Name of the milestone:	Report on Step 1: Data Collection and Analysis. Identification of the Climate Change trends (evidences) based on observation data (136 stations of UKR hydromet and 7 stations in Moldova HydroMet network)
WP:	5
Activity:	5.6 Upgrading agricultural drought monitoring and forecasting: the case of Ukraine and Moldova
Activity leader:	Dr.Tatiana Adamenko – UkrHydroMetCentre, Ukraine Dr. Ecaterina Kuharuk – Moldova
Participating partners:	GWP-Ukraine GWP-Moldova
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1. Background information about agro sector and droughts: Ukraine and Dniester river basin

1.2. Ukrainian agricultural sector

Ukraine is one of the main producers of grain at the world food market, enters into the eight largest wheat exporters – these are the U.S., Canada, UE27, Australia, Russia, Kazakhstan, Ukraine, Argentina. These countries account for about 50% of world production and 80% of world wheat export. Any extreme events in one of these countries pose a threat to the establishment of world food supplies, because they are located in the regions with a significant change and variability of climate.

At the end of 2012/2013 marketing year, Ukraine is one of the leaders in the food supply to the world markets. In the production of all agricultural crops it ranks the 10th place, wheat – the 9th place, maize – the 7th place, barley – the 7th place (Table 1).

Table 1. Indices of Ukraine at the world market of food production [1]

Grains	**Production**	**Consumption**	**Export**
Grain crops	10 (46,2 mln. t)	18 (26,6 mln. t)	7 (21,7 mln. t)
Wheat	9 (15,8 mln. t)	10 (12,0 mln. t)	9 (6,2 mln. t)
Maize	7 (20,9 mln. t)	14 (8,0 mln. t)	4 (13,0 mln. t)
Barley	5 (6,9 mln. t)	6 (5,0 mln. t)	4 (2,5 mln. t)

Agriculture is the main branch of the Ukrainian economy, which gives more than 55% of national income. Grain production ranges from 20-29 million tons in the years with the adverse weather conditions up to 46-56 million tons in favorable years (Table 2).

Table 2. Grain production in Ukraine (thsd quintals) [2]

Year	**Production**
2007	29294,9
2008	53290,1
2009	46028,3

2010	39270,9
2011	56746,8
2012	46216,1

Ukraine is also one of the world leaders in the cultivation of sunflower and rapeseed. Planting areas of the major agricultural crops under different crops are presented in Table 3.

Table 3. Sown area under agricultural crops (thsd. ha) [2]

Year	All sown area	Including			
		grain and leguminous crops	industrial crops	potatoes, vegetables and cucurbitaceae crops	fodder crops
1990	32406.0	14583.4	3751.3	2072.5	11998.8
1995	30963.2	14152.1	3748.2	2165.3	10897.6
2000	27173.3	13646.5	4186.8	2276.9	7063.1
2005	26043.6	15004.8	5260.1	2040.9	3737.8
2010	26951.5	15090.0	7295.8	1966.6	2599.1
2011	27670.5	15723.8	7441.1	2028.3	2477.3
2012	27801.3	15449.0	7854.1	2023.3	2474.9
2013	28115,0	16274,1	7664,9	1954,6	2221,4

The increase in the grain production in the world has been achieved by increasing yields. Ukraine has not reached the level of the average global yields and has a great potential for increasing it. In Table 4 are presented the data on the yields of major agricultural crops in Ukraine.

Table 4. Yield of agricultural crops (canters per 1 ha of the harvested area) [2]

Year	Grain and leguminous crops	Sunflower	Rape
1990	35,1	15,8	14,5
1995	24,3	14,2	8,5
2000	19,4	12,2	8,4

2005	26,0	12,8	14,6
2010	26,9	15,0	17,0
2011	37,0	18,4	17,3
2012	31,2	16,5	22,0

Climatic peculiarities of territory

Annual crop losses due to the adverse weather conditions in Ukraine constitute from 10 to 70% (from 200 to 1,500 million Euros). The main reason for these losses is droughts. More than 30% of the areas with the best lands (about 65% of the production of grains) undergo a constant moisture deficit. Even in the "normal" years, the total amount of precipitation in arid lands does not exceed 400-500 mm, which is on the verge of the efficient agricultural production. The situation escalates dramatically in the years with below-normal precipitation (250-300 mm).

In Table 5 are presented the data on the yields of winter wheat in arid years, and in the years with the precipitation near or above normal for the period of April-June. The norm for the baseline period (1961-1990) is 175 mm.

Table 5. Yields of winter wheat in arid and humid years

Arid			**Humid**		
Years	**Yields, c/hectare**	**Precipitation amount, mm**	**Years**	**Yields, c/hectare**	**Precipitation amount, mm**
1999	23,0	140	1993	38,0	174
2000	20,0	136	2001	31,4	224
2003	14,1	107	2004	32,6	167
2007	23,9	122	2008	37,1	284
2010	27,1	143	2011	33,9	180

Droughts, which cover more than 50% of the territory, are found in the average 1 time in 10-12 years. During the period of 1981-2012 years the atmospheric and soil droughts of various intensity (spring-summer, summer, autumn) were observed in Ukraine every year. In only two years from the whole period (1993 and 1997), arid events were not found.

2. Existing zoning of Ukraine and Moldova territories: basic approach, description of zones and actual agro-zoning maps

2.1. Ukraine

The monitoring of droughts in Ukraine is carried out by the organizations of Hydrometeorological Service (meteorological stations, regional centers for hydrometeorology, Ukrainian Hydrometeorological Center). The droughts monitoring system includes the following blocks:

- Collection of information;
- Automatic data processing,
- Synthesis, systematization and analysis of information,
- Preparation of recommendations and expert conclusions for damage minimization;
- Provision of information to different users.

The key users of this information are farmers, the Ministry of Agrarian Policy, the Water Resources Agency, the state authorities at all levels, insurance companies, mass media.

The existing monitoring system provides the information on the occurrence of atmospheric and soil droughts in terms of reducing the relative yields of different agricultural crops for a particular sector, the administrative units and the whole country; on the necessary norms and terms of irrigation. The information is available for all users - from the farmer to the Administration of the President.

The **studies of droughts in Ukraine** developed in theoretical and experimental directions from the late 19th century. The agro-climatic zoning of the Ukraine territory was introduced based on the meteorological observations for the period of 1956- 1985 years. The basis of zoning was the moisture indicator of territory – Selyaninov's hydrothermal coefficient (HTC) [3,4]**.**

HTC = R/0.1∑ T

R – Amount of precipitation for the period with the air temperature above +10º C

∑ T **-** Amount of average daily air temperatures above **+**10º C

The territory of Ukraine was divided into 3 agroclimatic regions (Fig. 1): Marshy - the probability of soil droughts is 0-10%, annual precipitation 596-760 mm; Forest-Steppe – the probability of droughts is 15-40%, annual precipitation 575-650 mm; Steppe – the probability of droughts is 40-70%, annual precipitation is 350-540 mm.

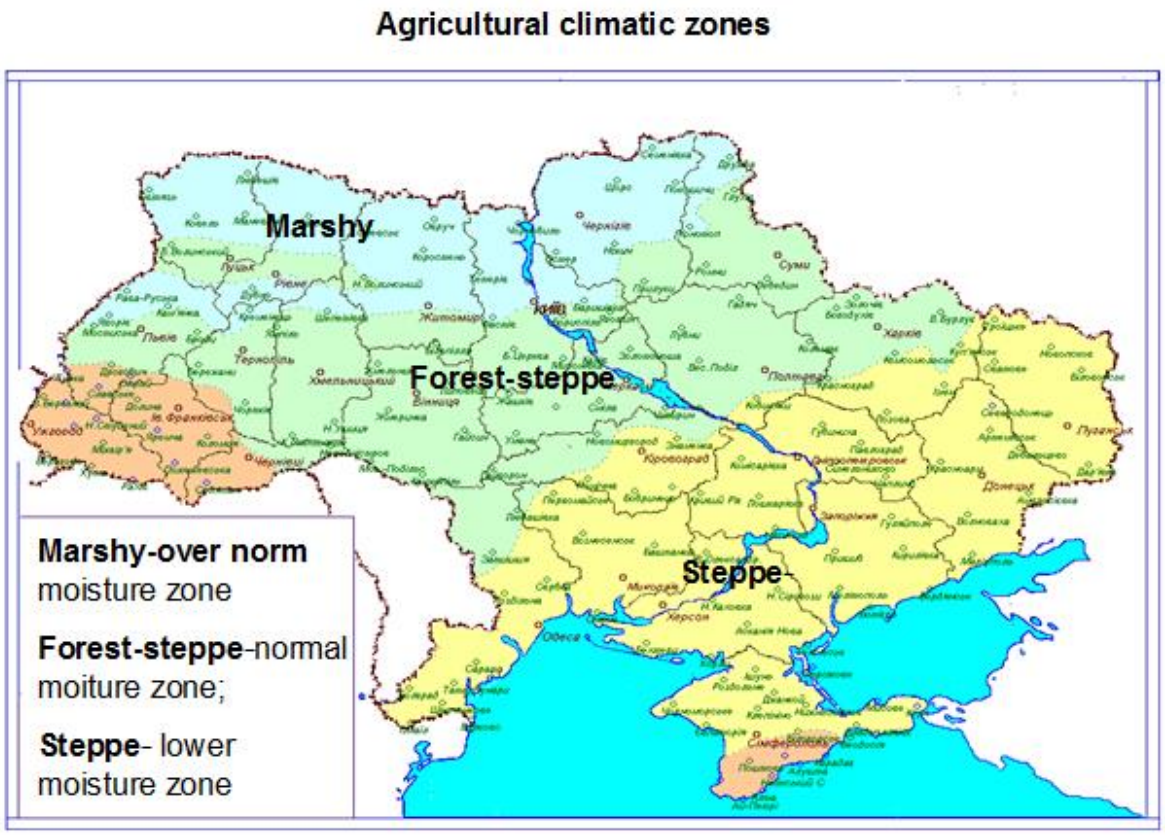


Fig.1 Agroclimatic zoning of the territory of Ukraine

3. Trends in air temperatures and precipitations' distribution in space and time in Ukraine and Dniester river basin

3.1. Ukraine: Trends in climate changes

For the characteristic of the modern climate of Ukraine and the assessment of its changes were chosen two of the most important climatic indicators that have the most significant effect on the territory hydration - the air temperature and precipitation. The evaluation of climate changes was performed under the data of continuous instrumental observations of 136 meteorological stations

located in the agriculture area. Meteorological stations have the continuous series of observations from 60 up to 140 years.

Temperature

The modern climate of Ukraine is characterized by asymmetric territory warming, pronounced in winter and summer months. The average annual temperature in the early 20th century has increased by more than 0,8 °C. Changing of the temperature regime by decades (the data of 20 meteorological stations with the period of observation more than 100 years) in the anomalies of the average annual temperature is shown in Figure 2.

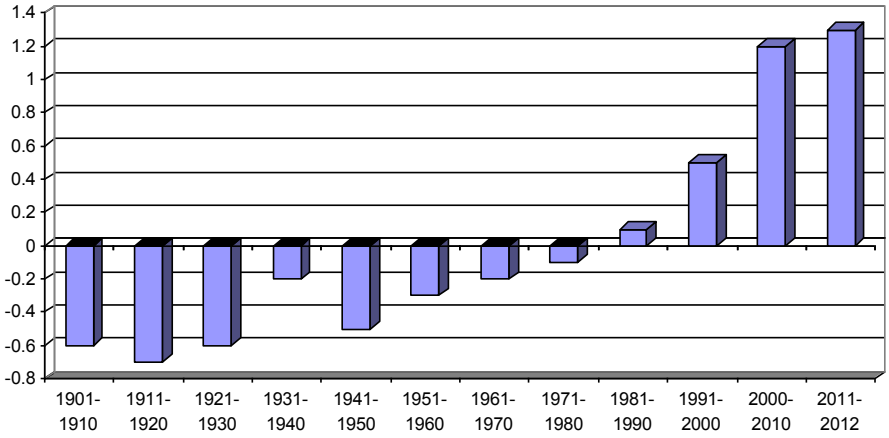


Fig. 2 Anomalies of regional average annual air temperature (°C) in Ukraine as compared with the baseline period (1961-1990)

Throughout the country, the positive fluctuation in air temperature during the years 1989-2012 was the most powerful in the whole history of instrumental observations (Fig. 3). The temperature increase in the cold period constitutes the average of 1,35 °C, in the warm one - 1,1 °C.

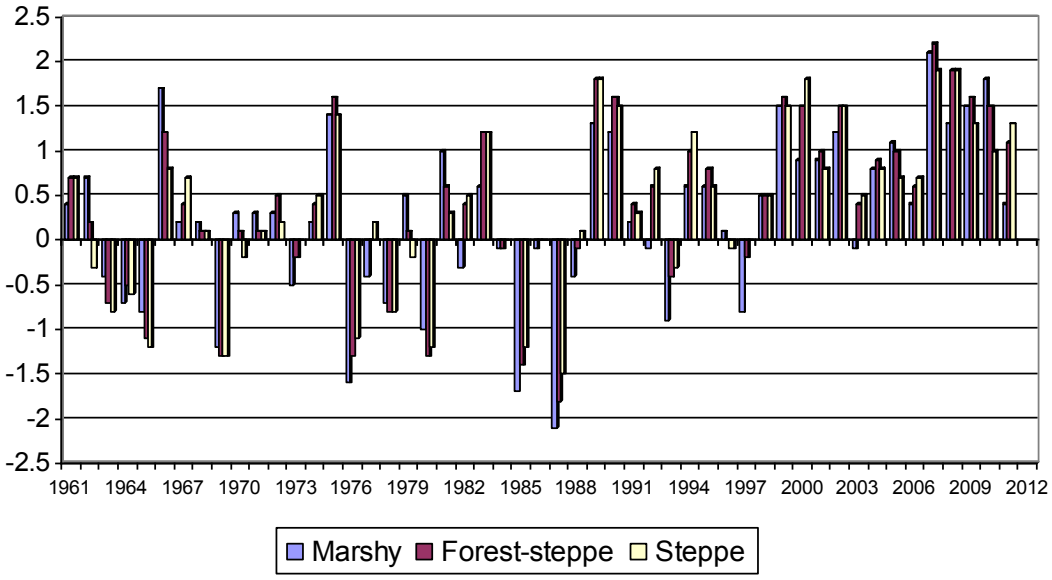


Fig. 3 Anomalies of the average annual air temperature (° C) during the period of 1961-2012 years under agroclimatic areas as compared with the baseline period (1961-1990)

Before 2000, the increase in the average annual temperature was due to the cold period, the most intensive temperature increase was observed in January and February (Fig. 5). Since 2000 the tendency of the air temperature increase was observed in July and August. The frequency of hot days (maximum temperatures > 35 ° and 40 ° C) increased nearly twice.

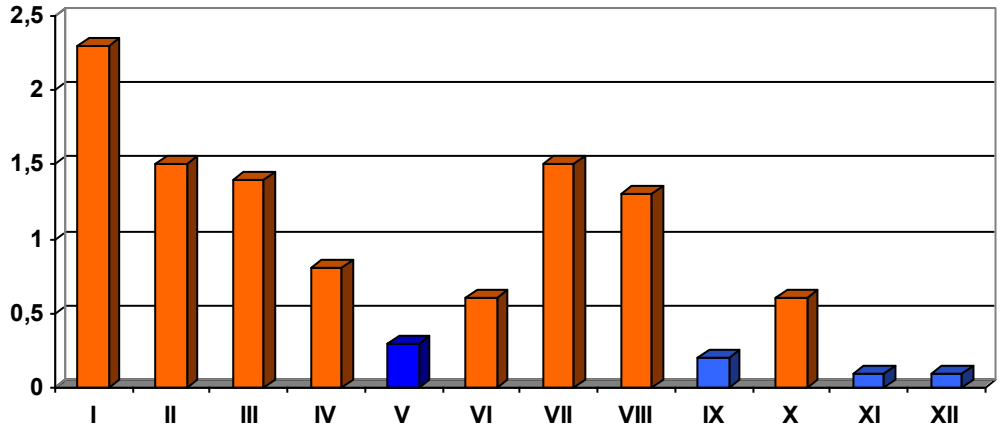


Fig. 4 Anomalies of the average annual air temperature (° C) during the period of 1989-2012 years as compared with the baseline period (1961-1990)

There have been significant changes in the temperature regime in the context of agro-climatic zones of Ukraine. The zones of woodland and forest-steppe (according to zoning these are the zones of sufficient moisture) are warming faster than the steppe, which aligns the thermal resources of the territory.

The winters of the last decades of the 20th century and the beginning of the 21st century were characterized by deep prolonged thaws in all agroclimatic zones. The duration of the winter period has decreased by almost a month. The air temperature increasing in the winter months has led to an earlier beginning of spring, the enlarging of vegetation season, to speed up the development of agricultural crops, pests and diseases.

Since 2000 the heat availability for agricultural crops during vegetation period in all agroclimatic zones has been increased significantly.

Precipitation

Since 1989 during the period of almost uninterrupted warming the average annual precipitation in Ukraine has not decreased, in some areas the increasing of average annual precipitation on 3-10% (Fig. 5) has been observed. During the baseline period (1961-1990) the average amount of annual precipitation was 576 mm, for the period of 1991-2012 years it is 595 mm.

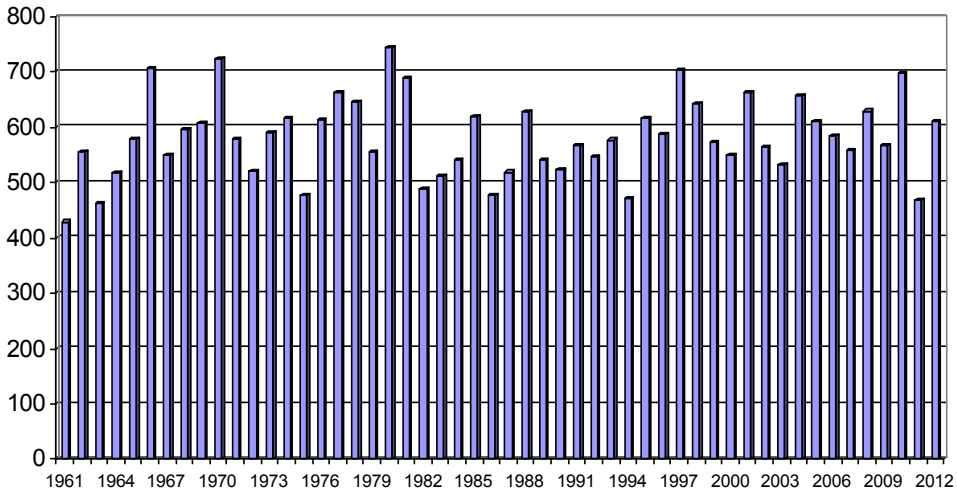


Fig.5 Annual amount of precipitation in Ukraine, mm

Under the air temperature increasing and with the almost constant precipitation conditions, the number of droughts of various intensity in the Steppe zone has nearly doubled. The particularly strong droughts were observed in 1989-2012 years. In this period (in 16 from 23 years) the two or more months droughts during vegetation period were observed on large areas. At the same time, the number of extreme precipitation events (heavy rainfall, snow) increased. In the southern Forest-Steppe and Woodland areas (the zones of sufficient and unstable moistening), the tendency of annual precipitation decreasing was observed.

The changes in precipitation distribution within the year and in the separate years have been significant. This is especially visible in the winter months, when the monthly precipitation (January, February) decreased on one-fifth. The summer amount of precipitation has increased at the average on 5-15% (Fig. 6). But the effectiveness of the summer precipitation increasing is smoothed over by the temperature increase.

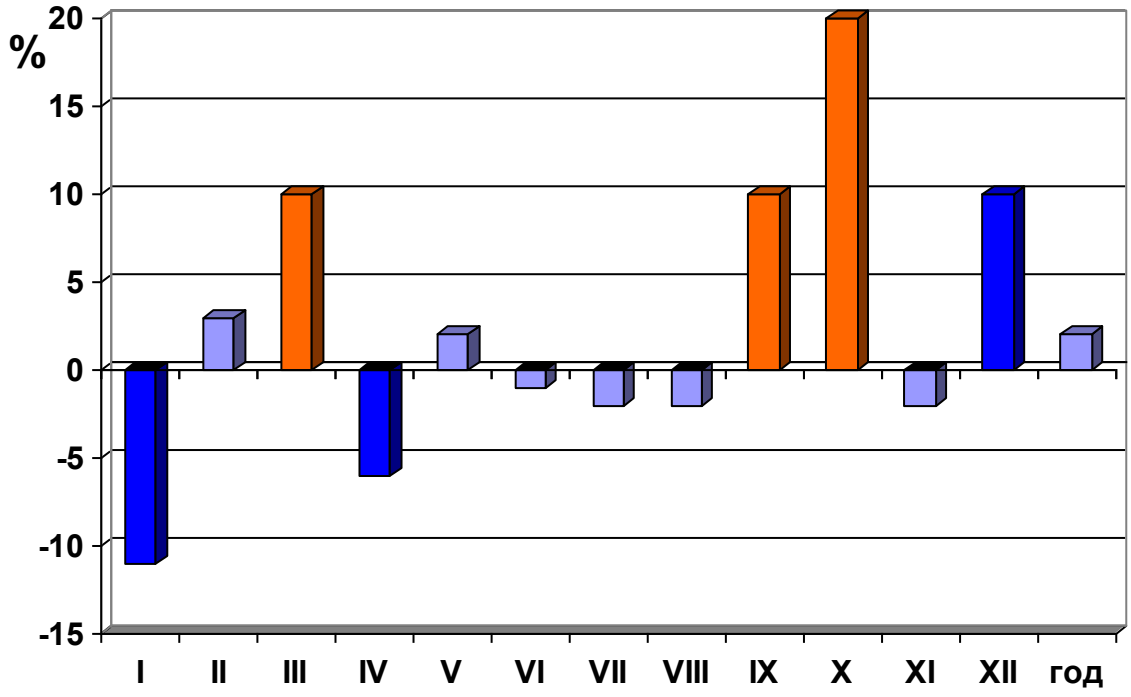


Fig. 6 Changes of precipitation amount (% of the norm of 1961-1990) in Ukraine by months for the period of 1991-2012 years.

Due to the intensive increasing of the air temperature in the summer months, with almost constant precipitation amount, the character of hydration of different territories is changed. In the last decades the droughts are spreading in zone with a sufficient hydration and covering more areas, what can resulted in disappearing of this zone. According to the calculations the average rate of warming in Ukraine is 0,45 ° / 10 years, at this rate of warming in 30 years the average temperature could rise by 1,5 °, which will lead to increasing aridity of climate a 1,5 -2 times.

According to the conclusions of the IPCC there is the probability that in the South-East part of Europe, including Ukraine, the climate variability and change, as compared with other regions of Europe, will appear in a greater degree. Thus, the probability of expanding the zone of risky agriculture in Ukraine has increased. According to the calculations about 4,235,800 ha are under the threat of desertification in Ukraine. In this regard, the management of droughts and the fight against desertification are vitally important and economically justified.

The existing zoning is currently out of date and does not take into account the climate change of the recent decades. The improper use of the changed heat and water resources of the territories for the cultivation of agricultural crops leads to the additional losses of harvest by farmers and the state. In this regard, the modern agroclimatic zoning, using the European indices of droughts assessment, will facilitate the proper placement of the major crops in the territory taking into account the modern climatic resources.

The Dniester basin

The Dniester is a transboundary river with a length of 1380 km, which starts in the Ukrainian Carpathians, flows through the Republic of Moldova and reaches Ukraine again near the Black Sea. The Dniester basin extends into the territories of 7 oblasts (provinces) of Ukraine (Lviv, Ivano-Frankivsk, Chernivtsy, Ternopil, Khmelnitsk, Vinnytsia, and Odessa), covering 13% to 80% of their areas. Within Moldova, the Dniester basin covers the major part of country's area (59%), with 19 districts and one territorial unit in the left-bank part of the Basin being drained by the river fully or partially.

Climatic trends in Ukrainian parts of the Dniester river basin.

According to the observations of the closest to Moldova Ukrainian meteorological stations located in the basin of the Dniester [5] are observed the following changes in key climatic indicators:

Temperature

The increase of the average annual air temperature of 0,8 ° is observed. In monthly basis the air temperature increased more in January, February, March, July and August.

Air temperature. Meteorological station Zatishye. Odessa region

month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Norm	-4.2	-2.9	1.5	9.5	15.5	19.0	20.6	20.4	15.9	9.5	3.5	-1.2	8.9
Fact.(1991-2012)	-2.7	-1.9	3.0	10.0	16.0	19.8	22.4	21.7	15.9	9.8	3.7	-1.5	9.7
Δ T	1.5	1.0	1.5	0.5	0.5	0.8	1.8	1.3	0.0	0.3	0.2	-0.3	0.8

Air temperature. Meteorological station Razdelnaya. Odessa region

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Norm	-3.6	-2.1	2.0	9.6	15.7	19.3	21.0	20.7	16.3	9.9	4.0	-0.6	9.4
Fact.(1991-2012)	-2.2	-1.4	3.4	10.3	16.3	20.3	23.0	22.3	16.3	10.4	4.2	-0.9	10.2
Δ T	1.4	0.7	1.4	0.7	0.6	1.0	2.0	1.6	0.0	0.5	0.2	-0.3	0.8

Precipitation

The annual amount of precipitation has changed insignificantly, on a monthly basis is marked the decrease of winter precipitation and the increase in September and October.

Amount of precipitation. Meteorological station Zatishye. Odessa region

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Norm, mm	39	39	32	35	46	66	68	43	36	27	36	40	505
fact., mm	31	30	28	35	50	67	62	40	51	39	39	40	512
% to the Norm	80	77	88	101	108	101	91	93	140	145	107	100	101

Amount of precipitation. Meteorological station Razdelnaya. Odessa region

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Norm, mm	38	38	31	34	45	66	68	43	35	27	36	38	498
fact., mm	32	31	31	27	44	65	58	49	58	38	38	39	510
% to the Norm	85	81	99	80	99	98	86	114	165	139	105	103	102

At the Ukrainian up stream part of the Dniester basin the areas are related to Forest-Steppe zone. The main trends in temperature and precipitation are the followitng.

Temperature (Δ T)

The increase of the average annual air temperature of 0,8-1,0°C is observed. In monthly basis the air temperature increased more in January, February, March, July and August.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Sambor (Lviv region).	1.4	0.8	0.6	0.7	0.7	0.8	1.6	1.3	-0.1	0.1	0.3	0.0	0.7
Dolina (Ivano-Frankivsk region)	1.0	1.2	1.0	1.0	1.0	1.2	1.8	1.6	0.0	0.1	0.5	0.1	0.9
Chertkov (Ternopil region)	2.1	1.2	1.4	0.9	0.7	0.9	1.8	1.4	0.1	0.2	0.4	-0.1	0.9
Nova Ushitza (Khmelnitsky region).	2.0	1.1	1.4	0.7	0.6	1.0	1.8	1.3	0.1	0.2	0.4	-0.4	0.8

Precipitation

The annual amount of precipitation has changed insignificantly, on a monthly basis is marked the decrease of winter precipitation and the increase in September and October.

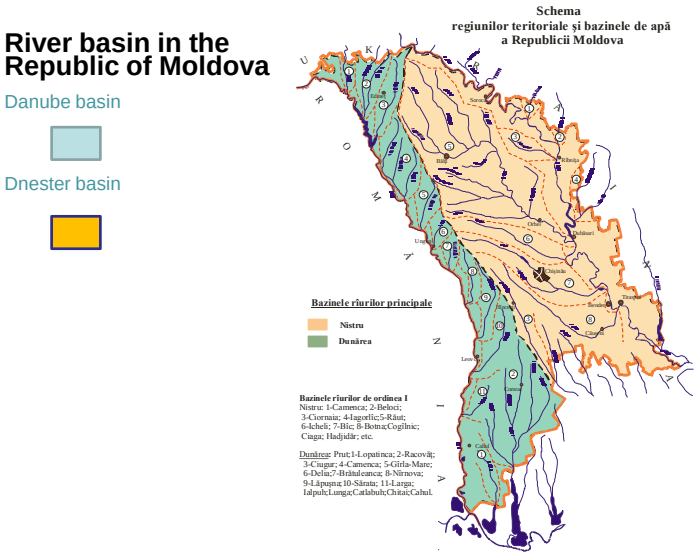
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Sambor (Lviv region).	99	119	102	103	97	91	110	107	133	117	103	88	105
Dolina (Ivano-Frankivsk region)	93	112	106	92	90	98	115	97	122	118	95	89	102
Chertkov (Ternopil region)	85	101	107	106	98	95	91	103	151	118	101	104	103

Nova Ushitza (Khmelnitsky region).	80	91	96	101	92	82	109	118	133	131	90	87	100

4. Trend in the climate change patterns in Moldova based on the instrumental measurement

1.1. Introduction

The territory of the Republic of Moldova is 33483, 4 km^2 and is divided between Danube river basin - 40% and Dnester - 60% (see map 1).



Moldova is predominantly agricultural country with total agricultural lands of around 80% of its territory and around 60% of these lands are arable ones. Main crop cultivation cultures are cereals (winter wheat, maize, multiannual plantations: orchards and grape, vegetable plantations etc. Main crops production for the year 2011 is presented in table 1

Crop	**Production**	**Average per ha**
Wheat	**700000 tones**	**2,2 t**
Maize (grain)	**500000 tones**	**3 t**
Fruits (apples – 80% from total orchards plantations)	**1000000**	**270t**
Grape	**500000 tones**	**2 t**
Sunflower	**100000 tones**	**1,8 tones**
Root beats	**6000000 tones**	**30 tones**

Agricultural sector is main part of national economy giving around 60% of the GDP. Around 65% of population live in rural areas and depend on the development of the agricultural sector. Due a poor developed irrigation system this sector depends on weather conditions, which for last 15-20 years became more severe in regard to the precipitation and high temperatures in the summer period. According to the estimations made on the base of analysis for the drought in 2012 economic losses were around 2,5 billion leis (1 euro = 17 MDL) or around 15% of the state budget for the year 2012 (1).

1.2. Evaluation of the weather conditions in Moldova

Estimation of the evolution of the hidrotermic regime in the Republic of Moldova started in 1887 and observations on precipitation started in 1891. Actually the concept of climate change evolution in the limits of one year is based on *(2)* and is calculated *$T=2,0^{o}C$ and $T=0,015^{o}C/year$*. This methodology is very important for the development of effective measures in adaptation to climate change.

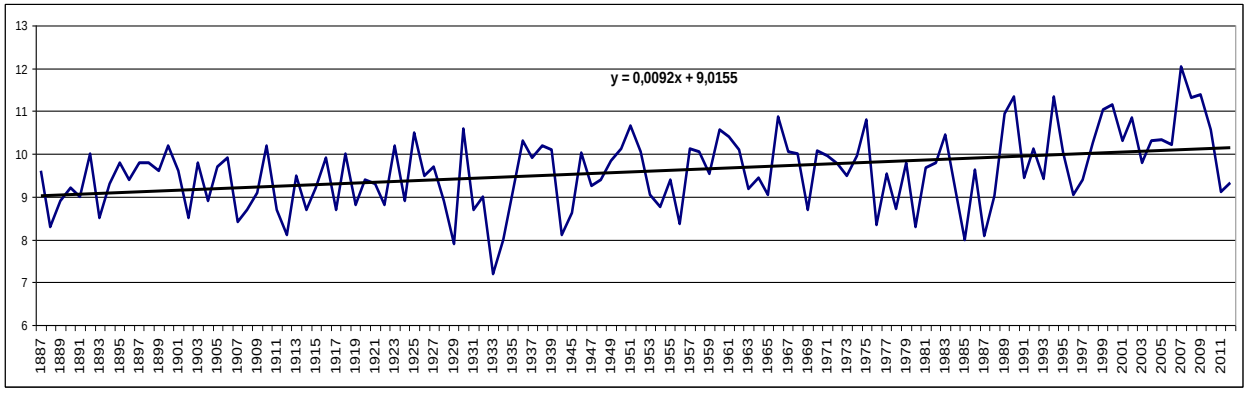
The base for the report is data collected from 17 meteo stations located in the Republic of Moldova.

1.2.1. Evaluation of trends in modification of the air temperature in the Republic of Moldova

Analysis of the evolution of the average air temperature is based on the analysis of the data accumulated in the period 1887-2012. Actually average air temperature grows for 0,0092^{0}C/year or corresponds to the trends of the air temperature for Europe (fig.1.1a).

Analysis of climate termic abnormalities reported to the climatic norm calculated for the period 1961-1990 denotes that with exception of last two years (2011, 2012) the termic abnormalities starting from 90 th had only positive trends (fig 1.1). (a, b)

a



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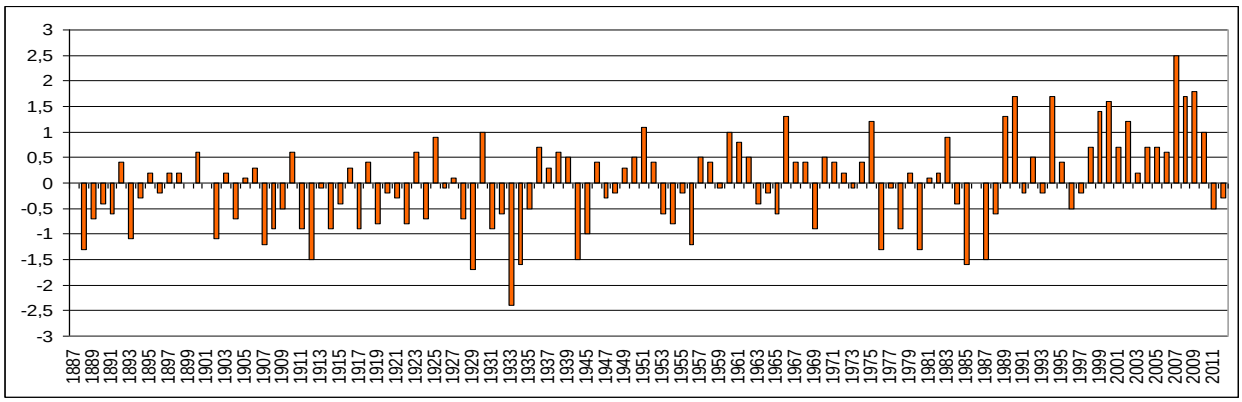


Fig.1.1. *trends in modification of the average annual temperatures in the period 1887-2012 (a) and termic abnormalities in the period 1961-1990 (b)*

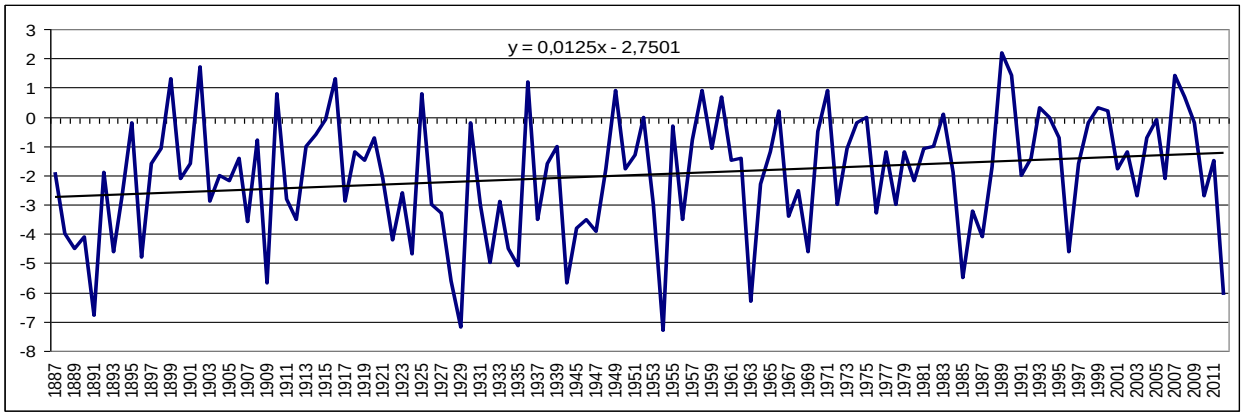
The hottest year in the Republic of Moldova during the period of instrumental observations was 2007, when average temperature exceeded climatic annual norm for 2.5^{0}C. in addition years 2009, 1990, 1994, 2008, 2000, 1999, 1966, 1989, 2002 also had very hot when average temperature for the year was 10.8^{0}C , when climatic norm for the annual temperature is 9.6^{0}C. according to the data presented in the table 1.1. repeatability of the extreme warm years for the last 15 years was one time per 2 years. The coldest years were registrated in 1933 and 1929 when average temperature was 7.2-7.9^{0}C.

Table 1.1. Top of the 10 most warm and cold years (average annual temperature)

Cold years ($T_{med.year.}$, 0^0C)		***Hot years*** ($T_{med.year}$, 0^0C)	
1933	**7,2**	**2007**	**12,1**
1929	**7,9**	**2009**	**11,4**
1934	**8**	**1990**	**11,3**
1985	**8**	**1994**	**11,3**
1912	**8,1**	**2008**	**11,3**
1940	**8,1**	**2000**	**11,2**
1987	**8,1**	**1999**	**11**
1888	**8,3**	**1966**	**10,9**
1976	**8,3**	**1989**	**10,9**
1980	**8,3**	**2002**	**10,8**

In case of winters temperatures have been also increasing during the century with 0.0125^{0}C/year (fig.1.2 a). Starting from the 60th of the XX century one could observe a stable tendency in increasing of the average annual seasonal temperatures (fig.1.4 a, b, tab.1. 3). In the period 1887-1959 winters were colder with -0.7^{0}C, in comparison with recent winters. Starting from 60th warm/cold winters were on the ratio 2:1. (fig.1.2b), table 1.2.

a



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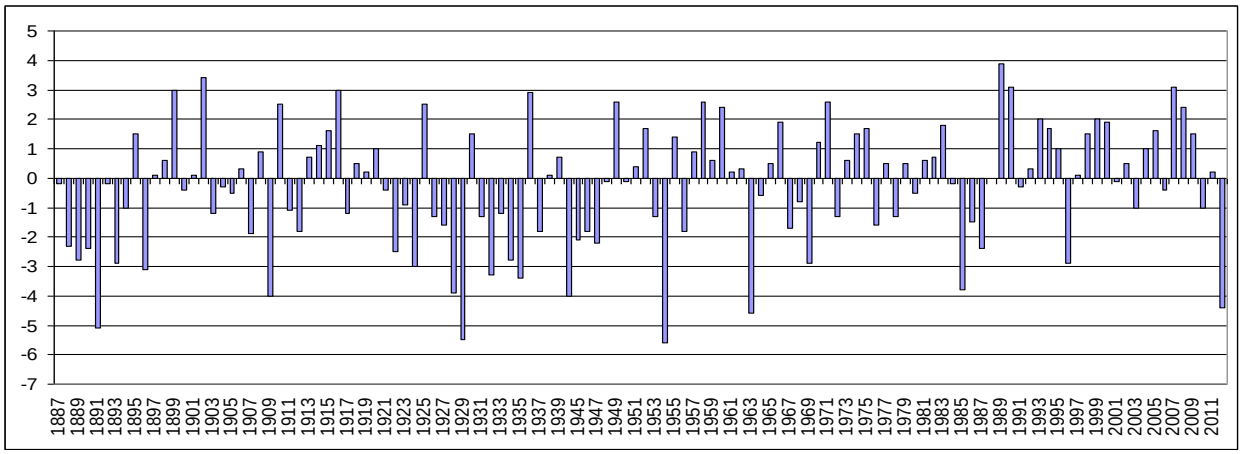


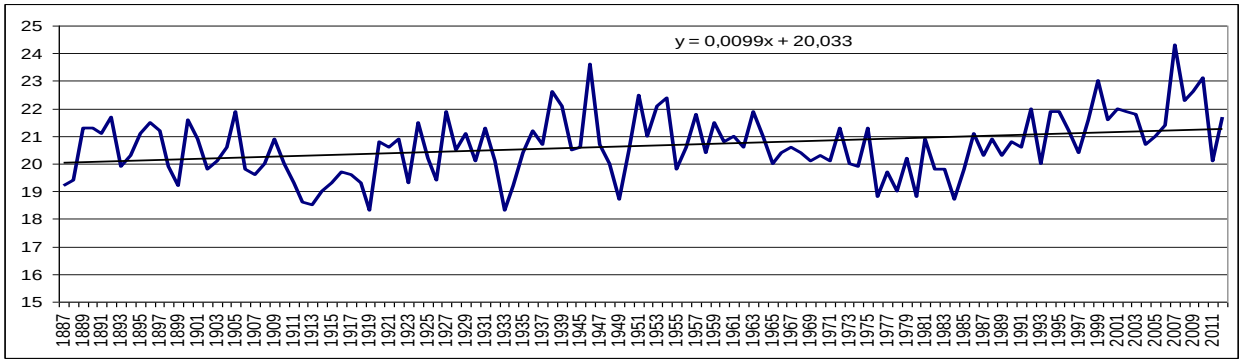
Fig.1.2. *Trends in winter temperatures in the period 1887-2012 (a) and termic anomalies from the climatic norm for the period 1961-1990 (b)*

Table 1.2. Top of the 10 warm and cold winters (seasonal average temperatures)

Cold winters ($T_{med.winter}$, 0^0C)		***Warm winters*** ($T_{med.winter}$, 0^0C)	
1954	**-7,3**	**1989**	**2,2**
1929	**-7,2**	**1902**	**1,7**
1891	**-6,8**	**1990**	**1,4**
1963	**-6,3**	**2007**	**1,4**

2012	**-6,1**	**1899**	**1,3**
1909	**-5,7**	**1916**	**1,3**
1940	**-5,7**	**1936**	**1,2**
1928	**-5,6**	**1949**	**0,9**
1985	**-5,5**	**1958**	**0,9**
1935	**-5,1**	**1971**	**0,9**

Trends for increasing of the summer temperatures show its increasing for 0.0099^{0}C/year, and stable summer temperature increasing is being registrated for last two decades (fig 1.3).



b

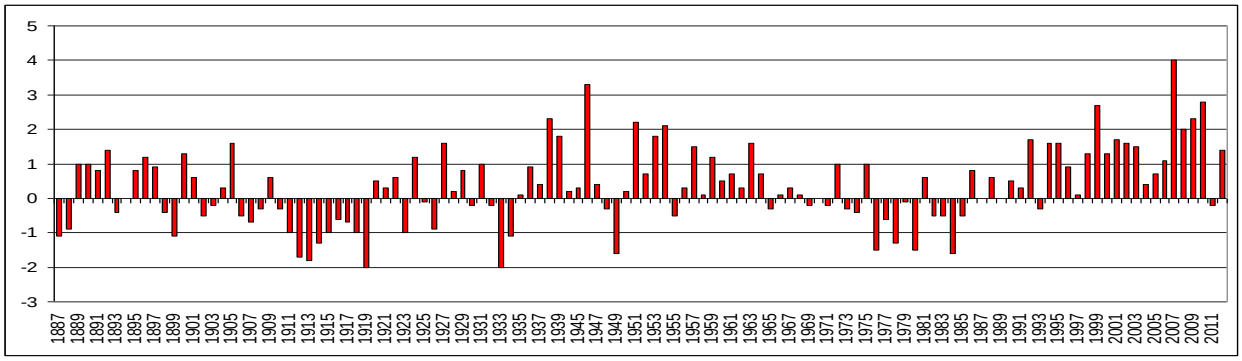


Fig.1.3. *Tendency in modifications of the average seasonal temperatures of the summer period 1887-2012 (a) and abnormalities from the climatic norms in the period 1961-1990 (b)*

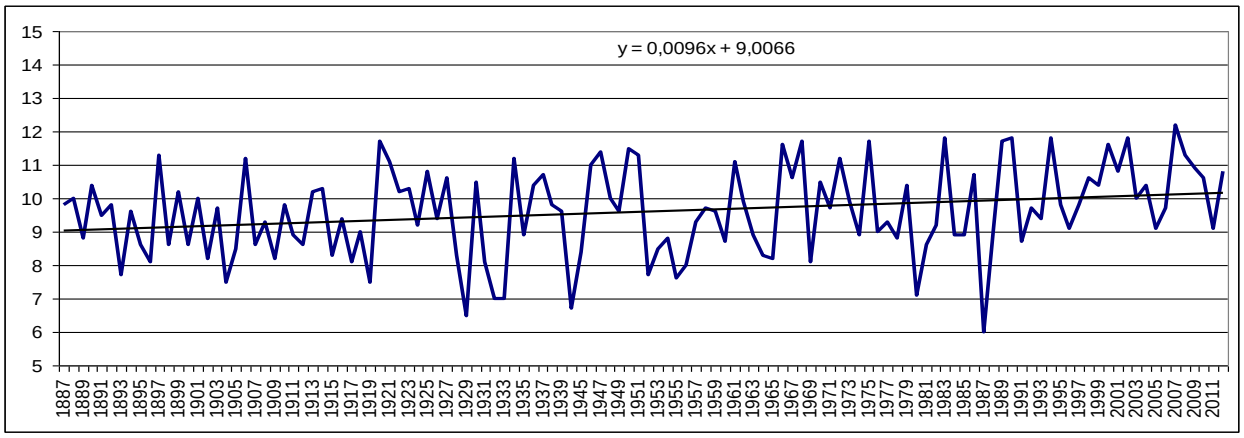
The hottest and coldest summers are presented in the table 1.3

Table 1. 3. Top of the hot and cold summers (according to the seasonal temperatures)

Cold summers ($T_{med.summer}$, 0^0C)		**Warm summers** ($T_{med.summer}$, 0^0C)	
1919	**18,3**	**2007**	**24,3**
1933	**18,3**	**1946**	**23,6**
1913	**18,5**	**2010**	**23,1**
1912	**18,6**	**1999**	**23**
1949	**18,7**	**1938**	**22,6**
1984	**18,7**	**2009**	**22,6**
1976	**18,8**	**1951**	**22,5**
1980	**18,8**	**1954**	**22,4**
1914	**19**	**2008**	**22,3**
1978	**19**	**1939**	**22,1**

Evolution of the temperatures in the spring season shows warming with 0.0096^0C/year (fig.1.4.a, b). the coldest springs had a temperature less than 7.7^0C (climatic norm - 9.6^0C), while hot springs 11.6^0C (table 1.4).

a



b

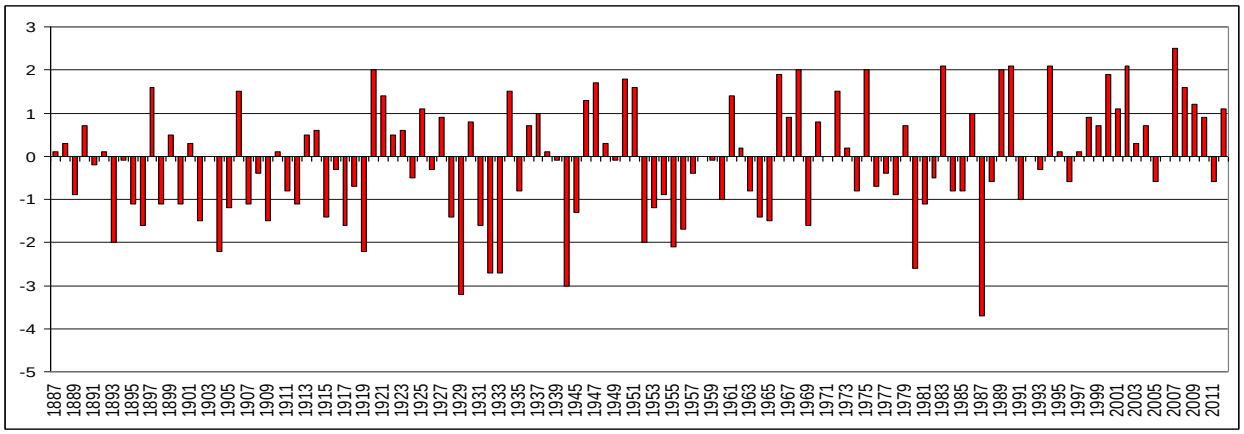


Fig.1.4. *Trends of modification of the seasonal average temperature of springs 1887-2012 (a) and 1961-1990*

Table 1. 4. Top of the warm and cold springs (average seasonal temperatures)

Spring cold ($T_{med.spring}$, 0^0C)		**Spring hot** ($T_{med.spring}$, 0^0C)	
1987	**6**	**2007**	**12,2**
1929	**6,5**	**1983**	**11,8**

1940	6,7	1990	11,8
1932	7	1994	11,8
1933	7	2002	11,8
1980	7,1	1920	11,7
1904	7,5	1968	11,7
1919	7,5	1975	11,7
1955	7,6	1989	11,7
1893	7,7	1966	11,6

Autumn temperatures have also increased for the period of observations for 0.0052^{0}C/year.

Table 1.5

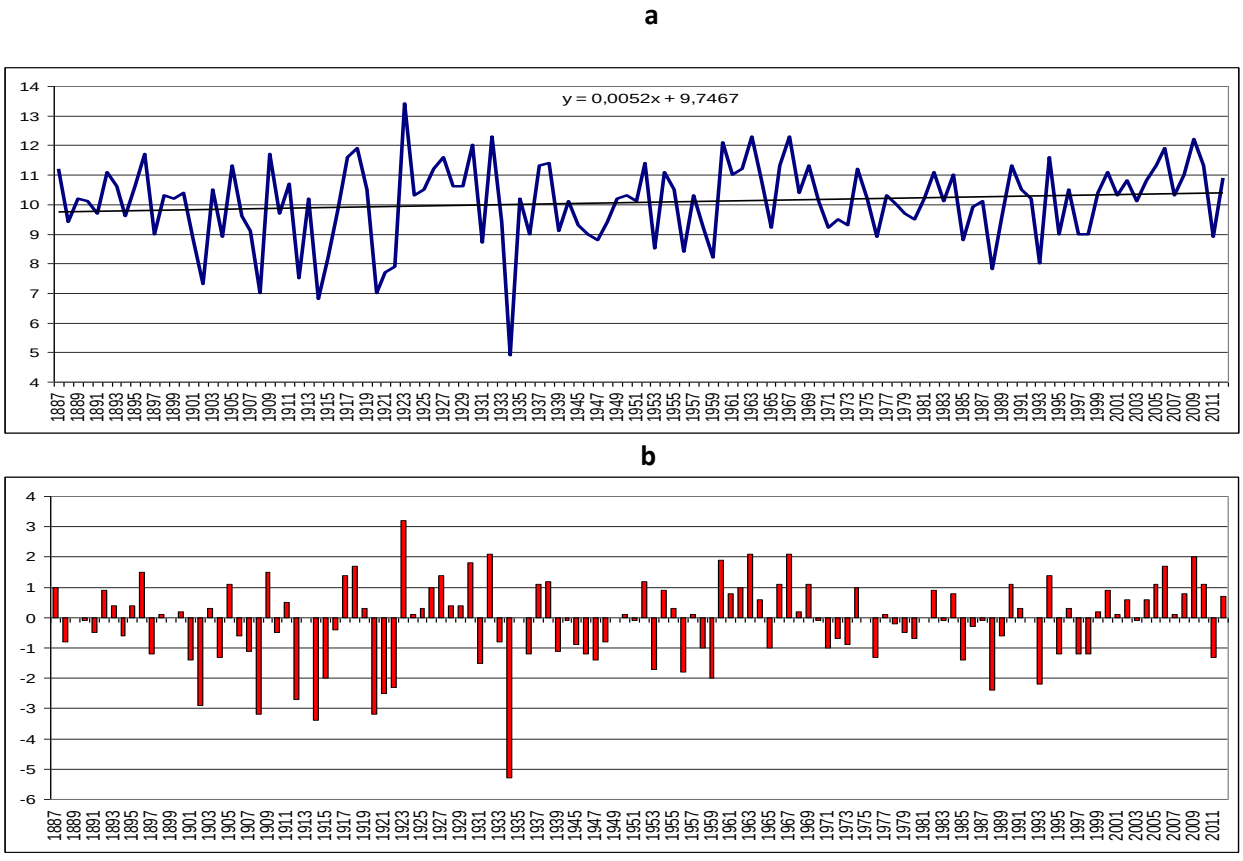


Fig.1.5. *Trends in modification of the temperature during autumn season in the period 1887-2012 (a) and deviations from the climatic norm in the period 1961-1990*

In the most cold autumns average temperature was less then 8^0C (average seasonal temperature 10.3^0C), while the warmest ones had seasonal value 11.7^0C. table 1.5.

Table 1. 5. Top of the warm and cold autumns (average seasonal temperature)

Autumn cold ($T_{med.autumn}$, 0^0C)		Autumn warm ($T_{med.autumn}$, 0^0C)	
1934	**4,9**	**1923**	**13,4**
1914	**6,8**	**1932**	**12,3**
1908	**7**	**1963**	**12,3**
1920	**7**	**1967**	**12,3**
1902	**7,3**	**2009**	**12,2**
1912	**7,5**	**1960**	**12,1**
1921	**7,7**	**1930**	**12**
1988	**7,8**	**1918**	**11,9**
1922	**7,9**	**2006**	**11,9**

Spatial distribution of the temperatures in the recent period (1960-2012), shows that practically whole territory of the country is sunder growing of the annual temperatures in average 0,001-0,002^{0}C/year).

1.2.2. Estimation of the termic extremes

Variability of the extreme temperature events was made on the base of calculations annual average values and presented in table 2.1

Table 2.1. 1960-2012

Briceni (northern part)		Chisinau (central part)		Cahul (southern part)	
Years	Extremes	Years	Extremes	Years	Extremes
2000	1,3	2000	1,1	2000	0,9
2001	1,3	2001	1	2001	1
2002	1,3	2002	0,9	2002	0,8
2003	-0,2	2003	-0,8	2003	-0,4
2004	0,7	2004	0,2	2004	0,5
2005	0,5	2005	0,4	2005	0,6
2006	0,2	2006	0,1	2006	0,5
2007	2,1	2007	2,4	2007	2,3
2008	1,3	2008	1,2	2008	1,4
2009	1,6	2009	1,6	2009	1,9
2010	0,9	2010	0,7	2010	1,1
2011	0,4	2011	0	2011	0,2
2012	1,7	2012	1,7	2012	1,9

Modelling of the absolute minimums of the winter period in 2012 demonstrate that it varied in the limits -21,0...-30^{0}C, and strongly affected agricultural crops planted in the autumn (cereals, orchards, grapes etc) (fig.2. 1).

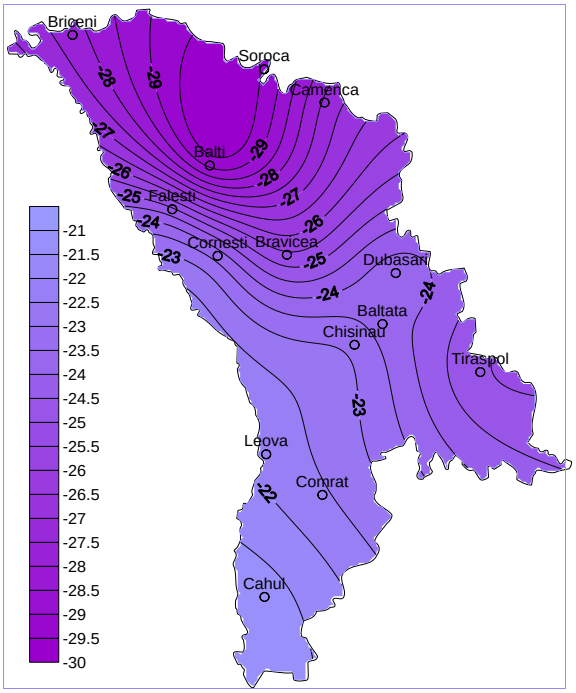


Fig.2.1. **spatial distribution of the temperatures in the winter of 2012**

In the year 2012 the difference between the lowest and the highest temperatures was 74,4^{0}C (+42,4^{0}C, Făleşti and -32,0, Bălţi), demonstrating further continentally of the climate in Moldova.

1.2.3. Spatial variability of the termic regime

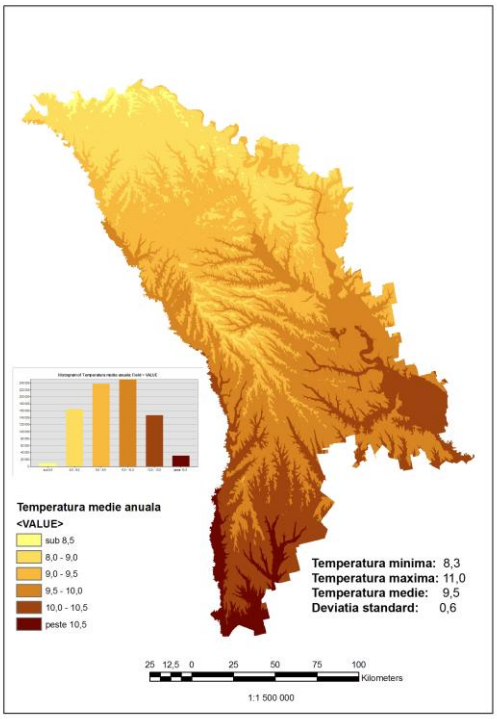
According to the data (table 3.1) warming of the air temperature in average varies in the limits of 0.5 till 0.9^0, (3).

Table 3.1. Spatial variability of the average air temperature

Meteo station	T annual average 2000- 2011	T average annual 1989 - 1999	**Warming in the first decade of the XXI century in comparison with the warmest decade of the XX century**
Balţata	10,5	9,9	0,6
Bălţi	10,2	9,7	0,5
Bravicea	**10,6**	**9,9**	**0,7**
Briceni	**9,1**	**8,4**	**0,7**
Cahul	**11,1**	**10,2**	**0,9**
Camenca	9,8	9,2	0,6
Chisinau	10,7	10,2	0,5
Comrat	10,9	10,3	0,6
Corneşti	**10,2**	**9,4**	**0,8**
Dubăsari	10,9	10,3	0,6
Făleşti	**10,5**	**9,8**	**0,7**
Leova	**10,6**	**9,9**	**0,7**
Soroca	**9,6**	**8,9**	**0,7**
Tiraspol	10,8	10,3	0,5

Maps developed for the different periods are presented in the fig.3.1, and 3.2.

1961-1990



2000-2010

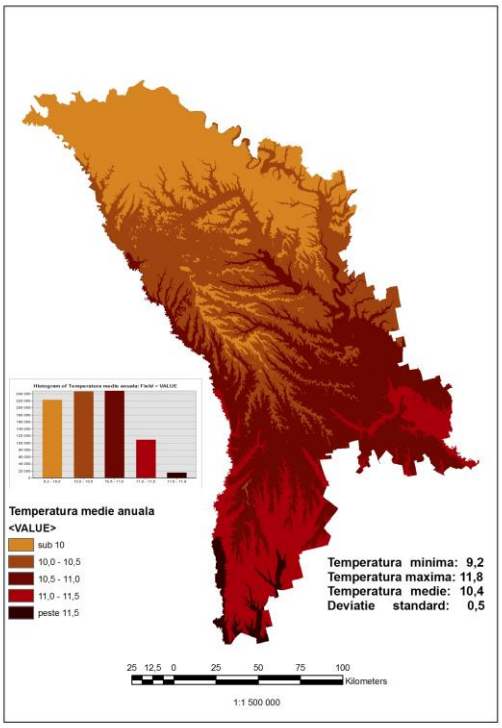
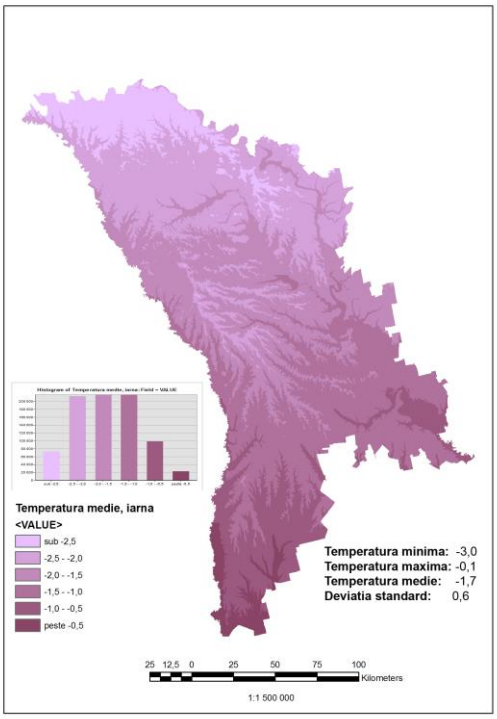


Fig.3.1. *Spatial distribution of the average annual temperatures*

1961-1990



2000-2010

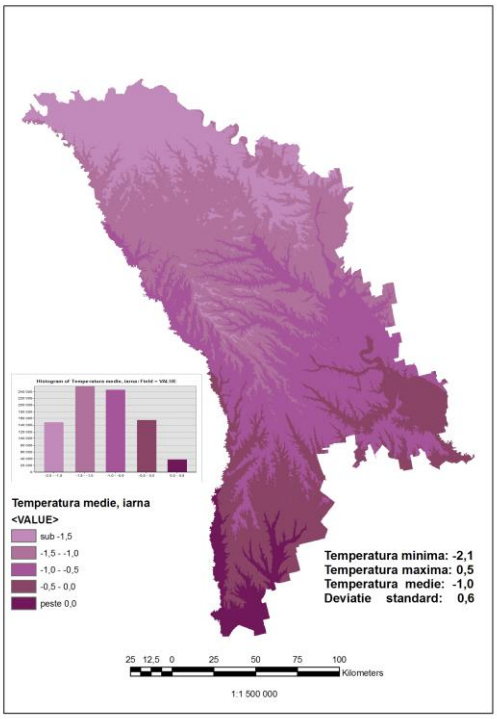
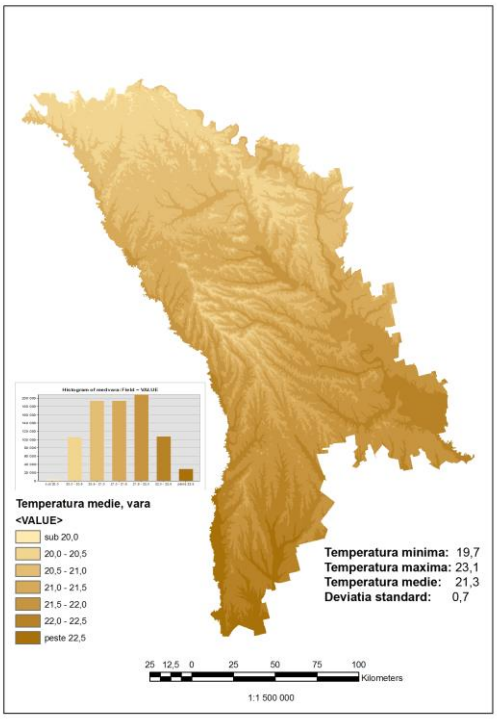
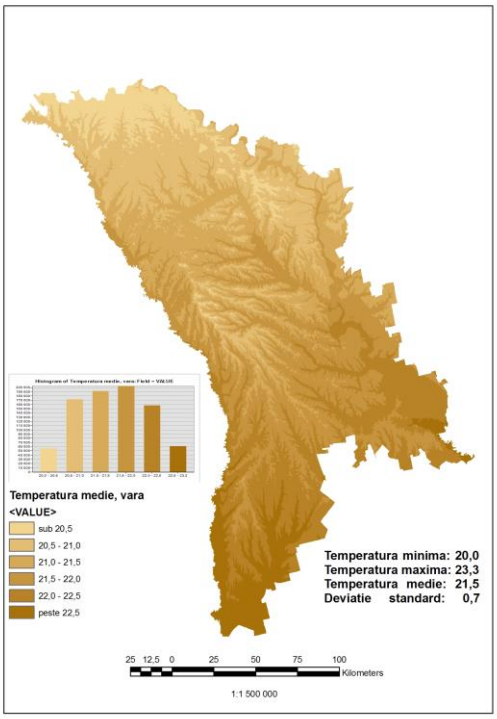


Fig. 3.2. *Spatial winter temperatures*

Fig 3.3. Spatial summer annual average temperatures *(*1961-1990)



2000-2010



1.2.4. Evaluation of the trends in precipitations in the Republic of Moldova

The base for the estimations served records of annual and seasonal precipitations for the period 1891-2012 (fig 4.1)

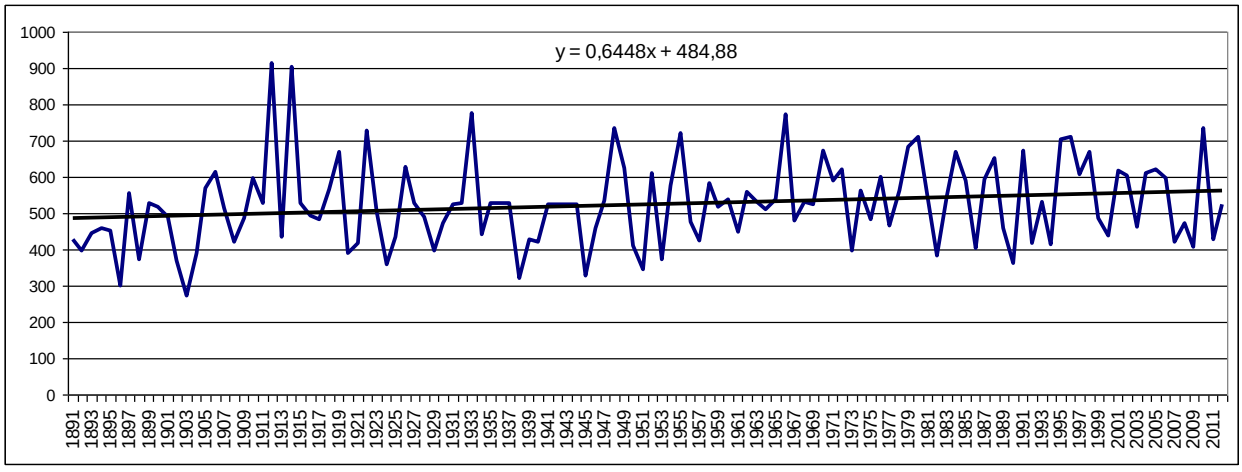


Fig.4.1. *Trends in the modifications of the annual precipitation sum (1891-2010)*

On the annual level one could observe increasing of the precipitations sum for the period 1891-2012 for 0.719 mm/year. Stable increasing is observed from the 50th of the last century (fig.4.1). years with the highest and lowest rate of precipitations are presented in the table 4.1.

Table 4.1. Top of the most drought and rainy years in Moldova

Drought years (mm)		Rainy years (mm)	
1903	**271,8**	**1912**	**915**
1896	**301**	**1914**	**903**
1938	**320**	**1933**	**777**
1945	**329**	**1966**	**774**
1951	**345**	**2010**	**735**
1924	**357**	**1948**	**734**
1990	**361**	**1922**	**729**
1902	**368**	**1955**	**721**
1953	**373**	**1980**	**712**
1898	**374**	**1996**	**711**

Atmospheric precipitations during winter period have a trend for increasing with an average value 0.2188 mm/year (fig.4.2). the most rainy (snow) and dry winters are presented in the table 4.2

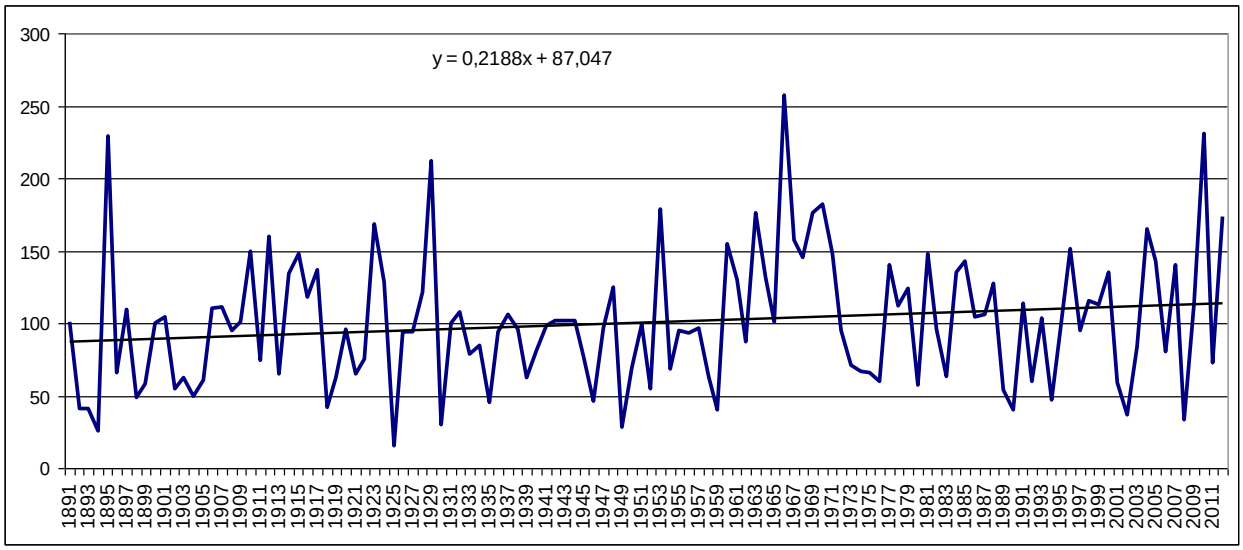


Fig.4.2. *Trends of modifications of the winter precipitation sum in the period 1891-2012*

Table 4.2. Top of the 10 most dry and rainy (snow winters) precipitations in mm

Dry winters		Humid winters	
1925	**15**	**1966**	**257**
1894	**26**	**2010**	**231**
1949	**28**	**1895**	**229**
1930	**30**	**1929**	**212**
2008	**33**	**1970**	**182**
2002	**37**	**1953**	**179**
1959	**40**	**1963**	**176**
1990	**40**	**1969**	**176**
1892	**41**	**1923**	**168**
1893	**41**	**2004**	**165**

Trend in pluviometric regime of springs during period 1891 – 2012 shows decreasing of the precipitation sums with 0,0373 mm/year, especially for last 15 years fig 4.3. The most dry and wet springs in Moldova are presented in table 4.3

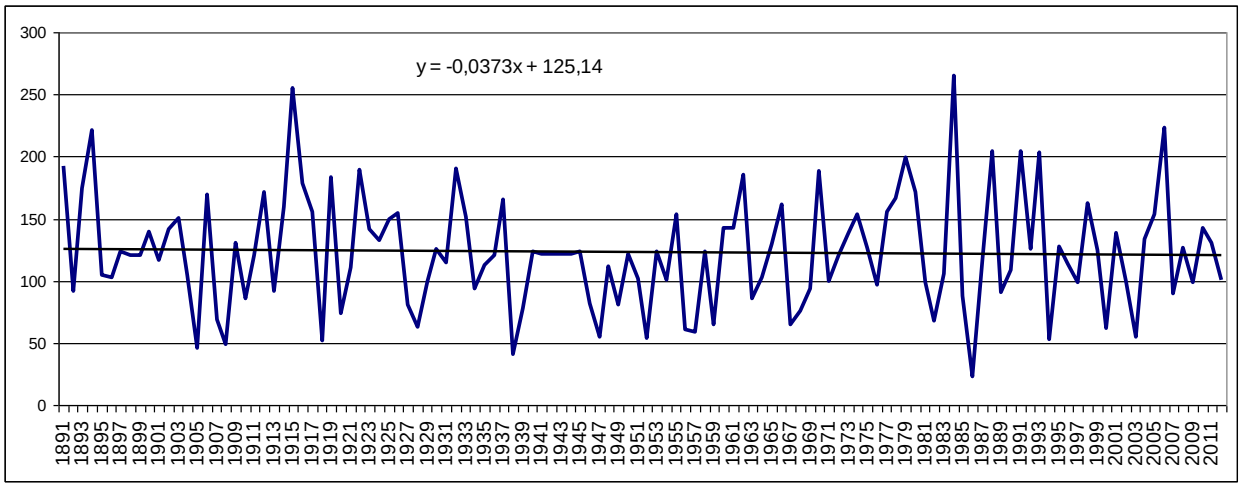


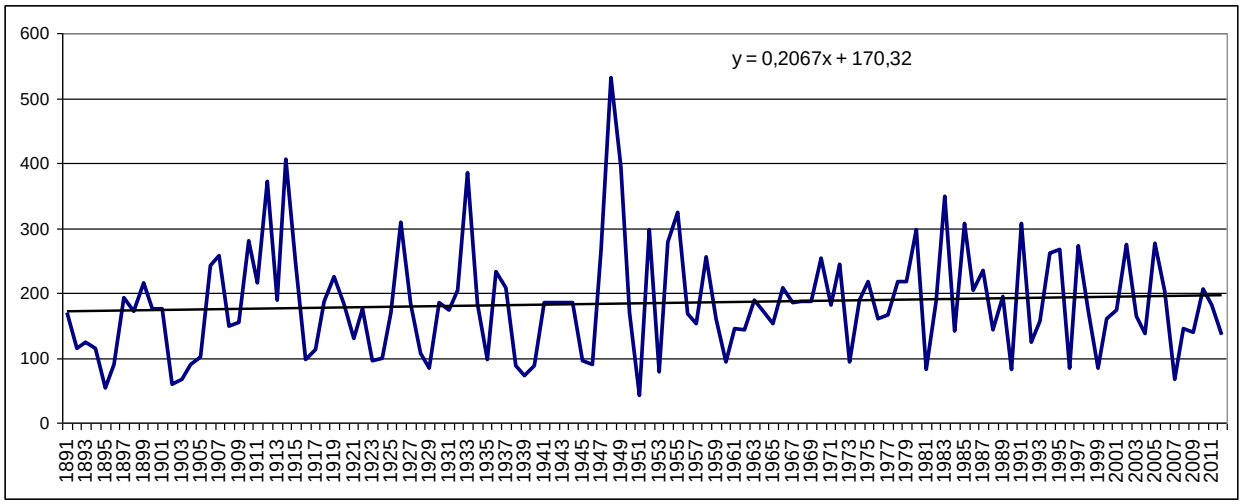
Fig.4.3. *Trends in modifications of the precipitation sum in the period (1891-2012) during spring season*

Table 4.3. Top of the 10 most dry and wet springs (average 120,7)

Dry springs, mm		Wet springs, mm	
1986	**23**	**1984**	**265**
1938	**41**	**1915**	**255**
1905	**46**	**2006**	**223**
1908	**49**	**1894**	**221**
1918	**52,1**	**1988**	**204**
1994	**53**	**1991**	**204**
1952	**54**	**1993**	**203**
1947	**55**	**1979**	**199**
2003	**55**	**1891**	**192**
1957	**59**	**1932**	**190**

Trends in precipitation sum modifications for the summer season show slight increasing of this parameter for 0.2067 mm/year (fig.4.4) with the most dry and wet summers presented in the table 4.4.

a



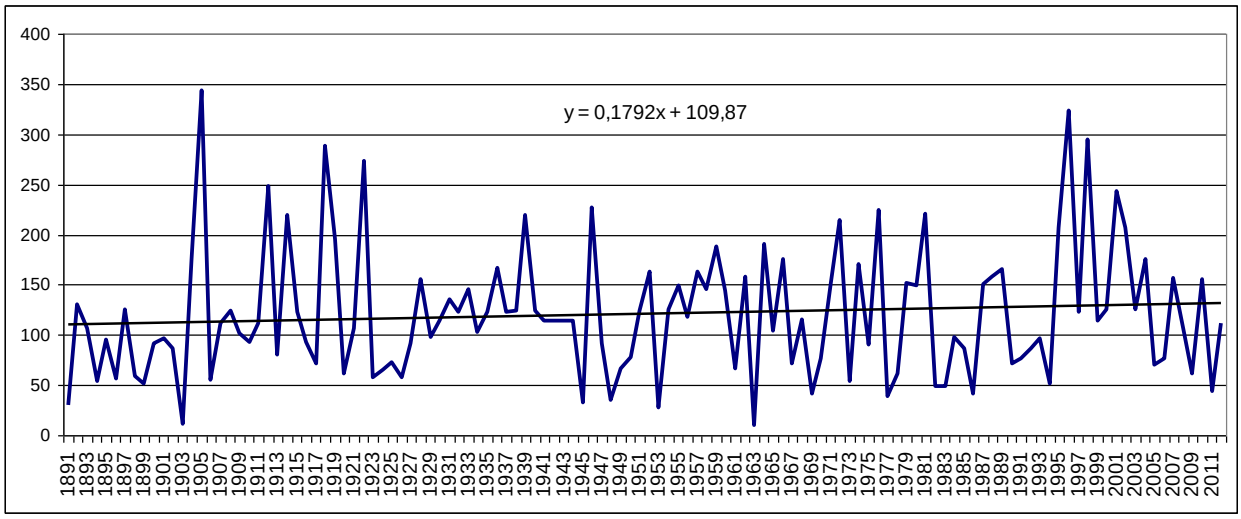
b

Fig.4.4. *Trends in modification of them precipitation sum in summer 1891-2012)*

Table 4.4. Top of the most dry and wet summers

Dry summers, mm		Wet summers, mm	
1951	42	1948	531
1895	53	1914	406
1902	59	1949	395
2007	66	1933	385
1903	66,5	1912	372
1939	72	1983	349
1953	79	1955	324
1981	81	1926	308
1990	81	1985	307
1929	83	1991	307

Autumn season is characterized with a slight increasing of the precipitation sum with 0.17922 mm /year (fig 4.5 and table 4.5)



b

Fig.4.5. *Trends in the modification of the precipitation sum 1891-2012 for the autumn season*

Table 4.5. Top of the most dry and wet autumns (precipitation sum)

Dry autumn, mm		Wet autumn, mm	
1963	**10**	**1905**	**343,5**
1903	**11,7**	**1996**	**324**
1953	**27**	**1998**	**295**
1891	**30**	**1918**	**288,9**
1945	**33**	**1922**	**273**
1948	**35**	**1912**	**248**
1977	**39**	**2001**	**243**
1969	**42**	**1946**	**227**
1986	**42**	**1976**	**224**
1982	**49**	**1981**	**221**

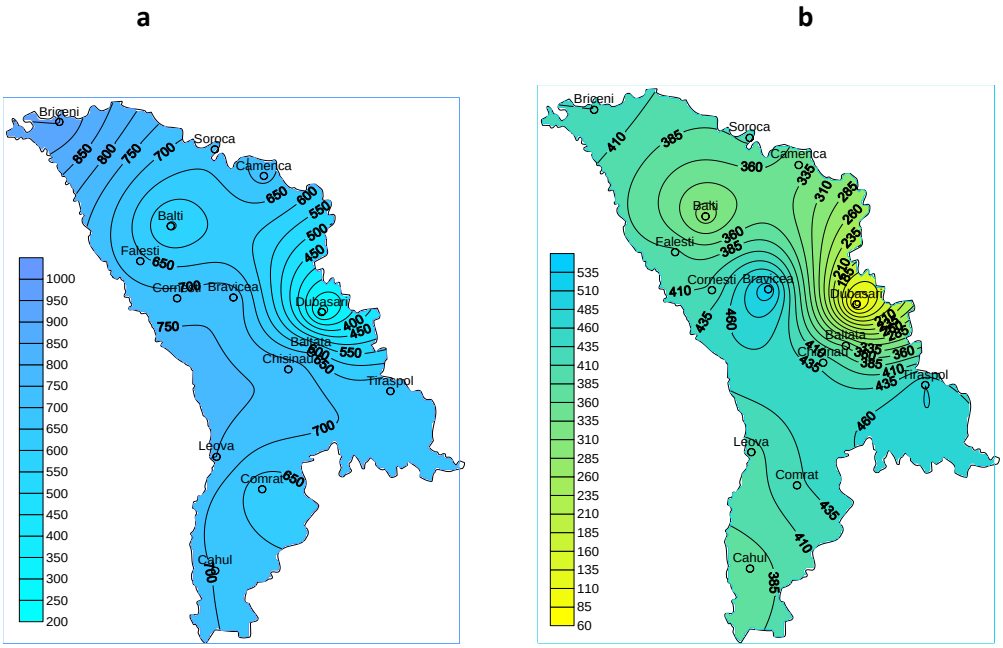
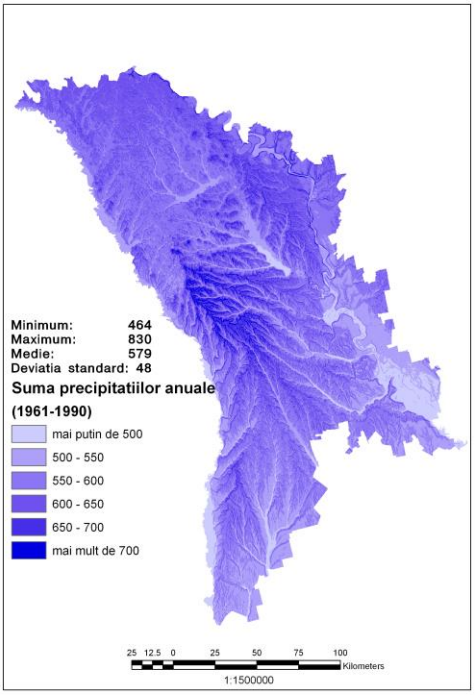


Fig.5.2. Map of the annual precipitations in the extreme pluviometric years (a -2010- wet year; b - 2011- dry year)

1.2.5. Spatial Variability of the pluviometric regime

In the first part of the XXI century (2000-2012) a trend on decreasing of the annual precipitation sum in the Lower Dnester and Prut basin was observed for 50 mm (fig 6.1)

1961-1990



2000-2010

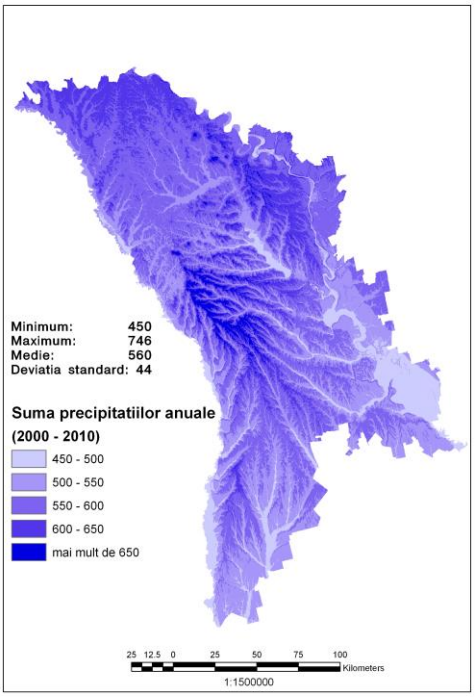
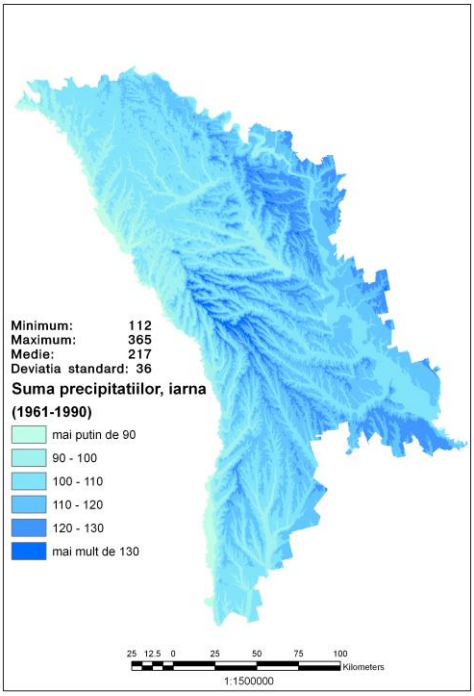


Fig.6.1. *Spatial distribution of the precipitation duet o the fizico-geographical particularities*

this particularity in spatial distribution has place and in the cold season of the year.

1961-1990



2000-2010

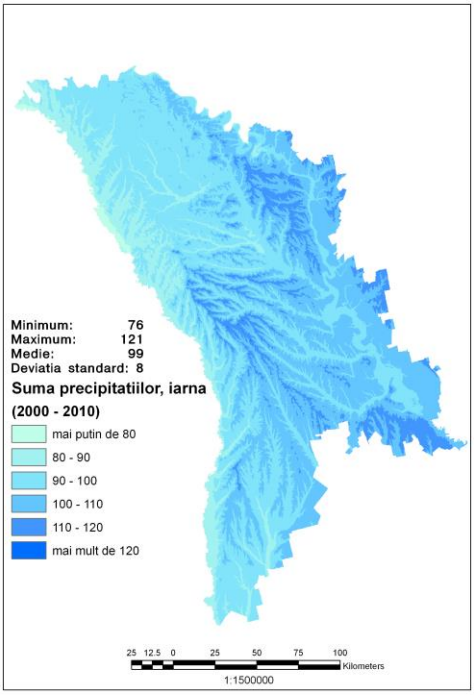
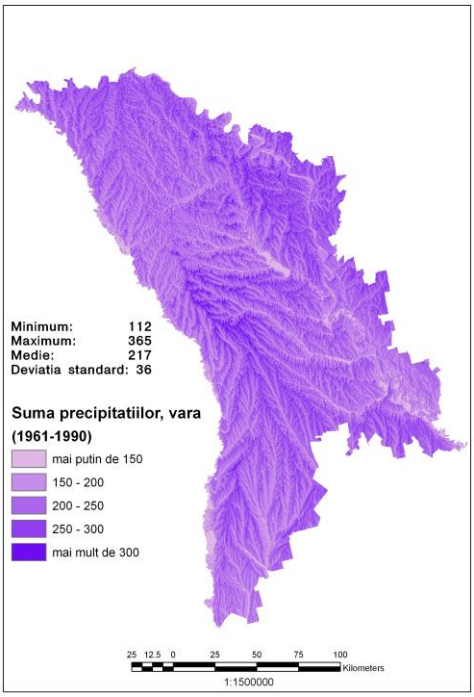


Fig. 6.2. *Spatial distribution of the precipitation sum in the winter season due to the physical and geographical factors (***1961-1990)**



2000-2010

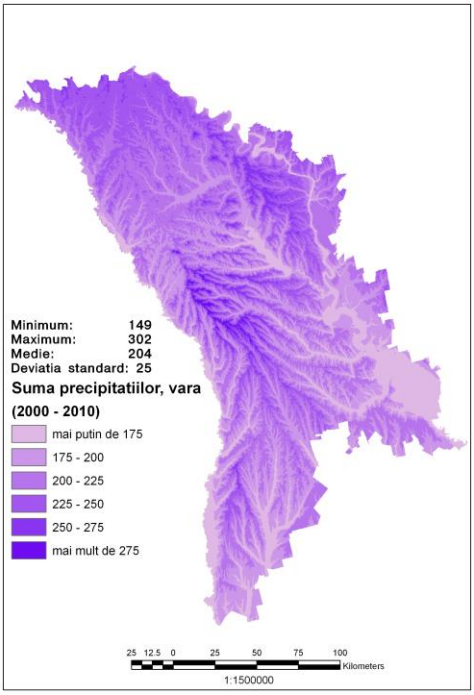


Fig.6.3. *Spatial distribution of the precipitation sum during summer period duet o the fizico-geographical factors*

5. Conclusions

According to the data obtained from the Hidrometeo records one could conclude:

- There is a tendency for the increasing of the annual temperatures in the region, especially during summer period. Temperature increasing has accelerated in the
- last 15 years and extreme temperature events have place every 2 years during this period.
- Precipitation sum remained practically at the same level, but its torentiality has also increased for last 15 years. It could associated with higher temperatures, especially during summer time and physico-geographical conditions of the territory
- Adaptation measures should be aimed at the moisture conservation in the soils and development of measures associated with the creation of the green carcasses.
- The speed of climate change has rose significantly for last 15 years and led to the decreasing of the precipitation sum in the lower part of the Prut and Dnester rivers.

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