Chapter 15
Vegetation and Plant Diversity of High-Altitude Mountains in Eastern Karadeniz (Black Sea) Region of Turkey and Climate Change Interactions

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15.1 Introduction

Eastern Karadeniz (Black Sea) is one of the richest regions in terms of biodiversity in Turkey (Gokler and Ozturk 1989; Ozturk et al. 1997, 1998). A total of 3210 vascular plant taxa have been reported as native or naturalized in the region and of these 465 taxa are endemic to Turkey. Fifty of the endemics are in the critically endangered list of the International Union for Conservation of Nature (IUCN), while 67 are in the endangered list. The endemism ratio of the region is very high lying around 14.5% (Ozturk et al. 1997, 1998; Ekim et al. 2000; IUCN 2001; Güner 2012; Fig. 15.1) (Table 15.1). High mountain areas in Artvin, Rize, and Trabzon are the places rich in endemism.

The ecologically important features of the region have attracted the interest of both the biodiversity specialists and international conservation organizations. In 2001, "Conservation International identified the area as Caucasus Biodiversity Hotspot" and listed it among the world's 25 biodiversity hotspots. This hotspot was designated by Conservation International as a conservation priority—meaning that it is a region with exceptional abundance of endemic species and at the same time it is undergoing an exceptional loss of habitat (Ozturk et al. 1997, 1998; Myers et al. 2000; Krever et al. 2001). The region has also been included in the list of the Global 200 Ecoregions and the name of the ecoregion is defined as "Caucasus-Anatolian-Hyrcanian Temperate Forests." Turkey is included in four of these "Global 200 Ecoregions."

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From the phytogeographical point of view, the region lies in the Colchic section of Euxine province of the Euro-Siberian region, one of the three floristic regions in Turkey (Davis 1971). This section represents the farthermost western extension of many species growing in the region. These species include the following trees and shrubs: *Acer cappadocicum, Alnus glutinosa* ssp. *barbata, Betula medwedewii, Daphne glomerata, Diospyros lotus, Picea orientalis, Quercus pontica, Rhamnus imeretina, Rhododendron caucasicum, R. smirnovii, R. ungernii*, and *Sorbus subfusca*.

The herbaceous taxa are: *Chamaesciadium acaule, Draba hispida, Geranium psilostemon, Hypericum bupleuroides, Lathyrus roseus, Lilium ponticum, Lycopodium* spp., *Pachyphragma macrophyllum*, and *Papaver lateritium*.

The alpine flora in the region is closely connected with that of the Caucasus, and shows little floristic connection with the rest of Turkey (Davis 1965). Many studies have been undertaken in the region related to biodiversity (Vural 1996; Ozturk et al. 1997, 1998; Küçük 1998; Terzioğlu 1998; Terzioğlu and Anşin 2001; Varol et al. 2003; Emianağaoğlu and Anşin 2003; Tüfekçioğlu et al. 2004; Terzioğlu 2005; Terzioğlu et al. 2007; Uzun and Terzioğlu 2008). But not much work has been carried out on the influence of climate change on biodiversity of high mountain areas in the region (Tüfekçioğlu et al. 2008). Climate change models predict a significant change in the climate of the eastern and western part of the region (Dalfes et al. 2007). Therefore, it is essential to compile and analyze the existing literature in the region related to biodiversity and climate change effects.

This chapter mainly deals with the areas above 1000 m from sea level which includes forest, the most widespread vegetation type in the region, and the subalpine–alpine ecosystem of the eastern Karadeniz region. The main objective here

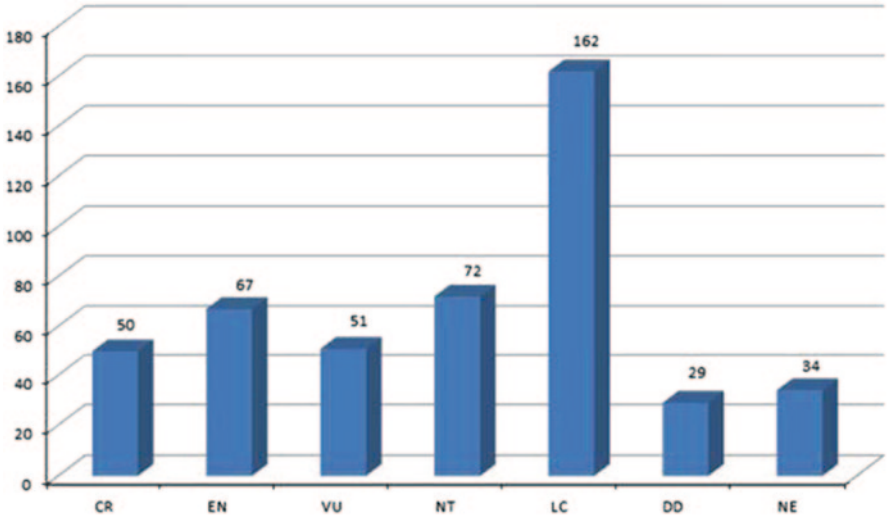

Fig. 15.1 Total number of taxa of the region in IUCN threat categories

Table 15.1 Native threatened taxa of the eastern Karadeniz region

Threat category	Taxa
CR	*Ferula mervynii*
CR	*Archanthemis calcarea* var. *calcarea*
CR	*Archanthemis calcarea* var. *discoidea*
CR	*Centaurea leptophylla*
CR	*Doronicum tobeyi*
CR	*Hieracium amblylepis*
CR	*Hieracium mannagettae*
CR	*Hieracium onosmaceum*
CR	*Hieracium polygonifolium*
CR	*Hieracium rizense*
CR	*Hieracium spodocephalum*
CR	*Hieracium subhastulatum*
CR	*Hieracium subrosulatum*
CR	*Hieracium tersundagense*
CR	*Hieracium tossianum*
CR	*Psephellus yusufeliensis*
CR	*Senecio trapezuntinus*
CR	*Tulipa gumusanica*
CR	*Tanacetum oxystegium*
CR	*Tripleurospermum ziganaense*
CR	*Alyssum nezaketiae*
CR	*Barbarea auriculata var. paludosa*
CR	*Barbarea platycarpa*
CR	*Minuartia buschiana* ssp. *artvinica*
CR	*Silene bayburtensis*
CR	*Colchicum lagotum*
CR	*Colchicum leptanthum*
CR	*Astragalus ansinii*
CR	*Astragalus eliasianus*
CR	*Astragalus olurensis*
CR	*Astragalus trabzonicus*
CR	*Hymenocarpos woronowii*
CR	*Erodium hendrikii*
CR	*Hypericum fissurale*
CR	*Iris nezahatiae*
CR	*Clinopodium serpyllifolium* ssp. *giresunicum*
CR	*Lamium tschorochense*
CR	*Lamium vreemanii*
CR	*Stachys bayburtensis*

Table 15.1 (continued)

Threat category	Taxa
CR	*Gagea tenuissima*
CR	*Acantholimon huetii* var. *huetii*
CR	*Alchemilla akdoganica*
CR	*Alchemilla ayazii*
CR	*Alchemilla ayderensis*
CR	*Alchemilla basakii*
CR	*Alchemilla beyazoglii*
CR	*Alchemilla glabricaulis*
CR	*Alchemilla hayirlioglii*
CR	*Alchemilla ovitensis*
CR	*Crataegus turcicus*
CR	*Viola yuzufelensis*
EN	*Galanthus koenenianus*
EN	*Angelica sylvestris* var. *stenoptera*
EN	*Heracleum sphondylium* ssp. *artvinense*
EN	*Arum rupicola var. rupicola*
EN	*Centaurea drabifolioides*
EN	*Helichrysum artvinense*
EN	*Hieracium diaphanoidiceps*
EN	*Hieracium foliosissimum*
EN	*Hieracium giresunense*
EN	*Hieracium radiatellum*
EN	*Hieracium tamderense*
EN	*Scorzonera mirabilis*
EN	*Senecio ovatifolius*
EN	*Tragopogon fibrosus*
EN	*Turanecio lazicus*
EN	*Onosma circinnata*
EN	*Onosma obtusifolia*
EN	*Paracaryum erysimifolium*
EN	*Symphytum savvalense*
EN	*Symphytum sylvaticum*
EN	*Aethionema grandiflorum* var. *sintenisii*
EN	*Barbarea integrifolia*
EN	*Clypeola raddeana*
EN	*Erysimum leptocarpum*
EN	*Hesperis buschiana*
EN	*Isatis undulate*
EN	*Noccaea sintenisii* ssp. *sintenisii*

Table 15.1 (continued)

Threat category	Taxa
EN	*Campanula choruhensis*
EN	*Campanula grandis* ssp. *rizeensis*
EN	*Campanula troegerae*
EN	*Morina persica* var. *decussatifolia*
EN	*Eremogone scariosa*
EN	*Silene choruhensis*
EN	*Silene manissadjianii*
EN	*Silene scythicina*
EN	*Sempervivum davisii* ssp. *davisii*
EN	*Sempervivum davisii* ssp. *furseorum*
EN	*Blysmus compressus* ssp. *subulifolia*
EN	*Rhodothamnus sessilifolius*
EN	*Cicer reticulatum*
EN	*Onobrychis lasistanica*
EN	*Vicia quadrijuga*
EN	*Erodium absinthoides* ssp. *latifolium*
EN	*Hypericum marginatum*
EN	*Crocus biflorus* ssp. *artvinensis*
EN	*Crocus biflorus* ssp. *fibroannulatus*
EN	*Stachys choruhensis*
EN	*Papaver arachnoideum*
EN	*Veronica gentianoides* ssp. *gentianoides* var. *alpina*
EN	*Acantholimon hypochaerum*
EN	*Elymus longearistatus* ssp. *sintenisii*
EN	*Festuca pontica*
EN	*Reseda armena* var. *scabridula*
EN	*Alchemilla ancerensis*
EN	*Alchemilla cimilensis*
EN	*Alchemilla elevitensis*
EN	*Alchemilla hemsinica*
EN	*Alchemilla ikizdereensis*
EN	*Alchemilla kackarensis*
EN	*Alchemilla trabzonica*
EN	*Potentilla umbrosa* ssp. *decrescens*
EN	*Sorbus caucasica* var. *yaltirikii*
EN	*Asperula virgata*
EN	*Galium tortumense*
EN	*Salix rizeensis*

Table 15.1 (continued)

Threat category	Taxa
EN	*Verbascum decursivum*
EN	*Verbascum trichostylum*
VU	*Bupleurum brachiatum*
VU	*Bupleurum schistosum*
VU	*Pastinaca armena*
VU	*Peucedanum longibracteolatum*
VU	*Seseli andronakii*
VU	*Eminium koenenianum*
VU	*Centaurea aggregata* ssp. *albida*
VU	*Centaurea rhizocalathium*
VU	*Cirsium poluninii*
VU	*Hieracium djimilense*
VU	*Hieracium gentiliforme*
VU	*Inula fragilis*
VU	*Lactuca boissieri*
VU	*Psephellus pecho*
VU	*Psephellus taochius*
VU	*Tephroseris integrifolia* ssp. *karsiana*
VU	*Tripleurospermum rosellum* var. *album*
VU	*Betula browicziana*
VU	*Onosma liparioides*
VU	*Hesperis schischkinii*
VU	*Isatis spectabilis*
VU	*Tchihatchewia isatidea*
VU	*Campanula argentea*
VU	*Gypsophila brachypetala*
VU	*Sedum euxinum*
VU	*Sempervivum staintonii*
VU	*Carex melanorrhyncha*
VU	*Astragalus acmophylloides*
VU	*Astragalus czorochensis*
VU	*Astragalus trachytrichus*
VU	*Onobrychis araxina*
VU	*Crocus aerius*
VU	*Iris histrioides*
VU	*Stachys inanis*
VU	*Papaver lateritium* ssp. *lateritium*
VU	*Linaria genistifolia* ssp. *artvinensis*
VU	*Veronica kopgecidiensis*

Table 15.1 (continued)

Threat category	Taxa
VU	*Elymus lazicus*
VU	*Festuca xenophontis*
VU	*Festuca ziganensis*
VU	*Consolida armeniaca*
VU	*Alchemilla rizensis*
VU	*Alchemilla ziganadagensis*
VU	*Potentilla doddsii*
VU	*Asperula woronowii*
VU	*Galium basalticum*
VU	*Acer cappadocicum* ssp. *divergens*
VU	*Saxifraga artvinensis*
VU	*Verbascum biscutellifolium*
VU	*Verbascum drymophilum*
VU	*Verbascum eriorrhabdon*

CR critically endangered, *EN* endangered, *VU* vulnerable

is to compile and analyze the data related to plant biodiversity and climate change effects in the region.

The native threatened taxa of the eastern Karadeniz region are:

Critical *Ferula mervynii, Archanthemis calcarea* var. *calcarea, A. calcarea* var. *discoidea, Centaurea leptophylla, Doronicum tobeyi, Hieracium amblylepis, H. mannagettae, H. onosmaceum, H. polygonifolium, H. rizense, H. spodocephalum, H. subhastulatum, H. subrosulatum, H. tersundagense, H. tossianum, Psephellus yusufeliensis, Senecio trapezuntinus, Tulipa gumusanica, Tanacetum oxystegium, Tripleurospermum ziganaense, Alyssum nezaketiae, Barbarea auriculata var. paludosa, B. platycarpa, Minuartia buschiana* ssp. *artvinica, Silene bayburtensis, Colchicum lagotum, C. leptanthum, Astragalus ansinii, A. eliasianus, A. olurensis, A. trabzonicus, Hymenocarpos woronowii, Erodium hendrikii, Hypericum fissurale, Iris nezahatiae, Clinopodium serpyllifolium* ssp. *giresunicum, Lamium tschorochense, L. vreemanii, Stachys bayburtensis, Gagea tenuissima, Acantholimon huetii* var. *huetii, Alchemilla akdoganica, A. ayazii, A. ayderensis, A. basakii, A. beyazoglii, A. glabricaulis, A. hayirlioglii, A. ovitensis, Crataegus turcicus,* and *Viola yuzufelensis.*

Endangered *Galanthus koenenianus, Angelica sylvestris* var. *stenoptera, Heracleum sphondylium* ssp. *artvinense, Arum rupicola var. rupicola, Centaurea drabifolioides, Helichrysum artvinense, Hieracium diaphanoidiceps, H. foliosissimum, H. giresunense, H. radiatellum, H. tamderense, Scorzonera mirabilis, Senecio ovatifolius, Tragopogon fibrosus, Turanecio lazicus, Onosma circinnata, O. obtusifolia, Paracaryum erysimifolium, Symphytum savvalense, S. sylvaticum, Aethionema grandiflorum* var. *sintenisii, Barbarea integrifolia, Clypeola raddeana, Erysimum*

leptocarpum, Hesperis buschiana, Isatis undulate, Noccaea sintenisii ssp. *sintenisii, Campanula choruhensis, C. grandis* ssp. *rizeensis, C. troegerae, Morina persica* var. *decussatifolia, Eremogone scariosa, Silene choruhensis, S. manissadjianii, S. scythicina, Sempervivum davisii* ssp. *davisii, S. davisii* ssp. *furseorum, Blysmus compressus* ssp. *subulifolia, Rhodothamnus sessilifolius, Cicer reticulatum, Onobrychis lasistanica, Vicia quadrijuga, Erodium absinthoides* ssp. *latifolium, Hypericum marginatum, Crocus biflorus* ssp. *artvinensis, C. biflorus* ssp. *fibroannulatus, Stachys choruhensis, Papaver arachnoideum, Veronica gentianoides* ssp. *gentianoides* var. *alpine, Acantholimon hypochaerum, Elymus longearistatus* ssp. *sintenisii, Festuca pontica, Reseda armena* var. *scabridula, Alchemilla ancerensis, A. cimilensis, A. elevitensis, A. hemsinica, A. ikizdereensis, A. kackarensis, A. trabzonica, Potentilla umbrosa* ssp. *decrescens, Sorbus caucasica* var. *yaltirikii, Asperula virgata, Galium tortumense, Salix rizeensis, Verbascum decursivum,* and *V. trichostylum.*

Vulnerable *Bupleurum brachiatum, B. schistosum, Pastinaca armena, Peucedanum longibracteolatum, Seseli andronakii, Eminium koenenianum, Centaurea aggregata* ssp. *albida, C. rhizocalathium, Cirsium poluninii, Hieracium djimilense, H. gentiliforme, Inula fragilis, Lactuca boissieri, Psephellus pecho, P. taochius, Tephroseris integrifolia* ssp. *karsiana, Tripleurospermum rosellum* var. *album, Betula browicziana, Onosma liparioides,, Hesperis schischkinii, Isatis spectabilis, Tchihatchewia isatidea, Campanula argentea, Gypsophila brachypetala, Sedum euxinum, Sempervivum staintonii, Carex melanorrhyncha, Astragalus acmophylloides, A. czorochensis, A. trachytrichus, Onobrychis araxina, Crocus aerius, Iris histrioides, Stachys inanis, Papaver lateritium* ssp. *lateritium, Linaria genistifolia* ssp. *artvinensis, Veronica kopgecidiensis, Elymus lazicus, Festuca xenophontis, F. ziganensis, Consolida armeniaca, Alchemilla rizensis, A. ziganadagensis, Potentilla doddsii, Asperula woronowii, Galium basalticum, Acer cappadocicum* ssp. *divergens, Saxifraga artvinensis, Verbascum biscutellifolium, V. drymophilum*, and *V. eriorrhabdon.*

15.2 High Mountainous Vegetation of Eastern Karadeniz Region

The high mountainous part of the region is mainly covered by forest and subalpine–alpine vegetation types. Plant associations of forest vegetation of the region belong to the Querco-Fagetea class, which is represented in the region with two endemic orders, namely Rhododendro-Fagetalia orientalis and Pino-Piceetalia orientalis (Fig. 15.2). Alnion barbatae and Castaneo-Carpinion alliances of Rhododendro-Fagetalia orientalis are represented widely in the region (Düzenli 1979; Güner et al. 1987; Küçük 1998; Terzioğlu 1998). This class is mainly characterized throughout northern Anatolia by *Aruncus vulgaris, Athyrium filix-foemina, Blechnum spicant, Carex ornithopoda* ssp. *ornithopoda, Carex sylvatica, Circaea lutetiana, Listera*

Fig. 15.2 Different forest types from eastern Karadeniz region of Turkey

ovate, Viburnum opulus, Millium effusum, Mycelis muralis, Myosotis sylvatica, Polystichum filix-mas, Sanicula europaea, Veronica officinalis, Stellaria holostea, and *Galeobdolon luteum* (Akman 1995).

Characteristic species of Rhododendro-Fagetalia orientalis are *Acer cappadocicum, Acer trautvetteri, Achillea biserrata, Daphne pontica, Epimedium pubigerum, Fagus orientalis, Rhododendron ponticum, R. luteum, Ruscus hypoglossum, Salvia forskahlei, Scilla bitynica, Festuca montana, Hedera colchica, Hypericum calycinum, Ilex colchica, Lapsana communis* ssp. *alpina, Quercus petraea* ssp. *iberica, Smilax excelsa, Sophora jaubertii, Tilia rubra* ssp. *caucasica, Trachystemon orientalis*, and *Vaccinium arctostaphylos*. This order is represented by three alliances: *Crataego-Fagion*, *Castaneo-Carpinion*, and *Alnion barbatae* (Akman 1995).

Characteristic species of *Pino-Piceetalia orientalis* are *Abies nordmanniana ssp. nordmanniana, Cardamine impatiens ssp. pectinata, Cyclamen coum ssp. caucasica, Dryopteris liliana, Dryopteris dilatata, Viburnum orientale, Paris incompleta, Picea orientalis, Pinus sylvestris, Sedum stoloniferum, and Ranunculus cappadocicus*. This order is represented by two alliances: *Veronico-Fagion* and *Geranio-Pinion* (Akman 1995).

Alpine and subalpine vegetation types are represented by one class, two orders, five alliances, and eight associations (Vural 1996). Alchemillo retinervis-Sibbaldietea parviflorae is characterized by *Alchemilla caucasica, A. pseudocartalinica, A. retinervis, Cerastium purpurascens, Crocus vallicola, Euphraisia sevanensis, Gentiana septemfida, Minuartia aizoides, Phleum alpinum, Polygala alpestris, Sedum annuum, Tripleurospermum oreades, Trifolium ambiguum, Veronica gentianoides, Anthoxanthum odoratum* ssp. *alpinum, Carex caucasica, Carex atrata* ssp. *atrata, Carex atrata* ssp. *aterrima, Gnaphalium stewardtii, Luzula pseudosudetica, Minuartia recurva* ssp. *oreina, Pilosella hoppeana* ssp. *testimonialis, Polygonum bistorta* ssp. *Carneum, Sibbaldia parviflora, Taraxacum crepidiforme*, ssp. *crepidiforme, Ranunculus brachylobus* ssp. *brachylobus, Viola altaica* ssp. *oreades*, and *Gentianella caucasae*. The class is represented in the region by two orders: Alchemillo retinervis-Sibbaldietalia parviflorae and Swertio ibericae-Nardetalia strictae (Fig. 15.3). The class is distributed over NE Anatolia between 2000 and 3100 m and is rich in herbaceous and very attractive flowering plant taxa.

Fig. 15.3 Views from alpine areas of the eastern Karadeniz region of Turkey

The characteristics are: *Alchemilla caucasica, A. pseudocartalinica, A. retinervis, Nathoxanthum odoratum* ssp. *alpinum, Carex caucasica, C.atrata* ssp. *atrata, C. atrata* ssp. *aterrima, Cerastium purpurascens, Crocus vallicola, Euphrasia sevanensis, Gentiana septemfida, Gentianella caucasae, Gnaphalium stewartii, Luzula pseudosudetica, Minuartia aizoides, M. recurva* ssp. *oreina, Phleum alpinum, Pilosella hoppeana* ssp. *testimonialis, Polygala alpestris, Polygonum bistorta* ssp. *carneum, Ranunculus brachylobus* ssp. *brachylobus, Sedum annuum, Sibbaldia parviflora, Taraxacum crepidiforme* ssp. *crepidiforme, Tripleurospermum oreades, Trifolium ambiguum, Veronica gentianoides*, and *Viola altaica* ssp. *oreades* (Vural 1996).

Characteristic species of Alchemillo retinervis-Sibbaldietalia parviflorae are *Achillea latiloba, Androsace albana, A. intermedia, Astragalus oreades, Carex brevicollis, Campanula aucheri, C. collina, C.stevenii* ssp. *beauverdiana, C. stevenii* ssp. *stevenii, C.tridentata, Centaurea nigrifimbria, Cerastium dahuricum, Chaerophyllum astrantiae, Daphne glomerata, Draba hispida, Erigeron caucasicus* ssp. *caucasicus, E. caucasicus* ssp. *venustus, Euphrasia petiolaris, Festuca chalcophaea* ssp. *chalcophaea, Geranium cinereum* ssp. *lazicum var. lazicum, G. cinereum* ssp. *lazicum* var. *ponticum, G. platypetalum, Gypsophila silenoides, Hedysarum hedisaroides, Minuartia imbricata, Pedicularis nordmanniana, Poa longifolia, Potentilla ruphrectii, Rumex tuberosus* ssp. *horizontalis, Sedum spurium, S. tenellum, Silene saxatilis, Stachys balansae* ssp. *balansae, Stachys macrantha,* and *Thymus praecox* ssp. *grossheimii*.

The order is represented by four alliances: *Agrostio lazicae-Sibbaldion parviflorae*, *Lilio pontica-Anemonion narcissiflorae*, *Centaureo appendicigerae-Senecion taraxacifolii*, and *Vaccinio myrtilli-Rhododendrion caucasici* (Vural 1996).

Characteristic species of *Swertio ibericae-Nardetalia strictae* are *Alchemilla mollis, Caltha polypetala, Cardamine uliginosa, Carex nigra* ssp. *dacica, C. nigra* ssp. *nigra, C. pallescens* var. *chalcodeta, C.pyrenaica, Geum coccineum, Nardus stricta, Pinguicula balcanica* ssp. *pontica, Primula auriculata*, and *Trifolium spadiceum*. This order is represented by one alliance Swertio ibericae-Nardion strictae (Vural 1996). All plant associations given below are distributed at altitudes over 1000 m above sea level (asl).

15.2.1 Deciduous Forests

15.2.1.1 Castanea sativa–Fagus orientalis

This association consists mainly of three layers—trees, shrubs, and herbs—and is distributed over the Karadeniz region. Characteristic species are *Castanea sativa, Fagus orientalis, Hedera colchica, Hypericum androsaemum, Trachystemon orientalis, Taxus baccata*, and *Ruscus colchicus*. Rhododendro-Fagetalia orientalis is characterized by 15 taxa, mainly *Rhododendron ponticum* and *Vaccinium arctostaphylos*.

Alnion barbatae is dominated by *Alnus glutinosa* ssp. *barbata* and *Thelypteris limbosperma,* and Castaneo-Carpinion is dominated by *Rubus platyphyllos*. These are characterized by more than 10 taxa.

Fagetalia sylvaticae, Pino-Piceetalia orientalis, and Quercetea pubecentis are also represented.

Querco-Fagetea is represented by 14 taxa mainly *Blechnum spicant* and *Corylus avellana* ssp. *pontica*. Although this mixed forest is distributed at an altitude lower than 1000 m, these species are seen up to 1500 m in forests with close canopy (Vural 1996).

15.2.1.2 Fagus orientalis–Rubus caucasicus

This association is distributed at Tiryal mountain (Artvin province) between 800 and 1550 m asl (Düzenli 1979). The forest vegetation has been dominated almost by oriental beech. Along the river, *Alnus glutinosa* ssp. *barbata* taxon is distributed as the dominant species.

This association consists mainly of three layers: the trees, shrubs, and herbs. Characteristic species are *Fagus orientalis, Rubus caucasicus, Brunnera macrophylla, Rhododendron ponticum, R. luteum, Viburnum orientale*, *Ilex colchica*, and *Neottia nidus-avis*.

Rhododendro-Fagetalia orientalis is characterized by nine taxa mainly by *Rhododendron ponticum, Rh. luteum, Ilex colchica*, and *Rubus platyphyllos*.

Alnion barbatae is mainly characterized by *Alnus glutinosa* ssp. *barbata, Thelypteris limbosperma*, and *Circaea lutetiana*.

Fagetalia sylvaticae, Pino-Piceetalia orientalis, and Quercetea pubecentis are also represented (Duzenli 1979).

15.2.2 Mixed Deciduous and Conifer Forests

15.2.2.1 Fagus orientalis–Picea orientalis

This association is usually dominant on the north-, east-, and south-facing slopes, at altitudes up to 1500 m asl and consist mainly of three layers such as trees, shrubs, and herbs. It has been recorded firstly from the Rize province. The total coverage

of the tree layer lies between 85 and 95 %, as the same coverage of shrub layer. It is a member of the Castaneo-Carpinion association. Characteristic and differential species are: *Castanea sativa, Fagus orientalis, Hedera colchica, Hypericum androsaemum, Trachystemon orientalis, Taxus baccata,* and *Ruscus colchicus*. Rhododendro-Fagetalia orientalis is strongly represented in the association (Quezel et al. 1980).

15.2.3 Pure Forests

15.2.3.1 Picea orientalis–Sedum stoloniferum

This association is usually dominant on the north-, west-, and northwest-facing slopes and at altitudes between 1100 and 1800 m asl, and consists mainly of tree, shrub, and herb layers, recorded from Rize and Trabzon provinces. The total coverage of the tree layer is between 85 and 95 %. Veronico-Fagion and Geranio-Pinion are represented. Characteristic and differential species are: *Picea orientalis, Sedum stoloniferum, Solidago virgaurea, Dryopteris expansa, Aruncus vulgaris, Digitalis ferruginea* ssp. *schiskhinii, Viola sieheana, Goodyera repens, Lonicera caucasica* ssp. *orientalis, Cephelanthera longifolia, Dryopteris borreri, Stellaria nemorum, Crepis paludosa, Symphytum asperum, S. longipetiolatum, Psoralea acaulis, Argyrolobium biebersteinii,* and *Aster caucasicus*. Pino-Piceetalia orientalis are strongly represented in the association. This association has two subassociations as *piceetosum orientalis* and *fagetosum orientalis* (Vural 1996; Terzioğlu 1998).

15.2.3.2 Picea orientalis–Paris incompleta

Here too, we find tree, shrub, and herb layers, but the moss layer is very rich including nine species. It is rich in characteristic species like: *Picea orientalis, Paris incompleta, Arenaria rotundifolia, Euphorbia oblongifolia, Cyclamen parviflorum, Ranunculus buhsei,* and *Oxalis acetosella.* These forests have very dense canopy and Rhododendro-Fagetalia orientalis has not been represented in it contrary to expectation. This pure coniferous forest is distributed up to 1900 m asl with the close canopy (Duzenli 1979).

15.2.3.3 Picea orientalis–Telekia speciosa

The association is distributed over the north slope of Zigana Mountains (around Trabzon and Gümüşhane province) and the canopy cover is about 80 %, consisting mainly of trees, shrubs, and herbs. The association is distributed between 1600 and 1800 m asl. According to Akman (1995), the characteristic and differential species are very clear to distinguish this association, which are: *Picea orientalis, Gentiana asclepiadea, Chaerophyllum macrospermum, Impatiens noli-tangere, Telekia speciosa, Valeriana alliarifolia, Alnus glutinosa* ssp. *barbata, Symphytum asperum,*

Thelypteris limbosperma, Geranium sylvaticum, Ranunculus buschei, Cardamine raphanifolia, Aruncus vulgaris, Geranium sintenisii, Thelypteris dryopteris, Cirsium pseudopersonata, Rhynchocorys stricta, Campanula latifolia, Senecio lazicus, and *Trollius ranunculinus*. In this association, Pino-Piceetalia orientalis is strongly represented and Rhododendro-Fagetalia orientalis is weakly represented. Nearly all characteristic species of Geranio-Pinion can be seen in this association (Quezel et al. 1980).

15.2.3.4 Picea orientalis–Doronicum macrolepis

The tree, shrub, and herb layers of this association are distributed in a restricted area around Trabzon along the Harşit River, but the plant species diversity is poor. Two of the four characteristic and differential species are endemics: *Senecio trapezuntinus* and *Doronicum macrolepis*. In addition to these, *Picea orientalis* and *Abies nordmanniana* ssp. *nordmanniana* are also found here. The floristic composition of the association includes the characteristic species of the alliance Buxo-Staphyllion. It has been pointed out that explanation of the exact phytosociological position of this association is difficult (Quezel et al. 1980).

15.2.3.5 Pinus sylvestris–Vaccinium myrtillus

This association is usually dominant on the north-, west-, and northeast-facing slopes and at altitudes between 1700 and 2100 m asl. The total coverage of the tree layer varies between 60 and 80 %.

Pino-Piceetalia orientalis and Veronica-Fagion are strongly represented in the association. It is closely related to association *Pinus sylvestris–Daphne glomerata* but this association is the member of Geranio-Pinion. Though some floristic differences are evident, the association is distributed in both Trabzon and Giresun. Characteristic and differential species are *Pinus sylvestris, Vaccinium myrtillus*, *Pyrola rotundifolia, Scilla monanthos, Monoses uniflora, Luzula campestris,* and *Orthilia secunda* (Quezel et al. 1980).

15.2.3.6 Pinus sylvestris–Lilium ciliatum

This association too exhibits tree, shrub, and herb layers and is related to the association *Picea orientalis–Telekia speciosa*, but differs from it in terms of dominant species (*Pinus sylvestris*) and lack of *Picea orientalis*; less hygrophytic species are seen in this association. The association is distributed between 1500 and 1700 m asl. The association includes the characteristic species of the Pino-Piceetalia orientalis order and the Geranio-Pinion alliance. *Carpinus orientalis*, the member of Querco-Carpinetalia, is dominant at lower altitudes of this association. It is distributed in a restricted area around Zigana Mountains (Trabzon and Gümüşhane provinces). Characteristic and differential species are *Pinus sylvestris, Lilium ciliatum,*

Ranunculus brachylobus, Viburnum lantana, Vcia freyneana, Primula vulgaris, Tripleurospermum monticolm, and *Melampyrum arvense* (Quezel et al. 1980).

15.2.3.7 Pinus sylvestris–Astragalus adzharicus

This association is distributed in Tiryal Mountain (Artvin province). It exhibits tree, shrub, and herb layers, and the total coverage of the tree layer varies between 40 and 70%. The association consists of many local endemic characteristic and differential taxa. Pino-Piceetalia orientalis is clearly represented. Distribution of *Pinus sylvestris* forest starts from 120 to 2000 m asl in Tiryal Mountain. However, *Pinus sylvestris* forest at the lower altitudes of the same watershed belongs to Rhododednro-Fagetalia order. Characteristic and differential species are *Pinus sylvestris, Astragalus adzharicus, Seseli andronakii, Uechtritzia armena,* and *Ferulago setifolia* (Duzenli 1979).

15.2.3.8 Pinus sylvestris–Daphne glomerata

This association resembles the associations cited above, but differs from them physionomically. *Abies nordmanniana* ssp. *nordmanniana* is found in this association. The total coverage of the tree layer lies between 60 and 80%. The shrub layer is very dense and dominated mainly by *Rhdodendron ponticum* and *R. luteum*. The association is distributed between 1700 and 2100 m asl and reaches up to the subalpine zone. This association includes the characteristic species of the order Pino-Piceetalia orientalis and the Geranio-Pinion alliance (Quezel et al. 1980).

15.2.3.9 Pinus sylvestris–Juniperus communis

This association too consists mainly tree, shrub, and herb layers. The total coverage of the tree layer lies between 60 and 80%. Characteristic and differential species of the association are *Pinus sylvestris, Juniperus communis* ssp. *saxatilis, Tripleurospermum melanolepis, Phleum exaratum* ssp. *exaratum, Daphne glomerata, Centaurea triumfettii, Echium russicum, Campanula sibirica* ssp. *hohenackeri*, and *Pilosella x auriculoides*. The association is distributed between 1900 and 2000 m asl on the south-facing slopes. In this association, the components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well presented (Eminağaoğlu et al. 2007).

15.2.3.10 Betula litwinowii–Anemone narcissiflora ssp. narcissiflora

This association occupies the subalpine zone of the Solaklı watershed (Trabzon province) and is distributed between 2030 and 2300 m asl. It exhibits mainly two

vertical layers, and the total coverage of the shrub layer is about 85%. However, the cover of tree layer is less than 1%. This association is very rich in plant species diversity with more than 100 taxa and includes many attractive flowering species. It is a member of the Lilio pontici-Anemonion narcissiflorae alliance and the Alchemillo retinervis-Sibbaldietalia parviflorae order. Characteristic and differential species are *Betula litwinowii, Anemone narcissiflora* ssp. *narcissiflora, Aconitum nasutum, Lilium corniolicum* ssp. *ponticum* var. *ponticum, Helianthemum nummularium* ssp. *tomentosum,* and *Euphorbia squamosal* (Terzioğlu 1998).

15.2.4 Mixed Forests

15.2.4.1 Picea orientalis–Quercus petraea ssp. iberica

This association also consists mainly of tree, shrub, and herb layers. The total coverage of the tree layer is between 65 and 90%. Characteristic and differential species of the association are *Picea orientalis* and *Quercus petraea* ssp. *iberica.* The association is distributed between 1100 and 1500 m asl on the south-, west-, and southwest-facing slopes. In this association, the components of the Carpino-Acerion and Querco-Carpinetalia orientalis order are well presented. It has two subassociations as *fraxinetosum angustifoliae* and *cratagetosum microphillae* (Eminağaoğlu et al. 2007).

15.2.4.2 Picea orientalis–Pinus sylvestris

This association also has tree, shrub, and herb layers. The total coverage of the tree layer is between 85 and 100%. Characteristic and differential species of the association are *Pinus sylvestris, Picea orientalis,* and *Limodorum abortivum.* The association is distributed at about 1400–1600 m asl on the south-, west-, and southwest-facing slopes. The components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well represented here (Eminağaoğlu et al. 2007).

15.2.4.3 Picea orientalis–Abies nordmanniana ssp. nordmanniana

The association again consists mainly of three layers as above. The total coverage of the tree layer is between 80 and 100%. Characteristic and differential species of the association are *Picea orientalis, Abies nordmanniana* ssp. *nordmanniana, Vicia crocea, Solidago virgaurea* ssp. *virgaurea, Symphytum longipetiolatum, Crepis paludosa, Digitalis ferruginea* ssp. *schischkinii,* and *Symphytum asperum.* The association flourishes between 1650 and 1750 m asl on the east-, southeast-, and north-facing slopes. The components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well presented in this association (Eminağaoğlu et al. 2007).

15.2.4.4 Pinus sylvestris–Juniperus oxycedrus

This association is composed of tree, shrub, and herb layers, distributed at about 1300–1400 m asl on the south-, west-, and southwest-facing slopes. The total coverage of the tree layer is between 80 and 90%. Characteristic and differential species of the association are *Pinus sylvestris, Juniperus oxycedrus* ssp. *oxycedrus, Lathyrus roseus,* and *Hieracium varigatisquamum.* The components of the Carpino-Acerion and Querco-Carpinetalia orientalis order are well represented in the association (Eminağaoğlu et al. 2007).

15.2.4.5 Pinus sylvestris–Abies nordmanniana ssp. nordmanniana

There are three layers such as tree, shrub, and herb in this association. The total coverage of the tree layer lies between 70 and 90%. Characteristic and differential species are *Pinus sylvestris, Abies nordmanniana* ssp. *nordmanniana,* and *Delphinium albiflorum.* It is distributed between 1750 and 1850 m asl on the south- and southwest-facing slopes. In this association, the components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well represented (Eminağaoğlu et al. 2007).

15.2.4.6 Abies nordmanniana ssp. nordmanniana–Fagus orientalis

This association is distributed at about 1800–1950 m asl on the north- and northwest-facing slopes, having tree, shrub, and herb layers. The total coverage of the tree layer is between 60 and 90%. Characteristic and differential species of the association are *Fagus orientalis, Abies nordmanniana* ssp. *nordmanniana, Daphne mezereum, Ranunculus caucasicus* ssp. *subleiocarpus,* and *Astragalus imbricatus.* The components of the Veronico-Fagion and Pino-Piceetalia orientalis order are well presented here (Eminağaoğlu et al. 2007).

Associations given below are mixed shrubby ones distributed in both pure and mixed forests.

15.2.4.7 Rhododendron ungernii–Laurocerasus officinalis

This association has been determined in Fırtına Valley (Rize province), exhibiting two to three vertical tree and shrubby layers; the total coverage of the shrubby layer is 100% and that of tree layer is less than 40%. It occupies altitudes between 950 and 1520 m asl, and is a secondary forest succession sere of *Picea orientalis* and *Fagus orientalis* forests. Other than some bryophytes and two fern species, there are no herbaceous taxa found in this association. *Ilex colchica* is the shortest member, with a height of 0.5–1 m. The Castaneo-Carpinion alliance is clearly represented. Characteristic and differential species are *Rhododendron ungernii, Laurocerasus officinalis,* and *Ilex colchica* (Vural 1996).

15.2.4.8 Betula medwediewii–Quercus pontica

This association is found on the south-, west-, southwest-, southeast-, and northwest-facing slopes over Artvin province, and is distributed at the altitudes varying between 1300 and 1700 m asl. There are tree, shrub, and herb vertical layers and the total coverage of the shrub layer is more than 90%, whereas cover of the tree layer is less than 1%. The association is highlighted as a member of the Geranio-Pinion alliance and the Pino-Piceetalia orientalis order. Characteristic and differential species are *Quercus pontica, Betula medwediewii, Rhododendron ungernii, Epigaeae gaultherioides, Ruscus colchicus, Veronica peduncularis, Doronicum balansae, Inula helenium* ssp. *orgyalis, Papver lateritium,* and *Helichyrisum artvinense* (Eminağaoğlu and Kutbay 2006).

15.2.5 Subalpine–Alpine Vegetation

15.2.5.1 Polygonum bistorta ssp. carnea–Stachys macrantha

This association is the type of Lilio pontici-Anemonion narcissiflorae alliance. It grows on lower slopes of alpine and subalpine zones, at about 2150–2700 m asl. It is rich in plant diversity and embodies many decorative taxa. There are two vertical layers. Characteristic and differential species are *Polygonum bistorta* ssp. *carneum, Stachys macrantha, Tragopogon aureus,* and *Tripleurospermum monticolum* (Vural 1996; Terzioğlu 1998).

15.2.5.2 Sibbaldia parviflora–Agrostis lazica

It is distributed as a long line from west to east between 2340 and 2850 m asl and has only one vertical layer. The total coverage of the layer is 100%, reaching 5–20 (-25) cm in height. Characteristic and differential species are *Sibbaldia parviflora, Agrostis lazica,* and *Alchemilla retinervis*. This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Agrostio lazicae-Sibbaldion parviflorae alliance (Vural 1996; Terzioğlu 1998).

15.2.5.3 Centaurea appendicigera–Anthemis cretica ssp. argaea

A type of Centaureo appendicigerae-Senecion taraxacifolii alliance, growing on the slopes of the alpine belt at about 2850–3020 m asl, is affected by erosion. There is only one vertical layer. It has two subassociations: *anthemisetum pectinati* and *senecietosum taraxafoliae*. Characteristic and differential species are *Centaurea appendicigera, Anthemis cretica* ssp. *argaea, Alopecurus glacialis, Alchemill ellenbergiana, Alchemilla rizensis,* and *Huyhnia pulchra* (Vural 1996; Terzioğlu 1998).

15.2.5.4 Lamium album–Saxifraga mollis

It is distributed around 2950–3050 m asl on the northwestern slopes of Kaçkar and Verçenik mountains and has only one vertical layer. The total coverage of the layer is about 40–55 %, reaching 5–20 cm in height. There are two subassociations as *arabietosum caucasae* and *cerastietosum lazici*. Characteristic and differential species are *Lamium album, Saxifraga mollis,* and *Veronica telephiifolia*. This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Centaureo appendicigerae-Senecion taraxacifolii alliance (Vural 1996).

15.2.5.5 Festuca lazistanica–Festuca woronowii

It occurs on the southwestern slopes of Verçenik mountain, between 2890 and 3000 m asl and has two vertical layers. The total coverage of the layer is about 80–90 %, reaching 10–50 cm in height. Characteristic and differential species are *Festuca woronowii* ssp. *woronowii, Festuca woronowii* ssp. *turcica, Chaerophyllum astrantiae, Tanacetum kotschyi, Allium dijimilense, Nonea pulmonaroides, Festuca anatolica* ssp. *borealis, Festuca lazistanica* ssp. *lazistanica, Helictotrichon argaeum,* and *Senecio ovatifolius.* This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Centaureo appendicigerae-Senecion taraxacifolii alliance (Vural 1996).

15.2.5.6 Rhododendron caucasicum–Vaccinium myrtillus

It is represented by the scrub formation of the alpine zone in the region, dominated by Ericaceae members and the Vaccinio myrtilli-Rhododendrion caucasici alliance. It consists of mainly two layers, the shrubs and herbs. Characteristic species are *Rhododendron caucasicum*, *Vaccinium myrtillus*, *Vaccinium uliginosum,* and *Deschampsia flexiosa*. Vaccinio myrtilli-Rhododendrion caucasici is distributed at 2400–2700 m asl and is represented by *Empetrum nigrum* ssp. *hermaphroditum, Milium schmidtianum, Oxalis acetosella, Rhododendron caucasicum, Solidago virgaurea* ssp. *alpestris, Vaccinium myrtillus,* and *Vaccinium uliginosum* (Vural 1996; Terzioğlu 1998).

15.2.5.7 Nardus stricta–Gentiana pyrenaica

This association is distributed at 2050–2460 m asl along the streams, near the melting snow, over the alpine zone of the eastern Karadeniz region and has only one vertical layer. It is the type of Swertio ibericae-Nardion strictae alliance. The total coverage of the layer is 100 %, reaching 15–25 cm in height. Characteristic and differential species are *Nardus stricta, Gentiana pyrenaica,* and *Poa annua* (Vural 1996; Terzioğlu 1998).

15.2.5.8 Cynosurus cristatus–Ranunculus kotschyi

It is distributed along the streams in the subalpine belt, at about 2000–2035 m asl and has two vertical layers. The total coverage of the layer is 100 %, reaching 15–70 cm in height. Characteristic and differential species are *Cynosurus cristatus, Ranunculus kotschyi, Alchemilla barbatiflora, Myosotis sicula,* and *Ornithogalum platyphyllum.* Members of Gramineae and Cyperaceae families are dominant in both layers. This association is clearly included in the Swertio ibericae-Nardion strictae alliance (Vural 1996).

15.2.6 Wetland Vegetation

15.2.6.1 Lythrum salicaria–Equisetum fluviatile

This association has been reported from Uzungöl (Trabzon province) and is distributed at an altitude of 1050–1100 m asl. It exhibits two vertical layers made up of herbaceous taxa and the total coverage of the layer is about 75 %. This association grows on wetlands alongside the edges of Uzungol Lake. It is a member of the Phragmitetea order. Characteristic and differential species are *Lythrum salicaria, Equisetum fluviatile, Scutellaria galericulata,* and *Thypha shuttlewortthii* (Terzioğlu 1998).

15.3 Factors Threatening Biodiversity

One of the main factors that may cause loss and/or decline of plant diversity at local, regional, national, and/or global scale is the "introduced or naturalized species" (WRI 1992). More than 40 flowering plant taxa have been naturalized in the eastern Karadeniz region of Turkey (Terzioglu and Ansin 2001). The diaspores of the naturalized taxa germinate easily under the favorable climatic conditions of the region and become new individuals. Some of the typical examples are: *Robinia pseudoacacia, Ailanthus altissima, Sicyos angulatus* (Fig. 15.4), *Conyza canadensis, Paspalum dilatatum,* and *Commelina communis.* All have local detrimental effects on the native species. *Sicyos angulatus* is one of the most threatening invasive alien species/an aggressive annual vine in the world and it flourishes in wet areas of the region such as riversides where many native species are seriously threatened by its invasion. It was firstly recorded in 1990s (Terzioğlu and Anşin 1999) from the sea level and in the eastern corner of the region. Unfortunately, it has already been seen throughout the region starting from Artvin to Giresun at altitudes varying between 0 and 1150 m asl.

Some newly recorded invasive alien plant species in the region are *Lysimachia japonica* (Terzioğlu and Karaer 2009), *Acalypha australis* (Duman and Terzioğlu 2009), *Bidens frondosa* (Coşkunçelebi et al. 2007), and *Sigsbeckia pubescens*

Fig. 15.4 *Sicyos angulatus* as an invasive alien species in the region (1–1150 m asl)

(Karaer and Terzioğlu 2013). Another invasive alien species, *Pueraria hirsuta,* an aggressive perennial vine, has been monitored by the authors in Batumi (Georgia), close to the border of the studied region. It is estimated that this species will extend its distribution toward Turkey in a short time. It has been introduced to Georgia from Japan as a decorative plant and has gotten acclimated well, growing in a narrow zone at altitudes varying between 100 and 200 m asl (Kemertelidze et al. 2008).

Other factors that negatively influence the plant diversity in the eastern Karadeniz region of Turkey are:

1. Conversion of forests and grasslands in to agricultural fields
2. Fragmentation of habitats and populations due to the rapid population increase, which results in small and often isolated demes suffering from local extirpation
3. Overexploitation of plant species, which exceeds the ability of species to recover
4. Pollution of soils, water, and atmosphere, which either kill individuals outright or impair their natural functioning
5. Overgrazing.

Some of these factors result from intentional actions taken to meet the needs of a growing human population. Often, however, the changes are undesired results of human actions.

15.4 Climate Change Scenarios for the Region

Analyzing the meteorological data from the stations located in the eastern Karadeniz region from 1951 to 2004, Dalfes et al. (2007) have observed increases in winter and spring precipitations in Artvin, a decrease in spring precipitation in Trabzon, and

a decrease in the mean annual temperature in Artvin. In the same report, the future climate of the region has been predicted using a RegCM3 regional climate model.

According to this regional climate model, the temperatures will increase 2–4°C in the region in the next century. Future climate scenarios predict 200–300-mm increases in precipitation in the eastern part of the region while the western part will not have any increase in precipitation in the next century.

15.5 Influences of Climate Change on Biodiversity

Climate change will influence the distribution, structure, stability, and diversity of different ecosystems in the region. With the influence of predicted changes, it is possible to observe 200–400-m upward shifts in the plant belts in the western part of the region and upward movement of the tree line in the eastern part (Figs. 15.5 and 15.6). The upward shift in the tree line will probably threaten the plant diversity of the alpine grassland areas where most of the endemic taxa thrive. An important part of these areas will possibly be covered by spruce or pine forests. According to Tüfekçioğlu et al. (2004), alpine grasslands support 550 plant species, while spruce forests support around 100 plant species.

Temperature increases in the region will put more stress on spruce trees and will probably increase the bark beetle attacks. Around 100,000 spruce trees have been killed by the bark beetle attacks in Hatilla National Park, Artvin (Tüfekçioğlu et al. 2005; Tüfekçioğlu 2008). This will influence the diversity of these forests. Insect-attack-regulated secondary successions will possibly be more common in spruce ecosystem. Especially the members of Ericaea such as *Rhododendron ponticum, R. ungernii, R. x sochadzeae*, and *Vaccinium arctostaphylos* are the dominant species of the secondary succession and they are the allelopathic species which have side effects for the seedlings of oriental spruce and other taxa of the optimal succession.

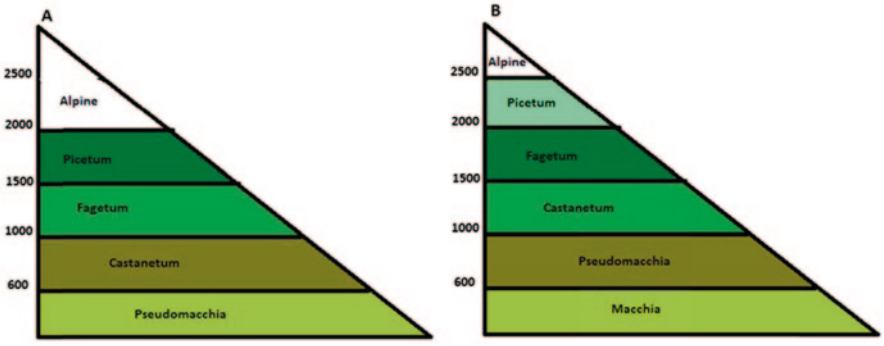

Fig. 15.5 Current (**a**) and expected (**b**) (after 3 °C warming) plant belts in the region

Fig. 15.6 Tree line of *Picea orientalis* in the region

Fire could become an important threat in the western and inner parts of the region with the predicted climate change (Ozturk et al. 2010). Currently, fire is not a problem in oriental spruce ecosystems. These ecosystems in Turkey have a humid climate in summer season; therefore, it is unusual to see fire in these areas. However, fire is an important factor in maintaining the structure, diversity, and health of boreal spruce ecosystems. The influence of fire on the plant diversity of the region will possibly be positive up to a certain level. It will be possible to see fire-induced secondary succession taking place in the western part of the region. Replacement of some spruce and beech forests with the pine forests will increase species diversity in the region because spruce and beech are shade-tolerant species, while pine is a shade-intolerant species. Stands of shade-intolerant species have more plant species in understory compared to shade-tolerant stands.

Conclusions

The plant associations of the high mountainous areas of the eastern Karadeniz region include forests and the subalpine–alpine ecosystems (Table 15.2). According to the predicted climate change, some plant species are expected to move both taxonomically as well as syntaxonomically. In the latter case, the plant associations are expected to move up to 200–400 m according to RegCM3 regional climate model (Dalfes et al. 2007). One of the most important results of this change is that the tree and forest line, especially dominated by oriental spruce, will surge to subalpine upward. It is clear to monitor this possible change in the mentioned area using up-to-date technologies such as geographic information systems (GIS), remote sensing data, satellite images, and aerial photos. Many of the endemic plant taxa are distributed around 1800 m and upward, and predictions are that these plant taxa will be influenced clearly from this change.

The ongoing process of upward movement of vascular plants may not have the same process for each plant taxa. For example, *Taxus baccata* is predicted not to

Table 15.2 Plant associations of eastern Karadeniz region of Turkey distributed at altitude above 1000 m

A. Deciduous forests	B. Mixed deciduous and conifer forests	C. Pure forests	D. Mixed forests	E. Wetland vegetation	F. Subalpine–alpine vegetation
A.1.*Castanea sativa–Fagus orientalis*	B.1. *Fagus orientalis–Picea orientalis*	C.1.*Picea orientalis–Sedum stoloniferum*	D.1.*Picea orientalis–Quercus petraea* ssp. *iberica*	E.1.*Lythrum salicaria–Equisetum fluviatile*	F.1. *Polygonum bistorta* subsp. *carnea–Stachys macrantha*
A.2.*Fagus orientalis–Rubus caucasicus*		C.2. *Picea orientalis–Paris incompleta*	D.2.*Picea orientalis–Pinus sylvestris*		F.2.*Sibbaldia parviflora–Agrostis lazica*
		C.3.*Picea orientalis–Telekia speciosa*	D.3. *Picea orientalis–Abies nordmanniana* subsp. *nordmanniana*		F.3.*Centaurea appendicigera–Anthemis cretica* subsp. *argaea*
		C.4.*Picea orientalis–Doronicum macrolepis*	D.4.*Pinus sylvestris–Juniperus oxycedrus*		F.4. *Lamium album–Saxifraga mollis*
		C.5.*Pinus sylvestris–Vaccinium myrtillus*	D.5.*Pinus sylvestris–Abies nordmanniana* subsp. *nordmanniana*		F.5. *Festuca lazistanica–Festuca woronowii*
		C.6. *Pinus sylvestris–Lilium ciliatum*	D.6.*Abies nordmanniana* subsp. *nordmanniana–Fagus orientalis*		F.6.*Rhododendron caucasicum–Vaccinium myrtillus*
		C.7. *Pinus sylvestris–Astragalus adzharicus*	D.7. *Rhododendron ungernii–Laurocerasus officinalis*		F.7. *Nardus stricta–Gentiana pyrenaica*
		C.8.*Pinus sylvestris–Daphne glomerata*	D.8. *Betula medwediewii−Quercus pontica*		F.8.*Cynosurus cristatus–Ranunculus kotschyi*
		C.9.*Pinus sylvestris–Juniperus communis*			
		C.10.*Betula litwinowii–Anemone narcissiflora* ssp. *narcissiflora*			

move easily toward upper levels. Mediterranean elements that occur naturally in the eastern Karadeniz region such as *Pinus pinea* and *Ostrya carpinifolia* too are not predicted to move easily to uplands as expected.

Plant associations distributed at altitudes over 2800 m, such as *Centaurea appendicigera–Anthemis cretica* ssp. *argaea, Lamium album–Saxifraga mollis,* and *Festuca lazistanica–Festuca woronowii,* are expected to lose some of their habitats. Some plant species may become extinct in the alpine and nival vegetation zones due to upward movement toward the mountain peaks. For example, the association *Centaurea appendicigera–Anthemis cretica* ssp. *argaea* is an endemic and may easily be influenced by this shift.

Subalpine and alpine ecosystems are rich in plant species diversity. Endemism ratio is the highest in alpine and nival vegetation in the region with many threatened local endemics such as *Rhodothamnus sessilifolius*. In the peaks of eastern Karadeniz Mountains, snow patches staying throughout the year are important components of plant life in the region and effect the distribution of plant taxa. The persistent snow cover also will be forced to move to upper areas by climate change. Many of the geophytes which are clearly seen in the edge of snow patches may be affected by carrying or completely melted snow.

From a chorological point of view, the alien plant taxa are worth monitoring during the expected change in the climate in the region. Most of the naturalized taxa in Turkey have been recorded in the eastern Karadeniz region (Terzioğlu and Anşin 2001), and the number is expected to increase in the future. On the other hand, the present naturalized alien taxa will move in to new habitats, especially by wind and animals, and the threats of these taxa on the natural ones will increase.

The lower altitudes (< 1000 m) of the region include several different plant associations like:

- *Castanea sativa–Campanula alliarifolia* (Quezel et al. 1980),
- *Carpinus orientalis–Erica arborea* (Quezel et al. 1980),
- *Alnus glutinosa–Oplismenus undulatifolius* (Guner et al. 1987),
- *Rhododendron ponticum–Vaccinium arctostaphylos* (Guner et al. 1987),
- *Alnus glutinosa* ssp. *barbata–Thelypteris limbosperma* (Akman. 1995),
- *Euphorbia paralias–Otanthus maritimus* (Karaer et al. 1997), 0–5 m asl, extremely destroyed by highway construction,
- *Ostrya carpinifolia–Scutellaria albida* ssp. *colchica* (Anşin et al. 2003),
- *Pinus pinea–Crucianella gillani* susbp. *pontica* (Varol et al. 2003).

The Castaneo-Carpinion alliance is well represented at the altitudes less than 1000 m and includes nearly all the mixed deciduous forest of the region. This alliance starts from Ordu in the west and is distributed throughout the eastern Karadeniz region. It is characterized mainly by three subseries *Castanea sativa, Carpinus betulus,* and *Pinus sylvestris* f. *lazica* (Akman 1995).

With the influence of predicted changes, it is possible to observe upward shifts of these syntaxa (except for the *Alnus glutinosa–Oplismenus undulatifolius* association) in the western part of the region. Especially the *Pinus pinea* enclaves in both Trabzon and Artvin provinces are expected to be influenced positively by the

predicted changes. These forests are represented with the same plant associations but differ from each other having two subassociations. The climate of these forests is not as rainy as in the most of the region and clearly similar to a Mediterranean climate. It is also estimated that these enclaves, dune, and pseudomacchia vegetation in the lower altitudes will be easily affected. The *Alnus glutinosa–Oplismenus undulatifolius* association is distributed along the river on the alluvions and may easily be affected too.

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