10 messages for 2010
Mountain ecosystems

European Environment Agency

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This document is the 8th in a series of '10 messages for 2010'. Each message provides a short assessment focusing on a specific ecosystem or issue related to biodiversity in Europe. The remaining messages will be published at various intervals throughout 2010. More detailed information on the published and forthcoming messages can be found at www.eea.europa.eu/publications/10-messages-for-2010.

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Mountain ecosystems

Key messages

- European mountain regions provide essential ecosystem services for lowlands and host a great diversity of habitats and species, many adapted to specific extreme climatic conditions.
- Mountain ecosystems are fragile and vulnerable, and face severe threats from land abandonment, intensifying agriculture, impacts of infrastructure development, unsustainable exploitation and climate change.
- Frameworks for cooperation are the basis for sustainable mountain management and development in Europe. Long-term success depends on detailed implementation at regional and local levels.

1 European mountain regions provide essential ecosystem services for lowlands

1.1 Mountain ecosystem goods and services provided

Mountain ecosystems play a key role in the water cycle for lowland regions in Europe. They influence temperature and precipitation, and modulate the runoff regime. Water from both rain and snow is stored in mountain vegetation and soils and then gradually released. It transports sediments downstream, providing nutrients for lowland areas, replacing fluvial and coastal sediments, and contributing to groundwater recharge in lowland areas.

Mountain ecosystems contribute to preventing and mitigating natural hazards such as landslides and avalanches. They maintain ecological processes and provide goods and services not only to mountain people but also in lowlands where demand from population centres, agriculture and industry is high (Regato and Salman, 2008; Table 1.1).

Ensuring the continued delivery of such services requires careful management of these delicate ecosystems. For example, the massive carbon store laid down over thousands of years in mountain peatlands and organic mountain soils is not only an essential part of rare and threatened peatland habitats but also a potentially huge source of further climate warming if not managed appropriately.

1.2 Habitat and species diversity in European mountains

Ranging from the Arctic to the Mediterranean and experiencing climates from the oceanic to the

Table 1.1 Examples of ecosystem goods and services provided by mountain ecosystems in Europe

Provisioning services	Regulating services	Cultural services	Supporting services
E.g. freshwater, fresh air, timber, food, renewable energy supply.	E.g. climate, water, air, erosion and natural hazard regulation, carbon sequestration.	E.g. recreation/tourism, aesthetic values, cultural and spiritual heritage.	E.g. ecosystem functions, including energy and material flow, such as primary production, water and nutrient cycling, soil accumulation, and provision of habitats.

Source: Adapted from Harrison *et al.*, 2010.

continental, Europe's mountain ecosystems are highly diverse and cover 36% of the continent , including 29% of the European Union (EEA, 2010). Across the continent, forests cover 41% of the area of mountain ecosystems and over half of the area of the Carpathians, the mountains of central and south-east Europe, the Alps, and the Pyrenees.

As a result of sharp altitudinal gradients in both temperature and precipitation, habitat and species diversity are generally higher in mountain areas than in lowlands (Regato and Salman, 2008). Mountain grasslands, for instance, show remarkable biodiversity, which is comparable to certain types of tropical rainforests (EEA, 2002). To a large extent, this biodiversity derives from centuries of intervention by people and their grazing animals; if grazing or mowing decreases below a certain level, many of these species are lost as plants of higher stature take over (Nagy and Grabherr, 2009).

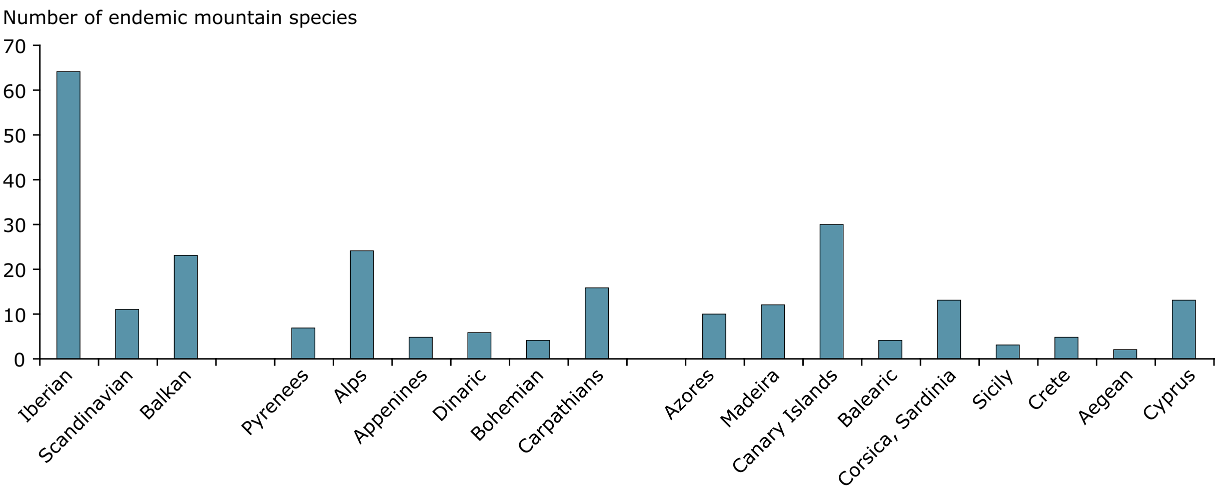
Although alpine areas above the treeline cover only 3% of Europe's land surface, they host 20% of its native vascular plant species. It is estimated that there are more than 2 500 species and subspecies of alpine flora confined to or predominantly occurring above the treeline. The proportion of species restricted to the alpine zone varies from less than 0.5% of the total flora in Corsica to about 17% in the Alps (Nagy *et al.*, 2003). Numbers of vascular plants decrease from south to north, whereas numbers of cryptogams (bryophytes and macrolichens) show the opposite trend (Virtanen *et al.*, 2003).

Species endemism, in particular, often increases with altitude within mountain regions, partly due to the isolation of populations and speciation processes over geological time scales (Regato and Salman, 2008; Nagy and Grabherr, 2009; Schmitt, 2009). For example, the Caucasus ecoregion has the highest level of endemism in the temperate world, with over 6 500 vascular plant species, at least 25% of which are unique to the region (Wilson, 2006). In the rest of Europe, the highest number of endemics and narrow range taxa are found in the Alps and the Pyrenees, with high numbers also in the Balkan mountains, Crete and the Sierra Nevada, the Massif Central, Corsica, and the central Apennines (Väre *et al.*, 2003).

The mountain regions of the Iberian peninsula (excluding the Pyrenees) show a particularly high number (64) of endemic Species of Community Interest listed in Annexes II and IV of the EU Habitats Directive, followed by the Balkans (24). For individual massifs, the highest number of Species of Community interest is found in the Alps (24 endemic species), followed by the Carpathians (18). The highest number of mountain Species of Community Interest on islands are found on the Canary Islands (30) (ETC/BD, 2010; Figure 1.1).

Mountain areas are also at the heart of Europe's remaining wilderness areas. Maps 1.1 and 1.2 show that Annex 2 (Habitats Directive) species are located in wilderness areas protected under the Natura 2000 network. Many of these are mountain areas.

Figure 1.1 Number of mountain Species of Community Interest (Annex II and IV of the EU Habitats Directive) endemic to mountain regions, mountain ranges, and islands of Europe



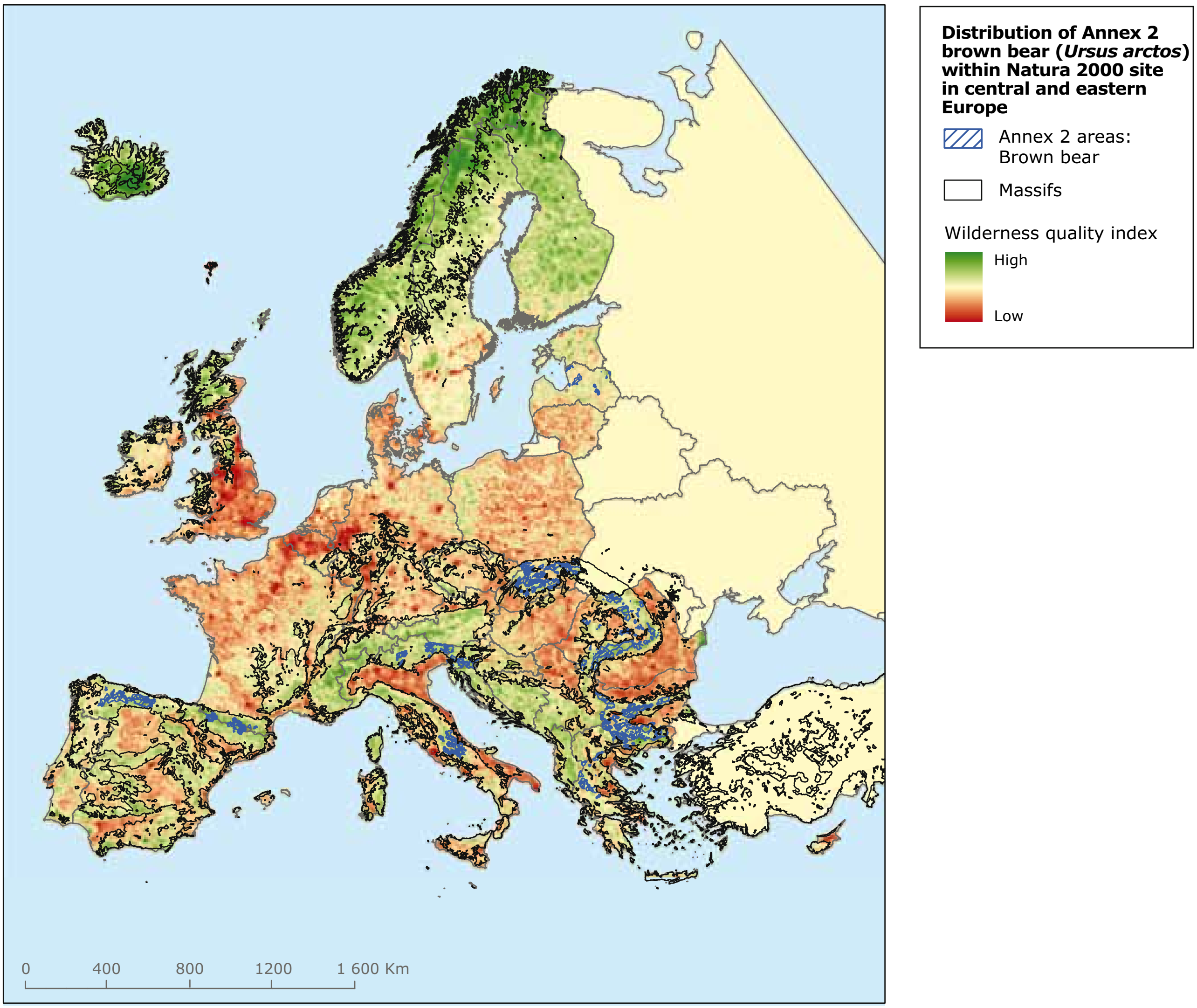
Source: ETC/BD, 2010.

Box 1.1 Biodiversity in Mediterranean mountains

The Mediterranean region has 13 000 endemic plant species — the second largest number among the world's regions. The number of distinct elevation belts, geological variety, sharp latitudinal and broad oceanic-continental gradients from coastal areas to inner mountain regions, and the frequent isolation of mountains all contribute to the high diversity of the Mediterranean mountain flora.

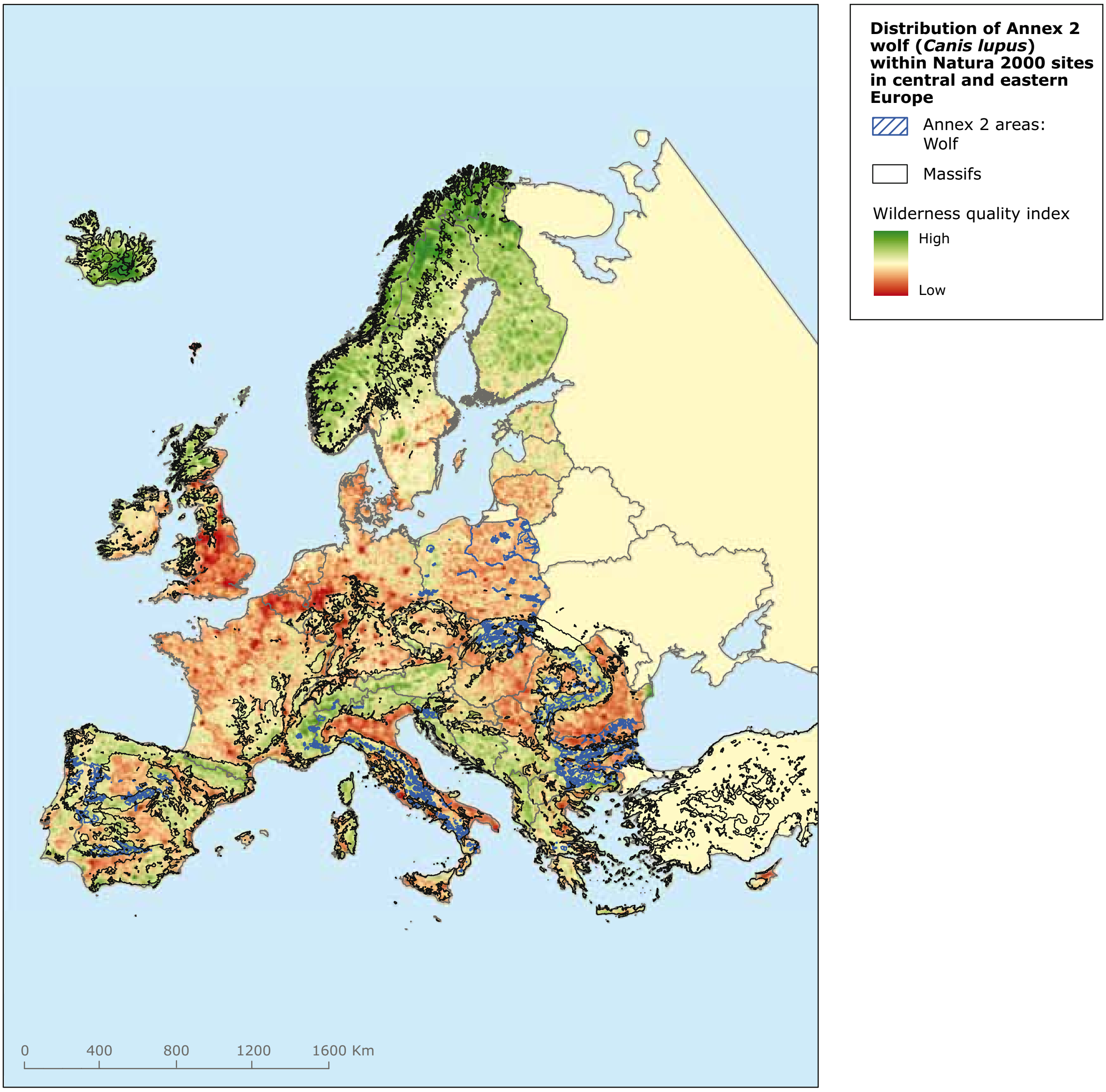
Centres of plant diversity and endemism in the Mediterranean region are almost exclusively high-mountain areas. In particular, more than 20% of species are endemic in the Betic–Rifan complex on either side of the Strait of Gibraltar; in the Middle Atlas and High Atlas in Morocco; in the Iberian Sistema Central; on the islands of Corsica, Sardinia and Sicily; in the Pindos Mountains of Greece; and in Crete, Cyprus, the southern mountains of Turkey (Taurus and Amanus) and the mountains of Lebanon. For instance, 20–30% of the plants are endemic in the high summit pastures of the Greek island of Crete, and 10–20% in the Taurus Mountains of Turkey (Medail and Quezel, 1999).

Map 1.1 Distribution of Annex 2 brown bear (*Ursus arctos*) within Natura 2000 site in central and eastern Europe



Source: © ORNL LandScan 2008TM/UT-Battelle, LLC; EEA Copenhagen 2007; DLR 2010; ESRI 2010. Analysis and cartography by Wildland Research Institute (WRi), University of Leeds.

Map 1.2 Distribution of Annex 2 wolf (*Canis lupus*) within Natura 2000 sites in central and eastern Europe



Source: © ORNL LandScan 2008TM/UT-Battelle, LLC; EEA Copenhagen 2007; DLR 2010; ESRI 2010. Analysis and cartography by Wildland Research Institute (WRi), University of Leeds.

Mountain habitats in Europe (mainly forests and agricultural grasslands) are estimated to support 73 priority bird species and contain 558 Important Bird Areas (IBAs). More than half of these bird species are declining strongly in Europe or even threatened by extinction. Reasons include inappropriate forest management, changes in agricultural practices and poorly planned tourism development (BirdLife International, 2009).

Just as mountain biodiversity varies across Europe, so do human impacts on this biodiversity. Most research has been done on the Alps but factors such as the density of human activity and its impact on biodiversity differs in ranges the Pyrenees or Carpathians. This in turn affects mountain biodiversity conservation policy.

1.3 *Low-intensity farming supports biodiversity in European mountains*

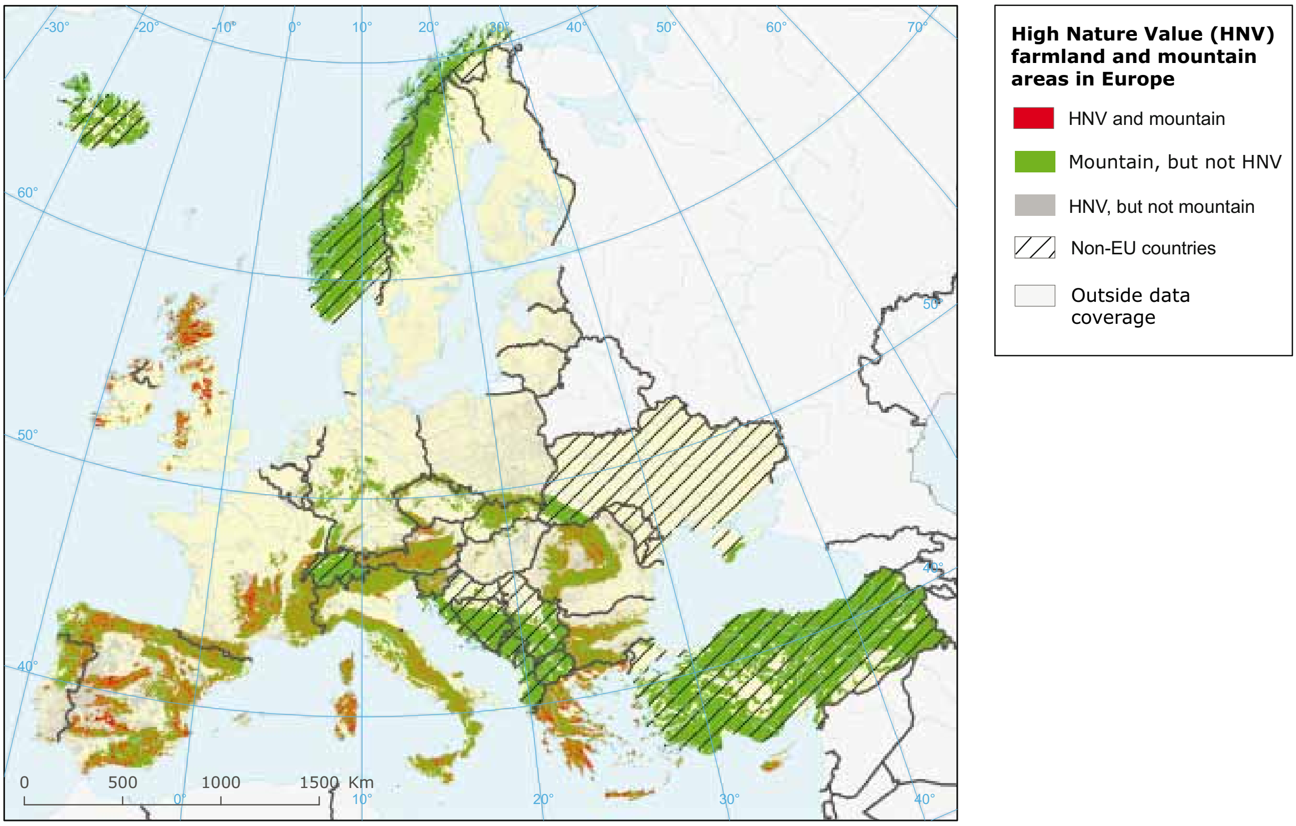
Low-intensity farming in Europe, particularly livestock rearing and traditional cultivation methods, has created semi-natural habitats that support a range of species such as species-rich grasslands, hay meadows and grazed wetlands. The functional diversity in many ecosystems depends directly on traditional types of agricultural land use and farming practices (Cerquiera *et al.*, 2010).

High Nature Value (HNV) farmland is typically associated with low-intensity agriculture, especially grazing. Fifty-one per cent of Europe's HNV farmland is situated in mountain areas (EEA, 2010; Map 1.3).

1.4 *European mountains also support a rich cultural heritage*

The specific environmental conditions and resources of mountains — steep slopes, poor and shallow soils, and extreme climate conditions — have also resulted in high cultural diversity and varied adapted land-use practices that reflect traditional knowledge, cultural and spiritual values (Regato and Salman, 2008; NORDREGIO, 2004). People and nature together form diverse and rich cultures, which attract tourists from the European lowlands and far beyond, supporting a large tourism industry in summer and winter (EEA, 2009).

Map 1.3 Distribution of High Nature Value (HNV) farmland and mountain areas in Europe



Note: Mountain definition (based on 1*1 km DEM)
Elevation > = 2 500 m
Elevation 1 500–2 500 m and slope > = 2°
Elevation 1 000–1 500 m and slope > = 5° or
Elevation 1 000–1 500 and local elevation range > 300 m
Elevation 300–1 000 and local elevation range > 300 m
Elevation below 300 m and standard deviation > 50 m
Minimum area > = 10 km²

Source: EEA, 2010 based on Nordregio/UNEP WCMC, 2004; HNV data: EEA-JRC project on high nature farmland; data source: 100*100 m HNV data, delivery May 2008; ETC-LUSI/EEA (March 2010): project 827 mountain areas; project leader: Martin Price; GIS: Gebhard Banko.

2 Mountain ecosystems are fragile and vulnerable

2.1 European mountain ecosystems face a complex of rapid changes

Mountain ecosystems are fragile and vulnerable to changes due to their particular and extreme climatic and biogeographic conditions. In the Alps, for example, the main pressures on mountain biodiversity are caused by changes in land use practices, infrastructure development, unsustainable tourism, overexploitation of natural resources, fragmentation of habitats, and climate change (EEA, 2002).

European mountain regions, in general, are experiencing strong climate change (glacier retreat, temperature increases, changes in precipitation), as well as land-use changes due to socio-economic pressures (EEA, 2009; EEA, 2010). Marginal land in European mountain regions is being abandoned, while land use is being intensified on productive sites in the lowlands and along the bottoms and lower slopes of mountain valleys (Hagedorn *et al.*, 2010).

2.2 Biodiversity suffers from land use intensification and abandonment

In comparison to traditional land-use practices, plant diversity is reduced in the alpine zone by both intensification and land abandonment (Spehn and Körner, 2005). While agricultural management on economically profitable sites in the Alps is being intensified, remote areas or those with potentially lower yields are being abandoned (Kampmann *et al.*, 2008).

Mountain grasslands are very vulnerable to decreased use because activities such as regular mowing are important for maintaining high species diversity in certain grasslands (Galvánek and Lepš, 2008). In western Europe, such grasslands are often abandoned in unprofitable locations with steep slopes, poor soils or underdeveloped road infrastructure or where pastureland is infrequently used, becoming overgrown with bushes and trees (Gellrich *et al.*, 2007).

A study in the border area between Poland, Slovakia, and Ukraine in the Carpathian mountains revealed similar occurrences in eastern Europe. Here, however, forces such as speculation, unemployment, land-reform strategies and changes in rural population density during the post-socialist period also complicated matters by affecting land ownership patterns (Kuemmerle *et al.*, 2008).

Abandonment and intensified farming of mountainous agricultural land is evident across Europe (Map 2.1). Overall, the area of forest has increased since 1990. At the national scale, changes in agricultural land use have been most marked in the Czech Republic, especially from 1990 to 2000 when the annual rate of land cover change was 1.3% (EEA, 2010).

2.3 Infrastructure development is a major cause of fragmentation of mountain ecosystems in Europe

Lowland-focused policies that ignore the vulnerability and disadvantaged character of mountains, and the high demand for mountain resources by lowland people, often worsen human pressures and environmental disturbances in mountains (Regato and Salman, 2008). For example, constructing highways and motorways increases the isolation and fragmentation of mountain natural environments and the number of physical barriers to the natural movement of many organisms (UNEP, 2007).

In specific locations, developing skiing infrastructure can cause considerable damage to soils and vegetation. Soils become more vulnerable to water erosion, and hillsides with low vegetation cover have higher water runoff levels, increasing the risk of flooding lower areas. Producing artificial snow increases water consumption, which may disturb the hydrological cycle for habitats of high conservation value such as bogs, fens and wetlands at high altitude (EEA, 2002; EEA, 2009).

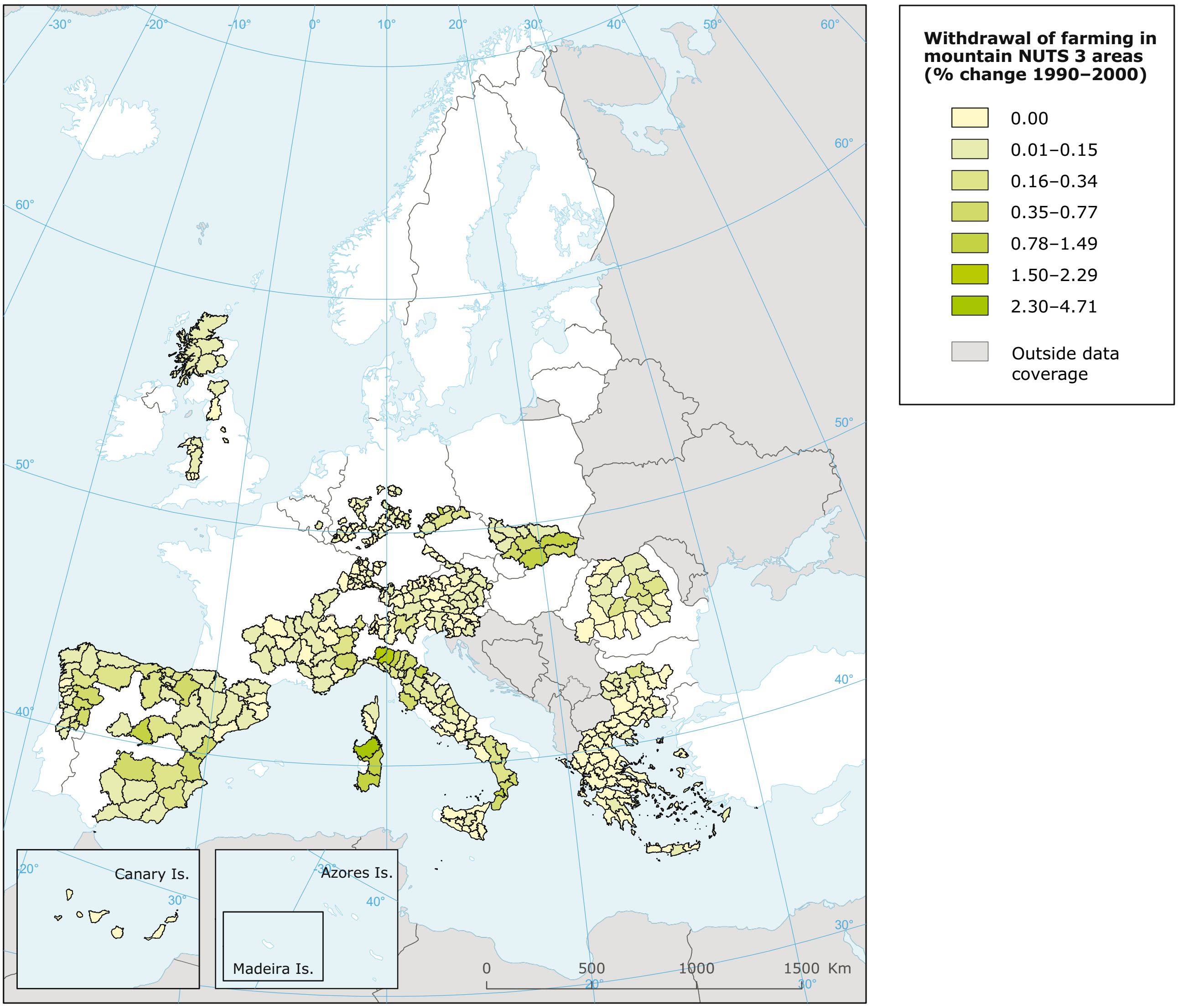
2.4 Unsustainable exploitation threatens European mountain ecosystem goods and services

Mass tourism can pose a major threat to biodiversity, as development can lead to large-scale damage to nature and landscapes. It also favours the introduction of invasive alien species into native habitats (UNEP, 2007). Invasive species are being encountered at ever higher altitudes (Pauchard *et al.*, 2009).

In the Caucasus ecoregion, highly valuable mountain forests are threatened by unsustainable management and exploitation in the form of harvesting wood for fuel and the timber trade. This will lead to irreversible loss of biodiversity and the goods and services on which many local people depend (Williams *et al.*, 2006).

Hunting and poaching in the Carpathians generally focus on rare and endangered species such as

Map 2.1 Withdrawal of farming in mountain NUTS 3 areas (percentage change in the period 1990–2000)



Source: Price, 2008a, based on Corine Land Cover.

large carnivores, eagles, owls, chamois, marmots and many small invertebrates and plants. As their populations are small and isolated, they may not maintain long-term viability and become extinct (UNEP, 2007).

2.5 *Climate change has severe consequences for European mountains*

Climate change threatens important mountain ecosystem services, including supporting rich biodiversity heritage and providing freshwater to vast lowland areas.

Climate change is affecting Europe's mountains in different ways. At the regional level, changes in temperature and precipitation result in changes in snow cover, glacier volume and extent, permafrost and surface runoff (EEA, 2009). In the Alps, average temperatures increased by approximately 2°C between the late 19th and early 21st centuries. This was more than twice the rate of change in the Northern hemisphere as a whole (Auer *et al.*, 2007) and resulted in significant loss of glacial volume (e.g. Zemp *et al.*, 2007).

The rising temperature will increase the proportion of precipitation falling as rain instead of snow, so that there will be more runoff in winter and less in spring and summer (EEA, 2009). Changes in precipitation in the Alps have already been associated with changes in vegetation (Cannone *et al.*, 2007). The frequency of natural hazards such as mudflows, floods and droughts is expected to increase. Climate change also affects many mountain ecosystems directly and indirectly together with other factors such as economic and planning policies (Price, 2008b).

The sensitivity of mountain biodiversity to climate change has been shown by models and validated by in situ observations of phenomena such as upward shifts of vascular plants and changes in species composition at Mount Schrankogel in the Austrian Alps (Pauli *et al.*, 2007). There are projections that the treeline could shift upward by several hundred meters (EEA, 2009; Figure 2.1), and evidence that this process has begun in Scandinavia, the Urals, the western Carpathians and the Mediterranean (EEA, 2010).

Flora and fauna are expected to migrate upwards in order to stay within their bioclimatic envelope. Evidently, however, there is no upward escape from the top of a mountain. Sixty per cent of mountain plant species in the Alps may face extinction by 2100 if they cannot adapt to climate change by moving northwards or upslope (EEA, 2009).

2.6 Mountain species can only adapt to climate change to a very limited extent

Many alpine species have limited dispersal capabilities (Nagy and Grabherr, 2009), and habitat fragmentation may further limit their mobility (Higgins *et al.*, 2003). Small isolated populations face bottlenecks, which decrease their genetic viability and adaptability to a changing environment and may cause extinction in the long term.

Species and habitats associated with water bodies, flowing water, and wetlands are likely to be especially affected by the expected shifts in water regimes. These include less precipitation and runoff in summer and more in winter, runoff peaks earlier in the season, a shorter duration of snow cover and melting of glaciers and permafrost.

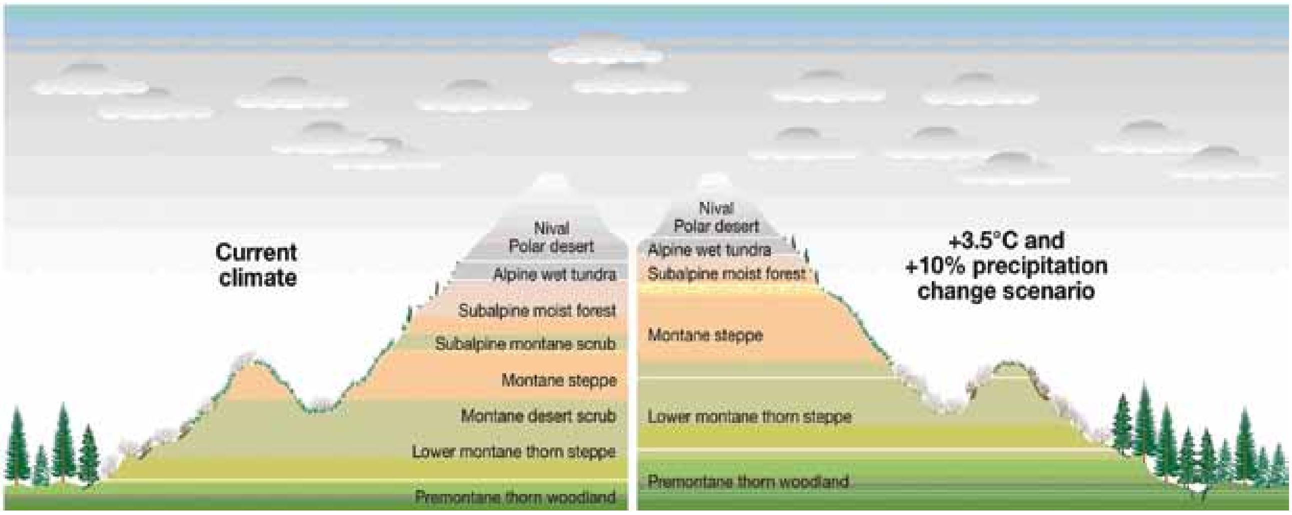
A temporary habitat enlargement can be foreseen for some macrofauna in the Alps, for instance the ibex (*Capra ibex*), the Alpine chough (*Pyrrhocorax graculus*), and the rock partridge (*Alectoris graeca*). Other more isolated species populations such as snow finch (*Montifringilla nivalis*), water pipit (*Athus spinoletta*) and ptarmigan (*Lagopus mutus*) are threatened by global warming (Niedermair *et al.*, 2007).

3 From international cooperation to local change

3.1 International and European policy recognises the role of mountain ecosystems

At the global scale, the importance of mountain areas has been highlighted in Chapter 13 of Agenda 21, entitled 'Managing fragile ecosystems: sustainable mountain development' (UN, 1992) and by the Conference of the Parties to the Convention on Biological Diversity (CBD, 2010). In addition, legal frameworks have been developed at the regional level for the Alps and Carpathians and are

Figure 2.1 Comparison of current vegetation zones at a hypothetical dry temperate mountain site with simulated vegetation zones under a climate-warming scenario



Source: UNEP/GRID-Arendal, 2009.

under discussion for the mountains of south-east Europe and the Caucasus (UNECE, 2007).

The Alpine Convention, which was signed in 1991 and came into force in 1995, applies the 'polluter pays' principle, and supports cooperation between the signatory states towards a holistic approach to protecting and preserving the Alps (Tappeiner *et al.*, 2008; Treves *et al.*, 2004). The Alpine Network of Protected Areas is a particularly important outcome.

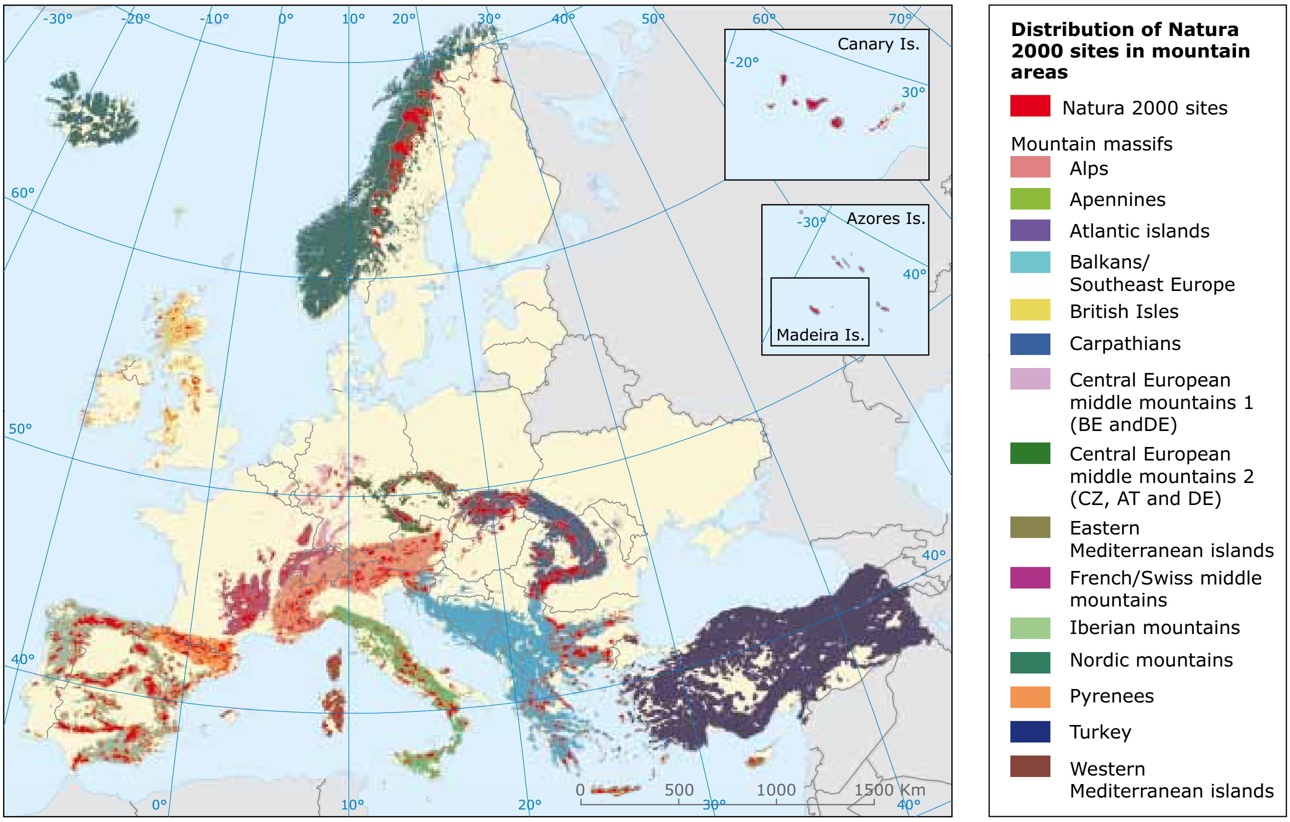
These international agreements and processes indicate that there is adequate recognition at the European level of the need for international cooperation. It is important to consider which policies have been successful at regional and local levels.

Within the EU-27, 92% of the total mountain area has been designated as Less Favoured Areas (LFA). Seventeen per cent has been designated as HNV farmland, with just 5% of this lacking LFA status.

At the national level, the proportion of mountain areas designated as protected (within the Natura 2000 network and under national legislation) is particularly high. Mountains account for 43% of the total area of Natura 2000 sites in the EU-27 (Map 3.1). While 21% of mountain habitats within these sites have a favourable status, 28% have an unfavourable-inadequate status and 32% have an unfavourable-bad status. The status of 18% of mountain habitats (mainly in Spain) is unknown.

Further research is required to investigate these results in the light of the generally high level of protection of mountain areas. Nevertheless, in most countries, the proportion of habitat types with a favourable status is higher in mountain areas than elsewhere, sometime by a very significant margin. This is true in both countries with large mountain areas (e.g. Austria, Greece, Italy) and those with small mountain areas (e.g. Finland, Poland, Sweden) (EEA, 2010).

Map 3.1 Distribution of Natura 2000 sites in mountain areas



Source: EEA, 2010.

3.2 *Economic, social, and environmental factors need to be integrated in management strategies for mountains and other ecosystems in Europe*

Mountain regions in Europe vary not just in terms of their biogeographic environmental conditions but also their political and socio-economic circumstances (EEA, 2009; NORDREGIO, 2004). In addition, our knowledge of these very diverse environments varies greatly with, in particular, much more knowledge regarding the Alps than other regions (EEA, 2010).

European and international legal frameworks can serve as tools to mitigate severe pressures such as climate change through targets and actions to reduce greenhouse gas emission reductions agreed at global (UNFCCC, Kyoto Protocol) and EU levels, and to adapt to some inevitable climate change.

However, there are many complex interacting reasons for negative trends in biodiversity, which are often driven by national forces (e.g. employment and income imbalances), European activities (e.g. Common Agricultural Policy) and even global policies. This implies a need to integrate management strategies, which should be developed and implemented with the active participation of the public concerned and the relevant stakeholders (Partidário *et al.*, 2009; Fonderflick *et al.*, 2010).

Measures to increase ecological connectivity are particularly important, especially within and between the many mountain ranges along national borders (Worboys *et al.*, 2010). As for each major ecosystem type in Europe, it is essential to monitor the success of regional mountain biodiversity actions and to undertake applied research (Borsdorf and Braun, 2008) and targeted public relations (UN, 1992; CBD, 2010; GMBA, 2010).

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