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## Abstract

The document contains an overview of the agricultural production and environmental status, data collection and initial processes, and identification of major drivers of agriculture and environment trend. The time horizon of the report is the period 1990-2010. The information and the analysis in this report are mainly at the country level.

## Executive Summary

The aim of D5.2 is to lay a basis for the modeling analysis of agri-environmental trend in the Black Sea region. D5.2 is the outcome of the first part of WT5.3 Agriculture. The second part of WT5.3 will feed the data and information from the first part to the GEPIC (or SWAT) model to analyze the agri-environment under the status quo conditions and under different scenarios concerning changes in various influencing factors. The outcome of the second part of WT5.3 will be reported in D5.5 (month 36). The current report (D5.2) contains an overview of the agricultural production and environmental status, data collection and initial processes, and identification of major drivers of agriculture and environment trend. The time horizon of the report is the period 1990-2010. The information and the analysis in this report are mainly at the country level.

The raw data for the modeling analysis of the Black Sea region's agri-environmental trend will be partially provided by WP3 and WP4. However, a substantial part of the base data is collected by the partners involved in WT5.3, i.e., Eawag, IGAR and OUN. The information collected by these partners mainly concerns the anthropogenic aspects of agricultural and environmental data. This is complementary to the data provided by WP3 and WP4 where land use and hydrological information mainly concern the physical statues of the elements with their natural boundaries or on grid cell scale. The data collected by the partners in WT5.3 cover the following aspects: landuse structure, water use in agriculture, agricultural population, irrigation areas, fertilizer production and consumption, crop areas and production, agricultural trade, rural labor force, and social-economic statistics.

The Black Sea catchment area covers entirely or partially 23 countries. Of which, six countries are located in its coastal zone and 17 countries are closely linked with the sea via the rivers that flow into the sea. In this report, we focus on the countries located in the coastal zone with a substantial part of the national territories falling within the Black Sea catchment. The countries included are: Romania, Ukraine, Turkey, Bulgaria and Georgia. As the agroecosystems and farming conditions within the region vary widely, the baseline analysis in this report is conducted at both the regional level, and at the case study level focusing on Romania and Ukraine.

Agriculture is an important sector in the Black Sea region. The region has relatively favorable land and water endowments. Currently, the agricultural productivity is low compared with its western European counterparts as well as the world average. The potential for increasing production is therefore considered to be high. It is expected that the region's agricultural production will increase in the coming years in the wake of the recent hike of the world food prices. Some projections have shown that the region has the potential to be a food exporter, especially to the Middle Eastern and North African countries (MENA).

The Black Sea is vulnerable to pressures from land-based pollution in its catchment areas (UNEP, 2005). Agriculture is one of the major sources of pollutions to the water bodies in the region, particularly to the Black Sea coastal ecosystems. The pollution was reduced during the 1990s following the collapse of the former Soviet Union. With the recovery of the agricultural production in the region in recent years, the pollution to the water bodies is likely to increase.

With the information collected and processed in the first part of WT5.3 and reported here, a large scale crop model, GEPIC (or SWAT), will be applied in the next step to analyze the impacts of various factors on crop yield, water use, and environment in the Black Sea region. To facilitate the application of the GEPIC and SWAT models, several training workshops on the models were held during the last 24 months for the partners participating in the project. The workshops also serve as a platform for capacity building beyond the project.

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# 1. Introduction

## 1.1. Importance of agriculture in the region

The Black Sea region has always been an important trade crossroad between Europe and Asia. The region is a unique combination of EU Member States and Non-member States. Sustainable agriculture in the region is a shared concern between the EU and the Black Sea region. The region is considered to have major potentials in agriculture and energy. Understanding its agricultural and environmental trend provides basis for the protection and sustainability of the agriculture and environment in the region.

The countries in the Black Sea catchment are characterized by varying degrees of economic development, including great disparities in national GDP in terms of absolute figures, per capita values, sectoral compositions and annual growth. Table 1 shows the total and agricultural GDP as well as the % contribution of agriculture to total GDP. In Figure 1, the trend in the contribution of agriculture (in %) to total GDP is shown. Most countries, except Romania, show a decreasing trend from 2000 to 2007. Since 2007 the share of agriculture seems to be growing again.

**Table1. Economic structure of the Black Sea Countries in 2009**

| Countries | Total population ($\times 10^3$) | Total GDP* (Million $ constant 2000 prices) | Per capita GDP ($ constant 2000 prices) | Agriculture GDP (Million $ constant 2000 prices) | Share of agriculture in total GDP (%) |
|---|---|---|---|---|---|
| Bulgaria | 7545 | 18606 | 2466 | 1238 | 7 |
| Georgia | 4260 | 5256 | 1234 | 775 | 15 |
| Moldova | 3604 | 1973 | 548 | 327 | 17 |
| Romania | 21275 | 55997 | 2632 | 8175 | 15 |
| Turkey | 74816 | 357285 | 4776 | 29714 | 8 |
| Ukraine | 45708 | 45394 | 993 | 6149 | 14 |
| | | | | | |
| EU | 496435 | | | | |

* Total GDP is calculated by Per capita GDP multiplying population

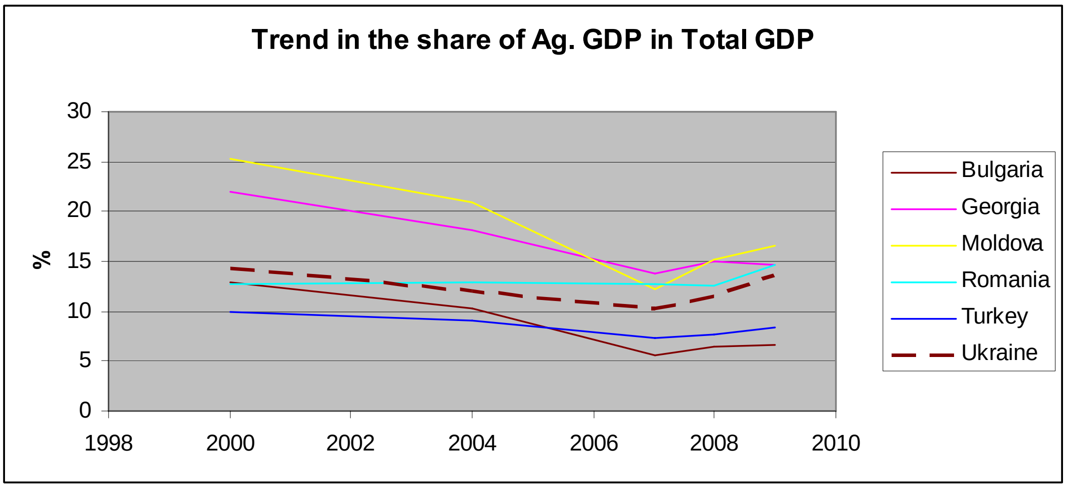



**Figure 1. The trend in the % contribution of agriculture to total GDP**

The trend in agricultural and total GDP from 1990 to 2009 is also given in Table 2. The trend shows a large disparity in growth with Turkey having the largest share of growth while Moldova stagnating in growth.

**Table2. Changes in agricultural and total GDP (1990-current) Total GDP (Million$ constant 2000 prices )**

| Countries | 1999-2001 | 2003-2005 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Bulgaria | 12516 | 15286 | 18481 | 19592 | 18606 |
| Georgia | 3085 | 4017 | 5351 | 5475 | 5256 |
| Moldova | 1305 | 1691 | 1957 | 2110 | 1973 |
| Romania | 37518 | 46495 | 55927 | 61199 | 55997 |
| Turkey | 255908 | 306426 | 372619 | 375074 | 357285 |
| Ukraine | 31687 | 42915 | 52368 | 53467 | 45394 |

## 1.2. Importance of agriculture of the region in the EU and the world

The importance of agriculture in rural activity differs among the countries in the region. One of the most important factors affecting the Black Sea countries' production and trade of grain is productivity. The productivity growth is likely at a moderate pace. As a result, the Black Sea region is most likely to become a medium-sized food exporter in the future. In Table 3 land and water resources are compared in different Black Sea countries, while Table 4 compares the agricultural production. An interesting observation is the relationship between total GDP and water resources. Figure 2 shows that the region has a relatively good water endowment. There is no major water limitation as far as agricultural production is concerned. Indeed, Turkey with one of the smallest water resources per capita has the largest agricultural GDP. In general, water resources per capita of larger than 1500 $m^3$ indicates no water stress (Yang et al., 2002).

**Table 3. Land and water resources of the region (2008)**

| Countries | Total Area (1000 ha) | Arable land (1000 ha) | Arable land per capita (ha/capita) | Water resources ($km^3$/year) | Water resources per capita ($m^3$/year/capita) |
|---|---|---|---|---|---|
| Bulgaria | 11091 | 3061 | 0.4057 | 21 | 2823 |
| Georgia | 6970 | 468 | 0.1099 | 63 | 14866 |
| Moldova | 3370 | 1822 | 0.5055 | 12 | 3233 |
| Romania | 23750 | 8721 | 0.4099 | 212 | 9960 |
| Turkey | 78058 | 21555 | 0.2881 | 214 | 2855 |
| Ukraine | 603623 | 32474 | 0.7105 | 140 | 3054 |

**Table 4. Agricultural production in the region (2009)**

| Countries | Total cereal production (1000 tones) | Per capita cereal production (tones/cap) | Wheat (tones) | Maize (tones) |
|---|---|---|---|---|
| Bulgaria | 6'243 | 0.827447051 | 3976852 | 1290833 |
| Georgia | 372 | 0.087237089 | 53800 | 290300 |
| Moldova | 2131 | 0.591287458 | 735000 | 1140000 |
| Romania | 14'874 | 0.699124512 | 5202526 | 7973258 |
| Turkey | 33'570 | 0.448695827 | 20600000 | 4250000 |
| Ukraine | 45'406 | 0.993392842 | 20886400 | 10486300 |
| | | | | |
| EU (15) | 298151 | 0.600584165 | 138725136 | 57778082 |
| World | 2'489'302 | 0.364499886 | 681915838 | 817110509 |

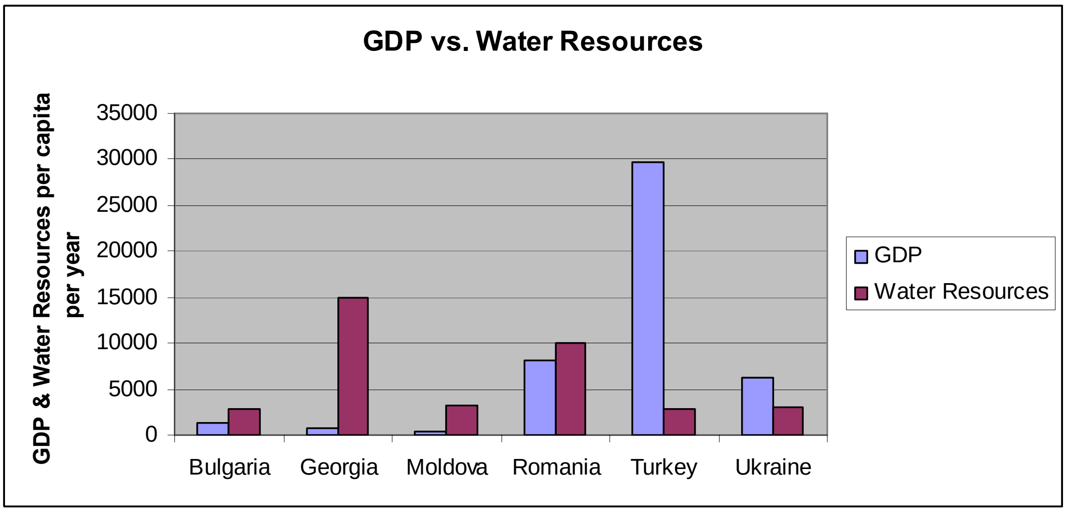



**Figure 2. Plot of agricultural GDP and water resources does not show a good correlation for the countries studied. This indicates water resources not being a limiting factor for agricultural production.**

### 1.3. Environmental status and pollutions relating to agricultural activities

The Black Sea area is a major industrial and agricultural region, with uncontrolled urban development. In coastal areas there are discharges from rivers, industry, agricultural pollution and domestic sewage. The Black Sea's Marine Ecosystem (BSMES) has a huge drainage basin of around 2,000,000 km$^2$. There is an acceleration of eutrophication due to excessive levels of nitrogen loading. The combination of eutrophication and uncontrolled fisheries has caused important alterations in the structure and dynamics of this BSMES. The almost entirely enclosed nature of the BSMES contributes to the eutrophication problem. There is decreasing transparency of Black Sea waters. Beaches are littered, and there are regular beach closures due to sewage discharge problems. There is a growing risk of losing valuable habitats in these areas. While there is little data on toxic contamination and heavy metal accumulation, the Mussel Watch program (http://www.ciesm.org/marine/programs/musselwatch.htm) (Thebault and Rodriguez

Baena, 2007) in each of the six countries assesses areas with high pollution. A chemical pollution study for the Black Sea was completed by 98 Black Sea scientists. This resulted in the publication of a "State of Pollution of the Black Sea" report. Oil pollution comes from land-based sources, and from shipping. There has been a rapid increase in traffic in Black Sea ports, and an oil spill occurred in 1994 when the "Nassia" collided with an empty freighter. A report on Black Sea Pollution leading to the depletion of fishing stocks raised international concern. In the 1970s and 1980s there were frequent explosions of phytoplankton and jellyfish (***Aurelia aurita***). Blooms and red tides have been reported in the northern and western sections of the Black Sea. The Global International Waters Assessment (GIWA) has issued a matrix that ranks BSMES according to pollution. GIWA characterizes the BSMES as severely impacted in terms of eutrophication and ecotone modification. However, these impacts are not increasing, according to GIWA (http://www.unep.org/dewa/giwa/areas/reports/r22/giwa_eutrophication_in_blacksea.pdf) A series of small Global Environmental Facility (GEF) projects have focused on reducing nitrogen loadings from the 17 contributing nations of the Black Sea basin. Following the successful completion of a Trans-boundary Diagnostic Analysis (TDA) and a Strategic Action Program (SAP) in the 1990s, there is a political commitment to reduce nutrients and abate persistent toxic substances being released from hotspots. Agriculture pollution is being reduced, and wetlands are being restored in the upstream basins to serve as nutrient sinks to protect the BSMES. A GEF Strategic Partnership was in place for 2001-2006, to assist the 17 nations.

### 1.4. Structure of the report

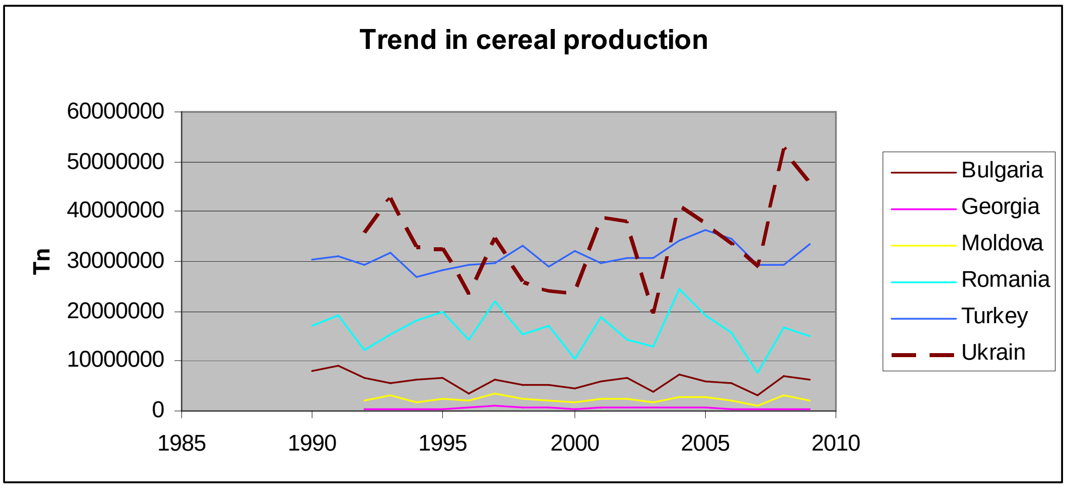
The rest of the report is organized as follows: Section 2 provides an overview of the agri-enviornmental trends in the region; Section 3 first introduces the large scale crop models applied in the literature. This is followed by a detailed introduction of the GEPIC and

SWAT models and their applications for the tasks in WT5.3; Section 4 provides an overview of the data collected for the modeling analysis; Section 5 contains two detailed case studies for Romania and Ukraine. Section 6 provides a brief summary of the report.

## 2. Overview of agricultural trend and environmental status in the region

### 2.1. Trend in agricultural production

Figures 3 shows the trend in cereal, wheat, maize and meat production for some example countries in the region. As illustrated, the cereal production has stayed constant for most countries with some recent increases in Ukraine, while meat production has decreased in Ukraine with Turkey showing an increasing trend. Maize production has seen a steady increase in Ukraine, which shows the most volatility in all productions.



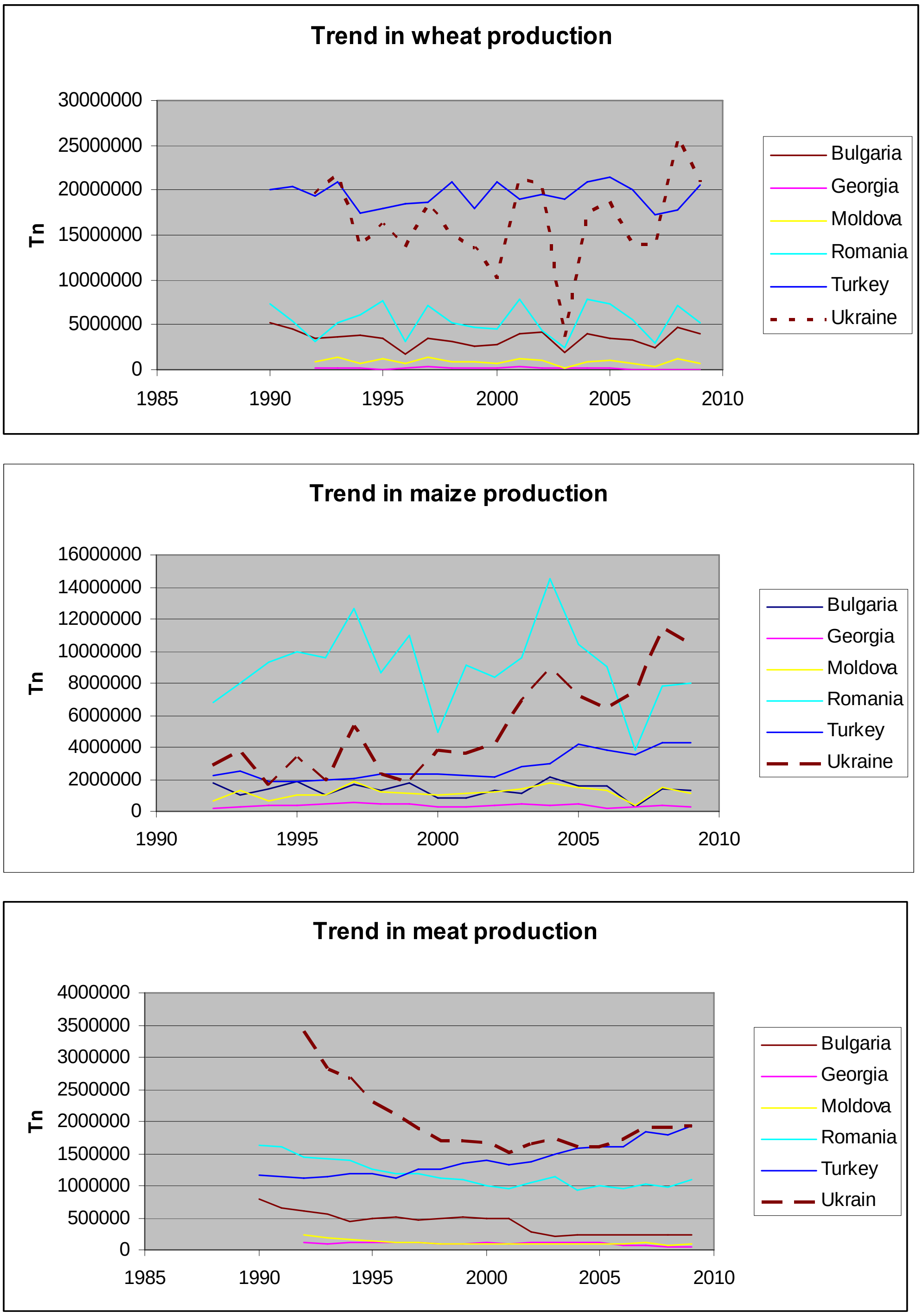


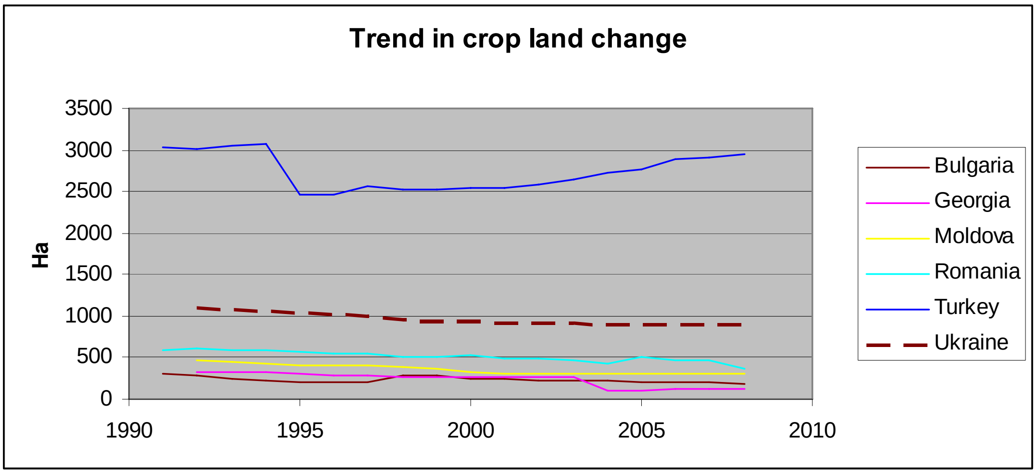

**Figure 3. Trends in cereal, wheat, maize, and meat production in some Black Sea countries**

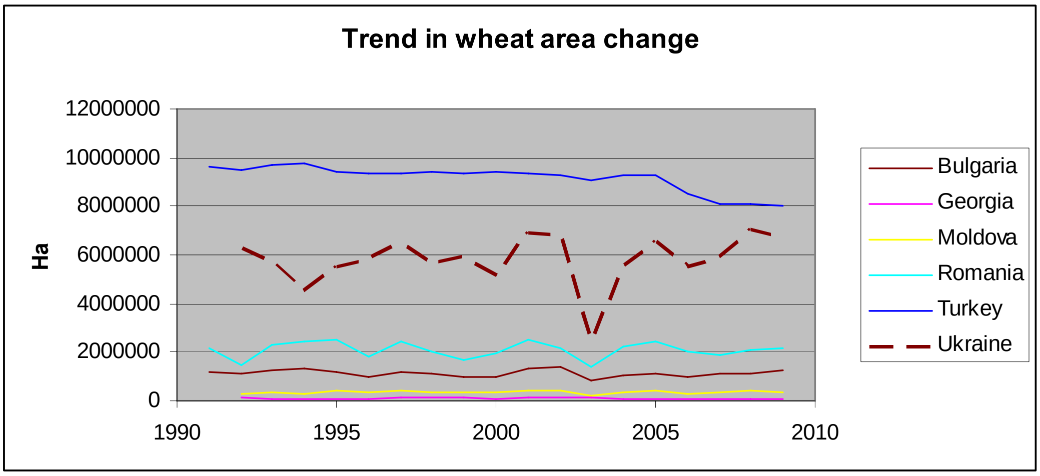
## 2.2 Agricultural land use and crop area changes

The structure of land cover is given in Table 5. Agricultural landuse has been rather constant in all countries as shown in Figure 4. Ukraine has the largest size of arable land and the largest per capita arable land (Figure 4), hence, the largest production as indicated in Table 4.

**Table 5. Structure of land cover/use (2008)**

| Countries | arable land (1000 ha) | permanent crop (1000 ha) | pasture (1000 ha) | Forest area (1000 ha) |
|---|---|---|---|---|
| Bulgaria | 3'061 | 184 | 1'929 | 3816.6 |
| Georgia | 468 | 115 | 1'940 | 2747 |
| Moldova | 1'822 | 303 | 360 | 376.8 |
| Romania | 8'721 | 375 | 4'450 | 6500.2 |
| Turkey | 21'555 | 2'950 | 14'617 | 11096.4 |
| Ukraine | 32'474 | 900 | 7'918 | 9653 |



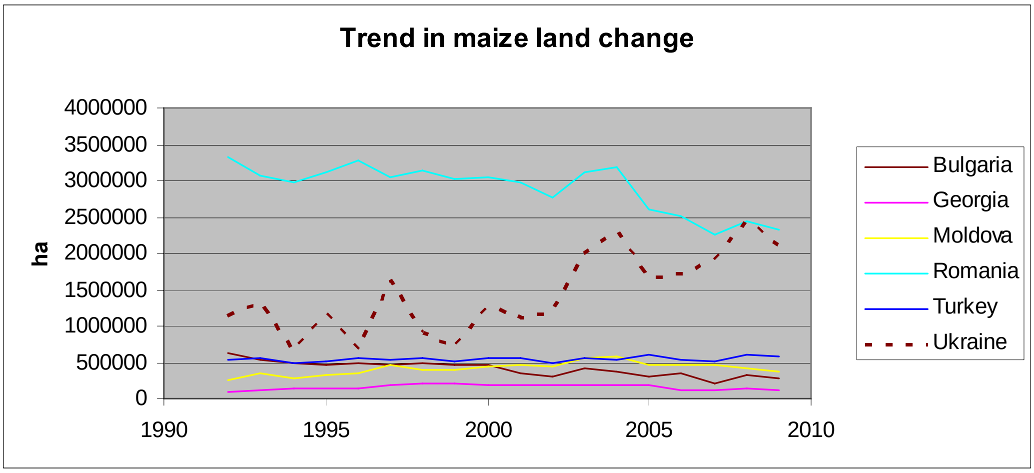




**Figure 4. The trend in agricultural landuse change showing crop lands, wheat, and maize**

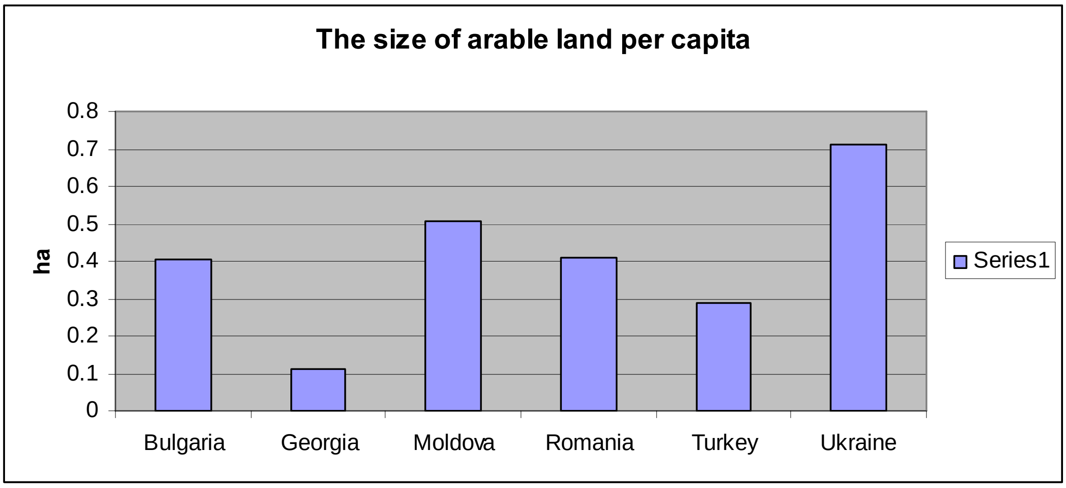



**Figure 5. Showing the size of arable land per capita**

## 2.3. Water endowments and water use in agriculture

Agriculture is an important sector in terms of total water use in the Black Sea region. In many areas, crop yield has been boosted over the last decades by newly established irrigation schemes. Increasing water withdrawal in many areas has caused environmental problems such as lower water tables, salinization and damage to terrestrial and aquatic habitats due to the installation of dams and reservoirs. In some areas, this has led to overexploitation of surface and groundwater resources. This may constrain agriculture and yields. The problem may be aggravated by climate change which already has led to severe droughts in the region in recent years.

In Ukraine, until 1992 irrigation infrastructure was installed on a total area of 2,624000 ha. The highest construction rate of irrigation systems was registered between 1965 and 1985. After 1992 the construction of new irrigation systems was virtually stopped and several of the existing schemes went out of operation. While the area actually irrigated was still 2,291,600 ha in 1990, it decreased to 1,845,100 ha in 1995, 1,402,700 ha in 1998 and only 543,300 ha in 2001. In 2002 area actually irrigated was 730,100 ha and in 2003 it was 731,400 ha. The reported lack of government funds to provide for proper operation and maintenance of the irrigation canals (total length 59,300 km), pumping stations (in total 13,700) and other hydro-technical constructions (in total 475,000) indicates that the area actually irrigated will, at least in the near future, very likely not reach the extent observed in the beginning of the 1990s again.

In Romania, the total agricultural land reclaimed for irrigation reached its maximum in 1996 at 3,210,000 ha and declined later to 3,176,000 ha in 2003.

As Turkey has the smallest water resources in the region, its irrigation is constraint by its water resources. For this reason it requires new water resources. The area equipped for irrigation in Turkey was 4,185,910 ha in 1994. The area actually irrigated was 3,143,000 ha in 1994.

In Bulgaria, the area equipped for irrigation was 1,288,000 ha in 1990 but declined later to 673,000 ha in 1995 and 545,160 ha in 2003. Even stronger was the decline in the area actually used for irrigation. While in 1985 about 1,014,000 ha of cultivated land was irrigated the area actually irrigated declined to 842,000 ha in 1989, to about 100,000 ha in the period 1992-1996 and to about 40,000 ha nowadays. Large parts of the irrigation infrastructure constructed before 1990 deteriorated because of the break up of large farms and the lack of finance for restructuring irrigation systems to meet the needs of small farmers.

For Georgia, in the Soviet period, infrastructure was built to irrigate 469,000 ha of agricultural land, mainly located in the more arid east of the country. In the 1990s, civil strife, war, vandalism and theft, as well as problems associated with land reform, the transition to a market economy, and the loss of markets with traditional trading partners, contributed to a significant reduction in the irrigated area. It has been reported that only about 160,000 ha were irrigated during the severe drought in 2000. Almost all pumping schemes (about 143,000 ha) were out of order. Therefore, a rehabilitation program was started by Georgia's State Department of Amelioration and Water Economy to renew the infrastructure of existing irrigation and drainage schemes and to establish amelioration service cooperatives. About 255,000 ha are covered by this program. Based on these reports, the area equipped for irrigation was reduced to 300,000 ha.

## 2.4. Agricultural inputs

The quantities of inorganic fertilizers used in the Black Sea countries with transitional economies were drastically reduced in the 1990s due to high prices and to the inability of the farmers to pay for fertilizers (Fig 6). Only Turkey shows a steady increase in fertilizer use. An increase in fertilizer use from the current low levels will be substantial with the rise in the world food prices.

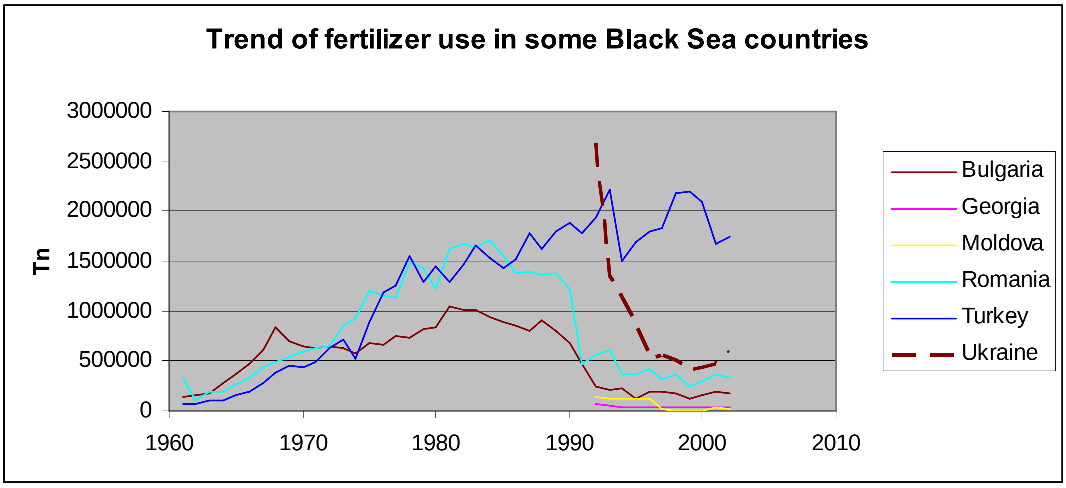



**Figure 6. Long-term trend of fertilizer use in Black Sea countries**

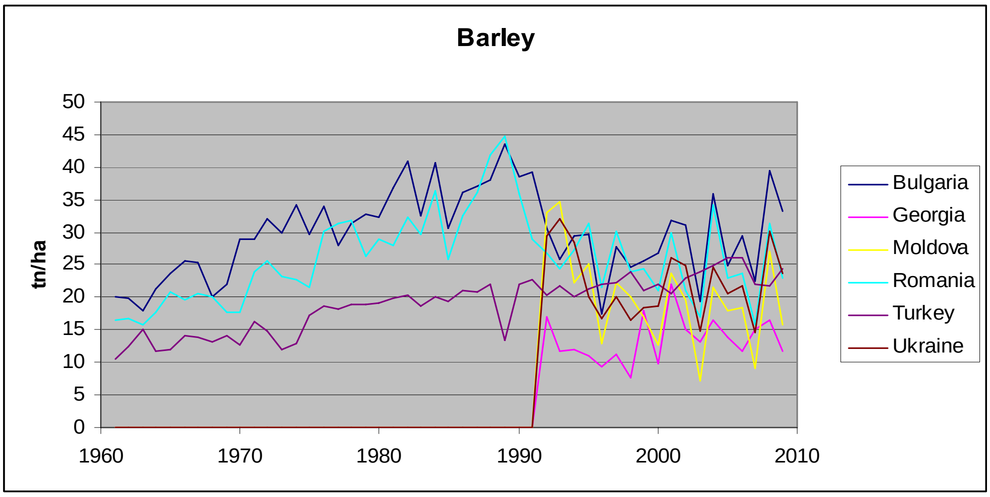
There are various reports of phytoplankton bloom in the Black Sea from year to year. (see Figure 7). The possibility of new demand for biofuels might also increase the fertilizer use. The production of biofuels could lead to significant changes in land use as well as the fertilizer use.


**Figure 7. Phytoplankton bloom in the Black Sea**

**Source (http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=16739)**

## 2.5. Crop production

Figure 8 shows crop yields for major grains for the years 1962 to 2010. The graphs show considerable variations in crop yield from year to year for most countries.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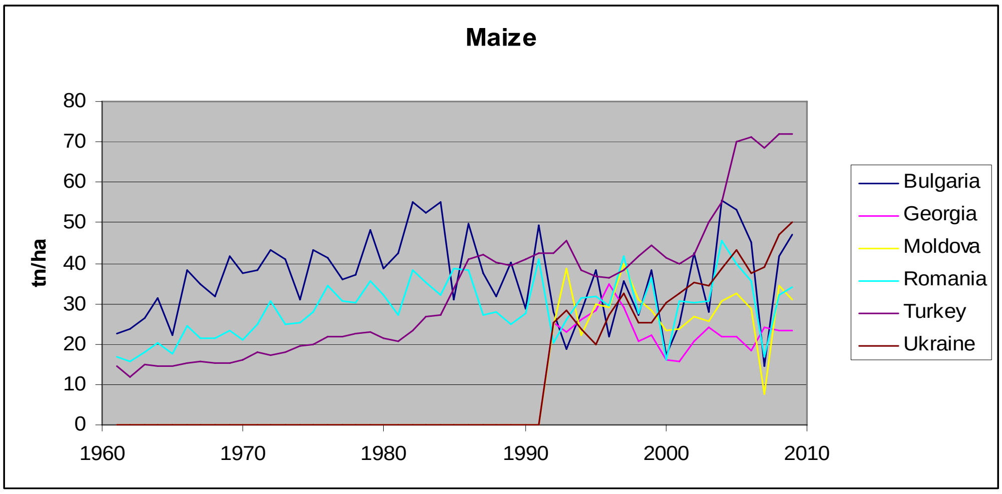
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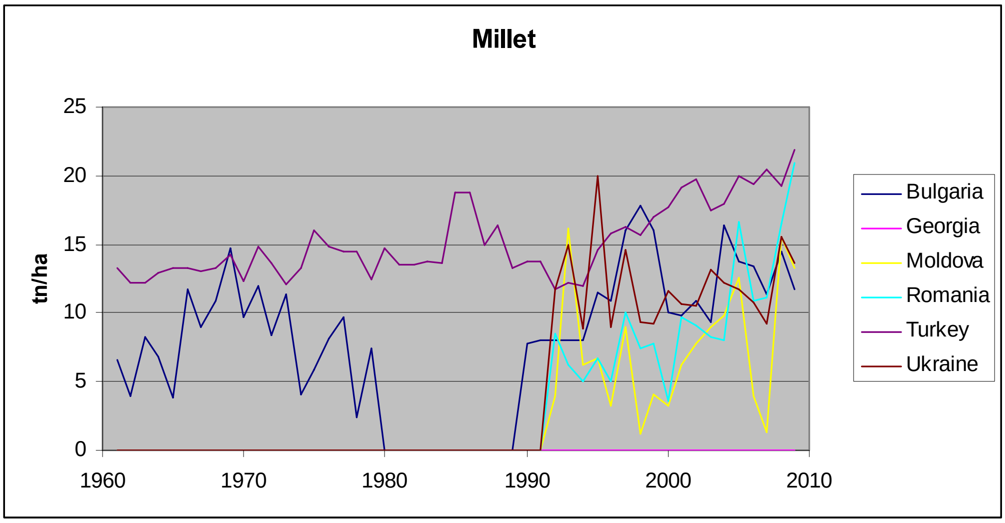
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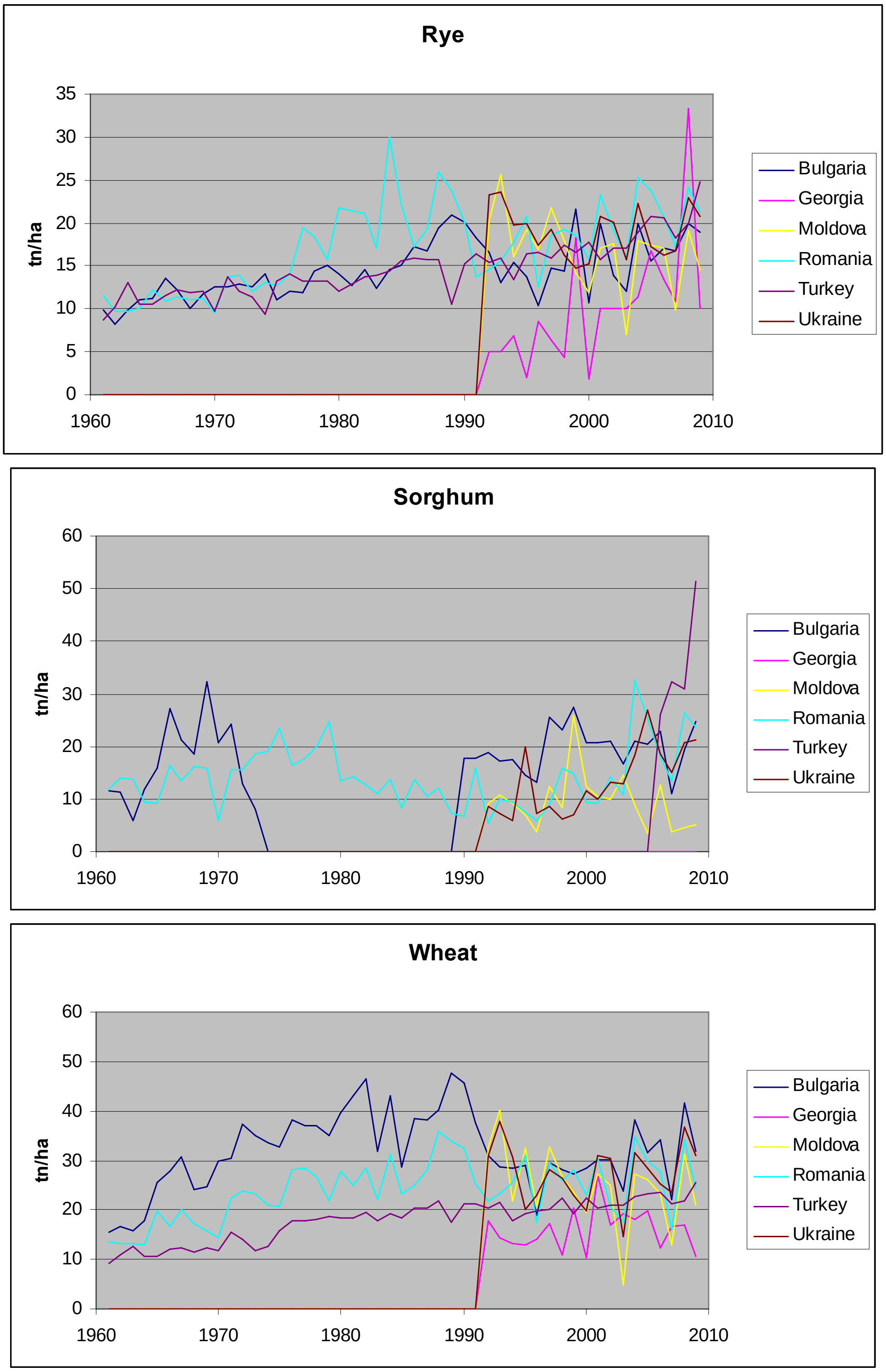



**Figure 8. Showing the trend in the yield of major grain crops**

## 2.6. Environmental impacts relating to agricultural activities

In a period of only three decades, the Black Sea has suffered the catastrophic degradation of a major part of its natural resources. Increased loads of nutrients from rivers caused an overproduction of tiny phytoplankton, which in turn blocked the light reaching the sea grasses and algae, essential components of the sensitive ecosystem of the northwestern shelf. Much of the coastal ecosystem began to collapse. This problem, coupled with pollution and irrational exploitation of fish stocks, started a sharp decline in fisheries resources. Poor planning has destroyed much of the aesthetic resources of the coastlines. Uncontrolled sewage pollution has led to frequent beach closures and considerable financial losses in the tourist industry. In some places, solid waste is being dumped directly in the sea or on valuable wetlands. Tanker accidents and operational discharges have often caused oil pollution. These problems have reached crisis proportion at a time when five of the Black Sea countries are facing an economic and social transition and therefore have difficulty in taking the necessary urgent remedial actions.

In order to make an early start to environmental action and to develop a longer-term Action Plan, the Black Sea countries requested support from the Global Environment Facility (GEF), a fund established in 1991 under the management of the World Bank, the United Nations Development Program (UNDP) and the UN Environment Program (UNEP) (http://www.unep.org/) . In June 1993, an initial Phase I three-year Black Sea Environmental Program (BSEP) (http://www.blackseaweb.net/general/enviprog.htm) was established, later phases have assured its existence up to present.

There have been some efforts in tackling the environmental problems, including pollution monitoring, emergency response, protection of biodiversity, environmental economics, integrated coastal zone management, sustainable fishery, public awareness, information exchange and data management. The Black Sea GIS was one of many products of the BSEP. Earlier products included a thorough bibliography of the Black Sea for the period from 1974-1994, bringing to light the extensive research published on the Black Sea during this particularly active score or time. Black Sea Information System (BLACKSIS) (http://www.blackseaweb.net/background2/content.htm) consists of several meta-data bases covering institutions profiles, scientists list and environmental projects description as well as description of environmental data sets available in the region. The Black Sea Environmental Internet Node (BSEIN) includes a wide range of the metadata and information relevant to the environmental conditions and research in the region. Now the Node includes these main directories: About (general information about the Black Sea), Metadata, Data, Selected Satellite Images, The Black Sea Red Data Book, Related Sites. BSEIN is located at the WWW server of the Marine Hydrophysical Institute (Ukraine, Sevastopol). The mirror-site is available recently at the server of UNEP/GRID-Geneva: http://www.grid.unep.ch/bsein/

*2.6.1. The Black Sea recovery and risk of reversal*

The Black Sea has endured serious anthropogenic pressures. Agricultural runoff together with the untreated wastewater is a major source of pollution. For example, one-third of Turkey's and Georgia's agricultural lands are in the Black Sea basin. As a consequence, agriculture has an important responsibility for maintaining or improving the quality and quantity of water resources to reach the environmental targets set for the Black Sea region.

The nutrient input into the rivers as a result of fertilizer usage was drastically extended in the agricultural sector in the 1960s until the 1990s. During the last two decades, nutrient pollution has seen a decrease. The observed reduction of the agricultural pollution to the water bodies is closely linked to the dramatically reduced use of fertilizers and the closure of large livestock farms that followed the economic collapse in central/eastern Europe in the early 1990s. The rebound of the fertilizer uses in association with the increase in food prices may lead to a reversal of the situation (UNEP, 2005).

### *2.6.2. Impact of climate change on agriculture*

Crop-yield analysis by some experts (e.g., Federoff et al., 2010) reveals that warming temperatures have already diminished the rate of production growth for major cereal crop harvests during the past three decades. The impact of climate change on agriculture can roughly be divided into three components: a yield effect because of increased CO2 concentrations, a temperature effect, and a water availability effect.

Using U.N. Food and Agriculture Organization data going back to 1960 in Figure 8, we can see in the illustration of Figure 9 that for major producers in Black Sea region, Bulgaria and Romania, the wheat yield had a decreasing trend - although changes in precipitation did not appear to be having an effect, yet.

This loss of yield translates directly into food prices, which have been rocketing upward in recent months and years. The new analysis suggests that the climate-related yield loss has contributed as much as 18.9 percent to the average price of a given crop during the period of the study. Climate change "is not disastrous but it's a multibillion-dollar-per-year effect already", says Lobell a coauthor in Federoff et al. (2010).
http://www.blackseagrain.net/about-ukragroconsult/news-bsg/climate-change-stunts-growth-of-global-crop-yields

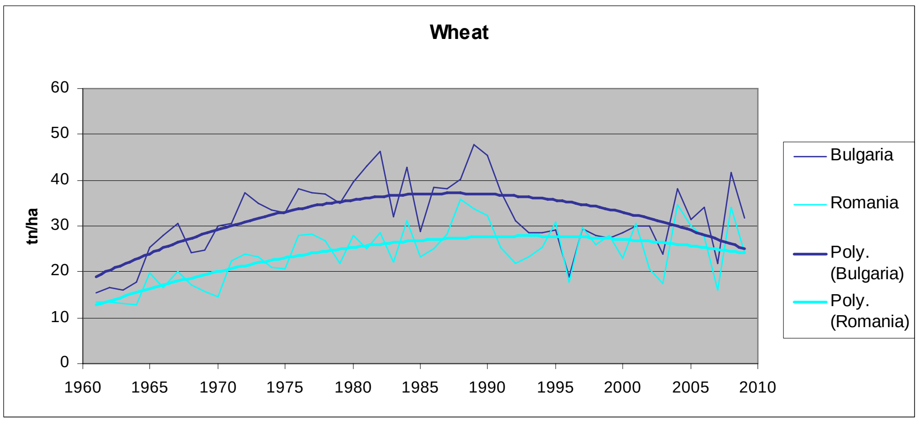



**Figure 9. Using the FAO statistical data it can be seen that yield of wheat while enjoying an increasing trend in the 70’s to mid 80’s, has started a decreasing trend due to climate change and increasing temperatures.**

# 3. Overview of large scale crop models in analyzing the impacts

## 3.1. Application for large scale crop models

### *3.1.1. Bio-physical crop growth models in simulating crop water productivity and yields*

Crop yield is a function of many factors relating to plant genotype, water availability, agronomic practices, soil conditions, climate, and so on. Many bio-physical crop models have been developed to simulate the individual as well as combined effects of these factors on crop growth. In the context of increasing water scarcity in many areas of the world, investigating both blue and green water constraints on crop production has received particular attention. To improve the spatial representation and visualization, many crop models have been coupled with GIS as in the case of GIS-based EPIC (GEPIC, Liu et al., 2007; Liu, 2009). Bio-physical crop models often require detailed field data and knowledge about soil, management, crop growth and other parameters. This has often limited their usability in large-scale studies. So far, there are no specific model setups that aim at representing the diverse local agricultural systems on the continental and global scale. In the existing large scale crop modeling, default parameters calibrated for the conditions where the model was originally developed are generally used as compromise. To overcome this limitation, reduced forms or empirical models have also been adopted, as for example the Global Agro-Ecological Assessment model (GAEA), developed by the International Institute for Applied Systems Analysis (IIASA) and FAO. The GAEA has been used for estimating crop production potentials as a function of climate conditions (Tubiello and Fischer 2007). But this approach does not allow for detailed assessments of impacts of crop management scenarios on agricultural water use and crop production.

Large-scale studies have the advantage of providing a comprehensive overview and allow for a comparison of different regions regarding agricultural productivity and production. The simulation quality has usually been satisfactory as simulated yields are mostly quite evenly distributed around a 1:1-line compared to reported yields. This can partly be attributed to the globally wide range of yields and the good fit of high yields in industrialized countries with high-input agriculture. Within specific areas, especially at the lower end of yields, large deviations are common and yields are often far over- as well as underestimated (Priya and Shibasaki, 2001; Stehfest et al., 2007; Wu et al., 2007; Liu, 2009). In the case of Sub-Saharan Africa, the large-scale modeling without adjusting the parameters to the local conditions can even lead to a misidentification of the main stressing factors to crop growth in many areas. It can be expected that using the unadjusted parameters for simulating climate change impacts on crop production could cause serious errors in the results. The problems specified here in large-scale crop growth modeling highlight the need to develop appropriate approaches to incorporate local conditions in the model setup.

### 3.2. GEPIC model

EPIC is a bio-physical model that simulates plant growth and yield as a function of climate, soil, and crop management using a set of experimentally derived algorithms (Williams et al., 1989). It has been used for more than 20 years in a wide range of agricultural studies and geographical locations (Gassman et al., 2005, Liu et al., 2007, Liu et al., 2009).

The model estimates crop development on a daily time-step. Potential plant growth and yield are calculated first and subsequently multiplied by stress factors to obtain actual increases in biomass and yield. Besides plant development, nutrient cycling and changes in soil structure are simulated. The main functions of plant growth are light interception, conversion of energy and $CO_2$ to biomass, and leaf area index (LAI) development. Growth is constrained by water, nutrient (N and P), temperature, salinity, and aeration stress.

The original EPIC model considers only the stress with the highest impact on potential plant growth on a given day. Based on field observations, de Barros et al. (2004) developed a modified version of EPIC for semi-arid regions (EPICsear) to take into account interactions between water and nutrient stresses, which they found to be most intense under these climate conditions. The daily biomass gain is in this version calculated as

$$\Delta B_i = \Delta B_{pi}(REG)_i(REN)_i \qquad (1)$$

where $\Delta B_i$ is the daily actual biomass production [kg ha$^{-1}$], $\Delta B_{pi}$ is the daily potential biomass production [kg ha$^{-1}$], $REG_i$ is the main non-nutrient plant stress on day *i* [-], and $REN_i$ is the main nutrient plant stress on day *i* [-]. The magnitude of each stress factor varies between 0-1 on each day of the crop growth period. The sum of the daily magnitudes for each stress factor for the whole growing season is referred to as "stress days".

The EPIC model was originally developed for the application on a uniform agricultural unit, such as a field. The coupling of EPIC with a GIS (GEPIC hereafter) has extended its application on large scale involving various agricultural systems. The GEPIC software, which was applied in this study, has been described in detail by Liu et al. (2007) and Liu (2009).

**Integration of EPIC with GIS – The GEPIC Model.** Loose coupling and tight coupling are two generally used approaches to integrate simulation models with GIS (Sui and Maggio, 1999; Huang and Jiang, 2002). The loose coupling approach relies on the transfer of data files between GIS and simulation models (Huang and Jiang, 2002). In contrast, the tight coupling approach is to develop models within a GIS (Huang and Jiang, 2002). In this study, the loose coupling approach was used mainly to avoid much redundant programming.

The GIS software ArcGIS (Version 9.0) was applied for the development of the GEPIC model. ArcGIS is used as input editor, programmer and output displayer. Visual Basic for Applications (VBA) is the main computer language used by the GEPIC model to develop the user interface, access input data, generate EPIC required input files, control the execution of the EPIC model, create output data, and visualize the output maps. VBA is a simplified version of Visual Basic and is embedded in ArcGIS.. VBA can use the ArcGIS Desktop's built-in functionalities,, making the programming much easier. (the sentence is deleted because you say it in line 258)

Some features of UTIL (Universal Text Integration Language) are used in the process of transferring raw input data into EPIC required input data. UTIL is a data file editor that comes with the EPIC model, and can edit the EPIC specific input data files by executing a series of command-lines (Dumesnil, 1993).

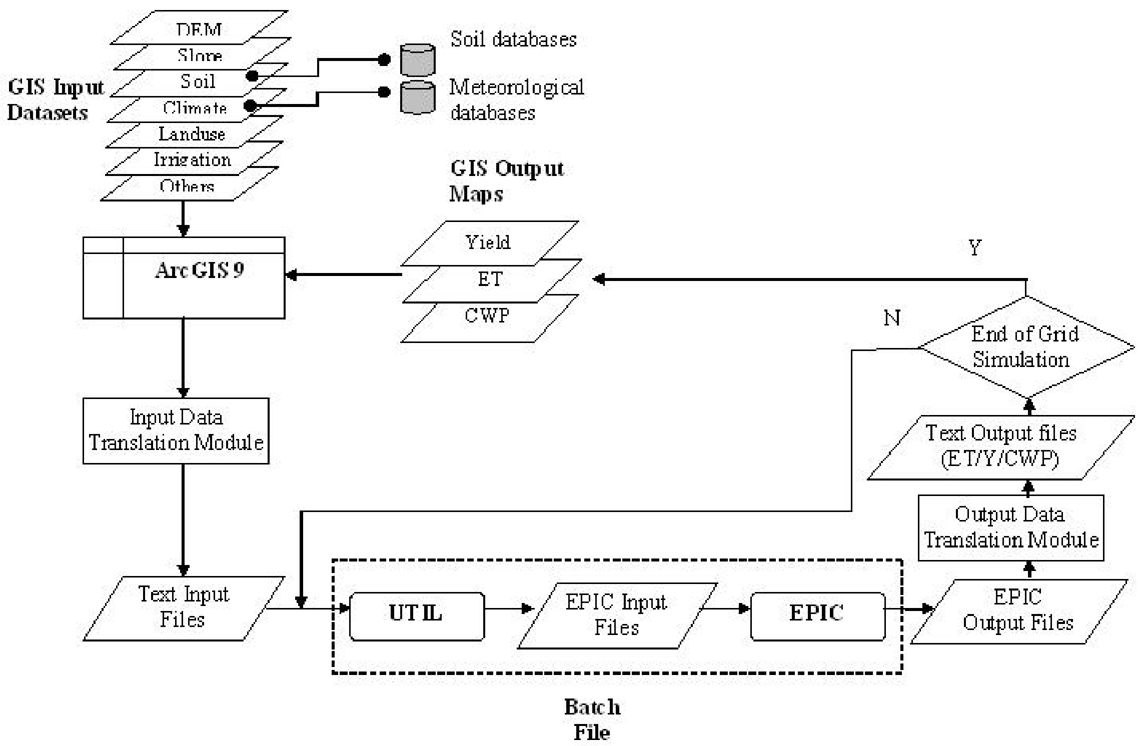



**Figure 10 The schematic representation of the integration of EPIC with GIS**

The steps of the development of the GEPIC model are illustrated in Figure 1. Input data are first added into GEPIC in terms of GIS raster datasets. Basic "GIS input datasets" include maps of DEM (Digital Elevation Model), slope, soil, climate, land use, irrigation and fertilizer. Climate and soil maps show the "code number" of the climate and soil files in each grid. These code numbers are connected with corresponding climate and soil files. Land use map indicates different land use types, including irrigated and rain-fed agriculture. Maps of DEM, slope, irrigation, and fertilizer show the real values of elevation (m), slope (dimensionless), maximum annual irrigation (mm), and maximum annual fertilizer application (kg $ha^{-1}$), respectively.

After adding the raster "GIS input datasets" into GEPIC, an "input data translation module" reads and writes input information to a "text input file". In the text input file, each line stands for one simulated grid, and consists of information of latitude, longitude, elevation, slope, land use, soil code, climate code, maximum annual irrigation, maximum fertilizer application. The information is then used to generate specific "EPIC input files" with the help of a "UTIL" program. This process is achieved by writing command lines into a "batch file". The batch file consists of two types of command lines: UTIL command line, and EPIC executive command line. UTIL command lines are used to edit specific "EPIC input files", while EPIC executive command lines control the running of the EPIC model. By executing the batch file, GEPIC runs the EPIC model for each simulated grid one by one. After one simulation, a set of "EPIC output files" are generated. With a "output data translation module", output variables, such as yield, evapotranspiration, crop water productivity, are written into a "text output file". Each line of the "text output file" presents latitude, longitude, and output variables for one simulation. This output file is used to generate "GIS output maps", such as yield, ET, and CWP maps. These maps can be visualized in GEPIC and can be edited by the user.

The GEPIC model has two unique advantages. First, it can estimate crop yield, ET, and CWP by considering the influencing factors with a flexible spatial scale ranging from a field, catchment and nation to the entire world. Second, it has an easy to use Graphical User Interface to access GIS data, to conduct the simulation, and to visualize the results.

### 3.3. SWAT model

SWAT is a basin-scale, continuous-time model that operates on a daily time step and is developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, landuses, and management conditions. The program has been successfully used in a wide range of scales and environmental conditions from small catchments to continental level (*Gassman, et al.,* 2007). It performs plant growth processes as well as water quantity and water quality modeling. In this study, we used the ArcSWAT (*Olivera, et al.,* 2006) program, where ArcGIS (ver. 9.1) environment is used for project development.
In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into HRUs that include homogeneous slope, landuse, and soil characteristics. Calculated flow, sediment yield, and nutrient loading obtained for each sub-basin are then routed through the river system.

The water in each HRU is stored in four storage volumes: snow, soil profile (0–2 m), shallow aquifer (typically 2–20 m), and deep aquifer. Surface runoff from daily rainfall is calculated using a modified SCS curve number method. Downward flow happens when water content exceeds field capacity for each layer. Percolation from the bottom of soil profile recharges the shallow aquifer. If the temperature in a particular layer is $\leq 0\ ^{o}C$, no percolation is allowed from that layer. Groundwater flow contribution to total stream flow is estimated by routing a shallow aquifer storage component to the stream (Arnold and Allen, 1996).

Depending on data availability, potential evapotranspiration (PET) can be calculated using different approaches. In this study, potential evapotranspiration was calculated using the Hargreaves method, which only requires minimum and maximum temperature. The daily value of leaf area index (LAI) was applied to partition the PET into potential soil evaporation and potential plant transpiration. LAI and root development were estimated using the crop growth component of SWAT. This element indicates the relationship between vegetation and hydrologic budget (Faramarzi et al., 2009, 2010; Luo et al., 2008).

The crop growth component of SWAT, which is a simplified version of EPIC model, is capable of simulating a wide range of crop rotation, grassland/pasture systems, and trees. Harvest index (*HI*) is the fraction of above-ground plant dry biomass that is removed as dry economic yield. Potential crop growth and yield are usually not achieved as they are inhibited by temperature, water, nitrogen and phosphorus stress factors. In the SWAT model the actual yield is calculated by multiplication of the actual aboveground biomass ($bio_{act}$) and actual harvest index ($HI_{act}$). In a given area, $bio_{act}$ is affected by all management stress factors (water, fertilizer, and temperature), while $HI_{act}$ is affected only by water stress factor. The latter can be calibrated to achieve a certain water-stress-limited yield. There are two options for irrigation and fertilization: user specified and automatic. Automatic irrigation can be used by triggering irrigation events according to a water stress threshold. Automatic fertilizer routine can be used to simulate fertilizer applications based on nitrogen stress. We selected automatic irrigation and fertilization option in this study because of the difficulty in obtaining irrigation and fertilization schedule data for different provinces. In the model we assumed an unlimited source for irrigation but controlled it through calibration of $HI_{act}$. This is a reasonable assumption as in most parts of Iran large amounts of water is extracted from deep aquifer or is transferred from other river basins for irrigation purpose. The fertilizer use in the model was limited to the available data at the provincial level and crop specific fertilizer use per year.

Plant growth is determined from leaf area development, light interception and conversion of intercepted light into biomass assuming a plant species-specific radiation use efficiency. Potential evapotranspiration (PET) in this study was simulated using Hargreaves method. Actual evapotranspiration (AET) was determined based on the methodology developed by *Ritchie* (1972). Leaf area index LAI and root development were simulated on daily time steps. The daily value of LAI was used to partition PET into potential soil evaporation and potential plant transpiration. A more detailed description of the model is given by *Neitsch, et al.* (2002).

## 4. Data availability and sources for modeling with GEPIC and SWAT

### DEM

Digital Elevation Model (DEM) extracted from the Global US Geological Survey (USGS, 1993) public domain geographic database HYDRO1k with a spatial resolution of 1 km and 90 meter DEM from SRTM which is refined in the no data sections. The vertical units are meter.
*SOURCE*:
(http://edc. usgs.gov/products/elevation/gtopo30/hydro/index.html) and
(http://srtm.csi.cgiar.org/)

### Landuse

Land use map from the USGS Global Land Use/Land Cover Characterization (GLCC) database with a spatial resolution of 1 km and distinguishing 24 land use/land cover classes was used for the eastern part of the Black Sea Catchment (http://edcsns17.cr.usgs.go/glcc/glc.html).

CORINE land cover map (CLC1990) with 100 m spatial resolution, which provides information for all EU countries that covers the western part of the catchment (http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster).

The CORINE land cover map contains 43 different classes. These two maps are combined and resized so that the final map with spatial resolution of 100 m covers the whole catchment.

*SOURCE:*

(http://edcsns17.cr.usgs.go/glcc/glc.html) and (http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster)

**River**

This data (bsr.shp)was downloaded from Envirogrids ftp site and it is in 50 meter resolution. It is projected to Lambert-Conformal-Conic.

*SOURCE:*

https://netstorage.unige.ch/netstorage/

**Soil**

Soil map obtained from the global soil map of the Food and Agriculture Organization of the United Nations (FAO, 1995), Which provides data for 5000 soil types comprising two layers (0–30 cm and 30–100 cm depth) at a spatial resolution of 1:5,000,000.

*SOURCE:*

http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116

**Yield** (5 arc min resolution)

MIRCA2000

http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/MIRCA/index.html

**ET**

Data-driven estimate of global land evapotranspiration from 1982-2008, compiled using a global monitoring network, meteorological and remote-sensing observations and a machine-learning algorithm (Jung et. al., 2010)

**Discharge stations**

River discharge monthly data required for calibration-validation were obtained from Global Runoff Data Center. for 63 hydrometric stations for the period 1970–2008. We are trying to get more data across the region.

*SOURCE:*

(GRDC, http://grdc.bafg.de)

**Precipitation stations** and **Temperature stations**

Weather input data (daily precipitation, maximum and minimum temperature, Figure 2a,b) mostly from the National Climatic Data Centre (NCDC, http://www.climate.gov/#dataServices/dataLibrary) and the European Climate Assessment & Dataset (ECAD, http://eca.knmi.nl/dailydata/predefinedseries.php). Periods covered by the available data were from 1970 to 2008. The WXGEN weather generator model (Sharpley and Williams, 1990), which is incorporated in SWAT, was used to fill gaps in the measured records.

**Social Economic data**

*Sources:*

FAO (The Food and Agriculture Organization of the United Nations) statistics:

http://www.fao.org/corp/statistics/en/

http://www.fao.org/economic/ess/ess-events/detail/en/?dyna_fef%5Bbackuri%5D=%2Feconomic%2Fess%2Fess-publications%2Fen%2F&dyna_fef%5Buid%5D=54350FAO Statistical Yearbook 2010

http://www.fao.org/economic/ess/ess-publications/ess-yearbook/ess-yearbook2010

## 5. Case Study Romania

### 5.1. Agriculture and environmental impacts in Romania

*5.1.1 Generalities*

Agriculture is a major branch of the national economy and has multiple functions: biological; ecological; main source of food for the population; economic activity; environmental protection; a way of life; a technical and cultural tradition and, last but not least, a type of civilisation.

The cultivation of plants in Romanian territory dates back to the Early Neolithic Age (5500 – 3500 BC), the practice of agriculture recording in time several systems of cultivating the soil: *sod breaking*, that is cropping the land for several years then abandoning it; *ploughing up*, soil sickened by repeated cropping is left derelict and cultivated again after a lapse of 5 – 20 years; *fallowing*, based on the simplest crop rotation system (1 – 2 years); *extensive agriculture*, fast-going expansion of farming land beginning with the $19^{th}$ century, and *intensive agriculture*, in use since the latter half of the $20^{th}$ century (Tufescu, V., 1966).

With the progress of the forces of production, this branch has been experiencing fundamental changes in the social structure, in the technical endowment, in the structure and distribution of land use categories and types of crop.

*5.1.2 Land reforms in Romania, brief historical overview of landed property and land relations in modern times*

Land reforms represent key moments in Romania's agrarian life, the materialisation of efforts to change traditional societal structures, eliminate routine and stagnation, and pave the way for new agricultural developments (Popescu, M. et al., 2003).

*The land reform of 1864* was implemented in Moldavia and Wallachia after the Unification of the two Romanian Principalities. Its aim was to abolish feudal servitudes, limit the landed estates of the nobility, the church and the state, and appropriate land to the peasants, who received an average of 3.77 ha/family from a total of 1,765 thou ha allocated to this category.

*The land reform of 1918 – 1921* was enacted after the First World War, within a new historical, national and political framework: completion of the Greater Union of Romania on December 1, 1918. Carrying out the reform was a matter of several years and brought about major changes in the structure of landed property. According to statistical figures, until 1937, 1,393,353 peasants (69.47% of those entitled to) received land through the expropriation of 5,804 thou hectares. The reform dismantled the landed estates (of thousands of hectares), leaving an important segment of owners with over 100 hectares (Popescu, M. et al., 2003).

*The land reform of 1945* came after the Second World War and the establishment of a communist regime on August 23, 1944. Its basic aim was to liquidate the property of big landowners. Expropriations covered 1,468 thou ha, of which 1,109 thou ha (i.e. ¾) were divided among the peasants. Whereas the 1864 and 1918-1921 land reforms had in view the development of a capitalist agriculture, the 1945 reform was to be a first step towards socialisation of agriculture. The year 1949 witnessed a transition to the Soviet-based model of socialist agriculture in which both the state and the collective property held dominant positions.

*The period of transition.* As from 1989, the fall of the communist regime led to a series of radical changes in all the fields of activity. For the national economy, transition meant the substitution of the free market system for the old centralised system. Agriculture was one of the first economic branches to be seriously affected by the restructuring process, by fundamental changes in the ownership of land, the basic factor of production.

The post-socialist period witnessed major transformations in the type of property over farming lands and forest lands and the establishment of a new social-economic organisation structure. A negative effect had the excessive fragmentation of farming land, the emergence of large numbers of individual farms practicing subsistence agriculture, poor services (irrigation, fertilisation, mechanisation, etc.) all of which have contributed to the severe degradation of the quality of agricultural land. In addition the number of livestock also fell to half over the 1990-2007 period.

Major changes accompanied Romania's EU accession, the aquis requesting the implementation of the Common Agricultural Policy (CAP). The key factors involved in this complex overhaul were the political ones, they interacting with the economic, technological and demographic factors. At the same time, the impact of global climate change cannot be overlooked.

*Changes in the type of property*. One of the major changes in the transition period was the expansion of private property over agricultural and forest lands.

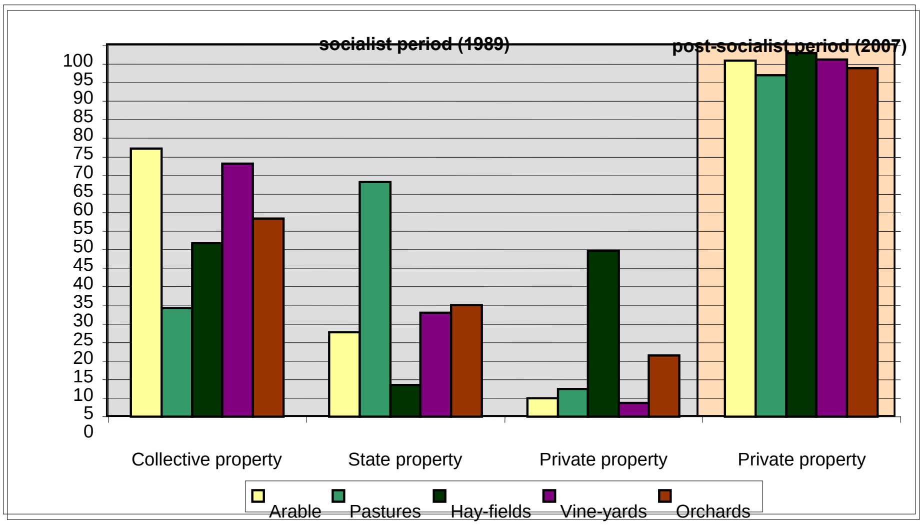



**Figure 11. Land fund by categories of use and forms of property**

In the socialist period (1945 – 1989), all land use categories, except for hay-fields, were *collective ownership*, *the state possessing* the largest high-grade land uses – vine-yards and orchards. *Private owners* held mainly pastures and natural hay-fields (Figure 11). The permanent expansion of private property is the direct outcome of the collectivisation and privatisation begun in 1990 under the provisions laid down in Land Law 18/1991 completed and modified by Law 169/1997, Law 1/2000 and Law 247/2005. On this basis, private property was continuously enlarged up to over 95.3% of all agricultural land and to over 34.1% of the forest land (2006).

*Changes in the type of land exploitation*. The land reform led to the formation of new structures of the farmers'social-economic organisation based on private property, with *individual farms* holding the highest share compared to *juristic person units*.

Before 1989, there were two main forms of agricultural exploitations: *collective farms* (3,776 units in 1989) which held 68.8% of the overall agricultural area, average surface 2,374 ha, and *state farms* (411 units in 1989) which owned 29.7% of the overall agricultural area, average surface 5,000 hectares. *Peasant households* possessed a mere 9.5% consisting mostly of pastures and hay-fields in hill and mountain regions.

**Table 6. Comparative number and size of farms**

| | **Socialist period** | | **Post – socialist period** | |
|---|---|---|---|---|
| | Collective farms | State farms | Individual farms | Juristic person units |
| Number | 3,776 | 411 | 3,913,651 | 17,699 |
| Average area (ha) | 2,374 | 5,001 | 2.29 | 270.45 |

After 1989, Land Law 18/1991 coming into effect, landed property would crumble excessively, large farms growing into peasant-type family exploitations.

In 2007, Romania had 3.93 million agricultural exploitations, of which 99.5% were individual farms that used over 65% of the overall agricultural area. Average agricultural area/individual farm was 2.29 ha, average number of plots/farm was 3.7 (Table 6). Juristic person units held only 0.45%, average surface 270.45 ha, average number of plots/unit 9.66, a plot having 27.95 hectares.

The efficient use of agricultural land depends on farm size (overall agricultural area and agricultural area used). One of the characteristic features of Romanian agriculture is the dominance of very small and small farms with little financial resources, owned by undertrained ageing people. This situation makes it almost impossible to use new production technologies, undertake efficient management and marketing, capable to increase productivity in agriculture and make it competitive. Most individual farms practice subsistence agriculture, for self-consumption of the farmers themselves.

Looking at *the size-class of the agriculture area used*, it appears that most of it belongs to very small and small farms (Figure 12), large, commercial farms (50 – 100 ha and over) holding only 0.4% of the area used. The multitude of small farms (under 5 ha/farm used area) and self-consumption hinder agriculture from becoming competitive and using the farming land in a sustainable manner.

The total number of individual farms and of juristic person units decreased over the past few years (2002 – 2007) by some 12% and by over 21.9%, respectively, while the average area used increased. The average area/individual farm grew from 1.73 ha in 2002 to 2.29 ha in 2007.

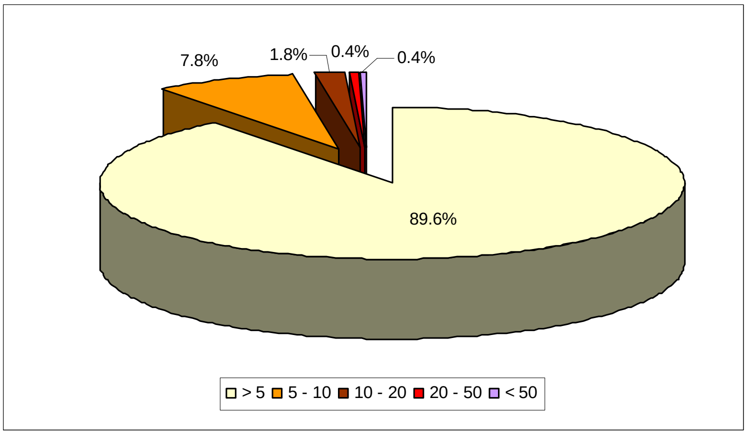



**Figure 12. Farms by size class of agricultural area used, 2007**

An important role in amassing agricultural areas has the annuity programme, expecting people to make farming an efficient activity capable to put up with European competition. The programme encourages small owners to sell or lease their land, for 100 euro/ha/year if sold, or 50 euro/ha/year if leased. At the beginning of 2007, the number of people petitioning for life annuity was of 37,627, which is a remarkable figure compared to previous years: 814 in 2005 and 23,700 in 2006.

*Fragmentation of agricultural lands*. The fragmentation of agricultural lands was one of the negative results of Land Law 18/1991 with significant impact on land use. The consequence of fragmentation was the continuous degradation of the land's productive potential, and the impossibility of practicing a modern agriculture.

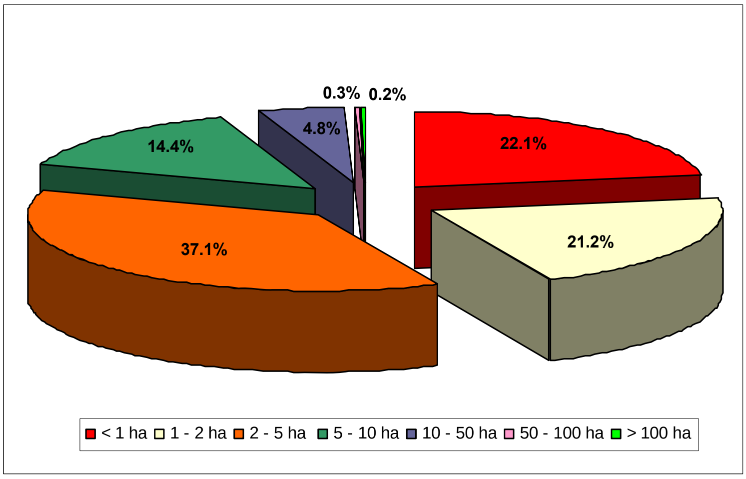



**Figure 13. Agricultural area: size of plots (ha), 2005**

Under the Land Law, over four million owners were restituted their agricultural property. In many cases the area received was made up of several plots, in terms of terrain configuration, fertility, location of crops in the field, etc. According to estimates, there were about 15 million plots, most of them (over 42%) less than 2 ha each (Figure 13).

### *5.1.3. The role of agriculture in the national economy*

After 1990, the share of agriculture in Romania's economy kept decreasing constantly, at a slower pace in the first years of transition and much faster after 1997. For all that, this sector made a significant contribution to GDP (9.5% in 2001) comparatively with the EU average (1.7 %).

**Table 7. The role of agriculture within the national economy**

| | 1990 | 1995 | 2000 | 2006 |
|---|---|---|---|---|
| GDP contribution | 18.0 | 19.3 | 11.8 | 9.5 |
| Share of employed in agriculture | 28.1 | 33.6 | 40.8 | 30.5 |
| Share to exports | 1.4 | 5.0 | 2.3 | 2.1 |

In 2005, agriculture contributed with 9.5% to gross added value compared to 12.5% in 2000 and 20.9% in 1995. The population active in this sector represented 30.5% (2006) per total employed population. The proportion of the former would steadily increase from 18.0% in 1990 to 40.8% in 2000, only to gradually decrease down to 30.5% in 2006 (Table 7).

*5.1.4 Land use*

*The land fund structure*. Romania is one of the European countries with important land resources (0.68 ha agricultural land and 0.43 ha arable land per capita). In terms of structure, the situation in 2007 was the following: 14,709.3 thou ha agricultural land (61.8% of Romania's surface-area), 6,740.9 thou ha forest land (28.3%), 849.9 thou ha terrains covered with water and ponds (3.5%), 685.7 thou ha built-up area (2.8%), 390.1 thou ha roads and railways (1.6%) and 463.2 thou ha of degraded and unproductive grounds (1.9%) (Figure 14).

Arable land/total agricultural area represented 64.5%, pastures and natural hay-fields 33%, vine-yards and wine nurseries 1.48%, orchards and fruit-tree nurseries 1.4% (Figure 15).

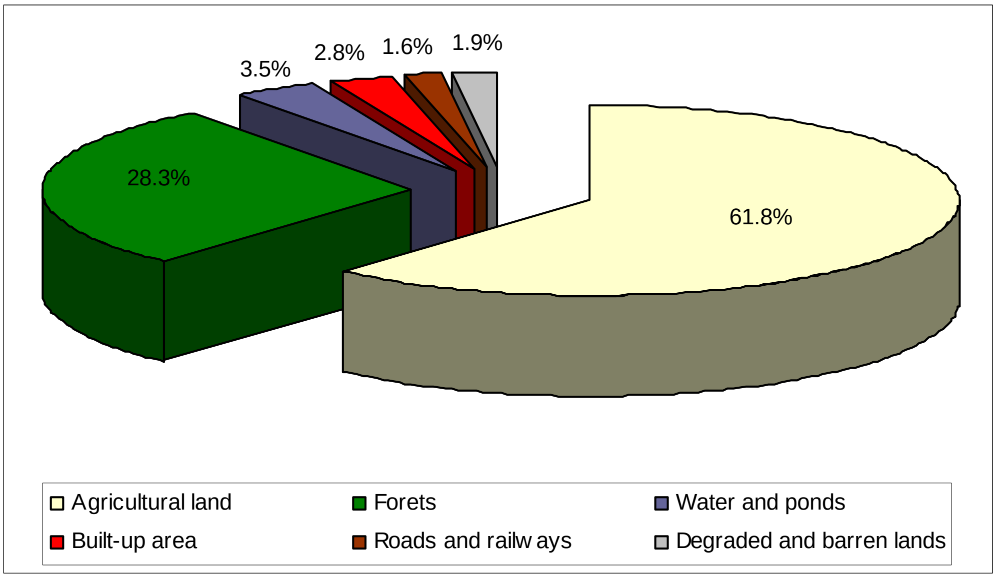



**Figure 14. Structure of land cover/use in Romania, 2007**

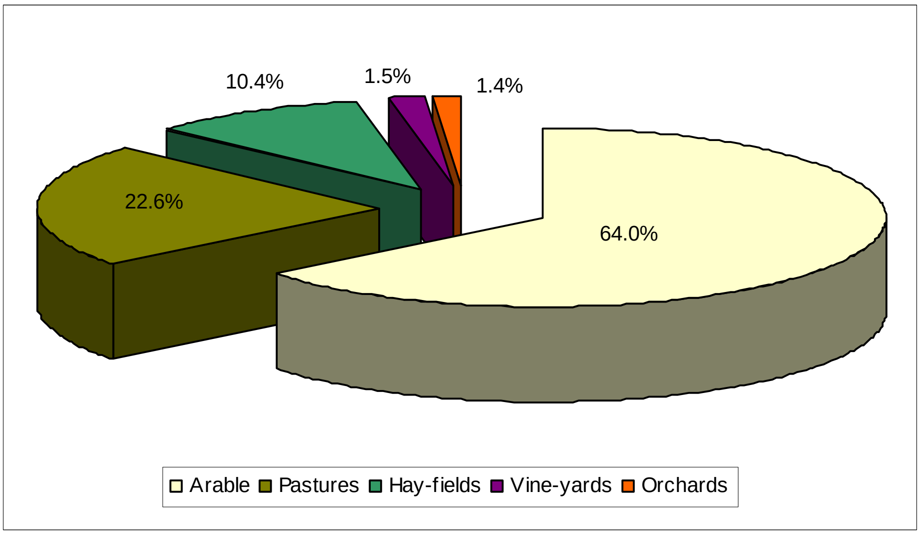



**Figure 15. Structure of agricultural land, 2007**

*Structure of agricultural lands*. The diversity and specificity of the pedoclimatic systems (mountains, hills and plains in almost equal proportions), together with the general and regional particularities of a social history and of the economic context account for the prevalence of agricultural grounds (over 62%) – arable, pastures and hay-fields, vine-yards and orchards, in nearly every relief step, but mainly in the plain (over 80%) – the Romanian Plain, the West Plain, the Central and South Dobrogea Plateau, their proportion decreasing to 40 – 60% in the hills and to under 20% in the mountains (Figure 16).

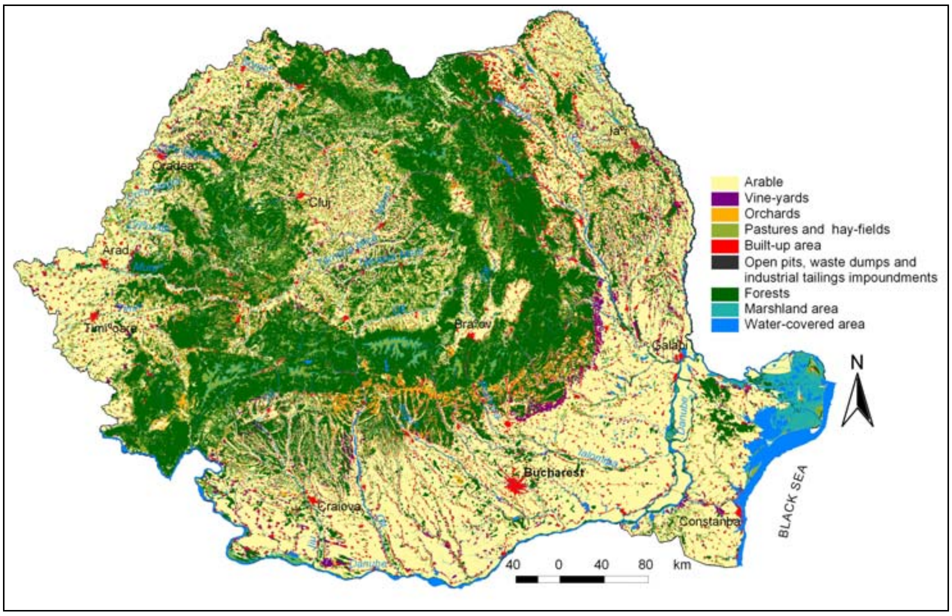



**Figure 16. Land use/land cover in Romania.**

A series of changes in the structure of agricultural lands took place over the 1990 – 2007 period, in that arable land, vine-yards and orchards shrank, while pastures and natural hay-fields extended. Between 1990–2000, arable areas were sharply reduced also because they had been abandoned by their new owners who were unable to work their plots repossessed under Land Law 18/1991. The same happened to vine-yards and orchards, many being abandoned or downright cleared off.

Within that same period, areas covered with vine-yards, orchards and arable land, which are high-class uses, shrank to the benefit of low-class ones (pastures and hay-fields).

After 2000, the period of Romania's pre-accession to EU, the situation would change, arable lands extending, but vine-and-fruit-tree areas continuing to subside (Figure 17).

The overall agricultural area also decreased in the past few years, making way for ever larger built-up terrains. In the wake of the house-building boom, conversion of agricultural to built-up terrain is an obvious phenomenon in almost every large urban centre. Over 2000–2007, the built-up areas increased by over 51.7 thou hectares.

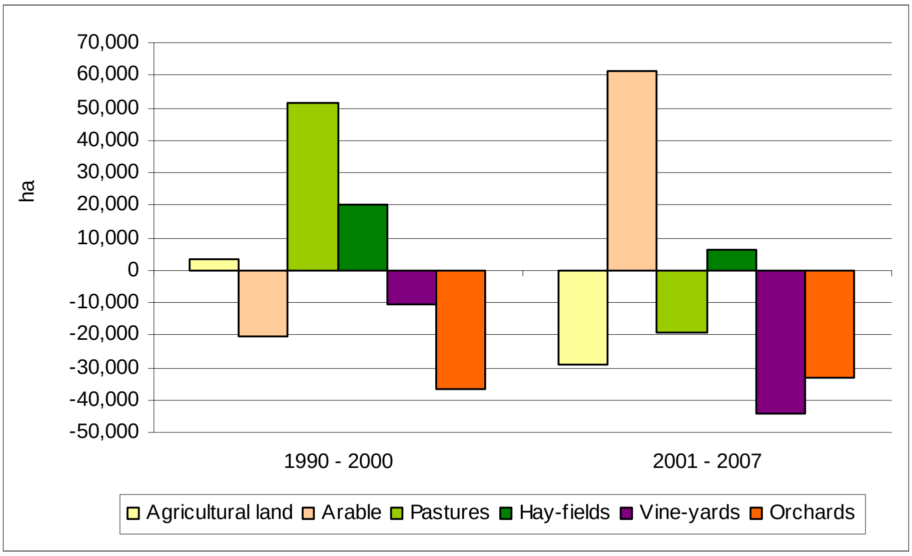



**Figure 17. Land use dynamics, 1990 – 2007**

The overall agricultural area also decreased in the past few years, making way for ever larger built-up terrains. In the wake of the house-building boom, conversion of agricultural to built-up terrain is an obvious phenomenon in almost every large urban centre. Over 2000 – 2007, the built-up areas increased by over 51.7 thou hectares.

*Arable lands* are the dominant category, representing over 80% of the agricultural areas of plains and lower tablelands (the Romanian Plain, Banat-Crişana Plain, and South Dobrogea Plateau), and of those alongside waterways (the Siret, Prut, Olt and Mureş rivers). At the contact between the Romanian Plain and the Getic Piedmont, in the Subcarpathian Hills, in the Moldavian Plain, The Bârlad Plateau, the central part of the Transylvanian Tableland, in the Western Hills and depressions, arable land amounts to 60 – 80% of the agricultural land.

In the higher, fragmented hilly regions and in the intra-montane depressions, arable lands represent 40 – 60% (the Getic Piedmont, the Transylvanian Plain, the Târnave and the Someşan Plateaus, partly the Getic Subcarpathians and the Moldavian Subcarpathians, the Făgăraş, Sibiu and Haţeg depressions), and 20 – 40% in the contact region between the Subcarpathians and the mountain space, between the Apuseni Mountains and the western piedmonts, etc. The mountain regions proper have under 20% arable land (Figure 18). Also in the Danube Delta arable surfaces are very small (because of morpho-hydrographic conditions), being reduced to embanked areas and fluvial levees.

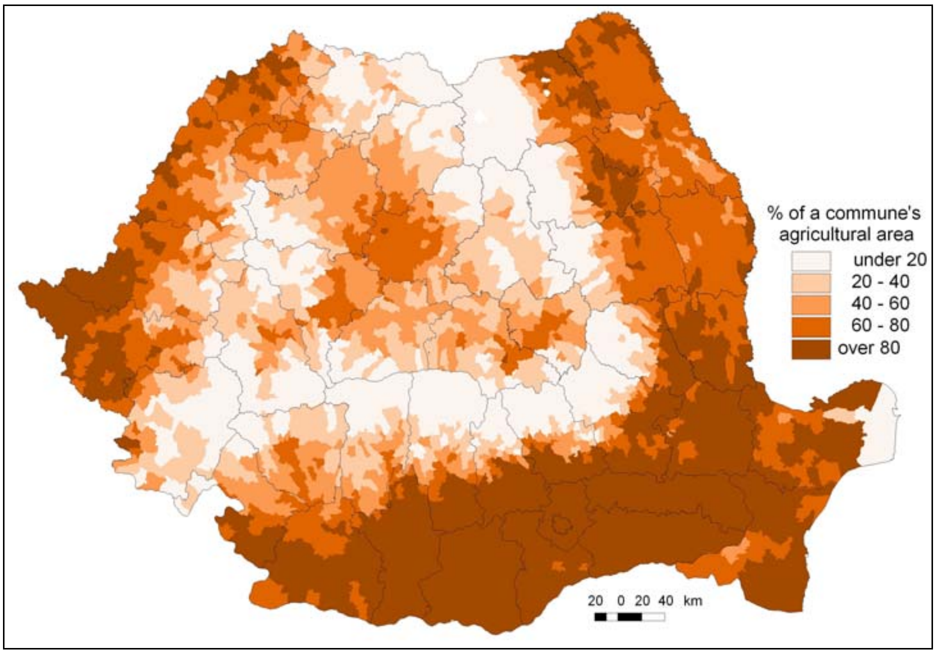



**Figure 18. Arable land, 2006**

After 1990, not only did arable areas shrink, but their productive potential was largely degraded, with negative effects on the quantity and quality of agricultural production.

*Cultivated area*. Over the past 18 years the cultivated area decreased from 9.6 million ha in 1989 to 7.6 million ha in 2007 (Figure 19), also because of much arable area (8.8 million ha in 1990 – 2006) being left uncropped (Figure 20).

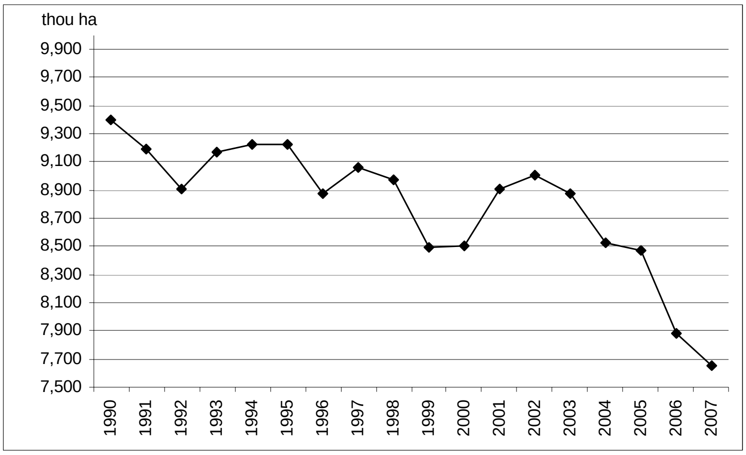



**Figure 19. Cultivated area**

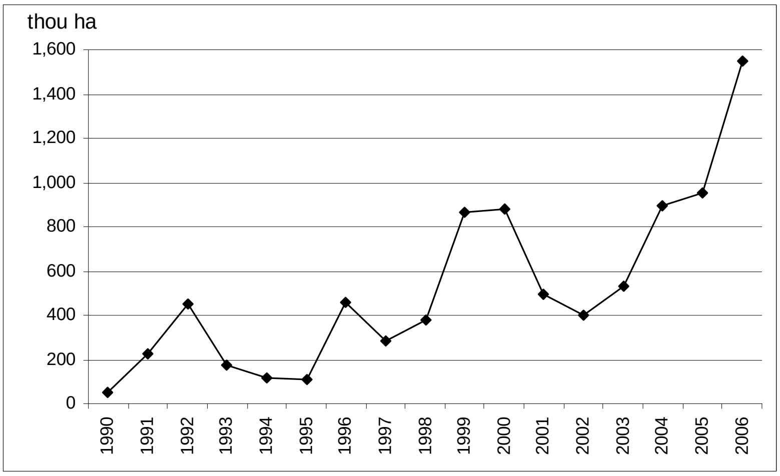



**Figure 20. Uncultivated area**

What caused that situation was people's uncertainty with regard to their property right, as well as money shortage, inadequate farm structure, the high proportion of elderly farmers (over 65 years old), lack of equipments and money to work the land with, lack of certitude that products could be sold at prices enabling the resumption of production, and no prospects in an unfriendly economic milieu. Moreover, the state failed to grant farmers the assistance they needed (Popescu, M. et al., 2003).

In terms of structure, most of the cultivated area is occupied with grain cereals (over 60%) which is suggestive of a cereal-growing agriculture; oleoginous plants (mainly sun-flower) over 15% and fodder plants 11% (Figure11).

*Cereal plants* occupy large areas (over 60% of the cultivated surface) and cultivating them is an old tradition in Romania; according to archaeological discoveries wheat, barley, oats and rye date back to the Early Neolithic Age. Maize, a crop widely spread now, was introduced in the 17$^{th}$ century, being first cultivated in the plains, and later on extended to all agricultural regions.

Grain cereals cover 5.1 million hectares (2007), with maize and wheat representing over 88.9%. This crop has good soil and climate conditions, especially in the plains (Romanian Plain, Banat-Crişana Plain and the Transylvanian Plain), but also in tableland regions (the Dobrogea Plateau and the Moldavian Plateau). With the exception of the mountain zone, small wheat and maize areas are seen all over the country. In the transition period, maize has been extensively grown for its multiple uses (human food and animal fodder), small farmers favouring this crop because of lower costs for seeds and harvesting done also by hand. The area cultivated with oats expanded, while surfaces with barley, two-row barley and rice crops decreased significantly.

*Leguminous grain plants (Dried pulses)* (beans and peas) are grown on 43.7 thou ha (0.56% of the cultivated area), but after 1990, relatively high costs and low outputs (Figure 21) would reduce it. Optimum bean growth conditions have the Romanian Plain, Moldavian Plain, Central Moldavian Plateau and the Siret Corridor. Peas are cultivated largely in the Romanian Plain, Banat-Crişana Plain, the hill and tableland regions of Moldavia, Dobrogea and Muntenia.

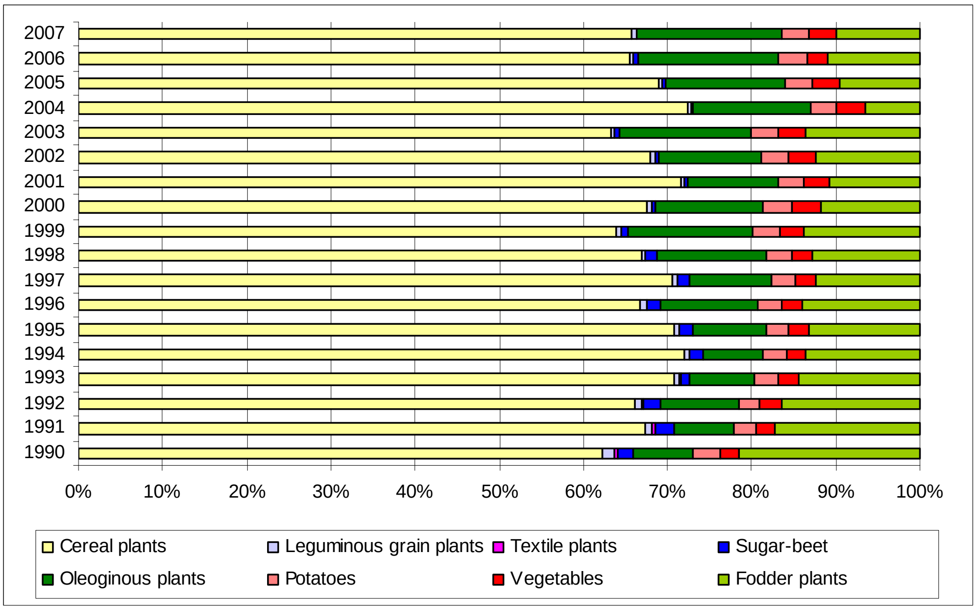



**Figure 21. Structure of cultivated area, 1990 – 2007**

The area allocated to *technical plants* has shrunk considerably over 1990-2007. Textile plants remained with only 0.3 thou ha, a drastic regression from 123.2 thou ha in 1989. The same downward trend in oleoginous plants – soy bean, brassica and flax for oil and ricin. On the other hand, areas cultivated with sun-flower (the Moldavian Plain, Siret Corridor, Moldavian Plateau, Dobrogea Plateau and Banat-Crişana Plain), doubled over the past few years, because prices are good and the export demand is simulative.

The situation of *other industrial plants*, e.g. sugar-beet, decreased significantly after 1990 because costs are high and products take a low price. This plant, easily adaptable to morphological, soil and climate conditions, is cultivated in various geographical regions: the Transylvanian Tableland, Braşov and Ciuc depressions, Moldavian Plain, Siret Corridor, Banat-Crişana Plain and the Romanian Plain.

*Vegetables* were grown on 253.4 thou ha (2007), mainy in the floodplain and on the river terraces of plain regions: the Danube Floodplain, the floodplains of the Argeş-Sabar, Olt, Jiu, Ialomiţa, Buzău, Siret, Prut, Mureş, and Someş, of the Three Criş rivers, etc.

*Potato crops* covered over 268 thou ha (2007), particularly in the north and central regions of the country (the Suceava Plateau, Braşov, Ciuc, Giurgeu and Maramureş depressions).

In 2007, *fodder plants* were grown on 768.4 thou ha, that is half the area used in 1990, one of the causes being the decline of the livestock sector once the big animal farms were closed down. Fodder plants were cultivated mostly in the plains, depressions, the Subcarpathian Hills and the tableland regions.

*Biofuel plants*. During the past few years, grain plant areas shrank in favour of oleoginous, textile and leguminous grain plants. Also, significant increases in biofuel plants (brassica, soy-bean, sun-flower and maize). There was a spectacular expansion of brassica cultivated areas, from 0.3 thousand ha in 1995 to 340.6 thousand ha in 2007 (Table 8). This plant thought to be best suited to biodiesel production, given that it has the highest caloric value of all oil plants. The reason for the increase in the cultivated areas with these crops is largely due to the financial assistance farmers received from the state.

**Table 8. Areas cultivated with biofuel plants (thou ha)**

| | 1995 | 2000 | 2007 |
|---|---|---|---|
| Brassica | 0.3 | 68.4 | 340.6 |
| Soy-bean | 73.3 | 116.9 | 113.1 |
| Sun-flower | 714.4 | 876.8 | 798.1 |

*Pastures and natural hay-fields* (over 60% in the mountains and below 10% in the plains) include several types in terms of the natural conditions of their growth environment: *floodplain pastures* are characteristic of the Danube Floodplain and the floodplains of the main rivers (the Argeş, Buzău, Ialomiţa, Olt, etc.); *pastures of the plain region*; *pastures and hay-fields of hills and tablelands*; *mountain pastures and hay-fields* at altitudes of over 700 – 800 m; *sub-Alpine and Apline meadows* beyond 1,600 – 1,700 m in the Southern Carpathians and at over 1,650 m in the Eastern Carpathians.

As there are few improvement works and erosion processes are intense, pastures and natural hay-fields have seriously been degrading. Despite being the most valuable land use ecosystems in respect of diversity, leaving some areas unmowed and ungrazed has contributed to the degradation of habitats and to major changes in the landscape. Besides, turning pastures into arable land is detrimental to biodiversity.

*Vine-yards*. Numerous archaeological finds, documents and maps attest that vine was grown in Romanian soil in the Bronze Age (in the Subcarpathians Hills from the south of the country), in Ancient Times (in 4$^{th}$ cent. BC Transylvania) and in the Geto-Dacian and Roman periods when this plant was widely cultivated (Strabo, the ancient historian, considered the Geto-Dacians skilled wine-growers). The Roman conquest contributed to the development of viticulture by introducing new varieties and wine-making techniques and procedures.

The best growth conditions for this plant are the southern, eastern or western slopes of certain hillside and tableland regions (300 – 700 m alt.). However, approximately one-third of Romania's vine-yards are found in the lowlands (100 – 300 m). The northern limit of this crop in Romania and in Eastern Europe, too, is the Ştefăneşti – Botoşani – Suceava – Seini – Tarna Mare line.

In 2007, this country had 218 thou ha of vine plantations, 187 thou ha with vines in bearing, of which 92.3 thou ha grafted and indigenous and 95.3 thou ha hybrid plants. After 1990, hybrid vine areas increased to the detriment of the other types which were left with 49.2% in 2007 from a total area of 76% in 1989. The largest areas of vine in bearing had the counties of Vrancea (23,438 ha), Galați (15,930 ha), Buzău (15,076 ha), Dolj (13,706 ha), Vaslui (13,623 ha), Constanța (11,099 ha), etc.

Several larger wine-growing areas, so-called zones, featuring a multitude of vine-yards and viticultural centres, have been outlined in terms of massiveness, geographical position, agro-climatic elements, exposition, soils, etc. (Figure 12).

The main viticultural zone in Romania is the *Curvature Carpathians*, vine covering the Subcarpathian slopes between the Trotuş and the Teleajen valleys (80 – 350 m altitude). Famous vine-yards has Vrancea (between the Trotuş and the Râmnicu Sărat valleys), Dealu Mare – Istrița a vine-yard in the lower piedmonts between the Teleajen and the Buzău valleys.

Another renowned viticultural *zone, Drăgăşani*, lies in the Getic Piedmont, with vine plantations at 200 – 450 m alt., mostly on the terraces of the Olteț and the Olt rivers.

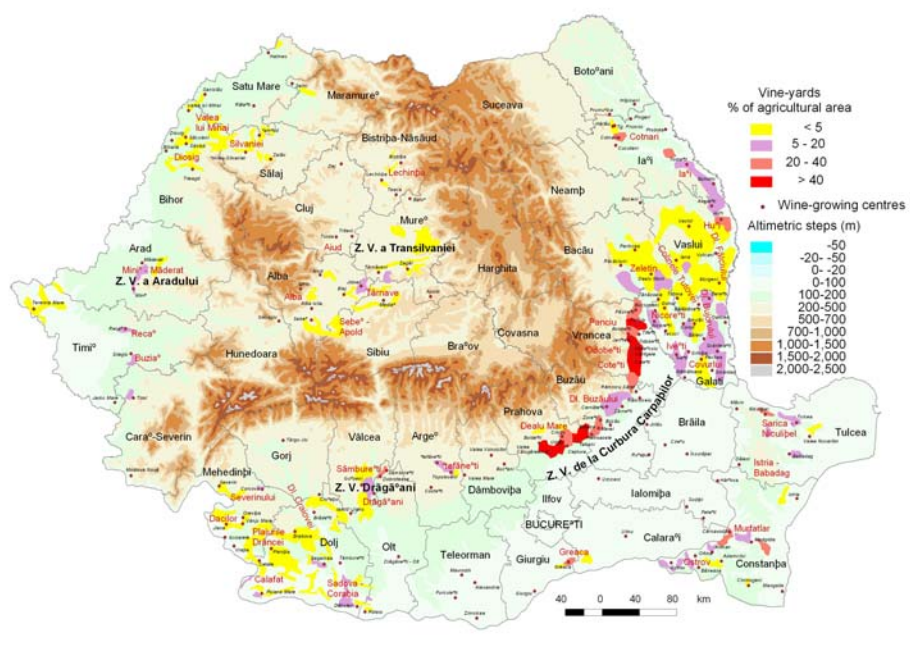



**Figure 22. Vineyards**
*Source: Corine Land Cover, 2000*

*Transylvania's viticultural zone*, with the renowned vine-yards of Târnavele and Alba Iulia, extends on the southern and western hill slopes between the two Târnave rivers and the Mureş River.

*Arad viticultural zone* stretches out along the piedmont lining the contact between the Zarand Mountains and the Banat-Crişana Plain, that is between the Mureş Valley and the Măgura Pâncota Hill. It is one of the oldest wine-growing areas in Romania, documented in Dacian Times. Outstanding vine-yards: Pâncota, Siria, Lipova, Pauliş, etc.

Beside these important zones, there are also other vine-yards and viticultural centres, which cover smaller areas it is true, but are of superior quality, e.g. in the east of the country between *the Siret and the Prut rivers* (Cotnari, Iaşi, Huşi, Bârlad, Dealurile Bujorului, etc.), *in Dobrogea* (Niculițel, Murflatar and Ostrov), *on the Danube terraces*, *in Banat Province* on the lefthandside hills of the Mureş River (Recaş, Buziaş and Bistriţa), *in north-west Transylvania*, from 60 – 80 m alt in the plain region to 150 – 200 m alt. in the hillsides.

*Orchards*. In the transition period, fruit-growing areas and nurseries shrank by some 30,000 ha, while pastures and natural hay-fields expanded. Many intensive fruit-growing plantations were cleared after being restituted to their former owners or to their heirs, new fruit-trees being planted usually on small, dispersed plots. In 2007, orchards and nurseries covered 206 thou ha of which 194 thou ha were privately owned.

Natural factors, as well as material and financial difficulties account for output fluctuations, producers striving hard to obtain stable and high-quality yields. The overall 2007 production looked as follows: apples (43.7%), plums (34.3%), cherries and sweet cherries (6.0%), pears (5.7%), apricots (2.5%), nuts (2.3%), peaches (1.5%), strawberries (1.5%), other fruit (2.1%). Highest productions reported the counties of Dâmboviţa (187 thou tons), Argeş (114 thou tons) and Vâlcea (79 thou tons).

Fruit-growing in Romania depends on the natural environment and the tradition of each zone. The biggest orchards have the Subcarpathian regions, the tablelands and the lowlands. There are three major fruit-growing regions:

*The Subcarpathian fruit region*, situated in the south of the Southern Carpathians and of the Curvature Carpathians, encompasses the counties of Gorj, Vâlcea, Argeş, most of the Dambovița, Prahova and Buzău, the northern half of Mehedinți and the northern extremities of Dolj and Olt.

*The Banat fruit region's* orchards are located in the drainage basins of the Lower Mureş (downstream of Simeria), Bega, Timiş, Caraş, Nera and Cerna, more frequently in the mountainous depressions and in the hillsides.
*The North-West fruit region*. One sees orchards in the drainage basins of the Vişeu, Iza, Someş, Crasna, Barcău, Crişul Repede and Crişul Negru.

Within these fruit-growing regions, but also elsewhere, there exist pomicolous basins and centres of large orchard areas.

Counties boasting the largest fruit-growing areas are Argeş (22.8 thou ha), Vâlcea (13.1 thou ha), Prahova (11.8 thou ha), Caraş-Severin (11.6 thou ha) and Buzău (10.9 thou ha). At the other end of the spectrum stand Teleorman (0.15 thou ha), Călăraşi (0.17 thou ha) and Ialomița (0.31 thou ha).

*5.1.5. The quality of agriculture land*

In Romania, there are some 12 million agricultural hectares (of which 7.5 million hectares of arable land) affected by soil quality limiting factors.
After 1990, physical and agro-chemical degradation would intensity over ever larger areas (twice as many over 1992 - 2002), mostly because of drought, excess humidity, various erosional processes and little mechanisation and fertilisation of the land (Table 9).

The natural factors involved in the degradation of soils were first and foremost the extreme natural phenomena, such as droughts, floods, and landslides. Each year, larger or smaller areas suffer from lengthy periods of drought that damage crops and degrade the quality of soils. Most drought-prone is the south-east of Romania (Drobogea, the Baragan Plain and the Moldavian Plateau), where desertification phenomena are already in place

(Figure 13). After 1990, disastrous floods affected large areas, damaged settlements, routes of communication and terrains. There were cases when whole villages had to be relocated, roads became impracticable, and significant surfaces could no longer be cultivated. Erosion and landslides in hill and tableland regions deteriorated the quality of soils.

**Table 9. Soil quality limiting factors and size of affected area, 1992 - 2002**

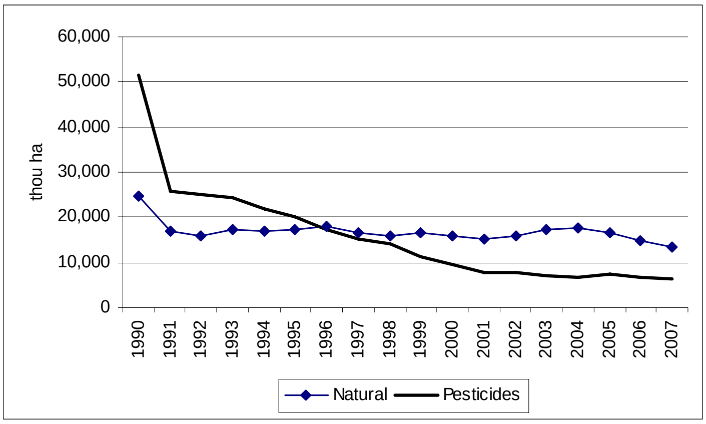
| Soil quality limiting factors | Affected area | | |
|---|---|---|---|
| | 1992 | 2002 | |
| | Thou ha | Thou ha | As per cent of total agricultural land |
| **Frequent droughts** | **3,900** | **7,100** | **48** |
| **Frequent moisture excess** | **900** | **3,781** | **26** |
| **Water erosion** | **4,065** | **6,300** | **43** |
| Landslides | 700 | 702 | 5 |
| Wind erosion | 387 | 378 | 3 |
| Salty soils | 600 | 614 | 4 |
| Soil compaction due to inadequate cultivation | 6,500 | 6,500 | 44 |
| Natural soil compaction | 2,060 | 2,060 | 14 |
| Crust formation | 2,300 | 2,300 | 16 |
| **Small and very small humus deposit** | **7,114** | **7,485** | **58** |
| **Strong and moderate acidity** | **2,350** | **3,437** | **23** |
| **High alkalinity** | **165** | **223** | **1** |
| **Very poor and poor content of mobile phosphorus** | **4,475** | **6,330** | **42** |
| **Poor content of nitrogen** | **3,438** | **5,110** | **34** |
| Microelement deficiency (zinc) | 1,500 | 1,500 | 10 |
| Chemical pollution | 900 | 900 | 6 |
| Oil and salt water pollution | 50 | 50 | 0 |
| Pollution by wind-borne substances | 147 | 147 | 1 |

*Source: National Institute of Statistics*

Soil quality is also affected by the marked fragmentation of agricultural lands and the very high proportion of small individual farms that have little financial resources, and resort to inappropriate farming practices. Services in agriculture are poor, works are little mechanised, new production technologies are difficult to implement, crops are not fertilised as much as they should, irrigation and other land improvement systems are abandoned or destroyed, etc.

A particularly important problem is the agro-chemical degradation of agricultural soil following *inadequate crop fertilisation*. What was seen in the 1992 – 2002 period was the significant expansion of farming soils having a small and very small humus reserve, low mobile phosphorus, and nitrogen content, high acidity and alkalinity. The quality of the natural fertilisers used was half that of 1990; similarly, three times fewer chemical fertilisers and seven times fewer pesticides. As a result, vast areas were yearly deprived of fertilisation (Figure 23).

a.




b.

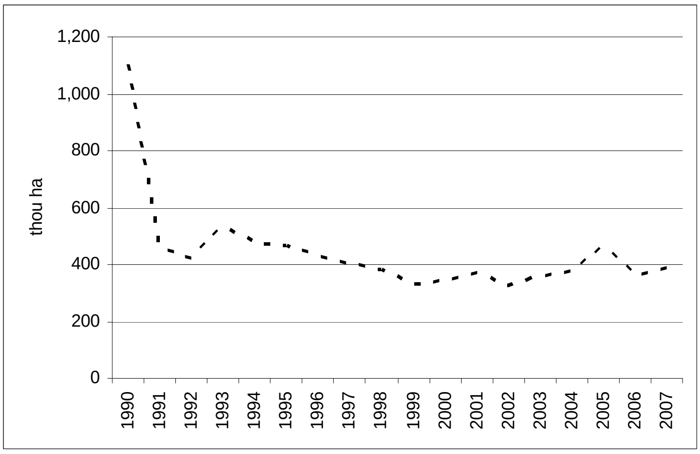



**Figure 23. The quantity of fertilisers, 1990 – 2007**
**a) natural fertilsers and pesticides, b) chemical fertilisers**

Practicing agriculture based solely on the natural fertility of soils and failing to compensate for the loss of fertilising elements by adding chemical and organic supplies, prevented soil nutrients to regenerate through natural processes, soil reserves steadily exhausting and fertility depleted. Insufficient quantities of fertilisers showed up in the top soil nitrogen balance which indicated a gap between soil nitrogen input and output/year over three periods of time: 1) 1985 – 1990, a nitrogen surplus of 50 kg/ha agricultural land; 2) 1991 – 1996, a nitrogen surplus of 12 kg/ha and 3) after 1997, nitrogen-deficient soil. The same situation with phosphorus and potassium fertilisers (Popescu et al., 2004). What was used in 2007 were 387 thou tons of chemicals compared to an estimated optimum mineral amount of 1,957 thou tons (Research Institute for Soil Science and Agrochemistry).

In most cases, chemicals are arbitrarily applied, without specialist advice for the optimal dosing and spraying time required by the respective plants and the soil demand for nutrient supply.

*Distribution or abandonment of land improvement systems*. In 2007, irrigation systems covered 3,155 thou ha, draining systems 3,250 thou ha, embankments 216 thou ha and erosion control works 2,278 thou ha (Figure 24). These systems began degrading extensively in the 1990s, fact that had a negative effect on the quality of soils and the productivity of land.

The south and south-east of Romania, most severely hit by drought and desertification, had had large areas equipped with irrigation facilities, most of them being destroyed after 1990, or left in an advanced state of degradation. In 2007, only 10% of the total agricultural area was managed for irrigation (3 mill. ha). In the absence of irrigation during long periods of severe drought (e.g. in 2000), cereal productions were dramatically diminished, e.g. by 40 percentage points compared to the year before (Table 10).

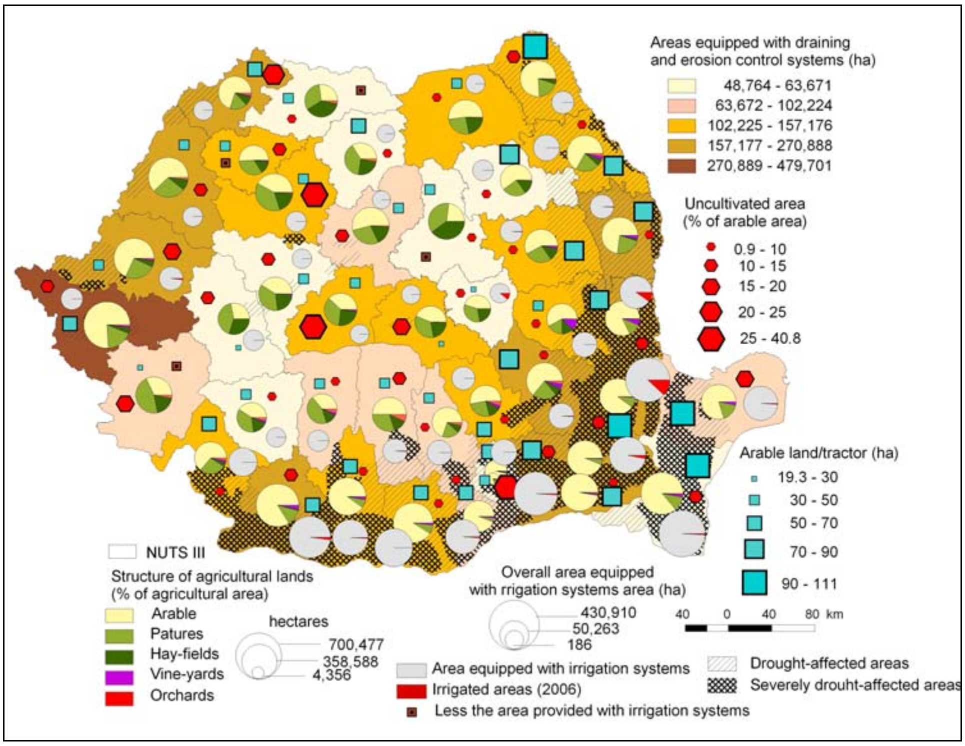



**Figure 24. Types of land management in Romania**

Table 10. Agricultural areas requiring improvement works

| | | |
|---|---|---|
| Air-water regime control | | 1000 ha |
| | Irrigations | 7,500 |
| | Drainage | 6,700 |
| | Flood defenses | 2,100 |
| Soil erosion prevention and control | | 6,400 |
| Improving soil quality | Reducing acidity | 2,200 |
| | Soil loosening | 3,200 |
| | Salt washing | 500 |
| | Increasing humus content | 10,000 |

Source: 'Soil Improvement' National Administration

The low level of mechanisation and the difficulties in introducing new production technologies in agriculture are the result of poor financial resources and the inadequate farm structure.

In 2007, there were 54.1 ha arable land/tractor, as against the EU average of 20.0 hectares; 204.7 ha cultivated with cereal plants/harvesting combine. The situation looked even bleaker with the other machines and equipments (ploughs, motor cultivators, sowing machines, sprinklers, straw-and-hay packing presses) which were far below the minimum number needed for performing mechanical works in the optimum periods set by cultivation technologies, a situation that caused huge crop losses. The insufficient number and obsolescence of tractors and machines, and prohibitive tariffs for the small farmers, makes many return to animal traction and manual work.

*Distribution of agricultural land by capability class*. There are five classes of soil capability/crop, in terms of productive potential established by complex soil studies.

Class I land capability for various uses, without improvement measures being applied, represents 2.8%; class V, very low land capability represents 27.3% (Table 11). Most arable lands fall into the first three classes, pastures and hay-fields, vine-yards and orchards listing in the last two classes. Pastures and natural hay-fields are severely degraded, 46.6% of their area falling into class V (very poor quality).

**Table 11. Distribution of agricultural terrains by capability class, 2002**

| | Land use | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Capability class | Agricultural land | | Arable | | Pastures and hay-fields | | Vine-yards and orchards | |
| Total area | 1000 ha | % | 1000 ha | % | 1000 ha | % | 1000 ha | % |
| - capability class | 14,800 | 100.0 | 9,351 | 100.0 | 4,906 | 100.0 | 543 | 100.0 |
| I very good | 411 | 2.8 | 355 | 3.8 | 54 | 1.1 | 2 | 0.4 |
| II good | 3,656 | 24.7 | 3,353 | 35.9 | 220 | 4.5 | 83 | 15.3 |
| III moderate | 3,086 | 20.8 | 2,369 | 25.3 | 597 | 12.1 | 121 | 22.3 |
| IV poor | 3,613 | 24.4 | 1,726 | 18.4 | 1,750 | 35.7 | 137 | 25.2 |
| V very poor | 4,034 | 27.3 | 1,549 | 16.6 | 2,285 | 46.6 | 200 | 36.8 |

### *5.1.6. Agricultural production*

Post-1989 changes in the structure of land ownership, means of production and relations among agriculture, industry and other branches of the national economy, did have an impact on the evolution of agricultural production, too. Plant and livestock productions (Figure 25) evolved distinctively different, the percentage of the former increased, while of the latter decreased significantly.

In 2007, the agricultural production accounted for 50,649,602 thousand lei – Ron, of which 60.2% plant production (28,723,475 thousand lei – Ron) and 38.3% (18,291,624 thousand lei - Ron) livestock production. The overall value of agricultural services that year was of 473,788 thousand lei – Ron (1.5%). The private sector produced 95.7% of the overall output.

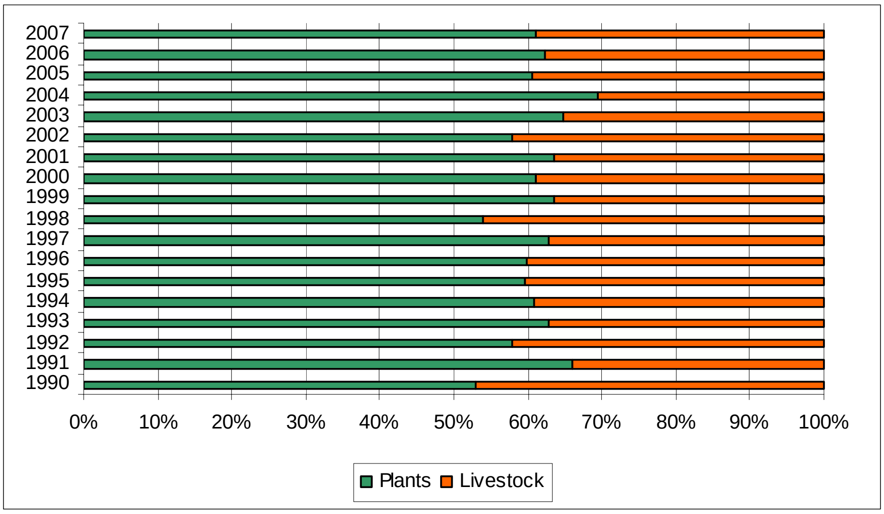



**Figure 25. Structure of agricultural production**

***During the post-socialist period, there were major changes in the evolution and structure of the cultivated area and of plant production.***

Evolution by main crops are given in Table 12. Over 1990 – 2000, the production of most crops kept decreasing because the allocated surfaces shrank and technological regression largely reduced average outputs. After 2000, overall and average yields, especially of maize, sun-flower, sugar-beet, potatoes and vegetables would improve.

Since 2005, in order to help farmers comply with European standards and become more competitive, certified seeds and planting material from internal production have been subsidised.

Wine-and-fruit growing holds an important place, Romania being known worldwide in this field. After 1990, the areas occupied with these crops shranking considerably, grape and fruit yields would decrease accordingly, with fluctuations from one year to the next due both to natural factors and material and financial difficulties.

**Table 12. Total and average production/ha of main crops (yearly averages)**

| | Total production (thou tons) | | | | Average production (kg) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1986-1990 | 1991-1995 | 1996-2000 | 2001-2006 | 1986-1990 | 1991-1995 | 1996-2000 | 2001-2006 |
| **Grains** | 18,286 | 17,031 | 15,836 | 17,616 | 3,060 | 2,728 | 2,761 | 2,998 |
| *Wheat and rye* | 7,403 | 5,607 | 4,942 | 5,885 | 3,081 | 2,563 | 2,517 | 2,584 |
| *Barley and two-row barley* | 2,788 | 2,026 | 1,052 | 1,089 | 3,835 | 2,775 | 2,181 | 2,417 |
| *Maize* | 7,836 | 8,916 | 9,350 | 10,168 | 2,918 | 2,958 | 3,066 | 3,487 |
| Sun-flower | 705 | 756 | 1,027 | 1,292 | 1,584 | 1,270 | 1,096 | 1,320 |
| Sugar-beet | 5,086 | 2,959 | 2,003 | 2,668 | 21,280 | 19,986 | 20,487 | 25,407 |
| Potatoes | 4,111 | 2,830 | 3,353 | 4,001 | 12,728 | 11,841 | 12,652 | 14,327 |
| Vegetables | 3,589 | 2,631 | 2,630 | 4,167 | 13,857 | 12,463 | 11,847 | - |

*Source: Romanian Statistical Yearbook, 1987–2007*

*Livestock production*. Besides the cultivation of plants, raising livestock has always been one of the basic occupations with the Romanians, given the vast expanses of pastures and hay-fields and the cultivation of plants over ever larger areas. There are numerous historical proofs that shepherding was a major activity on Romania's territory, animal husbandry dating from the Geto-Dacian times to the early 20$^{th}$ century, when arable land expanding rapidly to the detriment of grazes and natural hay-fields, this activity gradually subsided. Changes also occurred in the structure of species, in that the proportion of cattle decreased in favour of horse-breeding.

As from 1990, raising animals passed through difficult times, both effectives and productions dropping significantly. By the end of 2007, the number of cattle fell by 55.1% compared to 1990, swine by 43.7%, sheep and goats by 44.1%, and poultry by 28%, most species were basically halved (Figure 26).

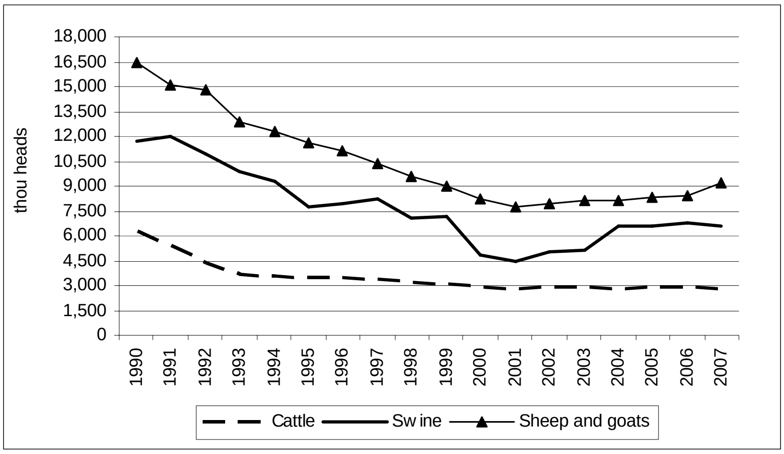



**Figure 26. Livestock dynamics, 1990 – 2007**

*Livestock density per unit of area* is an indicator of the total number of livestock/100 ha agricultural land (LLU - Large Livestock Units/100ha) which shows best how land is used. The indicator is calculated as ratio between the overall number of livestock 100 ha agricultural land, representing the quantitative reality of the animal breeding sector and the extent of intensive land use. The average livestock density in Romania was 53.2 LLU/100 ha agricultural land, a figure below the optimal 100 LLU/100 ha, values in the countryside varying between 4 and 718 LLU/100 ha agricultural land. In 71% of the settlements, the average density stood below 50 LLU/100 ha, in 25% it was of 50-100 LLU/100 ha, being above it only in 4 per cent (Figure27).

A calculation of this indicator by species (cattle, swine, sheep and goats) yields different values, which means that livestock resources in the territory are unevenly spread. *Cattle* are found everywhere, densities being the highest (30 – 50 heads/100 ha) in the counties of Suceava, Neamț, Covasna, Argeş, Vâlcea, Maramureş, Bacău, Dâmbovița, etc. At the other end of the spectrum (under 10 heads/100ha) are the counties from the south-east and west of Romania (Constanța, Tulcea, Călăraşi, and Timiş). *Swine-breeding* is closely connected with the growth of maize and potatoes, the average density in 2006 was 76.2

LLU/100ha arable land. In four counties (Gorj, Ilfov, Vâlcea, and Maramureş), and the city of Bucharest it was over 150 LLu/100 ha, while Ialomița (34 LLU/100 ha), but also Vaslui and Constanța had the poorest record. Sheep and goats were raised mostly in the counties of Sibiu, Covasna, Bistrița-Năsăud, Tulcea and Braşov, average densities 85 – 193 LLU/100 ha; Giurgiu, Dâmbovița, Teleorman, Ilfov, Călăraşi, and Ialomița had under 35 LLU/100 hectares arable land.

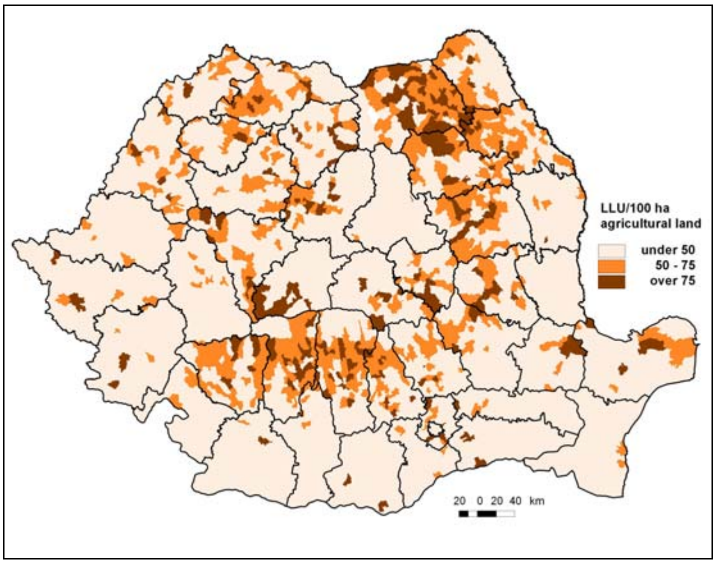



**Figure 27. Livestock density per unit of area, 2006**

The process of privatisation and the dissolution of collective farms had a negative impact both on livestock effectives and production. After 1990, the production of meat, wool and eggs slumped, with the exception of milk, due to increasing average production per farm animal.

This decline was caused by several factors, among which the closing down of the collective animal breeding farms, the semi-liquidation of former inter-cooperative economic associations of swine and poultry farms with state capital or majority state capital, the sector which had been best equipped technologically to compete with foreign products in the domestic and foreign markets; improper conditions for large-scale animal husbandry in the private sector dominated by peasant farms which lacked money, adequate constructions, fodder and a specific market-oriented behaviour, ignorant of performing technologies and the demands of a competitive market. However, some modern farms have already been established with EU funds.

*5.1.7. Current issues in Romanian agriculture*

Agriculture in Romania has still to cope with a series of problems caused by excessive fragmentation of land into very small plots (mostly under 2 ha), the very high proportion of small individual farms practicing subsistence agriculture, advanced ageing of individual farmers and very few people with specialist studies, as well as few farmers associations. Other drawbacks are:

- little mechanisation of agricultural works (obsolete equipments, high cost of new equipments, large farming area/tractor, etc.), difficulties in implementing new production technologies, low productivity because of money shortage, insufficient use of inputs, lack of technical aptitudes and technical managerial and marketing know-how, inadequate farm infrastructure;

- a cereal-based agriculture (high proportion of cereal-covered areas and regression of technical crop surfaces – ham and sugar-beet); under-developed animal breeding sector (constant reduction of livestocks and production); absence of alternative crops to the cultivation of plants;

- much arable land become fallow; difficult access of small farmers to information and credits; absence of farmers'specialisation programmes and requalification of the workforce;

- many imported goods to meet urban retail demand and few farming products exported (usually low added value items); low incomes in agriculture; difficulties in meeting quality standards, food security, animal health and environmental conditions.

### *5.1.8. Common agricultural policy (CAP) and development of sustainable agriculture in Romania*

Acceding to the European Union made Romania gradually adopt an agricultural policy and create an institutional framework compatible with the Union's Common Agricultural Policy (CAP). One of the basic concepts of this policy is to have activities adjusted to a series of standards, such as environmental protection, safety of fodder and food, livestock protection and health. The common agricultural policy is built around two poles: *common market organisations* and *rural development*.

Rural development policy goals have in view to improve farms, guarantee the safety and quality of farm produscts, secure stable and equitable incomes for the farmers, protect the environment, develop complementary and alternative job-generating activities in order to halt the depopulation of the countryside and strengthen the economic and social texture of the rural zones, improve working and living conditions there and promote equal opportunities.

A fundamental CAP objective is *environmental protection*, primarily by the sustainable use of natural resources. So, for farms to benefit from financial assistance (direct payments/ha), *land should be maintained in good agricultural and environmental conditions*. In view of it, several codes have been elaborated, e.g. GAEC – Good Agricultural and Environmental Conditions; Good Agricultural Conditions in Zones Vulnerable to Nitrates Pollution; Good Farming Practices.

Being eligible for direct payments under a single payment by surface-area scheme, farms should have a *minimum size*, that is one hectare of agricultural land maintained according to GAEC provisions, each component plot having at least 0.3 ha, and no less than 0.1 ha for vine-yards, orchards, hop plants, fruit nurseries, wine nurseries and fruit-trees.

The tasks assigned to the Integrated Administration and Control System (IACS) of the Agency for Payments and Intervention in Agriculture (APIA) is management and control of the farmers' payment applications. The IACS administers the following payment by surface-area schemes: SAPS (Unique Payment by Surface-area), CNDP (Complementary National Direct Payment), LFA (Less-favoured Areas), environmental measures in agriculture, fuel crops and transitory payments for tomato crops.

Checking out the plots of land eligible for payment devolves on the LPIS (Land Parcels Identification System) set up previously to Romania's EU accession. Plots were identified by remote sensing (using ortophotoplanes) and by Geographical Information Systems (GIS).

Since farms should be minimum one hectare in size to benefit from direct payment by surface-area, it appears that 64.8% of the farms are eligible, the other 35.2% having less than one hectare. The request for minimum farm and plot size stimulates farmers to associate themselves, which is expected to reduce the marked fragmentation of farming lands in Romania.

Romania's EU accession and implementation of the new CAP requirements stimulated an approach to sustainable land management. A comprehensive legal framework was created covering all the issues connected with the sustainable use of natural resources (Law 84/1996 on Land Improvements; Urgency Ordinance 23/2000 on the Foundation of the National Land Improvement Society; Law 289/2002 on Forest Belts; Fruit-growing

Law 348/2003; Law 312/2003 on Vegetable Production and Sale; Law 244/2002 on Vine-yard and Wine-making and the Organisation of the Common Viticultural Market; Law 205/2004 Law on Animal Protection and many other laws regarding protected areas; a forestry code, etc.

A key problem in securing the sustainable development of natural resources is to conclude the cadastral survey of real estates and forest lands, the only official register depicting the situation of land (type of property, use, quality of land, capability for various crops, etc.), and a reliable tool in elaborating well-grounded strategies.

***Developing sustainable agriculture***

Sustainable development has in view to protect the environment and the natural resources, to render agriculture efficient for farmers and secure its long-term practice, provide sufficient quality food for the population, and make it an activity equitable for man and society.

As an EU-member state Romania had to work out its own National Strategy for Sustainable Development (NSSD) in line with the Union's targets and the methodological guide-lines set by the European Commission. On July 1, 2008, a revised version (V) of this strategy for 2013, 2020 and 2030 was put forward.

The National Strategy for Sustainable Development was elaborated based on a series of sectoral programmes and strategies worked out before and after the country's accession to the European Union.

Part IV of this Strategy is devoted to sustainable development of agriculture, forestry and fishing. The national objective set for 2013 *is to make the economy of rural areas more dynamic, while maintaining a social equilibrium by means of the sustainable* *development of agriculture, forestry and fishing, inclusive of their afferent processing industries, and the conservation and improvement of natural resources*.

This stage should to lay the basis of the European agricultural model, with highlight on developing organic, ecologically-certified farming and food production and of niche production in zones where stable traditions and favourable conditions exist for it; steps shall be taken to protect Romanian products, recipes and preparation procedures in the Single EU Market, at the same time observing food safety norms, and adequately promote them.

Efforts are being made to put into effect the provisions of the Strategic National Plan for Rural Development, 2007 – 2013. General targets: to make farming and food, forestry and fishing more competitive, to improve the rural area and its environment, to consolidate good farming and forestry practices and the food processing industries; to secure food safety; to encourage a diversified rural economy and a better quality of life in the countryside and promote local development initiatives. Recommendations for requisite measures: elaboration and implementation of several development programmes (National Programme for Sustainable Forest Management; Medium and Long-term Programme to Modernise Irrigation Systems; National Programme for Soil Protection and Conservation).

The 2020 target *is aimed at consolidating farming, food and forestry structures concomitantly with the economic and social development of rural areas in order to further bridge the gaps and attain the average level of the EU-member states'performance, referred to the 2006 figures*. To this end, a new task programme spanning the 2014 – 2020 interval is to be elaborated with focus on sustainable development principles. Specific targets: improving environmental conditions (soil degradation control and protection of flood-prone areas, maintenance of forest belts at sustainable levels, assisting the disadvantaged zones, and improving landscape quality); making some sectors with environmental impact more competitive, improving the quality of life in the countryside, etc.

The national objective for 2030 *is to fully adopt EU policies in agriculture, forestry and fishing; complete the restructuring and modernisation of these sectors and of the rural space, generally*

***Ecological farming – a basic component of sustainable agriculture***

Romania has the necessary conditions of soil and climate for some 15% of the agricultural area to be farmed ecologically. Developing ecological agriculture has implied informing and promoting the idea among farmers and organising them with a view to selling their products at home and abroad.

**Table 13. Ecologically farmed areas (ha)**

| | Total | Cereals | Pstures and hay-fields | Oleoginous and fuel plants | Vegetables | Fruit | Spontaneous flora harvesting | Other crops |
|---|---|---|---|---|---|---|---|---|
| 2000 | 17,438 | 4,000 | 9,300 | 4,000 | 38 | 0 | 50 | 50 |
| 2001 | 28,800 | 8,000 | 14,000 | 6,300 | 100 | 0 | 100 | 300 |
| 2002 | 43,850 | 12,000 | 20,000 | 10,000 | 700 | 50 | 300 | 800 |
| 2003 | 57,200 | 16,000 | 24,000 | 15,600 | 200 | 100 | 400 | 900 |
| 2004 | 73,800 | 20,500 | 31,300 | 20,100 | 300 | 200 | 500 | 900 |
| 2005 | 110,130 | 22,100 | 42,300 | 22,614 | 440 | 432 | 17,360 | 4,884 |
| 2006 | 143,194 | 16,310 | 51,200 | 23,872 | 720 | 292 | 38,700 | 12,100 |
| 2007 | 190,129 | 32,222 | 57,600 | 26,491 | 310 | 650 | 58,728 | 14,128 |

*Source: Ministry of Agriculture and Rural Development*

After 2000, the overall area destined to ecological farming kept growing steadily up to 190 thou ha in 2007, which was approximately eleven times the 2000 figure (Table 13). More than 30.2% of this area was covered with natural pastures and hay-fields, 16.9% with cereals, 14.0% with oleoginous and fuel plants, 0.5% with vegetables and fruit, spontaneous flora products were harvested from 30.8% of the area and other crops were grown on 7.4 percent.

In 2000 – 2007, overall ecological farming increased by some 13%, while the range of processed products diversified. Plant production registered the most significant growth, from 13.5 thou tons in 2000 to over 169.3 thou tons in 2007 (Table 14). Farm animals also recorded positive evolutions (heads of cattle increasing to 4,165, of sheep and goats to 76,376) (Table 15).

**Table 14. Ecological farming: livestock and poultry**

| | Milch cows | Sheep and goats | Poultry |
|---|---|---|---|
| 2000 | 2,100 | 1,700 | - |
| 2001 | 5,300 | 3,700 | - |
| 2002 | 6,500 | 3,000 | - |
| 2003 | 7,200 | 3,200 | 2,000 |
| 2004 | 7,200 | 3,200 | 2,700 |
| 2005 | 8,100 | 40,500 | 7,000 |
| 2006 | 9,900 | 86,180 | 4,300 |
| 2007 | 6,265 | 78,076 | 4,720 |

*Source: Ministry of Agriculture and Rural Development*

**Table 15. Plant and livestock production and main ecologically processed products**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| **Plant productions (tons)** | | | | | | | | |
| Total | 13,502 | 24,400 | 32,300 | 30,400 | 87,200 | 131,898 | 166,573 | 169,312 |
| *Cereals* | 7,200 | 12,500 | 16,000 | 14,400 | 41,000 | 55,000 | 48,441 | 65,127 |
| Oleoginous and fuel plants | 5,500 | 7,200 | 11,000 | 12,480 | 37,000 | 45,600 | 73,082 | 52,982 |
| *Vegetables* | 600 | 4,000 | 4,000 | 2,000 | 3,000 | 7,200 | 8,707 | 3,410 |
| *Fruit* | - | - | 200 | 300 | 500 | 1,000 | 340 | 1,255 |
| flora harvested | 200 | 400 | 300 | 320 | 4,500 | 16,748 | 24,962 | 35,236 |
| *Other crops* | 2 | 300 | 800 | 900 | 1,200 | 6,350 | 11,041 | 11,302 |
| **Livestock production (hl)** | | | | | | | | |
| *Cow's milk* | 58,367 | 63,885 | 92,747 | 92,485 | 92,868 | 100,000 | 122,000 | 85,031 |
| *Sheep's milk* | 701 | 1,740 | 1,360 | 1,470 | 1,800 | 13,500 | 15,500 | 13,273 |
| *Eggs (thou pieces)* | - | - | - | 500 | 650 | 1,820 | 1,075 | 1,321 |
| **Main processed products (tons)** | | | | | | | | |
| *Feta-type cheese* | 18 | 46 | 36 | 45 | 48 | 480 | 520 | 510 |
| *Schweitzer* | 23 | 23 | 100 | 110 | 116 | 268 | 576 | 580 |
| *Caşcaval - Pressed cheese* | - | 121 | 250 | 220 | 253 | 330 | 642 | 640 |
| *Tinned vegetables and fruit* | - | - | - | - | 35 | 50 | 42 | 40 |
| *Honey* | 10 | 20 | 80 | 110 | 320 | 610 | 1,242 | 1,950 |

*Source: Ministry of Agriculture and Rural Development*

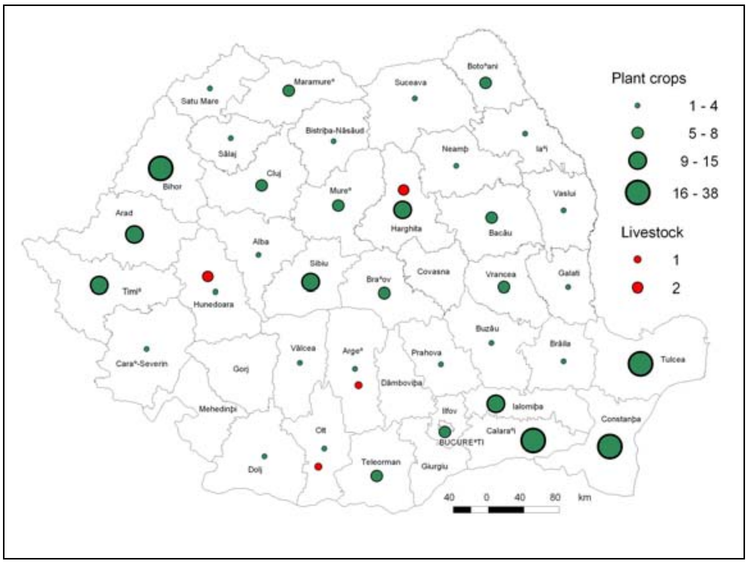



**Figure 28. Number of farmers in ecological agriculture, 2007**

In 2007 there were 3,834 registered farmers practicing ecological agriculture, basically 425 more than in 2006, the majority in the plant-growing sector of 34 counties, mostly in Tulcea – 38, Călăraşi – 26, Constanța – 23, Bihor – 21 and Bucharest Municipality (Figure 28), while the livestock sector numbered only 6 farmers in the counties of Hunedoara, Harghita, Argeş and Olt.

Much of the total quantity of ecological products (over 40%) was exported to Germany, Italy, Greece, Switzerland, The Netherlands and France. In 2007, Romania imported over three million euro worth of ecological products: brown sugar, coffe, chocolate, drinks made from soy-been, fruit juice, etc.

Ecological farming may become an important component of sustainable development and meet the demands of a continuously growing market. Developing an ecological agriculture is an efficient means of selling the products by 20 – 60% higher prices than the conventional ones. According to estimates, ecologically farmed areas are expected to cover 5.08% of the overall agricultural surface by 2013.

Putting in place the Common Agricultural Policy will further contribute to the development of agriculture by using environmentally-friendly farming practices and securing the sustainable use of natural resources.

### 5.2. Agriculture impacts on environment in Romania

**Agriculture** can contribute to environment degradation through: point pollution sources (large livestock farms) and diffuse pollution sources (domestic animal breeding; storage and use of chemical fertilizers and pesticides; inadequate agricultural practices, irrigations, etc.).

Having in view the large surfaces occupied by arable land, agriculture could be an important pollution source of environment, especially of water resources. But after 1990, agriculture was one of the first economic branches severely affected by the restructuring process from the transition period. The impact of agriculture on surface and groundwater quality kept shrinking, because each year, large areas covered by arable lands were left uncultivated, the total quantity of fertilizers and pesticides greatly decreased, most of the irrigation systems were destroyed, and also large animal breeding farms were closed.

However, there is a historical pollution which comes from the socialist period due to the intensive agriculture applied a long time, the uncontrolled organic and mineral fertilizers application in inappropriate moments are some of the elements that determined important nitrogen quantities accumulation, which represented a major source of nitrates in the groundwater.

A study conducted by the ICPA (Research Institute for Soil Science and Agrochemistry) in collaboration with National Administration "Romanian Waters" in 2003 and updated in 2008 shows that in Romania there were 255 areas (communes) vulnerable to nitrate pollution from agricultural sources, in some of them pollution comes from historical sources and the rest pollution comes from current sources (Figure 29). In 2003 the areas vulnerable to nitrate pollution covered about 8.64% of total country area and 13.93% of total agricultural area.

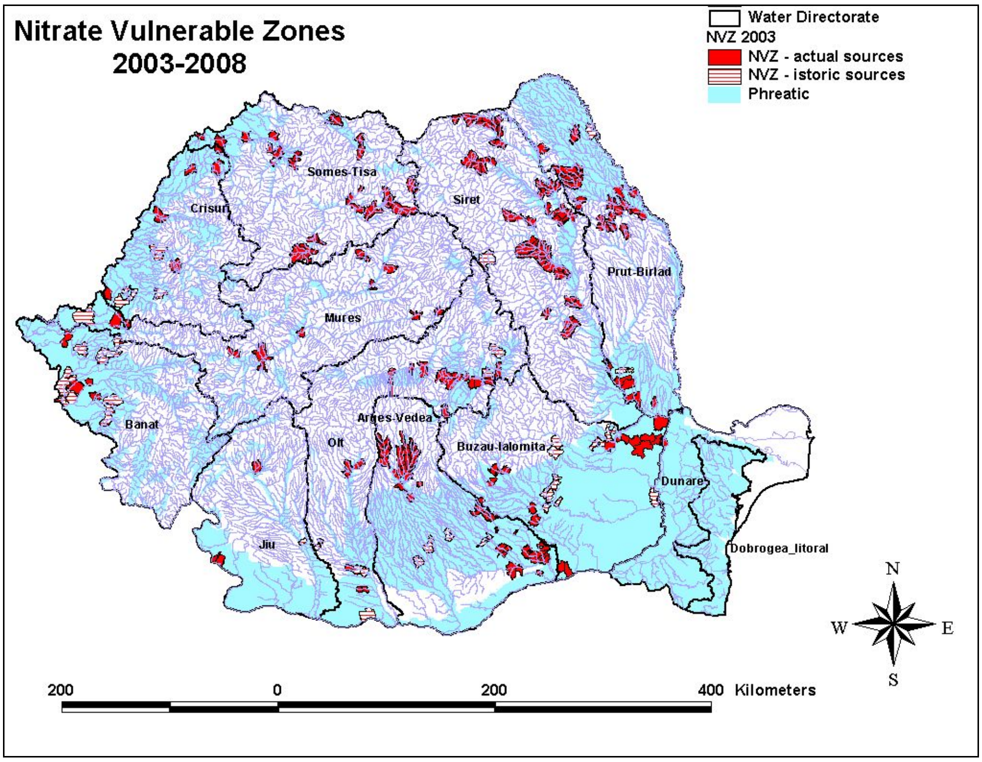



**Figure 29 Areas vulnerable to nitrate pollution from agricultural sources in Romania, 2003**
*Source: Research Institute for Soil Science and Agrochemistry*

In 2008 by redefining the areas vulnerable to nitrate pollution (according to *Directive 91/676/EEC* requirements, concerning the protection of waters against pollution caused by nitrates from agricultural sources), vulnerable areas have greatly increased since then to cover almost entirely agricultural area (Figure 30).

### *5.2.1. Landuse practices-induced land degradation and desertification*

In Romania the areas affected by long period of drought with dramatic effects on crops and land quality sum up about 34% of total country area, of which 16% is characterized by high risk to desertification. The south-east and south of Romania which suffered most from droughts (Dobrogea, The Bărăgan Plain, south of the Moldavian Plateau, south of the Romanian Plain), regions also hit by desertification. Also, the north of the Moldavian Plateau, north of the Romanian Plain and some parts of the Western Plain experienced important climatic drought, but present a low risk to desertification (18,7% of total country area).

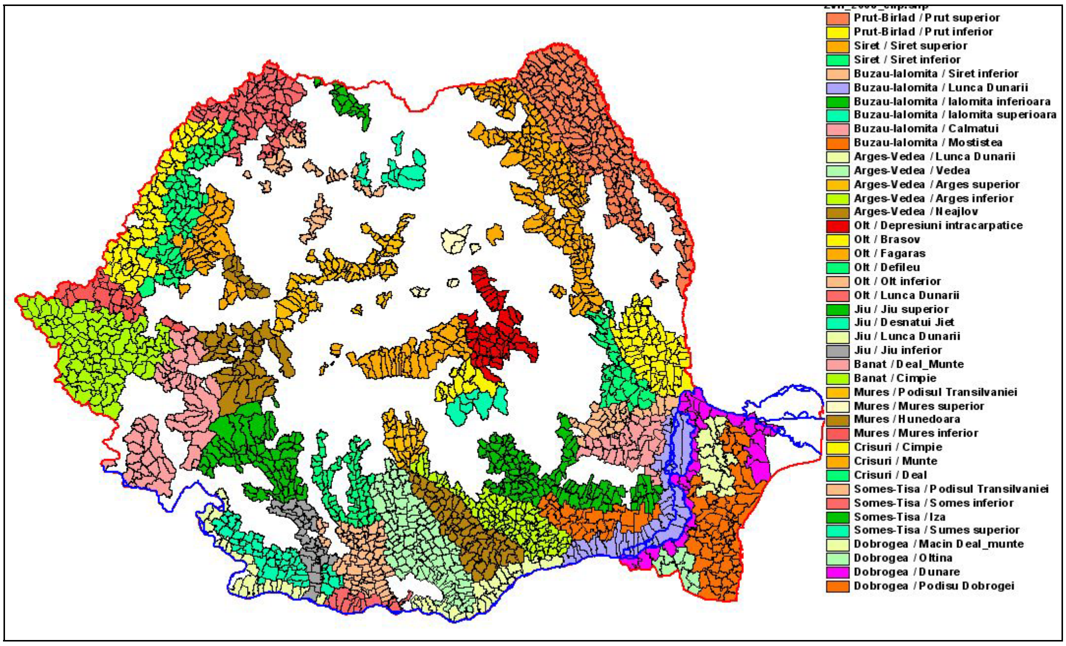



**Figure 30. Areas vulnerable to nitrate pollution from agricultural sources in Romania, 2008**
*Source: Research Institute for Soil Science and Agrochemistry*

After 1990, *physical and agro-chemical degradation* of agricultural soils would intensity over ever larger areas, mostly because of inadequate agricultural practices, such as poor fertilization of crop, little or unsuitable mechanisation of land, abandonment of irrigation and other land improvement systems, difficulty of implementing new production technologies, etc. Also, the marked fragmentation of agricultural lands and the very high proportion of small individual farms that have little financial resources, and resort to inappropriate farming practices have contributed to land degradation.

In the Romanian Plain, particularly in sandy soil areas (Oltenia Plain), by uncontrolled deforestation of protection belts accelerated the northward extension of desertification-affected surfaces, conducive to depleted arable-land productivity and, in time, abandonment of these lands. Much of the arable which falls into the high drought-affected sandy soils of the Oltenia Plain, were left fallow every year. At the county level 8.8 million ha of arable land remained uncultivated over 1990-2006 period.

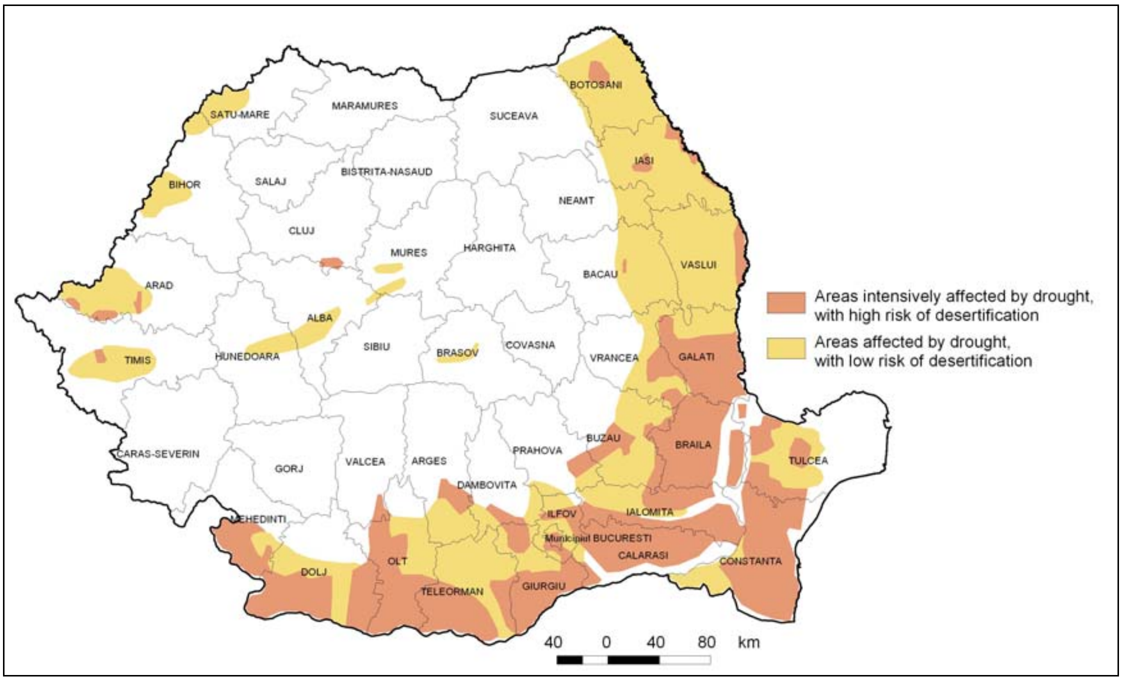



**Figure 31 Areas with risk of desertification in Romania**

Concerning the main land use categories, about 50% of total agricultural land is situated within the areas with high and low risk of desertification (Figure 31, Table 16). Agricultural land use categories most affected by desertification are vineyards (over 64% of total area is found in regions with risk of desertification), arable land (55%), pastures (25.8%) and orchards (13.5). On the opposite, a small percentage of lands covered with natural vegetation (forests and natural grasslands) are situated in areas with risk of desertification (11%, respectively 8.3%).

**Table 16. Land cover/land use categories in areas with high and low risk of desertification in Romania**

| Land cover/use classes | County level | High risk | | Low risk | | Total (High+Low risk) | |
|---|---|---|---|---|---|---|---|
| *Corine 2006* | *ha* | *ha* | *% of total area* | *ha* | *% of total area* | *ha* | *% of total area* |
| Buil-up areas | 1494937 | 246593 | 16,5 | 376555 | 25,2 | 623148 | 41,7 |
| Arable land | 10189906 | 2946301 | 28,9 | 2731310 | 26,8 | 5677612 | 55,7 |
| Vineyards | 409402 | 130333 | 31,8 | 134035 | 32,7 | 264368 | 64,6 |
| Orchards | 371777 | 10130 | 2,7 | 40245 | 10,8 | 50375 | 13,5 |
| Pastures | 2525661 | 191490 | 7,6 | 460559 | 18,2 | 652048 | 25,8 |
| Forest | 7593735 | 216935 | 2,9 | 617130 | 8,1 | 834065 | 11,0 |
| Natural grassland | 475126 | 24159 | 5,1 | 15314 | 3,2 | 39473 | 8,3 |
| Inland marches | 386303 | 40344 | 10,4 | 37810 | 9,8 | 78154 | 20,2 |
| Water-covered areas | 546338 | 66422 | 12,2 | 81027 | 14,8 | 147449 | 27,0 |
| **Total** | **23993184** | **3872707** | **16,1** | **4493984** | **18,7** | **8366691** | **34,9** |

Desertification is an advanced stage of ***land degradation*** where the soil has lost part of its capability to support human communities and ecosystems. Romania has an overall agricultural area of 14.8 million hectares, of which approximately 12 million hectares (7.5 mill. ha arable land) feature one or more quality limiting factors. At the national level the land degradation affects more than 2/3 of the total country area (Table 17). The impact of anthropic and natural factors over the post-socialist period would enhance land degradation and the expansion of areas affected by them.

**Table 17. Types of land degradation in Romania**

| Degradation type | Geographical distribution | Area | |
|---|---|---|---|
| | | $10^3$ ha | % from total country area* |
| Water erosion (sheet and gully erosion) | Hilly and table land region, peri-Carpathian hills | 6 300 (of which 1 376 is gulling) | 26.4 |
| Landslides | Hilly and table land region, peri-Carpathian hills | 702 | 2.9 |
| Wind erosion | Sandy areas in Romanian Plain and Danube Delta | 378 | 1.6 |
| Silting/colmatation | Inland river flood plains, Danube flood plain and Danube Delta | 950 | 4 |
| Soil compaction | Agricultural lands (plain regions) | 1 344 | 5.6 |
| Crusting and sealing | All agricultural lands on silty, loamy and clayey soils | 2 300 | 9.6 |
| Aridization | Locally in the Danube Flood Plain | 362 | 1.5 |
| Salinization | Eastern Romanian Plain, Western Plain, Moldavia Tableland | 614 | 2.6 |
| Loss of soil fertility by organic matter and nutrient depletion | Romanian Plain, Dobrogea | 3 342 | 14.1 |
| Acidification | Arable land from the external part of the forestry region | 841 | 3.5 |
| Land without natural vegetation | Rocky, sand, alpine peaks | 141 | 0.6 |

*Source: (Dumitru et al. 2000, Munteanu, 2000; 3rd Romania's National Report on the Implementation of the United Nations Convention to Combat Desertification.*
** Some land degradation types overlap so the values have to be considered individually. The total percent is higher than 100.*

The south and south-eastern regions of Romania, hit by extreme droughts and desertification even, have large areas provided with irrigation systems (2,486 thou ha), but unfortunately most of these systems were either destroyed, or are in an advanced stage of degradation (Figure 34). In 2006, only 3.14% of the overall managed agricultural area was irrigated (out of 3 mill ha provided with irrigation systems).

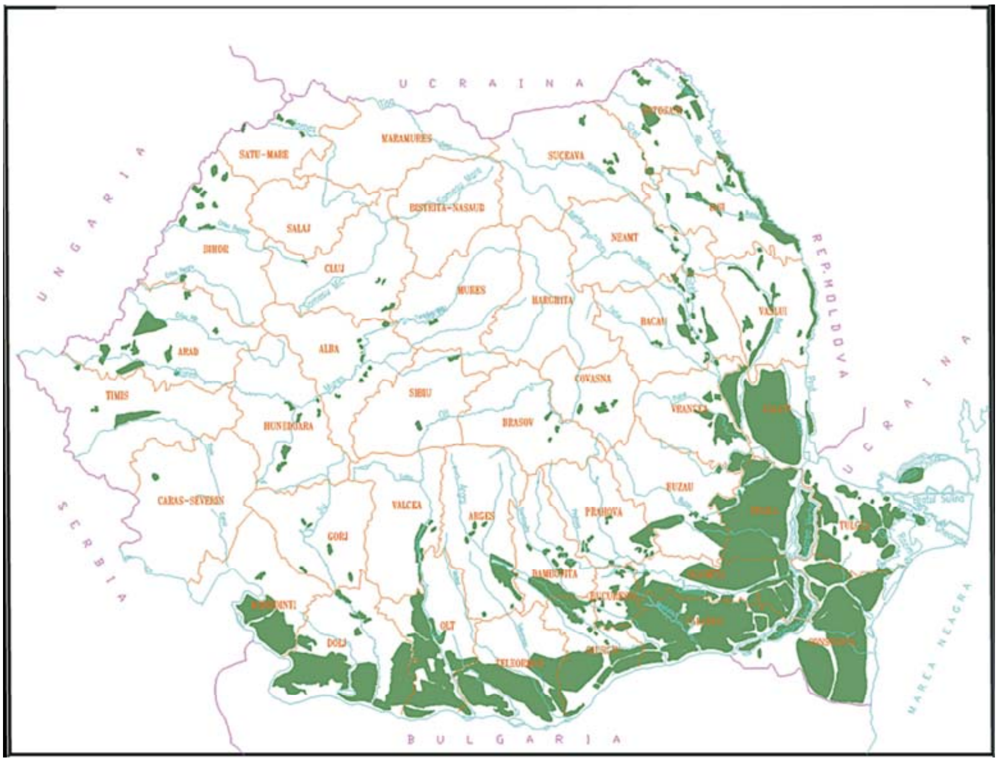



**Figure 34. Area equipped with irrigation systems and irrigated area**
*Source: National Land Improvement Administration*

For example, in the Oltenia Plain, in the absence of irrigation during long periods of severe drought cereal productions were dramatically diminished. Output variations in the main crops (wheat, maize and sun-flower) on non-irrigated grounds were climate-related. Average production/ha for main crops, in the very dry years (1993, 1996, 2000, 2002-2003, 2007), were extremely low (under 500 kg/ha for maize and under 600 kg/ha for sun-flower).

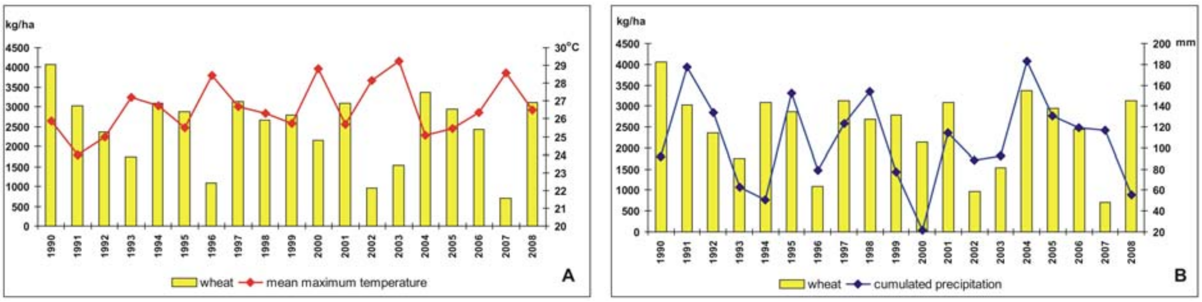



**Figure 35. Correlation between wheat yields and the main climatic elements from the season with maximum biological activity in southern Oltenia**

The correlation between climate variability and change and land use dynamics in southern Oltenia is more applicable and easier to measure in terms of arable land and agricultural production. In this respect, the correspondence between the main crops (wheat, maize and sunflower) and the most significant climatic parameters for the periods with maximum biological activity (May-June for wheat and June-August for maize and sunflower) (Păltineanu et al., 2007) points to an accurate representation of the dependence thermal and hydric resources have to annual production. As representative parameters of the thermal and hydric resources, mean maximum temperatures and cumulated monthly precipitation amounts were selected.

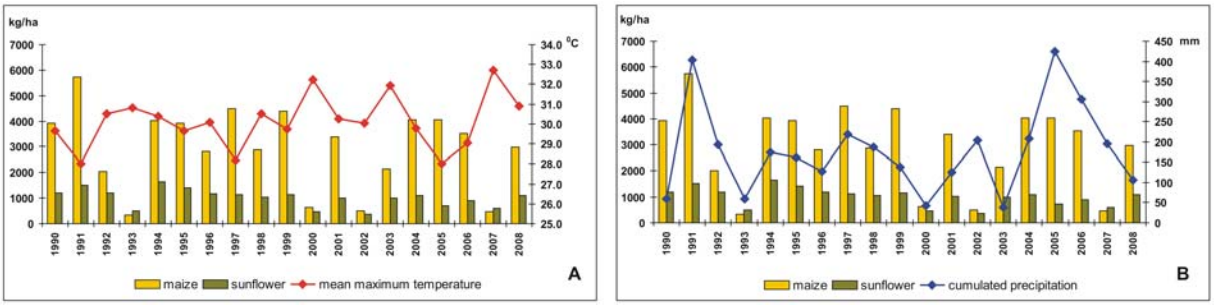



**Figure 36 Correlation between maize and sunflower yields and main climatic elements from the season with maximum biological activity in southern Oltenia**

For ***wheat***, a good correlation between the years with low productivity and the high values of mean maximum temperatures in May and June can be distinguished (the years 1996, 2002-2003, 2007, etc.) (Figure 35). When discussing the relationship between the crop productions and the cumulated precipitation amounts for the same time span, a directly proportional relationship is highlighted. Hence, the decreased yields are related to low precipitation amounts (the years 1993, 1996, 2002-2003 etc.), while increased productions are related to excess rainfall (the years 1991, 1995, 1997, 2004 etc.).

As for the ***maize*** yields, the correlation with the same climatic elements is much too firm stressing, in the case of thermal resources, some years with very low productions related to high maximum temperatures (the years 1993, 2000, 2002-2003, 2007), which highlights a strong dependency of this crop to the thermal factor (Figure 36). When talking about the hydric resources, the correlation between the production and the cumulated precipitation amounts indicates the same increased dependency (the years 1991, 1993, 2005) but also situations when moderate precipitation (150-200 mm) conditions increased productions (the years 1994, 1995, 1997, 1999 etc.).

The ***sunflower*** develops a quite week correlation between productions and temperature/precipitations. The higher temperature values determines production shrinking (the years 1993, 2000, 2002-2003 etc.), while increased and moderate precipitation amounts provide higher productions (the years 1991, 1994 etc.) (Figure 6). Therefore, following the correlation between the productions of the main crops and the ecoclimatic favorability of the study-area, several critical agro-climatic years (1993, 2000, 2002-2003, 2007) were identified pointing out the restrictive impact thermal and hydric resources have on yields' quantity and quality.

### 5.3. Data basis for the model application for Romania

**Selecting a pilot area** for modelling agricultural productivity and the impacts of irrigation on crop productivity under current and future climatic conditions - **Oltenia Plain** (8,300 sqkm) - a drought-prone area

**Data collecting** included the following indicators (*completed task*):

**Soil data** (soil maps, scale 1: 200 000) - the soil attributes - soil type, depth, bulk density, percent of sand, percent of silt, pH, etc. (Source: National Institute of Research and Development in Soil Science, Agro-chemistry and Environment).

**Climate data** (.cvs files): monthly average for precipitation, temperature and their standard deviation over 20 year interval-time (1990-2009) for 8 meteorological stations in the case-study area. The scenario data cover 2071 – 2100 interval (Source: National Meteorological Administration).

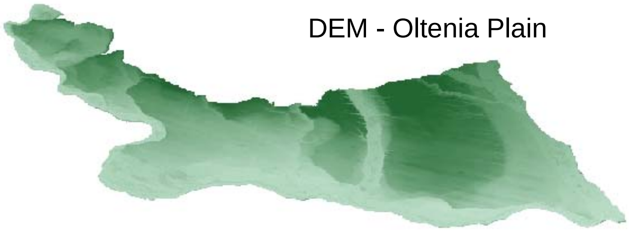
**Land management data:** irrigation water for corn and wheat (thou cubic meters), the irrigated area, the quantity of fertilizers for corn and wheat and the fertilized area (2006-2009) (Source: National Administration for Land Management – Dolj County Branch and the Agriculture and Rural Development Agency in Dolj County)
**Location data** provided by the Institute of Geography

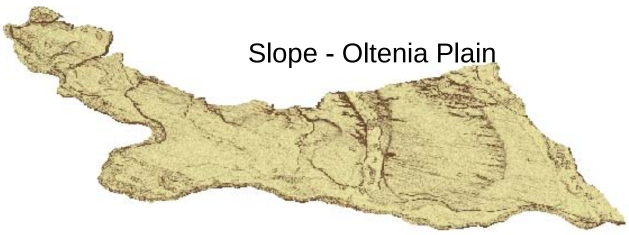
**Land use data** downloaded from European Environment Agency – EEA,
http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster

**Data integration into GEPIC** through a series of GIS techniques and file transfer operations between the spatial data format and the EPIC format (*ongoing activity*).

## Preparing the grids with the collected spatial/analogous data sets

Extent: ***grids of 0.05' by 0.05'*** (i.e. cell size of about 100m)




**Raster Information**

Columns_and_Rows: 2928, 1110

Number_of_Bands: 1

Cellsize__X._Y: 0.000833333, 0.000833333

Uncompressed_Size: 12.40 MB

Format: GRID

Source_Type: continuous

Pixel_Type: floating point

Pixel_Depth: 32 Bit

NoData_Value: -3.4028235e+038

Colormap: absent

Pyramids: present

Compression: Default

Status: Permanent

**Extent**

Top: 44.5789133981

Left: 22.4498908326

Right: 24.8898898566

Bottom: 43.6539137681

**Spatial_Reference**: GCS_WGS_1984

Linear_Unit

Angular_Unit: Degree (0.017453292519943299)

Datum: D_WGS_1984

**Statistics**

*Slope100_WGS1*

Build_Parameters: skipped columns:1, rows:1, ignored value:

Min: 0

Max: 22.64720153808594

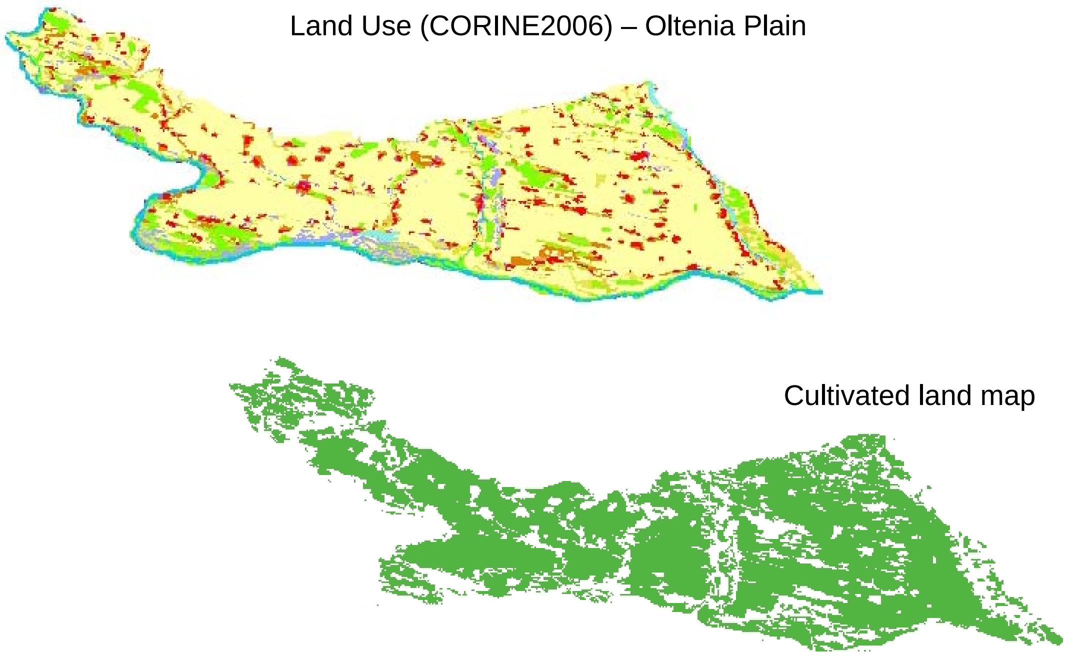
Mean: 0.6442609318828877

Std_dev.: 0.947873740025769

Classes: 0

**Figure 37. DEM and slope layers needed for GEPIC modeling**

**Land Use/Land Cover**




It is assumed that crops are only harvested in the grid-cells where cultivated land exists.

**Figure 38. Maps of landuse and harvested area**

**LAND MANAGEMENT DATA – Irrigation**

- 458,165 ha of area equipped for irrigation (10 irrigation units) - only 11.2% was irrigated (2006-2009)

- the *annual irrigation depth* calculated by dividing the irrigation water use by total irrigation area; i.e. the average, for the whole interval, for the volume of irrigation water (thou cm) applied in the irrigated areas (ha). It resulted an *average annual irrigation depth of 0.5 for the Oltenia Plain*

- It is assumed that the irrigation water use is equally distributed in each irrigation unit existent and functional in the Oltenia Plain.

- It is intended to use the **GIAM** product (**Global map of irrigated areas**, generated by the Center for Environmental Systems Research, University of Kassel http://www.fao.org/nr/water/aquastat/irrigationmap/index.stm) and the local data of irrigation averages for the 2006-2009 interval.

# 6. Case study Ukraine

## 6.1 Introduction

Ukraine is the second largest country in Europe (603,700 $km^2$) after Russia, and is larger than any country of the EU-27. It has a key location between Russia and the EU, and it has important access to many ports to the Black Sea. Ukraine's natural resources (especially fertile soil condition) provide the country with great opportunities for agricultural production.

After Ukraine became independent on 24 August 1991, the country experienced an economically severe transition period during the 1990's. Then, between 2000 and 2007, its economy grew on average more than 7% annually. The main reasons behind this development included the favorable trade environment and rising consumption. Ukraine has also benefited from subsidized Russian gas prices during this recent period of economic boom; however, this situation is not likely to last long. Russian gas prices increased more than 6 times in the last 5 years. Ukraine has, in addition, been strongly affected by the financial crisis. Due to decreasing wages, consumption is expected to drop along with investments, export and imports. External debt is likely to reach almost 90% of GDP.

The role of agriculture in the Ukrainian economy is remarkable. Almost two thirds of the country's area is used for agricultural production. The agricultural sector contributes significantly to the employment and the GDP. Furthermore, agriculture has a pivotal role in foreign trade.

Due to decreasing consumption, Ukrainian agricultural output has dropped significantly relative to its 1990 level. In 2007 livestock output was down at 50% while grain production at 75% in comparison to the level of 1990. The main reasons for such a low performance were a decline in inputs and hardly available financial resources.

Although Ukrainian farm structure is characterized by around 15,000 large agricultural enterprises having 2,000 hectares on average, the main part of the agricultural output is coming from smaller individual farms, comprising of peasant farms and household plots. The number of peasant farms has increased notably since Ukraine's independence; however, due to their large number, household plots own the largest part of the agricultural land and provide the largest part of the agricultural production.

The main agricultural policy measures include input subsidies through concessional taxes and credit availabilities for agricultural producers. An increasing role is given to direct payments based on the number or per tonne of animals and on the agricultural area. Domestic market support instruments are mainly used in the form of minimum prices. The most protected sectors comprise of poultry, beef, pig, and sugar. Due to WTO accession in 2008, considerable change has happened in trade policy measures. WTO commitments capped customs duties at bound rates ranging between 0% and 30% (with a couple of lines at 50%). Therefore import tariffs decreased, especially in the poultry, sunflower, and sugar sectors. In terms of export measures, Ukraine is obliged to ease on its most commonly used restrictive measures (export quotas and duties).

The largest drop in Ukrainian agricultural production occurred in livestock production. While the country was an exporter of meat products at the beginning of the 1990's, it is likely to turn into a net importer in the future. Milk products are more promising with possible export opportunities, mostly in cheese. Also, the area of oilseeds and grains has expanded, and Ukraine is expected to play an important role in the world export market. The area of vegetables and potatoes has remained mostly the same in comparison to 1990, but the area of fodder crops and sugar beet has significantly dropped due to decreasing animal production and more competitive sugar imports.

The overall trade balance of Ukraine turned negative in 2005 and has gradually increased until 2008. In contrary, the agricultural trade balance is positive and exhibits an increasing trend. Agricultural trade can be characterised mostly by exporting commodities and intermediate products, and imported high value products. Among the main exporting products oil crops and grains have a dominant share. On the import side, food/feed preparations and meat products (chicken and pig) have dominance.
Ukraine's main trading partner in agricultural products is the European Union (EU) both in terms of import and export. CIS countries and the Middle East countries have an increasing share in Ukraine's exports as well, while Russia has a decreasing, albeit important role as the third main export destination. Ukraine's agricultural imports come mainly from the EU, as well as from Russia and other CIS countries.

In order to see the real effects of the financial and economic crisis on Ukrainian agro-food trade further monitoring is needed as no reliable conclusions can be drawn based on the latest data available (first quarter of 2009). The report contains data about main agricultural production, farm structure, and agricultural policy. The main agricultural related data sources used in this report are from FAO, FAPRI, GTA, OECD, European Commission, State Statistics Committee of Ukraine and USDA. Economic data were taken from the World Bank and the IMF.

## 6.2 Natural resources

- Ukraine is located in Eastern Europe bordered by seven countries; on the southwest by Moldova and Romania; on the west by Hungary, Slovakia and Poland; on the north by Belarus, while on the northeast by Russia (Figure 39). The latter shares the longest border with Ukraine: 1576 km. From the south it is bordered by the Black Sea and the Sea of Azov with a coastline of 2782 km. The country extends 1316 km from east to west and 893 km from north to east (FAO Forestry), with a total area of 603,700 $km^2$, making it larger than any of the EU-27 countries.

Ukraine has a key geographical position, as it is located between the EU and Russia. Recent gas transit disputes have increased its importance as a transfer country of Russian gas to the EU. Nearly 80% of Russian natural gas goes via Ukraine to Europe (120 billion $m^3$ per year).


**Figure 39. Map of Ukraine. Source: Worldatlas.com**

This makes up two thirds of OAO Gazprom's revenue coming from the sale of gas crossing Ukraine. Ukraine also plays an important role in water transport in the Black Sea and Azov Sea regions. More than 30 ports operate there, whereof 19 are Ukrainian. These ports have a considerable role because some countries beside Ukraine, e.g.

Kazakhstan, use them as a key transport tool. The most important ports are called the "Big Odessa" and include the ports of Odessa, Ilychevsk and Yuzhny. In 2008 these ports contributed to nearly 65% of Ukrainian grain ship trade. The ports remain ice-free all year round and provide a favourable location for important markets in the Middle East, CIS, North Africa, and the EU. Ukraine is characterised predominantly by plains as more than 90% of its area is less than a few hundred meters above the sea level. The lowland is interrupted by elevations; the highest is around 300-500 m above sea level while the lowest point is around 40-70 m and can be found in the south. The mountainous section includes the Carpathian Mountains and their foothills on the west, together with the Crimean Mountains along the southern coast of the Crimean Peninsula. The highest peak of the Carpathian Mountains is at 2.061 m above sea level while the highest point of Crimean Mountains is at 1.546 m.

**Figure 40. Map 2: Relief Map of Ukraine. Source: Arid Ocean Maps**

Ukraine has an extensive river network with more than 22,000 rivers that have a total length of 170,000 km (Figure 40). All but one river flow to the Black Sea. The Northern Bug runs north to the Baltic Sea. The largest river, the Dnepr, rises from Russia and flows across the country from south to north. The Danube forms the border with Romania for 120 km before flowing into the Black Sea.

Ukraine has 3.000 natural lakes with a total area of 2.000 km². The country also has swamps whereof 32.000 km² have already been drained and brought into agricultural production, however, in the north of Ukraine there are still about 12.000 km² of swamp lands.

Table 18 summarizes the four agro-climate zones of Ukraine. The humid zone can be characterised by moderately warm summers and cold winters. Precipitation concentrates between May and October. Snow plays an important role as a water source; land is covered by it for 70-90 days from December until February.

**Table 18. Climate zones in Ukraine**

| | Location | Share of total area | Average yearly precipitation | Temperature (Celsius) |
|---|---|---|---|---|
| **Humid zone** | Northwest | 35% | 600 mm | -4/+17 |
| **Warm zone** | Eastern/central forested steppe | 25% | 500 mm | -6/21 |
| **Semi-arid zone** | Central, far east | 25% | 450 mm | -6/21 |
| **Arid zone** | South | 15% | 360 mm | 0/23 |

Source: FAO Aquastat

In the warm zone precipitation is expected between February and April while in the semi-arid zone between April and October. Mild winters characterise the arid zone with precipitation between December and May. In the mountains precipitation can reach 1600 mm yearly.

Ukraine is endowed with very high quality soil for agricultural production. The country is located in one of the "chernozem" ("black earth") belts. Thanks to this, more than half of the agricultural area (54%) is covered with valuable chernozem containing high percentage of humus.

## 6.3. Agriculture

### *6.3.1 Agriculture's role in the economy*

Agriculture has an important role in the Ukrainian economy. 71% of the country's area is **agricultural land** (compared to 45% in the EU-27), which makes around 41.7 million ha. Agriculture is important in the **labour market**: in 2007, 17% of workers (EU-27: 5,6%) were employed in this sector. Ukraine's agriculture also has the potential to become a major **export earner**. While in the beginning of the nineties 23% of **GDP originated from agriculture**, in 2007 this dropped to 8% (EU-27: 1,2%) (Table 19).

However, according to a report made by the World Bank, the entire contribution of the agrifood sector to the GDP approaches 20% if we add the upstream industries. The average share of household income spent on food was 57% in 2007. This figure increased from 42% in 1997, although one would expect the opposite trend assuming increasing wages. By comparison, in the EU 16% of household income was spent on food products in 2007.

Between 1995 and 2007 the share of agriculture in economic output decreased along with industry and manufacturing, while the output of the service sector has increased. **Gross Agricultural Output** (**GAO**) dropped significantly between 1990 and 2007. In 2007 total GAO was down to 60% of its 1990 level. The output of crops was 25% down while the output of livestock declined by half between 1990 and 2007 (Figure 41).

**Table 19. Basic agricultural indicators, 2000-2007. Source: WDI, OECD, World Bank**

| | 1990-1992 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| **GDP** *(current billion USD)* | 77,62 | 31,26 | 38,01 | 42,39 | 50,13 | 64,88 | 86,14 | 107,75 | 141,18 |
| **Agriculture, value added** *(current billion USD)* | 18,13 | 4,53 | 5,50 | 5,52 | 5,45 | 7,02 | 7,89 | 8,15 | 9,38 |
| **Agriculture, value added** *(% of GDP)* | 23 | 17 | 16 | 15 | 12 | 12 | 10 | 9 | 8 |
| **Employment in agriculture, forestry, fishing** *(% of total)* | 19,6 | 23,5 | 24,9 | 25,2 | 20,4 | 19,7 | 19,4 | 17,6 | 16,7 |
| **Agricultural land** *(% of land area)* | 72 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| **Rural population** *(% of total population)* | 33 | 33 | 33 | 33 | 32 | 32 | 32 | 32 | 32 |
| **Average share of household income spent on food** (%) | 42 | 65 | 63 | 61 | 58 | 58 | 58 | 54 | 57 |
| **GAO growth, crops** (% change y-o-y) | -7,4 | 23,2 | 12,6 | -2,0 | -14,6 | 35,4 | -3,0 | 1,7 | -9,5 |
| **GAO growth, livestock** (% change, y-o-y) | -8,9 | -3,6 | 7,0 | 5,3 | -6,5 | 2,0 | 4,7 | 3,6 | -2,3 |

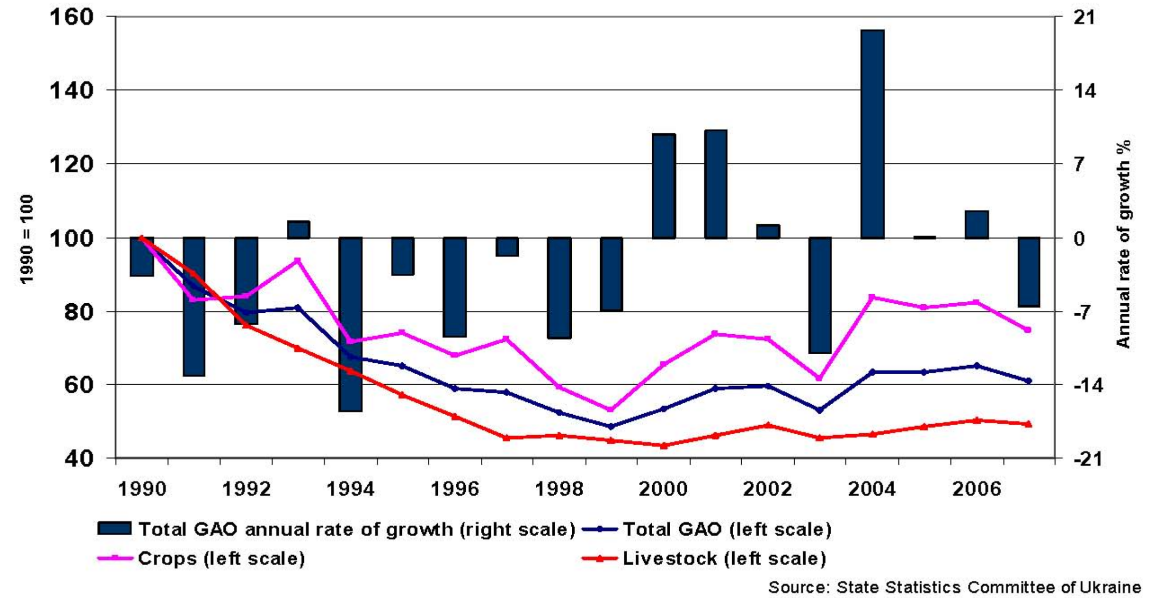



**Figure 41: Ukraine: Evolution and annual changes of agricultural output, 1990-2007**

The World Bank calculated a drop in agricultural output of 51% between 1990 and 1999. At the same time the share of GDP produced in agriculture has also decreased, because the decline in agricultural output was faster than the shrinkage of the overall economy.

There is a *difference between the productivity among the oblasts*. The central and eastern parts of the country are generally more productive while the northern, western and southern regions produce below the average due low precipitation and less suitable.

An important factor behind the decreasing GAO is the sharp decl*ine in the use of inputs* at the beginning of the 1990s and their constant low level thereafter. For example, in terms of wheat the usage of fertilizer dropped from around 150 kg/ha to 30 kg/ha and in case of maize from 250 kg/ha to 38kg/ha. One possible explanation for the drop could be the tremendous price increase at the beginning of the 1990s. Increase in input applications started to rise again from 2000 onwards.

Another typical feature of Ukrainian agriculture in the transition period was the *declining share in the investment.* The share of primary agriculture in total investment dropped from 21.3% to 5.2% between 1990 and 2002. This happened because the agricultural sector enjoyed strong governmental support through central planning before 1990 (OECD - World Bank 2004).

After the independence foreign direct investment (FDI) was a significant resource in many post-Soviet countries, however, Ukrainian FDI lagged behind that of other neighboring countries like Hungary (Figure 42). One of the main reasons for this was the inept regulatory framework – the absence of effective laws and policies – which discouraged potential investors. On the other hand, the government did not privatize extensively in order to attract foreign capital.

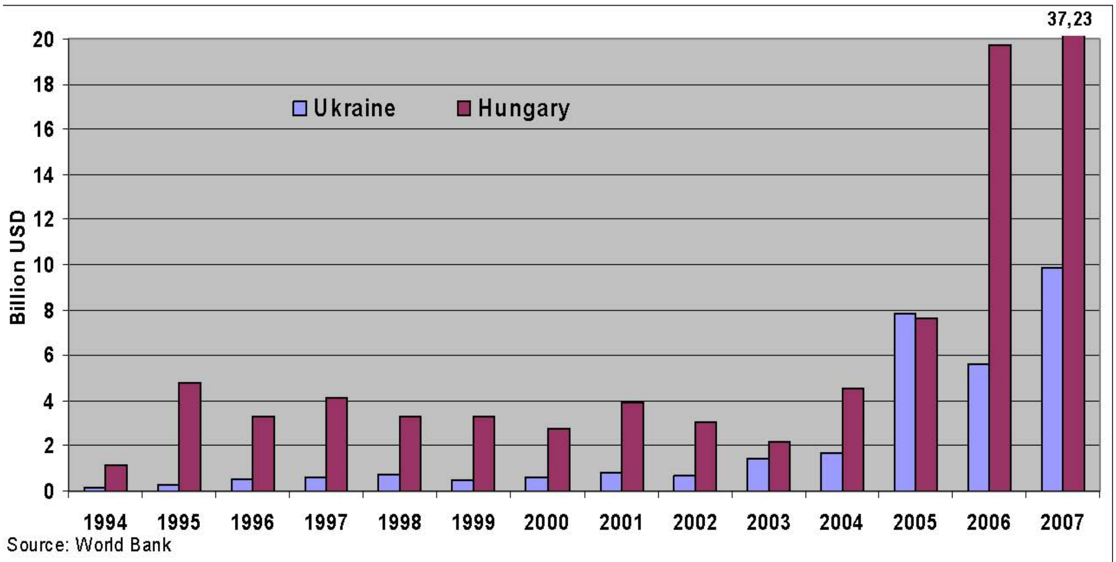



**Figure 42. Foreign direct investment in Ukraine and Hungary, net inflows (current USD)**

However, the expansion of the food and other agricultural processing industries has recently been very impressive. Between 2001 and 2006, this sector contributed to the increase in the industrial production and investment to a large extent, an annual 2.14% and 3.65% respectively (Figure 43).

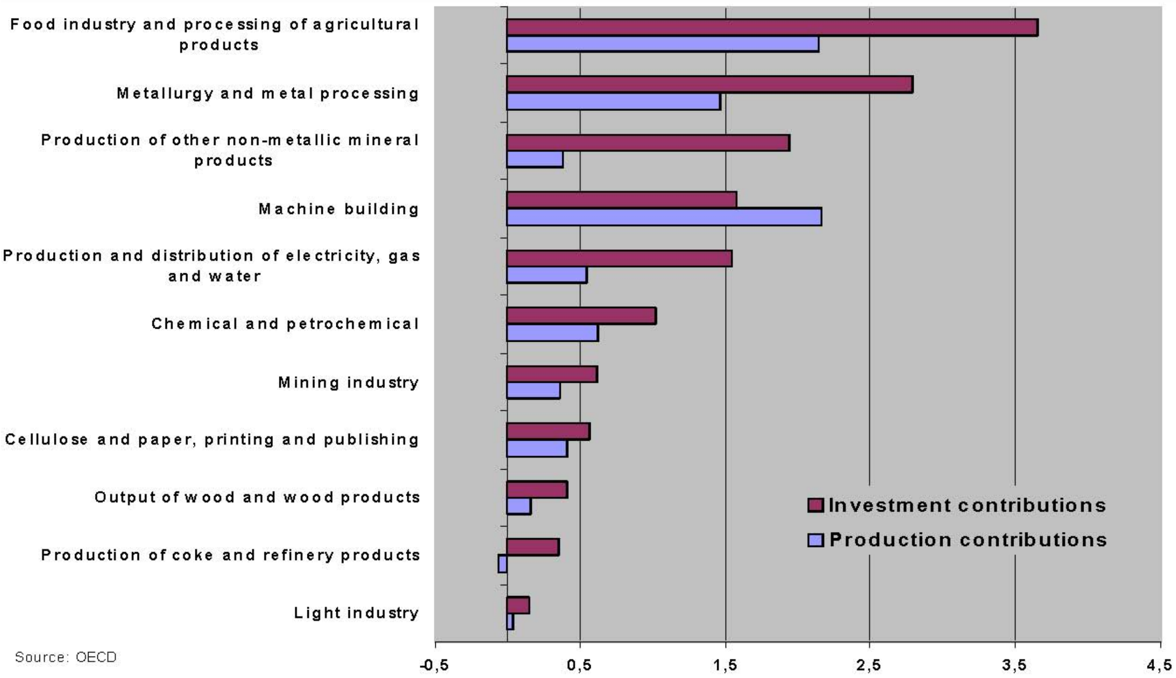



**Figure 43. Sectoral contributions to the growth of industrial production and investment**

- (Annual percentage change, 2001-2006)

## *6.3.2. Agricultural production*

A characteristic change in the Ukrainian agricultural production during the transition period was a decrease in the production of almost all of the main agricultural commodities, especially of animal products, which saw their share in total agricultural output decline from 1/2 to around 1/3. The main reason behind such a sharp decline was a decrease in real per capita income during the transition period. The effect on meat products was particularly visible because animal products have higher income elasticity than other products. Decline in meat production also affected feed production, which dropped to a large extent as well. The production levels in the grain sector rebounded in 2000-2002. Sugar beet production, however, could not compete with the more competitive import of raw sugar products. The production of potatoes, vegetables and sunflower remained relatively stable during the 1990s.

*CROPS*

Similarly to the animals, the total area of important crops has dropped since 1990. This is attributable to the decline seen in sugar beet and fodder areas each around 75%. The latter relates to the drop in livestock. The decrease in the sugar beet area proves the negative profitability of the production.

While the area of vegetables and potatoes remained mostly the same, the grain area has slightly increased (around 1 million ha) in comparison to the beginning of the 1990s. The area of sunflower production has risen by more than 100%, showing Ukraine's great interest as an important player on the world market in this crop.

*CEREALS*

Between 1992 and 2000 production of cereals decreased by about one third, however, in 2001 production recovered. The structure of grain production has been relatively stable with approximately 50% wheat, 25% barley, and the rest mostly maize. However, the share in cereal production is projected to change in the future with increasing maize production (Figure 44).

*Wheat* has been harvested on average on 5.8 million hectares in the last 10 years. Due to unfavorable weather conditions, 2003 was an exceptionally weak year, when only 2.45 million hectares were harvested. In 2008 Ukrainian wheat harvest was very high of over 25 million tonnes.

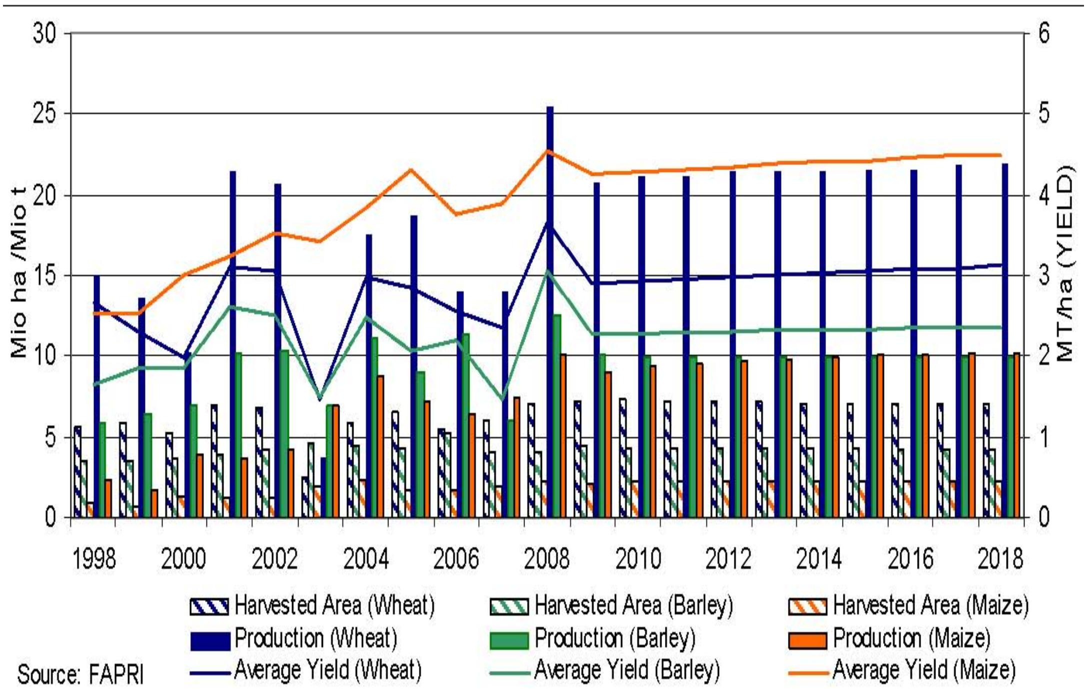



**Figure 44. Main cereals production**

The second most planted crop is barley with an average of 4.3 million harvested hectares between 1998 and 2008. In the mentioned time period the most and least productive years (2007 and 2008) happened to be at the same amount of harvested area; 4.1 million hectares. Favorable weather conditions and a more than 50% increase in the yield were the key reasons for the record harvest.

The third coarse grain is maize with an average of 1.7 million harvested hectares in the last 10 years. Maize production is projected to increase in the future and reach the level of barley production until the end of the projection period.

Ukraine is a significant exporter of cereals. One of its main exports is barley with an increasing share in the world export. In 2006/07 export amounted more than 5 million tonnes that gave 36% of the total net export, turning Ukraine the world's largest exporter that year. After a weaker year in 2008/09, Ukrainian barley export is projected to peak at almost 5.5 million tonnes contributing 30% to the world net export. This year Ukraine is projected to become again the world's largest exporter of barley leaving behind countries like the EU, Argentina, Canada or Australia, all notable exporters of cereal products. In the projection period its share in net export seems to stabilize at around 25-27%.

Wheat has the largest export volume among cereals with an average of 4.5 million tonnes between 1998 and 2008. Nevertheless, in 2000 and 2003 Ukraine imported wheat. The share of wheat among world's top net exporters averaged around 5%. Due to favourable weather conditions and excellent harvest, wheat export peaked in 2008 at almost 9 million tonnes. FAPRI projects that Ukraine's wheat export share in the total net export is about 7-8%.

*Maize* export has the lowest share among main cereals and also in the world total net export. However, the export volume has been gradually increasing from 328,000 tonnes in 1998 to almost 3.5 million tonnes in 2008. The share of Ukrainian maize among top net exporters is small, although it is slightly increasing. While in 1998 that share did not even reach 1%, at the end of the projection period it should reach around 6%.

*OILSEEDS*

Ukrainian oilseed crops are competitive agricultural products. Ukrainian farmers consider growing sunflower seeds more profitable than growing grains. Sunflower is the only large field crop that experienced a growth in production during the '90s. Production levels in the '90s were even higher than in the pre-reform era. The main reasons for this were increased profitability and a reliable export market.

Harvested sunflower area in 2008 was a record of over 4 million hectares (Figure 45). This increase contributed to a record harvest of more than 6 million tonnes. The average yield per hectare was the highest since 1998 at 1.54 t/ha. A decrease can be expected in the harvested area (and production) in the 2009/10 marketing year due to high price volatility as well as crop rotation requirements. Additionally, the financial turmoil and credit crunch may have a disadvantageous effect on farmers' input applications and technologies, which then may produce a negative effect on yields.

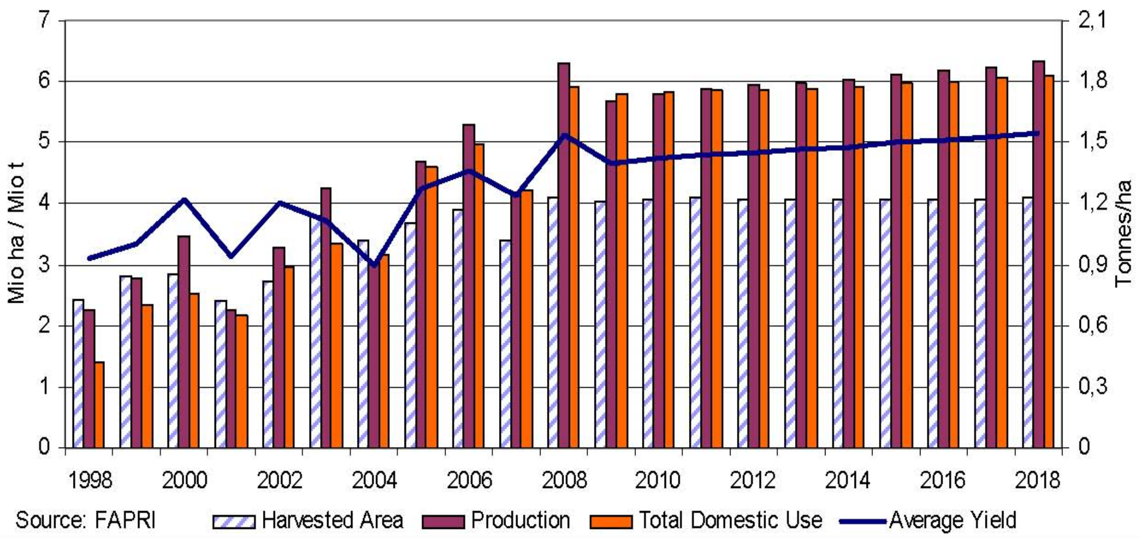



**Figure 45. Sunflower seed production**

Further important oilseeds in Ukraine include **soybean** and **rapeseed** (Figure 46). The increasing role of these products can be concluded from the rise in their planted area. In the case of soybean, it grew from 31,000 hectares in 1998 to more than 700,000 hectares in 2006. After this, the harvested area dropped slightly to its 2009 level of 650,000 hectares.

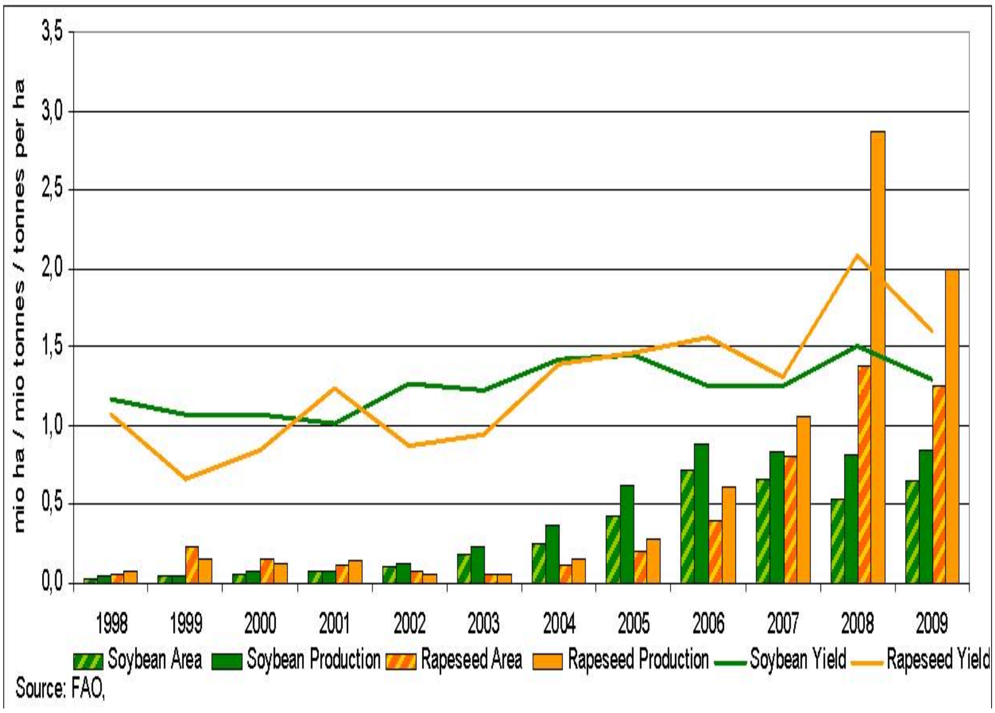



**Figure 46. Soybean and rapeseed production**

*Rapeseed harvested area* shows a slight decrease between 1998 and 2003. However, from 2003 to 2009 the harvested area exhibits a sharp increase from 54,000 hectares to almost 1,2 million hectares with a peak in 2008 (1,4 million hectares). Production also shows a significant increase: in 2008 soybean production was twenty-two times and rapeseed production was forty-two times higher than in 1998.

Ukraine has developed its **sunflower oil** production by introducing export tariffs on sunflower seeds in 1999 (Figure 47). The aim was to strengthen domestic crushing industry and to export sunflower oil in order to gain higher export earnings. This measure successfully increased sunflower oil production from around 1,5 million tonnes to around 2,2 million tonnes between 1998 and 2008. The same amount of production is projected by FAPRI in the future. Consumption has remained low, offering a large share of the production for export.

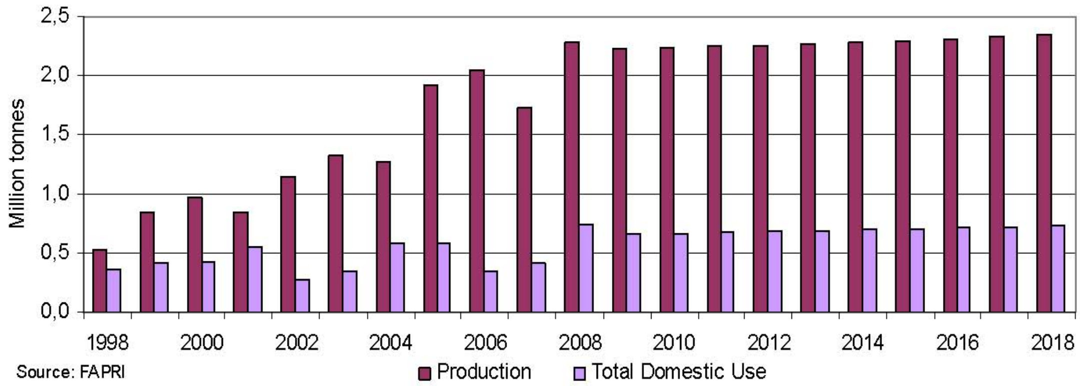



**Figure 47. Sunflower oil production and use**

Ukraine plays an important role in sunflower seed and soybean world export (Figure 48). *Sunflower seed export* has fluctuated heavily. In 2000 export declined significantly, particularly after the introduction of export restrictions. In 2003 record export reached 926 000 tonnes of sunflower seed contributing with more than 60% to the world net export. In 2004 the lowest sunflower seed export amounted 6 000 tonnes.

FAPRI projects sunflower seed share among world's top net exporters to be at around 40% over the projection period.

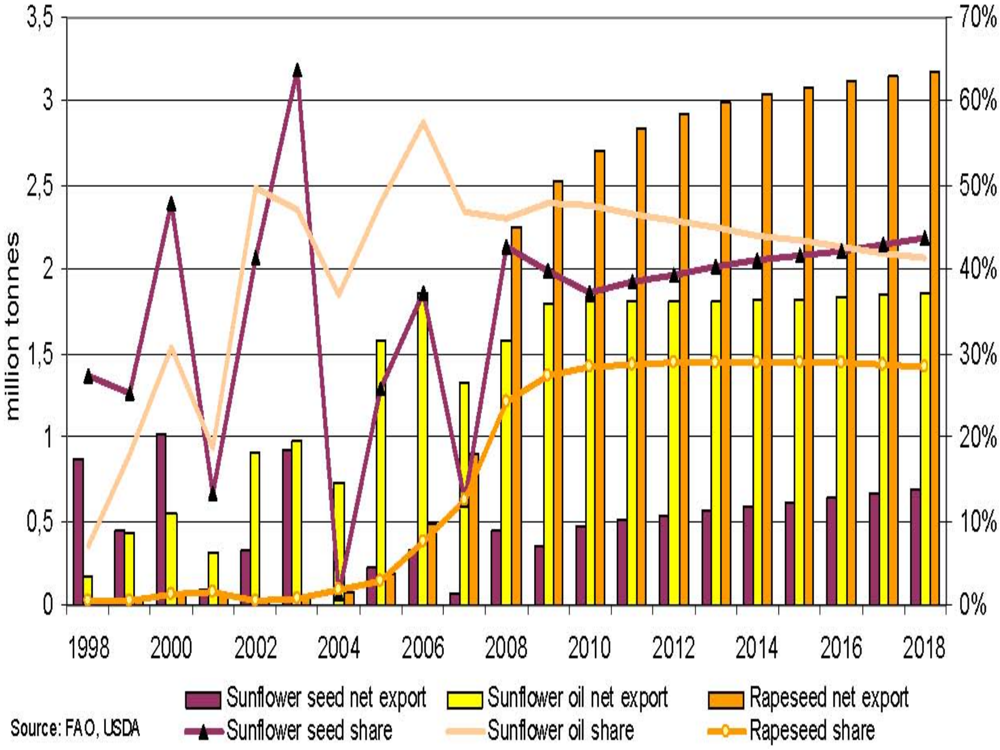



**Figure 48. Net exports of sunflower and rapeseed and share among top net exporters**

*Rapeseed export* has an increasing role in the world export. The first significant export in 2006 amounted 483 000 tonnes that comprised 8% of world's top net exporters. In 2009 rapeseed net exports is expected to hit a record of 2,5 million tonnes (27% share among world's top net exporters). In the projection period export seems to further increase to around 3 million tonnes per year, turning Ukraine into the second largest exporter of the world after Canada.

*Sunflower oil* is an important export product for Ukraine. While in 1998 only 175 000 tonnes were exported, in 2008 net exports has risen to around 1,5 million tonnes; and is expected to remain stable over the projection period. Ukraine gained an important role in sunflower oil exports around the world by being responsible for almost half of the world's sunflower oil trade.

Net exports of soybeans are not yet significant; however, an increasing trend is observed between 1998 at around 7 000 tonnes and 2009 at more than 230 000 tonnes.

- Although Ukraine has a significant supply of biofuel crops, local biofuel production has not developed yet. Therefore, oil crops are mainly exported to the European Union where biofuel production is more widespread.

SUGAR BEET

Sugar consumption in Ukraine has declined in the 1990s (from 50 kg per capita in 1990 to 30 kg in 1997), thereby unfavorably affecting the production sector (Figure 49). Sugar beet production was unprofitable in the 1990s due high production costs and inefficient processing facilities. As a result, the sugar beet area declined over the time period of 1992-2002 by around 50% (from 1,4 million ha to 763 000 ha). Accordingly, production dropped also by 50%, equalling 14 million tonnes. Between 2002 and 2006 the harvested area seemed to stabilise at around 600-700,000 hectares; however, in 2008 it dropped again and this trend is expected to continue until around 380 000 hectares and 10-11 million tonnes of production. During the 1990s yields fell by 20%.

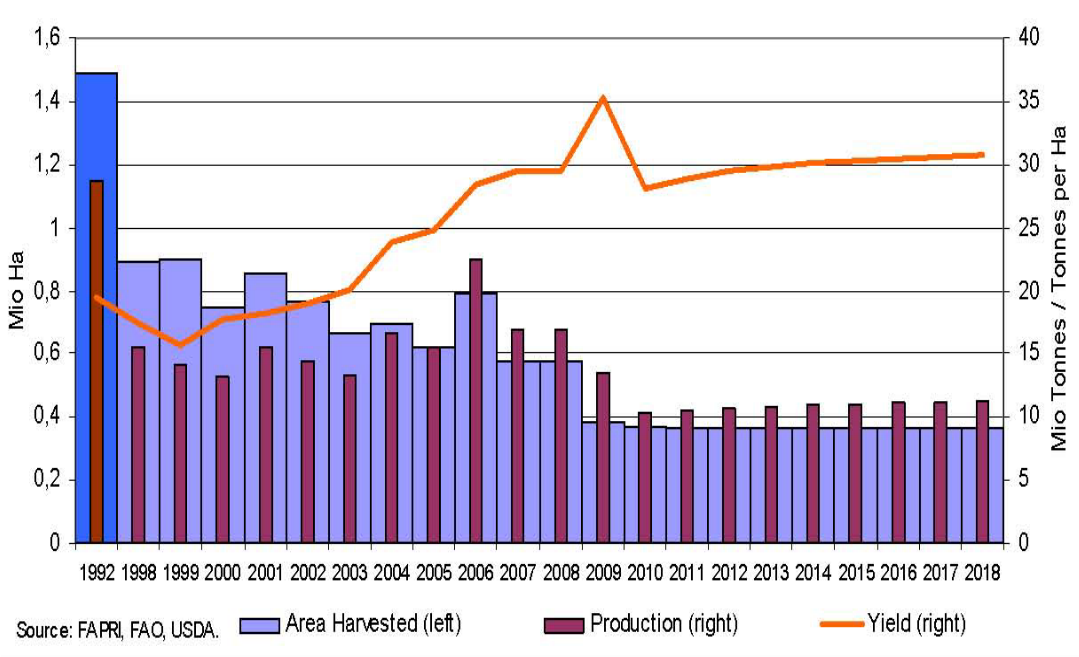



**Figure 49. Ukrainian sugar beet production in 1992 and 1998-2018**

Since 2000 the average yield has been improving constantly and reached around 30 t/ha by 2008 due to higher input application mainly by large agricultural companies. This increased the profitability of the sugar beet sector. A large portion of total sugar beet area is sown by very large vertically integrated companies that have their own sugar beet processing capability, or large land banks that may exceed 100 000 ha. The development of these large integrated companies is one of the drivers for the increase in sugar beet yield seen recently.

The number of sugar processing plants in Ukraine has sharply decreased. 192 plants existed at the beginning of 2000, while only 70 sugar plants operated in the 2008/2009 marketing year.

LIVESTOCK

Ukraine experienced a sharp drop in its livestock inventories and its animal production in the 90's. A dramatic decline occurred in its *cattle stock* where the number of animals has continued to drop. In January 2009 the stock stood at 22% of the level of early 1990s. The *pig sector* contracted in the same way. Today there are about 60% less pigs in Ukraine than at the beginning of the 1990s (Table 20).

**Table 20. Number of livestock (million)**

| | 1990-1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle | 22.9 | 10.6 | 9.4 | 9.4 | 9.1 | 7.7 | 6.9 | 6.5 | 6.2 | 5.5 | 5.1 |
| Pig | 17.1 | 10.1 | 7.7 | 8.4 | 9.2 | 7.3 | 6.5 | 7.1 | 8.1 | 7.0 | 6.5 |
| Sheep & Goats | 7.5 | 1.9 | 1.9 | 2.0 | 2.0 | 1.9 | 1.8 | 1.6 | 1.6 | 1.7 | 1.7 |
| Poultry | 219 | 126 | 124 | 137 | 147 | 142 | 153 | 162 | 167 | 169 | 178 |

Source: State Statistics Committee of Ukraine

*Sheep and goat* numbers decreased, although an upward trend started from 2007. The *poultry* stock experienced a sharp (over 40%) drop by 2001. However from then a constant recovery could be seen with numbers increasing by almost 50%.

The main reason of the decline in the number of animals is that production experienced a drop due to the reasons mentioned before. During the period of decline, most animal production remained unprofitable, with the exception of poultry and eggs (Figure 50).

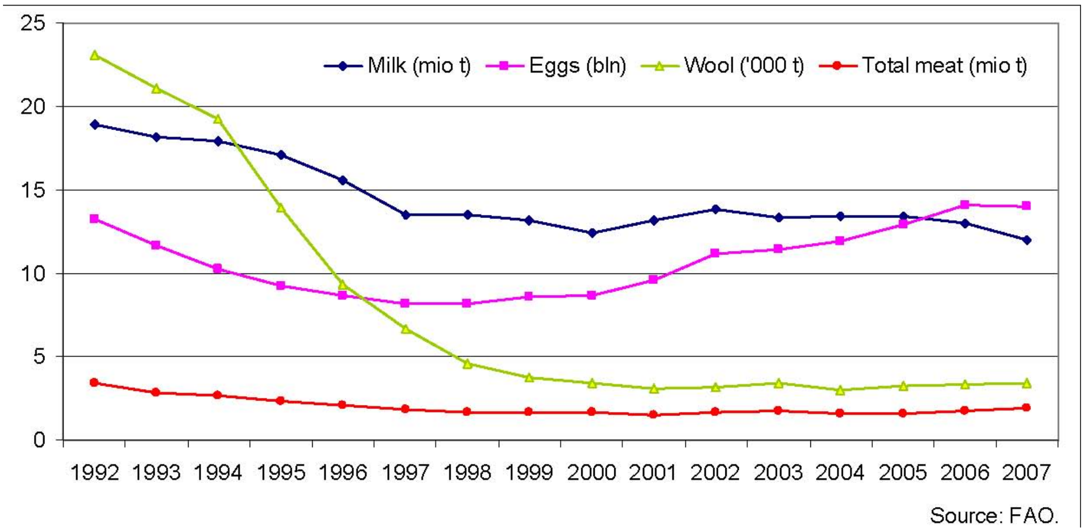
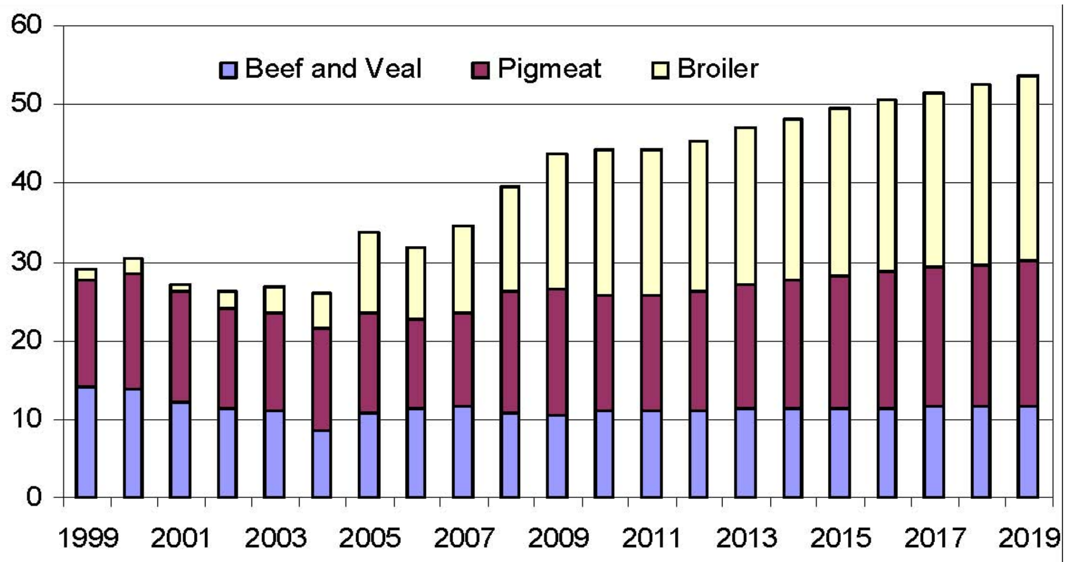



**Figure 50. Output of main animal products**

2000 production has not dropped to the same extent anymore, and signs of recovery could be revealed in some products, such as egg production. Due to higher prices the gross value of animal production increased by 5.3% in 2001 and again by 5.6% in 2002.

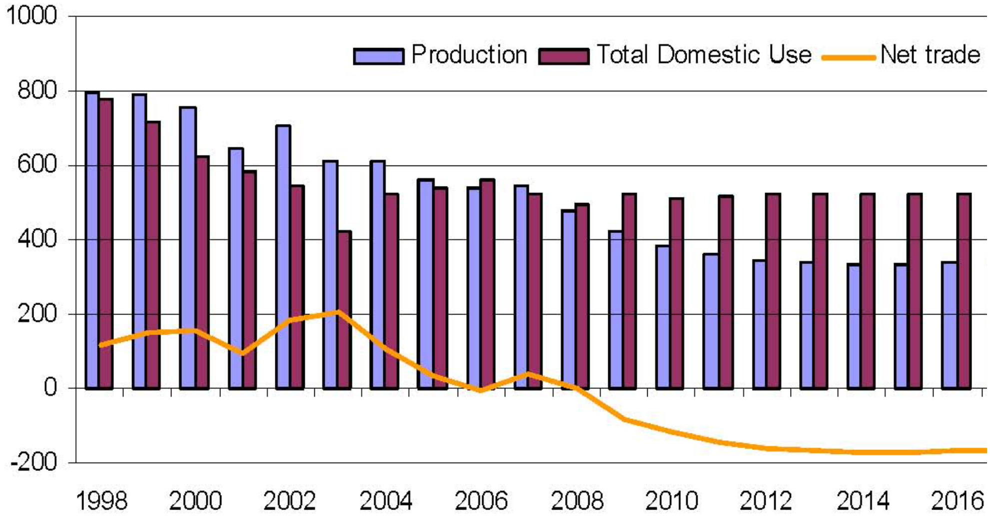
In the 1990s meat **consumption per capita** decreased sharply, and this in turn affected production (Figure 51). Around 1999, consumption started to increase and is now projected to grow further and reach 53.6 kg per capita in 2018 based on a projection prepared by FAPRI. Consumption can be characterized also by changing patterns. While beef and pigmeat were historically the most consumed meats, poultry should overtake them both by 2009.




Source: FAPRI.

**Figure 51. Ukraine: Meat consumption (per capita)**

Between 1998 and 2008 **beef meat production** decreased in particular and is now predicted to shrink in the projection period (Figure 52).




Source: FAPRI.

**Figure 52. Ukraine: Beef &Veal balance**

**Pigmeat production** has slightly decreased from its 1998 volume and is projected to slightly increase in the projection period (Figure 53).

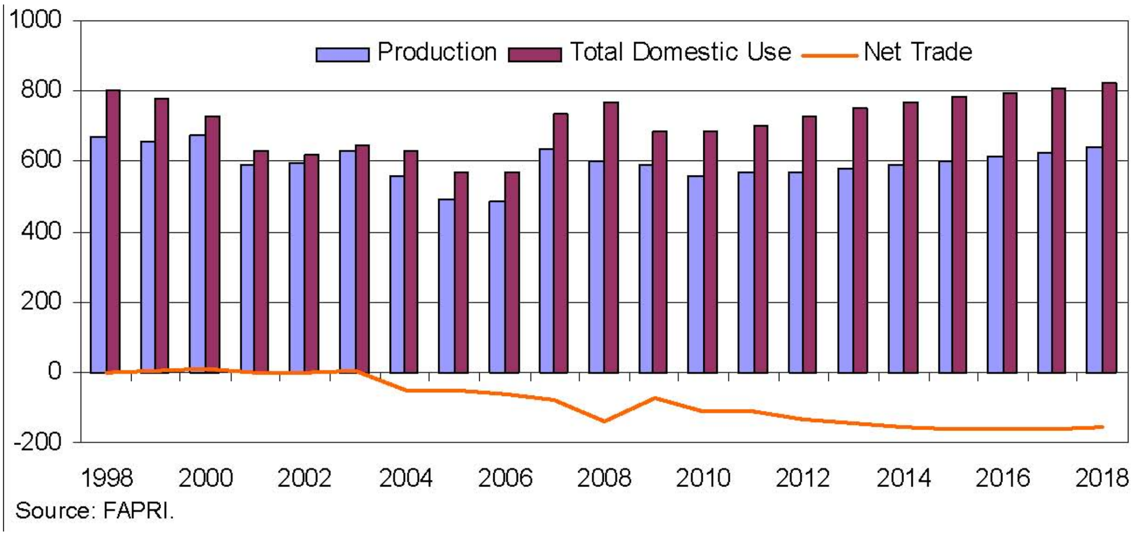



**Figure 53. Ukraine: Broiler balance**

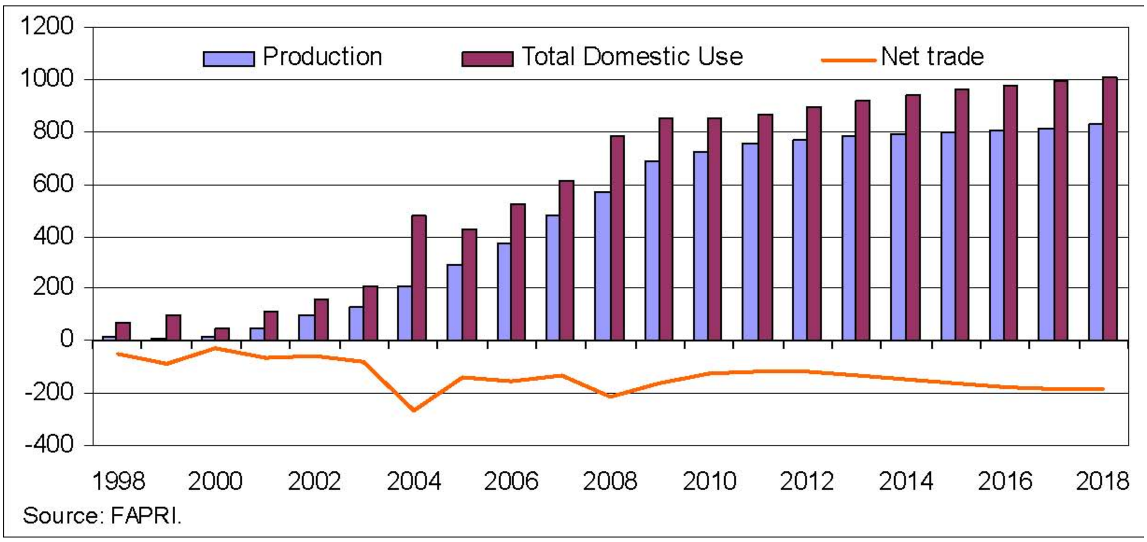



**Figure 54. Ukraine: Pigmeat balance**

Meat export shows a decreasing trend in Ukraine. While at the beginning of the '90s pigmeat and especially beef appeared among Ukraine's main agricultural export, from the end of the '90s they have tended to decrease (Figure 54).

Beef was the last meat product where significant export occurred in 2006. After this, Ukraine has become a net importer in meat products. However, the current economic crisis affects purchasing power; and therefore, in January 2009, consumption, and in turn import, have decreased for the first time in 8 years.

Unlike meat products, the consumption of milk did not experience the similar sharp decline during the transition, because milk is considered to be one of the cheapest sources of protein. Per capita consumption rose sharply from 2003 to 2004 (72 kg to 108 kg) and dropped dramatically in 2006 from 130 kg to 79 kg. However, this trend is projected to turn from 2009/2010 and to gradually increase until 2018 and reach 105 kg per capita. This figure is one of the highest among the countries that FAPRI analyses (EU 67 kg, USA 89 kg) (Figure 55).

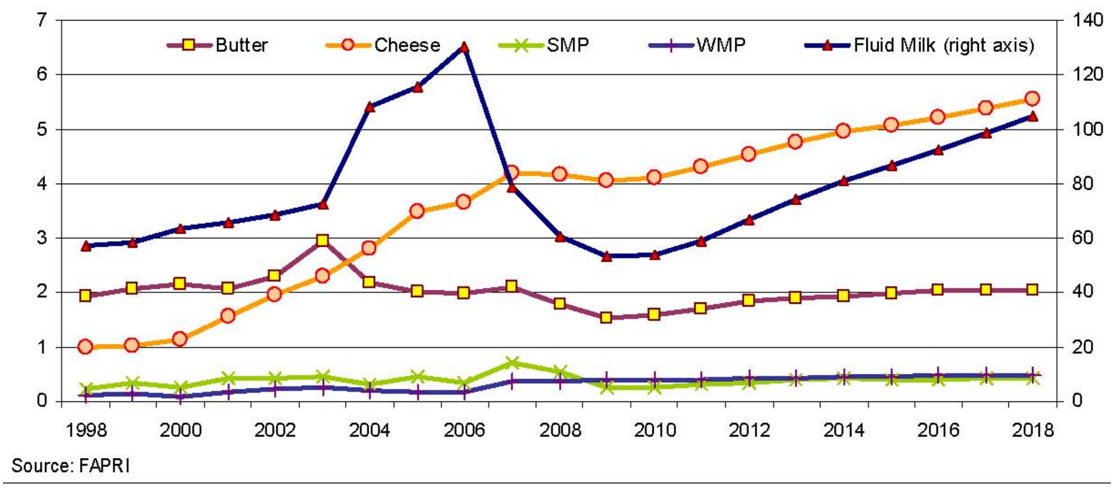



**Figure 55. Ukraine: Consumption of different milk products**

The consumption of other dairy products, like cheese (from 2 kg to 1 kg) and butter (from 5 kg to 2 kg) has dropped in the 1990s. Cheese consumption rebounded in 2000 and the FAPRI forecast suggests that the increase will continue until the end of the projection period. Butter consumption per capita is projected to stabilize around the level (with some fluctuation) it has fallen in the '90s. Milk production declined in the transition period mainly due to unprofitable production. The turnaround in the production occurred in 2001 with 6% and in 2002 by 5% increase in milk production. However, the recapture was not durable, and from 2006 production started to decrease again (Figure 56).

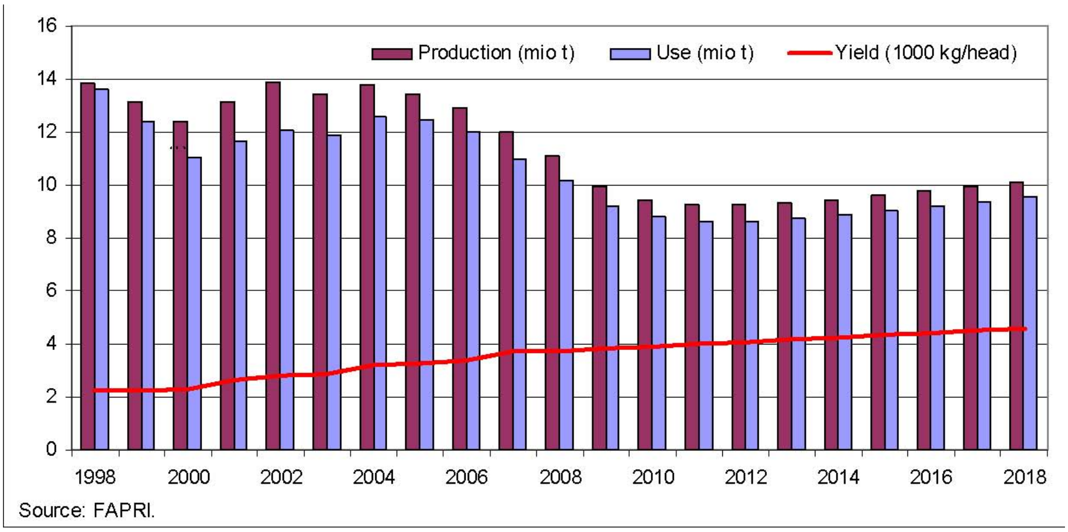



**Figure 56. Ukrainian milk production (fluid milk)**

The number of milk cows has decreased significantly after the independence. In 1998 there were 6.2 million dairy cows, but their number dropped to 2.6 million in 2008. The number of milk cows is projected to further decrease, albeit at a slower pace, to reach 2.2 million in 2018.

Similarly, production has also decreased from 13.8 million tonnes of milk in 1998 to 11 million tonnes in 2008. However, a small recovery can be seen between 1999 and 2004 from 2005. In the projection period the fall in production seems to come to halt and begins to increase from 2010 onwards. Yield has been improving gradually from around 2000 kg per head to almost 5000 kg per head. However, this still lags behind the EU data – 4700 kg and 6600 kg respectively.

Ukraine has good export potential in dairy products. It is already exporting various products, although at a lower level. On the other hand, cheese shows a reassuring performance after a sharp drop in export from 110.000 to around 40.000 tonnes between 2005 and 2006. FAPRI predicts that the value of cheese export will reach around 90.000 tonnes in 2018, and thereby place Ukraine as the fourth largest exporter in the world behind New Zealand, the EU, and Australia.

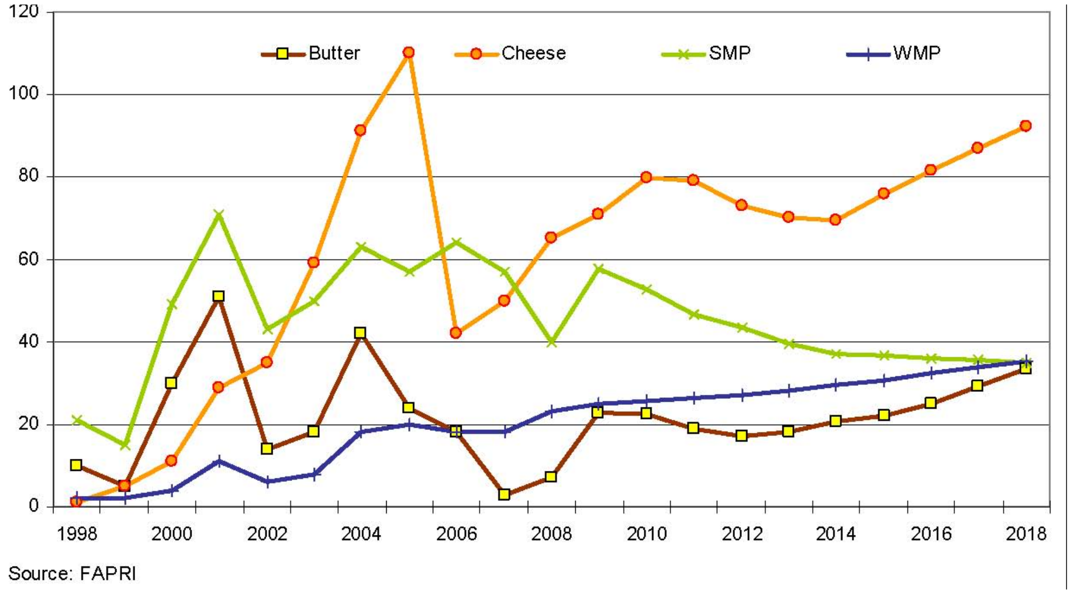



**Figure 57. Ukrainian export in different milk products**

Ukrainian butter and whole milk powder exhibit an increasing export value as well, although at a lower level; while non-fat dry milk export is projected to decline from 2009 onwards (Figure 57).

### *6.3.3. Farm structure*

In the Soviet Union most of the land was owned by the state, and so was in Ukraine. In 1988 a process began, which aimed to **privatize the land** in different stages. In 1998, 6.9 million farm members received land share certificates as preliminary evidence of their ownership. Altogether there are more than 11 million people today, who are recognized as owners of land parcels. In January 2008, 99% of farm members holding preliminary ownership, received certificates as a final proof of ownership. In January 2008, 91% of certificate holders received land property acts, which included the exact parcels owned by the owners.

This process is required for a well functioning land rental market. The privatization process is not yet over as there are still limitations on ownership, which need to be removed. Among others, these limitations include the ban on sale of agricultural land. This ban was extended at the end of 2007 from its previous start date just one month later. It is worth to mention, however, that the Memorandum between the IMF and Ukraine over the anti-crisis assistance agreed in October 2008 highlights the “creation of the functioning land market” among its required structural changes.

The farm structure of Ukraine can be characterized by 2 main types of farms: individual and corporate farms. Corporate farms are **large-scale agricultural enterprises**, successors of large state-owned farms from before 1990. According to the OECD, there are almost 15 000 *agricultural enterprises* with an *average size of agricultural land of 2 080 hectares*. These enterprises used to own the majority of the agricultural land; however, they seem to have lost this share. While some estimations suggest that the share of enterprises in agricultural land in 2004 was 59%, in 2006 it was only 46%. In the meanwhile *enterprises contributed by 39% of total agricultural output* in 2006. Another feature of these enterprises is the dominance (64%) in the total number of lease agreements in 2005 (Figure 58).

**Individual farms** have an increasing share in the agricultural land with 55% and a large contribution to the agricultural *output with 61%* in 2006. Among individual farms, one can distinguish **peasant (family) farms** and **household plots**.

- **Peasant farms** are characterized by an increasing number and average farm size. Between 1993 and 2005 the *number of family farms increased from 14,700 to 46,400***,** while their *average farm size grew from 19.9 ha to 74.7 ha*. Other estimations suggest that in 2006 their *average farm size was more than 100 hectares*. Peasant farms possess *11% of all agricultural area* (4 million hectares). Larger family farms are mostly in the eastern part of the country with an average size of 137-142 hectares; while smaller family farms are in the western part of the country (average size 7-13 hectares).
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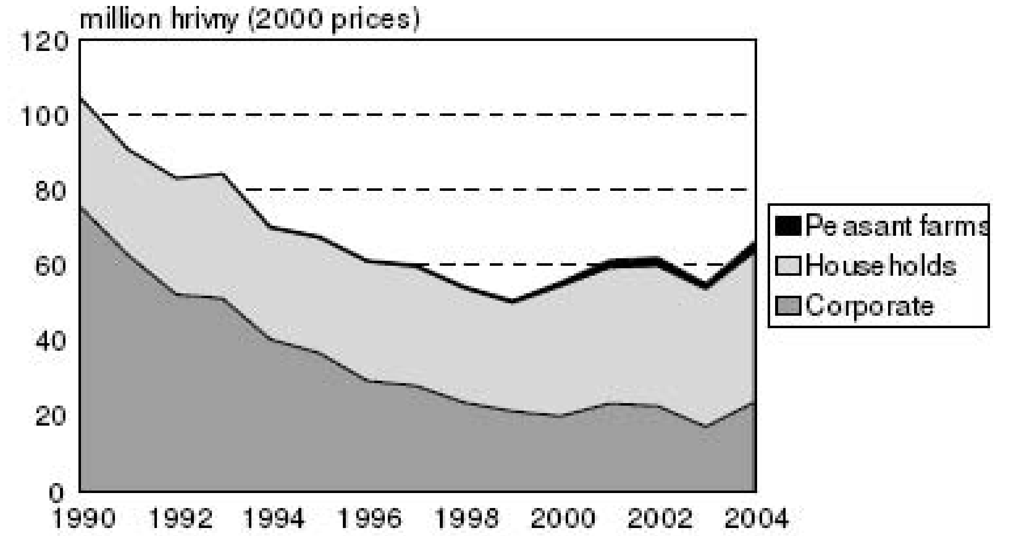


- **Figure 58. Gross agricultural output in constant prices by farm type in Ukraine, 1990-2004**

Another category of individual farms is the **household plot** with a smaller *average farm size, 2.8 hectares*. This farm type is the most common one, considering that in 2006 there were *5.5 million*. The activities of these farms are intended to *cover mostly own consumption***,** therefore they are mostly non-commercial in contrast to peasant farms and agricultural enterprises. Nevertheless, in some cases they produce goods that are in demand. In 2006, household plots amounted to 42.9% of the total agricultural area (15.6 million hectares) (WB 2008), representing the second largest share of farms after the enterprises. Regarding gross agricultural output, however, households overtake enterprises. It is notable that in 2004 household plots accounted for the largest share in the gross agricultural output (see Figure 58).

This is possible because household plots can *produce at a lower cost* than enterprises. On the other hand, the *lower productivity of enterprises* can slow down any improvement of the farms themselves, causing *inefficient input supply and output marketing* chains. Moreover, scarce credit markets, which they depend on, might also contribute to the lower performance.

*6.3.4. Agricultural environmental impact in Ukraine*

Agriculture dominates Ukraine's landscape, covering approximately 70 percent of the total land area. It accounts for 10 percent of GDP and 19 percent of employment. Ukraine's agricultural exports are the largest, at $3.5 billion, of any EECCA country. Ukraine's agricultural sector is estimated to cause 35-40 percent of all environmental degradation. After the 1986 meltdown at the Chernobyl Nuclear Power Plant, 8 percent of agricultural lands were removed from production because of radiation contamination. Products grown in these areas are subject to radiological monitoring, and many farms in the contaminated territories have become unprofitable. Ukraine's famously fertile and extensive black soils are suffering from serious erosion and deterioration after many years of intensive production. Many soils are eroded, depleted, acidic, saline, or alkaline due to unsustainable agricultural practices. Irrigated land has decreased by approximately 15 percent over the past 15 years, and water losses have increased due to inefficient management. Nutrient runoff, from both improper fertilizer application and inadequate manure management, pollutes Ukraine's water bodies and contributes to the eutrophication of the Black Sea. Although pesticide use has dropped significantly since the 1990s, a quarter of agricultural lands are contaminated by pesticides, and stockpiles of obsolete pesticides pose serious health hazards.

### *6.3.5. Agriculture policies, strategies and programs*

***Agriculture.*** Ukraine is signatory to major environmental conventions and protocols, and it is an active participant in the "Environment for Europe" process. However, there are few systematic efforts to integrate environment into its agricultural practices. No programs to restore soil fertility are in place, nor are there significant efforts to improve nutrient management, although Ukraine is a partner in the Danube and Black Sea programs. Regarding crop protection, the use of biological control techniques has dropped, due to the loss of insectaries and farmers' lack of training in integrated pest management (IPM) approaches. Organic farming offers potential for the country and has been adopted on nearly 1 percent of farm land. However, it is not being supported by the government. Some international donors have stepped in with pilot projects. Ukraine has a basic government extension service supplemented by the private sector, but coverage remains inadequate and sustainability issues are not properly addressed.

*The Extent of Mainstreaming and its Trends*

Mainstreaming environmental concerns into the agriculture and forestry sectors is limited, due to inadequate capacity of the responsible ministries to develop policy and strategic plans; subordination of environmental mainstreaming to economic development goals; lack of public awareness and recognition of environmental degradation as a major issue of concern. As a result, issues such as land degradation, erosion, water management, nutrient and pest management, illegal logging, and sustainable forest management are not being adequately addressed.

*Priority Needs*

- Improve monitoring and dissemination of information, and public awareness of rural environmental issues.
- Review the potential role of economic instruments (such as tax policy, subsidies, pollution fees, and water charges) to promote environmentally sustainable behavior.
- Promote organic farming and marketing, especially to the wider European audience,
- Streamline inter-ministerial coordination and consider creating an environmental unit within the Ministry of Agriculture,
- Expand the agricultural extension system, particularly for smaller, private farmers, with emphasis on good agricultural practices,
- Reinvigorate extension services in both agriculture and forestry,
- Pay special attention to agricultural forests and degraded agricultural lands for reforestation and afforestation efforts.

During the Soviet era, Ukraine was a major food producer, accounting for a quarter of all agricultural output. Since Ukraine's independence in 1991, production has fallen to less than 50 percent of former levels, due to changes in agricultural policy and land reform that have not attracted sufficient investment to the agricultural sector. Recent economic liberalization has encouraged greater investment, and production has generally increased since 2000. Agriculture and the food industry still represent a key sector of the Ukrainian economy. About 15 percent of GDP is produced within the agricultural sector.2 Employment in agriculture, forestry, and fisheries in 2003 was estimated at 23 percent of the total work force. Direct employment in the forestry sector, including wood industries, is about 350,000. Total employment (direct plus indirect) is approximately 500,000.

*Environmental Impacts of Agriculture*

The impact of the Ukrainian agricultural production system on the environment is estimated to cause 35-40 percent of the total environmental degradation (Stefanovska and Pidlisnuk 2002). The main environmental problems caused by agriculture in Ukraine include soil erosion and degradation, loss of biodiversity, water contamination (both surface and groundwater), mismanaged agricultural waste, soil contamination, and inadequate storage of obsolete pesticides. Another major issue is the 1986 catastrophe at the Chernobyl Nuclear Power Plant, which caused approximately 8 percent of Ukraine's land to be excluded from use. The contaminated area includes arable land, pasture, and forest.

***Degradation due to the Chernobyl catastrophe.*** Radiation contamination after the meltdown of the Chernobyl nuclear plant caused the outright removal of 8 percent of Ukraine's formerly fertile land from agricultural production (Figure 59). In addition, extensive areas that are still farmed contain radiation levels of up to 15 Ci (curies) of cesium/$km^2$. Products grown in these areas are subjected to radiological monitoring before being placed on the market. Government programs and techniques adopted by farmers help reduce the passage of radionuclide into food—for example, crop selection, fertilization and plowing methods, special additives to decrease transfer of radionuclide to milk. However, many countermeasures for agriculture require large subsidies, or the final produce becomes too expensive to sell. Many of the clean technologies developed after Chernobyl ended up being unsuitable for application in the private agricultural sector. Subsidies that encourage the use of clean technologies in the collective and state sectors have been falling in recent years. Many farms in contaminated territories have become unprofitable.

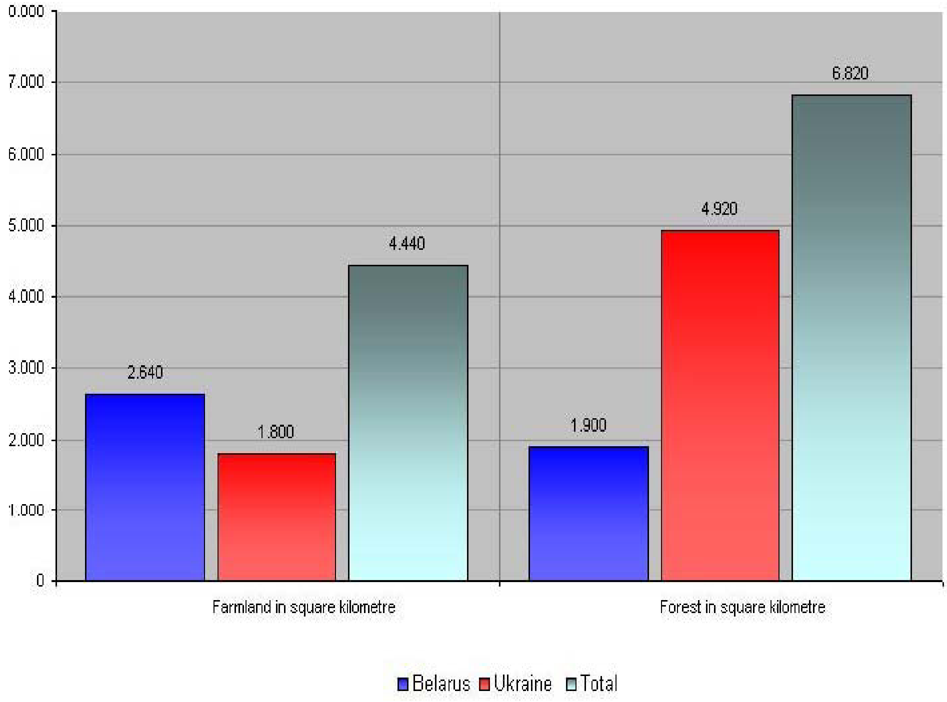


**Figure 59. Area of Agricultural Land and Forest That Can No Longer Be Used because of the Chernobyl Nuclear Power Plant Accident**

***Soil management.*** Ukraine is renowned for its highly fertile black soils. During the Soviet era, Ukraine was considered the "granary" of the Soviet Union. However, high agricultural production caused serious erosion and deterioration of water resources. According to the Food and Agriculture Organization of the United Nations, annual soil losses during that period were as much as 600 million tons and cost the country more than US$ 1.6 billion annually (Bogovin 2006). An estimated 40 percent of the country's territory is now eroded (Figure 60), and an additional 40 percent is subject to wind and water erosion. According to a study in the mid-1990s, 25.6 percent of Ukraine's soils were acidic, and 9.7 percent were saline or alkaline. A 1996 study by the State Committee of Land Resources reported that 13.2 million ha were exposed to water erosion, and 1.7 ha were exposed to wind erosion. These figures are estimated to increase by about 60,000-80,000 ha/yr.

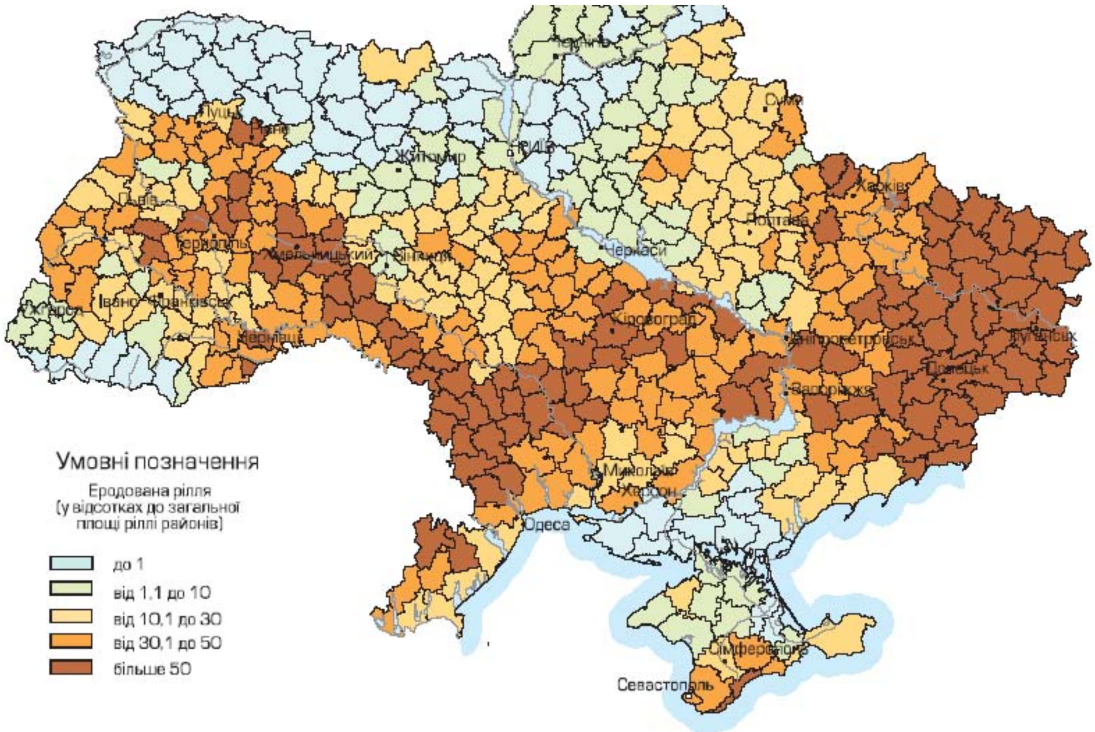


**Figure 60. Erosion Distribution**

Cultivation on steep slopes, excessive forest cutting, overgrazing, extensive row cropping, and tillage techniques that use up more organic matter than is replaced all lead to long-term loss of fertility in Ukraine (UNECE 2006). Erosion is encouraged by the recent significant decrease in the application of mineral and organic fertilizers, which caused a sharp decline in soil humus content. Further degradation of soil structure arises from poorly managed irrigation, continuous cultivation (without fallow periods), and compaction by heavy farm machinery. Ukraine's agricultural machines are outdated and inefficient, which exacerbates soil compaction.

**Water management.** According to Ukraine's State Committee for Land Use, 3.9 percent of land is irrigated. During the past 15 years, the area decreased by about 15 percent, from 2.6 million ha in 1990 to 2.1 million ha in 2005 (Lindeman 2007). Water withdrawals have likewise decreased, from 1,270 to 890 million $m^3$ from 2003 to 2004. Water use efficiency was never high and may have declined in the last decade. The portion of water lost during transport grew to 15 percent until 2004, and improved by a modest 1 percent thereafter. The adoption of drip irrigation systems is expanding (from a small base) for high-value crop s, perhaps due to better control of water application and the ability to add fertilizer to the drip lines.

Other hydrologic factors leading to decreased productivity include serious waterlogging and salinization problems. Waterlogged soils constitute 21.5 percent of the total irrigated area. In Kherson oblast (one of the more heavily irrigated oblasts), salinization affects 90 percent of irrigated lands, and 230,000 ha are now out of production for this reason. Water erosion is also a major problem. In extreme cases, farms suffer land slides—20,000 landslides were registered in Ukraine in 2003. Coastal erosion also leads to land loss.

Ukraine has lost a large portion of its wetlands, primarily due to conversion to farmland. Loss of wetland functions exacerbates serious environmental problems such as water quality degradation, biodiversity loss, habitat loss, flooding, pollution, climate ch ange (in peat-accumulating wetlands), and other issues of concern to Ukraine and the rest of Europe.

Nutrient management. During the Soviet era, Ukraine applied large amounts of mineral fertilizers on agricultural lands. This pattern has changed due to the removal of large agricultural subsidies and a reduced farming economy (Figure 5). In the 1990s, fertilizer application per hectare dropped by 78 percent, and then increase modestly since 2000. Although fertilizer use has dropped, improper fertilizer application still causes pollution problems in the Dnipro River, the Danube Basin, and the Black Sea. Eutrophication of these water bodies has caused loss of biodiversity, tourism dollars, fishing revenues, and increased water-borne diseases, among other problems. Despite the drop in fertilizer use, grain crop yields began rebounding in 2000 and have been doing well, due to "favorable weather and improved crop-management practices on the large agricultural enterprises," according to USDA's Foreign Agriculture Service.

Livestock nutrient management is also a challenge in Ukraine. Improper manure management on farms and excessive application as fertilizer on fields leads to land and water contaminatio n. Solutions such as legislative enforcement and containment have not been effectively developed (EEA 2003). However, the country's dramatic downturn in livestock production may reduce the problem.

Crop protection. More than 20 percent of Ukraine's agricultural lands are contaminated with DDT and its degradation products, and approximately 4 percent are polluted by hexachlorine-cyclohexane (EEA 2003). The region with the highest soil pollution levels is the Artemivsk District (Donetsk Region), which contains 2.2 times more than the "maximum permissible concentration" (Ukraine Ministry for Environmental Protection and Nuclear Safety, no date). Pesticide application has dropped significantly, from a high of 3-4 kg/ha in the 1980s to a current rate of 0.7-1 k g/ha and con traction in the agricultural economy, rather than an embrace of environmental concerns.

Although current pesticide use is far lower than in recent history, the legacy of past use remains in the country's stockpile of obsolete pesticides. An estimated 30,000 tons are stored in 25 regions (Pidlisnyuk and Stefanovska 2004). A number of laws, Cabinet of Ministers acts, and Ministry of Environmental Protection (MEP) regulations address pesticide use and disposal; however, many are not implemented properly. Existing legislation does not clarify ownership or responsibility for clean-up and remediation. Many storage facilities improperly or illegally store the chemicals, resultin g in area-wide contamination.

Genetically modified organisms. Ukraine does not currently have a law governing the registration, authorization, testing, or use of genetically modified organisms (GMOs) or other biotechnological products (UNDP, no date). However, a biological environmental safety system was launched in 1999 to meet the future requirements of GM agricultural crops. No methodologies or regulations have yet been designed for testing these products.

*6.3.6. Data for Ukraine*

DEM raster dataset: the average elevation in each grid cell

- Slope raster dataset: the average slope (in %) in each grid cell
- Country raster dataset and Land use raster dataset
- Soil raster dataset: code of the soil files in each grid cell
- Climate raster dataset: code of the climate files in each grid cell
- Irrigation raster dataset: annual irrigation depth in mm/yr.
- Fertilizer raster dataset: annual fertilizer rate in kg/h

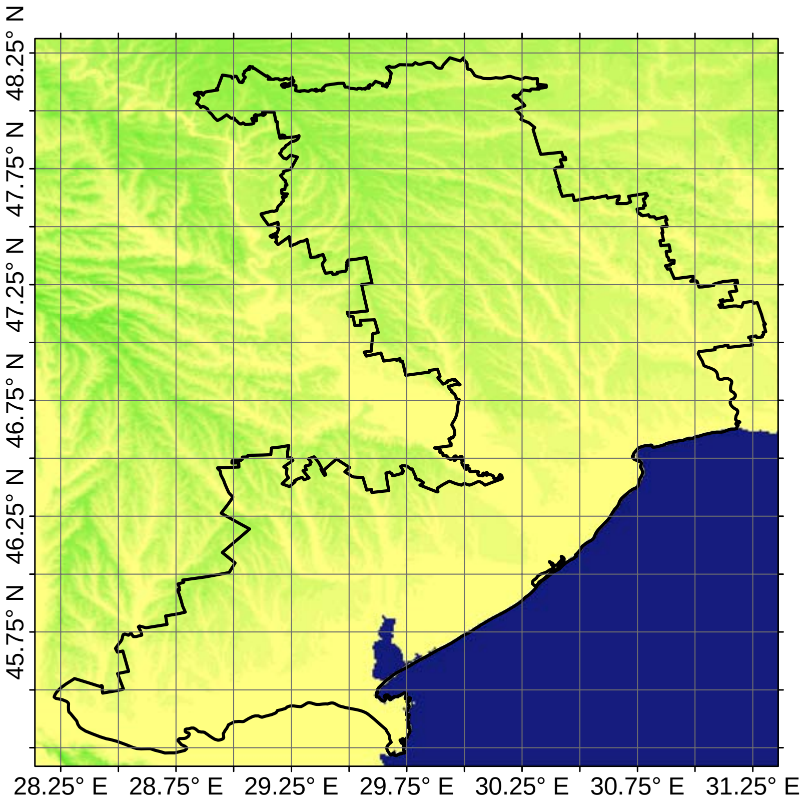


**Figure 61. Digital elevation model GTOPO30 for the Odessa region area (Ukraine)**

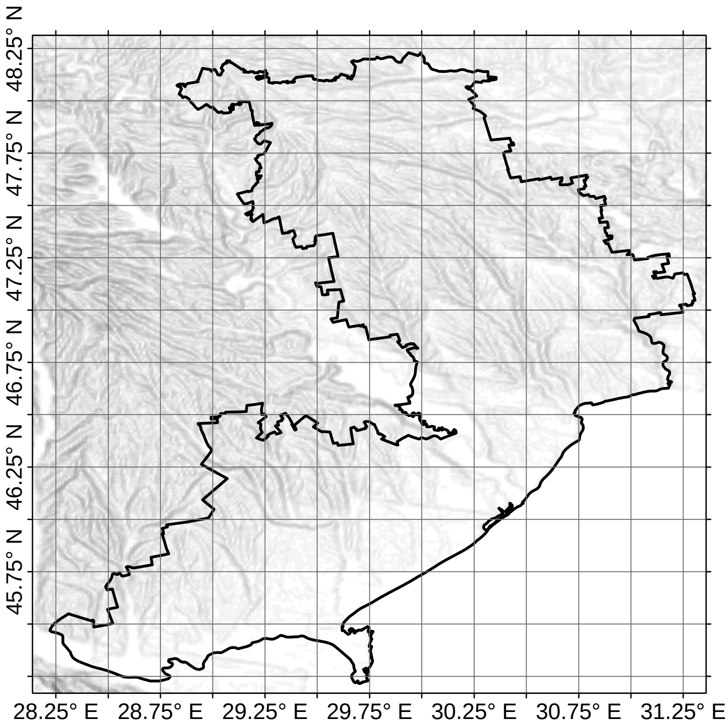


**Figure 62. The slope dataset GTOPO30 for the Odessa region area (Ukraine)**

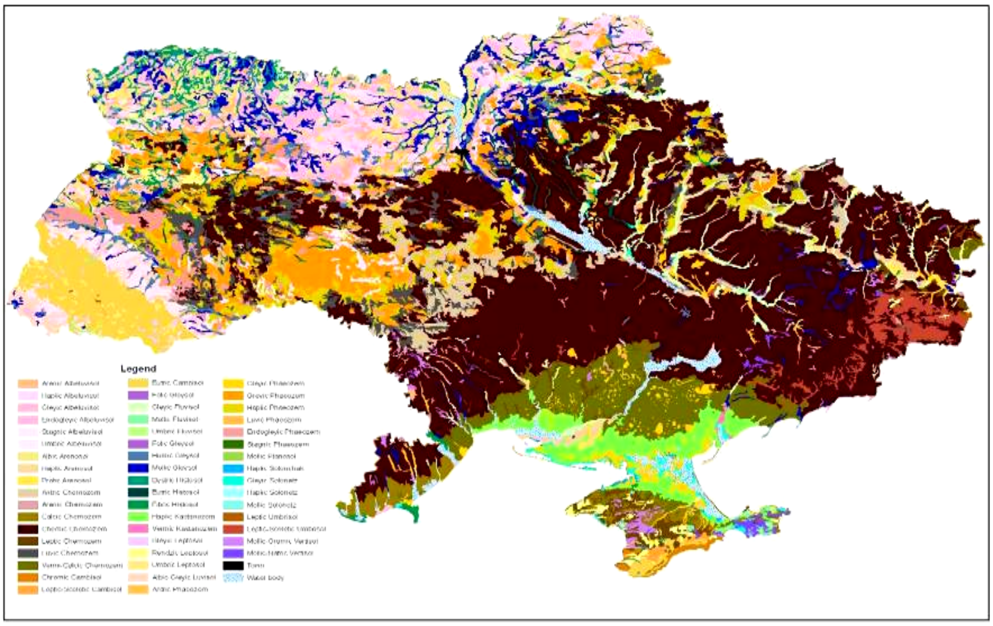


**Figure 63. The Soil Map of Ukraine in WRB Classification**

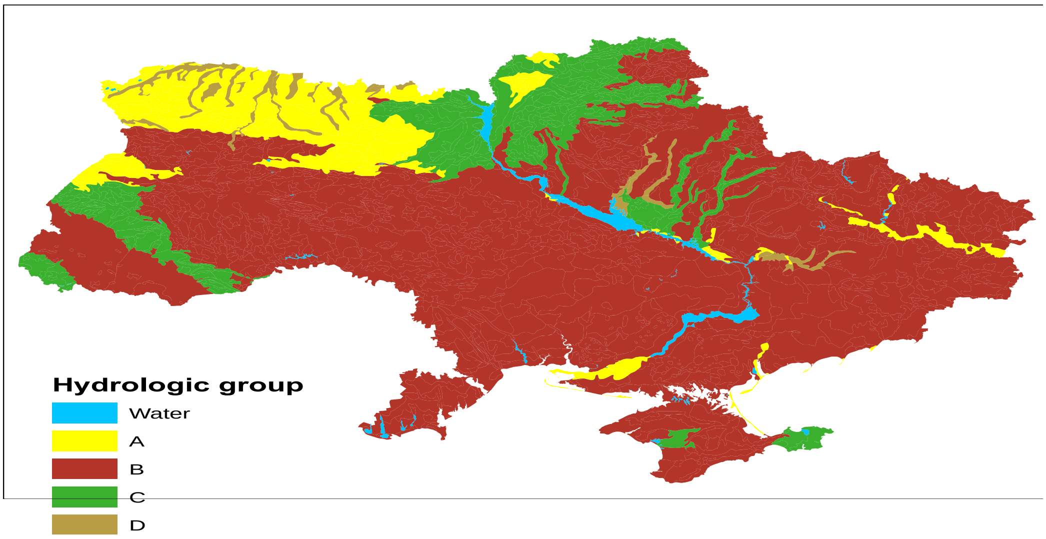


**Figure 64. Soil Hydrologic group map of Ukraine in GIS formats**

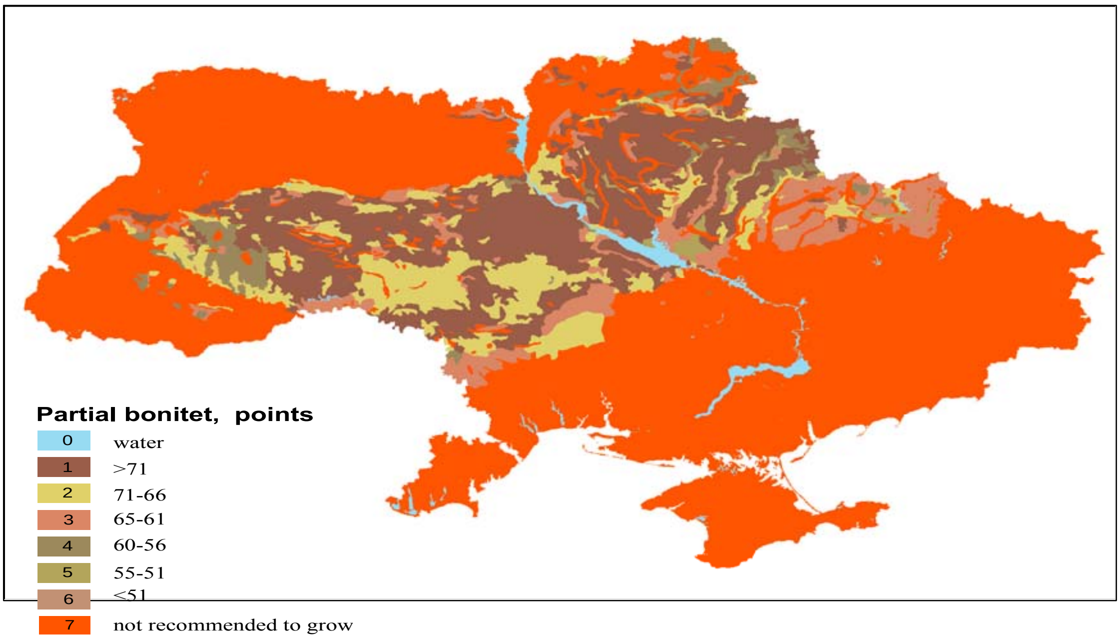


**Figure 65. Map of growth class for sugar beet in Ukraine in GIS format**

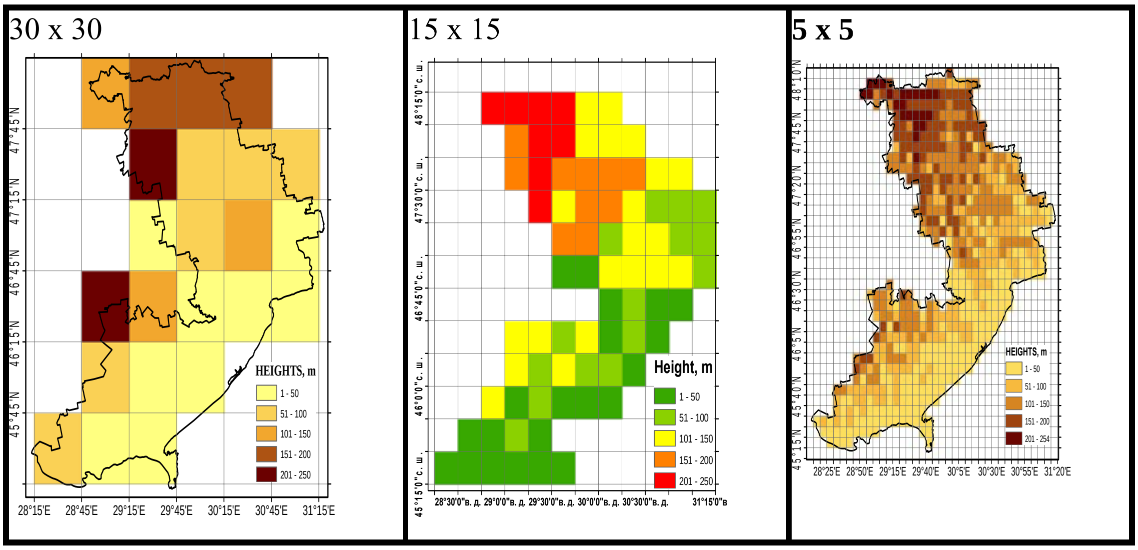


**Figure 66. DEM raster datasets**

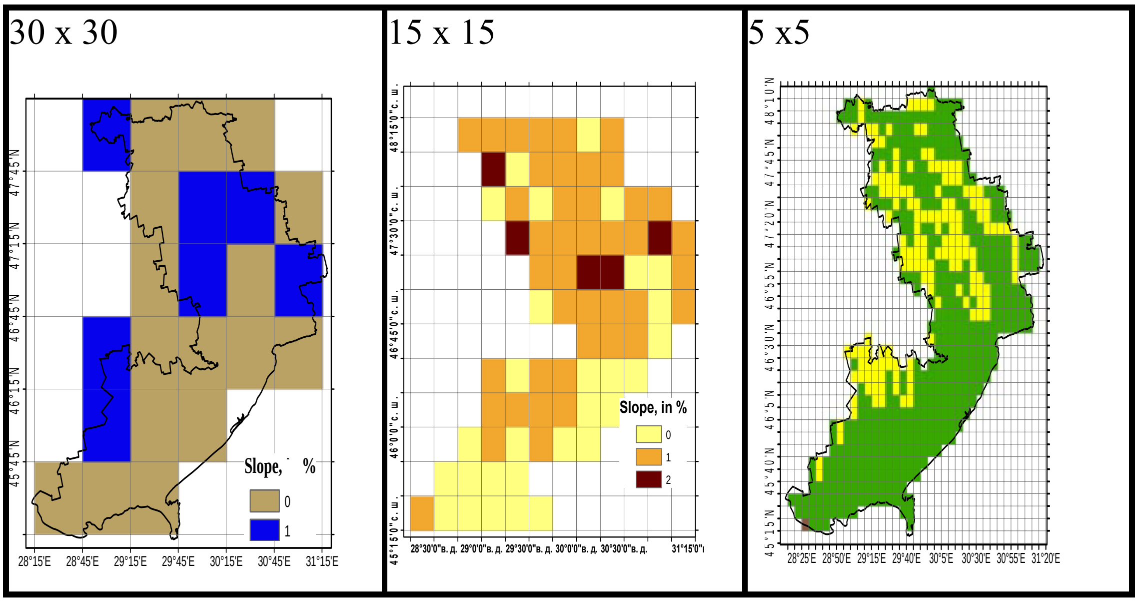


**Figure 67. Slope raster dataset**

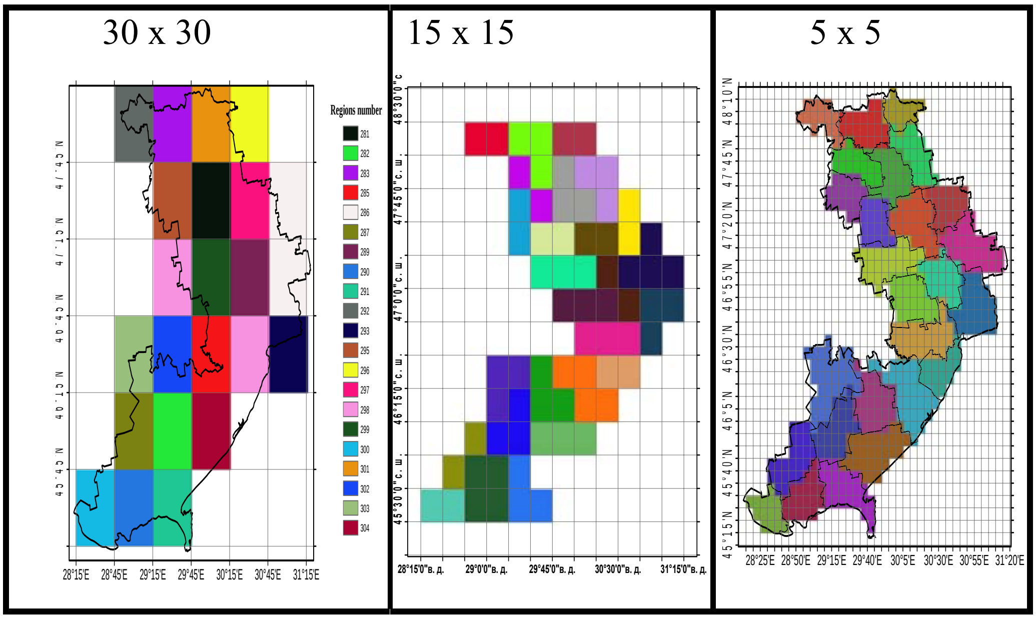


**Figure 68. Country raster dataset**

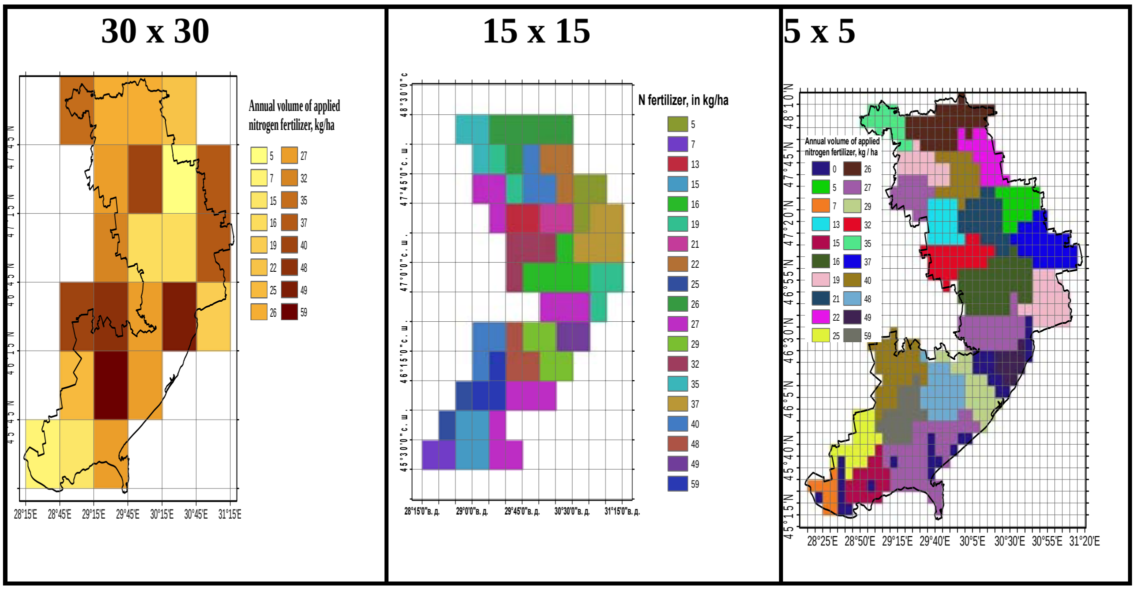


**Figure 69. Fertilizer raster dataset**

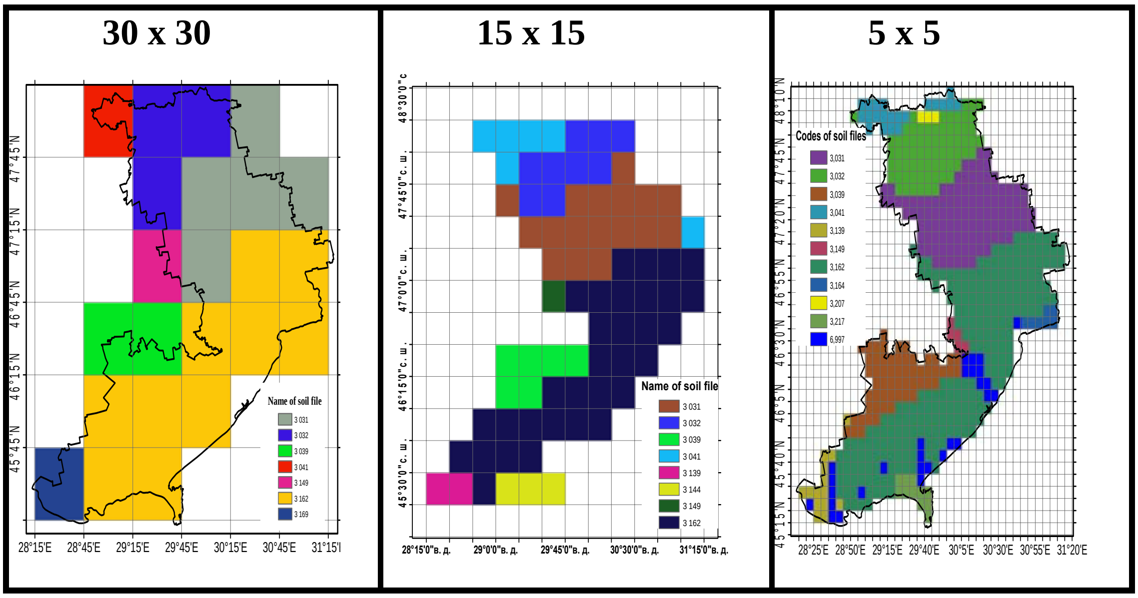


**Figure 70. Soil raster dataset**

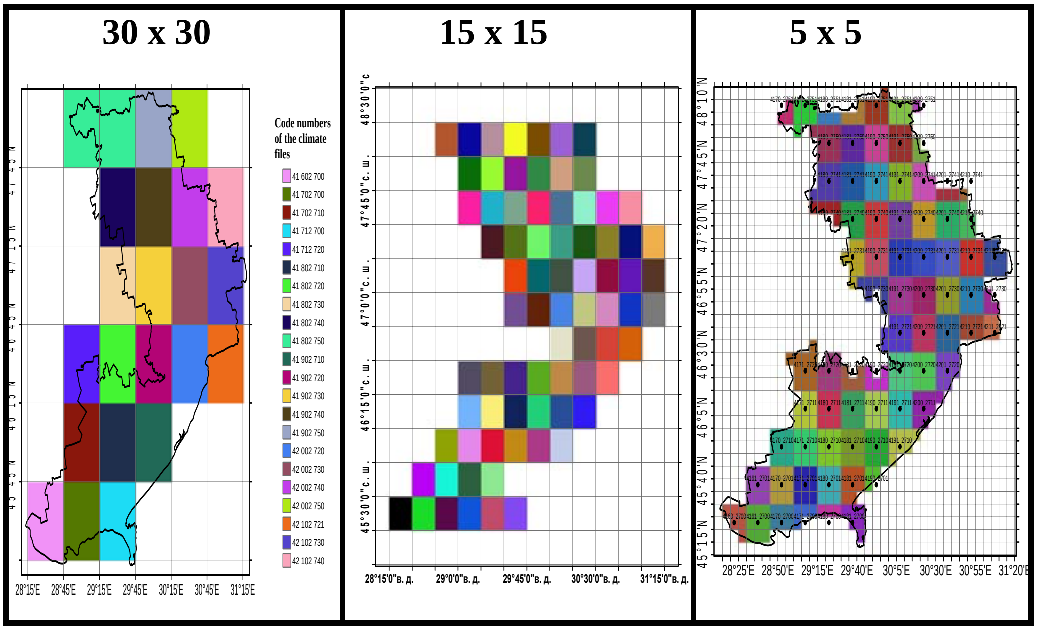


**Figure 71. Climate raster dataset**

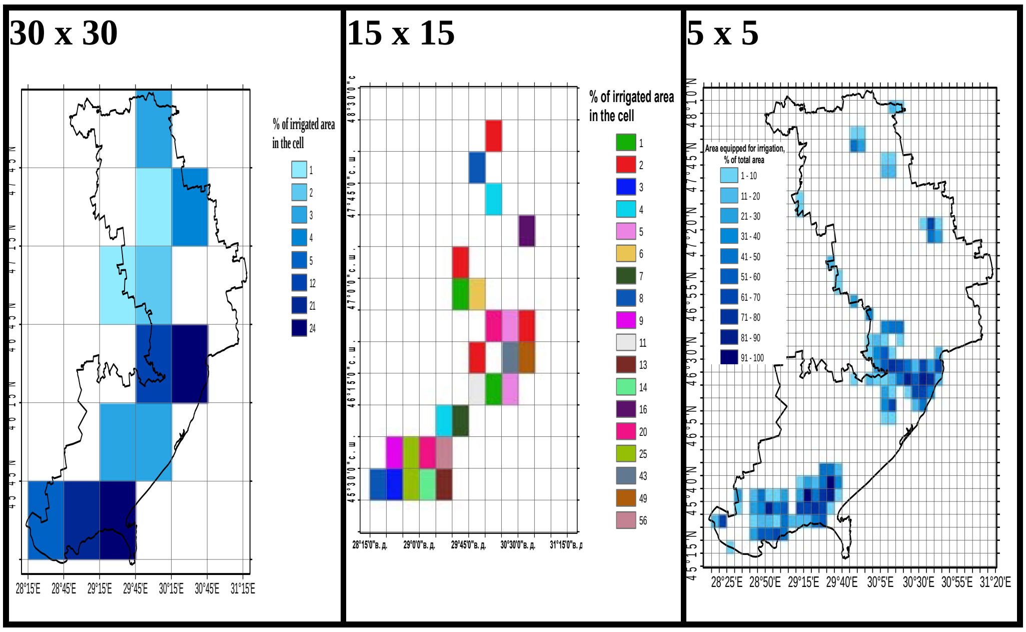


**Figure 72. Irrigation raster dataset**

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