CHAPTER 4. CLIMATE CHANGE WILL MAKE WATER AND LAND MANAGEMENT MORE COMPLEX

Physical impacts will vary depending on whether climate change manifests itself through slow changes in averages, through more frequent extreme events, or through sudden catastrophic changes (such as a collapse in the North Atlantic current or a collapse of the Greenland or Antarctic ice sheet). Slowly occurring changes are controllable for most human-managed systems—though not always for ecological ones. Extremes are, of course, much harder to cope with and more likely to impose irreversible damages.

This chapter describes the impact of slow-moving averages and more predictable extreme events (or so-called slow-onset disasters such as droughts), concentrating on direct physical impacts. The chapter looks at how climate change might complicate water resource management, and then we review how it is likely to affect ECA's coastal areas. Finally, the impact of a receding permafrost line is discussed.

More difficult water resource management—too much or too little of a good thing

As mentioned in chapter 2, ECA will be confronted with both more floods and more droughts. Rainfall is expected to become more intense and variable, resulting in increased flood risk everywhere in the region—particularly in Eastern and Central Europe. Droughts will be a serious issue for Central Asia, the Caucasus, and Southeastern Europe. Water management will become more complex everywhere, but—at least in the period up to 2030—this will be mostly driven by natural climate variability, socio-demographic trends, and unsustainable water resource management.

What climate change means for water resource management

Climate change can cause or exacerbate water stress in a variety of ways beyond reduced precipitation. Increased temperature reduces water availability by increasing evaporation, while at the same time causing an increase in demand (for irrigation or recreational purposes), and affecting water quality by intensifying the effect of aquatic pollution.

Warmer temperatures also reduce the share of precipitation that falls as snow, which is a natural mechanism for storing water that is gradually released in spring and summer.[25] Climate change affects sea level rise and storm surges, which can lead to salinization of coastal aquifers (see discussion of coastal areas below).

Finally, more concentrated rainfall and a decline in snowfall, with its water retention function, will likely lead to a lower recharge of aquifers as saturated soil conditions lead to more surface runoff.

Increased flooding is a growing concern across all of ECA. Central Europe has been particularly affected in recent years—particularly Bulgaria and Romania. The flooding can be riverine or coastal, but can also come from rising underground water, which is a serious issue for a number

[25] The melting of mountain snowpack over the summer is a natural redistributing mechanism of precipitation across seasons. Normally, greater winter precipitation is stored as snow and ice, and then gradually released throughout spring and summer as temperatures rise.

of Russian cities, such as St Petersburg. Increased intensity of rainfall along with storms and more rapid snowmelt in the spring are the climatic drivers of floods.

A number of non-climatic factors already threaten the sustainability of water resources, including urban growth, changing land use, and unsustainable agricultural and industrial water use (Arnell and Delaney 2006; Holman et al. 2005). One study (Vörösmarty et al. 2000) shows that for the early part of this century water stress in Europe and Asia will be almost entirely driven by increased water demand linked to socio-economic developments. Similarly, there is evidence that floods are often linked to poor land use and river basin management.

Generally, climate-related changes to freshwater systems have been small, compared with such non-climatic drivers as pollution, regulation of river flows, wetland drainage, reduction in streamflow, and lowering of the groundwater table (mainly due to extraction for irrigation). This mosaic of stresses calls for a shift towards more sustainable practices before the impacts of climate change are more strongly felt over the next 20 years.

A varying regional picture but more flooding (almost) everywhere

As discussed in chapter 2, Central and Southeastern Europe, Central Asia, and the Caucasus will experience reduced precipitation, while the rest of the region (Northern Europe, Russia except for the Northern Caucasus, Kazakhstan) will mostly see increased rainfall. Annual runoff—meaning the water that runs over land, and a measure of water availability—is projected to decrease in Central and Southeastern Europe and Central Asia but increase for most of Russia and the Baltics (map 2.4, map 4.1). Winter runoff is projected to increase, especially in western Russia, with the most pronounced changes projected for the spring for the rest of ECA (Kattsov et al. 2008).

Projections are grim in terms of frequency and intensity of extreme flooding in ECA. The Danube and Tisza valleys in Hungary are very prone to frequent flooding. Floods are projected to be more frequent in Northern, Central, and Eastern Europe as well as in Asian Russia. Intense short-term precipitation and the risk of flash flooding will rise across most of Europe. Flood protection traditionally relies on reservoirs in highland areas and dykes in lowland areas.[26] However, other planned adaptation options are becoming more popular, such as expanding zoned floodplain areas (Helms et al. 2002), emergency flood reservoirs (Somlyódy 2002), preserved areas for flood water (Silander et al. 2006), and flood warning systems, especially for flash floods.

Anticipating and responding to flood risk will require intelligently managed institutions that identify water use trends, areas vulnerable to climate change, and opportunities to respond to the emerging challenges. Particular measures for flood management include effluent disposal strategies under conditions of lower self-purification in warmer water, design of water and wastewater treatment plants to work more efficiently, even during extreme climatic conditions, and ways of reusing and recycling water (Luketina and Bender 2002; Environment Canada 2004; Patrinos and Bamzai 2005).

[26] The discussion of flood protection is adapted from Bates et al. 2008.

Climate change will compound Central Asia's already serious water shortages[27]

Central Asian countries are confronting a shared problem of future water shortages, probably the most dramatic in the region. Increased winter precipitation will be more than offset by declining summer precipitation and warmer temperatures. Declines in river runoff—estimated to be about 20 percent in the next 50 years—will compound already unsustainable water management.

The nature and extent of water vulnerability varies. In Kazakhstan, where the decline in runoff is expected to be milder, there is a potential problem of water resource management in the Ili River basin, which is shared with China. Kyrgyzstan and Tajikistan will have enough water for their own needs but may not be able to meet demand in their role as critical suppliers of water to the region—Kyrgyzstan has 30 percent and Tajikistan 40 percent of total water resources for the five countries (table 4.1).

TABLE 4.1 WATER RESOURCES OF CENTRAL ASIA: SUPPLIERS OF THE MAIN RIVERS (KM^3/Y)

State	Amu-Darya River basin	Syr-Darya River basin	Balhash Lake basin	Issyk-Kul Lake basin	Tarim River basin	**TOTAL, km^3/y**	**Share of country's resources in regional total**
Kazakhstan	-	5	24	-	-	**28**	**18%**
Kyrgyzstan	2	34	0	4	7	**47**	**30%**
Tajikistan	63	1	-	-	1	**65**	**41%**
Turkmenistan	2.8**	-	-	-	-	**3**	**2%**
Uzbekistan	5	4	-	-	-	**9**	**6%**
TOTAL	**79***	**38**	**29**	**4**	**8**	**157***	**100%***
Share of basin's contribution to regional total	**50%**	**24%**	**19%**	**2%**	**5%**		**100%**

Notes: * Including contribution of Afghanistan in Amu-Darya runoff, that is, 6.2 km^3/y or 3.9% of the total water resources of the region. ** Including Iran's small contribution in Amu-Darya runoff.
Source: Alamanov et al. 2006, page 105 as quoted in Kokorin 2008.

The rapid melting of the glaciers of Kyrgyzstan and Tajikistan is worrisome, particularly in the case of Tajikistan, whose glaciers contribute 10 to 20 percent of the runoff of the major river systems of the region (up to 70 percent during the dry season). The glaciers are critical to the Amu-Darya water basin, the most important in Central Asia and the principal source of water for Turkmenistan. In addition, Kyrgyzstan is also seeing a troubling decline, partly attributable to climate change, of the water level of Lake Issyk-Kul, which is important to its economy and ecosystems.

[27] This section is based on the background paper by Kokorin.

The water situation in Turkmenistan and Uzbekistan is dramatic, but would be so even without climate change. Uzbekistan is the main water consumer of the region—it is the most populated country with an economy largely based on irrigated farming. Almost all (90%) of its water resources come from mountains located in other countries. Adaptation will require more sustainable use of water, starting with implementation of low water consuming technologies and more effective irrigation management. It may also include reservoirs and regulation of runoff.

Unsustainable water management has caused the Aral Sea to shrink, which will be made worse by climate change. Once the fourth largest lake in the world, the Aral Sea is nearing extinction, having decreased over the last four decades from 68 to about 28 thousand km^2 (Glantz and Zonn 2005). Where once 178 species inhabited the Aral region, there are now fewer than 40 (Alamanov et al. 2006). Salt air pollution from the open sea bottom is dangerous for agriculture and human and animal health. Warming temperatures are only making it worse—for example, by increasing evaporation over the 1300 km man-made Karakum channel.

Significant damage has already occurred in the Amu-Darya River delta, and measures to manage today's stresses will be even more important to refine as the climate changes. The Amu-Darya is a key source of water for Uzbekistan, Tajikistan, and Turkmenistan, which share in its use and therefore will have to coordinate efforts to save the Aral. The government of Uzbekistan is now attempting to stabilize the sea with a program that includes development of buffer protection basins, which are chains of local water reservoirs in the Amu-Darya River delta and surrounding areas.

BOX 4.1 PLACING MORE EMPHASIS ON RIVER BASIN MANAGEMENT

Integrated Water Resource Management (IWRM) is a systematic approach to planning and management that considers a range of supply-side and demand-side processes and actions, and incorporates stakeholder participation in decision processes. It identifies and balances trade-offs among the water management objectives of environmental sustainability, economic efficiency, and social equity. IWRM simultaneously addresses the two distinct systems that shape the water management landscape. The biophysical system—including climate, topography, land cover, surface water hydrology, groundwater hydrology, soils, water quality, and ecosystems—determines the availability of water and its movement through a river basin. Factors related to the socio-economic system, driven largely by human demand for water, shape how available water is stored, allocated, and delivered within or across river basin boundaries.

Integrated analysis of the natural and managed systems is arguably the most useful approach to evaluate management alternatives. This type of analysis uses hydrologic modeling tools that simulate physical processes including precipitation, evapotranspiration, runoff, and infiltration. In managed systems, analysts must also account for the operation of hydraulic structures, such as dams and diversions, as well as institutional factors that govern the allocation of water between competing demands, including consumptive demand, such as agricultural or urban water supply, and non-consumptive demands for hydropower generation or ecosystem protection.

IWRM at the river basin level seeks to manage the sharing of costs, benefits, and impacts among all uses and users across a river basin. But it is also the most challenging approach to water resources management because of the obstacles created by sector and administrative boundaries.

Source: contributions by Shelley McMillan.

Many problems, however, have not yet been addressed, including modernization of archaic , wasteful irrigation systems and other climate-sensitive infrastructures. Although most of the countries have developed adaptation policies, implementation is slow (Kokorin 2008). And, while integrated river basin management is essential throughout the region, it is complicated by the transboundary nature of the region's water resources (box 4.1).

More stress on already stressed coastal areas[28]

Coastal areas, defined as "areas on and above the continental shelf […] routinely inundated by saltwater, and adjacent land, within 100 km from the shoreline" (Martinez et al. 2007), are subject to impacts from both the sea and the land. This exposes them to the influence of climate change either directly (sea level rise, storm surges, floods, droughts), or indirectly through events that originate off-site but whose consequences propagate down to the coasts, like river floods and changes in the seasonality, pulses, and quality of runoff from inland sources.

Coastal vulnerability varies tremendously across ECA's four basins (the Baltic Sea, the East Adriatic coast and Mediterranean coast of Turkey, the Black Sea, and the Caspian Sea) and the Russian Arctic Ocean. Some basins are experiencing a decrease in sea levels (Caspian and northern Baltic), while others face varying degrees of sea level rise. Seawater acidification—caused by higher concentrations of CO_2—and increases in water temperature affects them all. Vulnerability in all basins is exacerbated by poor coastal management and existing stresses—pollution, overfishing, construction too close to the coast, and the damming of rivers, which prevents sediment flows from reaching the coast, worsening erosion.

Vulnerability also depends on whether a significant share of a country's population or economic activities is situated in low-elevation coastal zones. This share is highest in Latvia, where 34 percent of the population lives in coastal zones less than 10 m above sea level, and significant in a number of other ECA countries (table 4.2).

TABLE 4.2 SHARE OF THE POPULATION LIVING IN LOW ELEVATION COASTAL ZONES (LESS THAN 10 M ABOVE SEA LEVEL)

Country	Total population in low lying coastal zone	As a share of national population (%)
Latvia	814,288	33.6
Albania	317,894	10.1
Georgia	328,396	6.2
Lithuania	186,901	5.1
Turkey	2,449,027	3.7
Romania	760,789	3.4
Croatia	139,930	3.0
Ukraine	1,315,903	2.7
Poland	973,501	2.5
Russia	3,552,274	2.4
Moldova	87,726	2.0
Bulgaria	121,581	1.5
Montenegro	8,583	1.3
Bosnia-Herzegovina	700	0.0

Notes: Armenia, Azerbaijan, Belarus, Hungary, Kazakhstan, Kyrgyz Republic, Macedonia FYR, Serbia, Slovakia, Tajikistan, Turkmenistan, Uzbekistan have no exposed population. *Source:* SEDAC–CEISIN.

[28] This section is based on "Adaptation to Climate Change in Coastal Areas of the ECA Region" by Nicola Cenacchi, a background paper commissioned for this report.

Baltic Sea

Variations in the Baltic Sea level are strongly affected by the uplift of the Scandinavian plate in the north and the lowering of the southern Baltic coasts. This, combined with the increase in mean ocean level, has resulted in a recorded sea level rise of 1.7 mm per year in the southeastern Baltic, but a decrease of 9.4 mm per year in the northern part (HELCOM 2007). Projected sea level rise will depend mostly on land uplift and global sea level rise, with the latter apt to balance the former in the northern areas. The best studies on coastal vulnerability in the Baltic have been carried out in Estonia and Poland, which provide the richest examples.

To date, no obvious trend of sea level rise has been recorded in Estonia, whose coast is only moderately vulnerable. A 1m sea level rise, for example, would threaten important ecological sites, but few settlements (Kont et al. 2008). This is because the coast is scantily populated. The only two vulnerable sites are the city of Tallinn (the capital of Estonia) and the Sillamae industrial center. The latter is the dumping site for the radioactive wastes of a former uranium enrichment plant. These wastes regularly leach into the soil and water, and are separated from the sea only by a narrow dam.

Increased storminess and sea level rise could cause radioactive material to be flushed directly into the Baltic. The city of Tallinn is protected for one-third of its coastline by seawalls, but the defense system will require adjustments because of increased storminess. Increased coastal development—partly for tourism—would increase vulnerability.

In contrast, Poland's coast seems more vulnerable. Global circulation models project increased frequency and strength of storm conditions along with a continued rise in sea level that could reach 45 to 65 cm by 2100 (Pruszak and Zawadzka 2008).

And Poland's low-lying and mostly sandy coasts are exposed to flooding and erosion, which has increased since the 1970s because of the rise in sea level, greater storminess, and sediment starvation, brought about by the regimentation of rivers.[29] The socio-economic vulnerability of Poland's coast is particularly high at the eastern and western extremities (the cities of Gdansk, Gdynia, and Szczecin). Sensitivity could increase, as coastal development, which began in the 1990s after a jump in GDP, continues its course.

Runoff into the entire Baltic Sea will likely increase over this century as precipitation linked to climate change becomes heavier, altering the delicate coastal water nutrient balance. More runoff will translate into a greater input of nutrients, and possibly intensify eutrophication (HELCOM 2007).[30] This, combined with the projected continued warming of sea water, will spark an increased phytoplankton growth that could be harmful to human and animal health (see chapter 3).

[29] Subsidence has had little effect on the Polish coast, being only of 1 mm/year.

[30] Eutrophication literally means over-nourishment. The term refers either to atypical algal blooms, or to the massive death of organisms following the decomposition of algae and the loss of oxygen in the water. These events are triggered by the availability of enormous quantities of both inorganic and organic nutrients, such as from runoff from fertilized fields.

Caspian Sea

The Caspian Sea has in the past displayed significant sea level fluctuations. The causes are not well understood, but may include changes in precipitation and runoff, along with tectonic movements.

Climate models project a six meter *decrease* in the level of the Caspian Sea from 1975 to the end of the twenty-first century because of increased surface evaporation, which is expected to exceed the augmented runoff from the Volga (Renssen et al. 2007, Elguindi and Giorgi 2007). A significant drop in sea level combined with increasing temperatures will impact fish stocks and put additional stress over the already imperiled sturgeon population. It would also affect infrastructure and economic activity, increasing costs for industry (mainly oil and gas) and transport.

Unfortunately, awareness of the unpredictable sea levels has not discouraged coastal development on land freed by the retreating sea. Past rises have caused vast damages along sections of the Caspian coastline, a prominent example being the Russian coast (Frolov 2000, GEF 2002). A new drop in level could result in another rush to occupy newly available land, exposing the population to potentially dangerous substances, such as pesticides, arsenic, and other heavy metals locked in coastal sediments.

Mediterranean Sea (East Adriatic and Mediterranean coast of Turkey)

The Mediterranean is a difficult place to gather data on sea level forecasts. Tectonic activity, changes in density of deep waters, and local changes in air pressure systems complicate measurement activities (Karaca and Nicholls 2008). Within the East Adriatic, observations of sea level rise at different locations show great differences, with the average rising at one site and dropping at another.

In Croatia, for example, studies project a significant sea level rise, but with high levels of uncertainty (e.g., +65 ± 35 cm by 2100). For this reason, a UNDP/GEF project is working on a qualitative assessment of vulnerability to a wide range of possible sea level changes (Barić et al. 2008).

Croatia's rocky coast would protect it well against a small sea level rise (e.g., 20 cm) but not against much higher rises. Particularly vulnerable are tourism, fisheries, and shipping infrastructures built right up to the shore. Further analysis is needed to understand the vulnerabilities of coastal cities, notably to salt water intrusion into groundwater tables (Barić et al. 2008).[31]

The northern part of Albania is highly sensitive to floods and more frequent storms. Unregulated urban development has allowed building right to the shoreline, exposing infrastructures to a high risk of weather-related damages. The impact will vary with the extent of sea level rise: the 48–60 cm rise projected for 2100 would flood coastal areas and cause significant saltwater infiltration (UNDP-Albania 2002), whereas the 20–24 cm projected for 2050 should not have major impacts despite the fact that all the coasts of Albania are considered lowlands.

[31] At the same time that the sea is rising, projected declines in precipitation (or increased extraction) would lower the level of underground freshwater supplies, making inflow of saltwater for a given amount of sea level rise even more likely.

Along Turkey's Mediterranean coast, a rise in sea level will have mostly local impacts. The coastline's geophysical characteristics indicate a low physical vulnerability, but some settlements and productive activities will be vulnerable (UNDP-Turkey 2007).

Nevertheless, sea level rise and storm surges could impact tourism and agriculture (Karaca and Nicholls 2008). Delta plains where land has been reclaimed for agricultural use (Gediz, Seyahn and Ceyhan) are especially vulnerable (Karaca and Nicholls 2008). The movement of populations towards coastal cities is amplifying the sensitivity of the socio-economic system to sea level rise. Istanbul is particularly exposed, as 10 percent of the population lives within 1km from the shore, and the city by itself accounts for 21 percent of national GDP. The biggest concerns involve saltwater intrusion, particularly in two coastal lagoons and to Lake Terkos, which supply freshwater for the city (Karaca and Nicholls 2008).

Black Sea

Sea level rise has been higher in the Black Sea than in the Mediterranean (27 ± 2.5 mm per year, versus 7 ± 1.5 mm per year, Valiela 2006) though the few studies that exist lack consistency.

The Georgian coast appears to be subsiding relative to the rest of the Black Sea basin (Karaca and Nicholls 2008), while the Russian coast with its numerous ports and high economic activity will be vulnerable to floods and salt water intrusion into the aquifers (Frolov 2000). Ukraine is already experiencing erosion problems that are prompting a loss of housing, arable land, and industrial and touristic sites.

The Black Sea coast of Turkey is vulnerable mainly in a few deltaic areas (Karaca and Nicholls 2008). Storm surges are already affecting some settlements and worsening conditions may bring damages to the 23 ports along the Black Sea. Furthermore, storms, erosion and sustained flooding are predicted to damage the very important east-west road system that runs along the coast very near to the shoreline.

Climate change will add to the stresses already felt in the Black Sea coast. The economically critical fishing industry is already threatened by overfishing and pollution, and will be further stressed by the projected increase in water temperatures. The Black Sea is also an important source, refinement point, and transport route for oil and gas, and there are fears that increased storminess and erosion will stress oil and gas infrastructure on the Russian, Ukrainian, and Georgian coasts. Accidents, in turn, would spread further pollution. Coastal landfills in the Black Sea are pollution hot-spots (GEF 2007); and along the Georgian coast, and some other areas, sea level rise and coastal erosion may further damage these landfills and increase the volume of pollutants flushed to sea.

Finally, the damming and channeling of rivers, along with ill-managed coastal development, is altering the sediment balance and distribution, resulting in erosion problems. In Russia, Ukraine and Georgia, unregulated building close to the shore is also advancing erosion and increasing sensitivity to climate impacts.

Declining arctic ice, tundra and permafrost[32]

Climate impact is fastest and most visible in the Arctic region. Projections of Arctic Ocean ice show decreases in area and mass throughout the twenty-first century, with the decreases more pronounced in the seasonal minima (September) than in the seasonal maxima (March) (Kattsov 2007, 2008). While there is a lot of inter-model variation, studies project a mean reduction in September ice on the order of 40 percent by mid-century. Zhang and Walsh (2006) project the multi-year arctic ice to decrease on the order of 45–65 percent in the last two decades of the twenty-first century, while seasonal ice (meaning ice that melts in the summer) is projected to increase 14–28 percent over the same period. In some models, the Arctic Ocean's ice cover becomes entirely seasonal by the end of the century.

Regarding Russian permafrost, seasonal thaw depths are projected to increase by more than 50 percent in the most northern parts of Siberia by 2050, and by 30–50 percent in most other permafrost areas (Anisimov and Reneva 2006). Projections also suggest increased seasonal thawing depths along with a northward shifting of the boundary between seasonal thawing and seasonal freezing (map 4.2)**.** Finally, over the next 100 years, Russia's tundra is projected to shift to forest (Scholze et al. 2006), with estimates of total converted tundra area ranging from 10–50 percent (Anisimov and Vaughan 2007).

The implications of the large scale thawing of the permafrost go far beyond the urgent biodiversity problem caused by the loss of ice in the Arctic and the impacts on buildings and infrastructure (chapter 6). Permafrost is thought to hold about twice the amount of carbon in the atmosphere. And while some of it would be captured by the encroachment of trees in the tundra, emissions of carbon (as carbon dioxide or methane—a much more potent greenhouse gas) from microbial decomposition of organic carbon in thawing permafrost could amount to roughly half those resulting from global land-use change during this century (Schuur et al. 2008). The large scale thawing of the permafrost is a major catastrophic event that could lead to runaway global warming.

Threats to biodiversity are significant[33]

ECA countries are home to a significant part of the world's biodiversity. This includes the world's largest contiguous steppe and intact forest ecosystems along with 21 mountain chains (Brylski and Abdulin 2003), 9 of 15 major biomes, and nearly 100 different eco-regions (map 4.3). Much of this biodiversity is already threatened. Indeed ECA is also home to 26 of the World Wildlife Fund's (WWF) global 200 priority areas (map 4.4), and three hotspot regions:[34] the Mediterranean basin, the Caucasus, and the Mountains of Central Asia.

The first impact of increasing temperatures will be to change species' ranges, meaning it will induce a movement of ecosystems themselves. Some species and ecosystems—those that

[32] The material on projections is based on the background papers by Westphal as well as by Kattsov et al., while the discussion of the implication of permafrost melting and adaptation options is from the background paper by Kokorin.
[33] This section is based on "Biodiversity Adaptation to Climate Change in the ECA Region" by Nicola Cenacchi, a background paper commissioned for this report.
[34] The WWF 200 Global priority areas are a set of ecoregions where conservation efforts and resources should be concentrated—based on the level of species richness and endemism. Hotspots are areas "featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat" (Myers et al. 2000).

already occupy the most extreme areas in the mountainous or arctic regions—will have nowhere to go and are under threat of extinction. Others will not be able to adapt fast enough, given the unprecedented rates of temperature change. As species push northward or upward, warmer and wetter conditions are also expected to create more opportunities for invasive species to expand their range (Reid 2006, Alcamo et al. 2007). Climate change will also affect the timing of natural cycles, such as flowering or mating seasons.[35]

Two key lines of intervention: conservation and minimizing non climate change-related stresses

A first step entails tackling directly those stressors that undermine adaptation of species and ecosystems—one of the arguments behind establishing protected areas. However, protected areas—still basic to biodiversity conservation—will become less effective as habitat ranges, and with them the distribution of species, shift.

The key to an adaptation strategy then is an anticipatory framework enabling the natural systems to adapt on their own, to the extent possible, to climate change. The preferred approach is the establishment of networks of protected areas, shielded by buffer zones and connected through vegetation corridors, which allow species' migration along altitude and latitude gradients (Price and Neville 2003).[36] But to be effective, they must have a landscape-regional (or "bioregional") approach (box 4.2).

BOX 4.2 BIOCLIMATIC MODELS

Ideally, the design of protected areas should be informed by bioclimatic modeling, i.e., modeling of the range shifts of species. Regional modeling of biodiversity responses (including magnitude and direction of change) is necessary since the global models are not useful for conservation of biodiversity (Hannah et al. 2002).

One of the challenges is how to test the various models' predictive ability; obviously, there are no future data to test the predicted distribution of species in relation to climate change. One solution has been to make use of past climate and species distribution data (Araujo and Rahbek 2006). But this type of data is hard to find and testing of models is restricted to a few regions and a few species within them.

In ECA, there is a large amount of untapped historic data that may be extremely useful (one example is "Chronicles of Nature," an official document produced in each of the about 200 protected areas of Russia, recording past changes in the distribution of species, both flora and fauna); the situation calls for a program to track and recover such material and use it to support regional biomodeling of future changes.

One example is the EU's central conservation measure, the Natura 2000 Network—26,000 protected areas covering all member states with a total area of 850,000 km2 or more than 20 percent of EU territory. It does not exclude all human activity, but rather includes both nature

[35] These cycles are known as phenological cycles. The effect of a phenological shift on a species depends on whether the other species on which it relies—for food, pollination, or seed dispersal—change with it.

[36] A **buffer zone** has the double purpose of benefiting local populations while providing an additional level of protection to the conservation area; it is intended for both conservation and development fostering research, tourism, etc., and for prohibiting activities like logging, mining, and construction. **Corridors** typically indicate landscape vegetational structures that facilitate the migration of both animal and vegetal species, as well as the exchange of human populations, to reduce the chance of genetic isolation.

reserves and privately owned land where extensive agriculture or pasture are allowed and managed according to sustainable practices (European Commission 2005).

The UNESCO World Network of Biosphere Reserves is an example of the extension of the landscape approach to the global scale. Unlike national protected areas, this network spans across national boundaries. Examples within ECA are the biosphere reserve at the southwestern end of the Tien Shan Mountains, and the Carpathians.

Adaptations by biome

ECA's hotspots and WWF's Global 200 priority areas—spanning a number of ecoregions—face great stresses of habitat destruction and fragmentation, requiring forward-looking adaptation measures (table 4.3).

Grasslands and **forests** are vulnerable due to the increased risk of wildfires and invasive species. A key adaptation strategy centers on control of exotic species. Monitoring the migration of wild grazers is also a critical factor. The Daurian steppe (see table 4.4) contains rare plant species and is currently exposed to unregulated road construction and unsustainable grazing practices. Both factors are potentially disastrous for maintaining resiliency to climate change—as plant genetic diversity will be key in efforts to identify forage and other plants that thrive in the changing climate— and have to be addressed urgently as an initial adaptation measure.

Given the need for northward migration, physical barriers to migration must be avoided. For instance, in the north of the Central Asian steppe lies a vast swatch of agricultural land that is difficult for species to cross. Corridors or "stepping-stones" could allow the southern grassland species to move into and across the land occupied for human use.[37]

Global warming will cause **mountain ecosystems** to migrate upward (rather than northward). This will result in a loss of the ecological zones at the summit of the mountains—since they have no place to migrate to (Price and Neville 2003) . This phenomenon is already observable all over the world, from the Italian Alps to the Urals to the Altai-Sayan Mountains. In mountain chains with a north-south geographical orientation (such as the Urals), the process may be delayed as species may find temporary refuge in the northernmost areas.

In the Urals the main threats are the clear-cutting of old-growth forests, mining, agriculture and pasture, air pollution, and tourism. However, the threats are not equally distributed along the chain. While the mountain tundra seems to have been degraded all across the ecoregion (apart from a few protected areas), the northern taiga is still in relatively good condition.[38] Its protection is therefore critical.

In the Altai-Sayan and Khangai mountains, stressors are hunting, poaching, logging, overgrazing, and mining. In the Carpathians, poaching and air and water pollution are the main issues, along with logging for ski resorts and building of hydroelectric dams.

[37] In corridors, stepping stones are smaller disconnected areas or protected habitat that has been tested to facilitate movement of animals, including insects, birds, and large mammals.
[38] http://www.worldwildlife.org/wildworld/profiles/terrestrial_pa.html

TABLE 4.3 CATEGORIES OF ADAPTATION OPTIONS

Protected areas	• Identify ecosystem, species, and processes particularly sensitive to climate change; • Design areas to protect species, habitat, and ecosystems; • Evaluate and improve management and monitoring capabilities.
Conservation networks	• Create a network of protected areas endowed with buffer zones and connected through corridors that allow species to move along different altitudes and latitudes; • Use stepping stones and landscape management to allow movement through mostly anthropogenic landscapes.
Bioregional approaches	• Create a network of protected areas covering and crossing political boundaries (e.g., the EU Natura 2000 Network) to allow more protection on species movement and preserve functions of large ecosystems.
Participation in management	• Involve local people in the management of protected areas; • Improve locals' livelihoods by decreasing their dependence on natural resources and provide incentives for people to value and sustain ecosystem services.
Monitoring	• Key element of any adaptive management; • For example, GLORIA—Global Observation Research Initiative in Alpine environments. This is a long-term observation network to detect effects of climate change.
Supporting policies	• Develop policies and plans for specific geographical areas, sectors, and agencies, including legal provision and economic instruments.
Minimize non-climate change related stresses	• This is a landscape-level prescription, and applies also to protected areas. Minimize pollution, control exotic species, and minimize pressures from land-use changes, development, and tourism.

As a priority, conservation networks (ideally collaborations of governments, NGOs, and technical experts) must be recognized by neighboring countries to eliminate political obstacles. For example, the Altai-Sayan mountain environments are shared by Russia, Mongolia, and Kazakhstan; the Carpathians span across Romania, Ukraine, Slovakia, Czech Republic, and Poland. Finally, because poverty is endemic in these areas, conservation goals are unlikely to be achieved unless local livelihoods are improved and dependence on unsustainable exploitation of natural resources is reduced.

Given the scale of projected climatic impacts over the **Arctic**, the only adaptation strategy is to enhance natural autonomous adaptation capacity. This requires tackling current stressors, particularly pollution. The city of Norilsk is one of the major sources of sulfur in the world because of its nickel smelters plants. Sulfur dioxide has already destroyed a vast part of the forests in the Taimyr and central Siberian tundra—one of the WWF priority areas (National Geographic 2001). The Lena river delta, one of WWF's freshwater priority areas, is partially protected, but the delta is threatened by mining activities, forestry, and agriculture development (WWF 2008). This is critical as permafrost melting, in combination with sea level rise, is projected to increase coastal erosion. The developed areas around the Lena wetlands represent a barrier to species migration, and they may also cause a coastal squeeze, impeding the retreat of wetlands in the face of sea level rise.

TABLE 4.4 BIOMES, AREAS OF HIGH CONSERVATION INTEREST, AND ADAPTATION MEASURES

Biome	Global 200 Priority Areas and CI Hotspots in ECA	Anticipatory planned measures to promote autonomous adaptation
Alpine/montane ecosystems (Temperate coniferous forests; montane grasslands and shrublands)	• Carpathian montane forests (22) • Altai-Sayan montane coniferous forests (21,25) § • Altai-Sayan alpine meadows and tundra (55,59) § • Khangai Mountains alpine meadow (56) • Tien Shan montane conifer forests (26) † • Ural montane forests and tundra (35)	• Minimize all non climate-related threats (habitat destruction/fragmentation, pollution etc.) • Promote the establishment of protected areas and protected networks • Promote the participation of local people in conservation by improving their livelihoods • Monitor and actively control the introduction and spread of exotic species
Temperate broadleaf, mixed or coniferous forests	• Caucasus Anatolian Hyrcanian temperate forests (3,6,10,24) ∫ . • Ussuri broadleaf and mixed forests (16) [Russian Far East broadleaf and mixed forests priority area]	• Control current threats, particularly degradation, fragmentation, and exotic species • Modify protected areas to take CC-induced shifts into consideration, and to increase connectivity
Boreal forests/taiga	• East Siberian taiga (27) [Central and Eastern Siberian taiga priority area] • Kamchatka taiga (28,29)	• Change management of forests to larger biogeographic scales, including an increased control over buffer zones • Make sure all habitat types are represented in the protected areas and protect mature and old growth stands
Mediterranean forests, woodlands, and shrub	• East Adriatic coast, Greece, Turkey and East Mediterranean-south Anatolian coasts (74–79) ¶	
Temperate grasslands and steppe	• Sayan intermontane steppe (49) § • Alai-Western Tien Shan steppe (37) † • Gissaro-Alai open woodlands (43) † • Tien Shan foothill arid steppe (52) † • Daurian forest steppe (40)	• Monitor and control the spread of exotic species through roads • Regulate the unsustainable grazing (e.g., in the Daurian steppe) • Promote connectivity to prevent fragmentation during migration processes
Arctic ecosystems (including tundra)	• Kamchatcka mountain and forest tundra (65) • Chukchi peninsula tundra (64) • Kola peninsula tundra (66) [Fenno Scandia alpine tundra and taiga] • Northeast Siberian coastal tundra (67) [Taimyr and Russian coastal tundra]	• Habitat protection • Reduction of non-climatic stresses (pollution, overharvesting) • Monitoring and regulation of tourism • Monitoring and control of invasive species • Implementation of the WWF "Conservation First" principle
Freshwater areas	• Volga River Delta • Danube River Delta • Lena River Delta • Balkan rivers and streams • Russian Far East rivers and wetlands • Lake Baikal	• Protect a variety of potential habitats, including thermal refugia • Protect water flow and hydrological characteristics • Protect habitat connectivity between rivers, lakes, and wetlands • Control spread of exotic species

* Name of the priority areas is supplemented with numbers identifying the relative ecoregion in map 4.4. § Part of the Altai-Sayan priority area. ¶ Part of the Mediterranean basin hotspot. † Part of the Middle Asian montane woodlands and steppe priority area (also a hotspot). ∫ Also a Conservation International (CI) Hotspot.