Chapter 11
Highland Vegetation of Inner and Eastern Anatolia and the Effects of Global Warming

L. Kurt, O. Ketenoglu, G. N. Tug and F. Sekerciler

11.1 Introduction

Turkey exhibits a peculiar heterogeneous ecology in temperate zone. The altitudinal changes in climatic parameters prevent the development of trees over some elevations called as "alpine zone" depending on the regions.

In Turkey, the changes in timberline through the regions are as follows: 2100–2200 m in Mediterranean and Central Anatolian, 1900–2000 m in Aegean, 2000–2050 m in Eastern Black Sea, and 2800–2900 m in Eastern Anatolia region (Colak and Rotherham 2007; Fig. 11.1).

Alpine zones are widespread in Northern Hemisphere and many mountain ranges in Turkey have the same zone as well, Eastern Black Sea Mountains, East and West Taurus Mountains, and East Anatolian Mountains. Also, Uludag, Koroglu Mountains, Sultan Mountains, Ilgaz Mountains, Erciyes, Hasan, and Ak Mountains have alpine zones at their peaks. The highest peaks and their altitudes in Inner Anatolia are as follows: Erciyes (3917 m), Melendiz (2963 m), Hasan Mountain (3268 m); and in Eastern Anatolia are Great Agri Mountain (5137 m), Little Agri Mountain (3896 m), Tendurek Mountains (3533 m), Suphan Mountain (4058 m), Nemrut Mountain (3050 m), Kisir Mountain (2197 m), and Akbaba Mountain (3040 m; Erinc 2000).

Alpine zones exhibit very harsh conditions for the plant life. Therefore, plants of this zone have to have some adaptations to cope with these conditions. Increase in altitude results in low air pressure, which leads to changes in temperature, precipitation, and light conditions that are effective on plants survival (Atalay 2006).

The ecological conditions in alpine habitats are harsh for plant life and plants that have adaptations can survive. These harsh conditions and short vegetation period create different morphological, physiological, reproductive, and ecological characteristics on these plants (Billings 1974). Also, these conditions change in

L. Kurt (✉) · O. Ketenoglu · G. N. Tug · F. Sekerciler
Biology Department, Science Faculty, Ankara University, Tandogan, Ankara, Turkey
e-mail: kurt@ankara.edu.tr

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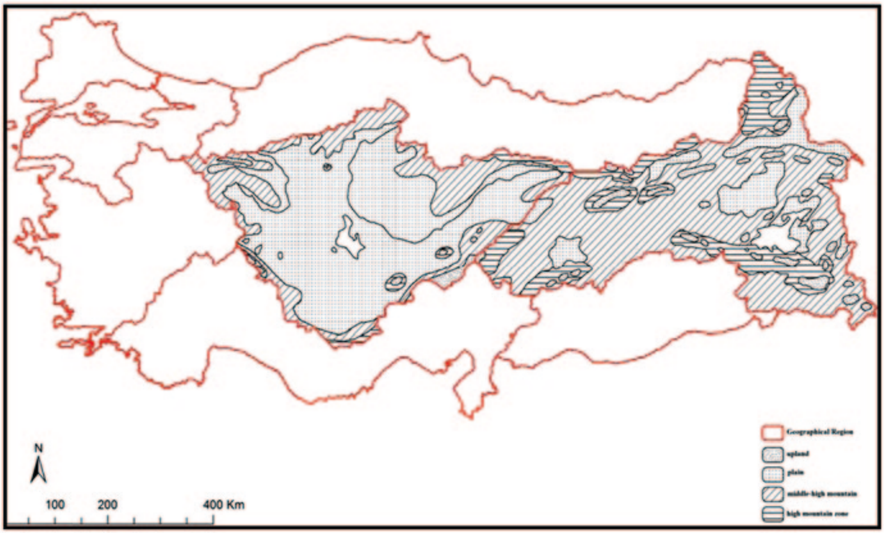

Fig. 11.1 Altitudinal changes at Central and East Anatolia regions

short distances significantly depending on the roughness, slope and microhabitats (Atay et al. 2009; Körner 2001). Perennial herbs are the most dominant life forms in alpine habitats. There are also some annual herbs, prostrate shrubs, and caulescent woody plants. Most of the species have well-developed root systems, and many of them store carbohydrates. Annual species are so small and rare. Seeds of alpine plants are dormant and require chilling to germinate (Amen 1966; Billings and Mooney 1968). Vegetative growth is fast in alpine habitats and starts when snow cover melts and soil temperature rises over 0 °C. They also have drought resistance and similar adaptations like xerophytes. Alpine plants reproduce both vegetatively and sexually. Almost all alpine plants produce flower primordia to guarantee the flowering in a short growing period (Mondoni et al. 2012). Shrubs and small trees form groups and live together to cope with the adverse effects of the environmental conditions, they form krummholz structure. Most of the species have small leaves with thick cuticle and waxy layer against transpiration. Having all these characteristics not only provides these plants to survive in these conditions but also restrict them to these vulnerable areas (Körner 1999). So destruction of the alpine habitats, which are generally considered sensitive especially against global warming, results in a threat for these plants (Pauli et al. 2003). When the conditions change, especially increase in temperature, the only thing these plants do is to migrate to higher altitudes as the lower belt plants. At one point they will reach the peak and there will be nowhere else to go to survive, their habitats getting narrower due to global warming (Parolo and Rossi 2008; Vittoz et al. 2009; Peters and Darling 1985; Ozenda and Borel 1991; Markham et al. 1993; Beniston 1994).

11.2 Phytogeographical Position of Central and Eastern Anatolian High Mountain

Turkey is situated in the intersection area of tree phytogeographical regions, Euro-Siberian (Circumboreal), Mediterranean, and Irano-Turanian. Central and Eastern Anatolian regions are considered in Irano-Turanian phytogeographical region.

Through the science of biogeography, different authors named the Irano-Turanian phytogeographical region with different names. Grisebach (1872–1884) differentiated the Irano-Turanian from its western and eastern neighbors excluding the Eurosiberian and Mediterranean areas. Although some authors included the region in Mediterranean phytogeographical region, others like Engler (1908), Rikli (1913), and Lavrenko (1950) considered some part of Central Asia as Central Asian region. Eig (1931/1932) implied that Irano-Turanian region is not completely uniform and considered the west part as “High Asia.” According to some opinions and the last results from some parts of the phytogeographical region, the idea of division of the region in two parts as west and east is accepted.

Irano-Turanian region in Turkey was divided in four sectors by Zohary (1973):

1. East Anatolian High Mountains
2. Central Anatolian Sector
3. South-East Anatolian Sector
4. Mesopotamian Sector

But nowadays this division is not widely accepted. The area can be evaluated as:

a. West Asian Subregion
b. Middle Asian Subregion (Takhtajan 1986)

The West Asian Subregion was then divided in eight provinces: Mesopotamian, Central Anatolian, East Anatolian and Iran, Turanian or Aralo-Caspian, Hyrcanian, Turkmenistan, North Blucistan, and West Himalayan.

So Central and Eastern Anatolia belong to Central Anatolian and East Anatolian–Iran provinces, respectively.

11.3 Central Anatolian High Mountain Vegetation

11.3.1 Topography and Soil

Central Anatolia is a plateau peripherally surrounded by mountains such as Taurus Ranges in south and Black Sea Mountains in north. The altitude increases from west to east. Vertical timberline is 2100–2200 m in Central Anatolia. At the middle part of the karstic plateau, there are some extinct volcanos: Erciyes Mountain

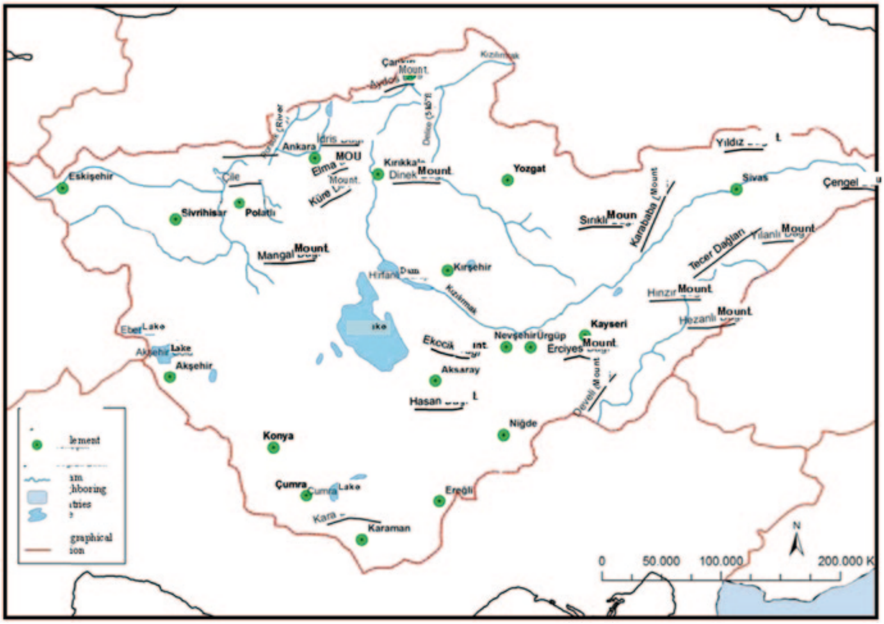

Fig. 11.2 Map of the mountains in the Central Anatolia

(3917 m), Hasan Mountain (3268 m), Melendiz Mountain (2963 m), Karadag (2271 m), and Isik Mountain (2015 m), which are the highest peaks of the area (Akman 1976; Erinc 2000; Fig. 11.2).

The mountainous parts of Nigde, southeastern part of Central Anatolia, are divided into two parts by Ecemis River from north to south. West part is composed of Nigde massif and Karadag extinct volcano, east part is composed of Aladag (Erinc 2000). Aladag ranges have some high peaks and the highest ones are Demirkazik and Kizilkaya having an altitude over 3700 m.

11.3.2 Climate

The mean minimum temperature of the coldest month is generally below 0 °C over 2000 m in Central Anatolia, which matches the mountainous and high mountain zones of Mediterranean region both climatically and floristically. The Mediterranean originated primary forest vegetation in Central Anatolia was destroyed especially by anthropogenic factors like overgrazing, reclamation, illegal logging, fires, etc., and replaced by steppe vegetation. So the Irano-Turanian originated plants took place of Mediterranean originated ones and therefore biogeographically there was a great change in the structure of vegetation (Kasapligil 1977), although the high mountainous parts of Central Anatolia have links with Mediterranean region, Irano-Turanian originated species are dominant due to the above mentioned facts.

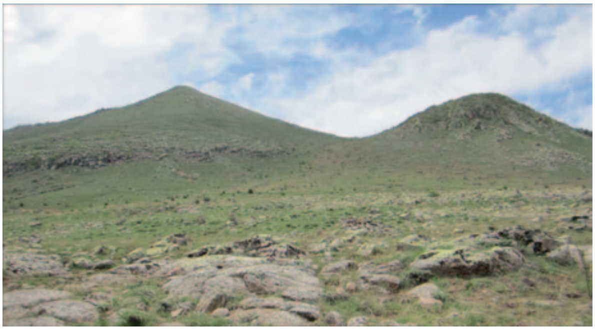

Fig. 11.3 Melendiz Mountain in the region of Central Anatolia

11.3.3 Plant Dynamics

Over the timberline, physical and chemical properties of soil results in the development of different plant communities. Although the vegetation seems uniform partially, dwarf shrubs or trees are present as well. Also, due to the ecological peculiarities, the dominant species are hemicryptophytic members of Poaceae like *Bromus tomentellus* Boiss., *Festuca valesiaca* Schleich. ex Gaudin, *Rostraria cristata* (L.) Tzvelev var. *cristata*, *Stipa lessingiana* Trin. & Rupr., *S. Holosericea* Trin., and some chamaephytes like *Astragalus angustifolius* Lam., *A. microcephalus* Willd., and *Onobrychis cornuta* (L.) Desv.

11.3.4 Vegetation

Central Anatolian high mountain vegetation phytosociologically belongs to class Astragalo-Brometea (Quezel 1973). Although this class is defined to classify high mountain écorchée grasslands of Taurus Mountains, it also includes almost all of the steppic communities in Turkey.

Although the mountainous steppe of Taurus Mountains and high mountain steppes of Central Anatolia syntaxonomically belong to the same class, their floristic structures are not same, due to the different precipitation regimes and mother rock properties. Although there are many phytosociological and floristical studies about Taurus, anti-Taurus, and North Anatolian Mountains, less is known about high mountains of Central Anatolia. Over the timberline of Erciyes Mountain, Hasan Mountain, Melendiz Mountain (Fig. 11.3), and Karadag Mountains in Central Anatolia, steppic communities dominated by chamaephytes and hemicryptophytes and xerophytic plants grow on undeveloped soils.

The cover ratios of these communities are about 40–60 % and the rest is bare and rocky area. The high mountain steppe vegetation of Central Anatolia belongs to Mediterranean high mountain zone physiognomically. The majority of plants are perennials from tertiary era. Especially species from Lamiaceae, Scrophulariaceae, Caryophyllaceae, Brassicaceae, and Boraginaceae are dominant. Many chamaephytes and perennial grasses form humid high mountain steppes, spiny cushion forming plants correspond almost half of the species with cover ratio of 20–40 %.

The most dominant and major cushion forming chamaephytes of high mountain zone of Central Anatolia are *Astragalus angustifolius* Lam. subsp. *angustifolius, Acantholimon echinus* (L.) Boiss., *Onobrychis cornuta* (L.) Desv., *Minuartia juniperina* (L.) Maire & Petitm, and spiny *Astragalus* spp. The alliance Minuartion juniperino-pestalozzae Ketenoglu et al. 1996 was defined on Hacibaba Mountain around Konya province at 2000–2350 m of 20–40 % slope with calcareous mother rock (Ketenoglu et al. 1996). Spiny chamaephytes are dominant in the species composition of the alliance. The dominant species within the area are *Minuartia juniperina* (L.) Maire & Petitm, *Minuartia pestalozzae* (Boiss.) Bornm, *Astragalus angustifolius* Lam. subsp. *angustifolius, Marrubium globosum* Montbret & Aucher ex Benth., *Silene pharnaceifolia* Fenzl, *Dianthus zederbaueri* Vierh., *Poa alpina* L. subsp. *fallax* F.Herm., *Centaurea mucronifera* (DC.) Wagenitz, *Veronica cuneifolia* D.Don subsp. *isaurica* P.H.Davis, *Paronychia davisii* Chaudhri.

11.4 East Anatolian High Mountain Vegetation

11.4.1 Topography and Soil

East Anatolia has a rough and mountainous topography with mean elevation of 1600–1800 m. The major mountains are Cimen, Kop, Esence, Karasu, Allahuekber at north, Mercan (Munzur), Karasu-Aras at central part, southeastern Taurus and Buzul mountains at south. Agri, Tendurek, Aladag, Suphan, and Nemrut are extinct volcanic mountains at north of Van Lake (Figs. 11.4 and 11.5; Erinc 2000).

Anatolian diagonal is a natural barrier that separates Central and East Anatolia. This diagonal is a high mountain range that divides Anatolia into two parts from Northeast to Antakya. It starts around Gumushane-Bayburt and reach to southwest anti-Taurus where it splits into two branches, one towards Amanos and the other towards Taurus Mountains. Anatolian diagonal is composed of Allahuekber, Kesis, Kargapazari, Munzur, Binboga. Tahtali and Amanos Mountains are located at the southernmost edge of this diagonal. Therefore, the southernmost distribution area of Euro-Siberian elements is the Amanos Mountains (Aytac 2010).

11.4.2 Climate

In general, East Anatolia is under the influence of semi-continental climate. Due to continentality, precipitations concentrated in summer months. So the vegetative development at grasslands reaches maximum at summer months. Therefore, high mountain areas of eastern Anatolia are dominated by damp grasslands.

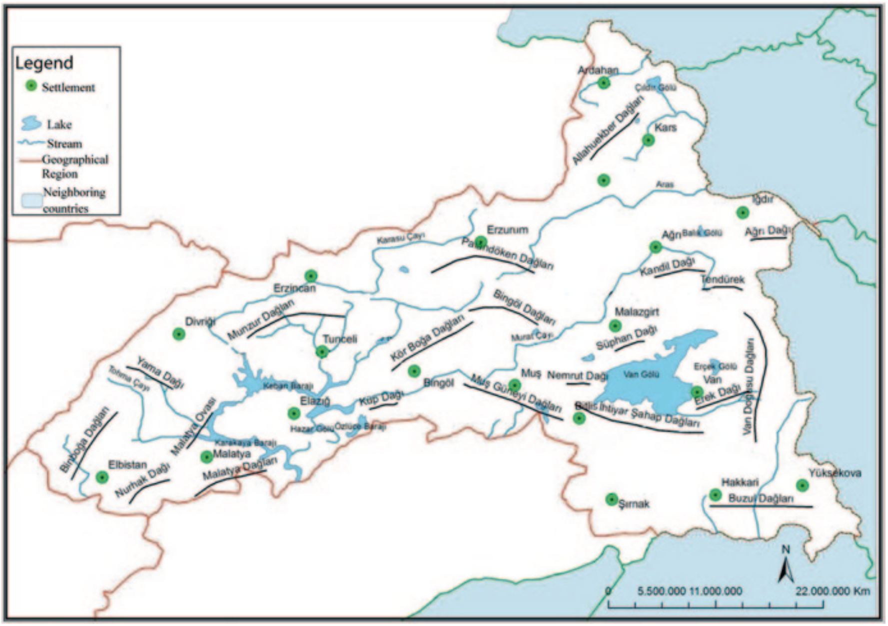

Fig. 11.4 Map of the mountains in the East Anatolia

Fig. 11.5 Agri Mountain in the region of East Anatolia

11.4.3 Plant Dynamics

Natural vegetation is structured by altitude and climate. The mean altitude in Eastern Anatolia is over 1600–1800 m. The climax community of the area is *Pinus sylvestris* L., but it shows a discontinuous distribution. Human activities cause regressive development at *P. sylvestris* L. forests and turn them into damp grasslands outside of agricultural areas.

Glacial movements at geological era contributed the biodiversity in Anatolia. Flora and fauna of Anatolia are influenced from the migration during glacial and interglacial eras. Many species sheltered at Anatolia and during the interglacial era draw back leaving some relict forms behind.

At the East Anatolian plateau, which can be named as the roof of Anatolia with high water table and alluvial and hydromorphic soils over 1600 m, damp grasslands

Fig. 11.6 A view of high mountain steppe from Kisir Mountain

with rich biodiversity develop. These areas are dominated by mesophytic species of almost 100 % cover. Vegetative development starts with melting of snow cover and increasing of temperature at the end of April, and at the end of June and beginning of July flowering and then ripening of seeds occur (Atalay 2006).

Fallowing areas after cereal farming around alluvial-hydromorphic grasslands are covered by *Papaver orientale* L., *Gladiolus atroviolaceus* Boiss., *Onobrychis stenostachya* Freyn, *Vicia cracca* L., *Dianthus calocephalus* Boiss., *Senecio vernalis* Waldst. & Kit., *Anthemis cretica* L., etc.

Due to the influence of continental climate, vegetation period continues till the end of September. The major species of alluvial-hydromorphic grasslands are as follows: *Anthemis cretica* L., *Bromus japanicus* Thunb., *Cyanus depressus* (M.Bieb.) Soják, *Dianthus calocephalus* Boiss., *Eremopoa persica* (Trin.) Roshev, *Erigeron acris* L., *Filago arvensis* L., *Filipendula vulgaris* Moench, *Gladiolus atroviolaceus Boiss.*, *Lotus corniculatus* L., *Medicago x varia* Martyn, *Onobrychis stenostachya* Freyn, *Papaver orientale* L., *Papaver rhoeas* L., *Phleum montanum* K.Koch, *Rumex acetosa* L., *Rumex alpines* L., *Senecio vernalis* Waldst. & Kit., *Sanguisorba minor* L., *Salvia verticillata* L., *Trifolium repens* L., *Trifolium pratense* L., *Vicia cracca* L.

The alluvial-hydromorphic grasslands are dominated by hydrophytes at the places where water table is high. At these areas, naturally growing trees cannot be seen.

These damp grasslands occur either at the sloppy areas with low water table or at partially flat areas, which distinguish them from alluvial-hydromorphic grasslands. Between 1800 and 2700 m, it is the most common vegetation type of the forest and agricultural areas.

The characteristic species of the high mountain steppes of East Anatolia are graminoids (Fig. 11.6) like *Festuca cyllenica* Boiss. & Heldr., *Agrostis stolonifera* L., *Alopecurus aequalis* Sobol., *Bromus pumilio* (Trin.) P. M. Sm., *Dactylis glomerata* L., *Gaudiniopsis macra* (M.Bieb.) Eig, *Phleum pratense* L., *Poa nemoralis* L., *Poa bulbosa* L., *Poa pratensis* L. and *Acanthus dioscoridis* L., *Aster alpinus* L., *Helichrysum plicatum* DC., *Myosotis lithospermifolia* Hornem., *Sibbaldia parviflora* Willd., *Alchemilla caucasica* Buser, *Anthemis cretica* L., *Draba bruniifolia* Steven, *Gentiana verna* L., *Minuartia anatolica* (Boiss.) Woronow.

High mountain steppes are important for livestock production. Vegetative growth increases after the melting of snow cover at the end of April and temperature increases due to continentality. At the beginning of June, transhumance starts and causes early and over grazing, which destroy the vegetation. At the overgrazed

Fig. 11.7 A view of volcanic mother rock from Tendurek Mountain

areas the common species are *Elymus hispidus* (Opiz) Melderis subsp. *hispidus*, *Elymus repens* (L.) Gould, *Alopecurus pratensis* L., *Artemisia* sp., *Alchemilla caucasica* Buser, *Bromus tomentellus* Boiss., *Bromus erectus* Huds., *Cyanus depressus* (M.Bieb.) Soják, *Galium verum* L., *Lotus corniculatus* L., *Medicago x varia* Martyn, *Onobrychis cornuta* (L.) Desv., *Ranunculus millefolius* Sol. subsp. *millefolius*, *Salvia verticillata* L., *Taraxacum officinale* F.H. Wigg., *Trifolium hybridum* L., *Thymus fallax* Fisch. & C.A. Mey., *Veronica orientalis* Mill., *Vicia sativa* L.

11.4.4 Vegetation

The syntaxa of high mountains of East Anatolia belong to the class Astragalo microcephali-Brometea tomentelli. High mountain steppes of East Anatolia connected to the order Festuco oreophilae-Veronicetalia orientalis (Hamzaoglu 2006). This order extends from western side of Anatolian diagonal to Black Sea Mountains at north and to Taurus Mountains at south between 1500 and 3200 m. Hemicryptophytes and chamaephytes reflect the physiognomy. The mother rock on which the order spreads is generally volcanic but also marly and calcareous (Fig. 11.7).

The diagnostic species of the order are *Astragalus lagopoides* Lam., *Astragalus onobrychis* L., *Securigera orientalis* (Mill.) Lassen subsp. *orientalis*, *Festuca brunnescens* (Tzvelev) Galushko, *Medicago papillosa* Boiss., *Onobrychis transcaucasica* Grossh., *Rosa spinosissima* L., S*cutellaria orientalis L.* subsp. *orientalis*, *Thymus transcaucasicus* Ronniger, Veronica *orientalis* Mill. subsp. *orientalis*, *Acantholimon caryophyllaceum* Boiss., *Alyssum pateri* Nyár subsp. *prostratum* (Nyár) T.R. Dudley, *Pulsatilla violacea* Rupr. subsp. *armena* (Boiss.) Luferov, *Artemisia spicigera* K.Koch, *Asperula prostrata* (Adams) K.Koch, *Astragalus cinereus* Willd., *Centaurea rhizantha* C.A.Mey., *Coluteocarpus vesicaria* (L.) Holmboe subsp. *vesicaria*, *Cephalaria sparsipilosa* V.A. Matthews, *Daphne oleoides* Schreb subsp. *kurdica* (Bornm.) Bornm., *Erysimum leptocarpum* J.Gay, *Festuca oreophila* Markgr.-Dann., *Gypsophila bitlisensis* Barkoudah, *Helichrysum arenarium* (L.) Moench. subsp. *rubicundum* (K.Koch) P.H.Davis & Kupicha, *Malabaila dasyantha* (K.Koch) Grossh., *Pimpinella peucedanifolia* Fisch., *Silene montbretiana* Boiss., *Thymus pubescens* Boiss. & Kotschy ex Celak.

Between Gumushane and Bayburt around Coruh and Kelkit at 1500–2200 m at the transition zone between Irano Turanian and Euro Siberian phytogeographical regions, the alliance Tanaceto aucherani–Thymion pubescentis (Hamzaoglu 2006) individualizes. Although the distribution area is not clear, this alliance spreads from Anatolian diagonal from West to Northeast Black Sea Mountains at north and to Otlukbeli, Kop and Gavur mountains at south. The diagnostic species of the alliance are *Achillea schischkinii* Sosn., *Astragalus lagopodioides* Vahl, *Centaurea carduiformis* DC. subsp. *orientalis* Wagenitz., *Isatis candolleana* Boiss., *Tanacetum aucherianum* (DC) Sch. Bip., *Thymus pubescens* Boiss. & Kotschy ex Celak, *Eremogone armeniaca* (Boiss.) Holub, *Erysimum pycnophyllum* J.Gay, *Onobrychis hajastana* Grossh., *Salvia rosifolia* Sm., *Turanecio lorentii* (Hochst.) Hamzaoglu.

The alliance Astragalo aurei-Festucion caucasicae Hamzaoglu 2006 occupies Gavur and Palandoken Mountains around Erzurum, Van, Suphan, and Nemrut Mountains between 2400 and 3200 m at subalpine zone. The alliance spreads on the soils derived from the basalt and andesite mother rock of volcanic origin. The dominant and common species are *Festuca woronowi* Hock. subsp. *caucasia* (St. Yves) Markgr.-Dannenb. and *Astragalus aureus* Willd. The chamaephytes and the hemicryptophytes dominate the physiognomy. The diagnostic species are *Astragalus aureus* Willd., *Cephalaria procera* Fisch. & Avé-Lall., *Festuca woronowii* Hack. subsp. *caucasica* (St. Yves) Markgr.-Dannenb, *Nepeta transcaucasica* Grossh., *Silene arguta* Fenzl, *Vicia alpestris* Steven subsp. *alpestris*, *Erigeron caucasicus* Steven subsp. *venustus* (Botsch.) Grierson, *Poa longifolia* Trin., *Senecio pseudo-orientalis* Schischk.

11.5 The Influence of Global Warming and Climate Change on High Mountain Ecosystems of Central and East Anatolia

Increase in the use of fossil fuels due to the industrial revolution and other greenhouse gasses from anthropogenic sources, cause to change in climate types, to increase in sea level, and to melt of glaciers, which are global environmental problems and lead to threaten the global life.

Global warming have some impacts on alpine habitats like duration of snow cover and its depth decrease (Valt and Cianfarra 2010), rapid glacier retreat reduce (Paul et al. 2004) that change the distribution, phenology and physiology of several plants (Grabherr et al. 1994; Sandvik et al. 2004; Klanderud and Totland 2005; Gottfried et al. 2012).

Consequently, the global warming influences alpine biomes as the others. Also, anthropogenic activities like increasing recreational activities, overgrazing, mining, power sector, etc., seriously threat the alpine biomes locally or regionally (Beniston et al. 1997).

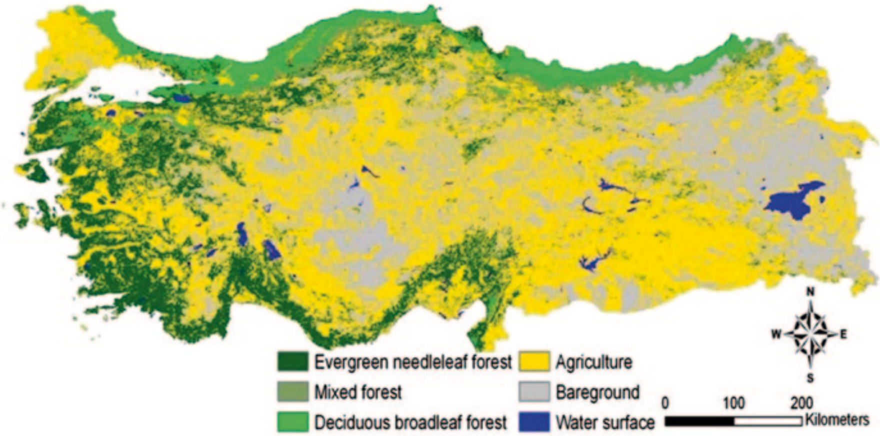

Fig. 11.8 Land cover classification map of Turkey using the MODIS images. (Gulbeyaz 2007; Onder et al. 2009)

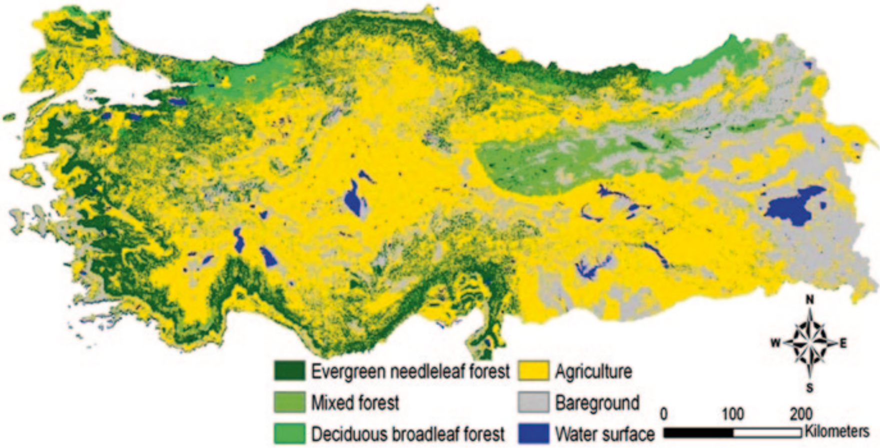

Fig. 11.9 Predicted land cover distribution as a result of future aridity index. (Onder et al. 2009)

Due to its localization in temperate zone, global warming and climate change will influence Turkey most. There is a 70-year model of Turkey about the influence of climate change (Onder et al. 2009; Figs. 11.8 and 11.9). According to this model, precipitation will be 29.6 % lower than today at Mediterranean coast, Central parts, and Firat basin. On the contrary, there will be a 22 % increase in Black Sea coast. This model predicts 2.8–5.5 °C increase in temperature over the country. The increase in temperature triggers the evaporation and raise it by 17.8 % in Mediterranean coast, 18.4 % at Black Sea coast and 22.2 % over the country (Onder et al. 2009; Turkes 2007)

Most of the carbon in the world is accumulated in frozen soils of alpine zone and peatlands. The release of carbon into atmosphere accelerates the warming process. Especially warming triggers the disappearance of permanent snow cover. So, ice cap of volcanic mountains in Central and East Anatolian regions like Agri, Suphan, and Erciyes Mountains are expected to be disappeared.

When the today's vegetation and the expected vegetation of future are compared, it is thought that the evergreen coniferous forests will take the place of deciduous broad-leaved forests. Mixed forests can be spread in middle parts of East Anatolia and Northwest parts of the country (Onder et al. 2009; Sano et al. 2007).

Drought risk is expected to increase in central and southern parts due to increase in temperature, which leads to increase in evapotranspiration and decrease in precipitation. The deficiency of current water sources to meet the demands results in "water stress" locally and naturally. Influences of drought on natural ecosystems have also some sociocultural effects.

Almost 13 million ha of forests was destroyed per year, but nowadays this value is decreased to 7 million ha by reforestation and conservation efforts (FAO 2000). Deforestation is responsible for 20 % of the green house gasses emissions, which lead to global warming and so threaten the alpine zone.

There is a desert zone at the south of Turkey. In the next 50 years, it is expected that this zone will extend towards north and increase the temperature especially in Central and Southeast Anatolia, which leads to aridity and desertification. The geographical position, climate, topography, and soil properties of Turkey increase the vulnerability of desertification and drought. There are some important indicators of such situations. In fact, global warming, urbanization, and anthropogenic pressures on natural ecosystems cause extinction of 13 species in last 20 years. And the worst will be expected in next decades.

The expected climate change in the next 50–100 years will influence the biodiversity, ecological processes, natural resource managements, and also the sectors relied on these sources significantly. It is very important for public institutions and universities to deal with the climate change that can lead severe results on ecology, economy, and social life (Aksay et al. 2005; Ketenoglu and Kurt 2012).

For the sustainable use of ecosystems during the climate change, scientific, technological, and sociological capacity should be strengthen. Long-time-monitoring infrastructure should be generated, early warning systems should be built, and risk management should be guaranteed.

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