# Executive Summary

*A project "Reducing vulnerability to extreme floods and climate change in the Dniester River basin" was one of the pilot projects under the program of adaptation to climate change in the transboundary basins, carried out in accordance with the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes. The Convention is considering the climate change not only as a challenge to mankind, but also as one of the drivers of transboundary cooperation, which can be the starting point in activities to improve relations between the riparian countries. A joint analysis of problems, priorities and solutions as the determining factor of transboundary cooperation, defined the agenda and methods to execute the task of a project. Harmonization of efforts of the executors from Ukraine and Moldova, as well as used means, models and scenarios, information exchange and the increased using of results of researches, projects and programs in the field of a studied problem have determined the format and content of a present report.*

## 1. Methodological approaches to assessment of vulnerability

The assessment of vulnerability to climate change of the Dniester River basin is based on the Concept of the Intergovernmental Panel on Climate Change (IPCC, 2007a) which provides differentiation between three main components of vulnerability: exposure, sensitivity and adaptive capacity. *Exposure* in this triad is determined by nature, magnitude and the rate of climate change represented by the long-term observed or expected changes in the climatic conditions. *Sensitivity* determines the extent to which the system is sensitive, positive or negative, to the direct or indirect impact of climate change. *Adaptive capacity* describes the ability of a system to adapt to actual or expected climatic stresses, or to cope with their consequences. Exposure is usually interpreted as an *external dimension* of vulnerability, while both sensitivity and adaptability – as its *internal dimension*.

The assessment of vulnerability has also emanated from two approaches to its interpretation: *an analysis of the final results* and *an analysis at the initial point*. A first approach considers the vulnerability as a result of sequential analysis entailing to the *final* assessment of vulnerability or residual effects that occur after adaptation; while the second one, as the current inability of the system to cope with climatic, ecological, social and other pressures. A preliminary assessment suggests that elimination of the current vulnerability reduces the vulnerability to the foreseen climate conditions. To that end, *the current vulnerability* of the Dniester River basin, which refers to the current regional climate variability and the current capacity of both natural and social systems to cope with the variability of the hydrological regime of river, varies from *the future vulnerability* which refers to the foreseen climatic conditions and the future ability to resist them.

Since vulnerability to the climate change depends on a set of factors, its assessment includes a number of the criteria for identification of the vulnerable systems and groups covering several aspects: *physiographic, socioeconomic, ecological, adaptive.* Their quantitative assessment demanded to use a specific set of indicators; based on them, there were identified the areas mostly being at risk for subsequent setting of the priorities of actions on planning and implementation of the adaptive measures.

As a *basic material* was used the national statistics of both Ukraine and Moldova, the results of researches conducted for other tasks within a current project as well as other international projects carried out in the Dniester River basin earlier, along with the various scientific publications that reveal certain aspects of this topic. Where it is possible, the summary estimations belong to the basin at whole, regardless to the administrative ownership of its particular parts. This evaluation was carried out separately for the Ukrainian and the Moldovan parts of the basin where this task was difficult to execute due to existing differences in the national statistics as well as due to amount and availability of information. Given the fact, that 67% of the Moldovan territory is located in the Dniester basin, in some cases, the general estimations for the country were qualitatively evaluated as representative for this part of the basin; while evaluations of the Ukrainian part were based on the data from covered areas.

## Physiographic aspects of vulnerability of the Dniester basin

### 2.1 Urbanisation, land use, geomorphologic processes

*An average density of population* in the Dniester basin (total population - 8.4 million people) is 116.4 pers/km² (100 pers/km² in the Ukrainian part of basin and 165 pers/km² - in the Moldovan part), which is above the average for the Eastern European countries. This high density of population determines the level of anthropogenic impact on the natural and water resources, especially in the middle and upper parts of the basin. The Dniester River is a source of drinking water for the administrative centres in five regions of Ukraine, for the capital of Moldova (Chisinau), as well as for a number of large industrial centres.

Three quarters of the *land resources* in the Moldovan part of the basin are used for agriculture, and somewhat less (66%) used in the Ukrainian part, it is unduly high share from the point of view of science-based efficiency of land use as well as from the standpoint of a stable maintenance of the natural resources of territory. The situation is complicated with the structure of agriculture as arable land is covering up to 45% - 55% of the total lands, permanent crops cover up to 9% in Moldova and 30% in Ukraine, as well as pastures cover 7% and 15%, respectively. Meadows, dead fallow and deposits cover 7% of the Ukrainian part of a basin while only 0.3% belongs to Moldova with an onward tendency to reduction. In terms of a greater diversification of the land use, one can talk about a slightly lesser vulnerability in Ukraine. The excessive pressure on soil leads to its progressive degradation and development of the erosion processes that reduce the soil quality and productivity; in 2005, the area of soils affected by erosion accounted to approximately 26% of the territory of Moldova, with annual increase by about 6.4 thousand hectares. The most typical processes for the basin are shown in the Table 2.4 and 2.5[1].

**Table 2.4** Natural and anthropogenic geomorphologic processes in the Ukrainian part of the basin

| Form of occurrence | Area (oblast) and percentage of its territory within a basin | | | | | | |
|---|---|---|---|---|---|---|---|
| | Lvovskaya 50% | Ivano-Frankovskaya 65% | Chernovitskaya 32% | Vinnitskaya 27% | Ternopolskaya 82% | Odesskaya 16% | Khmelnitskaya 37% |
| ***Landslides*** | | | | | | | |
| Total number | 1,347 | 805 | 1,467 | 339 | 117 | 5,835 | 420 |
| Area, km² | 292.6 | 301 | 760 | 16.55 | 11.74 | 66.3 | 20,98 |
| % of territory | 1.34 | 0.08 | 9.4 | - | 0.09 | 0.20 | 0,10 |
| ***Karst*** | | | | | | | |
| Total number of occurrence | 5,100 | 2,077 | 328 | 271 | 2,472 | 112 | 769 |
| Area, km² | 17,790 | 10,290 | 6,390 | 10,890 | 13,800 | 32,650 | 17,440 |
| % of territory | 81,6 | 74,0 | - | 41.1 | 100 | 98 | 84,7 |
| ***Mudflow*** | | | | | | | |
| Number of streams | 52 | Local | - | Not typical | Not typical | Not typical | Not typical |
| Area, km² | 240 | | - | | | | |
| ***Loess soils*** | | | | | | | |
| Subsidence, km² | 2,060 | 1,700 | 4,350 | Not typical | 9,380 | 13,920 | 14,830 |
| % of territory | 9.43 | 12.27 | 53.75 | | 67.95 | - | 72 |
| ***Submergence*** | | | | | | | |
| Area, km² | 250 | 0.014 | 400 | 50 | Local occurrence | - | 60 |
| % of territory | 1.15 | 0.01 | - | 0.02 | | - | 0.29 |

Notes: 1. Dashes indicate a lack of information

[1] Numbering of tables and figures in the summary is given in accordance with their numbering in the Report.

**Table 2.5** Natural and anthropogenic geomorphologic processes in the Moldovan part of the basin

| Form of occurrence | Total | River basins with a length of | | | |
|---|---|---|---|---|---|
| | | > 100 km | 100-50 km | 50-25 km | > 25 km |
| | | Average density, km/km$^2$ | | | |
| ***Landslides*** | 143.5 km$^2$ | 0.003 | 0.017 | 0.007 | 0.001 |
| ***Landfalls*** | 131.4 km$^2$ | 0.011 | 0.001 | 0.006 | 0.005 |
| | | Average frequency, units per 1 km$^2$ | | | |
| ***Gullies*** | 17,399 units | 0.870 | 0.640 | 1.000 | 1.045 |
| ***Open pits*** | 509 units | 0.035 | 0.022 | 0.026 | 0.019 |

## 2.2 Exposure to the current and foreseen climate of the Dniester basin

The assessment of the climate component of exposure is based on the historical performance of air temperature and precipitation for the period of observations (1961-1990) as well as on the calculated projections of their changes by 2021-2050 (Balabukh, 2012; Krakow, 2012). The generalisation of projections is carried out by three regions of the upper, middle and lower parts of the basin (Fig. 2.3). The assessment was carried out separately for warm and cold periods of the year, as well as separately for the current and foreseen climate, with an emphasis on its extreme occurrences.

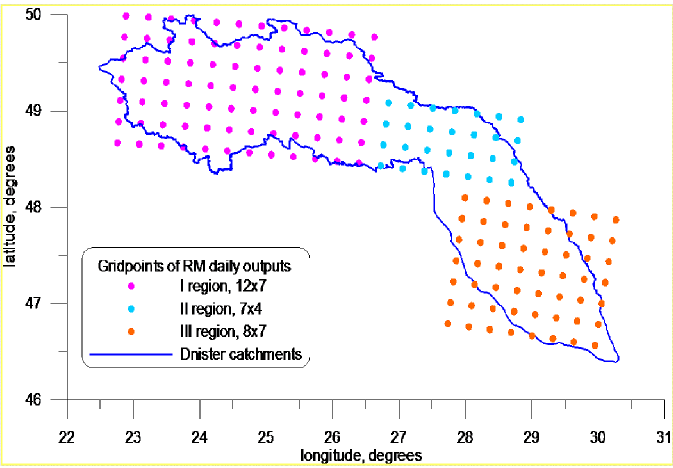



**Fig.2.3** Sectoring of the Dniester River Basin by the areas of simulation of climate change in the grid of the regional model MPI-M REMO, ECHAM5

There were three indicators estimated to the *cold period of year*: extremely low temperatures, heavy rainfalls, snow cover. First two factors were considered as the negative ones while a presence of snow cover based on its function of a runoff formation and protection of agricultural lands was indicated as a factor reducing vulnerability.

A basic frequency of occurrence of the negative temperatures which are hazardous for human activities is presented in the Table. 2.6. By the middle of this century, a number of the frosty days may reduce by 2-2.5 weeks; accordingly, the frost-free period will increase as well and, as a result of it, the duration of the heating season will decrease, influencing positively to the economy of region. However, a possible increase in the number of thaws may adversely affect the ecosystems. A number of the days with strong frost ($T_{min}$<-25⁰C) may drop by 2-3 days, but it is expected an increase in the frequency of occurrence of *strong winds* (15 m/s and more) which can bring significant damages to the systems of power supply, communications, agriculture, communal services, transport, as well as to population in general.

**Table 2.6** A number of the days with frost in the Dniester basin in 1961-1990, by different gradations (T°C)

| T,°C | T,°C | T,°C | T,°C |
|---|---|---|---|
| *≤-10* | *≤-10* | *≤-10* | *≤-10* |
| *≤-15* | *≤-15* | *≤-15* | *≤-15* |
| *≤-20* | *≤-20* | *≤-20* | *≤-20* |
| *≤-25* | *≤-25* | *≤-25* | *≤-25* |
| *≤-30* | *≤-30* | *≤-30* | *≤-30* |
| *≤-35* | *≤-35* | *≤-35* | *≤-35* |

Redistribution of precipitation occurs in the direction of more intensive ones (Table 2.7) which should be considered as a negative trend in combination with the reduction of solid sediments. Taking into account, that the most snowy winters are taking place in the Carpathian mountains, the expected drop of about a quarter of snow in the middle of century may have a negative impact on the regime of runoff of the Dniester River.

**Table 2.7** The foreseen changes in the number of days with heavy precipitation of varying intensity in the cold period of year in the Dniester basin in 2021-2050, comparative to 1961-1990

| Index | *Upper Dniester* | | *Middle Dniester* | | *Lower Dniester* | |
|---|---|---|---|---|---|---|
| | >20 mm | >30 mm | >20 mm | >30 mm | >20 mm | >30 mm |
| *Changes, days* | 6.6 | 2.6 | 4.5 | 0.3 | 4.2 | 0.3 |
| *Expected number of days* | 16 | 13 | 32 | 5 | 28 | 7 |

The assessment of exposure to climate in the *warm period of the year* is concentrated on the humidity, as well as on the change of some applied climatic characteristics, first of all, those that representing an interest for agriculture.

In particular, a slight increase of precipitation that is expected in the upper and middle reaches of the Dniester does not compensate the significant growth of air temperature which will lead to the increased aridity, especially in the lower part of basin where the warm period may become semi-arid and even dry at the end of summer. Worsening of the humidity adversely affects both the status of basin ecosystems and the reserves of water resources. At the same time, an increase in the duration of warm period will strengthen the agro-climatic potential of the territory contributing to the growing of late and more productive crops and also supporting introduction of the new warm-season crops. However, the earlier coming of spring may «provoke» the earlier vegetation period of plants creating a threat to their damage by the late spring frosts.

The growth of average temperatures will be accompanied by an increase in the number of *hot days* with daily temperatures ≥ 30$^0$C (in 2-3 days) hazardous for human health and *very hot days* with T ≥ 35$^0$C.

In 1971-2010, there was mentioned an increase in the frequency of occurrence of strong and heavy rains. Further growth of the number of days with intense precipitation will occur downstream of the Dniester River: from about 5 days in the Carpathian mountains up to 14 days in the mouth of the river with precipitation >20 mm a day, and from a certain decrease in the upper reaches up to 10 days in the middle and lower parts of the basin with precipitation >30 mm a day. Strengthening of precipitation should be considered as the increasing vulnerability because heavy rains destroy soil and intensify the runoff creating this way the preconditions expansion of the erosion processes and deterioration of the surface waters quality. An increase in the intensity of convective processes may lead to an increase in the frequency of occurrence of thunderstorms, hails, squalls and whirlwinds with particularly negative consequences.

The expert assessment of the effect of exposure of the Dniester River basin to the certain climate indicators and their expected changes see in the Table 2.14.

**Table 2.14** A basic scheme of the exposure effect of various sites of the Dniester basin to the extreme weather events

| Climate indexes | Exposure effect and the sites of basin | | | | | |
|---|---|---|---|---|---|---|
| | *1961-1990* | | | *2021-2050* | | |
| | *Upper reach* | *Middle reach* | *Lower reach* | *Middle reach* | *Upper reach* | *Lower reach* |
| **Cold period of the year** | | | | | | |
| Heavy frosts: | | | | | | |
| *≤-20* | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| *≤-25* | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| *≤-30* | ↓ | ↓ | | ↓ | ↓ | |
| *≤-35* | ↓ | | | ↓ | | |
| Snow cover and expected changes | ↑ | ↑ | ↑ | ↑ | ↑ | ↓ |
| Increase in the intensity and frequency of heavy precipitation | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Heavy snowfalls ( ≥ 15 mm/24h) | | | | ↑ | ↓ | ↓ |
| Increase in the duration of frost-free period (thaw) | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑↓ |
| Decrease in the heating period duration | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| Reduction in the severity of winter | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| Increase in the number of days with strong wind | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| **Warm period of the year** | | | | | | |
| Air humidity | ↑ | ↑ | ↓ | ↑↓ | ↓ | ↓ |
| Increase in the duration of periods with: | | | | | | |
| T > 5ºC | | | | ↑ | ↑ | ↑ |
| T > 10ºC | | | | ↑ | ↑ | ↑ |
| T > 15ºC | | | | ↑ | ↑ | ↓ |
| Increase in the number of hot days with T ≥ 30, ≥ 35ºC | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Increase in the frequency and intensity of atmospheric and soil droughts | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Expected increase in intensity of heavy precipitation | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Change in a number of the days with precipitation: | | | | | | |
| > 20 mm | | | | ↓ | ↓ | ↓ |
| > 30 mm | | | | ↑ | ↓ | ↓ |
| Increase in a maximum volume of precipitation per day | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Increase in the number of strong winds | ↓ | ↓ | ↓ | ↓ | ↓ | ↑ |

*Note:* ↑ – positive impact; ↓ – negative impact; ↑↓ – both impacts are possible depending on the estimated system and the intensity factor

## 2.3 Exposure of the water resources of the Dniester River to variability and climate change

Qualitative assessment of exposure of the water resources to the existing regional climate variability includes the following:

1. There was no any significant impact detected for the long-term climate variability on the river runoff. Certain anthropogenic impact can be traced only for the tributaries of the Dniester River in the lower part of a basin.

2. The long-term dynamics of average annual runoff is characterised by a combination of both the statistically significant and insignificant trends of periodic nature. Since the presence of trends in the long-term regime of runoff has periodic (cyclic) character, its fluctuations can be considered as quasi-stationary ones.

3. In recent decades, it is observed the low-water phase of the hydrological regime in the *yearly average runoff* which started in 1969-1977 and is typical for the

low-water flow during both the winter period and the period of open channel. Stabilisation of fluctuations of the *peak flow* to the mountain and semi-mountain rivers was mentioned in 1968-2010.

4. Over the past 120 years, the largest annual water flow had been formed in 80 cases during warm season (3-5 rainfall floods per year), with a frequency of maximum water flow of 1-5% probability that is 2-3 times higher than flows formed by the snowy rainfall floods with relevant probability.

***Projections of changes of the river runoff:***

**1.** The expected changes of the average runoff in the Carpathians and the Volyno-Podolskaya catchment areas will be in range with the natural variability; its decrease in 2021-2050 (about 24%) can only be expected to the Lower Dniester.

**2.** An increase in the intra-annual runoff distribution is possible during cold season in the *Carpathian part* of the basin along with a decrease in the spring flood and shifting of its peaks to the earliest possible time accompanied with a possible increase in the frequency of floods. The intra-annual runoff reallocation will be characterised by a significant range of its changes by month. Trends in the water volume change of the rivers in the *Volyno-Podolsky* part of a river basin have not been revealed. The runoff in the *lower reaches of the Dniester River* will be characterised by a clearly defined flood patterns (with a possible decrease in spring floods) due to increased intense precipitation.

**3**. Significant changes in the *maximum water flow rates* are not expected; it can be assumed 15-16% decrease for the Volyno-Podolsky and the lower parts of the basin. Insignificant increase in the *minimum water flow rates* may occur in the Carpathian and the Volyno-Podolsky parts of the basin while the significant increase (up to a quarter) may happen in the lower reaches of the Dniester River.

**4**. The runoff formation is influenced by zonal and azonal factors of impact which reflect the changes by latitude of the climate variables or violating its distribution by latitude, respectively.

Thus, the differences in vulnerability of water resources in the Dniester River basin which are observed in the current climate may aggravate even more to the middle of century. One may expect the retaining sufficiency of the water resources in the Carpathians, the almost absolute stability of the existing situation in the middle part of the basin largely determined by regulation of the runoff by the Dniester reservoirs; and the significant increase in vulnerability in the lower reaches of river where the exiting low level runoff will reduce even more, while the water scarcity will be combined with the increasing aridity of climate.

### 3. Sensitivity of the ecosystems of the Dniester basin to climate change

The climate change provokes aggravation of the problems caused by physical fragmentation of ecosystems linked to their genetic degradation or a high loss during migration, as well as by their qualitative fragmentation, due to reduction of the suitable conditions for their existence. Ultimately, it will result in the accelerated extinction of species, replacement of the grassy edificators of natural ecosystems by weeds and aggressive species, further impoverishment of the soil biota and a very weak possibility for the natural substitution of species forming the ecosystem by other species. The choice of ecosystems for research was determined by the degree of their significance in the formation of natural resources of the basin. As such were taken the Carpathian forests that largely determine the runoff of the Dniester River, the variety of floodplain ecosystems in the central part of a basin, the wetlands at the mouth as well as the ichthyofauna of river.

**3.1 Forest Ecosystems of the Carpathians.** The reduction in forest cover in the catchment area and the basin of Dniester, especially in the Carpathians, is an important factor of strengthening of the negative impact consequences of climate change on water resources. The Carpathians is one of the most humid regions in Ukraine where the main runoff of the river is formed; the natural vegetation of this zone plays an important role in water conservation and soil protection. The climate change impact may affect the Carpathian forests in both the negative and the positive aspects. The *negative consequences* include:

- violation of the phenological succession of the timber species which will have problems with adaptation to the changed environmental conditions;
- possible change of the heights limits of the timber species;
- further danger of desiccation of spruce monocultures outside of their natural growing environment;
- more frequent intervals of the extreme weather events and the risk of avalanches, floods, landslides, mud flows;
- more frequent appearance of storm winds creating danger of windbreaks;
- increase in the number of forest fires;
- expansion of the insect fauna which is dangerous to forests and the occurrence of fungal diseases caused by the increased humidity.

As possible *positive consequences* of climate change can be considered the following:

- reduction of the frequency of fruiting seasons as a result of warming, the increased productivity of the timber species and their improved fertility;
- possibility to enrich the forests with indigenous thermophilic and alien species enhancing this way their biodiversity;
- increment of the timber species and productivity of the standing timber crops along with increasing vegetation season;
- improvement of the burozemic pedogenesis;
- acceleration of re-naturalisation of the upper limit of forests and the improvement of their water and soil protection role;
- possibility to expand recreational areas in the upland forests and to increase their social value.

**3.2 Floodplain ecosystems of the Dniester.** In comparison with the forest and steppe zonal ecosystems, the impact of climate change on the azonal communities of floodplains is lower as they are mostly influenced by hydrological regime of the floodplain and the salt content in the soil. The hydrological regime, which is directly linked to the climate conditions in the catchment area, determines the duration of flooding that influencing the processes of accumulation and leaching out of salts in soil. The influence of river is prevailing over the direct influence of climate while in the stable hydrological regime of the floodplain the ecosystems correspond to the majority of indicators of the concept of sustainability; the sustainability of specific floodplain ecosystems will be determined by the conditions of humidity of their habitats which may lead to the lowering of the groundwater levels and the induction of the syngenetic processes in case of its significant and prolonged deterioration. Aridization may cause a partial (or complete) desiccation of some wetlands of the Dniester River which already have a surface water balance estimated to be negative or close to zero. The change in phytocoenosis will proceed in the process of change of a level of groundwaters.

**3.3 Wetlands of the Lower Dniester** are less dependent from the temperature factor and, therefore, are more resistant to climate change, but the limits of their resistance depend on a number of other factors too (content of oxygen dissolved in water, life cycles, conditions of recharge, etc.). Due to the fact, that the Lower Dniester is characterised by high natural diversity, the climate change impact may vary at the level of certain ecosystems. The most vulnerable are the shallow ecosystems which may face the complete drying after the reduction of runoff. The ecosystems in deeper reservoirs, which are developing in the conditions of a shorter inflow of atmospheric heat, are more sensitive to the changes of water temperature, the increase of which will contribute to the growth of biomass production in the ecosystems, their potential to resettlement and the capacity for biological purification of water. However, this increase may contribute to the mass reproduction of algae followed by the water "blooming", the reduction of the content of oxygen in water, the nutrient pollution of water bodies and the mass reproduction of pests and pathogens. The changes in balance of plant communities would entail a change of habitats of amphibians, reptiles and birds - up to changes in their habitat areas, colonisation of new territories and the introduction of new species. Many ecosystems will be forced to "reorganise" itself due to changes in the temperature and hydrologic factors while it not always be possible in the estuary zone extremely weakened by the anthropogenic impact.

**3.4 Ichthyofauna of the Dniester River basin.** An increasing number of facts indicate that changes in the temperature regime and associated dynamics of hydrological indicators of the aquatic environment are the main factors influencing the transformation of ichthyofauna. The growth of water temperature may have a negative impact on the reproduction and development of many fish species, especially the rare ones, the number of which is insignificant, while a sharp increase in temperature, both directly and indirectly, can lead to loss of adult species. A special role in the status of ichthyofauna plays operation of the waterworks.

## 4. Sensitivity to climate change of the water resources of the Dniester River

### 4.1 Water availability and its consumption

Rivers are the main sources of water in the Dniester basin. However, water availability of its certain parts considerably vary due to uneven development of the river network and the differences in climatic conditions, as well as due to existence of the mountain relief within the catchment area that creates special conditions for the flow formation and water regime. The most abundant are the Carpathian tributaries of the Dniester River; the rivers on the left bank are considerably smaller in terms of water content while the rivers in the lower part of basin have very small water content. The unevenness of runoff is somewhat compensated for by the regulation of artificial reservoirs. The underground water has considerable importance for the system of water supply, especially of safe drinking water; its estimated resources in the basin constitute 2,025 million $m^3$ per year. The largest volumes of the explored reserves are concentrated in the upper and middle parts of the basin; the lower reaches have the smallest reserves.

The economic downturn of recent decades has sharply reduced the volume of water consumption; however, due to uncontrolled abstraction from groundwater resources, the depths of the aquifers have dropped too, bringing some of them to a complete depletion, for example, in the floodplain and lower terraces of the Lower Dniester on the territory of Moldova. Reserves of fresh groundwater available for consumption are insignificant in Ukraine and account for about 9% of the total water resources of the country.

Along with the decrease in volume, the structure of water consumption has also changed. In 2008-2009, in the Moldovan part of the basin, 42% of water was used for household needs, near 14% was used for agricultural production (half of them - for irrigation) and less than 8% was used for production purposes. In the Ukrainian part of the basin these figures were respectively 34%, 10% and 27% in 2010. In both countries still remain large water losses during supply (up to 30% or more).

At present, there are no reasons to speak about water shortage across the region, but this situation is not typical for certain localities as it largely depends on the expected changes in water regime of the river and a further economic situation. The difficulty of assessing the foreseen vulnerability in terms of sufficiency of water resources is the uncertainty of projections of climate change, and the derived projections of changes in volume and influx of surface and groundwaters, as well as in the large uncertainties in estimates of the needs in water. A lack of reliable forecasts of economic development in the coming decades must be compensated by a corresponding modelling.

### 4.2 Water quality

In general, the water quality of the Dniester River in its natural status satisfies to the requirements of practically all types of water consumption. However, the ecosystems of the Dniester River do not face a strong anthropogenic impact in the upper part of the basin only. The *sources of pollution* in most cases are public utilities, agriculture and energy sector. The atmospheric precipitation mixed with water wastes which is washing out the various pollutants from soil is the additional contributor to pollution. Wastewater treatment facilities are worn-out and obsolete being maintained without rehabilitation for over 25-30 years and do not comply with the technological requirements. Thus, the efficiency of treatment at the existing treatment facilities of Ukraine does not exceed 50% on average.

The most unfavourable situation is observed at the low water tributaries of the Dniester River. The predominance of evaporation over precipitation in combination with intense pollution made the majority of small rivers unusable for any kind of water use, including recreation. The ability to self-purification of water in the tributaries is decreasing from source to mouth - from average (0.35) to low (0.25) and very low (0.1) (Figure 4.4). The ability to self-purification of natural and accumulation reservoirs can be characterised as an average (e.g., Dubossary Reservoir - 0.33).

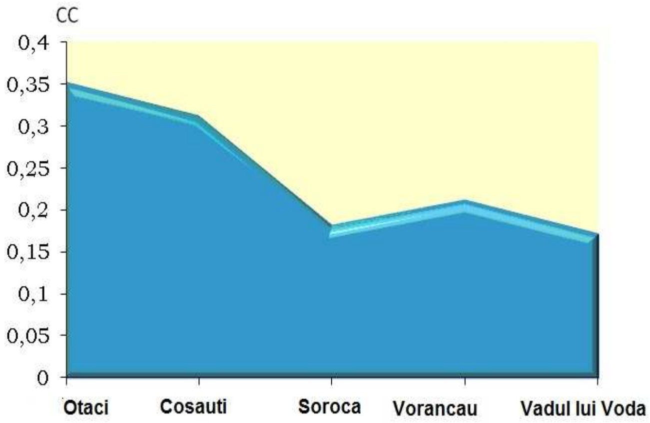



Fig. 4.4 Ability to self-purification of water in the Dniester River

### 4.3 Public access to safe water

The problem of supplying population with safe drinking water is still an acute social problem. The high morbidity and mortality of population, as well as the lag behind developed countries in terms of average life expectancy, to a certain extent, are also defined by the low quality of water consumed. The tariffs for water supply and sanitation in the majority of settlements do not reimburse expenses for supply and not take into account the investment component, that cause the general losses for the industry and its gradual decline.

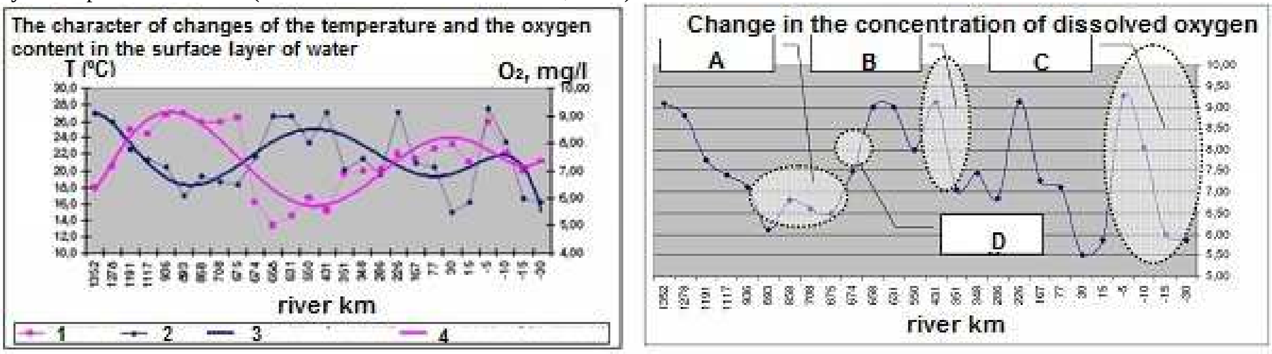
The laboratory control of the quality of water supplied to the *rural settlements* is not carried out in the majority of cases, the water disinfection is extremely rare and, therefore, its quality is not always guaranteed according to the sanitary requirements. 45% of population in Moldova does not have an access to improved water supply; even more population (47%) has no access to the advanced sanitation systems. The permeable toilets are used in the majority of rural settlements while the sewage systems and treatment facilities are absent or do not work. Poor sewage management and non-observance of protection measures for water sources are the main reasons of deterioration of the water quality in wells.

### 4.4 Climate Change and Water Quality

Climate change may contribute to significant physical, biogeochemical and ecological changes in the water quality, which directly or indirectly influences the socioeconomic and ecological products and services. It is expected that the increasing water temperature and the reduction (disappearance) of ice cover may cause the following consequences:

- *Reduction of the content of oxygen in the water,* caused by the increase in its temperature and the intensification of speed of biological respiration (Figure 4.8), which, in general, may cause stress and reduce the habitats of coldwater species;
- *More stable vertical stratification* and less mixing of the water in the deep-water reservoirs;
- *Eutrophication of water bodies* due to the increasing pollution of nutrients in the water at higher temperatures;
- *Changes in terms of* algae blooming and an increase in the number of harmful algae;
- *Changes in habitat*s and geographic dissemination of aquatic organisms to the northern direction and to the high altitudes, as well as disappearance of the certain aquatic species.

**Fig. 4.8** Link between dissolved oxygen in the Dniester River with a water temperature (left) and existence of reservoirs reported by the expedition of 2011 (*Source:* Melian and Kozhushko, 2012)




**(left ) 1. Temperature. 2. Oxygen. 3. Polynomial (oxygen). 4. Polynomial (temperature)**
**(right) A. Dniester Reservoir. B. Dubasari Reservoir. C. Dniester Estuary. D. Buffer Reservoir**

## 5. Adaptive capacity of the Dniester basin

### 5.1. Evaluation concept

The assessment of the adaptive capacity is based on two aspects: *economic and social* ones, which are considered primarily regarding to the level of human development in the basin countries. Adaptation requires certain costs and, in general case, the rich regions have more favourable opportunities for adaptation rather than their poor neighbours. No less important is the structure of economy. A limit, at which the economy can withstand a certain shock, to a large extent depends on the diversification of its structure, as the consequences of climate change affect, first of all, some certain most vulnerable sectors, such as agriculture.

While considering the level of human development, the structure of population and the prospects of its further changes were taken into account. The sustainable demographic structure and the number of population is a prerequisite to a high level of adaptive capacity; while the ageing of population and the intensive migration are striking it. The educational level of population contributes to the enhancement of adaptive capacity.

Finally, the adaptive capacity depends on the regional distribution of its determinants. As the climate change impacts occur specifically at the local and regional levels, the Dniester basin can not be considered as a homogeneous structure, and the regional differences between the two banks of the Dniester River regarding the adaptive capacity are not identical to those between Ukraine and Moldova, considered both in general and in specific sectors (systems).

### 5.2 Basic macroeconomic indicators

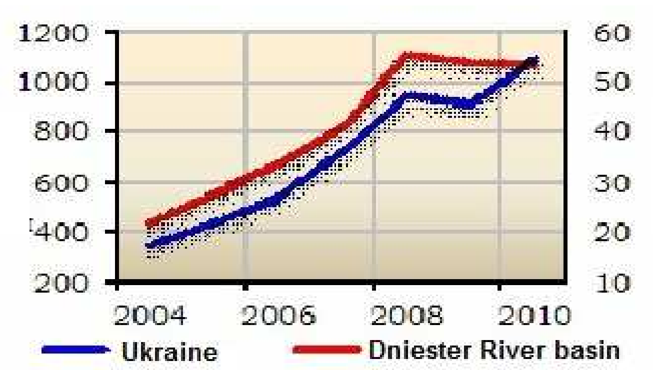



Fig. 5.1 Dynamics of the GDP of Ukraine in the region of the Dniester River basin

**Ukraine** has good industrial potential, fertile lands, skilled personnel and advanced education system. The country is rich in natural resources, including energy sources and it is independent from external electricity supply; moreover, the country is an exporter of it to other countries. There are well developed ferrous metallurgy, chemical and petrochemical industries as well as the high-tech industries including electronic industry, manufacturing of goods for military and space applications. Ukraine is one of the largest producers and exporters of grain, sugar and other food products. Dynamics of the GDP of the country and in the Dniester basin are shown in Fig. 5.1.

At the same time, it is observed the low level of diversification of production and foreign trade, high inflation, very low efficiency of manufacturing. Depreciation of the fixed production assets by 2007 constituted over 50%, in the industry it was about 70%. Conditions for business are characterised as unfavourable ones with a tendency to deterioration, which is largely due to a high level of corruption, monopolisation of economy and concentration of capital, the strengthening of fiscal and administrative pressure on non-oligarchic business, including the foreign one, as well as on some individuals. By the World Bank estimations, the shadow economy in Ukraine constitutes about 60% of the official GDP. Given the growth in the world food prices, it is expected an interest in purchase of the Ukrainian lands by foreign investors.

The low adaptive potential of **Moldova** is stipulated by a sharp and one of the most profound in the group of transition countries economic recession caused by the expenses of this period that was clearly demonstrated by the political instability in the last three years as well as by the droughts of the past decade (Figure 5.4). It is clearly

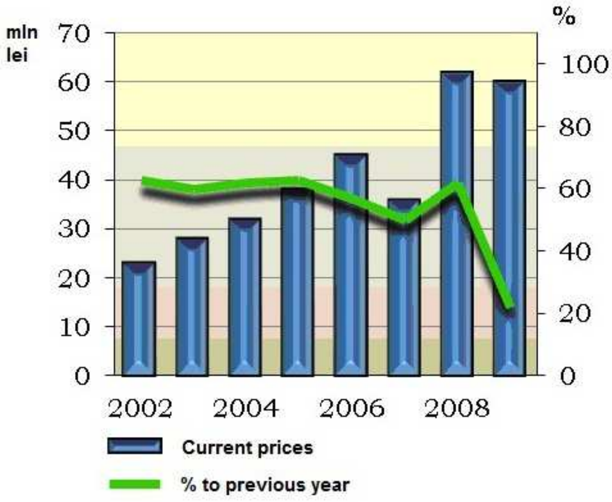



**Fig. 5.4** The GDP of Moldova in the current prices (million lei) and in % to the previous year

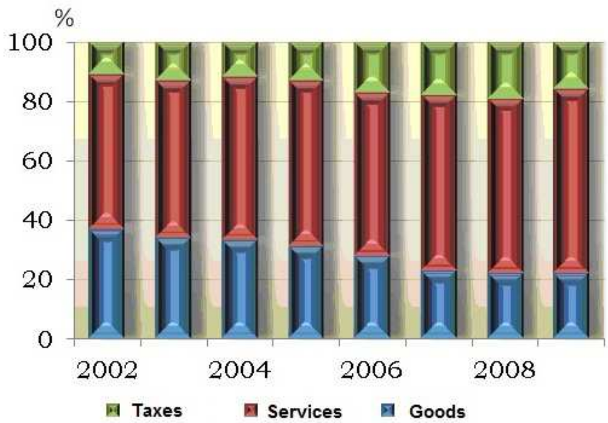



**Fig. 5.5** A structure of the GDP of Moldova according to the method of production.

visible a decline in production caused by drought of 2003 and a larger decline after the record-breaking drought of 2007; the maximum of GDP growth (7.8%) was achieved in 2008 followed by a decline of 6.5% next year. The vulnerability of economy of the country is caused to a great extent by the structure of GDP, which was formed in 2007-2009 by mostly services sector – near 60%, 16-17% - by taxes and less than a quarter – by the production of goods (Fig. 5.5). The share of manufacturing in the GDP has been steadily declining, and it is reflected in the growth of dependence of Moldova from the import products which constitute over 70% in its foreign trade balance undermining this way the economic security of the country.

In the context of climate change, the unbalanced development is extremely dangerous for both the urban and rural areas where the economy continues to remain stagnant, and the added value which is created here is practically not growing; and due to dependence of agricultural production on the weather conditions it is the most vulnerable to climate variability and change the sector of economy. *Because of this, the* *situation in agriculture has been taken as the basis for estimating the vulnerability of economy of the whole basin.*

### 5.3 Agriculture in the Dniester River basin

All trends and processes typical for agriculture of the whole country are also typical to the *Ukrainian part of the basin* with historically developed agricultural production (46% of the territory): the capitalisation of agricultural production based on the land concentration with the character of shadow control over its distribution and market; the deterioration of socioeconomic conditions for the overwhelming majority of rural population; the decrease in capital- and energy potential because of reduction of material and technical base, and, as result, the reduction in the volume of agricultural production (up to 20% per 1 person); the displacement of rural population from agricultural production due to the hard and poorly paid work, unsatisfactory living conditions, unavailability of the medical and educational services.

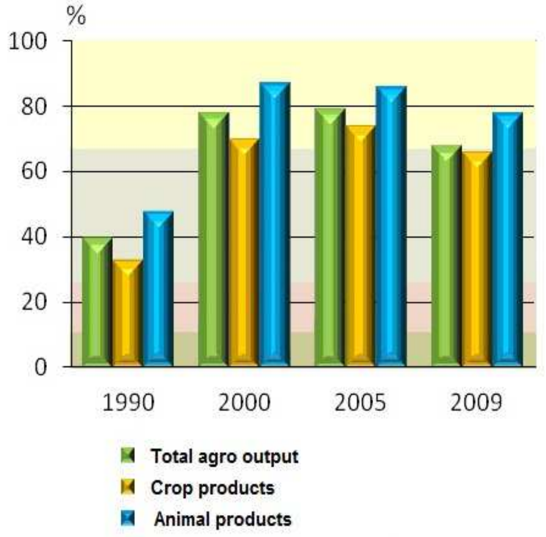



**Fig. 5.8** A share of of the gross agricultural farms output in the basin of the Dniester River in Ukraine.

43% of agricultural lands in the Dniester basin are owned and used by agricultural enterprises of different forms of ownership, 53% are owned by the private farmers. The development of agriculture goes in the direction of increased role of the private farms (Figure 5.8) with predomination of hand labour and the natural character of production with an extremely low technical support. The extensive farming leads to the visible destructive changes in soil fertility. In 2009, the use of organic and mineral fertilisers amounted to 22% and 8%, respectively, from that of 1990, while an average content of humus in the soil has decreased by 10-14%. The inter-annual variability of yields of the winter crops varies from 20% to 50%, of the spring ones - from 35% to 75%, though with the beginning of climate warming, the conditions for overwintering of crops have improved and the current losses do not exceed 3%-6% vs. 15%-30% before 1980. The continuation of warming may result the growth of crop yields, although the increase in concentration of $CO_2$ in atmosphere will lead to the deterioration in the quality of grain.

About ¾ of the territory in the **Moldovan part of the basin** is represented by agricultural area of which 67% constitute the arable lands. The inter-annual variability of precipitation and temperature in conditions of practically destroyed irrigation systems (6.7% of the total land area in 2007-2009) and the infrastructure maintenance have transformed agriculture in extremely risky industry. Especially destructive is an impact on crops of the climatic disasters typical for region - droughts, hail, floods, late spring and early autumn frosts. The insurance payments, including for fires, constituted in 2006-2009, on average, 6.5% of the amount of compensations for the country. The state and the public resources which are necessary in such situations are relatively scarce. The depressed status of agriculture is stipulated, in many cases, by the number of ill-conceived macroeconomic and structural transformations: the excessive fragmentation of agricultural lands and the increasing share of subsistence farming that harms the commodity production (arable lands constitute 80% of the private lands); ineffective system of agricultural subsidies and the lack of investment funds; the inadequate implementation of reforms according to the goals set. The profitability of private enterprises in recent years reached, in average, 21% for crop production and 10.2% - for cattle breeding. In 2009, the observed number of unprofitable agricultural businesses in the basin exceeded the number of profitable ones by 1.2 times. There is no doubt, that the loss-making enterprises not have, a priori, the surplus funds to reduce vulnerability and to increase adaptive capacity to climate change. The situation is complicated by predominance of the crop production industry in the structure of agriculture, which is the most sensitive to climate variability.

The low level of production provokes reduction of the level of consumption which adversely affects both the health of population and the export potential of the country. The actual failure in production is replaced by the growth of imports. Decline in the value of sales of products affects the incomes of rural population which has an average salary that is two times below an average one across the country; it leads to the massive migration or work abroad. In 2009, the share of agriculture in the GDP was 8.2%, involving only 28.2% of the labour forces of Moldova while in 2002 it was 21% and 49.6%, respectively (Figure 2.19). *Thus, agriculture in the Dniester River basin will be the most vulnerable to climate change if it will go, along with inadequate policies of the governments in respect to this sector, the use of obsolete technologies and lack of advanced adaptation practices.*

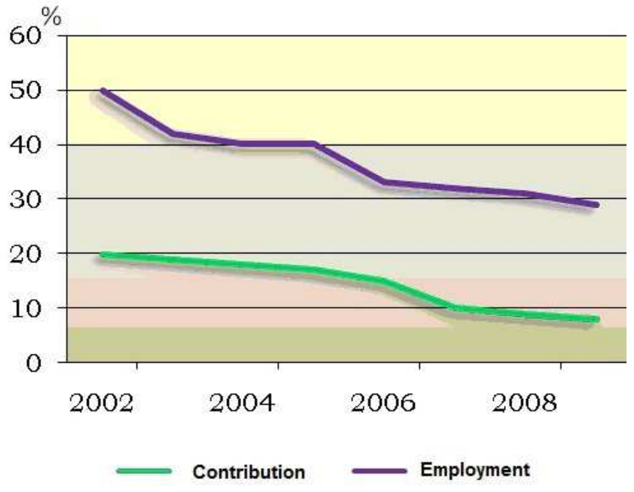



**Fig.5.19** Employment of the Moldovan population in agriculture and forestry and the input of both sectors to the GDP of the country.

### 5.4 Transport network

The level of development of the transport system and the road infrastructure determines in a large extent the state of economy and the adaptive capacity of the country. Thus, in 2009, the cargo turnover of motor transport was about 72% of the total cargo turnover of Moldova. From the point of view of vulnerability to climate change, the quality of motorways is very important. By the length of motorways, both states are far behind many of the European countries, while the low quality of roads and car service create problems to integration of their transport networks into the pan-European network, which is especially important in the transboundary basin. Although the density of roads in Moldova (30.6 km/100 km$^2$ by 01.01.2010) is in line with the regional standards (37.6 km), they are estimated as the worst ones in Europe by its quality. Only about half of the roads have permanent surface (concrete or asphalt), while the rest of them is covered by the so-called "light surface" (asphalt, gravel) or has no cover at all becoming difficult to overcome or completely impassable in bad weather. About 78% of national and 88% of local roads have reached the limits of the period of their functioning and are technically outdated, which significantly hinders economic development and poverty reduction in the remote areas reducing the opportunities for sales of manufactured products, first of all, of individual farmers and small farms.

An important role in the Ukrainian transport infrastructure play pipelines, passing through the territory of the basin that includes gas and oil pipelines of national and international importance.

## 6. Social potential

### 6.1 The demographic structure of population

The number of women prevails across the territory of the Dniester basin in the structure of the basin population by sex (Table 5.12). This distribution slightly increases the overall sensitivity of the society because women along with children and the elderly are regarded as the most vulnerable part of population to climate stresses. Similarly, as most vulnerable is considered the rural population, the share of which in the Ukrainian part of basin is practically twice as much as the urban one. The rural population also prevails in the Moldovan part of the basin (52.6%), except for Transdniestria, where the urban population more than in 2 times exceeds the rural one.

**Table 5.12** Resident population by sex and by place of residence in the Dniester basin

| Part of basin | Total | Distribution by place of residence | | | | Distribution by sex | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *urban* | | *rural* | | *men* | | *women* | |
| | | total | % | total | % | total | % | total | % |
| ***Ukrainian*** | 5,200,000 | 1,626,000 | 32 | 3,574,000 | 68 | 2,444,000 | 47 | 2,756,000 | 53 |
| ***Moldovan*** | 2,497,702 | 1,184,226 | *47.4* | 1,313,476 | *52.6* | 1,196,672 | 47.9 | 1,301,030 | 52.1 |
| ***Transd-niestrian*** | 522,500 | 360,525 | *69.0* | 161,975 | *31.0* | 240,400 | 46.0 | 282,100 | 54.0 |

The most alarming is a decrease of the total population in the Dniester basin which started to decline rapidly since the early 1990s due to the reduction of birth rate and increased mortality. The mortality rate for rural areas is significantly higher than for urban areas (13.8 against 9 per 1,000 pers.) and it is not compensated by birth rate. Since 2005, it was marked some growth of the population in Moldova, mainly in the cities; but in the Ukrainian part of the basin the negative population growth remains. Population decline is accompanied with its ageing. The value of the coefficient of ageing in Ukraine is over 18%; in Moldova, the share of persons older than 65 years reached 14.7% in 2011 that on the scale of Jacqueline Beaujeu-Garnier is measured as the average level of demographic old-age. Depopulation leads to the loss of ability of population to demographic self-development while the unfavourable age structure already creates a serious problem regarding the reduction of labour resources. Currently, there are 50-60 unemployables per 100 persons of working age in Moldova.

### 6.2 Employment

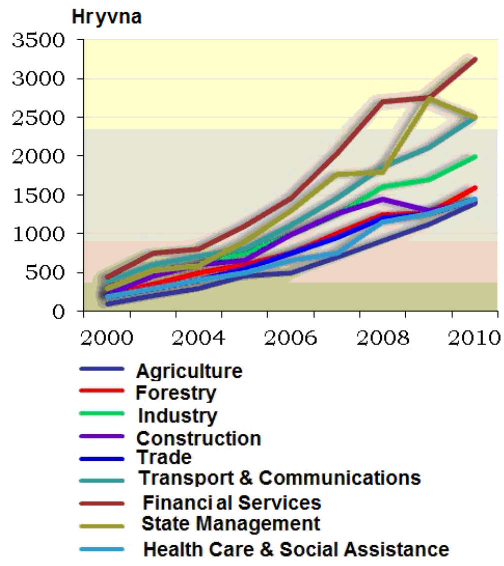
Employment in the Dniester basin is extremely low due to the predominance of the rural population and people living in the small settlements with a permanent shortage of jobs. The level of official unemployment in Moldova constituted 6.4% by 01.01.2010; in the Ukrainian part of the basin it varies from 7% to 11% depending on the region.

Very low employment of the population is in the industrial sector not exceeding 10%. Deindustrialization of the economies in both countries is accompanied by the transfer of active population from the production industries to non-production sphere, first of all, to services, which also leads to the reduction of the adaptive capacity.

### 6.3 Health care and social welfare of the population

Public health in the context of vulnerability is seen as a condition of complete physical, mental and social well-being and not merely as the absence of diseases or physical handicaps, i.e., basically, it is estimated as the *quality of life* of the population according to an essential criteria of the achievement of certain minimum acceptable living standards and reflecting the potential ability of the society to the most effective implementation of biological and social functions of a person. In both countries, the risks to human health not only sharply increased, but has also changed the correlation between risk factors: *the socioeconomic component of risk began to prevail over the natural component.* Thus, adaptation to climate change is superimposed on the need to adapt to completely new conditions of economic transformation, forming a huge social and spiritual burden on the person. Hence, *the main focus of the vulnerability assessment was aimed at the identification and analysis of specific impacts, which have economic, social, demographic and other consequences on the quality life of the population.*

***Welfare of population and social infrastructure.*** With every year, the costs of transition worsen the living standards of population, provoking the incomes inequality and the social polarisation of population. General ineffectiveness of the current economic model is increasing. The real income (the GDP per capita) in **Ukraine** is almost 10 times lower than in the developed countries of the world; at the same time, 10% of the richest population had 25.7% of the national income before the crisis in 2008, compared to 3.4% for 10% of the least privileged. In 2011, 12-14% of the population was living in the conditions of absolute poverty, especially families with children (76.4%) and families under a double pressure, i.e. with children and unemployed (26.4%). A weak progress in the economy does not allow to significantly improve the well-being of citizens while the problems of deep cross-sectoral and inter-regional disparities as well as the extremely low salaries in the industrial and social spheres still remain (Figure 5.26).



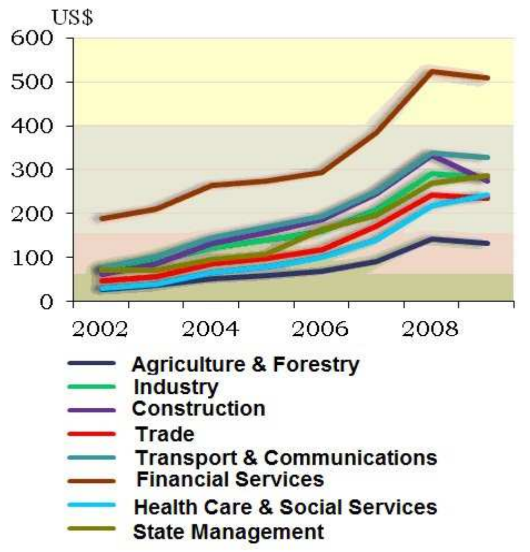




**Fig. 5.26** Dynamics of the average monthly salaries in the region of the Dniester basin: Ukraine - on the left; Moldova - on the right

An average monthly salary in the Moldovan part of the basin is about 75% of the national average salary in the country ($247.2 in 2009) with large disparities in its distribution between different categories. Pensioners are in a particularly disastrous situation. An average pension in Moldova amounted to about $65 in 2009, an average pension in Transdniestria is slightly higher ($77). A better situation have the pensioners in Ukraine, where a systematic assistance is provided to needy families along with the higher pensions, though support covers less than 10% of the population.

Availability of housing is broadly consistent with the generally accepted norms, which constitute, at an average, for the territory of the Dniester basin: 20.6 $m^2$ per person in Moldova and 23.9 $m^2$ per person in Ukraine. However, the quality of housing in the rural areas is significantly different from the urban ones, first of all, due to lack of sanitation and the centralised water supply.

**Mortality, morbidity and health care system.** In overall, the situation across **Ukraine** with morbidity and mortality in the Dniester basin reflects the general situation in Ukraine reaching 12-16 deaths per 100 thousands of the population at the beginning of 2010. The death rate on the right bank of the Dniester River is slightly lower. The main *mortality factors* are heart diseases, cancer and gastro-intestinal diseases that, in a large extent, is due to the poor quality of drinking water. In both countries is registered the high level of tuberculosis. The key factors behind declining of the life expectancy at birth are the high infant mortality and the rapid ageing of the population. Life expectancy of the urban population is higher than the rural one where men are identified as a group with a highest risk of early death. It can be explained by more difficult access of the rural residents to the health care institutions, differences in the content and quality of food, poor water quality and increased poverty which limits the size of personal resources spent on health.

A typical attribute of the processes observed in the quality of life and health of the population is their territorial differentiation which requires implementation of the relevant regional policy. Differentiation can be seen not only in the spatial diversity in morbidity and mortality, but also in the access to medical services provided to population. Health care system is mainly belongs to the state and financed from the state and local budgets, and even though the share of private clinics is increasing, this growth is not very significant. The inefficient management in the absence of adequate funding and the inequitable distribution of resources led to depreciation of the equipment, extremely low salaries, the spread of bribery and, in general, to the low level of medical services.

**Public education.** Formally, the situation with a basic education in both countries is quite good being inherited from the Soviet time and maintaining a high level of literacy of the population. Nevertheless, *it may not be considered as favourable for the creation of adaptive capacity*, which is explained, first of all, that it is a reflection of the ongoing transformation processes. In particular:

**Table 6.8** Ranking of administrative-territorial units of the Dniester basin by the degree of reduction of their vulnerability

• The current system of training for specialists does not reflect the practical requirements with evidently disproportional number of students in higher educational institutions compared to their number in the secondary vocational institutions;

• Wide integration of the private higher educational institutions into the system of higher education, many of them do not have highly trained teaching staff and the required material as well as educational base, and prefer to train specialists of humanitarian profile, which in conditions of the long-term decline of production a priori doomed to unemployment;

• The extremely low share of specialists trained for agriculture which amounted in Moldova, in 2009, less than 1% of the graduates of agricultural universities and 2.6% of colleges;

• The continuing decline in the number of students in lyceums and gymnasiums which is a consequence of both the sharp fall in the birth rate and the coverage of children with compulsory education, especially in rural areas, that is often associated with high level of poverty and the closing of rural schools;

• Transition to the two-level education sharply decreased *the quality* of training of specialists, as a consequence of that, the best graduates of lyceums and gymnasiums, and then universities are seeking to continue their education abroad, often staying there forever;

• «Brain drain» automatically leads to a decrease in the country's scientific potential which makes impossible the widespread development and implementation of the advanced methods and technologies, including in the combating climate change;

• A sharp decline in the quality of education has a negative impact not only on the economic development of the country, but also on the whole society, appearing, for example, in its criminalization.

## 7. Assessment of vulnerability to climate change at the local level

The specific objectives at this stage were limited by vulnerability assessment of the certain administrative units (areas) and identification of the most vulnerable of them being prioritized in adaptation interventions. A major limitation for evaluation was the objective impossibility of accounting for future socio-economic conditions in each administrative unit, as well as the large uncertainties in the projections of climate change calculated at the scale of certain parts of the basin.

That is why it was used only statistics that reflects the current sensitivity and adaptive capacity, believing, that in the conditions of climate change some of indicators rather deteriorate than improve. In the absence of the evidence-based monetary, bonitet or other objective evaluations by each indicator allowing their safe «weighing» in summation, it was selected the rank score evaluation as a main method of analysis, where the relative vulnerability of the administrative units is measured by its «place» in the rank of the estimates of each component of vulnerability. Undoubtedly, the obtained results should be considered only as a kind of «quick assessment».

| Oblast, district | S | AC | ∑ | *Rank* |
|---|---|---|---|---|
| **Moldovan part** | | | | |
| *Anenii Noi* | 7 | 13 | 20 | *7* |
| *Balti* | 10 | 12 | 22 | *10* |
| *Donduseni* | 15 | 14 | 29 | *19* |
| *Drochia* | 3 | 16 | 19 | *5* |
| *Dubasari* | 20 | 1 | 21 | *8* |
| *Calarasi* | 16 | 5 | 21 | *9* |
| *Causeni* | 18 | 8 | 26 | *16* |
| *Chisinau* | 5 | 22 | 27 | *17* |
| *Criuleni* | 6 | 11 | 17 | *2* |
| *Ocnita* | 11 | 20 | 31 | *21* |
| *Orhei* | 14 | 15 | 29 | *20* |
| *Rezina* | 8 | 6 | 14 | *1* |
| *Riscani* | 4 | 19 | 23 | *14* |
| *Soroca* | 1 | 21 | 22 | *11* |
| *Straseni* | 12 | 10 | 22 | *12* |
| *Singera* | 19 | 3 | 22 | *13* |
| *Telenesti* | 22 | 2 | 24 | *15* |
| *Falesti* | 2 | 17 | 19 | *6* |
| *Floresti* | 17 | 18 | 35 | *22* |
| *Soldanesti* | 13 | 4 | 17 | *3* |
| *Stefan Voda* | 21 | 7 | 28 | *18* |
| *Ialoveni* | 9 | 9 | 18 | *4* |
| **Ukrainian part** | | | | |
| *Vinnitskaya* | 2 | 6 | 8 | *3* |
| *Ivano-Frankovskaya* | 3 | 2 | 5 | *1* |
| *Lvovskaya* | 5 | 5 | 10 | *6* |
| *Odesskaya* | 4 | 1 | 5 | *2* |
| *Ternopolskaya* | 1 | 7 | 8 | *4* |
| *Khmelnitskaya* | 7 | 4 | 11 | *7* |
| *Chernovitskaya* | 6 | 3 | 9 | *5* |

*Notes:* S - the rank of reduction of sensitivity; AC - the rank of enhancing adaptive capacity

***Evaluation of sensitivity*** included *physiographic and socioeconomic* packages, each one consisted from several sub-packages. According to the physiographic approach, the most sensitive in Moldova is Falesti district; the least sensitive is Ocnita district. In socioeconomic terms, the most sensitive to external stresses is Dubossary district; the least sensitive is Singerei. By complex of the both factors, as the most sensitive area is mentioned Soroca district, the least sensitive is Telenesti district.

***The adaptive capacity*** was calculated as a function of the package of *economic and social indicators*. The greatest adaptive capacity, as expected, has the municipality of Chisinau, the smallest has Dubossary district.

***The overall vulnerability index*** was calculated by adding the ranks of sensitivity and adaptive capacity. The highest relative vulnerability compared to other administrative units has Rezina district, the least vulnerable is Floresti district (Tab. 6.8).

In the *Ukrainian part* of the basin, the greatest relative vulnerability has Khmelnytskaya oblast, the lowest - Ivano-Frankovskaya oblast, where the relatively low sensitivity is combined with the comparatively high adaptive capacity. However, it is necessary to take into account the fact, that a bigger part of this oblast is located in the mountainous part of the Carpathians, and this assessment may be revised regarding other indicators, first of all, hydrological (floods etc).

**Mapping of the results**, with highlighting areas of high, medium and low levels of each component of vulnerability (Fig. 6.2), facilitates the decision-making process for potential users and stakeholders.


**Fig. 6.2** Vulnerability to climate change on the right bank of the Dniester River, calculated as a function of sensitivity to climate change and adaptive capacity of certain administrative-territorial units of Moldova

## 7. The vulnerability of the Dniester basin to floods and flooding

In general, the runoff of the Dniester River is characterized by almost continuous succession of floods, which are observed in both cold and warm periods of the year. The summer floods caused by heavy rains are often exceeding the spring floods caused by the sudden melting of snow by level. It can be largely explained by the fact that this region is located in the zone of intensive rainfall and, practically, every year the part of territory of this basin is flooded by the torrential floods of different extent and character, causing considerable economic and moral damage. A summary of outstanding floods in the Dniester region is given in the Tab. 7.1.

Level of protection from floods for small rivers entirely depends on the technical condition of dams and dikes that need a substantial rehabilitation. At the same time, their condition causes the greatest concern as floods happen here very often. The extent of damage can not be estimated enough accurately as not all of the local floods and individual victims as well as damages to the private property are registered. A particular concern is also an intensive and often uncontrolled construction of small dams and ponds as many of them are currently turned out to be abandoned and gradually degraded.

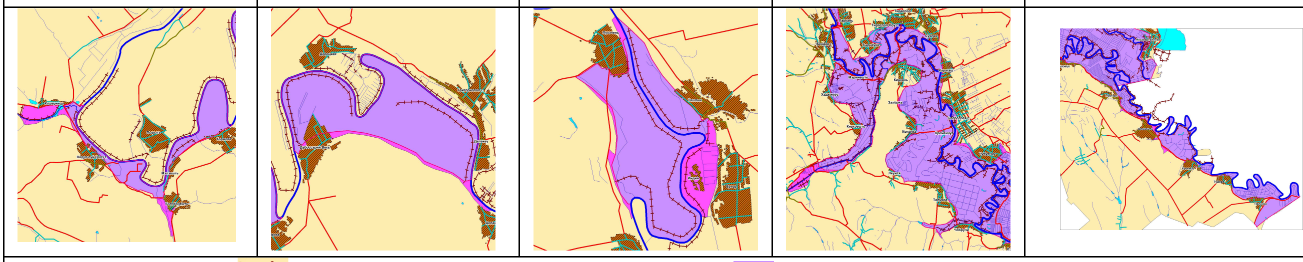
**Table 7.1** Maximum water level (ML, above zero post) and a maximum water flow (MD, $m^3/s$) for extreme floods in the basin of the Dniester River (Zaleschiki post)

| Year, month | ML | MD |
|---|---|---|
| 1993, June | 950 | 4440 |
| 1900, July | 860 | 3730 |
| 1906, June | 800 | 3070 |
| 1913, July | 895 | 4120 |
| 1927, Sept | 891 | 4070 |
| 1941, Sept | 1251 | 8040 |
| 1948, July | 865 | 3420 |
| 1969, June | 1078 | 5970 |
| 1980, July | 907 | 3910 |
| 2008, July | 1014 | 5400 |

Protection against floods and flooding remains one of the main priorities in functioning of the water-economic sector of both countries. As a result, the Dniester basin is quite well developed in terms of the flood management as well as in the improvement and development of regulatory and legal framework for such kind of management. In particular, it was carried out a range of research and organizational activities for the assessment of risks from catastrophic floods, and was developed the system of alert and response; it was also planned and implemented the complex of works aimed at further development and improvement of the system for flood protection and mitigation of possible consequences. The main technical solution for protection against flooding was construction of flood control dams and damming up of the banks of the rivers; along with the construction of flood control dams on the small rivers, the works for the straightening of rivers, deepening and clearing of the river beds were performed. However, the established system of protection is not a final one and it requires further development. A gradual erosion of certain parts of the hydro-technical facilities creates a permanent tense situation for the rivers of the basin due to financial impossibility for timely recovery.

Assessment of vulnerability to floods in the area between the Dubasari HPP and Palanca (Fig. 7.8) is based on the results of simulations and on the field trips to the river sites which are mostly exposed to the risk of flooding. For the models of flooding, there were considered the hypothetical 1% floods in the conditions of the current climatic period with instrumental observations, and also the conditions of the foreseen climate change with a possible 15% increase in the water flows. The water flows for the extreme periods of flooding were calculated for each flood scenario and further transformed into the width of the water layer with 1 m depth for conditions of overflow over the top of the flood control dams. The results of this simulation were clarified during the field trips to the site.

| Vadul lui Voda | Dubasarii Vechi | Puhaceni | Chitcani | Palanca |
|---|---|---|---|---|



Legend: flood control dams; the flooded area in the current climate; Increase in the flooded area in the current climate

**Fig. 7.8** Assessment of flooding of 1% provision in the current and foreseen climate

**Table 7.6** Characteristics of flooding of 1% provision in the current (CC) and foreseen (FC) climate

| Site of flooding | River bank | Scale of vulnerability | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Area of flooding, km² | | Number of villages in the area of flooding | Number of buildings in the area of flooding | | Area, km² | | |
| | | CC | FC | | CC | FC | Forests | Perennial | Pastures |
| ***Vadul lui Voda*** | R | 10.0 | 12.4 | 5 | 114 | 137 | 6.11 | 0 | 0.06 |
| ***Dubasarii Vechi*** | R | 23.9 | 25.2 | 2 | 64 | 77 | 9.2 | 0.89 | 0.39 |
| ***Puhaceni*** | R | 13.2 | 14.1 | 1 | 70 | 84 | 0.86 | 1.52 | 0 |
| ***Taslic*** | L | 4.1 | 7.3 | 1 | 240 | 288 | 0.36 | 0 | 0.13 |
| ***Serpeni*** | R | 12.7 | 12.8 | 2 | 43 | 52 | 4.2 | 0 | 0.02 |
| ***Speia*** | L | 2.0 | 4.4 | 0 | 0 | 0 | 0.07 | 0 | 0.06 |
| ***Gura Bicului*** | R | 17.3 | 18.2 | 1 | 50 | 60 | 0.88 | 0.2 | 0.42 |
| ***Parcani*** | L | 4.1 | 4.4 | 0 | 0 | 0 | 0.18 | 0.55 | 0.13 |
| ***Ternauca*** | L | 20.5 | 142.0 | 0 | 0 | 0 | 0.29 | 9.2 | 0 |
| ***Sucleia*** | L | 118.3 | 142.0 | 1 | 41 | 49 | 0.82 | 2.6 | 0 |
| ***Chitcani*** | R | 195.8 | 273.0 | 3 | 590 | 708 | 29.67 | 11.78 | 0.21 |
| ***Purcari*** | R | 654 | 273.0 | 6 | 231 | 277 | 2.46 | 0.27 | 0 |
| ***Total*** | | **487.2** | **499.7** | **22** | **1,443** | **1,732** | **55.1** | **27.01** | **1.42** |