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**Working Paper**

## Agriculturally induced environmental problems in Russia

Discussion Paper, No. 17

**Provided in Cooperation with:**

Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Halle (Saale)

*Suggested Citation:* Shvytov, Igor (1998) : Agriculturally induced environmental problems in Russia, Discussion Paper, No. 17, Institute of Agricultural Development in Central and Eastern Europe (IAMO), Halle (Saale), <https://nbn-resolving.de/urn:nbn:de:gbv:3:2-22823>

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## **DISCUSSION PAPER**

### **Institute of Agricultural Development in Central and Eastern Europe**

#### **AGRICULTURALLY INDUCED ENVIRONMENTAL PROBLEMS IN RUSSIA**

**IGOR SHVYTOV**

**DISCUSSION PAPER NO. 17  
1998**



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### **ABSTRACT**

This paper is concerned with environmental impacts in Russia, focusing in particular on agriculturally induced environmental impacts.

First it discusses the current environmental situation in Russia. The paper provides an overview of Russia, including a description of its geographical and bioclimatic resources. The environmental pressures induced by human activity have been covered in more detail.

The current situation regarding atmospheric emissions and waste water discharges are also considered in this paper.

The environmental impacts of agriculture are stressed, with a focus on land degradation and especially soil erosion. A discussion of some policy suggestions to avoid environmental problems concludes the paper.

### **ZUSAMMENFASSUNG**

Das vorliegende Diskussionspapier befaßt sich mit Umwelteinwirkungen in Rußland, insbesondere mit solchen, die von der Landwirtschaft ausgehen.

Zuerst wird der gegenwärtige Zustand der Umwelt in Rußland beschrieben. Das Diskussionspapier gibt einen knappen Überblick über Rußland, einschließlich einer Beschreibung seiner geographischen und bioklimatischen Ressourcen. Die durch menschliche Aktivitäten verursachten Umwelteinwirkungen werden detaillierter behandelt. Berücksichtigt werden dabei auch die atmosphärischen Emissionen und die Abwasserbeseitigung.

Die Untersuchung der Umwelteinwirkungen der Landwirtschaft konzentriert sich auf die Bodendegradation und vor allem auf Erosionsprobleme. Abschließend werden Politikmaßnahmen zur Vermeidung von Umweltproblemen diskutiert.

### **РЕЗЮМЕ**

Данная работа рассматривает и анализирует негативные воздействия на окружающую среду России с особым вниманием к тем из них, которые непосредственно связаны с сельским хозяйством. В первой части работы обсуждается текущая ситуация с окружающей средой в России. Дано краткое, схематическое описание географических и биоклиматических ресурсов России. Особое внимание в работе уделено процессам деградации окружающей среды, в связи с антропогенными воздействиями. Рассмотрена текущая ситуация с загрязнением воздушного бассейна и водных ресурсов. Особый акцент в работе сделан на анализе процессов деградации земельных ресурсов вообще и почвенной эрозии, в частности. В заключительной части работы обсуждаются подходы к разработке рекомендаций по политике решений, направленных на решение проблем окружающей среды.



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### LIST OF ABBREVIATIONS

μg	0.001 mg
BOD <sub>5</sub>	Biological oxygen demand (within 5 days)
NPK	Sum of nitrogen, phosphorus and potassium
NO <sub>2</sub>	Nitrogen oxides
SO <sub>2</sub>	Sulphur dioxide
USLE	Universal Soil Loss Equation





## 1 INTRODUCTION

This paper explores the agriculturally induced environmental problems of Russia, and thus an unusual subject that for a long time was (and in many respects still is) virtually unknown, not only to foreigners but also to the people of Russia. The Russian environment is changing under the influence of human activity and natural processes. There have been many unwanted side-effects related to the state of the air, the water and the soil; some of these were predictable, others came as a surprise. But not only Russia has been affected. For our planet, human-induced consumption and transformation of net primary productivity is estimated to be about 40 % of that carried out by the Earth's terrestrial ecosystems (VITOUSEK et al. 1986). According to a recent study by the UNEP (United Nations Environment Programme), the extent of degradation of cultivated soil has reached 1,964 m hectares in the last years, due to overgrazing, overexploitation and improper agricultural and industrial practices. In addition, since the eighteenth century, our planet has lost 600 m hectares of forests. Today, humanity is seen as the main force influencing ecosystems. The world economy is dependent on the natural environment, which, on the one hand, is a source of energy and materials, and on the other hand a sink for wastes and emissions. Besides, the environment provides a number of basic conditions for human life. In this paper, the following approach has been used:

- description of the present state of the environment in Russia;
- information on agricultural pressures;
- description of the possible measures that can be taken in order to monitor and control environmental degradation.

The Russian environment is closely linked to the global environment and world economic activities. Agricultural development in Russia not only depends on the trade in natural resources and food with other countries; it also contributes to pollution and the production of waste worldwide, and thus has a global impact.

## 2 AN OVERVIEW OF RUSSIA'S GEOGRAPHY AND BIOCLIMATIC RESOURCES

### 2.1 Geography

Russia has a territory of 1,707.5 million hectares, of which 4 % are inland water, 45 % virgin forests, 13 % cultivated land, 19 % natural deer pastures and 19 % other land. The total population is 148 million inhabitants, of which 27 % live in rural areas and 73 % in urban areas. The mean population density is 8.7 inhabitants per square kilometre GOSKOMSTAT ROSSII (1995a). Russia has traditionally been regarded as a country that is rich in natural resources. Although its full potential has not yet been thoroughly explored and studied, the known reserves of natural resources confirm this opinion. Russia's first and most important type of resource is land. Of the total land area, only 7.7 % are arable land. Forests, which cover 45 % of the Russian territory, contain vast reserves of timber. The fuel and energy resources of Russia include coal and lignite, natural gas, oil and peat, hydroelectric resources, as well as wind and ocean energies. Figure 1<sup>1</sup> shows a schematic map of Russia with the main sub-regions and cities (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997). The subregions marked are the European part of Russia, West Siberia, Middle East Siberia, East Siberia, the Far East of Russia, Chukotka, the Kamchatka peninsula, and the is-

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<sup>1</sup> All figures are contained in the Annex.

lands Sakhalin and Novaya Zemlya. Russia has 13 cities of more than 1 million inhabitants, namely Moscow, St. Petersburg, N. Novgorod, Kazan, Samara, Volgograd, Rostov on Don, Perm, Ufa, Ekaterinburg, Chelyabinsk, Omsk and Novosibirsk. The main deposits of fuel and energy resources are found in Siberia. In the European part of Russia, the oil and gas fields are concentrated in the south and east. The Far East of Russia has a large number of coal fields.

## 2.2 Bioclimatic resources

The richness and diversity of Russia's rural ecozones is a distinctive feature of this country. The main natural ecozones of Russia are tundra, taiga and steppe (INOZEMSTEV 1987). Tundra covers about 20 % of the total territory. In the European part of Russia, it covers a narrow zone bordering the Arctic Ocean. In Siberia, tundra stretches across more than 500 km from north to south. The southern border of tundra corresponds exactly to the climatic isotherm with an average daily temperature of  $+10^{\circ}\text{C}$  in July. Permafrost keeps tundra vegetation sparse and low (mostly moss). Taiga and broad-leaved forests cover more than 45 % of the total territory. The southern border of the taiga ecozone is near the line Moscow - N. Novgorod - Ufa - Ekaterinburg - Omsk - Novosibirsk. South of the line St. Petersburg - Kazan, mixed forests can be found. 30 % of the total land in this zone is arable land. Further to the south, near the line Voronezh - Saratov - Samara - Omsk, stretches forest-steppe. In that zone, total precipitation is 500 mm per year, and the biological efficiency of this climate is relatively good. Arable land covers 70 % of the total area. However, heavy downpours are frequent, and water soil erosion thus represents a severe problem. Immediately south of this line, Russia has steppe and arid ecozones with a warm and dry climate. Frequent storms induce wind soil erosion, which results in seedling damage, as well as intense soil degradation. In this zone, both the temperatures and a lack of soil moisture contribute to the good microbiological transformation of plant residues and humus accumulation. The steppe chernozem is the richest soil in Russia. Practically all steppe ecozone area consists of cultivated land, with only some relatively minor parts that are deserts. Figure 2 shows the location of the principal Russian ecozones. In Figure 2, uplands refers to mountainous areas that mostly consist of tundra or taiga and forest ecozones (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997).

Figure 3 shows the regionally distribution of the sum of temperatures in Russia (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997).<sup>2</sup> Table 1 indicates the temperature requirements for different crops. For example, to grow corn, rice, soya beans and sunflowers, the annual sum in an area has to be greater than  $2,200^{\circ}\text{C}$ . In Figure 3, we can see that only some minor areas in the southern part of Russia meet that requirement. In all northern parts of Russia, the annual sum is below  $400^{\circ}\text{C}$ . The climate of this territory only allows the cultivation of vegetables in greenhouses, as well as deer grazing. Another significant natural resource for cropping is water. Figure 4 gives the distribution of the ratio  $K$  of annual precipitation to potential annual plant evaporation for Russian territory (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997). In all northern regions of the European part of Russia, Middle-East Siberia and the Far East (except Yakutija), there is no limitation of potential plant evaporation; its ratio value is thus higher than 1. The south of West Siberia and one of the European parts of Russia have moderate limitation of potential plant evaporation; the ratio value is thus less than 1.

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<sup>2</sup> The sum of temperatures is defined as the annual sum of those average daily temperatures exceeding  $10^{\circ}\text{C}$ .

**Table 1: Crop temperature requirements**

Crops	<400° C	400 - 1000° C	1000 - 1600° C	1600 - 2200° C	>2200° C
<b>Vegetables in greenhouses</b>	yes	yes	yes	yes	yes
<b>Early potato, little radish, curled lettuce, leek, spinach</b>	no	yes	yes	yes	yes
<b>Cereals, flax, grain legumes, potatoes</b>	no	no	yes	yes	yes
<b>Wheat, sugar beet</b>	no	no	no	yes	yes
<b>Corn, rice, soya beans, sunflower</b>	no	no	no	no	yes

Source: FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA (1997).

To classify the Russian ecozones, the parameter of the biological efficiency of climates has been used. The parameter values have been calculated by multiplying the sum of temperatures and the ratio value (for  $K < 1$ , or  $K = 1$ ). Figure 5 represents a model characterisation of the Russian ecozones (FROLOV 1995; ISACHENKO 1995). Highly favourable climatic conditions exist in only a relatively small part of the total territory. One of these regions is bordered by the cities of Moscow, Kazan and Ekaterinburg in the north, and by the cities of Saratov, Samara and Ufa in the south. Another one of them is situated in the Caucasus. These regions have climate efficiency parameter values that are higher than 20. Moderately favourable conditions (parameter values higher than 12) exist in a relatively large south-western part of Russia (excluding a desert region in the Republic of Kalmykia near the Caspian Sea). Unfavourable and even extremely unfavourable climatic conditions exist in all north-eastern parts of Russia.

Figure 6 shows the distribution of rural and urban population densities in Russia (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997). In territories with unfavourable climatic conditions, the rural population density is less than one inhabitant per square kilometre. The region where rural population density is higher than 10 inh./km<sup>2</sup> is identical to that where climatic conditions are favourable. Most of the big cities (9 out of 13) are concentrated in this region. As for the pattern of agrarian structure, it depends both on the favourableness of natural conditions and the availability of labour resources. Figure 7 shows that a very large area in the northeast of Russia is used only for deer grazing management; this is, in fact, a tundra ecozone (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997). All central parts of Russia are covered by forests, with only minor local sites where cropping or animal breeding are practised. The Russian southwest is where the main national agricultural activities are concentrated. This again is where the most favourable natural conditions and the best labour resource availability can be found.

### 3 ENVIRONMENTAL PRESSURES INDUCED BY HUMAN ACTIVITY

#### 3.1 Atmospheric emissions

Many of the environmental problems currently facing Russia result from the release of pollutants into the environment. Emissions to the air arise from different human activities. Anthropogenic emissions are a result of the extraction, distribution and combustion of fossil fuels. Other sources of emissions are various industrial processes, waste treatment, and agriculture.

For example, sulphur dioxide (SO<sub>2</sub>) is released during the combustion of sulphur containing fossil fuels, and some industrial processes. Russia is one of Europe's main contributors to SO<sub>2</sub> emissions (10 % of total sulphur emissions). Nitrogen oxide emissions consist of the compound of nitrogen dioxide (NO<sub>2</sub>) and nitric oxide (NO). In addition to causing problems for humans, these emissions can reduce plant growth and cause damage to crops.

**Table 2: Annual average emissions of sulphur dioxide and nitrogen oxides from point sources in Russia until 1995** (German benchmark values in brackets)

Annual total emissions into air	Sulphur dioxide (1,000 t SO <sub>2</sub> )	Nitrogen oxides (1,000 t NO <sub>2</sub> )
Russia (Germany)	7,200 (5,800)	2,500 (3,190)

Source: GOSKOMSTAT ROSSII (1994, 1995b, 1996); STANNERS and BORDEAU (1995).

Table 2 gives the annual emissions of sulphur and nitrogen dioxides in Russia and Germany. For Russia it is estimated that the mean concentrations of these pollutants in the air are as follows: sulphur dioxide - 1.1 mg/m<sup>3</sup>, sulphate - 0.8 mg/m<sup>3</sup>, nitrogen dioxide - 1 mg/m<sup>3</sup>. Table 3 thus shows a dynamic of maximum daily concentration of sulphur dioxide in the air in Russia during the winter.

**Table 3: Dynamic of maximum daily concentration of sulphur dioxide in the air in Russia during the winter months** (in mg/m<sup>3</sup>)

Month/Years	1985/1986	1986/1987	1987/1988
December	7.6	6.1	0.5
January	16.6	8.0	0.8
February	3.2	2.8	58.8
March	5.3	11.3	2.5 (4.6 in 88/89)

Source: EUROSTAT et al. (1995).

We can see that the concentration of sulphur dioxide exceeds its mean value during the winter months. In addition, the precipitation may contain different pollutants. The total wet deposition of nitrogen with rainfall is only a few kg of N/ha per year.

### 3.2 Waste

In some of Russia's big cities the rate of waste generation is high and waste management has a wide range of potential environmental impacts. Waste materials may contaminate the soil and groundwater with heavy metals, nitrogen compounds and organics. These may cause pollution of drinking water sources, as well as the eutrophication of waterbodies. Municipal per capita waste production in Russia ranges between 100 and 200 kg per year, less than the amount of waste produced per capita in most West European countries (on average 350 kg). Annual production of municipal waste per km<sup>2</sup> in Russia is also lower than in any other European country (less than 25 t/km<sup>2</sup>, compared to 50 - 100 t/km<sup>2</sup> in Germany). The extraction of raw materials and energy production are responsible for much of the waste produced in Russia (GOSUDARSTVENNYJ KOMITET SSSR 1989; INFORMCENTR GOSKOMSTATATA SSSR 1991; ŠECHOVCOV et al. 1995; STANNERS and BORDEAU 1995). On the basis of official statistics, the OECD estimates that worldwide annual production of hazardous waste amounts to 340 million tonnes. In the former USSR, 25 to 30 million tonnes of hazardous waste were estimated to have been produced each year (STANNERS and BORDEAU 1995). Recently, the total waste

water discharge for Russia has amounted to about 70,000 m<sup>3</sup> per year. This waste water discharge consists of about 6 million tonnes of sulphates and 8.5 million tonnes of chlorides (ŠECHOVCOV et al. 1995; STANNERS and BORDEAU 1995). The impact of radioactive waste on the environment depends on the type of radioactive contaminants. In Russia, contamination of the soil with artificial radionuclides has given rise to much public concern since the Chernobyl accident in 1986. Contamination from nuclear tests, nuclear accidents and nuclear explosions carries a high risk due to the widespread transport of radionuclides by wind and water. Figure 8 shows the cities with the highest air pollution, some locations of radioactive contamination, and radioactively contaminated lands as a result of the Chernobyl accident (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997; GOSKOMSTAT ROSSII 1996).

#### **4 THE ENVIRONMENTAL IMPACTS OF AGRICULTURE IN RUSSIA**

##### **4.1 History of agricultural development in Russia**

The purpose of agriculture has historically been to prevent the threat of hunger and to meet the demand for agricultural products. Over the last few decades, the nature, structure and ways in which these demands have been met have all changed in Russia. Most changes have been due to genetic and other technological developments, as well as to the influence of national and international agricultural policies. The introduction of modern, more intensive agricultural techniques has accelerated these changes. Russian agriculture is a diverse and heterogeneous economic sector in terms of its nature and structure of production units. This results in the variability of potential environmental impacts of agriculture. The potential impacts of agriculture on the environment have strongly depended on shifting land use patterns in Russia. More than 90 % of the land in Russia is presently used for agriculture or covered by forests. The increasing demand for food and timber has affected the land use structure. Two major land use trends were recognised for Russia over the past three hundred years: an increase in the use of land for agriculture and for the development of industry, urban areas and transportation networks. By the end of the nineteenth century, the main land uses were forestry (in the northern and broad-leaved forest zones), arable farming (in the forest-steppe zone), and meadow and pasture (in the steppe zone). The period after 1960 has been characterised by a shift towards intensification of agriculture, with increasing land productivity as a result of the use of mineral fertilisers and machinery. During this time, much of the remaining land resource was taken into cultivation, resulting in a doubling of arable land. This increase of arable land was accompanied by considerable increases in the area used for pasture and as meadows. The area of tilled land stabilised at the level of 210 million hectares in the former USSR. Within the last few years, the nature of rural areas has changed considerably. In the northern part of Russia, agricultural land has been transformed into land for alternative uses. Natural pastures have been abandoned and some arable land has been left fallow. The rural population is forced to migrate due to both the low rates of return in the agricultural sector and increasing pressure from the urban population. Currently, the total area of arable land in Russia amounts to approximately 130 million hectares. The area of forested land in Russia has begun to increase due to the reforestation of abandoned agricultural land. Forests were and still are threatened by exploitation, industrial and recreational activities.

Over the last three hundred years, farming practices have developed in three basic stages: the primitive system, fallow farming and arable farming (KARAVAEVA et al. 1991). The primitive system was based on shallow ploughing, and intensive cultivation of the land for a few years, and subsequently abandoning it when yields began to fall. Farmers would move to a new place, leaving the abandoned piece of land to recover its fertility. Fallow farming, an alter-

nating system of crop and fallow, carries the risk of soil degradation, especially if the fallow is shortened due to economic pressure. The arable farming system is based on crop rotation. Until the 1930s, all three farming systems were in operation in Russia. Before the 1960s, land productivity was mainly limited by natural conditions. Manure and ash, peat and compost were traditionally used as fertilisers in Russia. However, from the 1960s onwards, significant changes in Russia's farming systems have been initiated in connection with the implementation of new technology related to mineral fertilisers, drainage and irrigation.

#### **4.2 Recent agricultural activities**

Mineral fertilisers have been widely used in Russia since the 1960s. The rate of fertiliser application increased until about 1985 (the start of perestroika in the former USSR), and has decreased since then. Table 4 shows the dynamic of the annual average fertiliser application rate in Russia (GOSKOMSTAT ROSSII 1996).

Drainage for agricultural purposes was widely implemented in Russia after the 1960s. At present, many wetlands are still being drained. Approximately 50 % of presently used cultivated land in the western part of Russia has at some time been reclaimed by drainage (mostly since the 1970s). The total drained arable land amounts to almost 5 million hectares. Most wetland in the Leningrad region has been drained. In Russia's agricultural development, irrigation has also played a significant role. At first, irrigation was used in the south-eastern part of Russia; later it also spread to the west. In 1960, the total area of irrigated land in the former USSR was 1.6 million hectares. At present, Russia alone has approximately 5 million hectares of irrigated land. These are mainly situated south of the line Moscow - Kazan.

**Table 4: Annual average application of mineral and organic fertilisers for agricultural crops in Russia**

Year	1985	1990	1993	1994	1995
	<b>Mineral fertilisers</b>				
<b>Total (m t NPK)</b>	9.8	9.9	4.3	2.1	1.5
<b>Mean application rate (kg/ha)</b>	85	88	46	24	18
<b>cereals</b>	69	81	44	23	17
<b>sugar beet</b>	426	431	247	150	120
<b>flax</b>	190	172	86	46	29
<b>vegetables</b>	275	163	120	94	79
<b>potatoes</b>	295	265	176	119	113
<b>forage crops</b>	84	78	37	19	14
	<b>Organic fertilisers</b>				
<b>Total (m t of organic matter)</b>	418	390	241	164	127
<b>Mean application rate (t/ha)</b>	3.6	3.5	2.6	1.8	1.4
<b>cereals</b>	3.0	3.3	2.6	2.0	1.5
<b>sugar beet</b>	7.0	5.3	3.8	4.4	4.3
<b>flax</b>	0.1	0.1	0.1	0.1	-
<b>vegetables</b>	18	13	13	12	10
<b>potatoes</b>	34	34	36	33	34
<b>forage crops</b>	3.2	2.8	1.9	1.3	1.0

Source: GOSKOMSTAT ROSSII (1996).

The intensive agricultural development has affected the environmental quality and has had a wide range of environmental impacts, in most cases both water pollution and soil degradation. Worldwide there are 1,200 million hectares with moderate, severe, or extreme land degradation (OLDEMAN et al. 1991). The largest areas are located in Asia (450 million hectares). The causes of soil degradation are about equally divided among unsustainable livestock grazing, agriculture and forestry practices. Some degradation is caused by overexploitation for fuel-wood collection, and mineral, oil, gas and coal mining and extraction. A small amount (about 1 %) of land is degraded due to waste disposal and excessive pesticide use. Figure 9 serves as an illustration, showing the locations of severe land deterioration problems in Russia (FEDERAL'NAJA SLUŽBA GEODEZII I KARTOGRAFII ROSSII, KARTOGRAFIJA 1997). Table 5 gives an assessment of the current situation regarding the quality of cultivated land in Russia (ŠECHOVCOV et al. 1995; JANSON 1988; NAPIER et al. 1994, INFORMCENTR GOSKOMSTAT SSSR 1991).



**Table 5: Deteriorated lands under cultivation in Russia**

<b>Deterioration caused</b>	<b>Reason</b>	<b>Area (in m hectares)</b>	<b>Percentage of total culti- vated land</b>
<b>Total soil erosion (wind and water)</b>	agriculturally induced	70.5	33
<b>Total acidification</b>	natural and human-induced	43.5	20
<b>Humus degradation</b>	agriculturally induced	16.8 <sup>1)</sup>	8
<b>Saline soil</b>	natural	10.4	5
<b>Salinisation</b>	irrigation	4.2	2
<b>Stony soil</b>	natural	3.9	1.9
<b>Waterlogging</b>	human-induced	1.7	0.8

Note: <sup>1)</sup> Theoretically estimated.

Source: INFORMCENTR GOSKOMSTAT SSSR (1991).

### 4.3 Soil degradation

Soil degradation is a crucial environmental problem in Russia today. Soil is a dynamic, living system which is formed very slowly. It is a complex system where crucial biogeochemical processes occur. In the top 30 cm layer of one hectare of soil, there are on average 25 tonnes of soil organisms. The soil fauna and flora recycle organic matter to form humus. Intensive exploitation of arable land in Russia has focused on three biogeographical zones: the taiga forest zone with podzol soils; the broad-leaved forest and forest-steppe zones with grey forest soils; and the steppe zone with chernozem soils. Poor management and nutrient deficiencies are good reasons for the degradation of podzol soils. The degradation of podzolic soils is more severe on arable land than on pastures or hay fields. Their humus content may decrease considerably and humus losses may intensify soil erosion processes. The western and suburban regions of Russia are characterised by major economic progress, and simultaneously serious negative environmental consequences. A decrease of soil organic material, an increase in soil erosion, and the reduction of land productivity are the main environmental impacts on soil in the forest and forest-steppe zones. Chernozem soils in the steppe zone are irreversibly transformed into soils with reduced land productivity. Unlike air and water, soil in Russia can be privately owned and soil conservation or protection policies can be difficult to enforce vis-à-vis landowners and managers. The impacts on soil therefore have to be recognised and assessed.

### 4.4 Soil vulnerability

Not all soils in Russia respond similarly to soil degradation processes. The vulnerability of soils to certain contaminants or degradation processes depends upon those characteristics which enable soils to resist alteration. The vulnerability of the main soil types to the main soil threats (erosion, acidification, compaction and pollution) is presented in Table 6. It is known that sandy soils are much more vulnerable to soil pollution than black soils. Moreover, pesticides are adsorbed by the organic matter in black soil, and degradation is usually fast in the fertile topsoil. Heavy metals, too, are strongly adsorbed by black soils, which prevents their uptake by plants or soil fauna. In contrast to black soils, sandy soils have mostly acid,

humus-poor topsoil with a limited capacity for the adsorption of pesticides and heavy metals. Therefore, pollutants are more available for uptake and leaching. In sandy soils, contaminants consequently threaten the groundwater as well the soil flora and fauna. Loamy and clayey soils have an intermediate position between sandy soils and black soils. The increase of both clay and organic matter content in soil means a higher buffer capacity and a lower vulnerability. Let us consider the most severe soil degradation processes in Russia in terms of their irreversibility.

**Table 6: Soil vulnerability**

Soil type	Erosion	Compaction	Acidification	Pollution
<b>Chernozem</b>	slight	no data	no data	no data
<b>Sands</b>	moderate	high	high	high
<b>Acid loams</b>	high	high	high	high
<b>Non-acid loams</b>	high	high	moderate	moderate
<b>Clays</b>	slight	moderate	slight	slight
<b>Acid shale</b>	high	no data	high	high
<b>Non- acid shale</b>	high	no data	no data	slight
<b>Semi-acid</b>	high	no data	no data	no data
<b>Salt-affected</b>	moderate	no data	no data	no data
<b>Wet</b>	no data	moderate	slight	high

Source: STANNERS and BORDEAU (1995).

#### 4.5 Soil erosion

Soil erosion is a natural phenomenon, but it is accelerated by human activities. Soil erosion may be caused by any human activity that promotes both raindrop and wind erosion impacts, or increases the amount and speed of surface runoff water. Soil erosion occurs mainly where land is used over-intensively. In Europe, for example, about 12 % of total land is affected by water erosion. In Russia, approximately 20 % of total land are areas with prevailing water soil erosion (cf. Figure 10) (GOSUDARSTVENNYJ KOMITET SSSR PO OCHRANE PRIRODY 1989; ŠECHOVCOV et al. 1995). Both the southwest and some southern parts of Russia are subject to wind erosion, in all roughly 3 % of its total land area. In some ecozones in the northwest of Russia, eroded soil accounts for more than 20 % of total cultivated land. In the Novgorod region, 42 % of regional cultivated land are affected by water erosion (ISACHENKO 1995). Moreover, on 7.7 % of cultivated land, soil erosion is severe. This may be due to some farming practices such as ploughing up and down slopes, the removal of vegetative soil cover or hedgerows, increased field sizes, abandonment of terraces, late sowing of winter cereals, overstocking, poor crop management, deforestation and overgrazing. In Russia, about 1,200 t/ha of top soil have been lost within the past one hundred years due to erosion of podzol soils (KARAVAEVA et al. 1991). The erosion of arable land in the taiga forest zone can be observed on 14 % of cultivated land. In areas with broad-leaved forests, up to 60 % of arable land are affected by soil erosion. In some cases, ploughing arable land in the steppe zone has intensified the gullyng process. Wind erosion has also become more of a problem in this zone. Eroded land is a typical picture in the steppe zone. In the Volgograd region, the annual loss of chernozem soil amounts to between 1 and 3.8 tonnes per hectare (SURMAČ 1976). Intensive

ploughing increases this loss to up to 5.5 tonnes per year on average. According to Janushenko data (LJACHOV 1975), the application of fertilisers may decrease the rate of water soil erosion due to more intensive plant cover development, resulting in extra soil protection. For example, winter wheat cropping with fertiliser application reduces the erosion rate to 0.7 t/ha per year, compared to 3.3 t/ha per year without fertilisers.

#### 4.6 Soil erosion impact assessments

Water soil erosion usually affects crop production through a decrease in plant rooting depth, the removal of nutrients and organic matter, and the uprooting of plants. This decreases soil fertility as shown in Table 7. It is estimated that the humus content of agricultural soil in Russia decreases by about 1 % each year due to erosion (KARAVAEVA et al. 1991). This rate of humus loss corresponds to the rate of topsoil loss, which is 0.2 - 0.3 mm per year. Intensive erosion may cause the loss of fertile topsoil at a rate of a few millimetres per year, which exceeds the rate of humus formation. The annual rate of humus formation is between 0.2 - 0.3 mm per year of topsoil for podzol and steppe chernozem soils, and between 0.35 and 0.45 mm for grey forest and forest-steppe chernozem. This can lead to a long-term deterioration of soil fertility. Moreover, the negative effects of erosion on the environment include pollution by pesticides, fertilisers, heavy metals and other contaminants transported from upstream areas. The deposition of both sediments and contaminants in waterbodies can severely affect aquatic life and human health.

**Table 7: Mean yields of crops on chernozem and on loamy soils with different degrees of soil erosion (in t/ha)**

Crop	Uneroded soil	Slightly eroded soil	Severely eroded soil
<b>Chernozem</b>			
Winter wheat	2.35	1.67	0.61
Winter rye	2.56	2.13	1.06
Corn	3.15	2.51	0.76
Sugar beet	25.6	23.4	11.3
<b>Loamy soil in the Tula region</b>			
Cereals	2.05	1.29	0.82
Winter wheat and barley	1.33	0.57	----

Source: LJACHOV (1975); SURMAČ (1976).

#### 4.7 Soil pollution by nitrates and phosphorus

Nitrogen and phosphorus are important plant nutrients, but overapplication may lead to nitrogen or phosphorus accumulation in the soil. This can cause nitrate losses in the groundwater, and a saturation of the soil with phosphates. Unlike nitrogen, phosphorus is usually strongly absorbed in soils. In cases where phosphorus is applied under wet conditions on soils with low adsorption capacity (such as sandy soils with low organic matter content in the northwest of Russia), phosphorus can be leached into the groundwater due to soil adsorption capacity saturation. In addition, the problem with phosphorus saturating the soil is that it can take many years before soil phosphorus saturation effects are seen. On slopes, runoff can contribute to

large quantities of phosphorus in surface water. In Russia, phosphorus runoff losses are found in regions with high levels of water soil erosion. Where there are high phosphate concentrations in freshwater, eutrophication may occur; a level of 0.02 mg phosphorus per litre is usually sufficient to cause eutrophication. In Russia, nitrate or phosphorus pollution of the environment occurs in the northwest and in some localities with high levels of fertiliser application or intensive large-scale livestock farming. At present, fertiliser application is being reduced to at least a third compared to the 1985 - 1990 level. At the same time, manure application is being halved compared to the same period. Arable lands in Russia have a negative annual balance of nutrients in the topsoil. The annual nutrient uptake of crops is 3 times higher than nutrient input through fertilizers. All the above information allows us to conclude that nitrate and phosphorus soil pollution are of minor significance and do not create severe problems for Russia, at least for the present.

#### **4.8 Soil compaction**

Soil compaction mostly affects highly productive soils and heavily mechanised agricultural land, or wet grassland with high cattle density. Due to the increasing weights and axle loads of farm vehicles, soil compaction in Russia takes place rapidly on lands with soil containing less than 25 % clay. This applies to loamy soils and, to a lesser degree, to sandy soils, which can be found in large areas in Russia. Decreases in yields of up to 50 % have been detected on compacted soils there (HAKANSON and PETELKAU 1994; JASAN 1985). Another consequence of compaction is the increase in surface runoff. This raises the risk of water erosion and the loss of nutrients. To prevent soil compaction, an increase in the number of axles and wheels under agricultural machinery, and a reduction of tyre pressures are recommended. Using machinery during wet conditions should be avoided.

#### **4.9 Soil organic matter losses**

In certain cases, intensive arable land cultivation can lead to a decline in soil organic matter and to a loss of biological activity. The ploughing up of grassland, the ignoring of rotations and the removal of crop residues all reduce the amount of organic matter in soil. In Russia, the black soil chernozem is in danger of losing humus and, as a result, suffering a reduction of fertility. Table 8 shows the long-term development of humus content in Russian chernozem. Within a hundred years, humus reserves have fallen by between 26 % and 61 %, depending on the type of chernozem. Most of all, the Volga catchment area leached chernozem has been degraded.

**Table 8: Humus content and humus reserves of chernozem soils in Russia**

Type of chernozem	Region	Humus content		Humus reserves		Humus decrease 1881-1981 (in %)
		1881 (in %)	1981 (in %)	1881 (in t/ha)	1981 (in t/ha)	
<b>Forest-steppe</b>						
Typical chernozem	Central European part	11.5	8.5	345	255	26
Typical chernozem	South-eastern part	14.5	8.5	435	255	41
Leached chernozem	Volga catchment area	14.5	5.5	435	165	61
Leached chernozem	Caucasus	8.5	5.5	265	165	38
<b>Steppe</b>						
Typical chernozem	Central European part	8.5	5.5	265	165	38
Typical chernozem	South-eastern part	10	7	300	210	30

Source: KARAVAEVA et al. (1991).

This was changed by intensive irrigation which caused the groundwater table to rise and resulted in waterlogged soil. Table 9 shows the changes in humus content in soils used as arable land in the Republic of Tatarstan, which is situated in the broad-leaved forest and forest-steppe zones in Russia. Tillage practices affect the majority of basic properties of grey forest soils. The tillage of land in this region has significantly intensified the microbiological decomposition of organic matter in soil. The intensive cultivation of cereals in this region is also responsible for the humus losses, since it reduces the input of organic matter into the soil.

**Table 9: Humus content and humus reserves of the soils in the Republic of Tatarstan of Russia**

Soil type	Category	Humus content in 1940s (%)	Humus content in 1950s (%)	Current humus content (%)	Humus reserves in 1940s (t/h)	Current humus reserves (t/h)	Humus decrease (%)
Grey forest	light grey	3.5	3.4	3.0	91	77	15
	grey	5.0	4.9	4.5	130	94	27
	dark grey	6.0	6.3	5.5	144	116	19
Chernozem	leached	8.5	8.4	7.6	204	154	25
	typical	11.5	7.9	7.2	276	158	42

Source: KARAVAEVA et al. (1991).

#### 4.10 Soil salinisation

Salinisation is very much linked to site-specific soil properties and climatic conditions. The distribution of soil salinisation is restricted to the southern regions of Russia. Generally

speaking, soil salinisation is reversible, but the reclamation of saline soils is expensive and requires complex amelioration techniques. Salinisation has a negative effect on soil biology and crop productivity alike. Irrigation in Russia has caused salinisation and alkalinisation of about 4.7 % of cultivated land (STANNERS and BORDEAU 1995; ŠECHOVCOV et al. 1995). Including naturally saline soils (solonchaks), overall about 7 % of agricultural soils are saline. Saline soils are mostly concentrated in the Precaspian depression, the Northern Caucasus, the Stavropol region, the Rostov region, and the Povolgje region (INFORMCENTR GOSKOMSTAT SSSR 1991).

#### **4.11 Waterlogging**

Waterlogging occurs mainly in the north of the Russia. It may be due to accidental or deliberate flooding, increasing runoff from higher areas that results from a lower infiltration rate or a raising of the water table (following irrigation, for example). Waterlogging increases the risk of soil compaction and the risk of salinisation. Waterlogging poses the greatest threat to wet soils and parts of the semi-arid and salt-affected soils.

#### **4.12 Soil acidification**

Natural soil acidification (resulting in a drop in the soil pH) has been recently enhanced through the emission of sulphur and nitrogen compounds. Russia has about 43 million hectares of acid soils (19.7 % of total cultivated land) (GOSKOMSTAT ROSSII 1996; INFORMCENTR GOSKOMSTAT SSSR 1991; ŠECHOVCOV et al. 1995), mostly as a result of natural processes. In Russia, acidic deposition is by far the most important example of human-induced soil acidification. However, it is estimated that 5 million hectares of strongly acidified arable land in Russia are limed. Acidification considerably reduces the fertility of the soil. There is also the risk of soil contaminants being released where pH values are low. As the soil pH drops, there is an increase in the rate at which most trace nutrients and heavy metals are released from the soil. This can also limit crop growth, due to their absorption by plants. Acidification may cause a depletion of the soil buffering capacity, particularly in sandy soils.

#### **4.13 Soil pollution by pesticides**

Pesticides are used in agriculture to protect crops and to ensure a good quality harvest. In Russia, the use of pesticides has been and still is only moderately widespread (81 million hectares in 1990) (GOSKOMSTAT ROSSII 1994, 1995b, 1996; STANNERS and BORDEAU 1995; ŠECHOVCOV et al. 1995). At present, there is a tendency to reduce the land area on which pesticides are used (only 33 million hectares in 1993). The pesticides were applied on an area of 240,000 hectares of cultivated land in the Lake Lagoda catchment area (ISACHENKO 1995; FROLOV 1995), located to the north-east of St. Petersburg. In the Arkhangelsk region, 15 % of total cultivated land are contaminated by pesticides, and in the Komi Republic 20 %. It is extremely difficult to identify and evaluate the threats to soils posed by pesticides. At least, the threat of pesticides to groundwater has received much attention in Russia. Most pesticides hamper the main soil functions for a relatively short period of time. After a few months, the soil may completely recover from temporary loss of activity. According to the World Health Organisation (WHO) (STANNERS and BORDEAU 1995), up to 20,000 fatalities per year at world level may result from acute pesticide poisoning. A wide range of different chemical compounds are currently in use as pesticides (insecticides, herbicides and fungicides). These compounds present a threat to human health, and have a direct or indirect impact on flora and fauna. Some pesticides may remain in soils for long periods of time due to their high persis-

tency, with a large number of possible consequences (loss of biodiversity, cancer, highly toxic or allergic reactions).

#### 4.14 Water pollution

The demand for high-quality water has risen in Russia over the last years. In addition to the domestic and industrial use of water, other requirements have become increasingly important. Among these, water for agricultural irrigation and livestock supply, cooling water for the power industry, as well as water for recreational purposes have gained in importance. Each of these uses affects the quality of the water. At the same time, the discharge of untreated domestic, industrial and agricultural wastes, as well as the excessive application of fertilisers and pesticides locally in agriculture have led to the increasing pollution of many waterbodies: rivers, lakes, reservoirs, groundwater and seas. Table 10 shows the state of both the demand for and discharge of water by agriculture in Russia (GOSKOMSTAT ROSSII 1994, 1995b, 1996). The table illustrates the impact agricultural waste water has on the environment.

**Table 10: Agricultural water demand and discharge**

<b>Agriculture</b>	<b>Percentage of total for Russia</b>
<b>Annual water demand</b>	27
<b>Annual water discharge</b>	19
<b>Quality of water discharge</b>	<b>Percentage of total agricultural discharge</b>
<b>Standard treated water</b>	1
<b>Standard clean water</b>	24
<b>Polluted water</b>	13
<b>No data</b>	62

Source: GOSKOMSTAT ROSSII (1994, 1995b, 1996); ŠECHOVCOV et al. (1995).

Table 11 shows the composition of waste water effluent. Agriculture is one of the greatest non-point sources of water pollution in Russia, polluting waterbodies with four main substances, namely organic matter, nitrogen, phosphorus and pesticides.

**Table 11: Composition of annual waste water effluent in Russia (in thousand t)**

<b>Contaminants</b>	<b>Total for Russia</b>	<b>Total from agriculture</b>	<b>Agriculture as percentage of total</b>
<b>Total BOD*</b>	---	29	---
<b>Ammonia as N</b>	161	7.5	4.6
<b>Nitrate as N</b>	141	4.4	3.1
<b>Total phosphorus as P</b>	56	7.1	12.7
<b>Pesticides</b>	0.1	0.022	22.0

Note: \* BOD = Biological oxygen demand.

Source: GOSKOMSTAT ROSSII (1994, 1995b, 1996); ŠECHOVCOV et al. (1995).

#### 4.15 Organic pollution

The organic matter naturally occurring in waterbodies originates from soil erosion and from dead plants or animals. It is normally relatively insoluble and decomposes only slowly. Organic matter originating from human activities is generally soluble and decomposes rapidly.

The most important sources of the organic waste feeding into rivers, lakes and reservoirs are domestic and industrial sewage. The annual sewage effluent from agriculture in 1993 was equivalent to 28.91 million tons of BOD (GOSKOMSTAT ROSSII 1996; ŠECHOVCOV et al. 1995). The majority of sewage water effluents came from livestock farms. In Russia livestock farms generate a total of 140 million m<sup>3</sup> of sewage water effluent annually. Only 67 % of this are used as manure; the rest pollutes the surface waters and groundwater. Moreover, this can lead to additional nitrogen input into the soil. It is estimated that the average load of nitrogen from animal manure amounts to 100 kg/ha for the central area of the European part of Russia. This also increases the load of nitrogen and organic matter in the soil, groundwater and surface waters. For example, before perestroika, annual livestock generation of manure in the Lake Ladoga catchment area amounted to more than 7 million tons. About 20 % of that amount reached Lake Ladoga and polluted its water (ISACHENKO 1995; FROLOV 1995).

#### 4.16 Nutrient pollution

Traditionally most evaluations of water quality are based on measurements of set concentrations of both organic and inorganic substances in the water. The excessive application of fertilisers and pesticides locally in agriculture may lead to the pollution of many waterbodies in Russia. Table 4 (cf. p. 12) shows the dynamics of mineral and organic fertiliser application in Russia. Amounts of fertiliser that are smaller than 50 kg (NPK) per hectare of cultivated land clearly do not cause agriculturally induced widespread pollution in Russia. Therefore, the chemical pollution of waterbodies in Russia by agriculture will only be a severe problem in specific areas. Long before perestroika in the former USSR, 180-200 kg/ha of mineral fertilisers in active substance were applied to the cultivated lands of the Lake Ladoga catchment area annually. This affected the water quality of Lake Ladoga and caused eutrophication. Let us now consider the current situation of water pollution in Russia. Table 12 reflects the current situation regarding the water quality of the main rivers in the European part of Russia. Those in the north (Severnaya Dvina, Onega and Neva) have a better water quality than those in the south (Volga, Don and Kuban).

**Table 12: Water quality of the six main rivers in the European part of Russia** (annual mean concentrations in mg/l)

River	Total alkalinity	BOD <sub>5</sub>	Nitrate	Total inorganic N
<b>Severnaya Dvina</b>	2.0	1.9	0.1	0.1
<b>Neva</b>	0.8	1.1	0.6	no data
<b>Onega</b>	1.7	0.9	0.1	0.1
<b>Volga</b>	1.6	2.9	0.4	0.6
<b>Don</b>	3.3	2.6	0.4	0.4
<b>Kuban</b>	2.1	1.9	1.0	2.9

Source: EUROSTAT et al. (1995).

Table 13 shows the water quality for two big lakes (Lake Ladoga and Lake Onega). The total phosphorus concentration values (27 and 10 µg/l respectively) for both lakes indicate that there is the danger of eutrophication. In Germany, approximately 50 % of all lakes have a phosphorus concentration that is lower than 25 µg/l; in the remaining 50 %, concentration ranges between 25 and 125 µg/l (BROUWER et al. 1991). One more large lake in Russia is Lake Ilmen, which has a phosphorus concentration of more than 70 µg/l. In 13 large reservoirs



on the Volga and the Dnepr, total phosphorus concentration ranges from 49 to 201  $\mu\text{g/l}$  (STANNERS and BORDEAU 1995; EUROSTAT ET AL. 1995).

**Table 13: Water quality of two large lakes in Russia** (in mg/l of N and  $\mu\text{g/l}$  of P)

Lake	Area in km <sup>2</sup>	Total nitrogen	Total phosphorus
Ladoga	17670	0.6	27
Onega	9670	0.6	10

Source: EUROSTAT et al. (1995).

A nitrogen concentration of less than 0.75 mg/l does not threaten the environment. For example, in Norway, 40 % of all lakes have a nitrogen concentration of between 0.3 and 0.75 mg/l (STANNERS and BORDEAU 1995). Phosphorus is usually the nutrient that most limits plant growth in lakes and reservoirs. In lakes with mean total phosphorus levels that are lower than 10  $\mu\text{g/l}$ , chlorophyll concentrations are low and the water is clear. In lakes with phosphorus levels that are higher than 10  $\mu\text{g/l}$ , water transparency is reduced and lake eutrophication has started. Besides, groundwater quality may be threatened by the high concentration of nitrate caused by an excessive use of mineral fertilisers and manure on cultivated land. In Russia, nitrate concentrations that exceed the drinking water standard (50 mg/l) may occur in some areas (hot spots) where a high load of nitrogen is applied to vulnerable soils overlying sensitive aquifers, such as the north-western part. This area has mainly sandy or sandy-loamy soils, and the rates of nitrogen content from mineral and organic fertiliser application (in the Leningrad and Novgorod regions, and the Karel Republic) are reaching 100 and 150 kg N/ha per year according to Eurostat et al. (1995).

#### 4.17 Pesticide pollution

Usually the average annual pesticide load on cultivated land in Russia does not exceed 1 kg/ha. For arable land in the central and south-western areas of the European part of Russia, the pesticide load amounts to 3 kg/ha per year. The highest annual load of pesticides (up to 10 kg/ha) can be found on the cultivated lands of the Northern Caucasus (EUROSTAT et al. 1995; STANNERS and BORDEAU 1995). For this region of Russia, as well as for its central European part, pesticide leaching in the topsoil of cultivated land is approximately predicted at more than 5  $\mu\text{g/l}$ . In the European Union, the standard for maximum pesticide concentration in drinking water is 0.1  $\mu\text{g/l}$  for a single substance and 0.5  $\mu\text{g/l}$  for all pesticides combined. So, these regions of Russia have a potential aquifer risk of pollution with pesticides.

## 5 SUGGESTIONS FOR A QUANTITATIVE ASSESSMENT OF POLICIES

Agricultural management policies are increasingly based on the intensive use of land, water and chemicals. On the one hand, these policies have ensured a large increase of agricultural production efficiency in the twentieth century. On the other hand, they have also caused severe environmental problems induced by agricultural production. At present, these problems are extremely difficult to resolve. For example, the effects of agricultural practices on chemical losses from cultivated lands and the long-term effects of chemicals (threat to human health as well as to the natural ecosystems) are poorly understood. No consideration is usually given to environmental impacts, and policy makers are reluctant to impose environmental control and conservation practices which may lower production levels. The environmental impacts of agriculture can be managed properly only if the environmental damages related to agricultural production practices will be quantitatively assessed (GOLUBEV and SHVYTOV 1982). Mathe-

mathematical models have become necessary tools for studying agriculturally induced environmental impacts. The variety of modelling approaches has increased in the last ten years. Moreover, the likely effects of environmental protection practices on both agriculture production and farm income levels must be determined. On this basis, practices must be identified that will have minimal negative impacts on food production. Besides, agriculture management policies have to be formulated that should feed the hungry without poisoning both the poor and the affluent. The present transition of Russia to a market economy shows that quantitative assessments of policies are very important.

### 5.1 Soil and water conservation policies and activities

In Russia, two main soil conservation practices have traditionally been in use, namely the liming of acid soils and the plastering of alkaline soils. Table 14 shows the dynamics of land areas which are annually limed or plastered.

**Table 14: Dynamics of soil liming and plastering in Russia (land area in m ha)**

Activity	1985	1990	1991	1992	1993	1994	1995
Liming of acid soils	4.9	4.7	4.4	3.8	2.8	1.5	0.9
Plastering of alkaline soils	0.098	0.159	0.170	0.099	0.043	0.015	0.004

Source: GOSKOMSTAT ROSSII (1994, 1995a, b, 1996).

Moreover, Table 15 shows the dynamics of land deterioration and recultivation in Russia. Modern agricultural practices have brought with them a number of severe environmental impacts. Some of these are recognised at the farm level, others at a global level. Figure 11 provides a principal scheme of possible interactions of policies with the environment. Above all, the links between agricultural activities and the environmental problems induced by them were considered. Following the principal scheme, the environmental problems that have appeared have necessitated the implementation of environmental policies. In this respect, policy options may be considered as a response to environmental problems.

**Table 15: Dynamics of land deterioration and recultivation in Russia (land area in m ha)**

Impact and activity	1980	1990	1991	1992	1993	1994	1995
Land deterioration	0.104	0.119	0.074	0.107	0.144	0.153	0.083
Land recultivation	0.074	0.110	0.070	0.065	0.129	0.177	0.160

Source: GOSKOMSTAT ROSSII (1994, 1995a, b, 1996).

Table 16 show the dynamics of soil erosion conservation activities.

**Table 16: Dynamics of soil erosion conservation activities in the Russian Federation**

Activity	1980	1985	1986	1988	1989	1990
Minimum tillage (m ha)	39.7	56.8	61.4	58.9	-	-
Using sod seeder (m ha)	38.4	44.9	43.3	40.0	-	-
Creation of protective forest areas (000 ha)	3.0	3.0	2.3	0.9	0.8	0.7
Reseeding of grassland (000 ha)	422	590	706	836	-	-

Source: INFORMCENTR GOSKOMSTAT SSSR (1991).

International investors increasingly prefer trade agreements which are instrumental in increasing the domestic production of Russia's agriculture. These have included barter agreements with West European companies, in which those companies provide equipment and technology to modernise Russia's agriculture. Modernisation of the cropping or livestock production could improve efficiency within the agricultural sector. However, some environmentalists are worried that new technology as well as equipment will lead to an increase of agriculturally induced environmental impacts in Russia. It remains to be seen whether Russia will develop its agriculture in a sustainable way. The Russian environment probably faces an uncertain future. The lack of long-term conservation incentives, effective management policies and property rights allow an uncontrolled exploitation of nature. For example, an increased demand for raw logs coupled with declining supplies in other parts of the world will increase pressure to log Siberian and far eastern forests. The future of Russia's environment is partly dependent on the land use activities. For example, most pollution originates from the extensive industrial, urban and agricultural developments. Reduction of pollution from all sources should be included in the strategy, action plans and policies. The large-scale degradation of Russia's environment has to be recognised as a problem warranting international interest and assistance. For example, the international importance of the unique natural heritage of the Volga Delta has been recognised through the Ramsar Convention of Wetlands (FINLAYSON and VOLZ 1994).

Recently, the Volga Delta has come under threat from industrial and agricultural developments. To develop the proper strategy and action plan for soil and water conservation will require some costs. This activity must be supported at least in part by financial contributions from many sources, namely other countries and international bureaus, agencies, and organisations. However, the Russian government may have time to create the new structures to manage the nation's environment.

## 5.2 Main objectives of agricultural policies for soil and water conservation

Coming back to Figure 11, let us consider the aims which have to be achieved by agricultural policies. Ultimately, soil and water conservation policies will have to affect farms. Both small and large farms are the main sources of agriculturally induced environmental impacts. These impacts may be recognised at the on-farm and off-farm levels. Most Russian territory belongs to temperate regions, and, at the on-site scale level, soil erosion impacts are therefore usually only considered as long-term effects. Recently, off-farm soil erosion impacts have received

some attention in Russia in connection with non-point water pollution problems. A number of local farms may generate severe environmental problems at the regional and national levels. Facing this, the Russian government is forced to use some policies to protect and improve the environment. Since the nature of environmental problems varies from one country to the other, the policy aims will also vary. For Russia, we may conclude that policies should at least take account of the soil erosion problem; soil acidification and soil humus degradation have considerably less significance. The present transition of Russia to a market economy has changed the main objective of farm policy, which was formerly to maximise agricultural output. Due to the economic reform, real household incomes have significantly declined. The Russian population has moved away from a high consumption of meat. This is likely to reduce environmental impacts from livestock production. However, the decreasing rate of fertiliser application in Russia may accelerate the rate of soil erosion. But farms clearly prefer to adopt farming systems which provide the most benefits for them. A major goal of conservation policy has to be the development of agricultural production systems that would benefit the farms as well as controlling soil erosion. For farms the policy has to provide:

- good access to information about environmental impacts and environmental quality;
- access to proper soil conservation technologies and techniques;
- access to financial resources to purchase the required technical and technological inputs;
- incentives for farms to protect the environment;
- training of farm operation and land management skills.

It is important that environmental conservation initiatives should be implemented in the context of other desirable national aims.

## **6 RECOMMENDED MEASURES TO CONTROL WATER SOIL EROSION**

### **6.1 Prediction of rainfall erosion losses for conservation planning**

Scientific planning for soil and water conservation requires knowledge of the relations between those factors that cause loss of soil and water, as well as those that help to reduce such losses. The greatest possible benefits can be realised only when the findings are converted to sound practice on the numerous state, collective, and private farms and other areas throughout Russia affected by erosion. The erosion rate at a given site is determined by the combination of numerous physical and management variables at that site. Physical measurements of soil loss for each of the number of possible combinations under field conditions should not be feasible. The Universal Soil Loss Equation (USLE) was developed in the USA (SMITH and WISCHMEIER 1957). It enables conservation planners to predict the rate of potential water soil erosion, and also to project limited erosion data for the many localities and conditions that have not been directly covered in the research. The USLE computes the soil loss for a given site as the product of six major factors (see section 6.2). At a particular location, the most likely values for these factors can be expressed numerically. Numerical values for each of the six factors are derived from analyses of the assembled research data and from US National Weather Service precipitation records. For most conditions in the United States, the approximate values of the factors for any particular site may be obtained from special charts and tables. For conditions in localities of Russia, where the rainfall characteristics, soil physical properties, topographic features or farm practices are substantially beyond the range of the United States, one has to develop comparable charts and tables.

## 6.2 Universal soil loss equation

The Universal Soil Loss Equation is  $A = RKLSCP$

where A is the computed soil loss per unit area; R is the rainfall and runoff factor; K is the soil erodibility factor; L is the slope-length factor; S is the slope-steepness factor; C is the soil cover and management factor; P is the support practice factor.

The standard rainfall erosion index estimates the erosive forces of the rainfall and its directly associated runoff. To obtain a more accurate result, the early spring erosion by runoff from snowmelt, thaw or light rain on frozen soil would also have to be included in the soil loss computations. To obtain the factor R value, one can thus add a subfactor  $R_s$  to the rainfall erosion index.

The rate of soil erosion may be influenced more by rainstorm characteristics, land cover, topographic features and management than by soil properties. The differences in the natural vulnerabilities of soils to erosion are referred to as the soil erodibility; this is difficult to quantify from field observations. The soil erodibility factor K is evaluated independently of the other erosion factors. Soil erodibility is a function of complex interactions between a substantial number of the soil's physical and chemical properties. Representative values for K for most of the soil types with different properties can be obtained from tables prepared by soil scientists. Both the length and the steepness of the land slope substantially affect the rate of soil water erosion. For reasons of convenience in field applications, the two factors L and S are considered as a single topographic factor LS. The value of this factor may be obtained directly from the slope-effect chart. One should enter the value of field slope length on the horizontal axis and move vertically to the appropriate percent-slope curve to read the LS value on the scale.

Cover and management effects (factor C value) cannot be independently evaluated because their combined effect is influenced by many significant interactions. The crop sequence influences the length of time between successive crop canopies. The erosion control effectiveness of meadow sod turned under depends on the type of meadow and on the length of time elapsed since the sod was turned under. Crop canopy soil protection not only depends on the type of vegetation and quality of plant growth, it also varies between months or seasons. Therefore, the erosion-reducing effectiveness of a crop depends on the particular combination of cover, crop sequence and management practices. In Russia, the correspondence of periods of expected highly erosive rainfall with periods of poor or good plant cover differs between regions or locations. Deriving the C values for a given locality requires knowledge of erosive rainfall distribution in that locality. A procedure for deriving local values of C is based on available weather records and research data that reflect the effects of crops and management in successive segments of a rotation cycle.

In general, the soil erosion protection offered by sod or close growing crops needs to be supported by practices that will slow the runoff water. The most important of these supporting cropland practices are contour tillage, stripcropping on the contour and terrace systems. The P factor values are available from special charts and tables.

## 6.3 Determining alternative treatment combinations and management decisions

Management decisions generally influence erosion losses by affecting the factors C or P in the erosion equation. The factor L is modified only by constructing terraces, diversions or contour furrows. At the same time, factors R, K and S are essentially fixed as far as a particular field is

concerned. When erosion is to be limited within a predetermined tolerance  $T$ , the term  $A$  in the equation is replaced by  $T$  and the equation is rewritten in the form

$$CP = T/RKLS .$$

Substituting the site values of the fixed factors in this equation and solving for  $CP$  gives the maximum value that  $CP$  may assume under the specified field conditions.

## **6.4 Support practices**

### **6.4.1 Contouring**

Contouring appears to be most effective on slopes in the 3 to 8 % range. Effectiveness of contouring is also influenced by the slope length.

### **6.4.2 Contour stripcropping**

Stripcropping is a practice in which contoured strips of sod are alternated with equal width strips of row crops or small grains, which is more effective than contouring alone. Alternate strips of winter grain and row crops are very effective on flat slopes.

### **6.4.3 Buffer stripcropping**

This practice consists of narrow protective strips alternated with wide cultivated strips. Buffer strips usually occupy the correction areas (steeps) on sloping land and are seeded to perennial grasses and legumes.

### **6.4.4 Terracing**

The most common type of terrace on gently sloping land is the broad base with the channel and ridge. The steep backslope terrace is most common on steeper land. Erosion control between terraces depends on the crop system and other management practices evaluated by factor  $C$ .

### **6.4.5 Efficiency of water soil erosion control**

Protection against soil water erosion normally refers to activities aimed at reducing soil surface water run-off. The efficiency of such protection varies according to soil type, relief and weather conditions. For example, in the Orlovsk region, using cross ploughing reduced soil water erosion by half, compared with uphill/downhill ploughing; at the same time, it increased crop yields by up to 12% (LJACHOV 1975). On slopes with gradients of more than  $3^\circ$ , cross ridging is more efficient. In the Smolensk region, cross ridging reduced soil erosion to 2.2 t/ha, as compared to 5.1 t/ha with normal ploughing, thus increasing the average yield of barley by an extra 0.25 t/ha. One of the best measures to accelerate soil water percolation and reduce surface run-off is the deep winter furrow. The reduction of surface run-off varies from 0.8 mm to 4 mm per centimetre of winter furrow depth (SURMAČ 1976). On agricultural lands with compacted soil or pastures and hay meadows, sometimes meadow ripper or rotary tillage are used to reduce surface run-off and consequently water soil erosion. On an experimental field in the Volgograd region, surface run-off was reduced from 41.5 mm to 19.9 mm, and soil erosion from 3.6 m<sup>3</sup>/ha to 1.7 m<sup>3</sup>/ha. These examples demonstrate that it is in principle possible to control water soil erosion, even using common agricultural methods. To increase the efficiency of these measures, one has to take into account all the characteristics of soil, crop, relief, and weather conditions. The Universal Soil Loss Equation (USLE) may be of help in this respect.

## 6.5 Quantitative evaluation of crop and management effects

For practical purposes, the year is divided into a series of crop stages so that cover and management effects may be considered approximately uniform within each period. The total number of periods and their respective lengths depend on crop variety, climate and management. Leaves and branches of crop canopy can reduce the effective rainfall energy by intercepting falling raindrops. The subfactor for the canopy effect can be estimated for each crop stage on the basis of knowing the percentage of ground cover by canopy, as well the average fall height of drops from the canopy.

## 7 CONCLUSION

This overview of environmental problems in Russia shows that agriculture is facing the dual task of food production and environment protection. But intensified agricultural activities may increase the risk of environmental degradation. Most importantly, the soil is in danger. Currently existing environmental impacts already require much effort to preserve or reclaim land resources in Russia. As has been shown, water soil erosion is the most significant environmental problem in Russia agriculture. Moreover, water soil erosion causes other environmental damage (water pollution and humus degradation), and accelerates these processes. At the same time, soil erosion directly lowers potential crop yield levels by reducing soil fertility. In the former USSR approximately 152 m ha of arable land and 175 m ha of pasture and hay-making land were either affected by soil erosion, or needed to be conserved (KAŠTANOV 1989). The total area affected by gully erosion amounted to approx. 13 m ha. Russia has inherited a significant part of this severe problem. Only a holistic approach to this problem can lead to positive results, since soil erosion combines various issues that need to be addressed, namely human, technological, economic, and political impacts. For example, the type of land use, the structure of the cultivated area, and rotations and varieties used all affect the intensity of soil erosion. For instance, in the selection of varieties, it needs to be taken into account which ones provide the best possible soil cover in periods of intensive rains, to reduce water soil erosion. As concerns crops, perennial leguminosae preserve the soil best of all, grasses provide a moderate level of protection against water soil erosion, and row crops do not help to reduce soil erosion at all. To construct and use soil conservation rotations in Russia, some economic or policy support has to be provided. Changing cultivated area structures can result in a significant reduction of water soil erosion. For example, refining beet rotations as well as moving sugar beet away from slope land to surface land resulted in reduced soil erosion in some parts of the Kursk region (KAŠTANOV and ZASLAVSKIJ 1984). At the same time, the profitability of sugar beet production was essentially increased. Arable land on slopes should not be cultivated for some time and instead be converted into grassland. The changes in land use are generally very much affected by the economic and political framework in Russia. In a free market environment, economic incentives given to farmers and the demand for specific agricultural products can affect the agricultural structure, land use, the structure of cultivated lands, as well as the choice of crops and varieties. This may not always be in line with soil conservation, and it is therefore very important to find control levers to ensure that soil conservation is fully taken into account in agricultural development.

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**ANNEX**



Figure 1: Russian Federation (schematic map)

Total territory - 1707.5 mill. ha. (virgin forest - 45%, inland water - 4%, cultivated land - 13%, other land - 38%). Total population - 148 million (rural - 27%, urban - 73%). Mean population density - 8.7 inh./km<sup>2</sup>

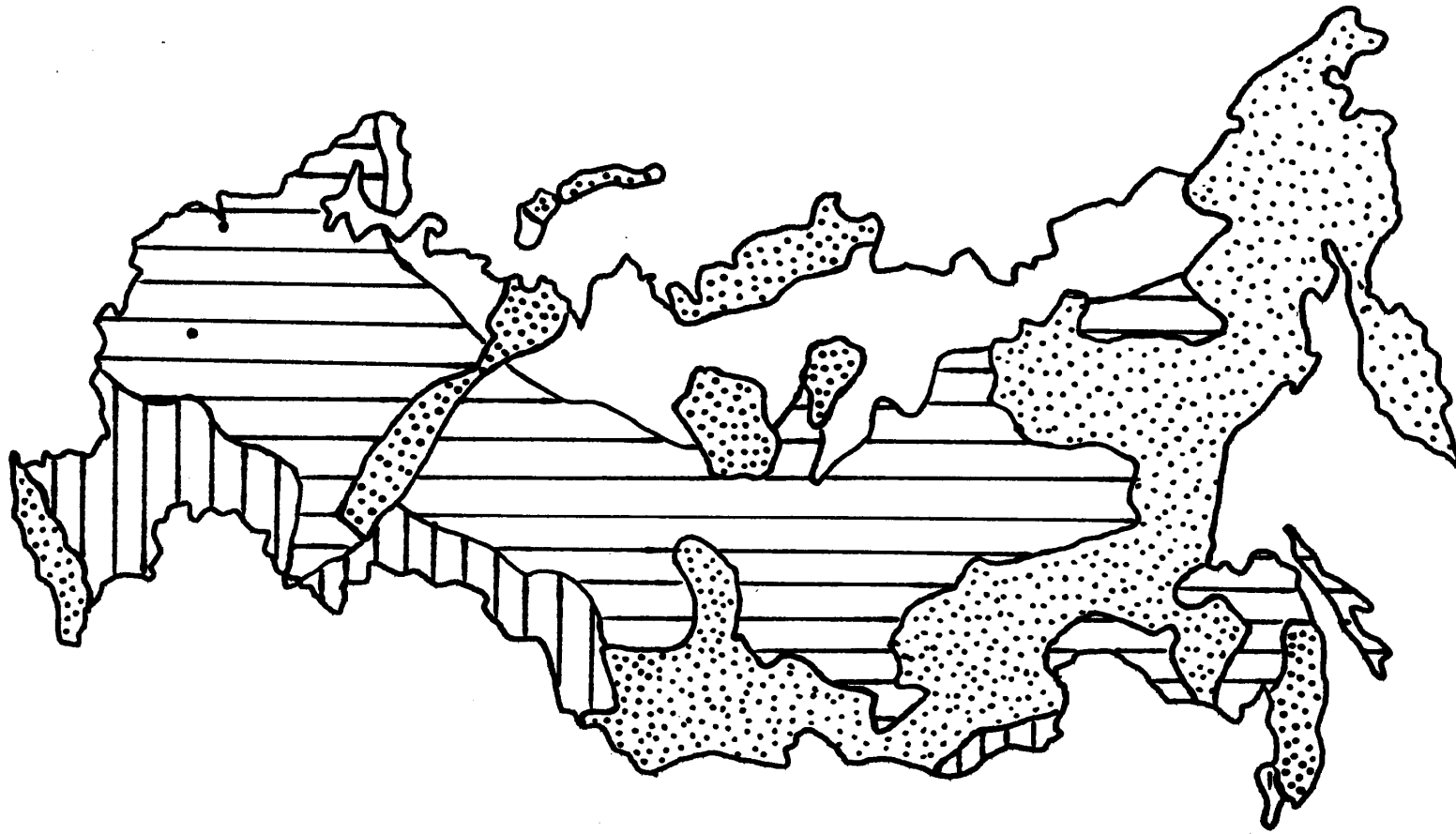


Figure 2: Russian ecozones



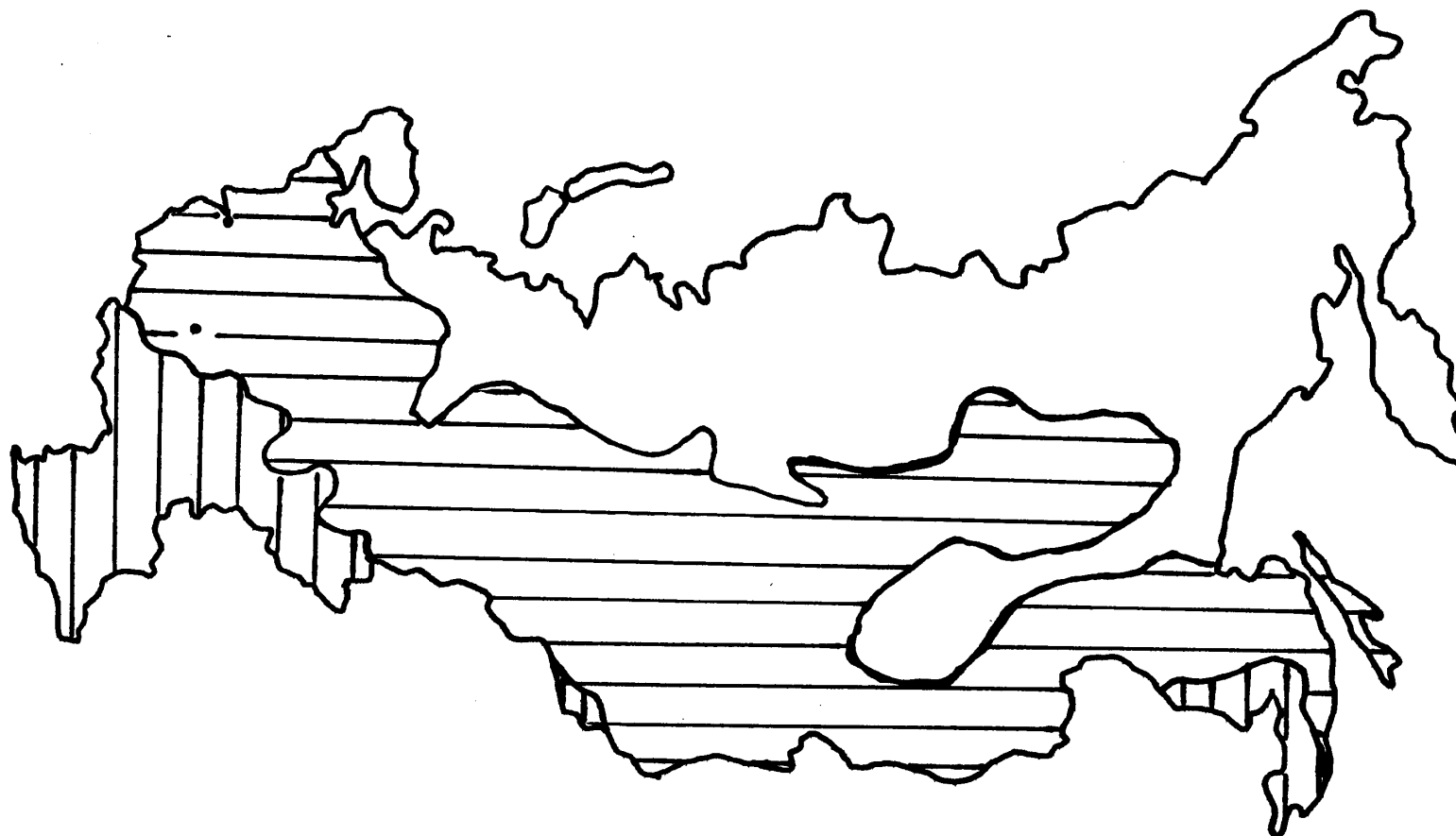





Figure 3: Regional distribution of the sum of temperatures in Russia

  $\Sigma T \leq 1000^\circ\text{C}$

  $1000 \leq \Sigma T \leq 2200$

  $\Sigma T \geq 2200^\circ\text{C}$

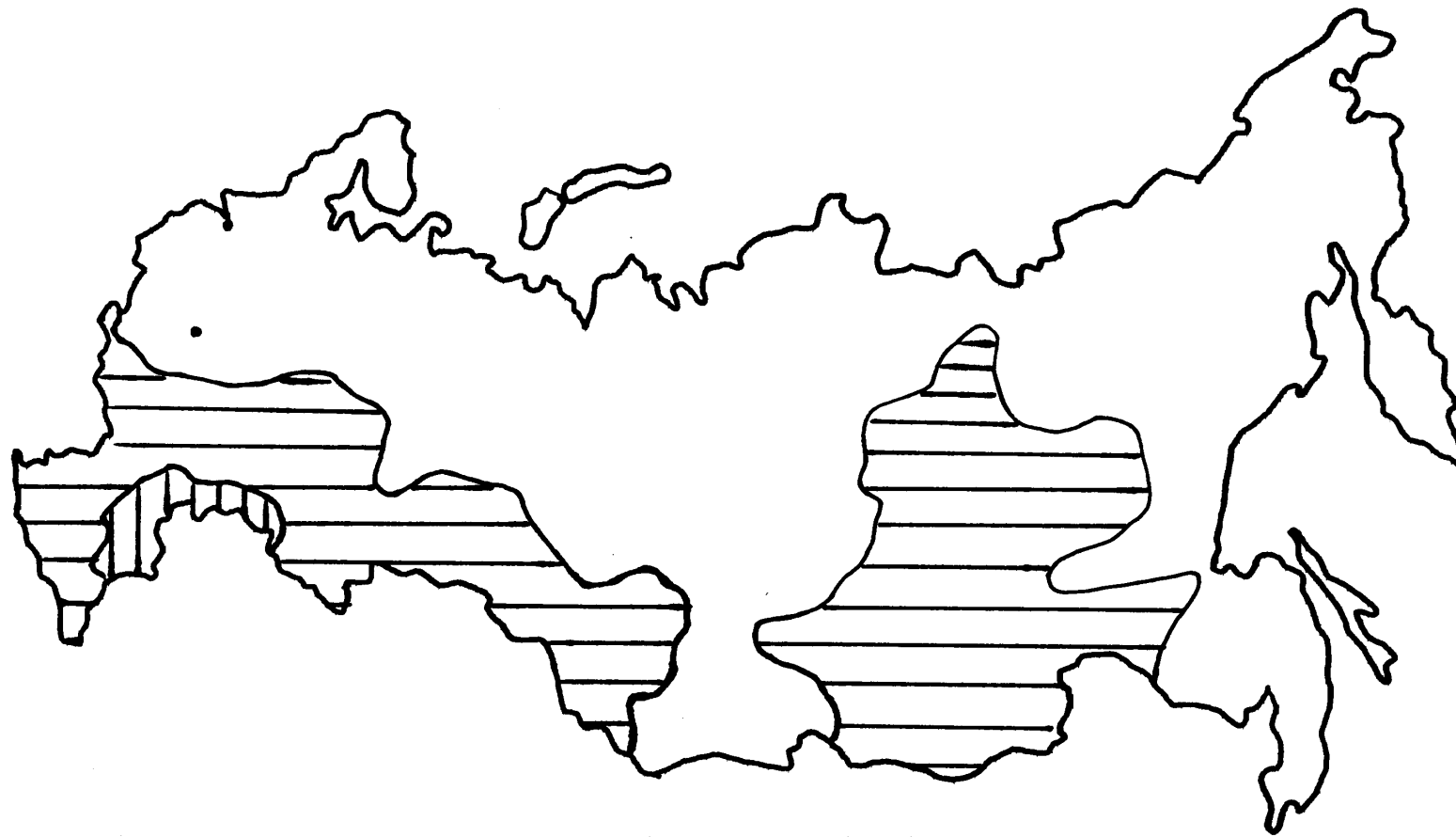
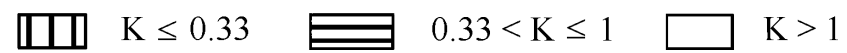


Figure 4: Annual precipitation: potential annual plant evaporation ratio (K) in Russia



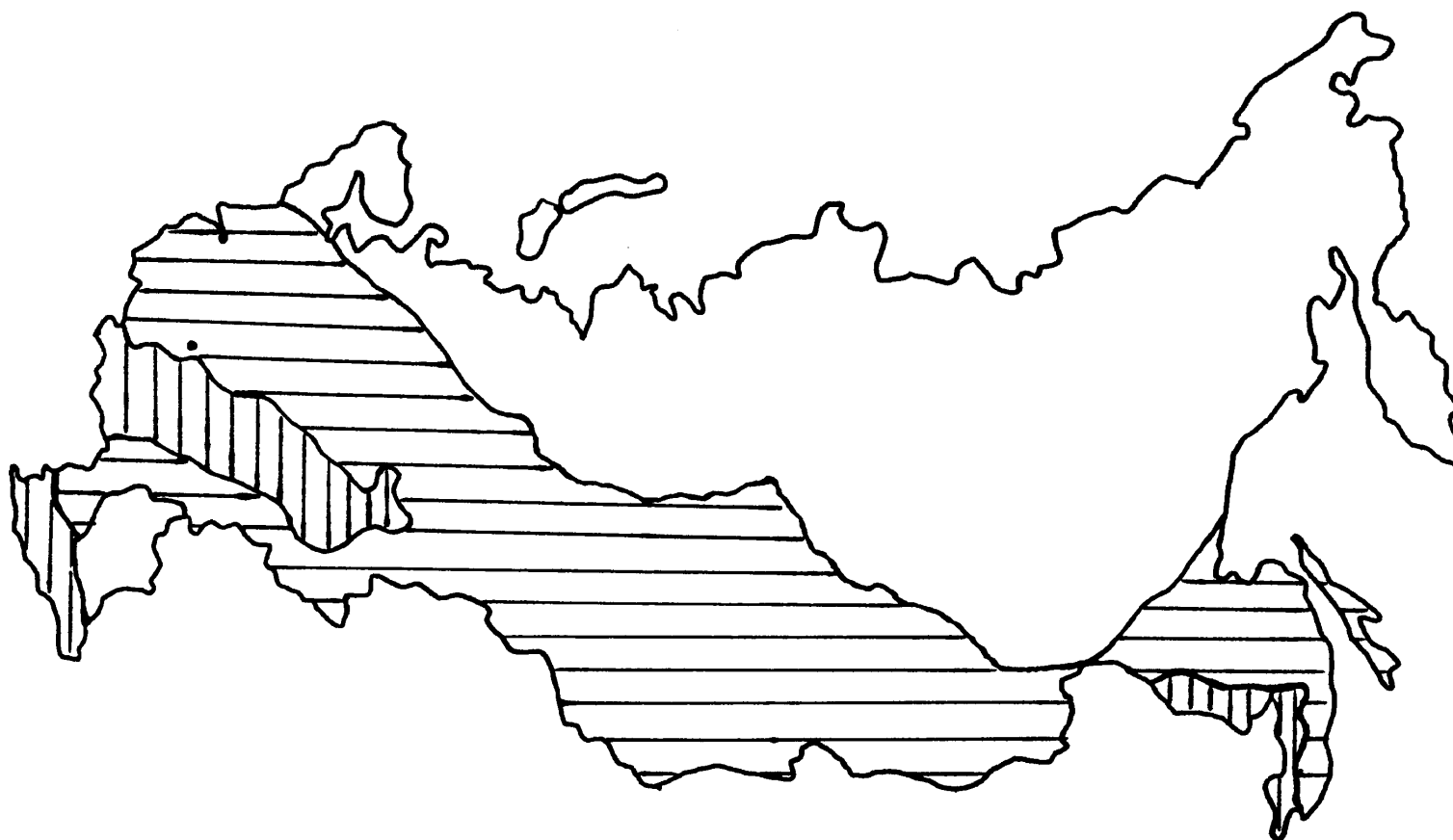
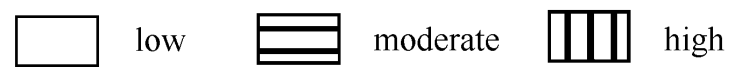


Figure 5: Biological efficiency of climate in Russia



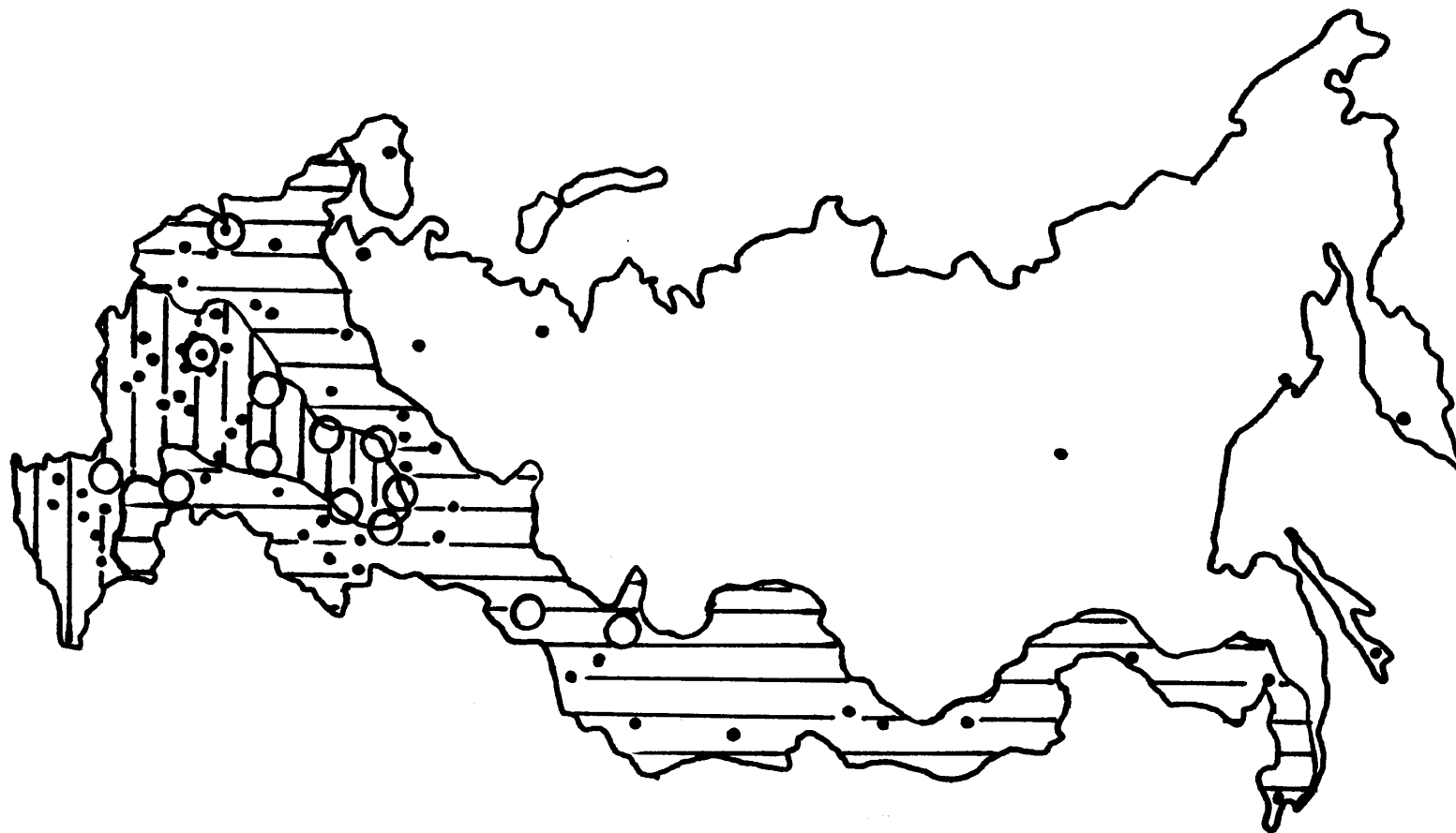





Figure 6: Population density of Russia

Rural:  less than 1 inh./km<sup>2</sup>     from 1 to 10 inh./km<sup>2</sup>     more than 10 inh./km<sup>2</sup>  
Urban:    • from 0.1 to 1 mill. inh.    ○ more than 1 mill. inh.



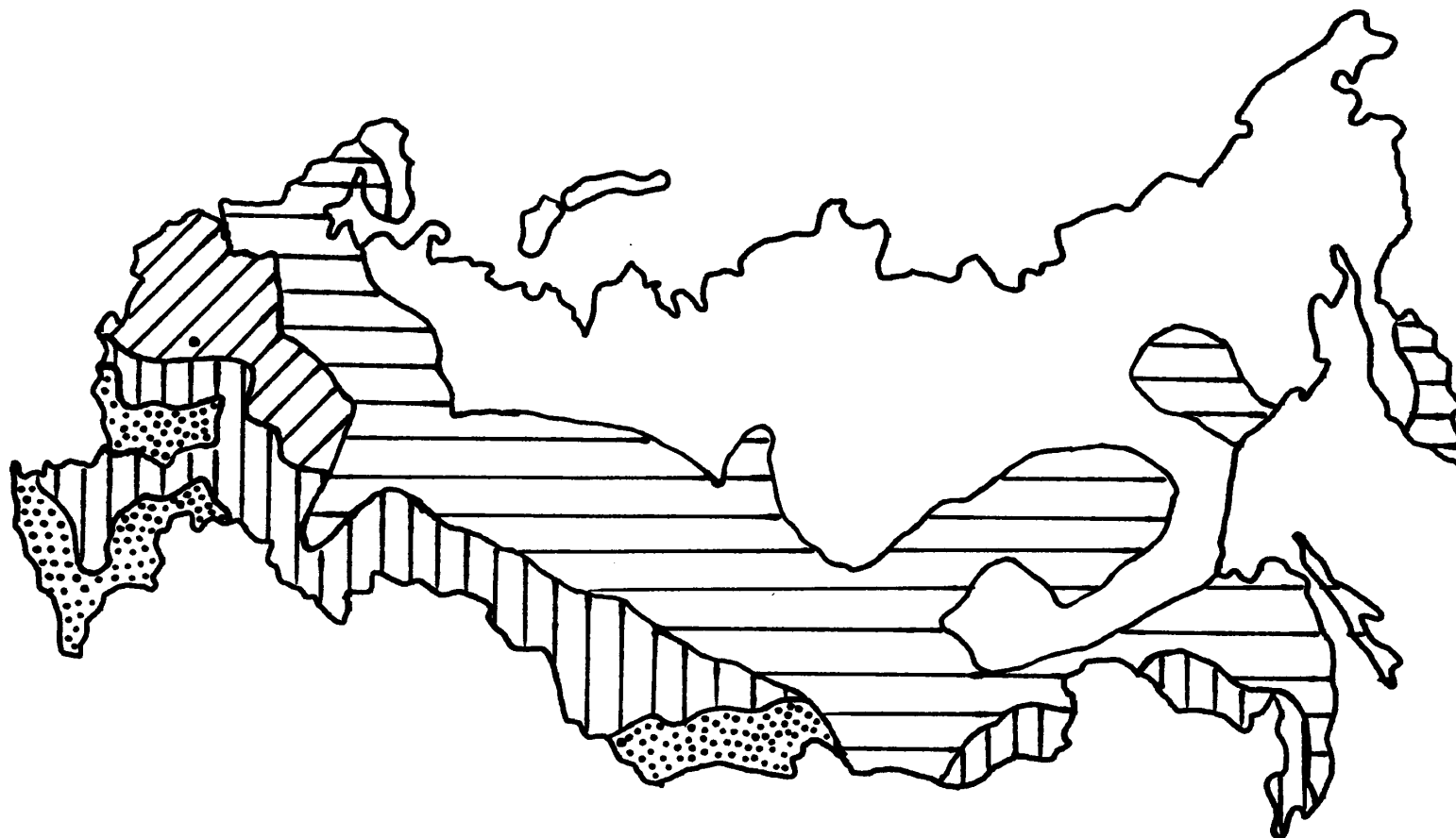
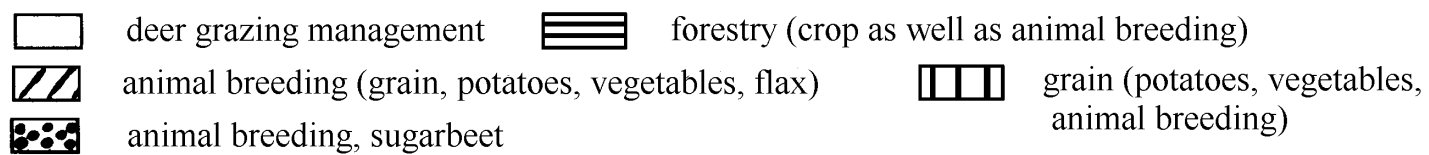


Figure 7: Agrarian structure of Russia



Note: Main activity or crop (in brackets: secondary activity or crop)



Figure 8: Air pollution and radioactive contamination

• urban-industrial air pollution      ○ radioactive contamination  
▭ radioactively contaminated lands as a result of the Chernobly accident

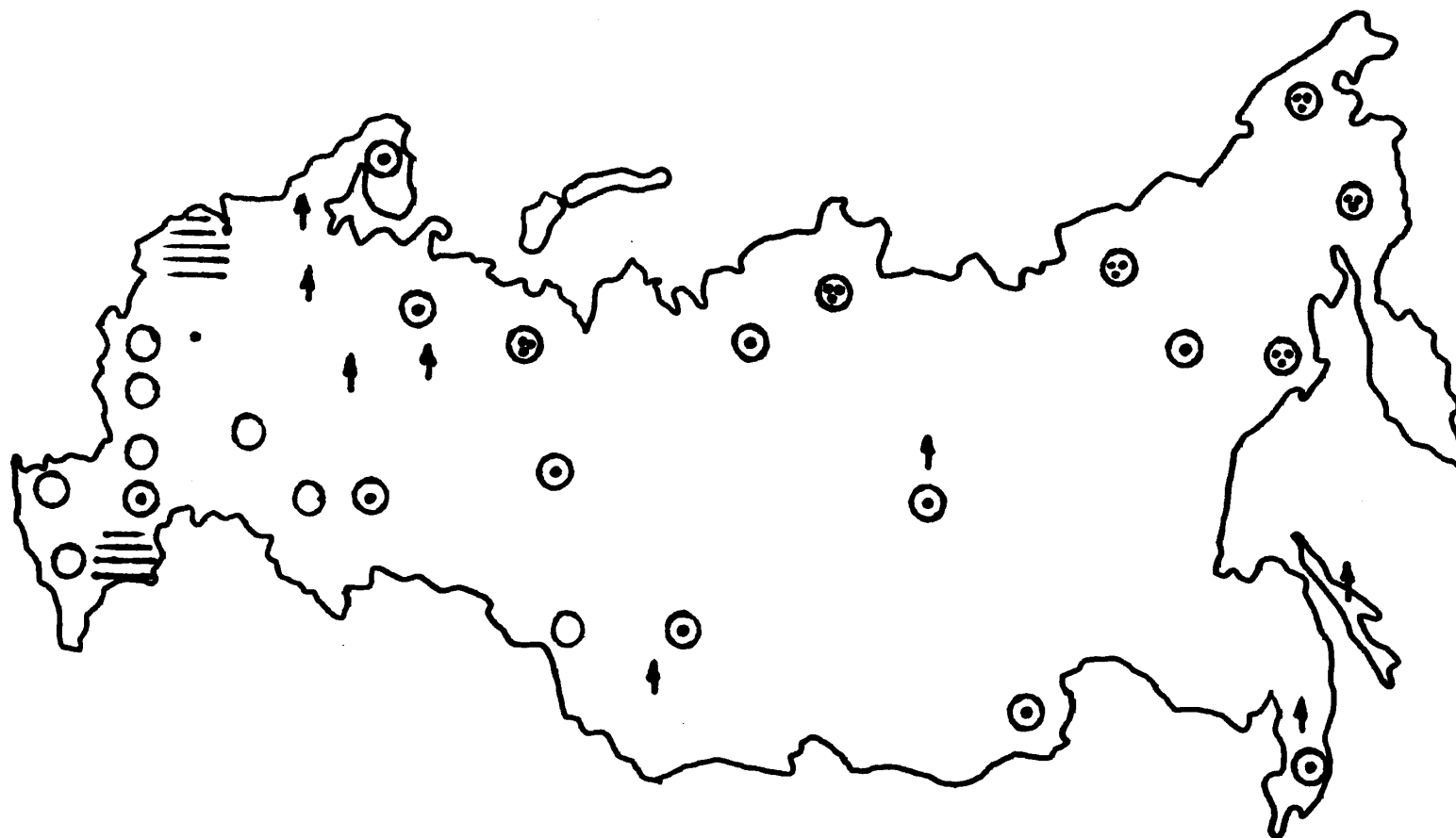


Figure 9: Land degradation processes in Russia

- |   |   |   |                                     |   |              |
|---|---|---|-------------------------------------|---|--------------|
| ⊕ | heavy grazing (trampling, overgrazing)  | ↑ | forest decline                      | ○ | soil erosion |
| ⊙ | land destruction (mostly due to mining) | ≡ | soil acidification and salinisation |   |              |

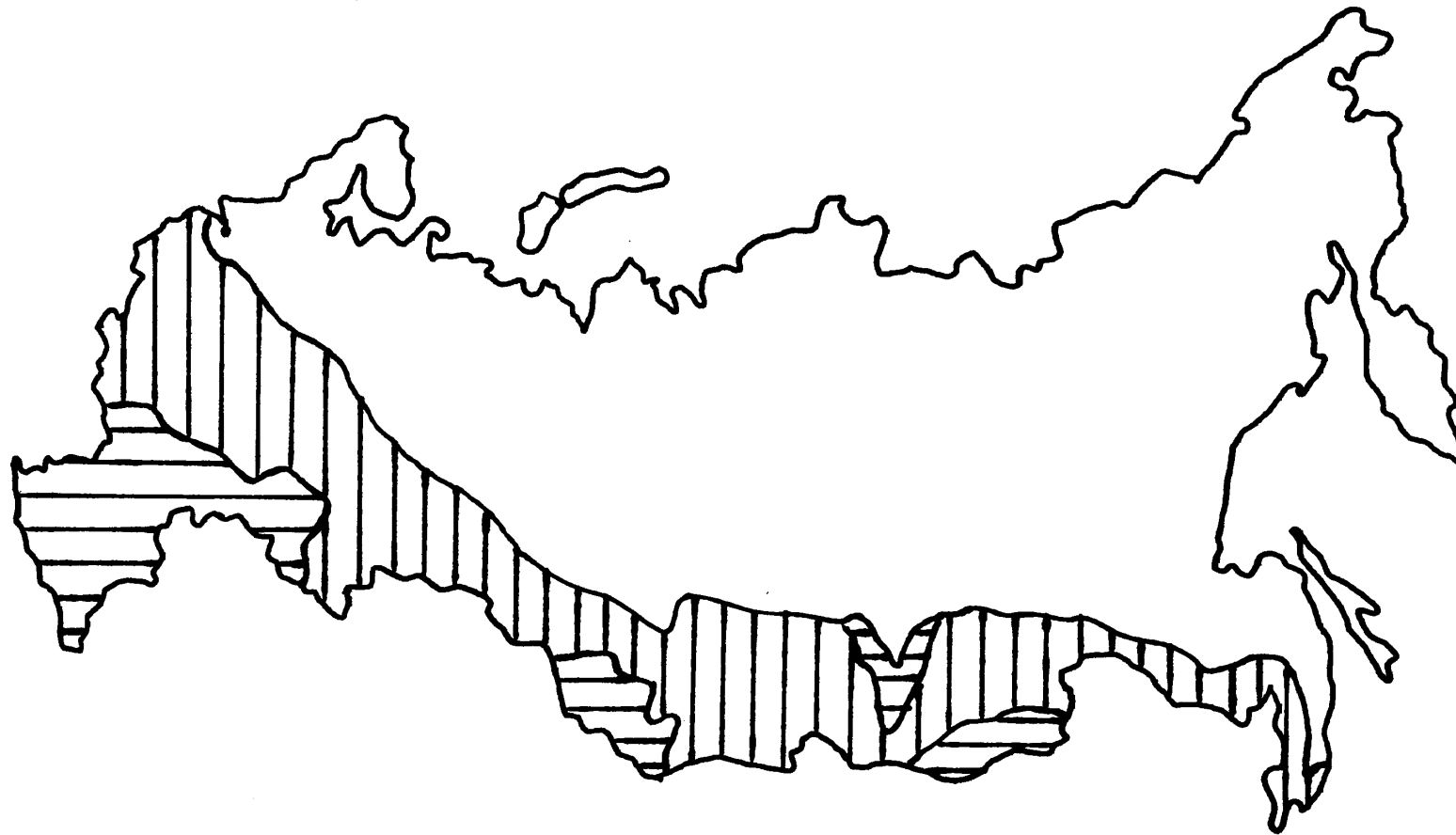
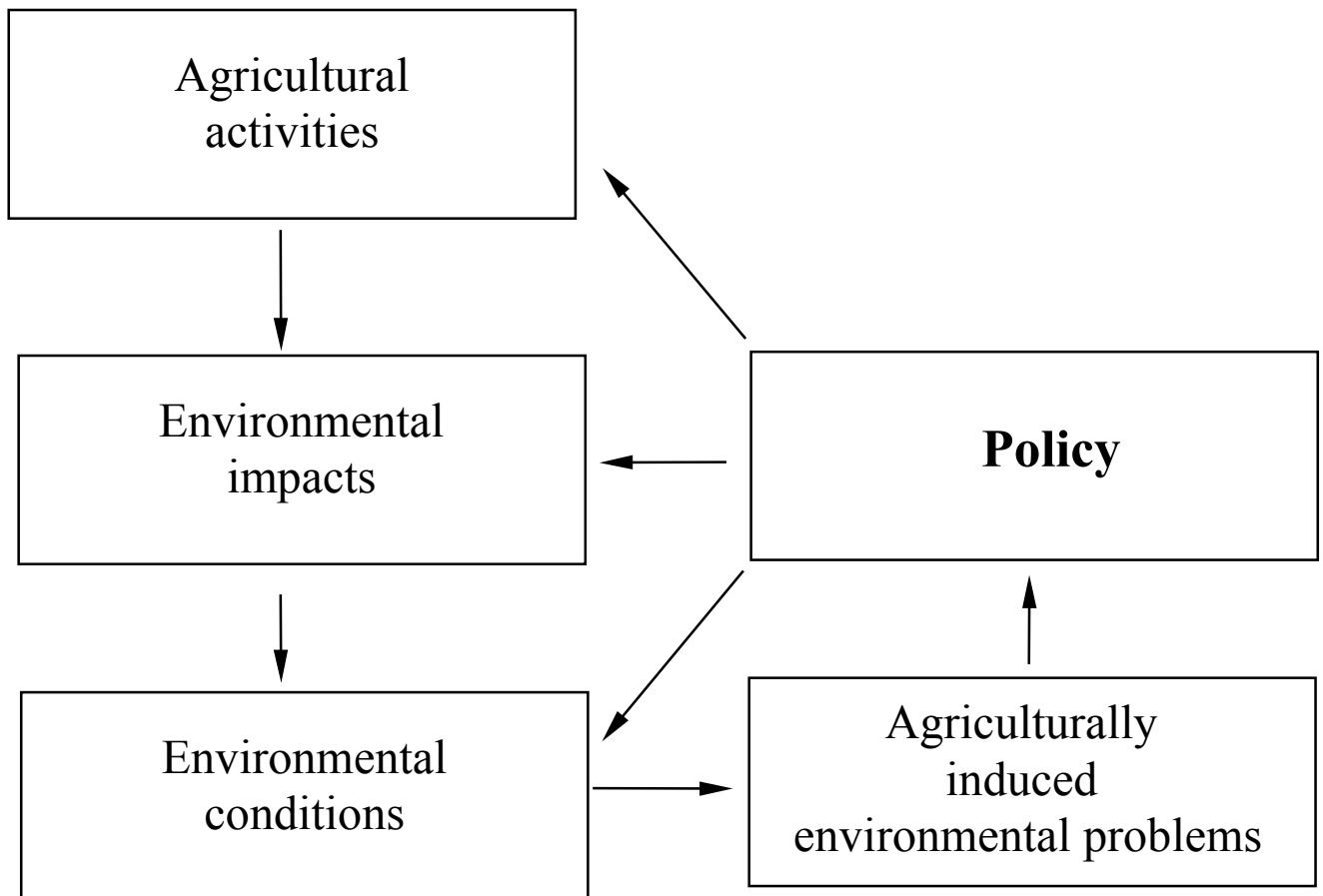


Figure 10: Land area of Russia affected by agriculturally induced soil erosion

 water erosion       wind erosion

Figure 11: Framework of possible interactions of policies with the environment



Source: Own figure.

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