Chapter 7
Impact of Climate Change on Mountain Flora and Vegetation in the Republic of Macedonia (Central Part of the Balkan Peninsula)

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7.1 Introduction

The Republic of Macedonia is situated in the central part of the Balkan Peninsula (Fig. 7.1). Its geographical position is between 40°51′16″–42°22′21″N and 20°27′32″–23°02′12″E. It has borders with Serbia, Kosovo, Bulgaria, Greece, and Albania (Fig. 7.1). The area of the country is 25,713 km^2 and there are 2,022,547 inhabitants (in 2002). The average population density is 78.7 inhabitants per km^2 (Stojmilov 2011).

7.2 Geology and Relief

The territory of the Republic of Macedonia, as part of the Balkan Peninsula, is characterized by complex geotectonics, which have led to the development of diverse relief and complex geology as well as a huge variety of soil types. During the complex geotectonic evolution, the relief morphoplastic has changed several times.

In general, four geotectonic regions (units) are present on the territory of the Republic of Macedonia: West Macedonian region, Pelagonian massif, Vardar region, and Serbo–Macedonian massif (Jovanovski et al. 2012).

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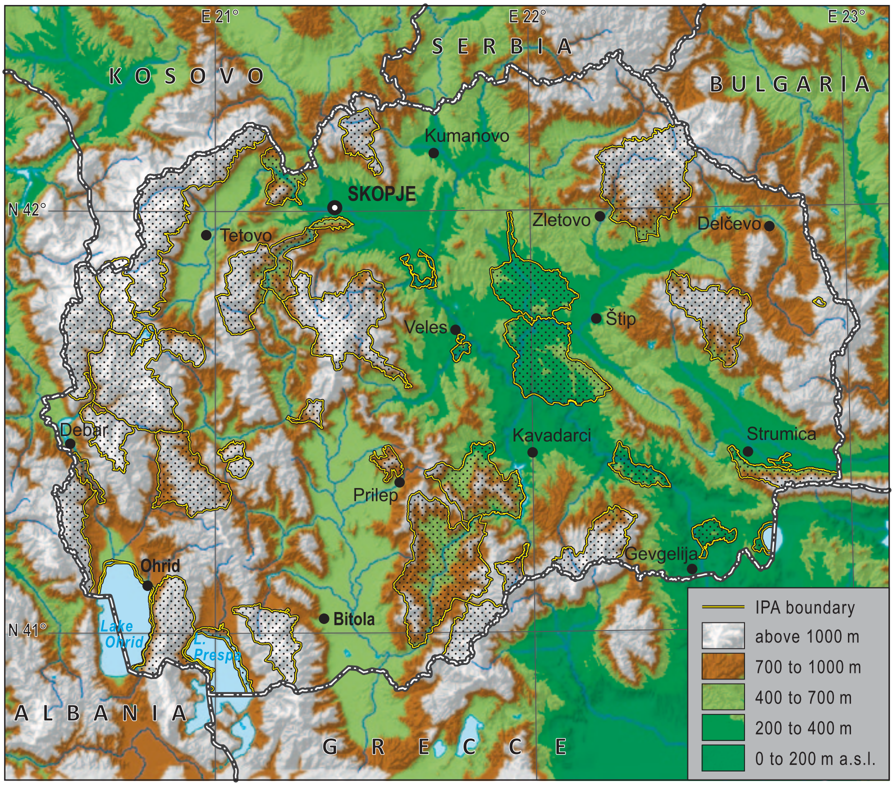

Fig. 7.1 Geographical map of the Republic of Macedonia with indication of *important plant areas* (IPA; after Melovski et al. 2010)

The West Macedonian region is a distinct geotectonic unit in the western part of Macedonia. Paleozoic and Triassic schists are most abundant in this region, while Jurassic, Cretaceous, and Paleocene rock formations and Neogene sediments are less present. The Pelagonian massif is a crystalline core with a continental type of Earth's crust that is built mostly of the oldest Precambrian formations. The Vardar region is a large and important lineament structure of the Balkan Peninsula that continues further on to Asia Minor. The intensive tectonic processes that took place at the end of the Jurassic period determined the shape of the structural forms of the Vardar region. The Serbo–Macedonian massif is an important continental structure of the eastern part of Macedonia, with a north–south orientation. It is built of metamorphic rocks of Precambrian, Riphean, Cambrian, and Paleozoic ages.

In the structure of relief, valleys and larger basins are spread over one third of the territory. The most characteristic are those along the river Vardar, such as the Polog, Skopje, Tikveš, and Gevgelija–Valandovo basins. These basins are connected with Žeden, Taor, and Demir Kapija gorges. The largest basin in Macedonia is Pelagonija basin (4000 km^2), located in the southwestern part of the country. In Western Macedonia, the most characteristic are Ohrid-Struga, Prespa, and Debar basins, while in eastern and southeastern Macedonia: Berovo, Pijanec, Kočani, Ovče pole basins, and the Strumica–Radoviš valley appear.

Traces of diluvial glacial relief and glacial cirques are preserved only in some mountains, mostly in Western Macedonia—Korab, Šar Planina, Bistra, Stogovo, Jakupica, and Galičica. Karst relief is present in the Paleozoic, Mesozoic, Paleogene, and Neogene limestones, so limestone masses are most represented on the mountains of Suva Gora, Žeden, Jakupica, Bistra, Galičica, and the higher parts of Šar Planina. The following karstic features can be found: cracks, coves, sinkholes, and karstic poljes, while caves and sinks are rare.

7.3 Climate

As a result of specific natural and geographical characteristics, the territory of Macedonia has two main types of climate—Mediterranean and continental. They cause the appearance of two specific periods of the year—a cold and wet winter, typical of a continental climate and a dry and hot summer, which corresponds to the Mediterranean climate. In higher mountain regions, the impact of a mountain climate can be observed, characterized by short fresh summers and a cold, moderately wet winter period, during which precipitation usually falls in the form of snow. Despite the proximity of the Aegean and Adriatic Seas, the influence of the Mediterranean climate does not penetrate deep into the territory of Macedonia, because the highest mountains rise in the western and southern part. The influence of the Aegean Sea can be recognized in the valley of the Vardar to Demir Kapija and less in the Skopje valley, as well as in the valleys of the rivers Strumica and Bregalnica. The influence of the Adriatic Sea can be recognized in Western Macedonia, in the valley of the river Drim. The continental influence penetrates from the north to the south and this climatic influence is most important in Macedonia.

The average air temperature of the country is 11.3 °C, the warmest towns are Valandovo (14.5 °C) and Gevgelija (14.3 °C). In regions with a mountain climate, average annual temperatures are as follows: Popova Šapka (4.7 °C), Lazaropole (6.8 °C), and Kruševo (8.2 °C). The mean annual precipitation on the territory of Macedonia is 683 mm. The largest amounts of rainfall were recorded in Mavrovi Anovi (1198 mm), while the driest part of Macedonia is Ovče Pole, where 490 mm of rainfall was registered (Filipovski et al. 1996).

7.4 Flora

In comparison with other European countries, Macedonia is characterized by high floristic diversity, with about 3300 species of high plants (about 3800 species, mosses included). This is a result of its central position in the Balkan Peninsula, as well as its geologic and tectonic history, climatic conditions, and other changes that have occurred in this part of the Balkan Peninsula, from the Tertiary to the present. Various floristic influences appear in the country, especially from the eastern and central Mediterranean, Asia Minor, Central Europe, boreal, and arctic areas of Eurasia (Matevski 2013).

The oldest in their genesis are Tertiary relicts, which have been preserved in certain refugial areas in the mountain belt or have migrated to lower regions where the climatic conditions were more favorable for their survival. Tertiary relicts that have found refugial areas in the higher mountain regions include *Pinus peuce* (Pelister, Nidže, Jablanica), *Pinus heldreichii* ssp. *leucodermis* (Šar Planina, Galičica, Nidže) and others. The Tertiary flora of the lowland belt has to a large extent disappeared, with only some relict species having been preserved in certain refugia, such as river gorges, where the influence of glaciation was much less pronounced (Košanin 1924; Micevski 1978a). Such is the case with two relict species of the tropical family *Gesneriaceae*: *Ramonda nathaliae* (preserved in the gorge of the Vardar river and its tributaries), *Ramonda serbica* (in the gorge of the Garska river, Radika, Crni Drim, Galičica), as well as *Aesculus hippocastanum* (gorge of the Crni Drim, Galičica, the upper part of the Treska river), and *Viola kosaninii* (Jakupica, Karadžica).

Boreal relicts in Macedonia are mainly distributed in coniferous forests—spruce, fir, and mountain heaths (*Picea excelsa, Listera cordata, Coralorhiza trifida, Parnassia palustris, Drosera rotundifolia,* and others).

Glacial relicts are found in the highest mountain regions, where they had refugial areas in moist and cold habitats, such as snow beds, alpine pastures, screes, etc., where the snow remains for a longer period (*Juncus trifidus, Aster alpinus, Ranunculus crenatus, Dryas octopetala, Salix reticulata, Salix retusa, Salix herbacea, Saxifraga aizoides, Saxifraga oppositifolia, Selaginella selaginoides, Diphasium alpinum,* etc.).

Xerothermic steppic relicts represent the remnants of steppe flora, which appeared at the end of the Tertiary (Pliocene) in certain parts of the Balkan Peninsula and found a natural refuge on the territory of Macedonia. The land connection between the southern part of the Balkan Peninsula and Asia Minor existed until the Pliocene. Steppic species have development centers in Asia Minor and Central Asia and arrived in this way. Evidence of this connection is the large number of common plant species, such as *Phelipaea boissieri, Capparis sicula, Morina persica, Astragalus parnassi, Convolvulus holosericeus, Kraseninnikovia ceratoides, Adonis vernalis, Comandra elegans, Asparagus tenuifolius,* etc.

The largest part of the recent flora of Macedonia derives from ancient Mediterranean flora, which was widespread in the Balkan Peninsula during the Tertiary. The main phytogeographic corridors by which the Mediterranean flora penetrated into the territory of Macedonia were the valleys of the Vardar and Drim rivers, through which a large number of species of Mediterranean and submediterranean floristic elements migrated (*Periploca graeca, Quercus coccifera, Punica granatum, Phyllirea latifolia, Arbutus andrachne, Salvia officinalis, Hyssopus officinalis, Convolvulus elegantissimus, Quercus trojana, Euphorbia characias* ssp. *wulfenii,* etc.).

A number of Balkan and local endemic species have special significance in the flora of Macedonia. Around 120 local (Macedonian) endemic species can be found in Macedonia. The most important centers of endemism are considered to be the high mountains (Šar Planina, Korab, Galičica, Jakupica, and Bistra) and river gorges (Vardar, Treska, Crna Reka, and Babuna) as well as some parts of the lowland belt (Mariovo, around Prilep, and steppic area in the central part of Macedonia).

Alpine endemic species are the most numerous so that almost every mountain in Macedonia has its local endemics (Micevski and Matevski 1987). The richest in endemic species are Galičica (*Crocus cvijicii, Centaurea galicicae, Centaurea soskae, Centaurea tomorosii, Laserpitium ochridanum, Astragalus mayeri, Edraianthus horvatii, Festuca galicicae, Helichrysum zivojinii, Micromeria kosaninii,* etc.), Šar Planina (*Crocus scardicus, Verbascum scardicolum, Potentilla doerfleri, Sempervivum kosaninii, Viola schariensis,* etc.), Jakupica (*Pedicularis ferdinandi, Colchicum macedonicum, Sempervivum macedonicum, Viola bornmuelleri, Dianthus jakupicensis*), Pelister (*Crocus pelistericus, Dianthus myrtinervius, Sempervivum octopodes, Alchemilla peristerica*), and Nidže-Kajmakčalan (*Silene horvatii, Dianthus kajmatzalanicus, Peucedanum lavrentiadis, Viola doerfleri*).

Some of the endemic species are of Tertiary *Thymus oehmianus, Viola kosaninii, Crocus cvijicii, Crocus scardicus, Colchicum macedonicum, Narthecium scardicum,* etc.). The second group represents neoendemics, such as *Thymus karadzicensis*, various species of the genus *Centaurea* (*Centaurea skopjensis, Centaurea kavadarensis,* etc.), *Dianthus* (*Dianthus macedonicus, Dianthus ochridanus*), which have limited distribution on the territory of Macedonia, which is explained by their evolutionary youth and lack of time to expand.

7.5 History of Floristic Research

The first person to have published data on the flora of Macedonia was August Grisebach (1814–1879), director of the botanical garden and professor at Göttingen University. He dealt with flora and especially phytogeography. He described about 30 new taxa for science from the territory of Macedonia (Grisebach 1843–1844). Mention should also be made of the well-known Swiss botanist, Edmond Boisser, and a whole group of Czech botanists: Formánek, Velenovský, Čelakovský, Vandas, Rohlena, Dostal, etc., Ignac Dörffer from the Botanical Garden and Museum in Vienna, Richard von Wettstein, professor of plant systematics from Prague and Vienna, Arpand Degen from Pest (Hungary), and Dimitrie Grecescu from Bukurest also carried out investigations in the country.

At the beginning of the twentieth century, there were enough floristic data for the synthetic phase to begin. One of the most important publications, Die Vegetationsverhältnisse von Balkanländer (1909), was prepared by Lujo Adamović (1864–1935) based on an ecological-physiognomical approach in the investigation of vegetation. He presented a horizontal and vertical zonation of vegetation in the Balkan Peninsula and the genesis and historical development of vegetation. He also dealt with flora, especially endemic and relict species. A professor of botany at Belgrade University, Nedeljko Košanin (1878–1934), dealt above all with endemic and relict flora. He was of the opinion that endemic taxa exist on every Macedonian mountain. He thought that these species also had a limited distribution pattern during the Tertiary, since these mountains are old and there were no geologic phenomena that would affect them. Mention should also be made of Fridrich Bornmüller (1862–1948), who worked on the territory of Macedonia during WW1. He published a series of papers about the flora of Macedonia. The most important work dealing with the synthesis of flora of the region was published by the Austrian botanist, August Hayek (1871–1928), who prepared a determination key for flora of the southern Balkans (Hayek 1924–1927, 1928–1931, 1933). The last in this era was William Bertand Turrill (1890–1961), who prepared and described the floristic and phytogeographic peculiarities of the Balkans (Turill 1929).

Some researchers that also focused on vegetation after this synthetic phase should be mentioned. Ivo Horvat (1897–1963) introduced the standard Central European method into the region. He visited the region in the period from 1933 to 1938 and later published several articles about the vegetation (Horvat 1934, 1935, 1936a, 1937, 1938). Two Macedonian researchers deserve mention: Hans Em (1983–1992), who began to investigate with I. Horvat and later dealt primarily with forest vegetation of the region and Kiril Micevski (1926–2002), who dealt with flora and nonforest vegetation (Matevski 2009).

7.6 Climatic Division

The main idea of the regionalization prepared by Filipovski and collaborators (1996) was that climazonal vegetation reflects the climatic condition of the area. At the same time, it must be taken into consideration that zonal soil types appear in each region, with their own successional series.

The appearance of vegetation is induced by a whole complex of natural and anthropogenic factors, as well as the historical development of vegetation in the area. However, factors that influence vegetation development are of different importance. Macroclimate is decisive for the appearance of zonal vegetation, which builds the potential natural vegetation of the region (climax), other more localized factors are important for other types of vegetation, e.g., the vegetation along rivers is maintained by the course of the river (paraclimax) and the anthropogenic factor is decisive for the formation of a vast range of anthropogenic vegetation.

In general, climatic regions are very broad in a horizontal direction but quite narrow in their vertical distribution. In the horizontal direction of the region, the most pronounced is the gradient of diminishing influence of the maritime and increasing influence of continental climate, i.e., the distance from the Aegean Sea (Ćušterevska et al. 2012). However, the main division is in a vertical direction, whereby several different climatic regions with special character can be found. (Table 7.1).

If it is recognized that macroclimatic changes result in changes of zonal vegetation, the distribution of zonal vegetation can be used as an indicator of climatic region. At the same time, it must be taken into consideration that each species and also vegetation community has its own climatic amplitude. This means that the climate is not homogeneous within one region but possesses a specific amplitude, so climatic and vegetation (sub) types can also be detected.

Table 7.1 Division of Macedonia to eight regions based on climate, vegetation, and soil. (After Filipovski et al. 1996)

Number	Name of region	Altitude	Mean annual temperature	Percentage of territory	Dominant species
1	Submediterranean (modified Mediterranean)	50–500	14.2		*Quercus coccifera*
2	Continental submediterranean	100–600	12.7	34.9 regions 1 and 2	*Carpinus orientalis*
3	Warm continental	600–900	10.9	27.4	*Quecus frainetto*
4	Cool continental	900–1100	8.8	13.3	*Quercus petraea*
5	Submontane-continental	1100–1300	8.0	9.7	*Fagus sylvatica*
6	Montane continental	1300–1650	6.4	10.4	*Fagus sylvatica*
7	Subalpine mountain	1650–2250	3.5	3.8	*Fagus sylvatica*
8	Alpine mountain	2250–2764	−0.4	0.5	Grasslands

According to Filipovski et al. (1996), Macedonia can be divided into eight regions based on climate, vegetation, and soil (Table 7.1). It comprises the following regions:

1. Submediterranean (modified Mediterranean) region
   This region is dominated by *Quercus coccifera* and *Carpinus orientalis*. *Q. coccifera* has the northern limit of its distribution here (Oberdorfer 1948). The area is in the southern part of Macedonia and the influence of the Aegean Sea is quite pronounced. There is a mixture of evergreen and deciduous thermophilic and xerophilic plant species. As degradation, there is the formation of shrub species called pseudomaquis. This is the transition from evergreen maquis towards more continental scrub communities called šibljak (Bergmeier and Dimopoulos 2008). In the case of further degradation, there is also garrigue dominated by *Cistus incanus* and early spring therophitic grasslands (*Romulion;* Čarni et al. 2010, 2014). Some characteristic species: *Quercus coccifera, Q. pubescens, Carpinus orinetalis, Phyllirea latifolia, Pistacia terebinthus*.
2. Continental-submediterranean region
   This region is dominated by *Quercus pubescens–Carpinus orientalis*. The region is widely distributed all over the country. The vegetation is the most xerophytic in the research area; the influence of the continental climate is well pronounced. Forests are fairly rare in this area. It was already settled several thousand years ago and it was converted to agricultural land (Bergmeier and Dimopoulos 2008; Čarni et al. 2009). Some characteristic species: *Quercus pubescens, Carpinus orientalis, Fraxinus ornus, Acer monspessulanum, Cornus mas, Ostrya carpinifolia*.

3. Warm continental region
   This is the typical vegetation of the large basins in the western part of the country. This region is mainly flat at the bottom of basins or on the lower part of mountains. The dominant species in these forests are *Quercus frainetto* and *Q. cerris*. Stands are dominated by *Q. frainetto* but *Q. cerris* is nearly always present. There are no endemic species in this area; the dry period eliminates mesophilous endemic species and winter frost eliminates the thermophilous elements. At the same time, these areas are agricultural, with well-developed anthropogenous vegetation. (Em 1964a; Matvejeva 1982; Matevski et al. 2011) Some characteristic species: *Q. frainetto, Q. cerris, Pyrus pyraster,* and *Malus florentina.*
4. Cool continental region
   There are no more flat surfaces from this region on, only more or less steep slopes. This is a relatively narrow region of about 200 m between the warm continental region dominated by *Q. frainetto* and *Q. cerris* and the submontane continental region dominated by beech (*Fagus sylvatica*). These forests are the last extension of thermophilous deciduous forest in the altitudinal range. Forests are dominated by *Quercus cerris* in the lower part and by *Quercus petraea* in the upper part of the region. Because this region is steep, forests have been mainly converted to pastures, rarely to arable land. (Em 1964b; Matevski et al. 2011) Some characteristic species: *Quercus petraea, Fraxinus ornus, Sorbus torminalis, Acer campestre, Corylus avellana*.
5. Submontane continental region
   Submontane beech forests (*Festuco heteropyllae-Fagetum*) can be found in this region. The region extends about 200 m in the vertical direction and forms a vegetation belt at altitudes from 1000 to 1200 m, although in warmer sites it can reach up to 1500 m. (Rizovski and Džekov 1990; Matevski et al. 2011; Marinšek et al. 2013) Beech (*Fagus sylvatica*) shows some genetic variability in comparison to beech in the western part of the Balkans and other parts of Europe. Beech in southeastern Europe has been treated as *Fagus moesica* in the past but new findings show that it cannot be treated as an independent species, although it nevertheless shows a certain genetic peculiarity (Brus 2010). This region seems to be an area in which lowland vegetation gradually disappears and (sub)alpine vegetation gradually appears. Here, we can still find the lowland dry grassland communities of *Saturejo-Thymion* (*Astragalo-Potentilletalia, Festuco-Brometea)* on carbonate substrate (Micevski 1970; Matevski et al. 2015). Dry grassland of the alliance *Armerio-Potentillion* can be found on noncarbonate bedrock (Micevski 1978b). On deeper soil, meadows are found that are classified within the endemic alliance *Rumicion thyrsiflori* (*Arrhenathereta, Molino-Arrhenatheretea*). (Micevski 1994; Melovski and Matevski 2008). Some characteristic species: *Fagus sylvatica, Carpinus betulus, Prunus avium, Corylus avellana, Quercus petraea*.
6. Montane continental region
   The montane region appears from 1300 to 1650 m. No dry season can be detected in the region. Extremely high temperatures are mitigated by altitude and there are often fogs. Climatic conditions in this region are favorable for beech, which, as a subatlantic species, appears in regions with humid and cool climate. Beech

and mixed beech–fir forest can be found; beech is mixed with *Abies alba* in the northern part of the country and with *Abies borisii-regis* in the southern part. The following associations can be found in the region: *Calamintho-Fagetum, Bruckentalio-Myrtillo-Fagetum* and *Abieti borisii-regis-Fagetum, Fago-Abietetum meridionale*. (Em 1974; Em 1975; Matevski et al. 2011). Some characteristic species: *Fagus sylvatica, Acer platanoides, Acer pseudoplatanus, Ulmus scabra, Abies borisii-regis, A. alba*.

7. Subalpine mountain region
The area extends over a relatively wide range of 600 m of altitude, between 1650 and 2250 m. The area is fairly small, since not many mountains reach such an altitude. It is the highest belt with forest vegetation, where forest vegetation meets its limiting climatic conditions. The forests are low, often in shrubby form and deformed (sabre trees). The area has been deforested in the past in order to obtain suitable areas for secondary subalpine grasslands. The timberline has, thus, been lowered by 300–400 m. Only a smaller part of the area is covered by forest today, the major part is secondary pastures or heaths. (Vassilev et al. 2011) These forests can be reconstructed on the basis of fragments or remnants found on some steep slopes unfavorable for pastures. The timberline can be built of *Fagus sylvatica, Abies alba, Picea abies, Pinus peuce, Pinus heldreichii, Pinus sylvestis,* and *Pinus mugo*.
Subalpine beech forests can be found all over Macedonia. They are linked to montane beech forests but they are different in the form of beech (sabre trees) and their floristic composition is also different (Em 1961; Rizovski and Džekov 1990; Matevski et al. 2011). Subalpine forests dominated by *Pinus peuce* appear on silicate bedrock on rocky soils (Pelister). Stands of *Pinus peuce* have also spread from these into secondary stands on sites of montane and even submontane beech forest. It is fast expansion. Subalpine *Pinus peuce* forest shows a similar floristic composition as subalpine beech forest (Em 1962). Forests of *Pinus heldreichii* are practically destroyed and only some remnants can be found on Galičica, over limestone bedrock (Horvat et al. 1974). *Abies alba* forests (they are sometimes mixed with *Picea abies*) appear up to 1800 m. They are found on sites with high air and soil humidity over carbonate and noncarbonate bedrock. In some cases, these forests are in contact with subalpine grasslands but Em (1974) thinks that subalpine beech forests also existed above fir forests that have been destroyed and, in such cases, *Abies alba* now builds the timberline (Em 1974). *Picea abies* forest can be found on small areas on Šar Planina mountain. It can appear as pure *Picea* forest or mixed with *A. alba* at altitudes from 1700 to 2000 m on humid and cool sites (Em 1986). On Nidže mountain, timberline built of *Pinus sylvestis* can be found. Both *Pinus sylvestis* and *Pinus nigra* can be found in the area but *Pinus nigra* is found on warmer sites. *Pinus sylvestis* is sometimes mixed with *Pinus peuce* in the area (Em 1981). Communities of *Pinus mugo* are rare in the country and can appear at the highest altitudes of the subalpine belt (Šar Planina and Jakupica) up to 2500 m and they protect the soil against erosion. These communities can be found on limestone and on noncarbonate bedrock (Em 1962; Šibík et al. 2010).

8. Alpine mountain region
   Forest vegetation cannot be found in this region and only herb species can survive the severe conditions. This vegetation can be found only on small areas, since only a few mountains reach this altitude (Kožuf, Nidže, Pelister, Dešat, Korab, Šar Planina, and Jakupica).
   The vegetation is adapted to severe conditions: thin soils, high water permeability, strong winds, accumulation of snow, steep slopes, etc. Depending on site conditions: aspect, inclination, depth of soil layer, strength of wind, duration of snow cover and human impact, various vegetation types appear.

The following vegetation types can be found on Macedonian mountains:

Grasslands of the class of alpine and subalpine calcareous swards *Elyno-Seslerietea* and the Balkan order *Onobrychido-Seslerietalia* can be found on carbonate bedrock. These grasslands are further divided into two groups: *Edvaiantho-Seslerion* in the alpine vegetation belt and *Onobrychido-Festucion* (syn. *Seslerion nitidae*) in the subalpine vegetation belt. The vegetation of *Onobychido-Festucion* appears at lower altitudes, on warm and protected sites. The soil horizons are deep and the habitat is covered by snow during winter. The tussocks of grasses are relatively dense and communities build fairly closed vegetation. This vegetation can also appear at lower altitudes on sites of subalpine beech forests. The other vegetation type is *Edvaiantho-Seslerion* (syn. *Anthyllido-Seslerion*). This vegetation is visually very different from the former one. The stands are dominated by sedges, low grasses, chamaephytic species, and many small herbs. These communities are adapted to extreme site conditions, low temperatures, and high day–night fluctuations of temperature. These communities are strongly influenced by wind, which has a mechanical and physiological influence on the communities. It removes the snow during winter and dries out the sites, so the vegetation is xerophytic despite precipitation (Horvat 1936b, Horvat 1960; Micevski 1994; Karagiannakidou et al. 2001; Redžić 2011a, 2011b).

Acidophilous grasslands of the alpine and subalpine belts are classified within *Caricetea curvulae*. These grasslands in the Balkan Peninsula belong to the endemic order *Seslerietalia comosae*.

Communities on deep acidic soils in wind-sheltered habitats are classified within *Poion violaceae*. These communities develop on deep soils in sheltered habitats. The stands are dense and fairly uniform. In the case of too intensive grazing, these communities are converted to *Potentillo ternatae-Nardion*. (Horvat 1960)

Grasslands on deep acidic soils in wind-exposed habitats of the Balkan Peninsula are assigned to *Seslerion comosae*. These communities appear on ridges that are exposed to wind, where the bedrock is without carbonates (Horvat 1935; Redžić 2011b).

Within *Caricetea curvulae*, the order of alpine acidophilous species-rich grassland *Festucetalia spadiceae* with the alliance *Knautio-Patzkeion* can also be distinguished. This alliance comprises tussock grasslands on decalcified deep soils at high altitudes of the Balkan Peninsula. The soil is leached and therefore acidic, which enables the development of these acidophilous communities (Čarni and Mucina 2015).

Under human impact, secondary mat-grass swards on nutrient-poor soils appear, which can be classified within *Nardetea strictae* and *Nardetalia strictae*. These oligothrophic mat-grass swards of mountains of the south-central Balkan Peninsula are further classified within *Potentillo ternatae-Nardion*. They cover large areas on both carbonate and noncarbonate bedrock but on carbonate bedrock appear only on sites with deep soil horizons. These communities are fairly similar all over the country, being differentiated according to the community that they replace. Mat-grass swards can appear on all sites except those that are exposed to strong wind (Horvat 1935; Velev and Apostolova 2009).

Chasmophytic vegetation appearing in crevices and on the surfaces of rocky cliffs and walls is classified within *Asplenietea trichomanis*. Because of the extreme ecological conditions, the vegetation is species poor, with low cover. However, specializied species nevertheless find their ecological niche in such conditions.

Chasmophytic vegetation of carbonate crevices in high mountains of the southern Balkans is further classified within *Potentilletalia speciosae*, and those of the alpine belt within *Ramondion nataliae*. The vegetation of these habitats is very diverse and many paleoendemic species can be found there.

The crevice vegetation of siliceous rocks is classified within *Androsacetalia vandelii* and the alliance *Silenion lerchenfeldianae*. The vegetation on noncarbonate bedrock is quite different from the vegetation over carbonate bedrock. Many breaks and fractures can be found on carbonate bedrock, which enable the development of chasmophytic vegetation; such sites appear on silicate bedrock only sporadically. As a consequence, the vegetation is not so widely distributed as the vegetation on carbonate bedrock. Moreover, it has to be taken into consideration that more endemic species appear on carbonate bedrock (Horvat et al. 1937; Simon 1958; Horvat 1960; Mucina et al. 1990; Micevski 1994; Dimopoulos et al. 1997; Ewald 2003).

Screes develop below steep cliffs and walls that are the result of tectonic movements. Under the influence of cosmic and atmospheric factors, cliffs decay and the material accumulates below them. The deeper scree is composed of small rock elements that move at every touch but below the scree can be found large rock blocks. Vegetation of scree habitats and pebble alluvia is classified within *Drypetea spinosae* and *Arabidetalia flavescentis*. Calcareous scree vegetation of montane to subalpine belts is classified within *Silenion marginatae* (Horvat et al. 1974; Dimopoulos et al. 1997; Valachovič et al. 1997; Dimopoulos 2011).

In comparison with dry scree vegetation of *Drypetea spinosae*, the vegetation of snow-beds of *Salicetea herbaceae* is much more moisture tolerant. These communities survive a very humid environment and long snow cover, which often lasts until the end of July, so vegetation develops at the beginning of August. This vegetation is classified within *Arabidetalia caeruleae* and *Arabidion caeruleae* on carbonate and *Salicetalia herbaceae* and *Salicion herbaceae* on silicate bedrock (Horvat 1960; Mucina et al. 1990).

The vegetation around small springs develops above all on silicate bedrock. The floristic composition is a result of the permanent flow of water, which maintains a relatively stable temperature of the site. It is classified within the class of vegetation of cold springs *Montio-Cardaminetea* and order *Montio-Cardaminetalia,* containing vegetation of cold oligothrophic springs. This vegetation in Macedonia is classified within the alliance *Pinguiculo balcanicae–Cardaminion acris* (Hájek et al. 2005; Čarni and Matevski 2010).

The class *Mulgedio-Aconitetea* encompasses shrub and tall herb vegetation of high altitudes growing on moist and fertile soils that are under the influence of percolation water. It can be further classified within the order *Adenostyletalia*. Two alliances can be distinguished within this order: *Cirsion appendiculati* and *Geion coccinei.* The first includes vegetation that develops only around springs and along streams and rivers. The other can be found on sites that are soaked with water for extended periods during spring, when the snow melts. Communities of tall-herb and fern-rich communities on acidic to leached carbonate soils *Calamagrostietalia* within the alliance *Calamagrostion villosae* can also be found. Nitrophilous vegetation that appears around stables for animals that are maintained in the mountains can also be classified within this group. It is classified within *Senecioni rupestris-Rumicetalia alpini* and *Rumicion alpini* (Horvat et al. 1937, Horvat 1960; Micevski 1994; Michl et al. 2010; Čarni et al. 2010).

Fen vegetation is widespread on all Macedonian mountains but fragmentarily, in places where small permanent springs soak sites and enable the development of moor vegetation. Fens appear on both silicate and carbonate bedrock. On silicate bedrock, they are classified within the class of vegetation of transitional mires, fens, and bog hollows *Scheuchzerio palustris-Caricetea fuscae*. Further fens and mires and fens developing on mesotrophic and oligo-mesotrophic peats and peaty mineral soils are classified within *Caricetalia fuscae* and *Caricion canescenti-fuscae.* The small-sedge rich-fen vegetation of oligo-mesotrophic calcareous peaty soils in springs and shallow fens is classified within the order *Caricetalia davallianae* and *Caricion davalianae*—small-sedge rich-fen vegetation of calcareous oligotrophic flushes (Horvat 1960; Hájek et al. 2005; Hájková et al. 2006).

Alpine heaths are built of chamaepytic shrubs that are accompanied by species from alpine grasslands. These communities can appear on large areas over silicate bedrock but are much more sporadic over carbonate bedrock. They also appear on areas of subalpine forests deforested in the past. Arctic-boreal tundra scrub and relict (sub)alpine acidophilous dwarf heath are classified within *Loiseleurio-Vaccinietea* and *Rhododendro ferruginei-Vaccinietalia*. Ericoid subalpine chionophilous dwarf scrub heaths of the southern Balkans are further classified within *Bruckenthalion spiculifoliae* (Zupančič 1992).

Subalpine and alpine dwarf heath on rocky calcareous soils is classified within *Rhododendro hirsuti-Ericetea carneae* and *Rhododendro hirsuti-Ericetalia carneae*. In Macedonia, this vegetation type is classified within *Daphno-Genistion radiatae* (Ranđelović and Redžepi 1980).

7.7 Important Plant Areas (IPA)

In order to implement effective protection and conservation of populations of wild species, an initiative has been undertaken to indicate IPA. IPA are defined as areas with natural or seminatural habitats that are extremely rich in plant diversity (rare, relict, and endemic plant species and/or plant communities that have a high botanical value, or are in any way threatened). The main objective is to identify and protect priority areas for the conservation of plant species and plant communities, using established international and regional criteria, such as the presence of international, regional, and locally important species, botanical richness, and the presence of endangered habitats. Based on the above criteria, 42 IPA on the territory of Macedonia were selected, of which 12 are transborder (Melovski et al. 2010). Some IPAs cover large areas (mountain ranges), while some of them have a relatively small area (these are usually areas with a high concentration of plant species and habitats represented on small surfaces). The major part of the IPA (26) encompass areas that are in the region above an altitude of 1000 m. This includes almost all mountain ranges in Macedonia, as well as botanically significant sites that are located at lower altitudes, at the foot of mountain massifs (Alšar, Baba Sač, Belasica, Bistra, Buković-Straža, Galičica, Ilinska Planina, Jablanica, Jakupica, Kožuf-Dudica, Korab, Dešat, Barbaros, Mariovo, Mavrovo, Nidže, Judovi Livadi, Pelister, Plačkovica, Markovi Kuli-Treskavec, Žeden, Skopska Crna Gora, Stogovo, and Šar Planina). The areas are shown on a map (Fig. 7.1).

7.8 Climate Change in the Recent Period

An analysis of climatic changes in the recent period and foreseen climatic scenarios have been published in the Third Communication on Climate Change (Zdraveva 2014) and in the climate change scenarios for Macedonia prepared by the Hydrometeorological Service of the Ministry of Agriculture, Forestry and Water Economy (Karanfilovski 2012).

Data provided by the Hydrometeorological Institute show trends of a slight increase in average annual temperatures for the period 1971–2000 and 1981–2010 compared to the 1961–1990 period (Fig. 7.2). A positive trend of temperature in-

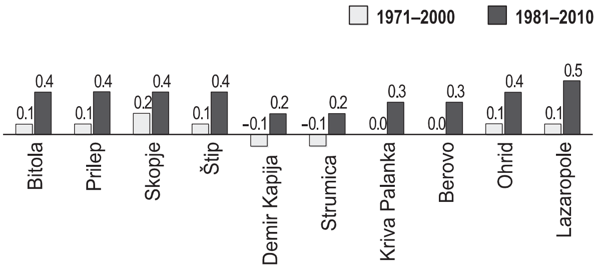

Fig. 7.2 Average air temperature. Deviation of the 30-year average in two periods, 1971–2000 and 1981–2010, compared with the period 1961–1990. (Source: Hydrometeorological Service in Zdraveva 2014)

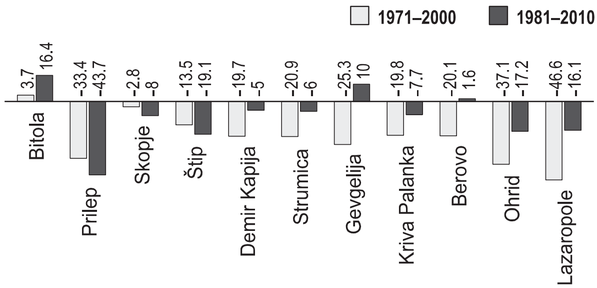

Fig. 7.3 Total average precipitation. Deviation in the 30-year average in two periods (1971–2000 and 1981–2010) from the 1961 to 1990 period. (Source: Hydrometeorological Service in Zdraveva 2014)

crease was registered for almost all studied regions. The smallest change can be seen in areas under the influence of the Mediterranean climate, such as Demir Kapija and Strumica (southern part of the country: first climatic region) and the largest in Lazaropole (1300 m)

The amount of precipitation in the last 30 years has dropped significantly for most regions in Macedonia compared to the period 1961–1990. The most significant changes (negative difference) were observed in mountain regions (Fig. 7.3).

7.9 Climate Change in the Future

Climate changes indicate statistically significant changes in average climatic parameters over time. There have been numerous studies dealing with this topic in the world: climate warming is clearly recognizable, the average temperature of air and oceans is increasing, snow is melting, glaciers and ice on the poles is diminishing and there is a rise of sea levels. There has been a linear trend of increasing average air temperature in the period 1906–2005, of 0.74 °C. On a time scale of 50 years, the trend is even more worrying; there has been an increase of 0.13 °C per decade in the period 1956–2005 (Karanfilovski 2012). Global warming is to a large extent a result of human activities, which substantially raise the atmospheric concentration of greenhouse gasses. It can cause adverse effects on natural ecosystems. Since humanity is aware of this danger and wants to prevent or at least mitigate the adverse effects of global warming on the environment and humanity, the United Nations adopted the Framework Convention on Climate Change in 1992. The Republic of Macedonia ratified this convention in 1997 and prepared three national communications on climate change that deal with global warming and measures to mitigate its effect. The data in this chapter were drawn from those reports (Azievska 2008; Zdraveva 2014) and represent the basis of our evaluation.

The prediction was prepared by Karanfilovski (2012). The study of global warming is based on a model that is intended to present future warming scenarios, based

Table 7.2 Predicted changes in air temperature for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

Season	Winter				Spring				Summer				Autumn				Annual			
Scenario:	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100
high	1.1	2.4	3.8	5.0	1.4	3.0	4.6	6.2	2.4	4.8	7.9	10.6	1.5	3.0	5.0	6.7	1.6	3.3	5.3	7.2
medium high	0.9	1.9	3.0	3.9	1.1	2.4	3.6	4.8	1.9	3.8	6.2	8.2	1.2	2.4	3.9	5.2	1.3	2.6	4.2	5.5
medium	0.8	1.5	2.2	2.7	1.0	1.8	2.7	3.3	1.7	3.0	4.6	5.8	1.1	1.9	3.0	3.7	1.2	2.0	3.1	3.9
medium low	0.7	1.0	1.5	1.7	0.9	1.3	1.9	2.1	1.6	2.1	3.4	3.9	1.0	1.3	2.2	2.5	1.1	1.4	2.2	2.5
low	0.5	0.8	1.1	1.1	0.7	0.9	1.4	1.4	1.2	1.5	2.4	2.7	0.7	1.0	1.6	1.8	0.8	1.0	1.6	1.7

Table 7.3 Predicted changes in the quantity of precipitation (%). (After Karanfilovski 2012)

Season	Winter				Spring				Summer				Autumn				Annual			
Scenario:	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100
low	-1	-3	-2	-1	-2	-5	-7	-9	-4	-12	-29	-36	-1	-5	-8	-9	-2	-6	-8	-8
medium low	-1	-4	-3	-2	-2	-6	-10	-12	-6	-15	-38	-47	-1	-7	-10	-13	-3	-8	-10	-12
medium	-3	-6	-7	-9	-3	-8	-13	-17	-13	-25	-46	-57	-2	-9	-14	-20	-4	-10	-15	-19
medium high	-4	-8	-11	-16	-4	-9	-17	-23	-20	-38	-54	-66	-4	-11	-21	-27	-5	-11	-21	-27
high	-5	-10	-14	-20	-5	-12	-21	-29	-25	-48	-68	-80	-4	-14	-25	-34	-6	-14	-25	-33

on natural factors (solar radiation, water cycle process, etc.), emission of green house gases, and prediction of future economic, technological, demographic, and sociological development.

During the modeling, several scenarios were constructed. Initially, four families of scenarios were built, designated A1, A2, B1, and B2. These scenarios were then divided into subfamilies, e.g., the A1 family was divided into three subfamilies on the basis of the intensity and manner of use of energy resources, designated A1FI, A1B, and A1T. Several models were also used, e.g., Asian Pacific Integrated Model (AIM). In the process, several scenarios of values for temperature and precipitation changes were produced: for each of the 12 months, for seasons: winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), and autumn (September, October, and November), as well as an average annual value.

An assessment of air temperature and precipitation changes was made for the period 2025–2100 on the basis of data from the period 1961 to 1990, which was used as reference point. Since the scenarios have a spatial resolution of 2.5° × 2.5°, only two points appear on the territory of Macedonia and we have chosen only the one that is valid for almost the whole country, indicated as A (41.25°N; 23.75°E), with a central point near Demir Hisar.

The predicted data are presented in the tables (Tables 7.2 and 7.3) according to the different scenarios for the years 2025, 2050, 2075, and 2100 (the year indicates the center of the period predicted):

- High (absolute maximum values, corresponding to the A1FI-MI scenario)
- Medium high (average maximum values)
- Medium (average mean values for the three values of climate sensitivity, very close to the A1B-AIM scenario)
- Medium low (average minimum values)
- Low (absolute minimum values, corresponding to the B1-IMA scenario).

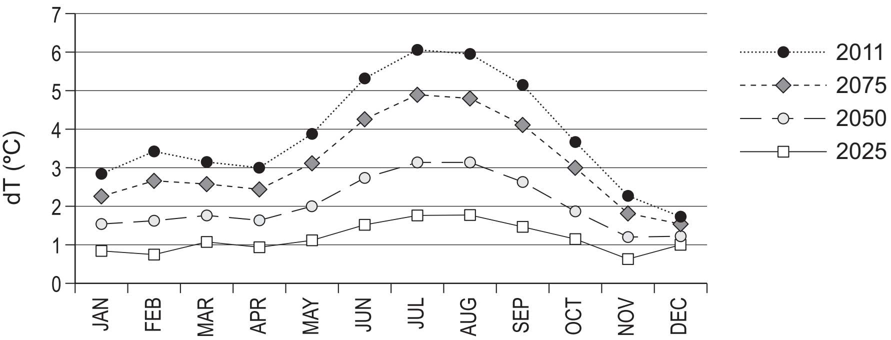

Fig 7.4 Annual course of medium predicted air temperature changes for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

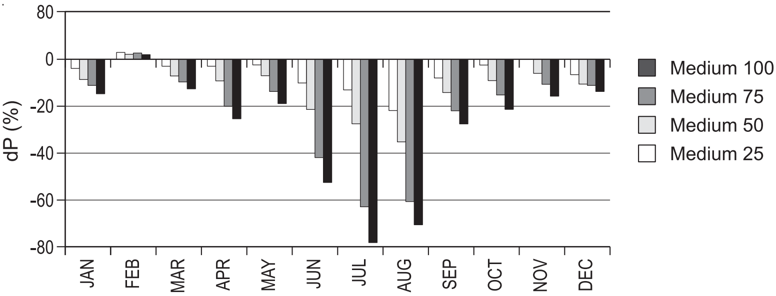

Fig. 7.5 Annual course of the medium predicted precipitation changes for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

The result shows that all temperatures are positive and that warming will continue in the period 2025–2100 (Table 7.2). There will be warming during the whole period. Summers in particular will get warmer and warmer, while the rise of temperature will be less significant during the winter months. There will be two peaks of changes, a large one in July and a less pronounced one in February. The changes will be at a minimum during April and December. The minimum change in April and increase in February will equalize the temperature during spring (Fig. 7.4).

A decrease of precipitation is foreseen in the period 2025–2100 (Table 7.3). The decrease will happen in all seasons; the only increase will be in February. The intensity of change will be greatest in the warm part of the year, in July and August. The intensity of change may reach 100 %, meaning that those months will probably be without precipitation. In the cold period of the year, a decrease of precipitation up to 40 % is predicted (Fig. 7.5).

7.10 Impact of Climate Change on Flora and Vegetation

Global changes have an impact on various environmental components. Biodiversity is one of the most dynamic and susceptible parts of the environment and is constantly subject to the impact of global changes. It reacts to the changes with its own adaptive capacity. Flora and vegetation can adapt to global changes; it can also migrate to other areas with more propitious site conditions, or new communities can be formed to adapt to new environmental conditions.

Since Macedonia is a relatively small, mountainous country, a minor change in latitudinal zonation can be expected, and only in the lowland region, where changes of influence of both maritime and continental climates can appear. In other parts of Macedonia, vertical zonation can be expected and changes in this direction are foreseen.

Refugial centers are greatly at risk (Em 1985, Brajanovska 2010). They are very important for the biodiversity of Macedonia due to the extraordinary species richness, especially with endemic and relict species. In these habitats, e.g., gorges or canyons, special microclimatic conditions can be found that are not directly influenced by macroclimatic conditions. Refugia are characterized by specific ecological conditions, such as a temperature regime without severe extremes, higher air and soil humidity during the dry season, etc. Species found shelter in these habitats during climate changes in the past.

The Second National Communication to the Convention on Climatic Change Sector Biodiversity (Matevski 2008) and the Third National Communication to UNFCC Sector Biodiversity (Melovski et al. 2013) provide the basis for the assessment.

Global climatic changes can have various impacts on a regional level, with different changes of temperature and precipitation in different regions. For certain regions, especially in the mountains, the temperature regime could be the more important factor causing disturbances and changes of composition of ecosystems, while other ecosystems are more sensitive to changes of precipitation, i.e., available humidity.

Considerable latitudinal movement of plant and animal species in a south–north direction is likely to be significant only in the lowland submediterranean region. Vegetation in the lowland submediterranean region (i.e., modified Mediterranean) is dominated by *Quercus coccifera* and *Carpinus orientalis*.

The predicted distribution of *Q. coccifera* has been modeled for the period to 2100 based on the A1B scenario (Fig. 7.6). This scenario is fairly pessimistic and foresees a market-oriented economy and fairly rapid economic growth. In this prediction, the world's population will grow until 2050 and then decline. Kermes oak (*Q. coccifera*) thrives at present in the southeast part of Macedonia, in the area along the Vardar river below the gorge of Demir Kapija, which stops the maritime influence from penetrating further into the Balkan Peninsula. The community is dominated by kermes oak, oriental hop-hornbeam (*Carpinus orientalis*) and pubescent oak (*Q. pubescens*), which build so-called pseudomaquis, a mixture of deciduous and evergreen species. The modeled current distribution and predictions

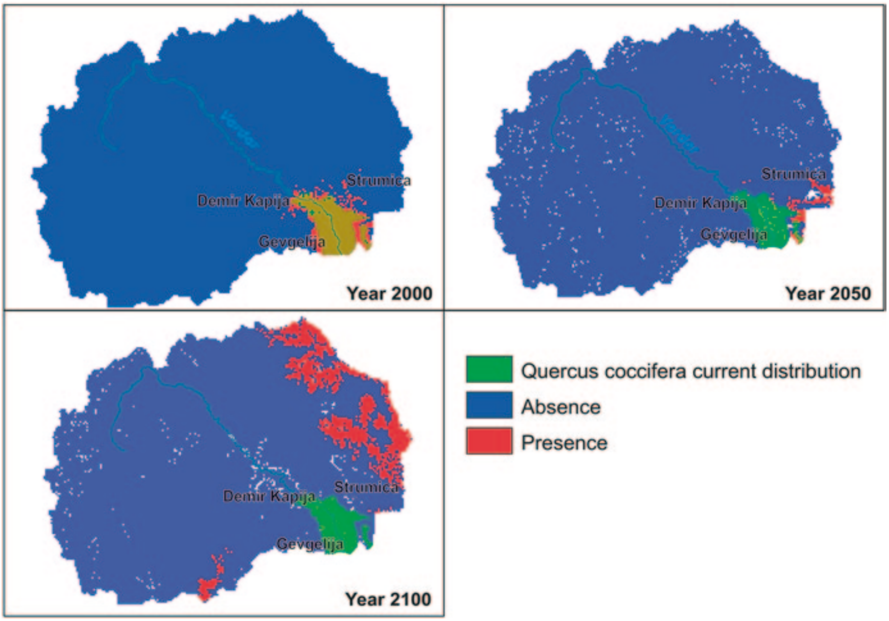

Fig. 7.6 Predicted distribution of *Quercus coccifera* for the period to 2100. (After Melovski et al. 2013)

are shown in Fig. 7.6. A shift towards the east of the country in the Strumica valley can be expected in 2050. A further shift towards the eastern part of the country is expected in 2010 (Osogovo, Plačkovica, etc.) It can be seen that the area of distribution will enlarge in the coming period.

The main changes will occur in the vertical distribution pattern. Major dislocation of vertical regions will appear, as well as a certain redistribution of species and ecosystems along the gradient. The size of the damage and species loss will depend on the rate of climate change, since changes of species distribution depend on their adaptation capacities and mobility.

Beech forests will extend their range towards the upper montane and subalpine belts. The reasons for such an expansion are not only climatic but also the abandonment of grazing in the country. Beech forests will reoccupy their natural stands in the area of subalpine pastures. Some problems in afforestation might be caused by degraded soil and rocky habitats that will not allow the beech forest to settle in the whole potential habitat.

A large part of the subalpine region of Pelister mountain is covered by *Pinus peuce* forests. *Pinus peuce* forests are spreading even today to the montane and even the submontane vegetation belts on potential habitats of beech or beech–fir forests. This is a result of past land use, such as cutting and grazing, which degraded the sites and thus gave the less demanding species *Pinus peuce* a competitive advantage. The current process in the area of Pelister is also of course a result of good conservation practices in Pelister National Park and the abandonment of sheep breeding in

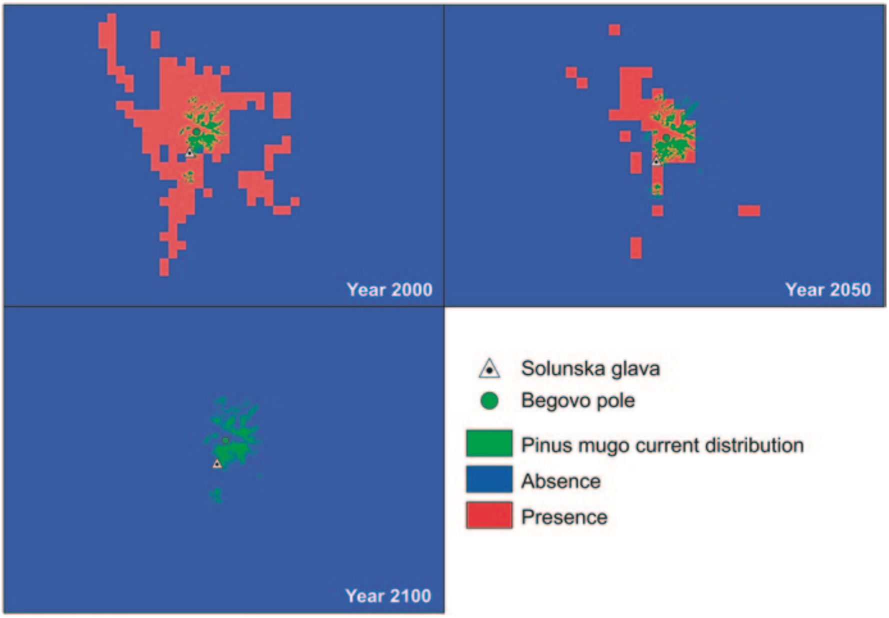

Fig. 7.7 Predicted distribution of *Pinus mugo* for the period to 2100. (After Melovski et al. 2013)

the region. Climate change will thus offer favorable conditions for *Pinus peuce*. *Pinus peuce* is an ecologically less demanding species than *Fagus sylvatica* and will therefore gain under further warming. A positive result can be expected, because the spread of *Pinus peuce* could also happen in a horizontal direction if biocorridors are safeguarded. *Pinus peuce* is known to have had a much larger distribution range in Macedonia historically (Meshinev et al. 2000).

Subalpine spruce forests in the area are at the southern limit of distribution. The timberline is built by spruce in the Alps, since spruce appears in areas with low temperature, low mineralization, and high snow cover. Warming will accelerate net mineralization, the snow will be converted to rain and spruce forests will therefore be endangered (Juvan et al. 2013). Fir forests and Scots pine communities will react in a similar way to beech forests.

Pinus mugo builds the timber line on Šar Planina and Jakupica. It builds large shrub communities only on Jakupica (Mt. Mokra) (Fig. 7.7). It covers habitats in the subalpine and alpine regions. The present distribution of *Pinus mugo* (indicated in green) is much smaller than the modeled one (red).The modeled distribution range is larger than the real distribution since the model predicts larger suitable habitat than those currently occupied. The problem is that the model does not take into account ecological factors (e.g., soil and bedrock types) and especially historic and anthropogenic factors. The model thus shows the potential distribution range. A considerable reduction of areas is expected in 2050 and the complete disappearance of *Pinus mugo* is expected by 2100.

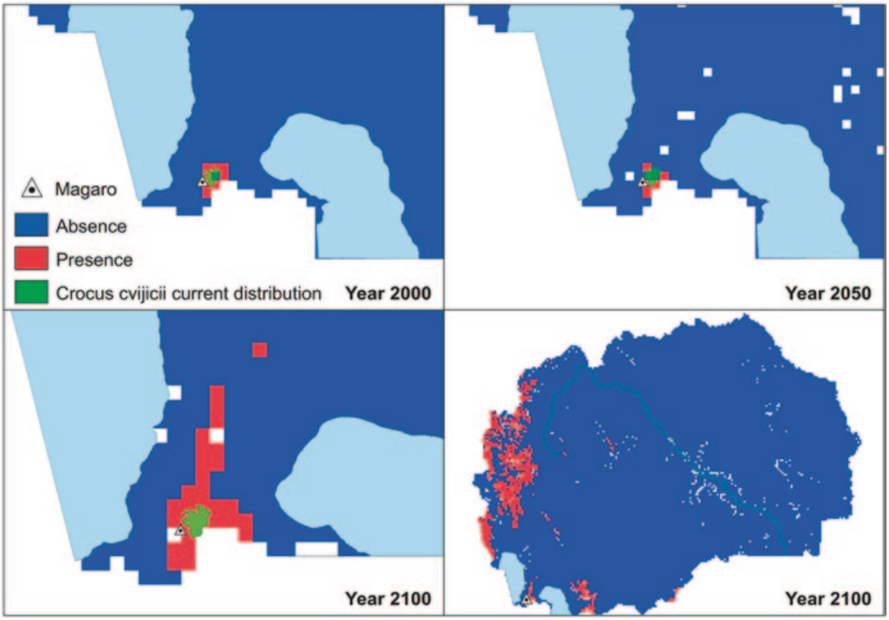

Fig. 7.8 Predicted distribution of *Crocus cvijici* for the period to 2100. (After Melovski et al. 2013)

Azonal communities, such as wetlands and riverine vegetation, can also be affected. The impact of climate change on wetlands and riverine vegetation is manifold. The water is warming, the ice-free period is longer and annual and seasonal water flow is changing. Wetlands can dry out and it is difficult for flora and vegetation to move to other places. The large floods induced by higher temperatures during snow melts in spring and the changed precipitation regime could also threaten the riverine flora and vegetation. An additional problem is the extraction of drinking water in the higher mountains, especially above the timberline.

7.11 Impact of Climate Changes on Alpine Flora and Vegetation

A rise in temperature will lead to shorter periods of snow packing on the mountains. Especially in mountains without a typical alpine belt, warming will affect species that grow around snow beds (e.g., *Crocus cvijicii* on Galičica). *Crocus cvijicii* is known to occur only on Galičica Mountain, in the subalpine region (1800–2150 m) on limestone. It flowers during late spring or early summer, mostly in humid sites near remaining snow patches (Ranđelović et al. 2007). The current distribution is presented in green polygons (Fig. 7.8). The modeled polygons are shown in red. The modeled area of distribution is larger, since the model shows all suitable sites

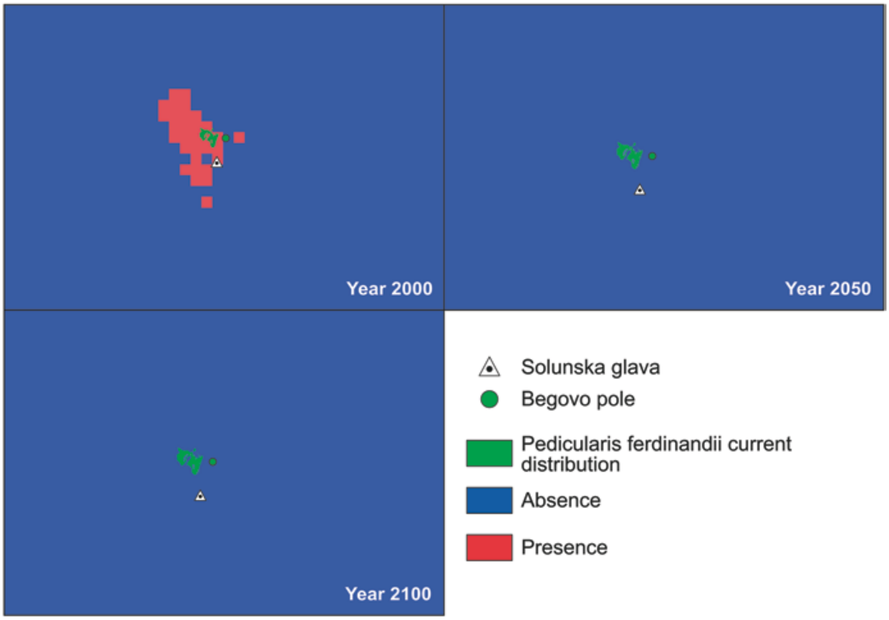

Fig. 7.9 Predicted distribution of *Pedicularis ferdinandi* for the period to 2100. (After Melovski et al. 2013)

for the species. However, it does not take into account ecological, historical, and anthropogenic influences. Climate change will shrink its potential distribution range. However, in 2100, the potential distribution range will expand and it will cover northern (lower) parts of Galičica. *Pedicularis ferdinandi* could serve as another example of alpine flora (Fig. 7.9). It is an endemic species of Jakupica and has several scattered localities at altitudes from 2100 to 2300 m, shown by green polygons. The modeled distribution is much larger, since it can be found in most of the areas in this region (red polygons). According to the model, this species will disappear by 2050.

Subalpine grasslands are of secondary origin (e.g., *Onobrychido-Festucion*), having been established in the subalpine belt on sites of subalpine forest ecosystems during past millennia and created through grazing practices. With global warming and in combination with the changing land use system (abandonment of grazing), these areas will be subject to afforestation.

Alpine grasslands, scree, and vegetation of cliffs are distributed only on the highest parts of the mountain summits that occupy a very small area (only 0.5 % of the country). The vertical movement of these communities will be hindered by relief obstacles, ecological conditions, and available space. The conical shape of mountains means a smaller area at higher elevations. The other possibility is that plants and communities will move to northern slopes, where ecological conditions are more propitious (cooler).

Well-developed alpine pastures can be found above 2100–2300 m, depending on the slope and aspect. Only the highest mountains in Macedonia have a real alpine region, since only Korab and Šar Planina have peaks above 2700 m. In these alpine areas, species are mostly arctic and glacial relicts, as well as endemics, the result of recent speciation. According to Beniston and Fox (1995), a rise of temperature of 3 °C corresponds to a change of altitude of 500 m. In that case, most of the present alpine vegetation would disappear. The only possibility for survival would be sheltered and north-facing slopes, which could provide conditions for the survival of alpine flora and communities.

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