fir-spruce forests (*Abies sibirica, Picea obovata*) with broad-leaved trees like *Ulmus glabra* and *Tilia cordata* as well as pine forests (*Pinus sylvestris*) with *Larix sibirica*.

6.3 BOREAL DOMAIN

6.3.1 Boreal coniferous forest (Ba)

This Ecological Zone occurs in the lower parts of Iceland and North Scotland. On the continent some parts of Norway, most of Sweden, nearly all of Finland and a wide belt in the European part of Russia south of the Arctic Circle belong to this region.

Climate

Within the boreal domain the coniferous/birch forest region has a cool-temperate, moist climate, varying from oceanic in the west to subcontinental in the interior and the east. Accordingly, mean annual temperature is generally low and ranges from 8°C in Scotland to just above 1°C in the northern parts of Russia. Precipitation ranges from > 900 mm in the west to 400 mm in the east, with extremes of 1200 and 300 mm. The short vegetation period (less than 120 days with >10°C mean daily temperature) is characteristic. Evaporation is low

and prolonged periods of drought are rare. Snow covers the ground for several months during the winter, more intermittently in the hemiboreal subregion.

Physiography

In the last glacial period, the north European ice sheet covered most of the boreal region. During its existence and withdrawal the ice carved out the landscape and left copious deposits which have shaped the boreal landscape in a characteristic way. The southeastern parts of this region were not covered by ice but were still greatly affected by the glacial climate and glacio-fluvial processes. The geology is characterised by old weathered sedimentary rocks and bedrock, such as gneisses and granites, generally poor in exchangeable nutrients. Locally outcrops of more nutrient-rich rocks occur. The rock formations are covered by extensive, but uneven, glacial moraine and glacio-fluvial deposits, as well as marine deposits in previously submerged coastal areas. Glacial erosion formed large undulating plains and rolling hills framed by the Scandes mountains in the west and the Ural mountains in the east, broken by occasional mountain outcrops and river valleys. Extensive forests, numerous lakes, rivers and mires form the characteristic mosaic landscapes.

Soils are generally young and shallow, with a poorly developed organic component. On well-drained ground, over large areas of the region, strongly layered, acidic podzols have formed as a result of organic acids leaching from the conifer needle litter. An intermediate soil between podzol and cambisol found in this region is podzoluvisol. Paludification, the extensive formation of peat soils or histosols, is another feature of the boreal region.

Vegetation

The glaciers of northern Europe essentially wiped the land clean of most plants and animals. This great natural perturbation is still reflected in the species and vegetation diversity of the boreal region. Most of the boreal forests are dominated by a few conifer tree species, primarily spruce (*Picea abies*) on moister ground and pine (*Pinus sylvestris*) on drier ground. East of the White Sea, mainly closer to the Ural Mountains, Siberian conifer species like *Pinus sibirica, Abies sibirica* and *Larix sibirica* may also occur. Deciduous species like birch (*Betula* spp.), aspen (*Populus tremula*), alder (*Alnus* spp.) and willow (*Salix* spp.) are characteristic as early successional stages (especially birch and aspen) or may form smaller stands among the conifers. Stands of deciduous trees are mainly associated with special habitats, often disturbed by fire or floods, or occupy particular soils. In Iceland only birch scrub and open forests occur due to the specific climate and phytogeography of the island. The vertical structure of mature boreal forests is generally quite simple, with a well-defined tree layer and a rather poorly developed shrub layer. For much of the boreal forests, the nutrient availability for the vegetation tends to be rather limited. The ground layer is dominated by ericaceous dwarf shrubs (e.g., *Calluna, Vaccinium, Empetrum* spp.), varying from dry and poor lichen and *Calluna*-dominated pine forests to somewhat moister and richer *Vaccinium*-dominated spruce forests. Grasses and herbs are more common in the ground layer on soils richer in nutrients, tall herbs being especially characteristic for the rather uncommon richest forests. The ground layer is often well developed, being dominated by bryophytes under moist conditions and lichens (e.g., *Cladonia, Cetraria* spp.) on drier ground with more accessible light. In moist old forests, an epiphytic vegetation of lichens and bryophytes is often well developed.

Mires, ombrotrophic and minerotrophic types, constitute another dominating feature of the landscape of the boreal domain. In parts of northern Finland, mires cover almost 50% of the land area. In other parts of the region, the extent of mires may vary, but generally they form characteristic landscape elements in mosaics with various forest types. Characteristic raised bogs, with a central raised area of peat, are mainly found in the southern part of the boreal domain. They are dominated by various *Sphagnum* mosses, but only a few vascular plants may be found on bogs, such as species of the genera *Carex*, *Juncus*, *Eriophorum*, additionally *Calluna vulgaris* and stunted pines (*Pinus sylvestris*). Special types of palsa mires, which are heaps of peat with a nucleus of ice, may be found in areas of permafrost, generally surrounded by minerogenous mires. The most common types of mire in the boreal region are fens on level or gently sloping ground, often mixed with smaller areas of open water, raised bogs and drier, firm ground. In Fennoscandia in particular, large areas of mires have been ditched and partly drained over the last 100 years for purposes of agriculture or forestry. This is especially the case for richer fens. The intensity of forestry in the Boreal region has increased considerably over the last 100 years. With modern technology, today forestry has the potential to restructure and transform boreal forests and the landscape over wide areas at an unprecedented scale. Since so much of biodiversity in the Boreal region is associated with forests, forestry may be considered the major force affecting biodiversity over much of this Ecological Zone.

Current forestry practices in the Boreal region are still somewhat varied, depending on access to technology, economic constraints, ownership structures and the structure and productivity of the land itself. Nevertheless, the basic model of clearcutting and forest stand management, often with planting of non-native trees, is now widely applied.

6.3.2 Boreal tundra woodland (Bb)

Boreal tundra woodland forms a narrow belt on the Kola peninsula and along the Arctic Circle to the Ural mountains.

Climate

Tundra woodlands are restricted to cold and humid climate. The average annual precipitation varies between 700 mm on the Kola peninsula and 500-550 mm east of the Pecora River. The mean annual temperature on the Kola peninsula amounts -1° to -2°C, in the north of the Russian plain -2° to -4°C (average of January -10° to -12°C or -14° to -17°C; average of July 9°-12°C or 11°-13°C). Permafrost is discontinuous but widespread.

Physiography

Altitude in this hilly country ranges from sea level up to about 500 m. Geomorphology of the region is quite heterogeneous. On the Kola peninsula old bedrock like gneisses and granites are covered by stony, shallow soils. Hilly and more or less glacial marine sites prevail in the north of the Russian plain with sandy-loamy quaternary deposits on siliceous bedrock. The geology and the actual climate support the development of podzols, podzolic gleysols and locally histosols. Cryogenous soil forming processes have induced a distinct micro relief. Soils are strongly acid (pH 4,2-4,3) to moderately acid, locally neutral.

Vegetation

The vegetation of this Ecological Zone at the forests limit comprises open woodlands of low growing trees, 4 to 6m tall, maximum up to 12m. The stands are predominantly composed of the trees *Betula pubescens* subsp. *czerepanovii* and *Picea obovata*. While *Picea obovata* dominates in the north of the Russian plain and in the Ural, *Betula pubescens* subsp. *czerepanovii*, a subatlantic-subarctic species, forms the woodland in the sub-oceanic areas of northeast Europe (Kola peninsula, sites at the left bank of the Pecora River). In the eastern parts of the zone *Larix sibirica* open woodlands may occur as small isolated stands on sandy soils. The shrub layer consists of *Betula nana*, *Ledum palustre*. In the herb layer various dwarf shrubs (*Vaccinium*-species, *Empetrum hermaphroditum, Arctostaphylos* spp.) form patches between the herb species (*Carex globularis*, *Rubus chamaemorus*, *Deschampsia flexuosa, Equisetum sylvaticum, Trientalis europaea*). Mosses and lichens (*Pleurozium schreberi, Polytrichum commune, Cladonia* spp., *Cladina* spp.) constitute in varying densities the ground layer. In the eastern parts Siberian species such as *Larix sibirica*, *Abies sibirica*, *Calamagrostis holmii* are present.

Due to the hilly landscape the tundra woodlands are often linked together with arctic-subarctic ombro-minerotrophic mires, especially palsa mires. These mires occupy the wet depressions, while the tundra woodlands cover the slopes and other well-drained sites.

6.3.3 Boreal mountain systems (BM)

The boreal mountain zone consists of 4 isolated mountainous regions. From the west to east they are the uplands of Iceland, the Scottish Highlands, the Scandinavian mountains and the parts of the northern Ural belonging to the boreal domain.

Climate

The average annual temperature is nearly everywhere below 4°C. Only in coastal areas of south Norway the temperature reaches 7°C. Annual precipitation amounts 400 mm in the east and increases westwards. Precipitation is particularly high at the Luv side of the mountains.

Physiography

Iceland has a volcanic origin, while the Scandinavian mountains and the Scottish Highlands are formed in the Precambrian and Cambrian period. Like the boreal lowlands, the mountains are highly affected by the ice age. Various glacial features like hummocks, trimline and fjords mark the landscape. Owing to various geomorphological and geological conditions different soil types occur, including podzoluvisols, podzols, gelic-dystric cambisols and gelic-dystic gleysols. The combined effects of glaciation and the cool, moist climate have strongly influenced soil formation and structure.

Vegetation

The western boreal birch woodlands have the widest distribution area in this Ecological Zone. They are composed of more or less open *Betula pubescens* subsp. *czerepanovii* forests partly with pine forests (*Pinus sylvestris*) in the eastern parts. The vertical structure is simple, with dwarf shrubs, mosses and lichens as common components. At higher altitudes above the timberline the forest vegetation is replaced by boreal alpine as well as subnival and nival

vegetation. Dwarf shrubs such as *Salix herbacea, Betula nana, Empetrum nigrum, Vaccinium myrtillus, Kobresia myosuroides* and herbs and grasses dominate the vegetation of dwarf shrub communities, grass heaths, scree vegetation and windswept heaths.

In Iceland sparse mountain pioneer vegetation occupies the highest altitudes while in the Scottish Highlands blanket bogs, heaths and dwarf shrub vegetation covers the rounded hills. In the Ural mountains coniferous forests (*Picea obovata, Pinus sibirica, Abies sibirica*) are common and widespread.

6.4 POLAR DOMAIN (P)

The Polar domain is restricted to the Island Jan Mayen, archipelagos of the Barents Sea, the north coast of the Kola peninsula east of the North Cape, as well as the European part of Russia north of the arctic circle including the neighbouring isles. In the Ural mountains the polar region stretches far to the south (nearly to 64° north).

Climate

The polar domain is characterised by a distinct cold climate. As southern boundary of the tundra for instance the 10°C July isotherm is defined. Temperature and precipitation vary, depending on geographical location and the proximity to the sea. Coastal regions under the influence of the gulf stream have a more balanced climate and a higher precipitation (Vardø: 1.1°C, 600 mm; Kolgujev: -3°C, 224 mm). The number of days with mean daily temperature above 0°C amounts to 55-118.

Physiography

Long frost periods, accompanied with cryoturbation, solifluction and permafrost, determine the landscape. Lithosols and tundra soils with polygon pattern are the main soil types.

Vegetation

In these extreme conditions trees are absent. They are replaced by shrub and dwarf shrub tundra (*Betula nana*, *Salix* spp., *Empetrum* spp., etc.). Further northwards the tundra gradually gives way to the arctic polar deserts with widely scattered individual vascular plants, where the July isotherm is 2°C and the roots of the plants do not form a continuous system.

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7 Asian part of the former Soviet Union (Northern Asia)

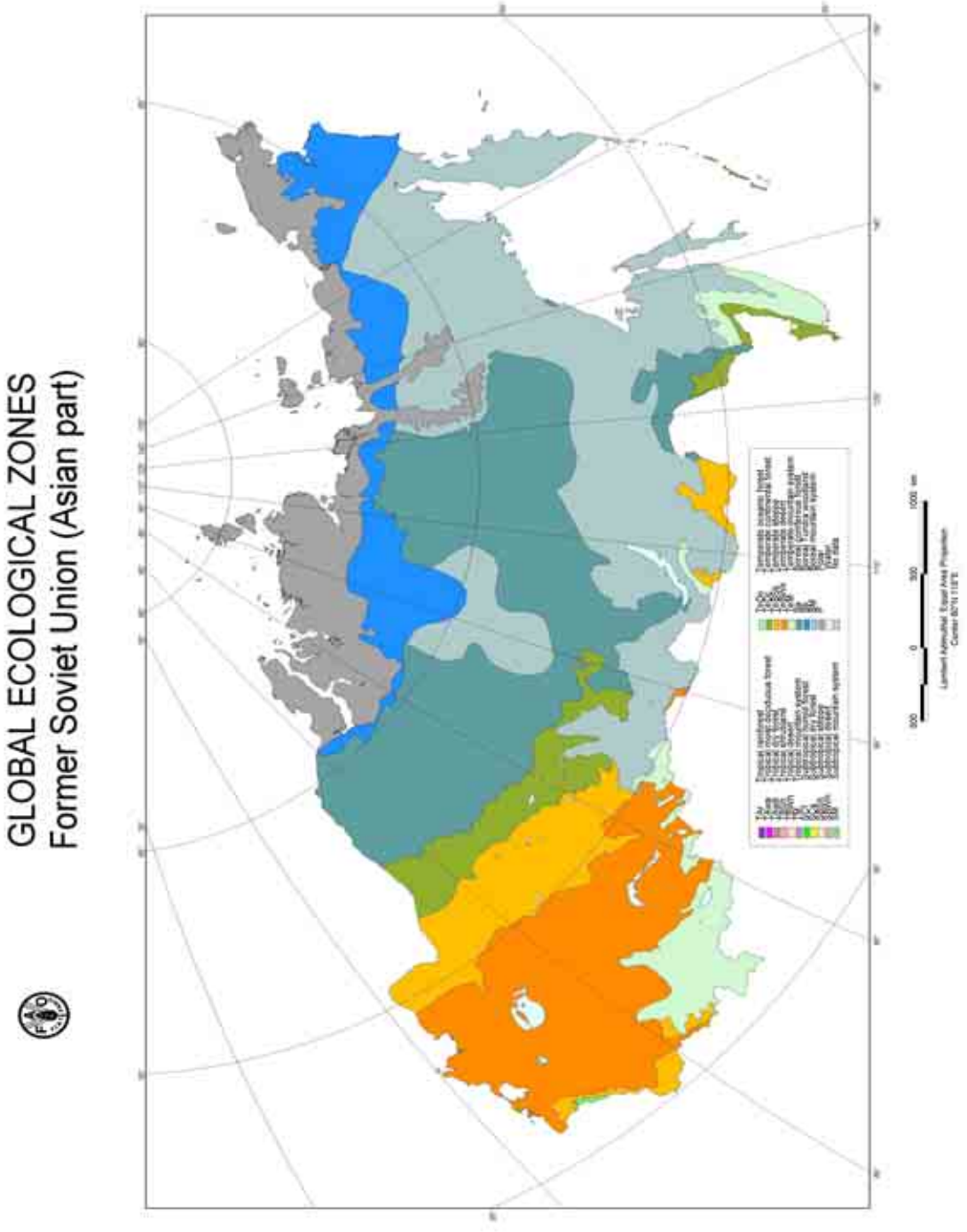

Figure 38. GEZ map of the former Soviet Union (Asian part)

Table 23. Global Ecological Zones of Asian part of FSU

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Subtropical mountain systems	6 962	0.0	0.1
Temperate oceanic forest	0	0	0
Temperate continental forest	761 670	4.6	10.1
Temperate steppe	1 202 708	7.2	20.4
Temperate desert	2 321 906	14.0	43.0
Temperate mountain systems	768 827	4.6	10.6
Boreal coniferous forest	3 924 347	23.6	46.4
Boreal tundra woodland	1 296 926	7.8	32.8
Boreal mountain systems	4 550 130	27.4	72.2
Polar	1 768 313	10.7	32.7
Total land area	16 594 827	99.9	

This vast geographic region covers the Asian part of the former Soviet Union. The European part, comprising the area west of the Urals, is described under Europe.

7.1 POLAR DOMAIN (P)

This Ecological Zone includes both the polar (arctic) deserts, including islands of the Arctic ocean-Severnaja Zemlja, Novosibirsk islands and northern upland part of the Taimir Peninsula and treeless tundras divided into three latitudinal belts - arctic tundra, northern (typical) tundra and southern (shrub) tundra. Big territories to the east from the Lena River are covered by mountain tundra which occupies plateaus and mountain systems. The southern boundary of the tundra zone is approximately along 67^{o}N in West Siberia, at Yenisey River about 69 ^{o}N and toward the east it significantly shifts to the north. In the Lena river basin the southern boundary of tundra is about 71^{o}N and in the Kolyma basin north of 68^{o}N. In basins of Okhotsk and along the Bering Sea, tundras are stretching further south (up to 60^{o}N).

Climate

The climate is extremely harsh. The severity increases from West to East Siberia and is moderated at the Arctic-Pacific coast. The temperature of the coldest month ranges from –23^{o} to -35^{o}C in West, -29^{o} to -40 ^{o}C in East Siberia and from -20^{o} to -34 ^{o}C in the Beringiiskaja tundra. The average annual temperature has similar character - from -10^{o} to -16 ^{o}C. Continuous permafrost covers all the territory. Amount of precipitation is low - basically from 100-250 mm yr^{-1} (and up to 400 mm in the western part), but everywhere significantly exceeds evaporation and humidity of soils is usually high. Length of growth period (here and below as a number of days with t > 10^{o}C) is from about 0 in the extreme north to 50 days in the south.

Physiography

Arctic country is covered with ice and snow throughout the year or through most of the year. To the south the tundra landscapes are mostly characterized by plain-like topography,

abundance of brooks, depressions and marshland. Uplands and plateaus are present in the eastern part of the belt.

Vegetation

In the southern part of the arctic deserts, on land free from ice and snow, occasional sparse vegetation of mosses and lichens is encountered, with a few grass species. Small areas are covered by grass-moss mires. Trees and shrubs are lacking. The tundras are also treeless owing to their marshiness and unfavourable climatic conditions. The northern part of the Ecological Zone is covered by prostrate dwarf shrub-herb-lichen-moss and herb-lichen-moss polygonal spotted tundras; sedge-grass-moss mires cover significant areas. To the south, in the sub-zone of typical tundras, the major vegetation types are presented by hemiprosrate dwarf shrub-lichen-moss, herb-lichen-moss hummock-spotted, tussock and low shrub tundras. Wetlands are basically presented by polygonal herb-dwarf shrub-lichen-moss mires. In the two above sub-zones, occasional low-growing willows (*Salix herbacea, S. polaris, S. reptans, S. rotundifolia, S. pulchra*) grow among the mosses as well as the creeping dwarf-birch (*Betula nana and B. exilis*). In the southern tundras, stretching further south, there are low thickets of dwarf birch, many species of willow (*Salix lanata, S. hastate, S. pulchra, S. arctica* etc.), wild rosemary (*Ledum pallustre*), bushy alder (*Alnus fruticosa*) and berry-like undershrubs, including bog bilberry (*Vaccinium uliginosum*), cowberry (*V. vitis idaea*), cranberry (*V. oxyococcus*) etc. The Taimir tundra has the highest biological production among the entire Northern Eurasia polar domain. The green foliage of the shrubs serves as summer fodder for reindeers.

7.2 BOREAL DOMAIN

The Boreal domain covers more than 85% of Asian Russia. A distinctive feature of this vast territory is a dominance of evergreen and deciduous cold coniferous forests. Although there is a limited number of major indigenous forest forming tree species (five coniferous species, i.e., pine, spruce, larch, Russian cedar pine and fir, dominate about 80% of the forests of Northern Eurasia), diversity of forest types and habitats is tremendous. The world's largest continuous larch forests (over 250 million ha) cover a major part of central and eastern Siberia. More than one third of this territory comprises mountains. There is an evident temperature gradient, which defines latitudinal zonality of lowland vegetation - from open woodlands (forest-tundra ecotone) through northern, middle and southern taiga sub-zones to transitional to the temperate domain, mixed forests. Natural disturbances - fire throughout the zone and insects outbreaks, the latter mostly in the sub-zone of southern taiga, - are a major driving force of succession dynamics and structure of forests. A major part of boreal forests is presented by different types of uneven aged forests. Altitudinal zonality in mountains repeats major regularities of latitudinal changes of vegetation and a shift of approximately 200 km northward provides similar vegetation changes as 100 m change in altitude.

7.2.1 Boreal tundra woodland (Bb)

The Asian part of the zone is a rather wide belt, stretching in longitudinal direction. Landscapes are mostly presented by the typical transition zone, with vast areas of tundra and bog vegetation, alternated by sparse low productive forests and shrubs. The northern part of

the zone, 100 to 250-300 km wide, is a "human-induced treeless belt", where lack of forests is assumed to be a consequence of anthropogenic and natural disturbances, mostly wild fires.

Climate

Climate of the Ecological Zone is under strong impact of continental and partially maritime, arctic atmospheric masses. Only in the extreme east, the impact of arctic maritime climate significantly increases, moderating the severity and continentality of climate. Severity of winter increases from the coast landinward. All territories are under continuous deep and cold permafrost. In West Siberia, in the lower reaches of the Ob River, average annual temperature is from -6° to -8 °C, January –24° to-26 °C, July 13°-14 °C. Growth period 47-57 days, the period with snow cover 235 days, precipitation 320-370 mm. In forest tundra of Central Siberia (between the Yenisey and Lena Rivers), the severity of climate increases: the average annual temperature decreases to -12° to -15 °C, January from –31° to -42°C, July 11°-14 °C. The minimal temperature reaches –58° to -65°C. The growth period is very short, from 35-60 days. Annual precipitation amounts 240-400 mm. Mountain relief in the eastern part causes a high variety of climatic indicators. The average annual temperature is from -4° to -5 °C in coastal regions to –12° to -14 °C in continental regions, January -26° to -34 °C, July - from 13°–14 °C. Growth period is short, 58-65 days and annual precipitation ranges from 310 to 550 mm. Throughout the Ecological Zone most of the precipitation falls during the warm period.

Physiography

In the west, West Siberian lowland swamps comprise a major part of the Ecological Zone. To the east from the Yenisey River, the zone occupies a part of North Siberian lowland and northern parts of Putorana plateau and Anabarskoe, which are parts of Middle Siberian upland. To the east of the Lena River, a major part of the territory is mountain, with uplands up to 400-800 m altitude, dissected by deep river valleys. The vast Kolyma lowland between the rivers of Indigirka and Kolyma adjoins the Arctic Ocean coast. The territory is a part of the Pacific belt of mezo-kainozoic plicateness. Carst and soliflucation processes are usual for the Ecological Zone like for all the Asian permafrost territories. Major soil types of the Ecological Zone are presented by tundra - and taiga frozen soils (podburs), humic and peaty soils.

Vegetation

Pretundra open woodland is usually found in lower-lying and better-drained terrain alternated by southern tundras and herb-lichen-moss palsa and herb-sphagnum-hypnum aapa mires. In the southern part of the Ecological Zone, sparse coniferous forests follow the river valleys in narrow belts of several kilometers wide. In most cases, trees are irregular in shape, with crooked boles, one sided “flag”-like crowns and sometimes a form resembling creeping arboreal plants. The soil cryogenic processes often cause the phenomenon of "tipsy forests". In the West-Siberian forest tundra, the dominant species is Siberian larch (*Larix sibirica*) with an admixture of Siberian spruce (*Picea obovata*), which form typical sparse forests with shrubs (*Betula nana, Salix phylicifolia, S. dasiclada, S. lapponum*) and a green floor of lichens and (green) mosses. In central Siberia, *Larix gmelinii* is dominant (the boundary between *Larix sibirica* and *L. gmelinii* is to the east from the Yenisey River); spruce forms the second canopy layer. The world’s most northern forest islands are described here - a forest massif Ari Mas is growing on an ancient high terrace of the Novaja River, a tributary

of the Khatanga River, at 72°30 N. To the east, in basins of Indigirka and Kolyma Rivers, the principal species are *Larix gmelini and L. cajanderi*. The latter replaces *L. gmelinii* to the east of the Lena River. A specific feature of the Ecological Zone is the abundance of dwarf pine (*Pinus pumila*) and bushy willows (*Salix udensis, S. schwerin*), which exceed in area the "high" forests. Mongolian poplar (*Populus suaveolens*) and Korean willow (*Chosenia arbutifolia*) grow in river valleys. The northern tree line goes along the reaches of the Kolyma River to the north of 69°N and to about 65°N in Chukotka, characterized by poplar, Korean willow and bushy alder.

7.2.2 Boreal coniferous forest (Ba)

The Ecological Zone of boreal cold coniferous forests covers major areas in Asian Russia. The taiga, divided in three sub-zones, northern, middle and southern taiga, is a major zonal vegetation type. The southern boundary of the southern taiga, the boundary of the Ecological Zone, goes from the interflow of rivers Tobol and Tavda to the line Tomsk-to the north of Krasnoyarsk, at about 57°N. A small island of lowland boreal forests is in the Russian Far East to the north of the Amur River.

Climate

Three major driving forces define climate of boreal West Siberia: solar energy, the Atlantic ocean from the West and the powerful East Siberian winter anticyclone from the east. Major variations of climate are two-dimensional: increase of heat from north to south and increase of continentality from west to east. The climate of the northern part is under influence of atmospheric processes of basically arctic origin. The latitudinal variation of climate is significant. To the south, the low winter temperature contrasts to relatively high summer temperature. The maximum precipitation (on average 500 mm) is in the centre of the plain (about 60° N); to the north and south amount of precipitation is lower. The snow cover plays significant role in West Siberia, defining the depth of frozen soils in winter and determining hydrology in summer.

For the northern taiga sub-zone of West Siberia: the average annual temperature is about -4 °C, January –22° to -24 °C, July 16°-17 °C, growth period 85 days, the period with snow cover 190-200 days, annual precipitation 410-450 mm. Continuous permafrost disappears in the northern taiga sub-zone. To the south, the climate becomes significantly warmer. In the middle taiga the average annual temperature is –1° to -3°C, January -19° to -22 °C, July 17°-18°C, growth period 95-105 days, with snow cover 185-195 days, annual precipitation 410-580 mm. In the southern taiga of West Siberian Plain, between the rivers Irtish and Yenisey, the average annual temperature increases to -0.4° to -1°C, January -18° to -21°C, July 16.5°-18°C, growth period 100-115 days, with snow cover 175-190 days, precipitation 410-550 mm. Throughout the Ecological Zone, rainfall is concentrated during the growing period or warm season.

To the east of the Yenisy River, continentality of climate and severity of winters significantly increase for the corresponding sub-zones. In the sparse taiga of the east part of Middle Siberian Plateau, climate is extremely continental, with little precipitation, dry spring and severe winter. The average annual temperature is -11° to -13°C, January -38° to –43°C, July 14°-17°C, growth period 63-73 days, with snow cover 228-237 days, precipitation 200-290 mm. The climate of the middle taiga (the basin of the Viljui River and more southern territories) is a little bit warmer: the average annual temperature is -6° to -10°C, January -30°

to -36°C, July 15°-19°C, growth period 80-95 days, with snow cover 195-215 days, precipitation from 220-275 mm in the north to 350-500 in the south. A major part of the zone is covered by continuous permafrost, deep (up to 600 m) and cold (-8° to -12°C) to the north, which crucially impacts structure and functioning of forest ecosystems. The melting layer is from 0.2 to 0.5 m on wetlands and up to 0.5-0.8 m on drained sites.

Physiography

The West Siberian lowland plain has a form of an amphitheatre, open to the north. Uplands, plateaus and inclined plains abound in the west, south and east, while lowlands prevail in the centre and the north where altitude does not exceed 150 m. In the north, the relief of the plain has been formed by Pleistocene glaciation, to the south from low hills of Sibirskie Uvali (63°N) - as a result of erosion and accumulative activities of rivers which belong to the basins of Ob and Yenisey Rivers. A major part of the plain is swamp. Soils of bogs are mostly presented by peat transitional moor and peaty-muck humic gleyic types. Drainage is very poor, better to the south and edges of the plain. At drainage sites, podzolic and podzolic-gleys peat and peaty soils are usual. Sod-podzolic, grey forest and humic-podzolic-gleyic soils dominate in the southern taiga. To the east of the Yenisey River the relief of the zone is presented by hilly upland territories, with altitudes up to 250-500 m. They comprise the southern and eastern parts of the Middle Siberian upland, including also Central Tungusskoe and Prilenskoe plateaus. At its eastern edge the zone includes plains along the Lena River, which are bounded by the Verkhojanky range from the east.

Vegetation

Distribution of vegetation is defined by zonality and continentality of climate. Higher humidity in the western part causes a dominance of dark coniferous forests (dominated by spruce, fir) and increasing dryness and continentality determines dominance of light coniferous forests (predominance of larch and also pine to the south) in the eastern part of the zone.

Swamps and marshland dominate the Northern taiga of the West Siberian plain. Forests of the zonal type are confined to well-drained river valleys. They are dominated by Siberian cedar pine (*Pinus sibirica*), with a mixture of spruce (*Picea obovata*), birch (*Betula pendula*), Siberian larch (*Larix sibirica*) in the north and slow growing fir (*Abies sibirica*) in the south. Secondary birch forests are extensive. Well developed green mosses cover with patches of *Sphagnum* and *Pleurozium schreberi* and lichens is typical for the northern part. The green forest floor is composed of bilberies (*Vaccinium vitis idaea* and *V. mirtillus*), different species of *Carex*, *Equisetum*. Pine with larch forests grow on sandy soils in this sub-zone; to the north pine disappears and single-species larch forests prevail. In these forests, lichens (*Cetraria cocullata, C. nivalis*) form a continuous ground cover. Wetlands are represented by raised *Sphagnum* bogs, either without trees or with a very sparse cover of pine, cedar, spruce and larch.

Watersheds in the middle taiga are covered by different types of raised and transitional bogs. Sparse cedar forests with birch usually grow in valleys. To the south, the share of wetlands significantly decreases. Uplands in middle and southern taiga are covered by cedar-spruce and cedar-spruce-fir forests on podzolic and humic-podzolic-gleyic soils. Towards the south, birch (*Betula pendula*) and aspen (*Populus tremula*) forests increase. Pine forests with lichens grow on drained sands.

To the east of the Yenisey River, dark coniferous taiga gives way to light coniferous larch and pine forests. In the northern part, in the basin of the Podkamennaja Tunguska River, larch - pine and pine forests with mosses predominate. Spruce and cedar forests with birch and aspen occur in river valleys. Hummock peat areas cover significant territories. To the south, pine dominates. The most productive Asian pine forests grow in the basin of the Angara River where growing stock volume in best sites can reach up to 500-600 $m^3 ha^{-1}$. Pine and larch forests are accompanied by lichens, mosses, grasses and fern-horse-tail forest types.

To the east, in Central Yakutia, larch is almost the single dominant species. Other species, pine and birch, occupy less than 10% of forested areas. The larch forests usually have an undergrowth of dwarf shrubs (*Vaccinium uliginosum, Arctous alpina*), the drier with *Vacinium vitis-ideae* and *Dryas crenulata* and the wetter with *Ledum palustre*. Other types include larch with *Arctostaphylos uva-ursi, Duschekia fruticosa*, mosses, *Ledum palustre, Sphagnum* on frozen taiga pale soils.

To the north, in the northwest part of Yakutia and partially in Evenkija and Taimir national district, northern taiga larch sparse forests cover about 95% of forested areas. In such forests, bilberry, mosses and lichens, together with *Betula exilis* and *Duschekia fruticosa,* form the green forest floor; presence of *Arctous erythrocarpa* and *Limnas stelleri* is a typical feature. Dwarf pine (*Pinus pumila*) cover about 4-5%, while birch is very rare. Small areas of low productive pine forests reach the Arctic circle near Zhigansk along the Lena River. Sparse larch forests are common in the south, on Olenek-Viljui plateau with sparse low canopy layer of Siberian spruce (*Picea obovata*).

7.2.3 Boreal mountain systems (BM)

The Asian mountain boreal domain is presented by two main areas - the higher part of Middle Siberian uplands, which we designate as Region 1 and vast mountain territories which occupy the south of Siberia and cover the major part of Yakutia and Far East. Considering the high diversity of vegetation in the latter area, we divide this territory in 5 regions: Region 2 - mountains of southern Siberia, 3 - mountain country from the Baikal lake to coastal Pacific ranges, 4 - the southern-west edge of the Russian continent, including the northern and middle part of Sikhote-Alin, 5 - the huge mountain territories of northeast Russia, from the Lena River including Central Yakutia toward the Korjak upland and 6 - the Pacific zone which includes Kamchatka peninsula, Sakhalin and Kuril islands.

Climate

Climate of this Ecological Zone is extremely diverse and generally severe. Snow cover is usually abundant and perseveres for considerable time of the year. Continuous, deep permafrost predominates. The harshest climate is found in the Middle Siberian uplands (Region 1) and the mountains of northeast Russia (Region 5). Here, mean annual temperatures range from -11^oC to -13^o, -14^oC, with January temperatures as low as -35^o to -43^oC and minimum temperatures of -50^o to -60^oC. July temperatures are 13^o to 16^0C and length of growing period in those regions is only 60 to 80 days. Annual rainfall amounts to 200 and 300 mm, predominantly as snow. In other mountain areas, conditions are less severe, particularly with higher minimum (January) temperatures. There is high variation in amount of precipitation; for instance the High West Altai (part of Region 2) receives up to 2000 mm of precipitation, which, together with rather warm conditions, favours growth of dark

coniferous forest vegetation. In lower East Altai, part of the same region, precipitation is much less, which favours development of larch forests. The climate of region 3, on average, is typical for the middle taiga sub-zone. Here, average annual rainfall ranges from around 450 mm in the west to around 550 mm in the east.

Physiography

Large impressive mountains border boreal Asia in the south. The Altai-Sajan system includes Altai, Salair, Kuznetsky Ala-Tau, West and East Sajan, Tuva upland of northern-west or sub-latitudinal directions. Baikal mountain country, mountains of the basin of the Baikal lake and Stanovoi range, is mostly oriented in northeast and latitudinal directions. Mountain systems and highlands alternate with low hills and inter-mountain depressions. Altai-Sajan system comprises high mountain ranges with peaks of the Alpine type, e.g. Katunsky range with a peak Belukha-4506 m, middle high mountains and accumulative plains. Vast highlands and mountain ranges with heights up to 2500-3000 m dominate Baikal mountain country. Intermountain plain hollows occupy significant areas at 500-1000 m. Mountains of Southern Siberia are a result of Mesozoic and Cainozoic activities.

Vast mountain territories stretch from the Baikal lake to the east, including ranges around the lake (Khamar Daban, Jablonevіy), Stanovoe and Aldanskoe uplands (“nagor'ja”) and Stanovoi range (up to 2400 m).

The southeast part of the mountain boreal domain comprises highlands of the basin of the Bureja River to the southeast, including northern and middle part of the Sikhote-Alin. In the north, a specific feature of the relief is a combination of high mountain ranges with deep and often wide valleys. A number of high ranges with peaks up to 1200-2500 m are situated here. The thermal regime of soil is very unfavourable due to thick ground litter (up to 40-50 cm). The extensive range Sikhote-Alin with major mountains up to 800-2000 m stretches along the Pacific coast. Between these highlands, significant lowlands with elevations of 50-100 m are situated along rivers Amur, Ussuri, Amgun' and Uda. Growth conditions correspond to middle taiga in the north and to southern taiga in the south.

The huge mountain country of Central Yakutia stretches to the north, behind the Lena River. It includes Verkhojansky range (up to 2389 m) and Chersky range (Pobeda peak, 3147 m) and Jukagir and Alazeja uplands. High mountains, Suntar-Khajt and Buordakh ranges, are covered by glaciers and everywhere continuous permafrost abounds. To the northeast Kolymskoe and Chukotskoe “nagor'ja” (uplands) are composed of medium altitude mountains. A plicate mountain system Sikhote-Alin (up to 2077 m) occupies the southeastern edge of Russian Asia. Finally, Korjak “nagor'e” (upland), Kamchatka, Sakhalin and Kuril islands consist of young geosynclinal belts of the Pacifics.

The central part of Middle Siberian uplands comprises medium altitude Putorana (up to 1701 m) and Anabarsk (905 m) plateaus and to the south, the Siverma and Viljuisk plateaus.

Vegetation

Distribution of forest vegetation, species composition and productivity of forests vary widely over these vast mountain territories. Altitudinal ranges of vegetation belts and forests in particular depend on many factors: geographical location and climate, average heights of mountain systems, exposition of macroslope, etc. While temperature is a major limiting

factor in the north, amount of precipitation and air humidity limit distribution of forest altitudinal belts in the south.

Region 1: In the Middle Siberian plateau, forests of the Putorana plateau are the most diverse. Three altitudinal belts are clearly separated here: nothern taiga (forest) belt, sub-alpine and alpine. Larch (*Larix gmelini*) forests grow up to 750-850 m in the southern part and up to 450-600 m on southern slopes in the north. Small areas of larch, usually as a dwarf form, occur up to 900 m on southern slopes. The relative productive larch forests with admixture of birch and spruce grow in southwest and western parts of the plateau. In the central and eastern parts of the plateau, forests cover only small areas at the mouth of some rivers. Lichens, green mosses, undershrubs, low grasses, grassy-bogs and sphagnum groups of sparse larch forest types occupy a major part of the territory.

Region 2: High productive dark coniferous taiga dominates in West Altai. The altitudinal zonation is as follows: the foothill belt of aspen forests with fir (*Abies sibirica*) replaces bunchgrass steppes which are situated below; uphill, the belt of fir ("chernevaja") taiga (from 400-600 to 800-900 m), with aspen in lower parts and cedar (*Pinus sibirica*) in upper ones; the next belt consists of typical dark coniferous forests (up to 1400-1500 m), dominated by cedar and fir and with very modest admixture of spruce. The sub-alpine belts (1500-1800 m) are occupied by low productive cedar forests. Undershrubs (*Caragana arborescens, C. frutex, Lonicera tatarica, Rosa* spp., *Spirea media, S. crenata, S. hyperfolia*) and high grasses (*Stipa pennata, Poa attenuata,* etc.) are well developed, in particular in lower altitudinal belts. Meadows dominate the sub-alpine belt, followed higher up by alpine tundra vegetation (*Seseli monstrosa, Doronicum altaicum,* etc.). Similar altitudinal zonation of vegetation occurs in the Salair range, Kusnetsky Ala-Tau and northern part of East and northern macroslope of West Sajan. The upper forest altitudinal belt (1800-2400 m) is usually formed by cedar-larch forests. Eastern Altai has a well-developed belt of larch forests. Forests of the Tuva region are mostly represented by larch, which cover foothills and middle mountains (up to 1400 m). Cedar forms a narrow belt above the larch forests, usually in the east part of Tuva (up to 1700-1900 m).

Region 3: An absolute dominance of larch is typical for the western part of the region with usually in association with cedar and spruce (*Picea obovata*) and *Pinus pumila* in undershrubs. Dwarf pine and alder form a sub-alpine belt. Pine forests grow in river valleys. Towards the east, dark coniferous species do not play any significant role, but pine and birch are common. Rather productive larch and pine forests are found in the east.

Region 4: In the northern part, forest vegetation is expressed by an alternation of larch forests on cold soils and spruce (*Picea ajanensis*) forests on warmer soils, with admixture of *Abies nephrolepis, Betula platyphylla* and *Pinus sylvestris*. Poplar (*Populus maximovichi*), bird-cherry trees (*Padus asiatica* and *P. maackii*) and others are common in the lower belt. *Pinus pumila* is widely distributed in high mountain areas. To the southeast, spruce (*Picea ajanensis*) and fir (*Abies nephrolepis*) with some admixture of Korean cedar pine (*Pinus korajemsis*) and some broadleaved species comprise the zonal forest vegetation. Korean cedar pine together with spruce, fir and broadleaved species, including *Tilia amurensis,* different maples, etc., constitute a common forest type. There is a significant admixture of *Fraxinus mandzhurica, Ulmus lacinata, Juglands mandzhurica,* forming a belt of mixed coniferous broadleaved forests, mostly in river valleys and lower parts of mountains. *Pinus korajensis* forests decreased considerably during last decades due to insufficient management. Lowlands

in lower reaches of the Amur River are covered by spruce and fir forests, like a major part of the forest belt in northern and middle Sikhote- Alin.

Region 5: In the north (Yukagir upland), sparse larch (*Larix cajanderi*) forests, either single-species or in association with *Betula kajanderi*, cover extensive areas. Korean willow and popular grow in river valleys. Dwarf pine (*Pinus pumila*) covers only small area due to high continentality of climate. In the central part, dominated by mountain systems of Vekhojansky and Chersky ranges, the top level is presented by stony deserts, which are replaced by mountain tundra downhill. Further down (1800-1400 m) followed by a sub-alpine belt with *Pinus pumila.* Low productive sparse larch forests generate a belt from approximately 1400 to 500 m altitude, on southern slopes. Relatively stocked larch forests cover the lower altitudinal belts and river valleys. Wild fires often decrease productivity of larch forests. Four major altitudinal belts are observed to the east, in the coastal zone of the Okhotsk sea, from low to high altitude: 1) a belt of stocked larch forests, on average up to 400-500 m; 2) low productive sparse larch forests with *Pinus pumila*, from about 400-500 to 700-1200m. Larch sphagnum sparse forests with *Vaccinium, Ledum,* etc., are common on northern slopes; 3) usually above 700-1000 m to 900-1400 m, the sub-alpine belt dominated by *Pinus pumila*, which cover here more than 50% of the area and 4) mountain tundra. To the west, on Oimjakon upland, continentality of climate increases significantly. *Pinus pumila* plays a significant role in the sub-alpine belt where precipitation is higher. *Larix cajanderi* is a major forest forming species, sometimes with admixture of birch and poplar. A specific feature of this region is the presence of cold steppe cenoses, which are widely distributed in dry lowland along the Jana River.

Region 6: The mild cool and very humid climate of the coastal part of Kamchatka favours a wide distribution of meadow vegetation. Forests are mostly dominated by stone birch (*Betula ermani*), which forms specific open park forests with strong meadow ground cover. Dwarf pine (*Pinus pumila*) and bushy alder (*Duschekia kamchatika*) and grassy-Sphagnum bogs with *Myrica tomentosa* can be found at the east coast and sub-oceanic raised bogs with *Empetrum sibiricum, Myrica tomentosa, Carex middemdorfii* at the west coast. In mountain depressions, along the Kamchatka River, bottom and foothills of the depression are covered by larch and, covering small areas, spruce forests. Further up-hill is a belt of park birch forests, followed by vegetation of *Pinus pumila* and *Duschekia kamchatica*. Peaks are covered by mountain tundra. The northern part of Sakhalin island is dominated by larch (*Larix kurilensis*) forests; while *Pinus pumila* and sparse forests of *Betula ermanii* occur along the coast and at the altitudinal treeline. Rather productive spruce (*Picea ajanensis*) and fir (*Abies sachalinensis*) forests grow on the middle part of the island. Elements of nemoral flora are found in forests of the southern part: *Quercus mongolica, Fraxinus mandzhurica and* others. Across the island, bamboo brakes (*Sasa kurilensis*) cover significant areas, in particular in the southern part, as a result of intensive man-induced forest fire.

7.3 TEMPERATE DOMAIN

7.3.1 Temperate continental forest (TeDc)

In Asian Russia, just east of the Urals, this Ecological Zone comprises a relatively narrow belt with a typical transitional character and getting narrower to the east. There are different classifications of this territory in Russian publications - zone of deciduous forests, southern subzone of mixed forests, sub-taiga forests, etc. In the FAO EZ system, the zone includes the

northern part of forest steppe. There is also a small island of temperate continental forest along the Amur River in the Russian Far East.

Climate

Climate of the Siberian part of the Ecological Zone is moderately continental. Continentality increases from west to east. For the western part of the zone, from Zaural (Behind-Ural) plain to the Yenisey River the climatic indicators change as follows: annual average temperature decreases from 0.2^{o} to -1.5^{o}C, the mean January temperature from -18^{o} to -20.5^{o}C. Mean July temperatures increases from 17.5^{o} to 18.5^{o} C, growth period 115-120 days, precipitation 360-450 mm. Deep snow, about 45-50 cm, stays for 165-175 days.

Physiography

A major part of the Ecological Zone is on the West Siberian plain. Areas of wetlands are smaller than in the north. Grey forest and sod-podzolic soils are usual for drained sites in the north; dark grey forest soils and different types of transformed chernozems are mostly presented in forest steppe. Peat-boggy and humic boggy soils are presented on bogs. There are usually clay soils on watersheds and sandy soils along rivers.

Vegetation

Birch (*Betula pendula*) in association with aspen (*Populus tremula*) constitutes a major forest type. Pine forests, sometimes with larch, grow on sandy soils along rivers. Dark coniferous forests are confined to small areas in the northern part. Birch forests vary from dense, high productive stands with a forest-meadow green floor in the north, to sparse park forests with steppe floor (*Calamagrostis arundinaces, Brachipodium pinnatum, Aeropodium podgraria*) in the south. In the zone of forest-steppe, islands of birch and aspen forests alternate with grass steppe (*Stipa tirsa, S. zalesski, Poa angustifolia, Calamagrostis epigeios, Carex pediformis, Filipendula vulgaris,* etc.). Bogs are mostly of the grassy types. To the south, the Ecological Zone includes the northern part of forest steppe - meadow steppes and steppificated meadows in combination with islands of small-leaved forests. In Middle Siberia, the zonal forest types are presented by grassy forest with dominance of pine, sometimes larch and birch and territories of forest steppe.

In the Far East, sub-taiga oak-pine and oak-larch forests (*Pinus sylvestris, Larix gmelini, Quercus mongolica, Betula davurica, B. platyphyyla*) grow along the Amur River, with a mixture of dark coniferous and broadleaved species (*Abies nephrolepis, Picea ajanensis, Tilia amurensis*). These mixed forests grade into Amur and Manchurian forest-steppe dominated by *Quercus mongolica* and *Ulmus pumila* mixed with *Betula davurica*. In the undershrubs and green forest floor one finds *Arundinella anomala, Filifoloium sibircum, Clematis hexapertala*. The share of *Corelus heterophylla*, *Lespedeza bicolor* and *L. juncea* increases to the south.

7.3.2 Temperate steppe (TeBSk)

Climate

Climate of the eastern part of the Ecological Zone (steppes of West Siberia and East Kazakhstan) is under strong influence of continental air of East-Siberian origin during winter, causing stable dry and cold weather. At the western side, impact of marine air coming from the Atlantic is sometimes significant, specifically during summer, as well as some influence of cold arctic air and dry and very warm air from arid regions of Middle Asia. As a result, severe winters and rather hot summers characterize the climate of the Ecological Zone. Major climatic indicators for the western part are: annual average temperature from -1.2^{o} to 0.3^{o}C, January –18^{o} to -20.5 ^{o}C, July 19-20^{o}C, growth period 125-135 days, precipitation 250-320 mm, snow depth from 25-45 cm. To the east, the annual average temperature increases to 0.7^{o} to 1.8^{o}C, while precipitation is lower, 210-270 mm. Very low winter temperatures, as low as –45^{o} to -48^{o}C, can occur throughout the Ecological Zone.

Two separated small areas of the zone are in Burjatia and in Dahurija of which the major part is outside Russia. The climate in these regions is continental. Average annual temperature decreases to -1.8^{o} to -3.4 ^{o}C, average temperature of January is –23^{o} to -32^{o}C, July 18-20 ^{o}C, growth period about 110-115 days, precipitation 290-340 mm. Absolute minimum in winter is –46^{o} to -56^{o}C.

Physiography

The Ecological Zone comprises a belt oriented from west to east, from the Pricaspian lowland, through low hills of the southern Urals and the northern part of the Turan lowland, to uplands of the “Kazhakhs melkosopochnik” (small hills).

Vegetation

From north to south, the Ecological Zone includes sub-zones of northern (forb-bunchgrass) steppes, middle (dry) steppes and southern (desertified) steppes. Severe winters hinder growth of broadleaves species, which are restricted to patches of natural birch and aspen forests. Small areas are covered by pine. Toward the south, forest areas are dramatically decreasing and a limited number of shrubs occur in the semi-desert part of the zone. The major woody vegetation includes: 1) pine, birch and aspen forests of dry sandy soils; 2) pine, birch and aspen forests of stony sites of the “melkosopochnik”; and 3) willow and poplar forests of flood-lands along rivers.

The steppe vegetation is composed of *Stipa zalesskii, S. capillata, S. lessingiana, S. pennata, Helictotrichon desertorum, Festuca valesiaca, Koeleria cristata, Peucedanum morisonii, Salvia stepposa, Filipendula vulgaris, Artemisia frigida,* etc., sometimes with shrubs, including *Spirea hyperecifolia, S. crenata, Caragana frutex, C. pumila, C. balchschensis*.

In the eastern part of the Ecological Zone, Burjatia and Dahuria, forest patches are formed by birch (*Betula platyphylla, B. davurica*), pine (*Pinus sylvestris*) and larch (*Larix sibirica and L. dahurica*) and in river valleys by *Ulmus pumila*. Steppe vegetation is of the Mongolian type. In the northern subzone, species include *Stipa baicalenis, Leymus chinensis, Festuca lanensis, Clematix hexapetala, Hemerocalis minor, Phlojodicarpus sibiricus*. On dry steppes one finds

Stipa krylovii, Cleistgenes squarrosa, Koeleria cristata, Agropyron cristatum, Poa botryoides, Artemisia frigida, Carex dariuscula.

7.3.3 Temperate desert (TeBWk)

Climate

Climate of the Ecological Zone is ruled by continental air under hot conditions. Masses of sea air coming from the Atlantic become dry and hot and practically do not bring any precipitation. In particular the southern desert zone remains very dry. Winter and mostly spring cyclones, formed along the polar front of tropical air at the southern boundary of the Ecological Zone, are a major source of precipitation. Long periods of very high temperature and lack of precipitation generate an extremely dry climate. Severe frosts are usual during winter. Average climatic indicators for the northern desert sub-zone, the northern coast of Caspian Sea, are as follows: annual average temperature 7-8^{o}C, January –10^{o} to -11^{o}C, July 25-28^{o}C, growth period 175 days and precipitation 160-230 mm. For the southern deserts of Turan lowland: annual average temperature 13^{o} to 16^{o}C, January –4 to 0.4 ^{o}C, July 30-32 ^{o}C, growth period 220 days, precipitation 90-110 mm and practically no rain during summer.

Physiography

The Ecological Zone includes the major part of the very diverse Turan lowland from the Caspian Sea to the mountain systems of Pamir-Altaj and Tien Shan. The lowest locations involve a number of depressions: Karagie (-132 m), Akchakaja (-81 m). Vast lowlands, Juzhno-Karakumskaj, Priaralskaja and Sirdar'inskaja, have elevations less than 200 m. Plains of marine -, alluvial, or arid-denudation origin are major elements of relief, among which there are neogene plateaus with steep ledges (Turgai, Ust-Yurt, Zaunguz, etc.) up to 300-400 m. Brown (semidesert) and brown solonetzic and solonchakous soils, as well as solonchaks and solonetzs are dominant soils of the desert zone. The Ecological Zone is usually divided in two, a northern and southern, or three desert sub-zones.

Vegetation

Existence of woody vegetation here is possible only through additional supply of humidity from soils or on sands. Only xerophytic species can grow under those conditions. The major vegetation types are dwarf semishrub, petrophytic and psammophytic shrub desert vegetation communities, with different species of wormwood (*Artemisia larchiana, A. pauciflora, A. arenaria, A. semiarida, A. terrae-albae, A. turanica. A. santolina and* many others) and grasses such as *Poa balboa, Stipa sareptana, S. lessingiana, S. sareptana.* To the southeast, juzgun (*Caligonum* spp.) and saxaul (*Haloxylon aphullum* and *H. persicum*) prevail. Two types of forest associations are present in the desert zone: *saxaul* and *tugai* forests. Saxaul forests are mostly formed by white saxaul (*Haloxylon persicum*), common in sandy deserts, black saxaul (*H. apphulum*) which grows on saline clay soils and to a much lesser extent by *H. ammodendron*. Saxaul forests are very specific: there is no shadow inside the forests and the above ground woody biomass does not exceed 20t/ha, usually only around 2-3 t/ha. Tugai forests grow on floodplains of big rivers (Amu Daria, Chu, Ili, Syr Daria, etc.), dominated by different species of willow (*Salix* spp.), poplar (*Populus diversifolia, P. liwinoviana, P. pruinosa*), ash (*Fraxinus patamopholia*) and accompanied by shrubs of the genera *Tamarix, Berberis, Hippophae* and others.

7.3.4 Temperate mountain systems (TeM)

In the Asian part, the Ecological Zone is basically represented by two isolated regions: a) the mountain systems Pamir-Alai and Tien-Shan with Jungar Alatau and b) the southern regions of Sikhote Alin in the Russian Far East.

Climate

The Pamir-Tien Shan mountain sytem is situated within significant desert areas and is under the impact of dry continental air. Nevertheless, marine air from the Atlantic reaching the system is rather humid in its upper untransformed part and leaves a significant amount of precipitation on windward slopes of the highest mountain ranges. Precipitation in foothills is exclusively generated by winter-spring cyclones. It defines a dry with hot summer climate in lower parts of mountains and a more humid type with increase of elevation. For the northern part of Tien Shan major climatic indicators are: a) at foothill belt of dry feather-grass steppe: average annual temperature 7.3^{o}C, January - 8.8 ^{o}C, July 22.2 ^{o}C, minimal –36^{o} to -38^{o}C, growth period 173 days, precipitation 300 mm; b) at the altitudinal belt of meadow and spruce forests from the lower to upper boundary of the belt: average annual temperature from 6.8^{o} to 2.6^{o}C; January, from -4.3^{o} to -7.3^{o}C; July, from 18.1^{o} to 12.8 ^{o}C; minimal –35 ^{o} to -38^{o}C; length of the growth period from 145 to 83 days, precipitation from 840 to 880 mm.

The Southern Sikhote Alin mountain system has a favourable, more moderate climate. Diversity of local climates is high and the warming effect of Japanese sea is significant. On western slopes of Sikhote Alin, in the zone of mixed forests, annual average temperature is 0.4^{o}C, January -23^{o}C, July 20^{o}C, growth period 130 days; precipitation 830 mm, concentrated in summer.

Physiography

Tien-Shan mountains, with Pobedi peak at 7439 m, are surrounded by two deserts: Mujunkum in the north and the Kizil-Kum to the west. The system comprises a number of high ranges, oriented in latitudinal direction. The West Pamir has an extremely rugged relief, with high ranges up to 6000 m oriented from west to east. The East Pamir comprises highlands with elevation up to 6200-6900 m. Trees cannot grow here and some shrubs (*Ribes villosum, Berberis kaschgarica, Hippophae rhamnoides*) reach here highest for all Central Asia elevations up to 4000-4700 m.

Vegetation

Northern macroslopes of the Middle Asia system are under impact of arctic air, which defines dominance of boreal elements such as aspen, birch and spruce. The foothills are covered by dry feather-grass steppe with xerophytic shrubs in gorges. Above this zone, a wide belt of forb-bunchgrass and meadow steppe alternates with shrubs, generated by the genera *Rosa, Crataegus, Rhamnus,* etc. and patches of deciduous forest on the more humid sites. This forest is dominated by *Populus tianshanica, Malus semenovii*, with *Juniperus turkestanica* and other shrubs in the eundergrowth. The next belt is formed by meadows and meadow steppe with areas of spruce forests (*Picea schrenkiana*) with a mixture of deciduous species and dense undershrubs. Dry stony slopes are covered by dwarf archa (*Juniperus turkestanica*). Upward we find Alpine meadows and tipchak steppes. A similar altitudinal succession can be observed on other macroslopes, however usually with a higher presence of thermophilous

elements (e.g. *Juglands regia*). Major types of forests in the Pamirs are broadleaved forests of *Platanus orientalis, Jugland regia, Acer turkestanicum, Malus silversii* at 1000 to 2400 m altitude. The upper belt is formed by archa (*Juniperus seravshanica, J. semiglobosa*), which extends from 1800 to 3400 m, different birches (*Betula turkestanica, B. pamirica*, etc.) and poplar (*Populus pamirica*). Small forest patches of the latter reach locally up to 3800 m.

The succession of altitudinal vegetation belts in Southern Sikhote-Alin is as follows (from low to high altitude):

- broadleaf forests (*Quercus mongoliva, Betula davurica*);
- mixed coniferous-broadleaf forest (*Pinus koraiensis, Tilia amurensis, T.mandshurica, Acer mono, A. pseudosibolfianum, Fraxinus fhynchphylla, Actinidia kolomikta, Vitis amurensis*);
- taiga (*Abies nephrolepis, Picea koraiensis, Orlopanax elatus, Clintonia udensis*);
- open woodland (*Betula lanata, Abies nephrolepis, Picea ajanensis, Weigella middendorffiana*);
- dwarf communities (*Microbiota decussata, Syringa wolfii, Pinus pumila*);
- mountain tundra (*Diapensia obovata, Ledum macrophyllum, Cassiope ericoides*).

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8 Oceania

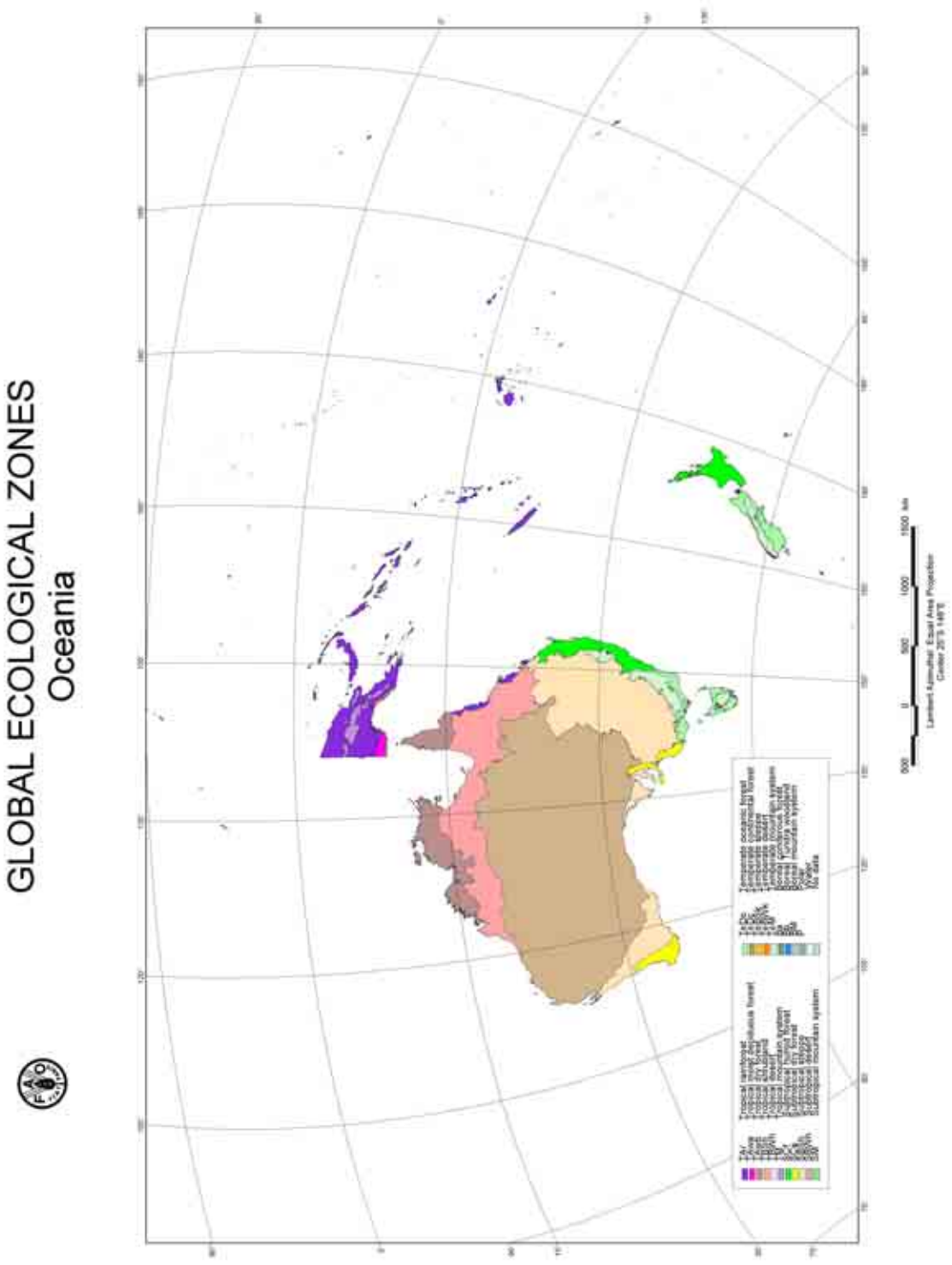

Figure 39. GEZ map for Oceania.

Table 24. Global Ecological Zones of Oceania.

Global Ecological Zone	Surface area		
	Km^2	% of total land area Region	% of GEZ worldtotal
Tropical rain forest	481 313	5.6	3.3
Tropical moist deciduous forest	26 298	0.3	0.2
Tropical dry forest	468 003	5.5	6.3
Tropical shrubland	1 063 413	12.5	12.8
Tropical desert	0	0	0
Tropical mountain systems	71 204	0.8	1.6
Subtropical humid forest	281 176	3.3	6.0
Subtropical dry forest	123 342	1.4	7.8
Subtropical steppe	1 461 055	17.1	29.8
Subtropical desert	4 139 152	48.5	26.9
Subtropical mountain systems	0	0	0
Temperate oceanic forest	218 534	2.6	12.1
Temperate continental forest	0	0	0
Temperate steppe	0	0	0
Temperate desert	0	0	0
Temperate mountain systems	193 632	2.3	2.7
Total land area	8 527 122	99.9	

Oceania comprises Australia, New Zealand, Papua New Guinea and the Pacific Islands (Micronesian, Melanesian and Polynesian Archipelagos). The descriptions of the Ecological Zones of Papua New Guinea are already dealt with under Asia. This country forms an ecological entity with the western half of the island of New Guinea, Irian Jaya, a province of Indonesia.

8.1 TROPICAL DOMAIN

8.1.1 Tropical rain forest (TAr)

In Oceania, the Pacific Islands and small patches in northeastern Australia (Queensland) constitute this Ecological Zone, in addition to a large portion of Papua New Guinea.

Climate

The climate of the Pacific Islands is dominated by the trade winds. These winds take up moisture over the ocean and most of the Islands have ample precipitation. The average annual precipitation generally varies between 1500 and 4000 mm and the dry season is not severe. However, abundance of rains depends on the relief and, in the case of relatively high islands, conditions on the leeward side may be fairly dry, locally less than 1000 mm. Mean temperature at sea level is about 23^{o}C near the Tropics and 27^{o}C at the equator. The difference in temperature between the between the hottest and the coolest month is small owing to the oceanic environment. Cyclonic disturbances, occurring generally at about the

end of the warm season, mainly affect the western Pacific archipelagos (Melanesia, western Micronesia).

The coastal area of northeastern Australia has a tropical wet climate and receives the highest annual rainfall in Australia. It has a mean annual precipitation of 1500-2500 mm with some areas exceeding 4500 mm per year. The precipitation distribution exhibits a marked summer maximum, with the majority occurring from January to March. The mean annual temperature is around 23^{o}C with summer mean maximum of around 30^{o}C and winter maximum of 20-23^{o}C degrees. Winter mean minimum temperatures are generally around 12-15^{o}C.

Physiography

With the exception of New Caledonia, where varied sedimentary rocks are found, the oldest dating from the Permian, the Pacific Islands are relatively recent and almost entirely composed of volcanic rocks of basaltic or andesitic composition, dating from the Miocene to the present. Lava flows have been partly covered by limestone during the period when the volcanic deposits were below the ocean; subsequently, coral-reef terraces may have been raised by a relative decline of the sea level. Most of the high islands have a rugged relief which involves great heterogeneity of the microclimatological and edaphic conditions. Common soils include various types of ferralitic soils developed from acid volcanic rocks. Around active or recently extinct volcanoes (Hawaiian Islands, Samoa, Vanuata), there are raw mineral soils and andosoils. On the low coral islands and calcareous cliffs, rendzinas are commonly found.

The landscape of the Northeastern coast of Australia began to evolve into their present form during the latter part of the Tertiary. During the Pliocene strong block faulting broke up an ancient peneplain, uplifting the tablelands but causing subsidence of the coastal plain and continental shelf. These movements were accompanied by sporadic volcanism. Three types of rain forest soils can be distinguished: a) granitic soils on foothills and mountains; b) metamorphic soils derived from ancient shales which underlay the old peneplain and c) the basaltic soils mainly of the tablelands.

Vegetation

Pacific Islands
The rain forests of the tropical Pacific are generally evergreen. Their structure is comparable to that of the Indo-Malaya forests, with several synusia, but the flora of the dominant strata is often relatively poor.

Various types of rain forest at low and medium altitudes do occur, related to soil type. The tallest hardwood forests are found on deep volcanic soils. Height of the formations ranges from 30 to 45m. About a dozen big tree species (*Calophyllum, Campnosperma, Dilenia, Elaeocarpus, Endospermum, Gmelina, Maranthes, Parinari, Schizomeria, Terminalia*) are the main constituents of the main canopy, overtopped at long intervals by banyan figs (*Ficus*) and by *Terminalia calamansanay*. Trees with large buttresses are frequent, especially in the alluvial areas. Vines and epiphytes abound. In Vanuatu, Fiji and Samoa this forest type is somewhat lower (about 30 m) and floristic composition is slightly different. The New Caledonia hardwood forests are found mainly on soils derived from sandstone. The flora is totally different from that of the forests in other parts of Melanesia. Clusiaceae (*Calophyllum, Montrouziera*), Cunoniaceae, Myrtaceae, Myrtoideae, Proteaceae, Sapotaceae predominate in

the upper stratum. On limestone of the atolls grows a poorer type of forest; trees are 15 to 25 m tall with some emergents. In certain special environments, (peaty soils, altitudinal margins of distribution) broad-leaved forests with a single species dominating the upper stratum are found. Examples are the *Nothofagus* forests in New Caledonia, linked to ultrabasics and mainly found at medium to high altitudes and the *Metrosideros collina* forests which is found throughout the tropical Pacific for instance as a pioneer vegetation on lava flows.

Coniferous forests, often mixed with broadleaved species, have a limited distribution throughout the Pacific. The coniferous trees belong to the Araucariaceae, Cupressaceae, Podocarpacea and Taxaceae.

Mangroves cover rather large areas in the Melanesian archipelagos and in the Caroline Islands. The forest can reach a height of 25 meters and the main constituents are Rhizophoraceae together with the genera *Avicennia, Lumnitzera, Sonneratia and Xylocarpus.*

Australia
Tropical rainforests constitute around 1 million hectares of Australia's forests. They are generally clearly demarcated from the eucalypt forest in their mature successional state. However, many areas currently exist where *Eucalyptus* species such as *E. grandis* occur as emergents in the canopy. The forest canopy ranges from around 30 to 40 m high, with emergent trees up to 50 m. In floristic composition, they resemble the rainforests of Indo-Malaya, except for the complete absence of Dipterocarpaceae. However, there are a number of Australian endemics, which are often a major component of the emergent tree strata. They include species of *Flindersia, Cardwellia, Musgravea, Placospermum, Buckinghamia, Darlingia, Backhousia, Blepharocarya, Castanospermum, Ceratopetalum* and *Doryphora*. The presence of several primitive and restricted angiosperm genera - *Idiospermum, Austrobaileya, Sphenostemon, Bubbia, Ostrearia, Neostrearia, Eupomatia* and *Galbulimima* – add a further distinctive character to the rainforests of the region. Comparison with other rainforests shows that the species richness of the forests is greater than tropical rainforests in Africa and the Americas but less than those in some parts of southeast Asia.

Local variation in forest types occur, related to soil type, slope etc. and is expressed in tree composition and forest structure. Specialised life forms such as vines, epiphytes and pachycauls are present in most communities. Vines are usually numerous and include several species of climbing palm (*Calamus* spp.). Palms, especially *Archontophoenix alexandrae, Licuala ramsayi, Orania appendiculata* and *Linospadix* spp. and tree ferns, mainly *Cyathea* spp. are often encountered in the mid to lower canopy. Epiphytic ferns and orchids can be conspicuous, especially at higher altitudes. In swamp forests, limited to the wettest part of the coastal zone *Melaleuca viridiflora* paperbark forest often occurs as the main canopy species along with numerous palms. In the lower strata *Pandanus* spp. and sedges are often encountered, as well as climbing ferns and pandans (*Freycinetia* spp.). In the more well drained lowland areas, medium layered woodlands and forest often occur which include *Eucalyptus tereticornis, E. tessellaris, E. intermedia and E. pellita*.

8.1.2 Tropical moist deciduous forest (TAwa)

Papua New Guinea is the only location in Oceania where this Ecological Zone is found and mapped. The zone is described under Asia. In Northern Australia and the Pacific Islands, little areas of this type of forest may be found, however they are to small to map and are being discussed under another Ecological Zone.

8.1.3 Tropical dry forest (TAwb)

This Ecological Zone is confined to the northern parts of Australia.

Climate

The northern tropics of Australia have a marked seasonal alternation in moisture conditions, with an intense drought lasting 6 to 8 months throughout the winter, followed by monsoon rainfall during the warmer months. The Ecological Zone receives an average annual precipitation of 1000-1400 mm with around 75 percent falling in the monsoon period between December and March. The lowest annual precipitation of around 800 mm occurs in the Eastern Kimberley region of Western Australia and the highest annual precipitation of around 1600 mm occurring at the top of Cape York in northern Queensland. Drought conditions prevail outside of the monsoon period with less than 10-20 mm monthly average precipitation from June to August in most areas. The mean annual temperature is around 27^{o}C with a mean summer maximum of 33^{o}C and winter maximum of 31^{o}C. Average minimum temperatures during the monsoon period are around 23^{o}C and winter average minimums are around 15^{o}C.

Physiography

This Ecological Zone is has a generally low relief, below 200 m, with hills in the west (Kimberleys) and centre (Arnhem Plateau). Except for the hills, the terrain is flat to undulating. A number of distinct physiographic units can be distinguished. The Arnhem and Darwin Coasts are dominated by gently undulating plains and low plateaux. The dissected plateau of the North Kimberly includes mainly shallow sandy soils derived from Proterozoic siliceous sandstones and red and yellow earths derived from Proterozoic volcanics. The Arnhem Plateau is comprised of hilly to rugged terrain derived from Proterozoic sandstones. Deep, well drained sandy or gravelly soils, mainly Red and Yellow Earth predominate. Lithosols are common in the rugged hills.

Vegetation

The main natural vegetation covering this Ecological Zone is Eucalypt forest and woodland. Various types do occur, each characterized by different dominant Eucalyptus species. Only the main ones are described.

The *Eucalyptus tetrodonta - E. miniata* suballiance occurs mainly west of the Carpentaria Gulf on flat to undulating terrain with well-developed soils. This community forms open to closed forests to 30 m high in the wettest areas, or in the drier areas, mainly woodlands 10 – 30 m high. The two characteristic species usually occur in equal proportions, though either may be dominant or occur in pure stands. In the Kimberly region this alliance often occurs on shallow sandy soils and gives way to a *Eucalyptus tectifica and E. grandiflora* alliance on yellow and red earths. *Callitris intratroopica*, now mostly removed for timber, once formed local associations on deep sand, either in pure stands or in association with *E. miniata*. The understorey species vary with mean annual rainfall. In wetter areas the tall forests often have a lower tree layer, composed of other eucalypt species.

Characteristic of the wetter stands is a small tree or tall shrub layer of broadleaved, mesomorphic species many of which occur in the rainforests, small stands sometimes

enclosed by the Eucalyptus forests. A few lianas occur and the herbaceous layer dominated by grasses, often 2 m high, which have become increasingly abundant following burning. In drier sites, including the climatically drier southern part of the Ecological Zone and ridges in the wetter areas, the communities are woodlands and mesomorphic shrubs are rare or absent. Xeromorphic shrubs are sometimes present, especially in the north where they may form a shrub layer of circa 2 m high. The grass layer is usually discontinuous. Similar Eucalypt forest and woodlands occur on the flat to undulating terrain of Cape York Peninsula (east side of the Carpentaria Gulf), with the main difference that *Eucalyptus polycarpa* replaces *E. miniata* as co-dominant.

Melaleuca forests occur throughout the Ecological Zone on damp or wet sites such as coastal or sub-coastal areas that dry out seasonally. Often these forests are narrow strips of dense pure stands, tens of meters wide, along streams and swamps. About 75 percent of the melaleuca forests in Northern Australia are large tracts of low woodland spread across estuarine plains and seasonal swamps. The dominant canopy species include *Melaleuca dealbata, M. leucadendra, M. minutifolia* and *M. viridiflora*.

Small patches of so-called semi-evergreen vine forests or monsoon forests occur along watercourses, around lagoons and on patches of soil fed by springs or runoff water from the uplands. They are best developed on the Arnhem Peninsula, with the largest areas on Melville Island. A high proportion of deciduous plants, chiefly the dominants, distinguishes this type of rainforest. The forest canopy reaches a height of circa 15 m, sometimes with emergents up to 20 m. The forests usually have two tree layers in wetter situations, one in the drier and a few species have buttressed trunks. Lianas are abundant but epiphytes are rare or absent

Along the muddy coasts of Northern Australia which receive tides of up to 10 m, mangrove forests occur, often with the following sequence of species (seaward to inland): a) pioneer outer zone of *Sonneratia caseolaris*, mostly 8 – 10 m high, with massive pneumatophores. On firmer substrate the outer fringe is dominated by *Avicennia marina*, forming forests up to 10 m high; b) *Rhizophora* forest dominated by *R. stylosa*, usually 6 – 12 high but up to 25 m on the most fertile soils; c) *Bruguira gymnorhiza* dominated zone, forming forests up to 30 m tall in the most favourable habitats (eastern Queensland); d) *Ceriops tagal* community, mostly some 6 m high, often very dense with the canopies interlacing; e) the inner zone, sometimes well developed with a variety of species, form a forest of 12 m high.

8.1.4 Tropical shrubland (TBSh)

This Ecological Zone is also confined to the Northern part of Australia and immediately follows the more humid coastal zones.

Climate

The semi-arid tropics of northern Australia have a marked seasonal variation in moisture conditions with a pronounced winter drought lasting 6 to 8 months followed by substantial monsoonal rainfall in the summer months. The Ecological Zone receives an average annual precipitation of 700 mm with around 350 mm in the southern Kimberley region in Western Australia to 1000 mm in the southern parts of Cape York in Queensland. Around 75 percent of the precipitation occurs during the monsoonal period between December and March, with drought conditions for the remainder of the year. The mean annual temperature is around

26°C with a mean summer maximum of 35°C and mean winter maximum of 30°C. The average minimum temperature during the monsoonal period is 23°C and 12°C during winter.

Physiography

The physiography of this Ecological Zone is rather diverse, stretching across the north of the continent and into central Queensland. It is comprised of 10 very distinct regions, 5 of which include:

- The plains of the Gulf of Carpentaria, which are dominated by marine and terrestrial deposits.
- The Einasleigh Uplands which is a 700 m high plateau immediately inland of Australia's tropical rainforest derived uplifted Palaeozoic sediments, granites and basalts.
- The Ord-Victoria Plains which are a mosaic of abrupt Proterozoic and Phanerozoic ranges mantled by shallow sandy soils; Cambrian volcanics that form extensive plains of dry calcareous soils and heavy cracking clays.
- The Gulf Fall Uplands which form steep hills on Proterozoic and Palaeozoic sedimentary rocks and
- The Northern Brigalow Belt, which is dominated by Permian and Devonian volcanics and sediments and numerous Tertiary deposits.

Vegetation

The natural vegetation of this Ecological Zone is largely Eucalypt forests and woodlands.

The Northern Kimberly is dominated by *Eucalyptus tetrodonta, E. miniata* forests and woodlands and in the southern Kimberly it is dominated by *Eucalyptus bevifolia* and *E. setosa* low woodlands and open woodlands.

The centre of the Ecological Zone within the Northern Territory is comprised mainly of Eucalypt woodlands and Acacia forests and woodlands. In the skeletal Cretaceous sandstones bloodwood species such as *Eucalyptus terminalis* low woodlands dominate along *with E. bevifolia* on the undulating plains. *Eucalyptus brevifolia* dominates large tracts of land west of the Carpentaria Plains, extending to the Indian Ocean. It often forms mosaics with other species, for instance *E. tetradonta, E. dichromophloia,* or *E. pruinosa*. In the drier south it adjoins the acacia woodlands and shrublands. The vegetation is open woodland reaching around 9 m in the wettest sites; in drier areas the trees are stunted. In the taller woodlands on deep sands, shrubs may occur. The herbaceous layer consists mainly of grasses and these become increasingly prominent as the vegetation becomes more open. Lance wood *(Acacia shirleyi)* is the most widespread of the central northern acacia woodlands. *A. shirleyi* is a tree to 18 m tall which forms low woodland in the drier parts of its range. The stands often intermingle with eucalypt woodlands. A grass layer is usually present.

In the eastern part of the zone, ironbark woodlands cover large areas in Queensland. *Eucalyptus drepanophylla* is the most common species and forms woodlands of 12 – 20 m tall. A few other eucalypts are confined to the alliance and many ecotonal associations occur, varying in physiognomy and species composition. The grass layer is always dense, with *Bothriochloa ewartiana, Heteropogon contortus* and *Themeda australis* as the main species. Another characteristic vegetation in this region are the "boxes", medium height eucalypt woodlands in drier areas. The main species are *Eucalyptus leptophleba, E. microneuro* and *E. normantonensis* and they form open woodlands 7 to 15 m, sometimes up to 20 m in the

wetter parts. These boxes have considerable economic importance as they all provide grazing for domestic stock. *Callitris glauca*, a common associate in some of the woodlands, is an important timber species. At the southern end of the Ecological Zone, silverleaf ironbark becomes dominant (*Eucalyptus melanophloia*), as does *Callitris glauca* and brigalow (*Acacia harpophylla*) with has now largely been cleared due to its natural preference for productive black soils which are also suitable for agriculture.

8.2 SUBTROPICAL DOMAIN

8.2.1 Subtropical humid forest (SCf)

The subtropical humid forest zone comprises the east coast of Australia, roughly between 23^{o} and 35^{o}S and North Island of New Zealand.

Climate

Australia
The coastal areas of southern Queensland and northern New South Wales have a sub-tropical humid climate with mild winters and hot summers. Mean annual precipitation across the region is 1100 mm, with areas on the Queensland/New South Wales border receiving in excess of 2200 mm and rain-shadow areas receiving as little as 700 mm annually. Precipitation is reasonably well distributed with most months receiving in excess of 70 mm of precipitation, although around 50 percent of the rain does fall between December and March, with summer precipitation increasing in the north. The mean annual temperature of the region is around 18^{o}C with the northern extent 3 degrees hotter and the southern extent 2 degrees colder. Average summer maximum temperature is 26^{o} to 29^{o}C and average winter maximums range between 17^{o} and 22^{o}C. The average minimum temperatures during winter range between 3^{o} and 7^{o}C and average minimum summer temperatures range from 15^{o} to 19^{o}C.

New Zealand
The climate of North Island of New Zealand is strongly influenced by the ocean. Extremes of heat and cold are absent. The mean summer temperature is 16^{o} – 18^{o}C and mean winter temperature around 10^{o}C. Rainfall is high, rather regular over the island and ranges from around 1000 mm to more than 1500 mm (on the central plateau), with maxima during winter.

Physiography

Australia
In the north this Ecological Zone is composed of metamorphic and acid to basic volcanic hills and ranges, with extensive alluvial valleys and Quaternary coastal deposits including high dunes, coastal plains. In the south, which includes the Sydney Basin, it is comprised of Mesozoic sandstones and shales which dominate dissected plateaus which have developed skeletal sands and podzolics.

New Zealand
The land of North Island is rugged with a few isolated mountains. The center of the island is a volcanic plateau much of which is at an altitude of more than 600 m, but northwards gradually becoming lower, it extends to the Bay of Plenty. The extreme north of the island consists of a small, narrow much dissected tableland some 300 m high, formed of hard

igneous and sedimentary rocks. An extensive plain of marine origin occupies the southwest of the island. River-formed gravel plains occur east and west of the main range. Yellow-brown soils of moderately low fertility predominate.

Vegetation

Australia
The dominant vegetation of this Ecological Zone is open Eucalypt forest which generally exceed 30 metres tall and can often reach 50 metres, while in the moist valley bottoms, warm temperate rainforests are the dominant life forms. The vegetation with the centre of this region is extremely diverse being the core of a major ecotone where northern species are at their southern limit and many southern species are ate their northern limit. There are also significant environmental gradients leading from the coast to the high mountain ranges that drive the distribution of a large range of forest communities.

In the north of the Ecological Zone the inland medium open Eucalypt forests are dominated by *Eucalyptus tereticornis* and *Corymbia maculata* (formally *E. maculata*), while the coastal forests are dominated by bloodwoods such as *E. intermedia* and *E. acmenoides*. Further to the west numerous rainshadows occur which are dominated by dry ironbark forests and woodlands comprised of *E. crebra, E. fibrosa, E. tessellaris and E. melanophloia*.

In the centre of the region, on the Queensland/ New South Wales border precipitation increases from around 1100 mm to approximately 2000 mm, where Australia's warm temperate rainforest occur as the dominant forest type. Outside of this area it mainly occurs as narrow strips in the valley bottoms of Eucalypt forest. These rainforests become progressively richer floristically from south to north, as they mingle with the richer tropical rainforest. Coachwood (*Ceratopetalum apetalum)* characterizes the rainforests between lat 37^{o} and 28^{o}S and a number of communities occur, differentiated by habitat and presence of co-dominants. Co-dominant trees include *Doryphora sassafras, Schizomeria ovata, Acmena smithii, Traustina laurina* and *Argyrodendron* spp. The canopy reaches a height of 20 – 30 m. Palms are often present, as are various climbing plants, epiphytes and ferns. In the northern reaches we find an alliance dominated by *Argyrodendron* spp. The forests have three tree layers and in this respect resemble the richest rainforest in the tropics. They are also characterized by the presence of the climbing palm, *Calamus muelleri*. Floristically this type is very rich. *Argyrodendron actinophyllum* and *A. trifoliolatum* are consistently in the stands and other tree species represented abundantly in this alliance belong to the Lauraceae, Simaroubaceae, Rutaceae, Meliaceae and succelent-fruited Myrtaceae, especially *Syzygium*. In areas with lower rainfall, a drier type of rainforest appears, characterized by *Drypetes australasica*, *Araucaria* spp., *Brachychiton discolor* and *Flindersia* spp.

To the south of the Queensland border medium to tall open Eucalypt forests again dominate the landscape, with dozens of distinct floristic communities. The main medium open forest types include *E. pilularis, E. saligna* and *E. maculata*, while the tall forests are dominated by *E acmenoides* and *E. microcorys*.

New Zealand
Conifer-broadleaf forest represents "subtropical" or warm-temperate evergreen forests of North Island. In its typical development in mild lowland areas, this forest is multi-storeyed. Conifers, where present form the tallest storey, usually as well-spaced, large-crowned trees, but they can also form continuous canopies. Most of the tree species are podocarps of the

genera *Podocarpus, Dacrycarpus, Dacrydium* and *Phyllocladus*, the tallest species reaching heights of over 40 m, or exceptionally 60 m. There are also two species of *Libocedrus* (Cupressaceae) and, north of 38°S, the massive kauri (*Agathis australis*). Hardwoods and some of the less-tall podocarps form the next storey at 15 to 25 m, which is usually the main canopy. Species include *Beilschmiedia, Knightia, Laurelia, Litsea* and *Nestegis*. A host of small trees form a subcanopy and fill gaps. Tree ferns and the palm *Rhopalostylis sapida* area usually abundant and contribute much to the subtropical appearance of vegetation. Shrubs belong mainly to the genus *Coprosma* and large ferns, such as *Asplenium, Blechnum, Hypolepsis* and others, constitute a usually well-developed ground layer. Lianas are abundant and in some forest form much of the canopy. In higher, colder or drier regions, the mixed forest becomes less rich floristically and is not so structurally complex. Small patches of beech forest (*Nothofagus* spp.) occur on poor soils and at higher altitudes.

In contrast with the flora of Australia, there is not a single native species of *Eucalyptus* or *Acacia* in New Zealand.

8.2.2 Subtropical dry forest (SCs)

This climatically very distinct Ecological Zone is found in two locations of Southern Australia; the southwestern tip around Perth and the central east around Adelaide.

Climate

The climate of this Ecological Zone occurs in two slightly different Mediterranean forms and has a significant rainfall gradient that has a major impact on the type of vegetation that occurs.

The area approximately 200 km south and east to 500 km north of Perth in Western Australia has hot, dry summers. Mean annual precipitation within this zone is around 750 mm, with up to 1000 mm falling on the Yilgarn Craton plateau, tapering off to around 500 mm as you move inland. Precipitation is highly winter dominant with 65 percent falling between May and August. The annual average temperature for the region is around 16°C. Average summer maximum temperatures range from 27°C in south to 30°C in the north and winter maximums average between 15° and 18°C from south to north. The average minimum temperatures in winter and summer range from 6° to 8°C and 12° to 16°C respectively. Again with a gradient from south to north.

The southern tip of Western Australia and areas to the south of Adelaide in South Australia have slightly cooler summers and are subject to a significant rainfall gradient. The region receives 400 to 800 mm of annual precipitation in Victoria and South Australia and between 1000 mm and 1300 mm on the southern coast of Western Australia, with approximately 60 percent falling between May and September. The annual average temperature of the region is 15°C. Average summer maximum temperatures range from 26° to 27°C and winter maximums average between 14° and 16°C. The average minimum temperatures in winter and summer range from 4° - 8°C and 11° to 13°C respectively. The south coast of Western Australia is generally around 2 degrees warmer than the rest of the Ecological Zone.

Physiography

The hot summer areas are largely confined to two regions. The Swan Coastal Plain, as its name suggests is a coastal lowland with marine sand dunes. In the east the plain rises sharply about 300 m to the Jarrah Forest region which is dominated by duricrusted Mesozoic sediments that form lateritic gravels interspersed with clayey soils.

Three regions make up the cooler summer zone. The Warren region on the southern tip of Western Australia which is largely undulating coastal hills dissected with deep loams and leached sandy soils. The Naracoorte Coastal Plain at the southern border of Victoria and South Australia is dominated by Tertiary and Quaternary sediments with a regular series of dunes and swales and the Lofty Block, which is a narrow strip of uplands derived from uplifted Cambrian and Late Proterozoic marine sediments which form gravelly yellow duplex soils wetter areas and red duplex soils in drier areas.

Vegetation

The vegetation in the southwest is floristically distinct from the rest of Australia. In the southern cooler climate that receives significantly more rainfall, the vegetation is dominated by tall eucalypt forest. On the more fertile soils derived from granite two tall forests occur; karri *(Eucalyptus diversicolor)* and red tingle *(E. jacksonii)*. On laterite and lateritic strew jarrah *(E. marginata)* and marri *(E. calophylla)* are dominant and on the coastal limestones, tuart *(E. gomphocephala)*. With diminishing mean annual rainfall these taller forests are replaced by other forests or woodlands. Karri is one of the tallest eucalypts in Australia, which can reach a height of circa 85 m and a diameter of c. 7 m. The species is restricted to a narrow belt in the south, where annual rainfall is more than 1000 mm. The forests are two-layered; a towering tree layer 40-70 m high with a more or less closed canopy and a tall shrub layer 3 – 7 m high. The herbaceous layer is poorly developed. Lianas are few, small and thin-stemmed and epiphytes are absent The *Eucalyptus marginata – E. calophylla* association is most widely distributed in this zone, between the 600 and 1300 mm isohyets. The vegetation ranges from tall forests to shrublands, but all are characterized by one of the two, or both species being dominant. Forests up to 40 m high, with an almost closed canopy, occur in the wetter areas. In drier areas the forests reach a height of 12 – 24 m and are more open. Three types of understorey occur: a) in the wettest areas of tall forest, a lower tree layer up to 13 m high and below this a shrub layer of 2-3 m high; b) xeromorphic shrubs dominate in most of the upland areas; c) in the drier segment of the association, xeromorphic shrubs form an open layer. Woodlands of the same association, reaching 10 – 15 m height, are found mainly on the western coast on stabilized dune sands. They are now mostly cleared for cropping and grazing. In drier areas, in ecotones with the mallee dominated shrubland, both *E. marginata* and *E. calophylla* become stunted and reach heights of only a few meters.

As with many agricultural regions, the original vegetation covering the Lofty Block and Naracoorte Coastal Plain was significantly different from the cropping lands, improved pastures and low open Eucalypt woodlands with grassy understoreys that occur there today. The region was originally dominated by low to medium Eucalypt woodlands in the lower rainfall areas with gum and peppermint species such as *Eucalyptus leucoxylon* and *E. odoratais* and shrubby understoreys. Medium open stringybark forests comprising *Eucalyptus baxteri, E. obliqua* and *E. viminalis* and shrubby understoreys dominated the higher rainfall areas. Vegetation of the Naracoorte Coastal Plain was similar in many areas to that of the Lofty Block with the addition of heaths in the poorly drained lowlands and inter-dune swales

and Eucalypt mallee formations (see next Ecological Zone) on the calcareous soils in the north of the region.

8.2.3 Subtropical steppe (SBSh)

The Ecological Zone is confined to Australia and separated in two distinct units following the Australian ecozoning: a northeastern part with typical subtropical characteristics and a southern part with "warm temperate" influences.

Climate

a) Northeastern part
This subzone comprises a significant climatic gradient that has a major impact on vegetation and landuse types that occur.

Southwestern Queensland and northwestern New South Wales have a sub-tropical semi-arid climate with mild winters and hot summers. The mean annual precipitation of 350 mm is fairly evenly distributed throughout the year, with a slight dominance from December to February. The mean annual temperature of the region is around 2^{o}C. Average summer maximum temperature is 35^{o}C and winter maximum is approximately 22^{o}C. The average minimum temperature in winter is 5^{o}C and average minimum summer temperature is 20^{o}C. The region is commonly known as the Mulga Lands.

Southern central Queensland and northern central NSW have a sub-tropical semi-arid climate with mild winters and hot summers. The ecozone has a mean annual precipitation of 560 mm with inland precipitation decreasing to 350 mm towards the interior and increasing to 700 mm on the western slopes of the Great Dividing Range. Precipitation is evenly distributed throughout the year, with a slight dominance from December to February. The mean annual temperature of the region is around 19^{o}C. Average summer maximum temperature is 32^{o}C and winter maximum is approximately 20^{o}C. The average minimum temperature in winter is 4^{o}C and average minimum summer temperature is 18^{o}C. This zone covers regions commonly known as the Southern Brigalow Belt, the Darling Riverine Plain, the South Western Slopes of NSW and the Cobar Peneplain.

b) Southern part
This unit has a semi-arid climate with a marked winter dominance in precipitation. It has an average annual precipitation of 375 mm with as little as 250 mm in inland areas and up to 600 mm in areas of higher altitude (300 m) towards the coast. Precipitation is markedly winter dominant with around 70 percent of the precipitation occurring between May and October. The winter dominance of precipitation increases from the east to the west. The mean annual temperature of the region is around 17^{o}C. The average maximum summer temperature 30^{o}C and average winter maximum is around 17^{o}C. The average minimum temperature in winter is 5^{o}C and average minimum summer temperature is 14^{o}C.

Physiography

a) Northeastern part
The Mulga Lands are comprised of low hills and undulating plains on Cainozoic sediments, red earths and lithosols. The Southern Brigalow Belt is predominantly Jurassic with younger deposits of the Great Artesian Basin and Tertiary deposits with elevated basalt flows. The

Darling River Plain is a series of alluvial fans and plans dominated by heavy grey clays. The South Western Slopes are an extensive area of foothills and isolated ranges on the inland sloped of the Great Dividing Range and the Cobar Peneplain is comprised of low hills and plains of Palaeozoic rocks, earths and lithosols.

b) Southern part
This subzone has a distinct climate and 4 very distinct landscapes that set it apart from other regions and create highly diverse flora:

- The Murray-Darling Depression and Riverina regions of the southeast are the core of Australia food bowl with extensive gently undulating Tertiary and Quaternary sand and clay plains frequently overlain by aeolian dunes.
- The Eyre and York Block region to the west of Adelaide in South Australia is comprised of Proterozoic sandstones overlain by undulating to hilly calcarenite and calcete plains which create duplex soils and calcareous earths.
- The Avon Wheatbelt and Mallee regions of Western Australia are gently undulating which dissect a Tertiary plateau with a range of sandy/clay duplex soils, calcareous earths and sandplains overlying Eocene limestone in the east.
- The Esperence Plains to the north of the Avon region is a sandplain overlaying Eocene sediments with abrupt granite and quartzite ranges and to the south the Geraldton Sandplains comprise of gently undulating sandy earths mantling Permian strata.

Vegetation

a) Northeastern part
The Mulga Lands are dominated by low *Acacia aneura* woodlands and shrublands commonly known as “Mulga”. This species occurs as small trees in the higher rainfall eastern margins and as a low shrub towards the interior. The original low shrubby understoreys have now been heavily modified as a result of pastoral use.

Five primary vegetation types occur within the Southern Brigalow Belt. These are: Ironbark woodlands on the eastern margins (*Eucalyptus crebra, E. alba*); Ironbark and Callitris forests *(E. crebra, E. fibrosa* and *Callitris glauca*) and Brigalow forests and woodlands *(Acacia harpophylla*) and poplar box woodlands (*E. populnea*) in the central and interior regions. All of which also occur as mixed forest and mosaics of relatively pure stands. *Callitris glauca* is a very important commercial species that can form very pure stands over extensive areas.

The Darling Riverine Plains are dominated by River Redgum (*E. camaldulensis*) and Blackbox (*E. largiflorens*). The Cobar Peneplain is dominated by Mulga (*Acacia aneura*) shrublands. Other species include Myall (*A. pendula*), Nelia (*A. loderi*) and Gidgee (*A. cambagei*). The South Western Slopes are dominated by box woodlands: *Eucalyptus albens, E. melliodora, E. Blakelyi* on the slopes and greybox (*E. microcarpa*) and ironbark *(E. sideroxylon*) woodlands in the lower rainfall regions.

All the above vegetation communities have considerable economic importance. They all provide grazing for domestic stock. Large tracts of woodlands have been cleared for the cultivation of grain crops, in particular wheat.

b) Southern part
Mallee is the dominant natural vegetation over large areas of the Murray-Darling, Riverina, Eyre and York Block and Mallee region of Western Australia. The term "mallee", an aboriginal word, describes a eucalypt with many stems arising at ground level from a large, bulbous woody structure called a lignotuber or "mallee" root. In more arid areas mallee is usually replaced by acacias and at the upper rainfall limit (circa 400 mm/year) by single-stemmed eucalypts, often of the same species. The tallest of the communities, reach up to 15 m high, however, they usually are 3 to 10 m tall, with multiple, flat-topped or domed crowns spaced at regular intervals. Crown density varies from dense, interlocking in wetter areas to open in drier areas. The understorey can be either a lower shrub layer, a dense low thicket or a grass layer. About 100 species of *Eucalyptus* constitute the dominants and floristic composition varies by region and site conditions. There are over 100 mallee species and many species that occur as both mallee and tree lifeforms. Common species include white mallee (*Eucalyptus diversifolia*) which dominates the wetter communities in South Australia; Lerp mallee *(E. incrassata)* and narrow-leaved red mallee (*E. foecunda)* occurring on deep sands; Giant Mallee *(E. socialis),* Congoo Mallee *(E. dumosa),* Yorell *(E. gracilis)* and Redwood *(E. oleosa)* characterizing the main mallee alliance in the east; Tall Sand Mallee *(E. eremophila)* confined to Western Australia and found over a wide range of soil types. Mallee lifeforms have in the past generally been classified as shrubs. Given the overall biomass (above and below ground of theses lifeforms which is far greater than typical acacia shrublands, in 1997 Australia decided to include mallee as a specific type of forest and woodland for national and international reporting purposes.

The Esperence and Geraldton Plains are dominated by Proteaceous heaths and mallee heaths which also at various locations near the coasts of Western and South Australia. They occupy deep sands of low fertility or soils developed on fossil laterite and to a lesser extent limestones. The communities in Western Australia are extremely diverse; the total flora contains circa 2000 species and includes many endemics. Scrub-heaths can reach a height of several meters, while the heaths vary in height from 0,5 to 1,5 m. The heaths on sand are characterized by a wealth of Protaceae, including many *Banksia* species.

The Wheatbelt region of Western Australia has been highly modified for broad-acre wheat cropping and today only remnants of the original vegetation exist. Medium height eucalypt woodlands of 10-30 m high with low understoreys were dominant with, *E. marginata* (jarrah) forests in the higher rainfall areas to the west which gives way to *E. wandoo* (wandoo) and then *E. salmonophloia* (salmon gum) as rainfall decreases.

8.2.4 Subtropical desert (SBWh)

Deserts occupy a large proportion of Australia, reaching the ocean in the north, south and west. This zone can be separated into the Arid shrublands and the Arid grasslands, which bear similar climates but very different vegetation.

Climate

The climate of Australia's interior shrublands is arid. With no mountains on the west coast the eastward movement of high-pressure systems from the Indian Ocean is not impeded and as a consequence, arid conditions extend from the coast to the interior. The ecoEcological Zone receives on average less than 250 mm of annual precipitation with a range of between 180 and 350 mm. Fifty percent of this precipitation occurs between December and March.

The annual average temperature of the region is 22°C. Average summer maximum temperature is 35°C and average winter maximum is around 23°C. The average minimum temperature in winter is 7°C and in summer the average minimum temperature is 21°C. The arid grasslands are concentrated within Australia's largest inland drainage basin leading to Lake Eyre. The region is affected by the same air currents as above, receiving an average annual precipitation of 310 mm. However, monsoonal flooding of several inland river systems has had a major impact on the Physiography of the region which in turn changes the vegetation types that occur. As with all other regions, a precipitation gradient exists, with interior areas receiving 150-200 mm and northern areas receiving up to 400 mm annual precipitation, around fifty percent of which falls between January and March. The annual average temperature across the region is 24°C. Average summer maximum temperature is 36°C and average winter maximum is around 26°C. The average minimum temperature in winter is 8°C and in summer the average minimum temperature is 23°C.

Physiography

The physiography of the arid shrublands is incredibly diverse. This ecozone includes: the Great Sandy Desert in the north west; the Tanami Desert in the North; the Gibson and Simpson Deserts in the centre from west to east, the Great Victoria Desert and the Nullabor Plain in the south and the Murchison and Gasgoyne regions in the west, in addition to many other smaller regions with distinct physiography.

The Great Sandy Desert is comprised of Quaternary longitudinal dune fields and gently undulating Jurassic and Cretaceous sandstones. The Tanami Desert is mainly red Quaternary sandplains overlaying Permian and Proterozoic strata which are exposed locally as hills and ranges. The Gibson Desert is comprised of laterised uplands on flat lying Jurassic and Cretaceous sandstones. The Simpson desert is mainly dunefields and sandplains. The Great Victoria Desert is an active sand ridge desert of deep aeolian Quaternary sands. The Nullabor Plain is comprised of Tertiary limestones. The Murchison is mainly Quaternary alluvial and alluvial surfaces and sandplains surrounding rugged Proteozoic and sedimentary and granite ranges and the Gasgoyne is mainly rugged low Proterozoic sedimentary and granite ranges divided by broad flat valleys.

The arid grasslands are situated in the north east of the Ecological Zone and comprised of two major regions: the Mitchell Grass Downs and Channel Country. The Mitchell Grass Downs are mainly undulating downs on shales and limestones with heavy grey and brown cracking clays. The Channel Country is comprised of mitchell grass downs, braided river systems and low hills on Cretaceous sediments.

Vegetation

The enormous local and regional variation in vegetation types across the arid shrubland zone is determined by mean annual rainfall, its seasonal incidence and by soil type. In the "wetter" parts, annual rainfall > 250 mm, *Acacia* woodlands predominate and mulga *(Acacia aneura)* is the dominant species over vast tracts of country. The various mulga dominated woodlands show some variation in structure. Mulga itself varies in height from c. 3 – 10 m. The tallest stands are almost closed woodlands with scattered or no shrubs below and a discontinuous grass layer. The woodlands become progressively shorter with diminishing rainfall and in the drier areas they grade into sparse shrublands which, in the driest areas are replaced by hummock grasslands of *Triodia*, *Plectrachne* and *Zygochloa*. Other common *Acacia* species

include *A .translucens, A. pachycarpa* and *A. sowdenii*. *Casuarina* is likewise well represented, occurring both on clays and sands, often in association with a species of *Acacia*. *Eucalyptus* is represented by many species, some of which occur in upland, sandy areas also often in combination with Acacia species, whereas other species are restricted to watercourses. In the southern regions on calcareous soils with greater than 250 mm rainfall, many Eucalypts occur in mallee formations (see detailed description above). On soils of finer texture, grasslands or halophytic shrublands occur. Grasslands of the summer rainfall zone are dominated by species of *Dichanthium* or *Astrebla* and other less abundant and in the winter rainfall zone by *Stipa* spp. The halophytic shrublands occupy saline and subsaline soils mainly in drier regions in the south. Other halophytic communities are present on playas.

On the grey and brown clays of the Mitchell Grass Downs and Channel Country, *Astrebla* spp create almost endless plains of tussock grasses. In recent years the density of these grasslands have been diminished through grazing and the invasion of exotic prickly *acacia (Acacia Nilotica*) which forms open tree savanna in the northeast of the former treeless plains. The braided river systems are lined with *Eucalyptus coolibah* woodlands and the low adjacent low hills are often dominated by *Chenopodium* spp. shrublands.

8.3 TEMPERATE DOMAIN

8.3.1 Temperate oceanic forest (TeDo)

This Ecological Zone covers the southeastern coast of Australia, Tasmania and lowlands of South Island, New Zealand.

Climate

Australia
The southeastern coast of mainland Australia and Tasmania has a humid, mild winter climate. With significant variations in relief and exposure, annual precipitation varies from around 600 mm in the low elevation areas of the Gippsland region in Victoria to in excess of 2000 mm in western Tasmania. Precipitation is distributed throughout the year with a slight winter dominance which is more pronounced in western Tasmania. The annual average temperature for the region varies from around 9^{o}C in western Tasmania to 13^{o}C in southern Victoria and eastern Tasmania. Average summer maximum temperatures range from 20^{o}C in Tasmania to 24^{o}C in Victoria and average winter maximums follow the same pattern with 14^{o}C in Victoria and 10^{o}C in Tasmania. The average minimum winter and summer temperatures for Victoria and Tasmania respectively are 4^{o}, 11^{o}, 2^{o} and 8^{o}C.

New Zealand
The western, coastal part of South Island has a humid climate with heavy rainfall. Annual rainfall ranges from around 1800 mm to locally more than 4000 mm and is rather evenly distributed throughout the year. To the east of the Alps, the climate is distinctly drier, with annual rainfall in the range of 400 to 800 mm, locally below 400 mm. Also, temperatures become more extreme here, as the region is sheltered from the prevailing western ocean winds. Mean annual temperature range from 13^{o}C in the north to 9^{o} in the south. Mean winter temperatures (July) range from 8^{o}C in the north to 2^{o}-5^{o}C in the south, summer temperatures average 15^{o} to 17^{o} C.

Physiography

Australia
On the mainland of Australia the east of this Ecological Zone is a series of deeply dissected near coastal ranges composed of Devonian granites and Palaeozoic sediments, inland of a series of gently undulating terraces (piedmont downs) composed of Tertiary sediments and flanked by Quaternary coastal plains, dunefields and inlets. Its western margins comprise of extensive basaltic plains with numerous volcanic cones and eruption points and the coastal areas are again dominated by Tertiary and Quaternary sediments on lowlands, low hills and low ranges.

Soils on the lowlands hills and ranges of western Tasmania are predominantly oligotrophic acid peats. To the north, lowland hills are mainly complexes of Cambrian and Pre-Cambrian metasediments and basic volcanics with deep loams while the coastal plains are mainly acid sandy soils from post-Carboniferous sediments. The eastern margins of this Ecological Zone in Tasmania are Permo-Triassic coastal plains low Jurassic mountain ranges dominated by deep granite soils.

New Zealand
South Island is dominated by the Southern Alps, forming a central range. To the west is a narrow coastal plain, mostly consisting of gavel deposited by the numerous glacial or snow rivers. The east and southeast of the island is flat to undulating country, with the Canterbury Plain and Southland Plains as most extensive lowlands. Yellow-brown earths cover most of the eastern part of the island, while in the west and south, the predominant soils are podzolic yellow-brown earths, podzols and gley podzols.

Vegetation

Australia
The natural vegetation of this Ecological Zone consists of a complex of formations. In the wetter parts of western Tasmania cool temperate rainforests are found within a complex mosaic of rainforest and buttongrass moorlands in higher elevation areas. These forests are often dominated by myrtle *(Nothofagus cunninghammii)*, with conifers such as huon pine *(Lagorostrobos franklinii)*, celery top pine *(Phyllocladus aspleniifolius)* and King Billy pine *(Athrotaxis selaginoides)* also forming part of the tree layer in Tasmania. In lowland areas, mainly in the wetter south in lowland or subalpine situations, the rainforests are dominated by *Anadopetalum biglandulosum*. These formations are relatively poor floristically and reach heights of 10 to 20 m. In Victoria the cool temperate rainforests occur in restricted areas in the coastal ranges. Dominant canopy species include southern sassafras *(Atherosperma moschatum)*, *Acacia melanoxylon* and mountain quandong *(Elaeocarpus holopetalus)*. The tallest stands reach a height of 40 – 50 m and are rich in ferns.

The moderate rainfall areas to the east of this zone on the mainland and Tasmania are dominated by 20 to 30 m high dry ash, stringybark and peppermint forests (*Eucalyptus sieberi, E. gummifera, E. botryoides, E. radiata, E. dives*) on the granites and sediments nearer the coast. These forests are replaced by tall wet forests dominated by *Eucalyptus viminalis, E. fastigata, E. obliqua* and *E. cypellocarpa* in higher rainfall and protected areas. Many of the wetter areas of this zone in Tasmania are dominated by tall messmate/stringybark forest (*Eucalyptus obliqua, E. nitida*). The basalt plains of western

Victoria were once dominated by wet *E. obliqua* and *E. cypellocarpa* forest but most of these have since been cleared.

Other vegetation types of this Ecological Zone include wet – and dry sclerophyllous woodlands, heaths (mostly along the coast) and grasslands often dominated by species of *Stipa*.

New Zealand
The distinct climatic west-east division is also reflected in the native vegetation. The western lowlands and lower hills are dominated by beech and conifer-beech-broadleaf forest. The latter forest type predominates in the northwest and central west and has similarities with the forests of the North Island described earlier. There is however variation in dominating species. *Nothofagus fusca* is characteristic for conifer-beech-broadleaf forests in the northwest. In these forests, conifers form a scattered overstorey with *Dacridium cupressium* and *Podocarpus ferrugineus* as the main species. Beeches form the main canopy, with *N. fusca* predominating on the deeper, more freely drained sites, but is usually mixed with *N. truncata, N. menziesii* and, on gradients towards gley podzols, with *N. solandri*. On the optimal sites, *Weinmannia racemosa* and in places *Quintinia acutifolia* form a tall subcanopy. *Weinmannia racemosa* is favoured by high rainfall and on lower hill slopes in Westland it is the main tall tree in a luxuriant aspect of conifer-broadleaf forest. In the extremely humid fjord country in the southwest, where rainfall exceeds 6000 mm, the *Nothofagus* forests are similar in nature to those of Southern Chile. *N. menziesii* is the dominant species in these southern beech forests.

The east of South Island has little forest vegetation, due to the much lower rainfall. Patches of beech conifer-broadleaf forest occur, adjoining a wide variety of, mostly anthropogenic, vegetation: *Pteridium* fernland, *Leprospermum* shrubland, tussock grassland, succesional forest, alien communities such as those dominated by *Rubus fruticosus* and *Ulex europaeus*. There is evidence that prior to human intervention a zone of microphyllous woodland, consisting of species such as *Coprosma virescens, Discaria toumatou, Leptospermum ericoides, Olearia lineata* and *Sophora microphylla*, grew under moisture regimes intermediate between those supporting forest and semi-arid grasslands.

8.3.2 Temperate mountain systems (TeM)

In Australia, this Ecological Zone consists of the Tasmanian Highlands, the Southeastern Highlands, Australian Alps and the New England Tablelands. New Zealand's Southern Alps on South Island are also part of the Ecological Zone.

Climate

The highlands and tablelands of southeastern Australia have a cool temperate climate. With an average elevation of around 750 m and many areas exceeding 1500 m, it has extremes of both precipitation and temperature. Annual precipitation throughout the region ranges from around 600 mm in lower elevation areas to 1200 mm in areas of higher elevation, with an overall average of 950 mm. Localised rainshadow areas are also common which receive less than 500 mm annually. The precipitation is evenly distributed throughout the year, with most months receiving 70-80 mm. The annual mean temperature is around 12^{o}C with mainland areas around 2^{o} hotter and Tasmania 4^{o} colder. Average summer maximum temperatures range from 20^{o}C in Tasmania to 25^{o}C on the mainland and average winter maximums follow

the same pattern with 12°C on the mainland and 6° - 8°C in Tasmania. The average minimum winter temperature of 0.5° to –1.0°C does not vary significantly across the region, whereas the average minimum summer temperatures range from 12°C in the northern tablelands, 10°C in the southern tablelands and 7°C in Tasmania.

The Australian Alps region of southeastern Australia receives an average annual precipitation of 1300 mm, with higher elevation areas receiving in excess of 2000 mm, much of which falls as snow. Precipitation is evenly distributed throughout the year, with a slight winter/spring dominance. The annual average temperature for the region is around 9°C. The average summer maximum temperature ranges from 16° to 22°C and winter maximum temperatures range from 2° to 6°C. The average minimum temperatures in winter and summer range from 0° to –4°C degrees and 6° to 8°C respectively. Variation in elevation is obviously the major driver of temperature variation.

Climate of the Southern Alps in New Zealand is cold temperate, characterized by high annual rainfall particularly on the western slopes. Frost and snow are abundant in winter and to some extent at all seasons.

Physiography

Australia
The Southeast Highlands comprise of rolling hills at lower elevations (600-800 m) in the north through to highly dissected mountain ranges. The geology is predominantly Palaeozoic and Mesozoic formations with small Tertiary basalt flows. The New England Tablelands is an elevated plateau of rolling hills on Palaeozoic sediments, granites and basalts. The Central Highlands and midlands of Tasmania is also an elevated plateau underlain by Jurassic dolarites and Tertiary basalts. The Australian Alps is a series of high elevated plateaux capping the South East Highlands. The geology consists largely of basalt and granite. The highest altitude is found in the Australian Alps where several mountain tops and plateaux exceed 2000 m in height.

New Zealand
The Southern Alps constitute a prominent feature of New Zealand's Southern Island. The highest peaks, situated at the centre of the range, reach from 3000 to 3764 m (Mt. Cook). Proceeding north and south the range gradually decreases in height, but few peaks are lower than 1800 m. The eastern slopes are formed of slaty shales and greywackes. Below the shales on the west, the rock is schist, but at low levels occasionally gneiss. The snowline in the Southern Alps is on average at about 2200 m, varying according to latitude, while it is lower on the west than on the east. The central part of the range is heavily glaciated, the size of the glaciers being correlated with the altitude of the peaks.

Vegetation

Australia
The lower elevation rolling hills of the Southeast Highlands and elevated plateaux and hills of the New England Tablelands were originally covered with Eucalypt forests and woodlands dominated by stringy bark/peppermint/box species, including *E. caliginosa, E. laevopinea, E. nova-anglica. E. melliodora, E. albens* and *E. blakelyi*. Today these communities mainly occur as open woodlands used for sheep and cattle grazing.

In areas sheltered areas receiving greater than 1000 mm annual rainfall, tall wet Eucalypt forests dominate with species such as alpine ash *(Eucalyptus delegatensis)*, mountain white gum *(E. dalrympleana)*, manna gum (*E. viminalis*) forming open forests where the canopy exceeds 40 m with understoreys of shrubs and ferns. The most brilliant example of theses forests occur in the southern ranges of Southern Victoria and Tasmania where mountain ash (*E. regnans*) trees commonly exceed 70 m in height and can reach over 90 m on the best sites. In Tasmania, cool temperate rainforests are dominated by myrtle *(Nothofagus cunninghamii)* and blackwood *(Acacia melanoxylon)* often forms an understorey 10-30 m tall.

Above 1500 m elevation, low snow gum (*E. pauciflora*) woodlands are prominent with diverse shrub and tussock grass understoreys. These woodlands also occur at lower altitudes on sites receiving cold air drainage. The treeline reaches a maximum altitude of around 1800 m elevation (less in cold air drainage zones) on the mainland and 1400 m in Tasmania, with Australia's highest point being 2228 m above sea level. Diverse mixtures of low shrubs including *Podocarpus lawrencei*, tussock grasses and forbs form a complex mosaic across these treeless areas.

New Zealand

The lower and medium altitude zones of the mountains are mostly covered by beech forest. *Nothofagus* var. *cliffortioides* or *N. menziessi* constitute most of the subalpine forests, forming remarkably level, abrupt timberlines against alpine grasslands. The timberline reaches at around 1200 m in the north and decreases to around 850 m in the south. In such subalpine beech forests, other than the dominant tree, which forms a dense canopy at 10 to 15 m, there may be only scattered *Coprosma* shrubs, corticolous lichens and bryophytes and bryophyte cushions (*Dicranoloma, Leucobryum*) on the forest floor. On moist concave slopes, however, there can be a dense understorey of the ferns *Hypolepis millefolium* and *Polystichum vestitum*. Locally, beech forest is altogether absent. Instead, depauperate conifer-broadleaved forest extends into the subalpine belt. Its conifer storey consists of *Podocarpus halii*, often accompanied by *Libocedrus bidwillii*, while the main canopy consists of *Weinmannia racemosa, Metrosideros umbellate*, or in certain circumstances, small trees such as *Dracophyllum traverssi, Griselinia litoralis* and *Olearia ilicifolia*. Upwards, this forest grades into very dense subalpine scrub dominated by composites (*Olearia, Senecio*), small podocarps (e.g. *Dacrydium biforme, Phyllocladus alpinus, Podocarpus nivalis*), epacrids (*Archeria, Dracophyllum*) and various other genera.

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Appendix III-1: Distribution of Global Ecological Zones

Global Ecological Zone	Area, km2							
	South America	North & Central America	Europe	Asia	Oceania	Africa	FSU	Total
Tropical rainforest	6631239,8	440879,9	0,0	3009375,5	481313,1	4017704,9	0,0	14 580 513,2
Tropical moist deciduous forest	4302306,2	678048,3	0,0	1379476,6	26297,7	4661180,5	0,0	11 047 309,3
Tropical dry forest	1681596,3	226004,1	0,0	1426603,5	468003,3	3669529,5	0,0	7 471 736,6
Tropical shrubland	103033,5	2146,5	0,0	1167106,6	1063412,6	5977939,2	0,0	8 313 638,5
Tropical desert	137638,4	0,0	0,0	2704536,5	0,0	8737673,8	0,0	11 579 848,7
Tropical mountain systems	1886495,2	259111,6	0,0	834930,9	71203,8	1473226,1	0,0	4 524 967,6
Subtropical humid forest	1199948,4	1068502,8	0,0	2047861,8	281176,4	85099,5	0,0	4 682 588,9
Subtropical dry forest	100504,0	87038,5	816399,8	129039,9	123341,7	334815,6	0,0	1 591 139,5
Subtropical steppe	639738,1	1167279,7	5007,8	1180329,6	1461055,2	456663,4	0,0	4 910 073,7
Subtropical desert	0,0	1083873,6	0,0	1446346,7	4139151,7	0,0	0,0	6 669 372,0
Subtropical mountain systems	238162,2	592296,6	149239,6	3459621,8	0,0	412355,6	6962,3	4 858 638,1
Temperate oceanic forest	259146,6	40122,6	1287121,2	0,0	218534,7	0,0	0,0	1 804 925,1
Temperate continental forest	0,0	2023769,7	2906693,6	1253135,0	0,0	0,0	761669,7	6 945 268,0
Temperate steppe	498297,9	2121768,0	955497,4	1115606,0	0,0	0,0	1202707,7	5 893 877,1
Temperate desert	0,0	742928,6	150342,7	2181946,1	0,0	0,0	2321906,4	5 397 123,9
Temperate mountain systems	76895,3	1976781,0	605384,1	3604836,3	193631,6	0,0	768827,1	7 226 355,4
Boreal coniferous forest	0,0	2186971,8	2195687,9	157449,6	0,0	0,0	3924346,7	8 646 455,9
Boreal tundra woodland	0,0	2566393,5	87788,3	0,0	0,0	0,0	1296926,4	3 951 108,2
Boreal mountain systems	0,0	1182345,2	457623,0	109168,1	0,0	0,0	4550130,1	6 299 266,4
Polar	0,0	3220371,6	422632,4	0,0	0,0	0,0	1768312,8	5 411 316,8
Water	0,0	405041,6	133,1	15623,3	0,0	158145,9	120187,5	699 131,4
No data	8248,7	311,4	3429,7	122,6	1752,5	9583,3	0,0	23 448,3
Total	*17.763.250,6*	*22.071.986,4*	*10.042.980,7*	*27.223.116,5*	*8.528.874,1*	*29.993.917,4*	*16.721.977,0*	*132 346 102,7*
Total without water	17.763.250,6	21.666.944,8	10.042.847,6	27.207.493,2	8.528.874,1	29.835.771,5	16.601.789,5	131 646 971,3
Greenland (Polar)			2.142.660,9					

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