9. Soil degradation

In many areas of Europe, soil is being irreversibly lost and degraded as a result of increasing and often conflicting demands from nearly all economic sectors. Pressures result from the concentration of population and activities in localised areas, economic activities and changes in climate and land use. Cultivation systems are among the most important influences on the quality of soils in agricultural areas. Consumer behaviour and the industrial sector are contributing to the increase in the number of potential sources of contamination such as municipal waste disposal, energy production and transport, mainly in urban areas. Tourism is a further cause of soil degradation especially along the coasts of the Mediterranean. Many of the problems stem from past activities and poor management practices in eastern Europe, Caucasus and Central Asia.

The combined action of these activities affects quality and limits many soil functions including the capacity to remove contaminants from the environment by filtration and adsorption. This capacity and the resilience of soil mean that damage is not perceived until it is far advanced. This partly explains the low priority given to soil protection in Europe until recently. Moreover, since soil is a limited and non-renewable resource, when it is damaged, unlike air and water, it is not easily recoverable.

Major problems in Europe are irreversible losses due to soil sealing and erosion, continuing contamination from local and diffuse sources, acidification, salinisation and compaction.

The geographical distribution of soil degradation depends on several factors. Soil problems are influenced by the diversity, distribution and specific vulnerability of soils across Europe. They also depend on geology, topography and climate and on the distribution of driving forces. Better integration of soil protection into sectoral policies and better harmonisation of information across Europe are needed to move to more sustainable use of soil resources and promotion of sustainable models of its use.

9.1. Introduction

Soil has many ecological and socio-economic functions including the capacity to remove contaminants from the environment by filtration and adsorption. This capacity and soil resilience mean that damage to soil is often not perceived until it is far advanced. Following the precautionary principle and taking account of the slow rate of soil formation, soil can be considered as a limited and non-renewable resource on a 50–100 year timescale.

The quality of Europe's soils is a result of natural factors, such as climate, the material out of which the soil was formed, vegetation, biota and topography, and human activities. As a consequence, there is a wide diversity of soil types, and soil degradation differs markedly across Europe.

9.1.1. Policy challenges

In many areas of Europe, soil is being degraded as a result of pressures coming from nearly all economic sectors. Among the most important influences on the quality of soil are the cultivation systems used in agriculture. Loss of organic matter, soil biodiversity and consequently soil fertility are often driven by unsustainable practices such as deep ploughing on fragile soils and cultivation of erosion-facilitating crops such as maize, and the continuous use of heavy machinery destroys soil structure through compaction (German Advisory Council on Global Change, 1994; EEA, 1999). In addition, overgrazing and the intensification of agriculture, some of which is linked in the European Union (EU) to the implementation of the common agricultural policy, may accelerate loss of soil through erosion.

In addition to agriculture, consumer behaviour is contributing to increases of sources of soil pollution: municipal waste, energy consumption, transport and emissions of exhaust gases (EEA, 2002a). The major impact of these is a reduction in soil buffering capacity, that is the capacity of soil to adsorb contaminants. The extent of this reduction is difficult to measure although there are signs that such capacity is near to exhaustion in many areas in Europe.

Many of these degradation processes have a direct impact on the global carbon cycle, particularly through the decrease in soil organic matter and the release of carbon dioxide to the atmosphere.

Soil erosion affects large areas of Europe — about 17 % of the total land area in Europe is affected to some degree, with around 27 million ha in the EU (Oldeman *et al*., 1991). Climatic conditions make the Mediterranean region one of the areas most severely affected. Changes in land use, such as abandonment of marginal land with very low vegetation cover and increases in the frequency and extension of forest fires, have had a strong impact on soil resources since historical times. In the most extreme cases, soil erosion, coupled with other forms of land degradation, has led to desertification in some areas of the Mediterranean and eastern Europe (see Box 9.1). Soil erosion is also an increasing concern in northern Europe, although to a lesser degree (EEA-UNEP, 2000; EEA, 2002a, b).

Despite the fact that a wide range of activities use and contribute to the depletion of soil resources, soil protection has not generally been the subject of specific policy objectives and targets, unlike water and air. Soil protection has rather been addressed indirectly through measures aimed at the protection of air and water or developed within sectoral policies. An important recent advance has been the inclusion of plans for a thematic strategy on soil protection in the sixth environment action programme (6EAP) in 2001 and the adoption of a Commission communication on soil protection, endorsed

Box 9.1. Implementation of the UN Convention to Combat Desertification

The UN Convention to Combat Desertification (UNCCD) was adopted in 1994 and came into force in 1997. Its provisions include a reporting obligation and the preparation of national, subregional or regional action programmes for its implementation. As of December 2002, 185 countries worldwide had ratified the convention.

The European Community and all but four countries in the area covered by this report have ratified the convention, although not all signatory Parties are affected by desertification. The area comprises three regional annexes of the convention: Asia (Annex II), northern Mediterranean (Annex IV) and central and eastern Europe (Annex V). Since its entry into force there has been some progress in implementing the convention in these regions, but it is still too early to register substantial progress and improvement in the state of environment.

Northern Mediterranean

In the northern Mediterranean, of ten affected countries, eight report regularly on progress in implementation; six are at different stages of preparing national action programmes and three (Portugal, Italy and Greece) are currently implementing them. Preparation of a subregional action programme is under way and a joint report has been presented. The development of these programmes and cooperation and exchange of information is supported by a number of projects. Interregional cooperation with northern African countries has started.

In general, countries report difficulties in establishing good cooperation and communication among stakeholders, with some exceptions. This could be crucial since desertification is a cross-cutting issue and combating it requires close integration of several policy sectors. Combating desertification often has a low priority so there is some difficulty in mobilising national funds. Even the three adopted national action programmes have no legal frameworks, and no independent budgets are assigned to the implementation of the convention.

Central and eastern Europe

In central and eastern Europe, nine countries have submitted national reports, three have adopted national action programmes (Armenia, the Republic of Moldova and Romania) and three have started preparing them (Bulgaria, Georgia and Hungary).

A common feature of the region is that most countries are only slightly affected by actual desertification, although large-scale land degradation is often reported. Countries use the convention as a tool for framing and fostering activities to combat land degradation.

In general, no specific budgets are allocated to combat desertification and measures are developed within sectoral policies. Limited resources are available at the national level to implement actions, as the countries of the region have economies in transition and most urgent basic needs get higher priority. However, some pilot projects are being implemented and trans-national cooperation is under way.

Caucasus and central Asia

The five Caucasus and central Asian countries have all adopted national action programmes and all report regularly to the convention.

Strategies to combat desertification are integrated within the national strategies for sustainable development. Strong links have been established with strategies to combat poverty and support socio-economic development.

Most of these countries are largely dry land (80 % of Uzbekistan, 90 % of Turkmenistan) and land degradation, drought and desertification occur on a large scale with dramatic effects on livelihood (e.g. the Aral Sea disaster). Combating desertification therefore has a high priority. However, lack of funds hinders the implementation of specific measures. Nevertheless, national institutional infrastructures have been established, monitoring and assessment activities have been set up and a number of pilot projects are being developed. Regional cooperation is well under way through the development of transboundary projects such as those being implemented in the Aral Sea basin and Caspian Sea.

Sources: UNCCD, 2002a; 2002b

by the European Council in 2002. The communication calls for the development of a European soil monitoring system capable of providing reliable, comparable and regular information on soil conditions in Europe (European Commission, 2002). Most international programmes also emphasise the need to improve soil monitoring in Europe (EEA-UNEP, 2000). However, the key to progress towards sustainable use of soil resources remains better integration of soil protection into sectoral, local and regional policies.

9.1.2. A regional overview

The occurrence and distribution of soil problems are influenced by the diversity, distribution and specific vulnerability of soils across Europe, coupled with physical aspects such as geology, relief and climate. A further factor is the distribution of driving forces across the continent (EEA-UNEP, 2000).

Western Europe

Soil contamination remains a problem in western Europe (WE) despite several national and international initiatives that have been set up during the past 10 years to reduce air emissions and control, for example, the application of sewage sludge and the use of landfill for waste disposal. WE is highly urbanised (built-up areas occupy 15 % of its territory) and competition for the limited land available results in the loss or degradation of soil resources and in particular the sealing of the soil surface at unsustainable rates, for example through urban development and the construction of transport infrastructures. Soil erosion greatly affects Mediterranean countries, where in the most extreme cases (arid and sub-humid climate) it leads to desertification. In addition, frequently repeated forest fires contribute to the desertification of marginal lands. Unsustainable irrigation systems contribute significantly to the salinisation and erosion of cultivated lands.

Central and eastern Europe

Soil degradation problems in the central and eastern European (CEE) countries are similar to those in WE, although there is less soil sealing. Most of the problems are inherited from the time of the former USSR, when environmental issues were of minor concern. Erosion is the most widespread form of soil degradation, linked to agricultural mismanagement and deforestation (van Lynden, 2000). Past agricultural policies that focused on increasing productivity led to incorrect use of mineral fertilisers, pesticides and heavy machinery. The combined effects of these resulted in increased rates of soil loss by erosion, pollution of groundwater and reduction of soil fertility. Increased awareness of environmental issues, the obligation to implement EU legislation upon accession and declining economies are reducing the pressures from agriculture (decreases in fertiliser and pesticide consumption).

Soil contamination is, to a great extent, a result of the legacy of inefficient technologies and uncontrolled emissions. Problem areas include some 3 000 former military sites, abandoned industrial facilities and storage sites which may still be releasing pollutants to the environment (DANCEE, 2000). One of the major impacts is groundwater contamination and related health problems. Major concerns are the long time needed to regenerate contaminated soil and the considerable investment required for remedial measures.

Conflicts in the Balkans have had impacts, not only in the countries directly involved, but also in neighbouring areas as a consequence of the migration of refugees and increased demand for basic resources (food and firewood). In Bosnia-Herzegovina it has been estimated that the war damaged soil resources in an area of about 6 000 ha through deforestation, erosion, compaction, waste disposal and damage to industrial facilities (REC, 2001). A specific post-conflict situation in Bosnia-Herzegovina and Kosovo concerns land mines and unexploded ordinances. It is estimated that in Bosnia-Herzegovina there are between 3 and 6 million land mines disseminated in more than 16 000 minefields and that 27 % of the total arable land is mined. Until land mines are cleared, opportunities for reconstruction and agriculture work will be severely limited.

Eastern Europe, the Caucasus and central Asia

Over the past 50 years, the priority given to increasing the productivity of agriculture, combined with climatic factors, has resulted in soil and water pollution from the overuse of pesticides and fertilisers. Large areas have experienced salinisation as a consequence of unsustainable irrigation schemes and cultivation practices (the best-known case is the environmental disaster of the drying-up of the Aral Sea — see Section 9.5., Box 9.2.).

The most extreme forms of degradation have resulted in the desertification of large areas.

In Kazakhstan an estimated 60 % of the territory is at risk of desertification (UNECE, 2000a). The process is accelerated by the large-scale collective farms and the abandonment of marginal land, which cannot naturally recover because of the harsh climate.

During the past decade, the relatively high extent of soil degradation has been increasing in Azerbaijan. In 2000, between 3.7 and 8.6 million hectars of land were degraded through erosion and 30 000 hectars were degraded through soil contamination by a number of substances, including oil products (14 000 ha).

In central Asia, a wide transboundary region — which includes Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan and is characterised by an arid and semi-arid climate — presents acute problems of desertification. For example, in Turkmenistan, livestock breeding is the most profitable and at the same time the least labour-intensive branch of the economy. About 90 % of the territory is covered by a desert landscape and serves as year-round pasture for sheep and camels. As a result, vast areas of pasture are degraded and have low productivity. Out of 39.5 million hectares of pasture, 70 % is degraded, 40 % receives poor water supply and 5 % has been transformed into bare moving sand, according to the report on the implementation of the UN Convention to Combat Desertification (UNCCD) in Turkmenistan (summarised in UNCCD, 2002c).

Heavy-metal contamination is common around major industrial areas (van Lynden, 2000). The problem is especially acute in the mining and metallurgical complexes of Kazhakstan (Rekacewicz *et al.*, 2000) and in the Caspian area, where oil spills are also a major source of contamination (UNDP and GEF, 1998). Existing and planned oil and gas pipelines in the area are leading, or are expected to lead, to pressures on soil and, among other impacts, to the fragmentation of habitats. Contamination with radioactivity is also important as a result of nuclear weapons tests, improper radioactive waste disposal and the Chernobyl accident (UNEP, 1998 — see also Chapter 10).

The recent economic decline has reduced pressures on the soil and resulted in a decrease in fertiliser, pesticide and water consumption, and a general slowing of industrial activity (UNEP, 2002). However, pressures on the soil are increasing at the local level mainly in urban areas and around rural settlements.

9.2. Soil sealing

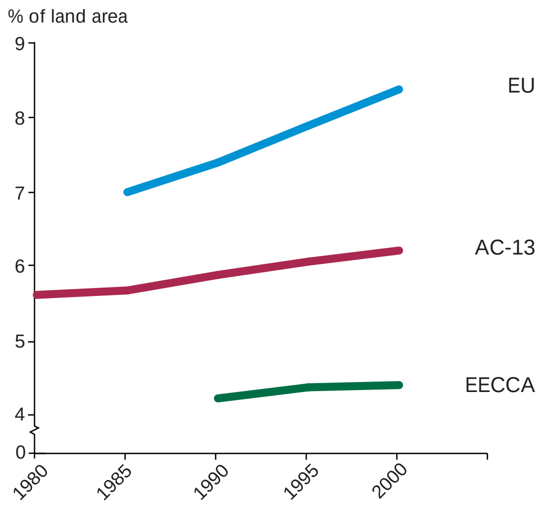
Soil sealing is the covering of the soil surface with an impervious material or the changing of its nature so that the soil becomes impermeable. The greatest impacts are in urban and metropolitan areas where large portions of the land are covered with constructions. The development of transport infrastructures is another important cause. Built-up land is lost to other uses such as agriculture and forestry, and the ecological functions of soil, such as storage of carbon and habitat for unique biota, are limited or impeded. Soil sealing can also result in the fragmentation of habitats and disruption of migration corridors for wildlife species.

Soil sealing can have a major impact on water flows. Runoff water from housing and traffic areas is normally unfiltered and may be contaminated with harmful chemicals. Surface runoff can increase significantly in amount and velocity, causing problems of local flood control. Although floods are natural phenomena, they may be intensified by human alteration, as has been observed in Europe in recent years (PIK, 2000). The increasing demand for land for new residential areas or industrial facilities has resulted in development in areas at high risk of flooding (UNECE, 2000b).

Over the past 20 years, built-up areas have been steadily increasing all over Europe (Figure 9.1). Although geographical coverage is not complete and estimation methods may vary slightly from country to country, socio-economic factors appear to be the main driving forces for this growth. The most dramatic changes have been in WE, where the area of built-up land is increasing more rapidly than the population (EEA, 2002a). This is the result of the steady

Soil sealing continues to increase especially in western Europe where the area of built-up land is increasing more rapidly than the population. This is a result of the steady increase in the number of households and average residential space per capita since 1980.

Figure 9.1. Built-up areas in Europe as percent of total land



Notes: EU: data for Austria, Belgium, Denmark, France, Germany, Luxembourg, Netherlands and Spain. Accession countries: data for Czech Republic, Latvia, Lithuania, Poland, Romania and Slovakia. EECCA: data for Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova, Tajikistan, Ukraine and Uzbekistan.

Sources: For EU and accession countries: Eurostat New Cronos (2001); for EECCA countries: EEA 2002 questionnaire

increase in the number of households and average residential space per capita since 1980, a trend that has accelerated since 1990 (EEA, 2001). At the same time, travelling distances to services increased with travelling mainly by private transport (EEA, 2000). As a consequence, the demand for new buildings and better transport infrastructures continues to rise. In addition, increasing prosperity has led to a higher demand for second homes, inevitably resulting in more soil sealing.

The countries with the highest share of built-up area (between 16 % and 20 % of total land area) are Belgium, Denmark and the Netherlands. In most cases, built-up areas have increased at expense of agricultural land, and to a lesser extent forests (EEA, 1999; 2002a) The effects of these changes can be observed, for example, in Spain, where highly productive agricultural land in the floodplains has been transformed into residential areas, transferring agricultural activities to less productive land. At the same time, intensive cultivation has been introduced to maintain productivity (MMA *et al.*, 2002). In the Mediterranean countries, urbanisation has been growing in the coastal zones of southern France, Italy, southern Spain and the Mediterranean islands, where tourism is the main driving force (EEA-UNEP, 2000; see also Chapter 2.7).

The extent of built-up area in the CEE countries was more or less constant during the late 1970s and the first half of the 1980s. Political and economic changes during the late 1980s resulted in the development of new infrastructures, the migration of rural populations to the cities and the development of new settlements (Baltic Environmental Forum, 2001). Slovakia and the Czech Republic have the highest percentage of built-up area (about 8 % of the total land area). Pressure is also increasing in some coastal zones, for example along the German, Latvian and Russian coasts on the Baltic Sea (Coalition Clean Baltic, 2002).

Soil sealing is still a minor problem in eastern Europe, the Caucasus and central Asia (EECCA) compared to other forms of soil degradation, such as erosion, salinisation and contamination. However, pressure is increasing around industrial and urban settlements and in tourist areas along the coasts of the Black Sea.

In the EU, policy measures explicitly related to land-use issues, such as spatial planning, have generally been the responsibilities of Member States, following the application of the principle of subsidiarity. Although mentioned in the fifth and sixth environment action programmes, spatial planning has only recently been specifically addressed, within the European spatial development perspective (1999) and the forthcoming European urban strategy. Although the communication on soil protection (2002) does not address the issue of spatial planning, it recognises sealing as a threat to soil.

The inclusion of environmental concerns and objectives in spatial planning is now widely recognised as a major tool for reducing the effects of uncontrolled urban expansion. This has led, for example, to the adoption of measures such as the reuse of underdeveloped or derelict urban areas (brownfields) and the adoption of specific targets in some countries (including Denmark, Germany and the United Kingdom) (EEA-UNEP, 2000). In 2003 the Commission will present a communication on 'Planning and environment: the territorial dimension'. This will address the need for rational land-use planning to enable the sustainable management of soil resources, limiting the sealing of greenfields and promoting the reuse of brownfields.

9.3. Soil erosion

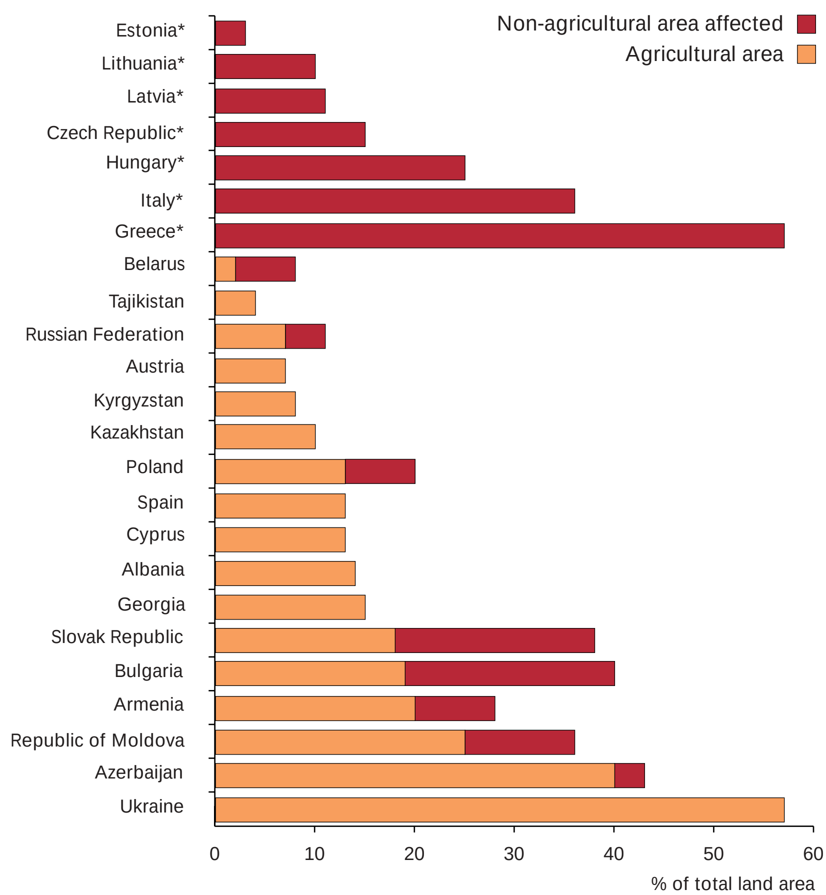
Soil erosion is a natural process linked to other processes such as seashore sedimentation. However, soil erosion has been exacerbated by human activities, leading to one of the major and most widespread forms of land degradation. About 17 % of the total land area in Europe is affected to some degree (Oldeman *et al.*, 1991; EEA, 2002b). Major causes are unsustainable agricultural practices, large-scale farming and overgrazing in WE and CEE, and poor water and irrigation management especially in EECCA (UNECE, 2001). In the Caucasus, the energy crisis and fuel shortages have resulted in an increase in woodcutting to obtain firewood for heating since the late 1980s, which has been one of the main drivers of soil erosion in this area (UNEP, 2002). In the past few years, the increase in frequency and extent of forest fires in the Mediterranean region has also had a significant impact on soil erosion. Tourism and transport may be important driving forces in localised areas (EEA, 2002b).

Soil erosion in Europe is due mainly to water (about 92 % of the total affected area) and less to wind. Wind erosion is localized in some parts of western Europe and CEE (EEA, 2002b). There is an increasing awareness that erosion, which is primarily responsible for the severe degradation occurring in topographically complex landscapes, is caused not only by wind and water but also by tillage, mainly due to the use of heavy powerful tillage machinery.

As the topsoil is eroded and washed away, the fertility and productivity of the remaining soil is reduced. Farmers have to apply more fertilisers to compensate for yield losses. Erosion is most serious in central Europe, the Caucasus and the Mediterranean region, where 50–70 % of agricultural land is at moderate to high risk of erosion (UNECE, 2001). Figure 9.2. and Figure 9.3 illustrate respectively the areas affected and the current rates of erosion in the various countries. The data show that the problem is

> Unsustainable agricultural practices, coupled with adverse natural and other factors, are increasing the loss of soil through erosion, some of which may be irreversible. About 17 % of the total land area in Europe is affected to some degree.

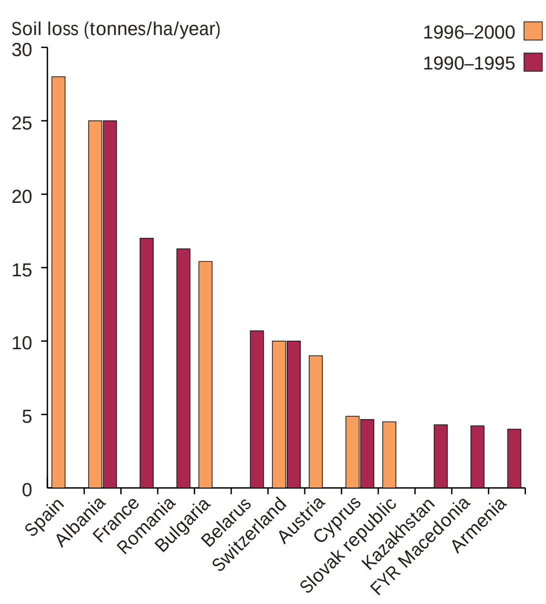
Area affected by erosion — Figure 9.2.



Notes: Asterisks indicate that data for agricultural area are not available. Ukraine: data includes area at risk of erosion. Data refer to 1990–99, except for Austria, Greece, Hungary, Italy, Poland, Slovak Republic and Spain where the data cover 1990–95.

Sources: EU: OECD-Eurostat (1997); eastern Europe: SOVEUR assessment (FAO and ISRIC, 2000) and EEA 2002 questionnaire; EECCA: EEA 2002 questionnaire; Azerbaijan (communication by EEA national contact point). Ukraine: State of the environment report (2002)

Annual soil loss through erosion in agricultural land in selected countries — Figure 9.3.



Source: EU: OECD-Eurostat (1997) and various national sources, EEA; eastern Europe and EECCA: national reports and EEA 2002 questionnaire mainly localised in agricultural areas. Olive plantations and vineyards, when intensively ploughed, are among the crops more susceptible to erosion because a high percentage of the soil surface remains uncovered by vegetation all the year round. Olive groves with minimum or no tillage are very effective agricultural systems in preventing erosion and desertification in the Mediterranean.

Since the rate of soil formation is so slow, any soil loss of more than 1 tonne/ha/year can be considered as irreversible within a time span of 50–100 years (EEA, 1999). Current rates of erosion in the Mediterranean countries, if confirmed, would mean that irreversible processes of soil degradation (and desertification in the most extreme cases) are already occurring in that region. In some areas, the situation is so extreme that there is no more soil left to erode.

Soil erosion has a major economic impact. Yearly economic losses in agricultural areas in Europe are estimated at around EUR 53/ha, while the costs of off-site effects on the surrounding civil public infrastructures, such as destruction of roads and siltation of dams, reach EUR 32/ha (García-Torres *et al.*, 2001). In Armenia, for example, the costs of the damage from soil erosion in the past 20 years amounted to 7.5 % of national gross agricultural product (UNECE, 2000c).

The effects of soil erosion are expected to get worse, since climate change is expected to influence the characteristics of rainfall in ways which might increase soil erosion in central Europe (Sauerborn *et al.*, 1999).

Policies to combat soil erosion comprise a wide range of actions: adoption of sustainable farming practices (including minimum tillage systems, contouring, terracing or strip cultivation); land planning to determine the most suitable crops for each area; ending set-aside of arable land; reclamation of highly degraded lands or areas affected by desertification; reforestation of watersheds; and incentives to promote more sustainable activities.

The common agricultural policy has undergone a substantial reform since 1992 and the adoption of Agenda 2000 in 1999. There has been a gradual elimination of many subsidies and a reinforcement of incentives to promote environmentally sensitive agriculture (see Chapter 2.4.). Soil protection measures have been reinforced and expanded to encourage organic farming, the maintenance of terraces, safer pesticide use, the use of certified composts and afforestation, among others. However, farmers' participation in agri-environment schemes is still very low in areas of high erosion risk. Implementation of agri-environment measures can have positive effects in the enlarged EU, but considerable effort is required to support the widespread adoption of these instruments in the accession countries.

9.4. Soil contamination

Soil contamination from diffuse and localised sources can result in the damage of several soil functions and the contamination of surface water and groundwater.

9.4.1. Diffuse sources

The main diffuse sources of soil contamination are atmospheric deposition of acidifying and eutrophying compounds or potentially harmful chemicals, deposition of contaminants from flowing water or eroded soil itself, and the direct application of substances such as pesticides, sewage sludge, fertilisers and manure which may contain heavy metals. The soil functions most affected by contamination are its buffering, filtering and transforming capacities. Currently, the most important soil contamination problems from diffuse sources are acidification, contamination by heavy metals and the effects of a surplus of nutrients.

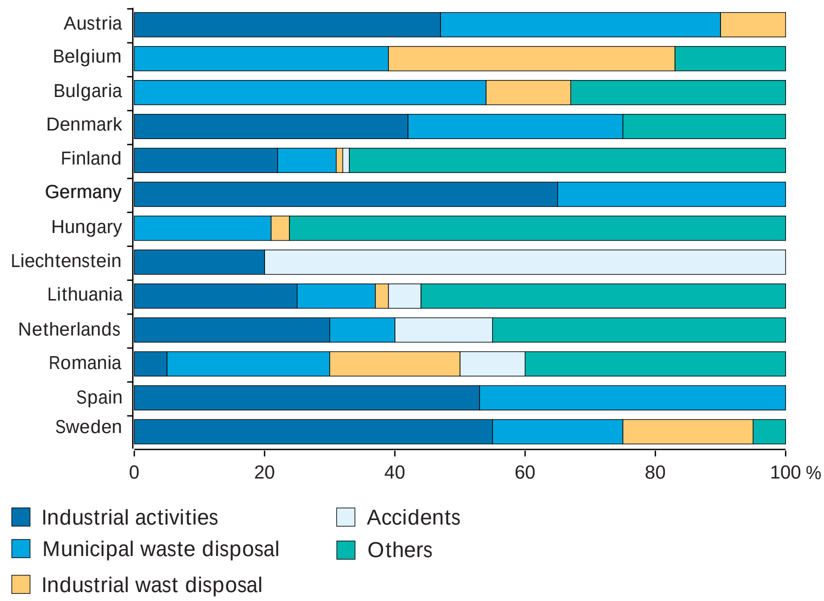
Acidification is the most widespread type of soil contamination in WE and CEE, where vast areas have been affected, especially in Poland (10 million ha including natural acidification) and Ukraine (about 11 million ha of agricultural land). High content of heavy metals in soils is reported in Ukraine at the local level (about 5 million ha, mostly in human settlements and around the industrial factories) and in Lithuania (nearly 3 million ha) (van Lynden, 2000). However, the relatively high heavy metal concentrations in Lithuania can be partly explained by high natural background levels. Contamination by pesticides is common in Ukraine (more than 5 million ha) and Romania (more than 4 million ha), where the estimated degree of contamination is light to moderate (van Lynden, 2000). The Chernobyl accident (1986) is still a major cause of contamination by radionuclides in Ukraine and some areas of the Russian

Federation. Nuclear tests performed in the past, uranium mining and processing, and the manufacture of nuclear fuel affected some areas in EECCA. Radioactive waste from uranium plants, mainly from former Soviet nuclear test sites, is still stored without protection in Kyrgyzstan and Kazakhstan (UNECE, 1999; 2000d; 2000c).

9.4.2. Localised sources

Soil contamination from localised sources is often related to industrial plants no longer in operation, past industrial accidents and improper municipal and industrial waste disposals. In addition, at industrial plants still operating, soil contamination often has its origin in the past, and current activities still have significant impacts (EEA-UNEP, 2000). Effects of industrial activity (either historical or currently in operation) that pose a risk to soils and groundwater, and the spectrum of the various polluting activities, vary between countries. These variations may result in different classification systems and in incomplete information being available in some countries (Figure 9.4).

Percentage contribution to soil contamination from localised sources Figure 9.4.



Notes: Belgium: data refer to Flanders. Germany: industrial activities also includes accidents and other, and municipal waste disposal also includes industrial waste disposal. Germany and Sweden: the percentage share refers to the total number of identified, suspected sites; data refer exclusively to abandoned sites (not in operation). Bulgaria: others include storage of pesticides, contaminated soils by mining and industry activities. Liechtenstein: minor accidents are not included. Denmark and Spain: municipal waste includes industrial waste.

Source: EEA

Sites contaminated in these ways can pose serious threats to health and to the local environment as a result of releases of harmful substances to groundwater or surface waters, uptake by plants and direct contact by people, and following explosion of landfill gases.

The largest and probably most heavily affected areas are concentrated around the most industrialised regions in northwest Europe, from Nord-Pas de Calais in France to the Rhein-Ruhr region in Germany, across Belgium and the Netherlands and the south of the United Kingdom (EEA-UNEP, 2000). Other areas where the probability of occurrence of local soil contamination is high include the Saar region in Germany, the Po area in northern Italy, and the so-called Black Triangle region located at the corner of Poland, the Czech Republic and the Slovak Republic. However, contaminated areas exist around most major cities and there are some individual contaminated sites in sparsely populated areas (EEA-UNEP, 2000).

A wide range of potentially harmful elements and chemical compounds is used in industry. Handling losses, defects, industrial accidents and leaching of hazardous substances at waste disposal sites can cause soil and groundwater contamination. Major pollutants include organic contaminants such as chlorinated hydrocarbons, mineral oil and heavy metals. In some parts of Europe, soil is contaminated by artificial radionuclides.

In the mining industry, which is a major driver of soil degradation in CEE countries, the risk of contamination is associated with sulphur and heavy metal-bearing tailings stored on mining sites, and the use of certain chemical reagents such as cyanide in the refining process. Acid mine drainage is a common long-term problem, as for example in the case of the serious incident at the Aznalcollar mine in Spain in 1998. The disaster affected a watercourse nearby for 63 km downstream and the adjacent land (Sol *et al.*, 1999). Another recent accident was the cyanide spill in Romania from the

Soil contamination from local sources, mainly waste disposal from municipal and industrial sources and industrial activities, is widespread in western Europe as well as in central and eastern Europe, the Caucasus and central Asia.

Aurul tailings re-treatment plant at Baia Mare in 2000. This disaster affected plankton and fish in the upper reaches of the Tisza River in Romania and Hungary. The spill occurred in an area already contaminated by heavy metals from a long history of mining and metal processing. Upstream locations unaffected by this particular spill also contained high levels of some heavy metals. The accident occurred in a region with a number of poorly maintained and operated plants and flotation ponds containing cyanide and/or heavy metals, many of which are leaking continuously (European Commission, 2000a).

Waste landfilling is another important potentially contaminating activity. On average, 57 % of municipal waste generated in the EU is landfilled, 84 % in CEE (see Chapter 7). Leachate from waste landfills can enter soil, groundwater and surface water. Particular concerns are related to landfills that operate or have operated in the past and that do not comply with the minimum requirements set by the landfill directive (Directive 1999/31/EC) (European Commission, 1999).

Contaminated land in CEE is the result of former military sites as well as industrial activities and waste management. Inefficient technologies and production systems, in terms of raw material and energy consumption as well as waste production, were common in the past. Heavily contaminated sites covering several thousand square metres (e.g. in traditional large-scale industrial areas) may still represent a considerable risk to human health and the environment. However, the extent of the contribution of the military sector to soil contamination is not known, as data on contamination of military sites are not usually publicly available.

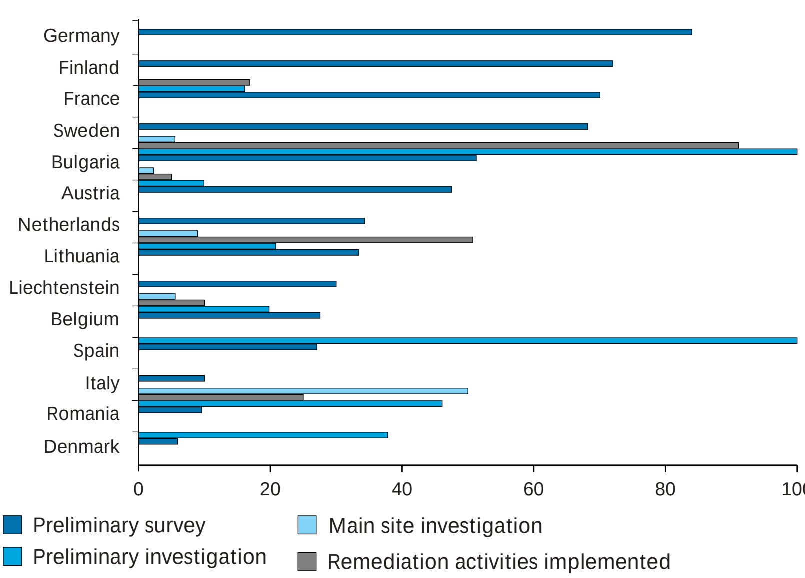
New legislative and regulatory frameworks at the national and EU level (landfill directive, integrated pollution and prevention control directive, water framework directive, environmental liability directive) are based on the precautionary principle. Their application should result in fewer inputs of contaminants, as a result of fewer handling losses and accidents at industrial sites, and in better control of soil contamination (EEA, 2001). Nevertheless, much effort is still needed to characterise and remediate old contaminated sites.

The management of contaminated sites is designed to remediate any adverse effects where impairment of the environment has been proved and to minimise potential threats. The whole process is carried out in several steps. Preliminary surveys provide a list of potentially contaminated sites and verify, or not, the existence of contamination and potential harmful effects to human health or the environment. The main site investigation focuses on the determination of the extent of the contamination. One of the next phases is the remediation plan, which includes a specific remediation investigation and measures to reduce adverse effects on human health or the environment. Targets for remediation and/or safety measures can vary according to the proposed land use. The management scheme must take into account the risk of secondary contamination due to further retention of contaminants by the soil.

Figure 9.5 summarises progress in the management of contaminated sites in 14 European countries. Preliminary surveys are far advanced in most of the surveyed countries. Further stages are proceeding slowly. However, data availability and data access have improved compared to earlier assessments.

In general, all countries apply the 'polluter pays' principle, to differing extents. However, a considerable share of total remediation costs has been provided from

Figure 9.5. Progress in the management of contaminated sites

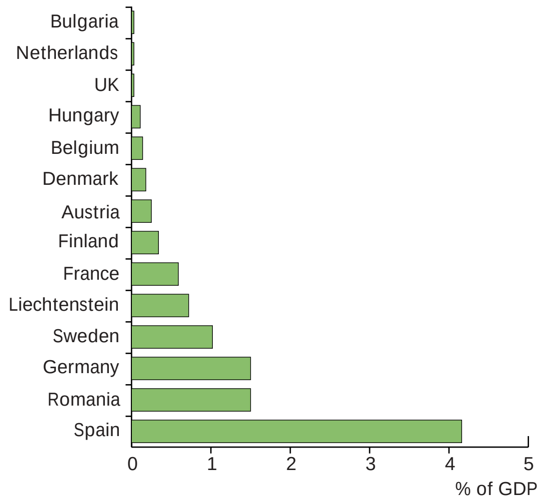


Notes: France: mean value of estimated total number of sites according to preliminary survey; Romania: minimum value of estimated total number of sites according to preliminary survey. Spain: methods to estimate the total number have been revised therefore data are under consideration. All: information on completed remediation has not been included; missing information in the graph indicates that no data have been reported for the particular country.

Sources: EEA, 1999; 2001

Expenditure on contaminated sites remediation in selected countries in 1999 as percentage of GDP

Figure 9.6.



Notes: Belgium: data on remediation expenditures refer to Flanders; data on GDP refer to Belgium. France: data from 2001. Germany: projection from estimates of expenditures from some of the Länder.

Sources: For EU countries and Liechtenstein, data request EEA (2002); for accession countries: data request new EEA member countries (2002); World Bank, 2001

The first step in the management of contaminated sites (preliminary survey/investigation) is well advanced in most of the surveyed countries, but subsequent phases are progressing slowly.

public money. Many countries have developed special funding tools for the clean-up of contaminated sites. For example, in some countries there are voluntary agreements with the petrochemical and oil industries to fund the remediation of abandoned petrol stations, financed by a fee included in the petrol price. Estimates of public expenditure are available from many countries, but information on private expenditure is scarce and depends on approximate estimates.

Annual remediation expenditure varies from EUR 35 to less than EUR 2 per capita in the reporting countries. The average cost for the countries surveyed was less than 1 % of GDP (Figure 9.6).

In the EU, implementation of new regulations that reflect the precautionary principle should help to avoid local soil contamination in the future. In the EU countries where data are available, expenditures on clean-up have remained constant over recent years (1997–2000). In future, expenditure will probably remain at a constant rate, except in countries that have only recently begun to address the problem, where an increase is expected. Many accession countries have started investigations, and the setting up of specific funding tools and cooperation with the EU are increasing.

Although the 'polluter pays' principle is generally applied, a huge sum of public money has to be provided to fund necessary remediation activities, which is a common factor across Europe. Even though a considerable amount of money has already been spent on remediation activities, the share of the total estimated remediation costs is relatively low (up to 8 %).

In CEE, most countries (e.g. Bulgaria) still do not have strategies and national policies for the management of contaminated sites or specific legislation regulating investigation and clean-up of contaminated land; others (e.g. Poland) have only recently introduced new laws on environmental protection. However, requirements for soil protection are generally included in several legislative acts (e.g. environment protection legislation and water, waste and mining legislation).

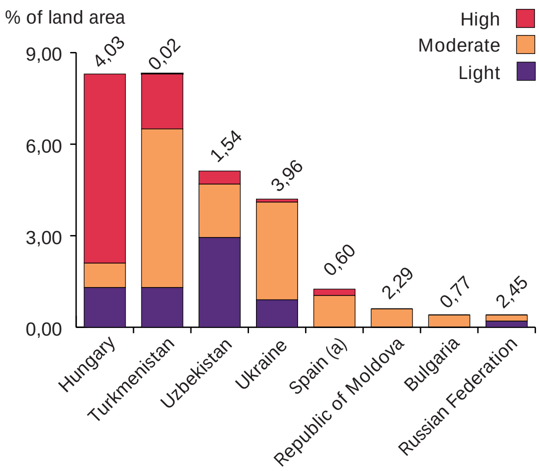
9.5. Salinisation

Salinisation, the accumulation of salts on or near the surface of the soil, results in completely unproductive soils, which are currently found mainly in the Mediterranean region, eastern CEE and EECCA. It is caused by improper irrigation methods and evaporation of saline groundwater, groundwater extraction and industrial activities (European Commission, 2000b).

Irrigated soils, particularly in arid regions, are affected to larger or lesser extent (Figure 9.7). For example, about half the irrigated land in Uzbekistan (State Committee of the Republic of Uzbekistan, 2000) and some 16 million ha (25 % of total irrigated cropland) in the Mediterranean countries (FAO, 1996) are affected.

Salinisation has major impacts on the economy. It has been estimated that in the central Asian republics, salinisation reduced cotton yields from 280 to 230 tonnes/km^2 between the late 1970s and the late 1980s, despite an increased use of fertilisers (Gardner, 1997). Salinisation may also have important off-site effects because salt that has moved to the upper layer of the soil can be carried by the wind to other areas.

Figure 9.7. **Area of land affected by salinisation in selected countries**



Notes: Light: some signs of degradation are present, but the process is still at an initial phase. Moderate: salinisation is apparent, but control and full remediation to its current function is still possible with considerable efforts. High: evident signs of degradation — changes in soil qualities are significant and very difficult, if not impossible, to restore within reasonable limits. Spain: area with light salinisation not available. Figures at the top of the graph bars refer to the total area of land affected by salinisation in million ha.

Sources: For Hungary, Ukraine, Estonia, the Republic of Moldova, Bulgaria, the Russian Federation and Slovakia: FAO and ISRIC, 2000; for Turkmenistan, Uzbekistan and Ukraine: state of environment reports; for Spain: 2000 plan to combat desertification.

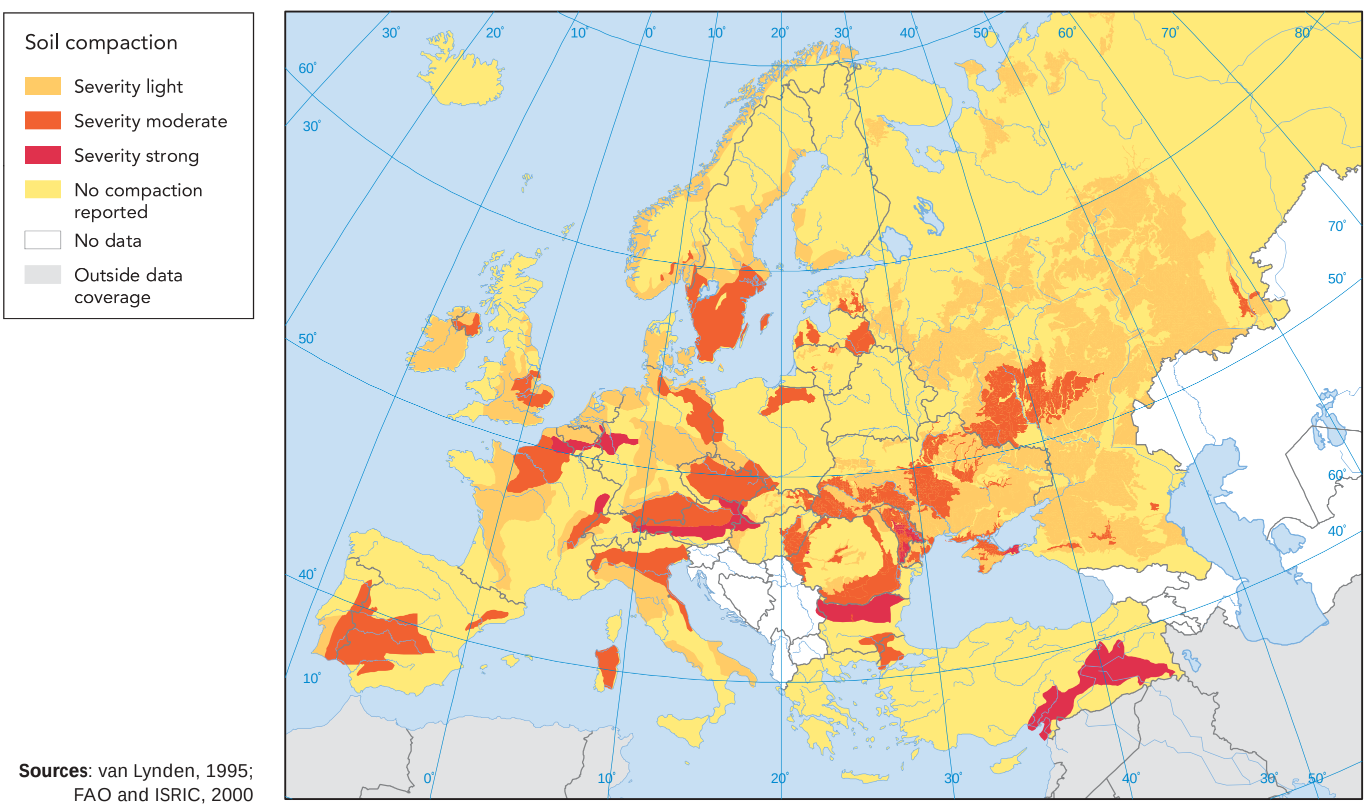
Moderate to high salinisation is affecting agricultural soils in the Mediterranean region and in eastern Europe, the Caucasus and central Asia mainly as a result of inappropriate irrigation systems. For example, salinisation affects 16 million ha or 25 % of irrigated cropland in the Mediterranean.

Salinisation has a major impact on soil quality and, above certain thresholds, restoration is very expensive if not impossible. Most remediation projects focus on improving soil condition and recovering the land for crop production by improving irrigation systems and the efficiency of water use, and by maintaining drainage systems. However, most of the severely affected areas are abandoned without any attempt at rehabilitation; for example, this applies to about 300 000 ha of affected soil in the Russian Federation (Stolbovoi and Fischer, 1997). Privatisation in EECCA and the lack of economic resources of private owners are making the implementation of improvements to irrigation systems and the maintenance of drainage systems difficult. Where drainage is too expensive, planting salt-resistant plants has helped to stabilise the soil and reduce erosion (Mainguet and Létolle, 2000). In most countries, rehabilitation projects are linked directly to programmes to combat desertification.

9.6. Soil compaction

Soil compaction is potentially a major threat to agricultural productivity (EEA, 1995a; Nolte and Fausey, 2000). The repetitive and

Map 9.1. **Degree and extent of soil compaction in Europe**



Sources: van Lynden, 1995; FAO and ISRIC, 2000

Box 9.2. Aral Sea: follow-up problems

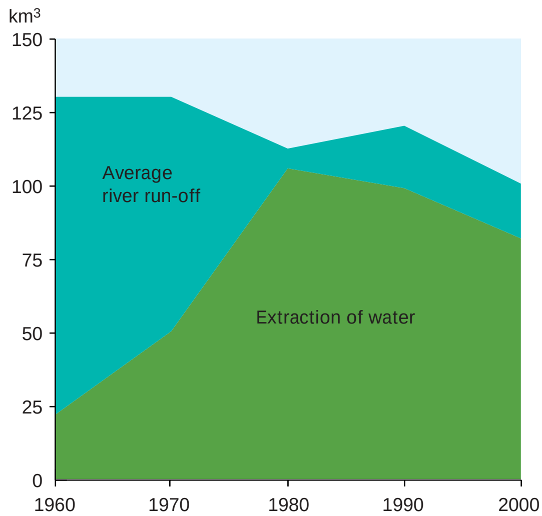
In the 1960s, central Asia became the major producer of raw cotton in the former USSR. Cotton crops require extensive irrigation and the Aral Sea and its tributaries seemed a limitless source of water at the time. The local population grew from 14 million to about 27 million and the extent of irrigated land from about 4.5 million to almost 7 million ha between 1960 and 1980. The demand for water almost doubled (Figure 9.8) with more than 90 % of the water withdrawal used for agriculture. The water balance in the basin collapsed and, by the mid-1960s, the Aral sea level began to drop, reaching a critical point in 1980 (mean level decreased by 90 cm a year) (Islamov, 1999). By that time, the excessive use of agrochemicals together with industrial and municipal sources of pollution had already seriously degraded the quality of the water. As the sea shrank, enormous quantities of salts accumulated on its bed, leaving nothing more than a salty desert.

Figure 9.9 shows the increase of this new salty desert to its maximum by the mid-1970s. Because of the concentration of toxic salts in the upper soil layer, lack of nutrients and shortage of fresh water, the resulting desert land has been proving extremely resistant to natural and artificial revegetation (Micklin, 1988). However, the most serious problem is the blowing of salt and dust from the dried seabed, the impact of which will last for decades. The area affected by the spread of salt and dust is increasing every year. The disaster has also affected the deltaic ecosystems and biological productivity, in particular fisheries, the basic economy of surrounding communities. Moreover, the population faces appalling health problems. A negative effect on climate has also been observed, which has reduced the crops significantly (Hiltunen, 1998).

In the catchments of the Aral Sea, mismanagement of irrigation and drainage infrastructures have resulted in increased river water salinity, soil salinisation and water-logging. In addition, catchment areas have lost about half of their forest cover and soil erosion has intensified. As well as creating considerable environmental problems in the upper watersheds, all these factors have a negative impact on downstream areas.

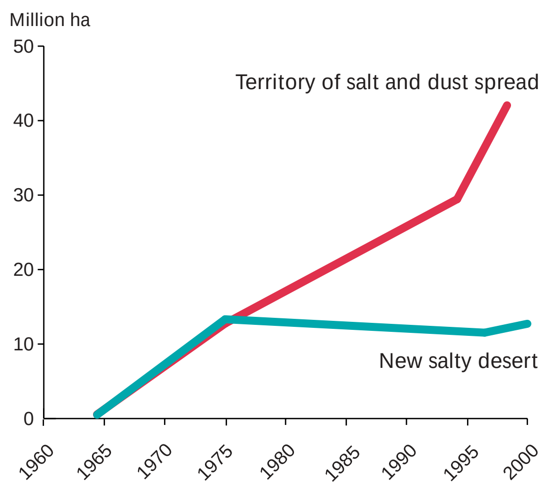
In the past decade, the countries affected have taken various initiatives to tackle the problem, with the support of international institutions. The Aral Sea Basin Programme was launched in 1994 with the main objectives of rehabilitating the degraded area around the sea, improving management of land and water resources in the basin, and building the capacity of institutions at all levels in order to plan and implement the programme. The programme had to confront many problems, especially limited economic resources in relation to the scale of the disaster. Demand for water has levelled off to some extent, but the cultivation of many crops remains inefficient because insolvency of the water users has precluded the use of advanced irrigation techniques. As a result the water balance remains very precarious. Some pilot projects are focusing on integrated management of the land to prevent erosion and rehabilitate the most degraded areas (Aslov, 2000). However, these projects are still at a preliminary stage and extensive action is needed to avoid irreversible losses (Dukhovny and Sokolov, 2000).

Water balance in the Aral Sea basin Figure 9.8.



Source: IFAS and UNEP/GRID-Arendal, 2000

Trends in wind erosion and salt deposition Figure 9.9.



Note: 'New salty desert' refers to the territory that appeared as a result of the sea drying out.

Source: IFAS

cumulative effect of heavy machinery on the same piece of agricultural land causes soil compaction — soil particles are pressed together and the pore spaces between them reduced. Soil compaction slows infiltration and increases the volume of surface runoff, thus accelerating water erosion and the loss of topsoil and nutrients. Compaction also changes the quantity and quality of biochemical and microbiological activity in the soil.

While compaction of topsoil can easily be countered by reworking the soil and can eventually be reversed if the biological processes in the soil remain undisturbed, deep compaction of subsoil is persistent and cannot easily be reversed (EEA, 1995b).

Deep soils with less than 25 % clay content are the most sensitive to subsoil compaction (Hébert, 2002). Sensitive soils are common in Belgium, northwest France, Germany, the Netherlands, Poland and the Russian Federation (EEA, 1995b). Soil compaction is the main form of soil degradation in CEE, where it has affected over 62 million ha or 11 % of the total land area in the surveyed countries (see Map 9.1). Particularly during the time of the former USSR, heavy machinery was used on soils sensitive to compaction. The degree of compaction is mostly light to moderate, but negative impacts on agricultural productivity have nevertheless been reported in more than half of all areas affected (van Lynden, 2000).

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