Integrated Drought Management Programme
in Central and Eastern Europe

Upgrading agricultural drought monitoring and forecasting: *the case of Ukraine and Moldova (activity 5.6)*

Analysis of long term uninterrupted monitoring data on water holding in different soil layers of typical fields (UA), research of 2 case areas in Dniester river basin and data (MD) and development the recommendations for farmers
(Milestone 2)

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Name of the milestone:	1.Report on Step 2: Analyses of the trends on water holding capacities of soils under climate change based on long term (1961-2010 period) observation at meteorological stations of Ukraine and Moldova
WP:	5
Activity:	5.6 Upgrading agricultural drought monitoring and forecasting: the case of Ukraine and Moldova
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Participating partners:	GWP-Ukraine GWP-Moldova
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Introduction

1.1 Ukraine

Droughts always posed and still pose problems to Ukraine. According to different sources, since XI century, from 5 to 28 droughts per century were observed at the territory of Ukraine. Moreover, in three recent centuries, droughts were observed particularly often (from 19 to 28 droughts per century).

In heavy drought years, negative deviations of grain crop yields from general trend lines reach up to 5 dt/ha at the whole territory of Ukraine and up to 10-15 dt/ha in steppe zones, sometimes crops may be lost altogether.

Soil moisture is a key variable for drought classification purposes:

- as an indicator of agricultural drought - because soil moisture controls transpiration and plant growth to a large extent;
- as an indicator of meteorological and hydrological drought - because soil moisture provides an aggregate estimate of accessible water (as a balance of precipitation, evaporation and different types of run-off/drain).

Due to extremely limited soil moisture data, it cannot be used to assess alterations in climate aridity at the global/continental level. Difficulties of application of soil moisture data for such assessments are associated with high diversity of soils and their hydrophysical properties. As a result, in the majority of cases, soil moisture studies are associated with limited territories or specific situations. In the case of specific territories (e.g. countries, regions) availability of continuous soil moisture observations and analysis of the relevant data are of major importance [1].

Difficulties of drought definition/identification are associated with the need to account for different components of the hydrological cycle, periods of time and media (i.e. where and when water deficiency is observed - e.g. in a situation of long-term water deficiency in deeper soil layers and short-term excess of water contents in upper soil layers). Therefore, soil moisture is a key indicator of droughts [2].

Droughts are triggered by factors that prevent water accumulation in soils, e.g. low snow cover in winter seasons, unfavourable conditions for melt water absorption in early spring seasons (such as intensive snow melting, deep freezing of soil, formation of ice crusts on surface). Development of an agricultural drought depends on availability of soil moisture and it may substantially lag behind a meteorological drought.

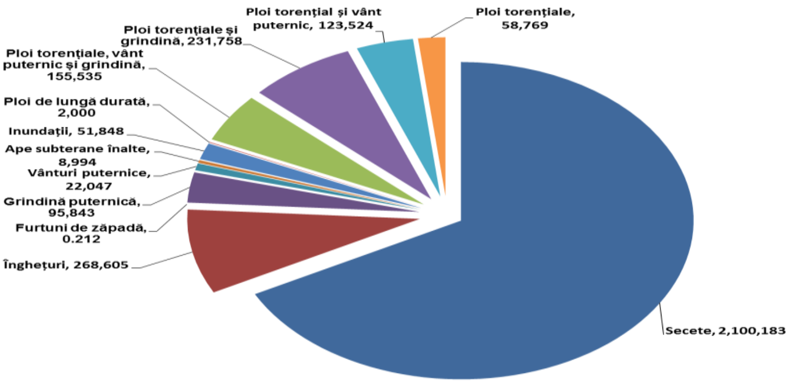
Drought is a natural phenomenon associated with water deficiency and it may be observed in all climate zones of Ukraine. Droughts cause substantial and sometimes even disastrous damages (e.g. in 1999, 2003 and 2007). Besides their direct impacts, droughts also accelerate desertification processes. Any heavy drought results in soil degradation and in normal climate conditions affected soils need at least three wet years to recover [3,4].

In recent decades, soil moisture regimes were under severe anthropogenic impacts and soil fertility declined in main agricultural regions of Ukraine.

Precipitation and river flow regimes have been studied sufficiently. Relevant study results rely on broad evidence-based materials that allow to identify existing trends. Soil moisture regimes have not been studied sufficiently. The concept, methods, indicators and criteria of drought-related damages in the agricultural sector are underdeveloped. So far, there are too little generalising studies on matters of agro-climate and operational assessment of soil droughts, their environmental impacts and negative impacts on crop yields. So, the presented section is fairly relevant for Ukraine.

1.2 Moldova

Climate change issues present a great concern to different level of authorities in Moldova. Droughts because of these phenomena significantly influence on the social and economic development of the country. According to estimations losses due to the droughts in Moldova consist around 2/3 total prejudice caused by natural disasters (see picture 1.)



Picture 1. Losses for national economy from different types of natural disasters (National Strategy for Climate change, Chisinau, 2013)

During heavy droughts, economic losses can reach around 70-80% of all crops losses and in some areas total loss of agricultural crops. According to the statistical data, such losses can cause price growing for 30-40% of alimentary foods, thus having negative impact on social development.

Main factor for maintenance of the productivity of agricultural lands is rational use of the moisture resources in soils. Recent climate change caused growing of annual temperatures and changes in precipitation rates (table 1). In the period 1887-2007 average temperature has increased for 1 degree, while precipitation level increased till 600 mm/year or for 11%

Table 1.

Season of the year	Air temperature last 100 years	Precipitations
Winter	+1,3	+9 mm
Spring	+0,9	- 5mm
Summer	+ 0,7	+20 mm
Autumn	+0,2	+32 mm
Average	+0,8	+56 mm

According to the data precipitation level has increased mainly in the autumn period. At the same time data for the last 15 years show reduction of precipitation rate during vegetation period and its growing in the winter.

These changes led to the decreasing of the soil moisture in soils and thus affected development of agricultural activities in Moldova. Actually such research are rather limited and are performed mainly for agrochemical service. At the same time a number of projects aimed at recovering of the irrigation systems in different parts of the country will contribute to the increasing of the soil moisture on agricultural lands.

Due to a small territory of Moldova during dry years droughts cover the whole area of the country. The most severe recent drought events happened in 2003, 2007 and 2012. According to the estimations of the slope agricultural lands occupy mainly south directed exposure, where the processes of soil moisture loses seem to be more intensive. It also leads to the soil degradation, which together with emotional processes strengths drought effect and moisture content reduces due to loss of humus and other organic substances. In recent decades, soil moisture content was under strong anthropogenic influence, affecting soil fertility, which strongly declined under main agricultural crops in Moldova.

Actually main target for soil research in Moldova is erosion and this process has been rather detailed developed together with data on precipitation and partially river flows. Small river resources are poor used for agricultural purposes and poor monitored water abstraction from local ponds, used for local irrigation, does not allow presenting of real picture on water resources use. So further evaluation of the soil moisture in soils under agricultural crops present a great concern for different level of sectoral agricultural authorities in Moldova.

Methodology and subjects of research, criteria of droughts

2.1. Ukraine

2.1.1 Criteria of droughts

Air drought means a lengthy lack of effective precipitation (> 5 mm/day) in a vegetation season accompanied by high average ambient air temperatures (> 25°C). In quantitative terms, the criterion means length of such periods of 30 or more days.

Soil drought means reduction of soil moisture to 10 - 15 mm or less in the soil layer of 0 to 20 cm, and to 50 - 60 mm (or less) in the soil layer of 0 to 100 cm.
Criteria for soil drought intensity: a very heavy drought is observed at reduction of soil moisture to 5 mm or less in the soil layer from 0 to 20 cm, and to 25 mm or less in the soil layer from 0 to 100 cm. Criteria for a heavy drought and a moderate drought are set as 6 to 10 mm and 26 to 35 mm; and as 11 to 15 mm and 36 to 50 mm, respectively.

See Fig. 1 for probability of droughts in different regions of Ukraine.

Fig. 1 Probability of droughts (%) at the territory of Ukraine

2.1. 2 Methodologies

Aridity assessments rely on data of specialised observations. Such observations include soil moisture monitoring in Ukraine for many decades. Regular soil moisture measurements are made by meteorological stations of Ukraine that maintain different hydrometeorological observations, including meteorological, agro-meteorological and hydrological ones.
Any statistical analysis crucially depends on sound and long-term observation time-series. Now, the Hydrometeorological Service of Ukraine has representative and long-term soil moisture data series. For more than 50 years, all meteorological stations made their measurements according to a standard methodology and at preset specific dates.

In this study, soil moisture data were got from results of continuous observations at test sites. The test sites are located at cultivated crop fields with the most common soil types for relevant agro-climate zones and nearby meteorological stations.

The test sites were selected based on three mandatory conditions:

- a site should cover a plain land area of 0.1 ha or more;
- the site's landscape and soil type should be representative for the surrounding territory and should not differ much from main landscape/soil types of the climate zone;

- Average groundwater level at the site and its seasonal variations should be typical for a large territory.

According to the due guideline manual on agro-meteorological measurements, soil moisture should be measured monthly in cold seasons and once in ten days in warm seasons [5]. In this study, only warm seasons were considered.

Soil moisture was determined by gravimetry - soil samples are weighted, dried and weighted again. The method allows to measure soil moisture with a high precision.
Soil moisture measurements allow to determine the overall moisture content, productive soil moisture and withering moisture levels. Productive soil moisture refers to the share of soil water that is available for plants and used by plants for growth and evaporation. Withering point means a threshold soil moisture level that - if reached - results in steady withering of vegetation. Productive soil moisture is estimated as the difference between the overall moisture content and the withering point [5].

2.1.3 Study objects

The study objects incorporated soil moisture data produced by Ukrainian meteorological stations located in areas nearby the Dniester basin:

1. Striy - Lvovskaya oblast;
2. Dolina - Ivano-Frankovskaya oblast;
3. Berezhany - Ternopolskaya oblast;
4. Chertkov - Ternopolskaya oblast;
5. Novaya Ushitsa - Khmelnitskaya oblast;
6. Kamenets-Podolskiy - Khmelnitskaya oblast;
7. Mogilev-Podolskiy - Vinnitskaya oblast;
8. Zatishie - Odesskaya oblast;
9. Razdelnaya - Odesskaya oblast.

See Fig. 2 for spatial distribution of soil moisture observation points in areas nearby the Dniester basin.

Fig. 2 Spatial distribution of soil moisture observation points in areas nearby the Dniester basin

Besides that, we studied average parameters for agricultural climate zones of Ukraine (see the zones at Fig. 3):

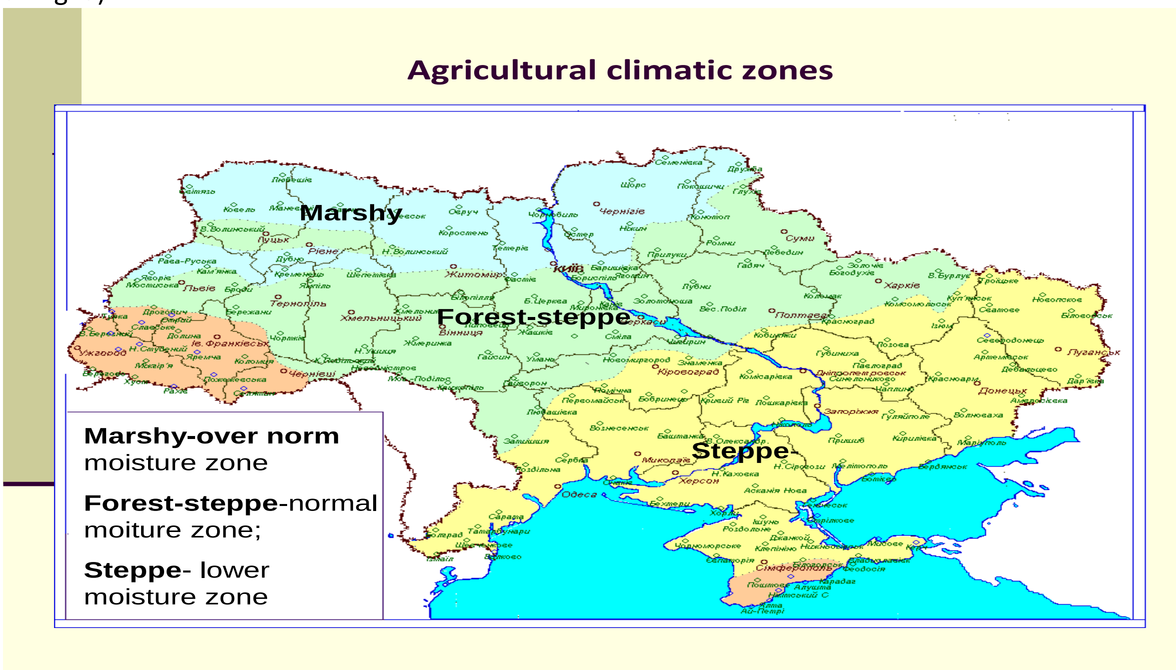


Fig. 3 Spatial distribution of soil moisture observation points in agricultural climate zones of Ukraine

1. Marshes/woodlands zone - sufficient and excessive soil moisture
2. Forest steppe zone - unsustainable soil moisture
3. Steppe zone - insufficient soil moisture.

The study relies on soil moisture data arrays for the period from 1961 to 2010. Long-term data series were analysed for soil layers from 0 to 20 cm (topsoil) and from 0 to 100 cm (1 metre layer).

2.2 Moldova

2.2.1 Criteria of droughts

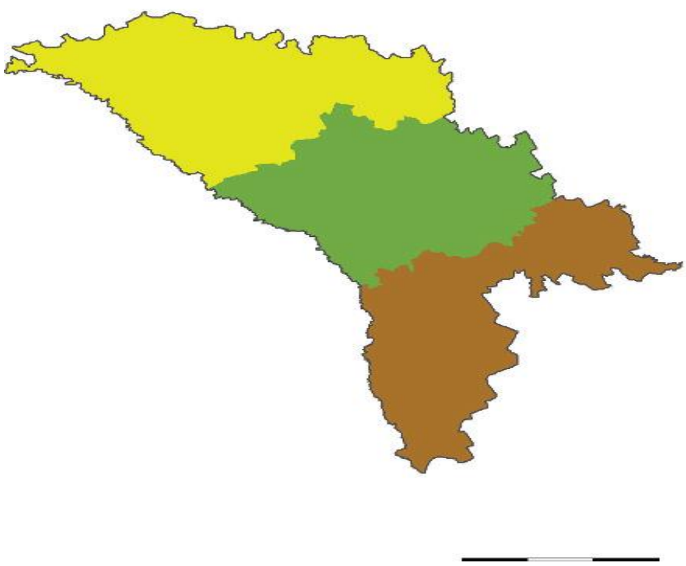
According to the drought estimations in Moldova the lack of precipitations > 5 mm/day with a period more than 30 days during vegetation with the temperature more than 25 degrees is considered as a drought. In regard to soil water content is expressed through percentage from the dried soil:

Wg% = (a:m). 100, where:

Wg - total moisture (% g/g) ;

a – quantity soil sample (g);
m - quntity of soil after drying (g).

Agroclimatic zonation of Moldova is presented in fig. 2.1.1 (World Bank Study 81591, Reducing of Vulnerability of Moldova's Agricultural Systems to Climate Change)



Zonation is divided in southern part, central and northern parts. Northern part of the country is mainly used for tobacco, root been, sunflower, wheat, apple orchards and maize. Central part is mainly for orchards (apple, plum), vine yards, cereals and southern part is mainly for multiannual plantations like vine yards, maize, cereals etc. Normally productivity of cereals in the northern part is 20-30% more than in the southern agroclimatic zone of Moldova. Probability of droughts in the country totally fits to the presented agro climatic zonation and is more than 50% for the southern region and 20-30% for the northern and central parts of the country.

2.2.2 Methodology for material accounting

Actual report is based on summary of existed data on soil moisture accumulated in scientific reports, observations performed in the Soil Resrach Institute of Moldova and data from the hydrometeo service of Moldova. Mainly moisture content is measured during agrochemical investigations, which periodicity has strongly reduced for last 20-25 years. Specific soil moisture monitoring in Moldova is poor performed, but implementation of a number of irrigational projects on the area of around 30000 ha will facilitate such analysis in future.

Average moisture content in soils due to aggregation is presented in table 2.2.1 (Annual report of the Soil research Institute of Moldova)
Table 2.2.1

Aparent density g/cm³	Field moisture (filed retention capacity), % g/g (RC)		Capilar water, % g/g (CW)		Water easily acessible for plants % g/g (RC+CW)	
	Argill and loam soil (water poor acessible for plants)	Argill soils (water poor acessible for plants)	Loam soils (capilar water)	Argill soils (capilar water)	Loam soils	Argill soils
1,10	29,1	30,2	19,8	24.1	9,3	6,1
1,25	27,0	€29,0	19,6	23,9	7,4	5,1
1,30	25,9	28,0	19,5	23,8	6,4	4,2
1,35	24,8	26,8	19,2	23,0	5,6	3,8
1,40	23,4	25,8	18,7	22,2	5,0	3,6
1,45	22,7	24,5	18,3	21,2	4,4	3,3
1,50	21,6	23,4	17,9	20,9	3,7	2,9
1,55	20,4	22,3	17,5	19,6	2,9	2,7
1,60	19,6	21,0	17,1	18,7	2,5	2,4
1,65	18,8	19,0	16,8	17,8	1,5	1,2
1,70	17,4	17,8	16,4	17,0	1,0	0,8

As one could see from the table easily accessible water in arable strata of soil decreases with the growing of its aggregation and in arable lands consists less than 10%.

Actually studies on soil moisture in Moldova are performed mainly during vegetation period and on fragmentary base. So for this study data on moisture content in arable strata (0 – 20 cm) were analysed. Moisture analyses are made on a standard methodology by weighting of the soil sample, its desiccation with a temperature of 105 degrees until constant weight and with further weighting. The difference in weighting was considered a moisture content. It allowed determine total moisture in arable strata, its productive part and withering moisture levels. Accessible moisture form for plants is a productive volume of water in soil. Withering level indicates a threshold for soil moisture level that lads to a steady withering of vegetation. Difference between these two options presents productive soil moisture (Annual report of the Soil Research Institute, Chisinau, 2012).

2.2.3 Discussion of the results of the study

For the study stations located in Dnester basin in Moldova were estimated:

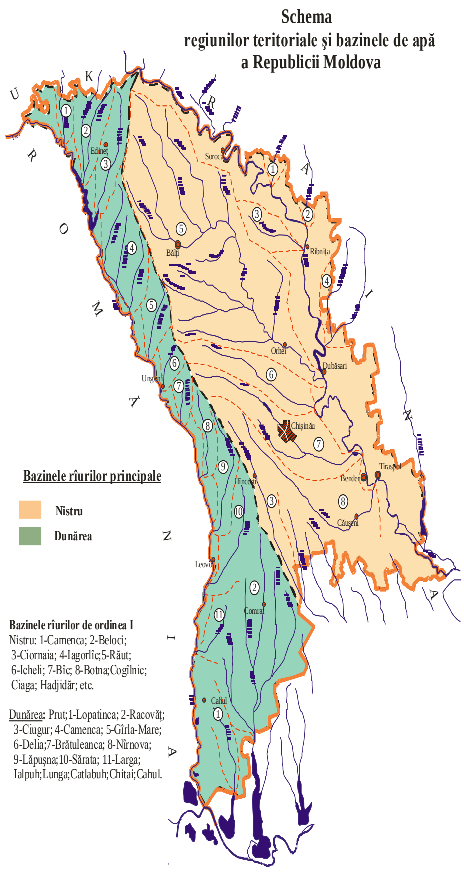
1. southern part of Moldova;
2. central part of Moldova;
3. northern part of Moldova;

Dnester part of the country occupies around 40% of the territory and main stations are located in Tiraspol (southern part of Moldova), Chisinau, Baltata and Orhei (central part) and Briceni (northern part). Meteo parameters of these stations were mainly used for actual study.

River basin mapping of Moldova is presented on fig. 2.3.1

Fig 2.3.1.

River basins in the Republic of Moldova



Results of analysis of climate-related soil water moisture changes in Ukraine based on long-term observations of the meteorological stations. Results of analysis of the soil moisture content in Moldova

3.1 Ukraine

3.1.1 Changes of soil moisture in Ukraine

Soil moisture data for the period from 1961 to 2010 in soil layer from 0 to 100 cm, including averages for spring/summer vegetation seasons (April, May, June) and abnormal yearly rainfall data for Ukrainian meteorological stations in the agricultural zone (135 stations) are shown at Fig. 4.

The analysis results suggest a week positive trend of growing soil moisture and annual precipitation in Ukraine in the period from 1990 to 2010.

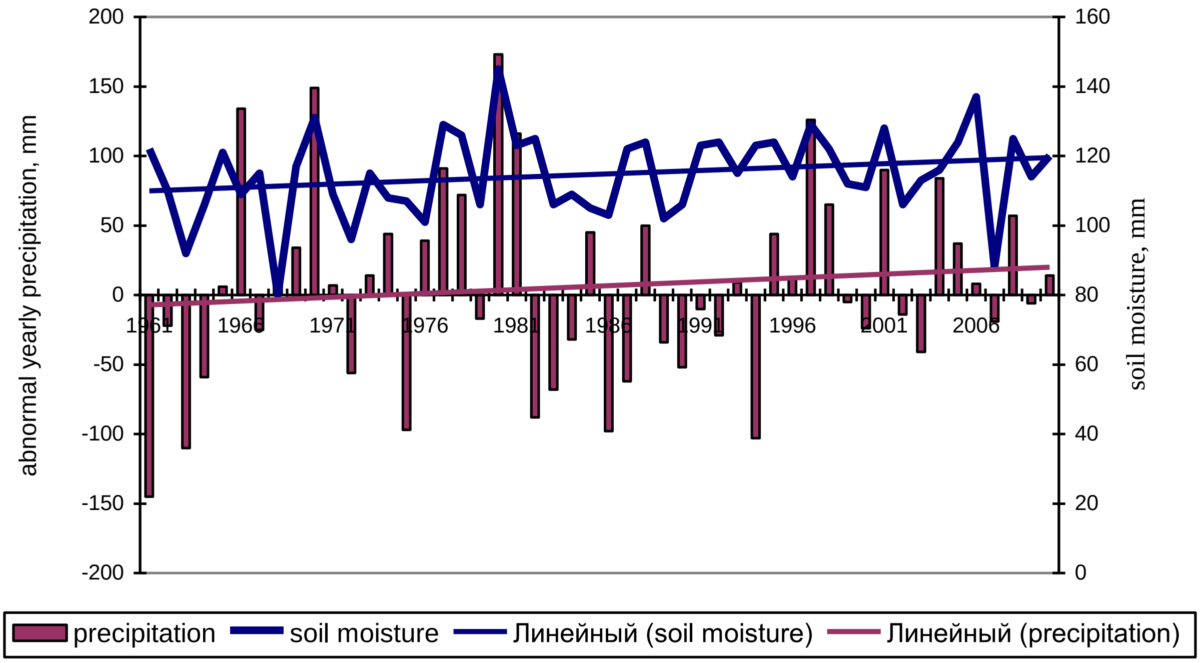


Fig. 4 Abnormal precipitation and soil moisture data of continuous observations in Ukraine. 1961 -2010

3.1.2 Changes in soil moisture by decades according to meteorological stations located close in the Ukrainian part of the Dniester Basin

Heavy spring/summer droughts cause particularly serious damages to grain crops at the territory of Ukraine. In this connection, we used soil moisture data for periods from May 20 to June 20. These dates are associated with crucial plant growth periods of decisive importance to eventual crop yields of winter wheat and spring barley (main grain crops of Ukraine). Winter wheat fields cover 30 - 40% (8 million ha), and spring barley fields cover about 20 - 25% (4 million ha) of the overall area of cultivated land in Ukraine. In such crucial periods of growth the plants consume maximal amounts of water. If these crucial periods coincide with droughts, crop yields fall dramatically.

See the analysis results in Table 1 and Fig. 4, 5, 6 and 7.

Table 1. Dynamics of soil moisture, by decades, in the soil layer from **0 to 20 cm** at winter wheat fields. Meteorological stations located nearby the Dniester basin

a) by May 20

		Decades				
Meteorological stations	**Normal**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
	Soil moisture, mm					
Striy	41	38	44	43	38	37
Dolina	47	49	52	41	28	38
Berezhany	26	22	32	25	26	24
Chertkov	29	25	34	27	34	32
Novaya Ushitsa	31	32	30	31	23	22
Mogilev-Podolskiy	19	25	18	15	14	22
Kamenets-Podolskiy	20	22	23	14	34	29
Zatishie	17	17	18	16	13	17
Razdelnaya	15	18	14	15	16	8

b) by June 20

		Decades				
Meteorological stations	**Normal**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
	Soil moisture, mm					
Striy	43	36	46	37	43	39
Dolina	51	50	58	44	33	38
Berezhany	27	30	30	28	23	26
Chertkov	30	23	35	33	37	32
Novaya Ushitsa	29	22	32	27	30	24
Mogilev-Podolskiy	17	22	15	17	17	16
Kamenets-Podolskiy	21	23	24	22	34	28
Zatishie	13	14	11	15	14	14
Razdelnaya	11	12	7	14	10	9

Table 2. Dynamics of soil moisture, by decades, in the soil layer from **0 to 100 cm** at winter wheat fields. Meteorological stations located nearby the Dniester basin

a) by May 20

		Decades				
Meteorological stations	**Normal**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
	Soil moisture, mm					

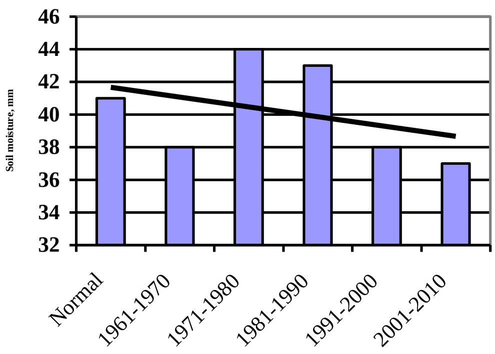
Striy	228	218	234	243	225	208
Dolina	210	220	253	204	176	201
Berezhany	150	136	158	160	149	150
Chertkov	153	134	174	152	152	144
Novaya Ushitsa	132	154	144	139	122	104
Mogilev-Podolskiy	123	144	124	105	116	135
Kamenets-Podolskiy	130	123	134	104	141	126
Zatishie	98	100	89	106	84	106
Razdelnaya	88	93	82	89	93	68

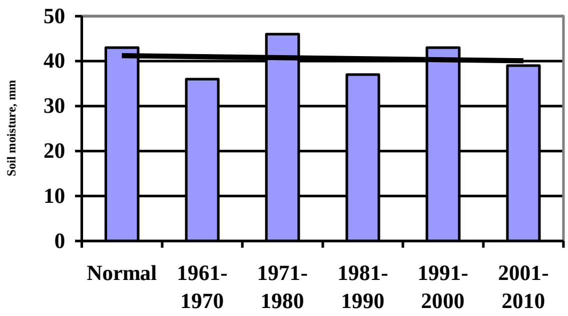
b) by June 20

		Decades				
Meteorological stations	**Normal**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
	Soil moisture, mm					
Striy	216	180	217	230	223	200
Dolina	200	219	204	189	168	194
Berezhany	139	126	143	146	134	140
Chertkov	133	104	154	141	157	143
Novaya Ushitsa	105	135	106	109	89	63
Mogilev-Podolskiy	102	115	86	100	105	106
Kamenets-Podolskiy	116	106	100	99	125	118
Zatishie	67	69	57	76	54	73
Razdelnaya	62	62	56	68	66	55

Fig. 5 and 6 illustrate dynamics of productive soil moisture in topsoil (**0 - 20 cm)** by decades (1961 - 2010) at winter wheat field by May 20 and June 20 for **the most "wet" and the most "dry" meteorological stations.**

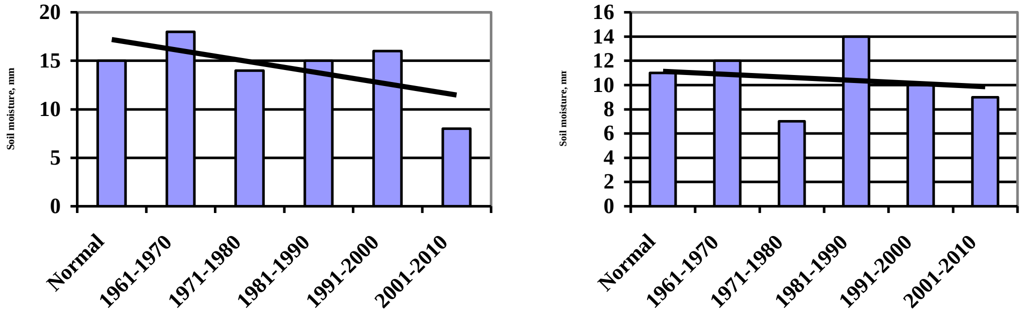
Normal = the average soil moisture for the period from 1961 to 1990**.**





a) May 20 b) June 20

Fig.5 Striy meteorological station - Lvovskaya oblast



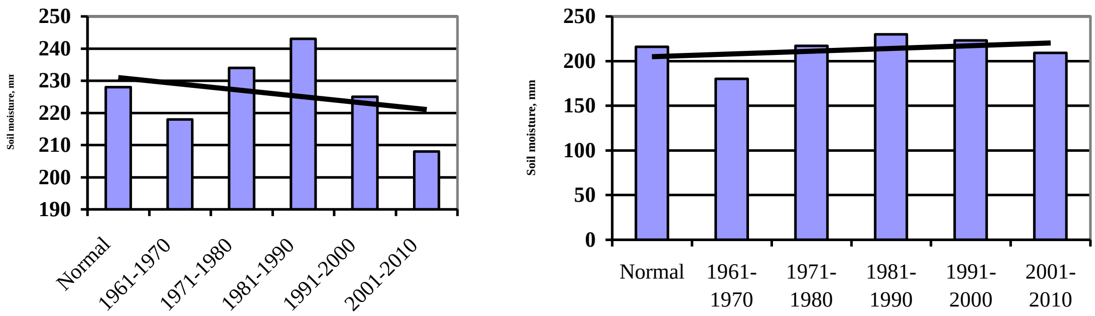
a) May 20 b) June 20

Fig. 6 Razdelnaya meteorological station - Odesskaya oblast

Analysis of decades-averaged soil moisture data for the topsoil layer (0 - 20 cm) suggested that no substantial changes were observed in the period from 1961 to 2010. Productive soil moisture deposits in the topsoil layer at winter wheat fields were found to vary close to the normal level for all the decades considered.

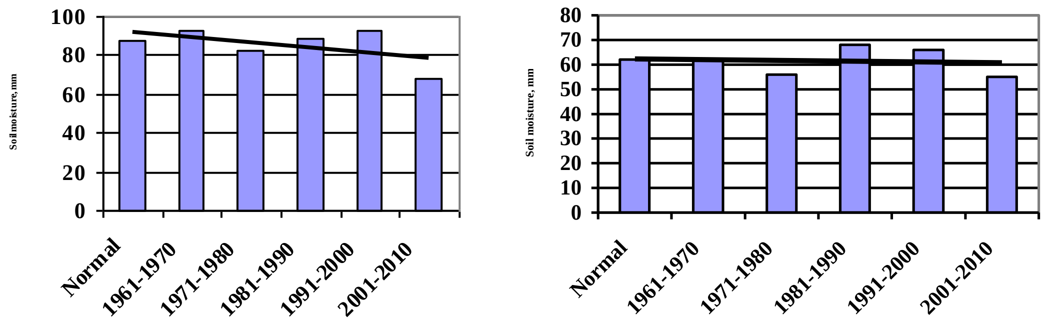
However, in the case of Western meteorological stations (Striy) located nearby the Dniester basin and Southern meteorological stations (Razdelnaya), a trend to decrease of May soil moisture data was observed for 2 decades (1991 - 2000 and 2001 - 2010). The average decrease reached 7 to 10%. In June, relevant changes were not substantial.

Fig. 7 and 8 illustrate dynamics of productive soil moisture in 1 metre soil layer (0 - 100 cm) by decades (1961 - 2010) at winter wheat field by May 20 and June 20 for the most "wet" and the most "dry" meteorological stations.



a) May 20 b) June 20

Fig. 7 Striy meteorological station - Lvovskaya oblast



a) May 20 b) June 20

Fig. 8 Razdelnaya meteorological station - Odesskaya oblast

In mid-May, in 1 metre soil layer, some soil moisture decrease was observed at meteorological stations in the Dniester basin. In the decade from 2001 to 2010, the average decrease reached 10 - 20%. In June, almost no changes were observed. In the case of Southern meteorological stations, soil moisture was found to decrease by 20% below the normal level in May and by 10% in June.

3.1.3 Soil moisture changes by agro-climate zones

The analysis results are shown in Tables 3, 4 and at Fig. 9,10,11,12, 13,14.

Table 3. Dynamics of soil moisture, by decades, in the soil layer from **0 to 20 cm** at winter wheat fields. Agro-climate zones of Ukraine.

a) by May 20

		Decades				
Agro-climate zones	Normal	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
	Soil moisture, mm					
Steppe	16	14	17	13	13	12
Forest-steppe	18	17	20	17	17	22
Marshes	32	33	31	31	29	31

b) by June 20

Agro-climate zones	Normal	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
	Soil moisture, mm					
Steppe	12	14	11	12	12	10
Forest-steppe	16	17	17	19	16	16
Marshes	26	23	26	28	26	26

Table 4. Dynamics of soil moisture, by decades, in the soil layer from **0 to 100 cm** at winter wheat fields. Agro-climate zones of Ukraine.

a) by May 20

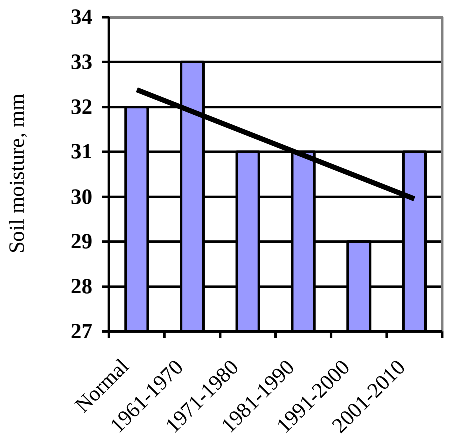
		Decades				
Agro-climate zones	Normal	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
		Soil moisture, mm				
Steppe	88	90	89	79	80	79
Forest-steppe	104	95	109	108	112	118
Marshes	152	158	149	147	151	162

b) by June 20

Agro-climate zones	Normal	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
	Soil moisture, mm					
Steppe	58	57	52	53	55	51
Forest-steppe	68	67	72	75	75	80
Marshes	119	115	120	121	132	141

In terms of agro-climate zones, the following specifics were found:

1. Marshes/woodlands - (a zone of sufficient and excessive soil moisture levels) a trend to decrease of soil moisture in the soil layer from **0 to 20 cm by May 20** was observed. In the soil layer from **0 to 100 cm** changes by May 20 were negligible.



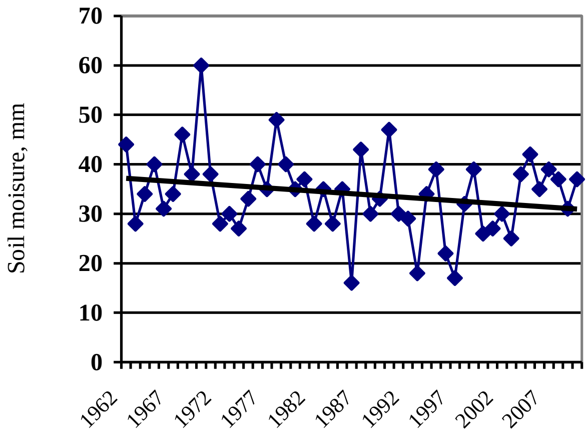


Fig. 9 Dynamics of soil moisture in marshes/woodlands zone, by decades, in the soil layer from **0 to 20 cm**, by May 20

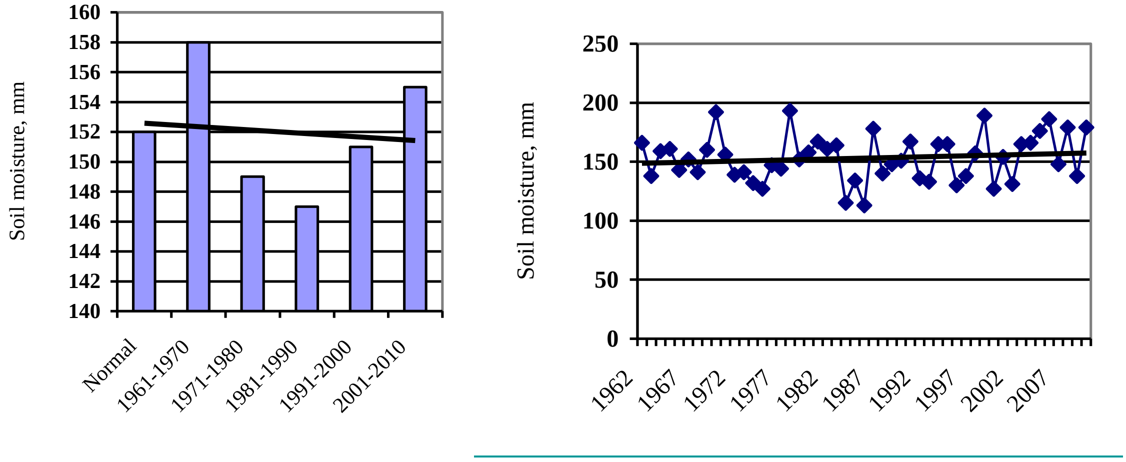


Fig. 10 Dynamics of soil moisture in marshes/woodlands zone, by decades, in the soil layer from **0 to 100 cm**, by May 20

2. Forest - steppe (a zone of unsustainable soil moisture levels) a trend to soil moisture increase in soil layers from **0 to 20 cm** and **0 to 100 cm** by May 20.

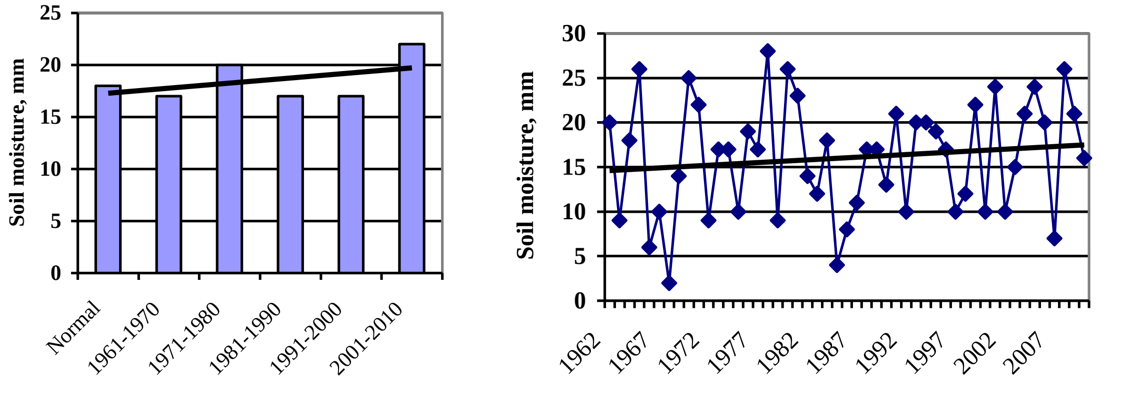


Fig. 11 Dynamics of soil moisture in forest - steppe zone, by decades, in the soil layer from **0 to 20 cm**, by May 20

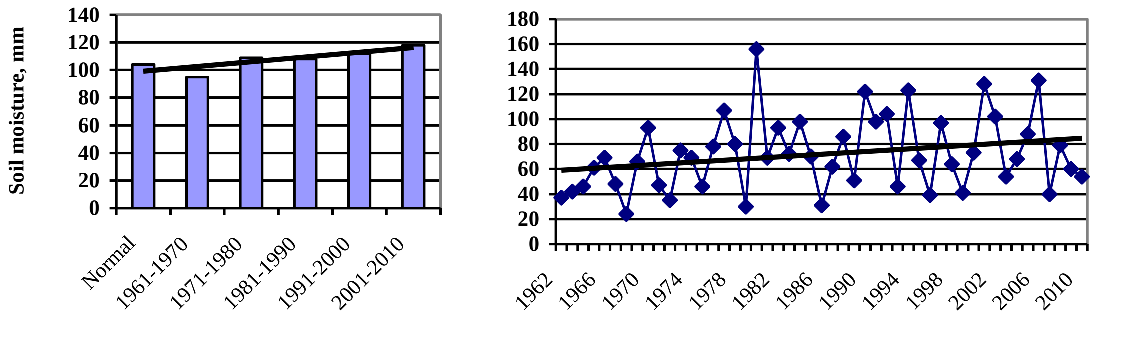


Fig. 12 Dynamics of soil moisture in forest - steppe zone, by decades, in the soil layer from **0 to 100 cm**, by May 20

3**. Steppe zone** (a zone of insufficient soil moisture) a trend to soil moisture decrease by May 20 was observed in soil layers of **0 to 20 cm** (by 15 - 20%) and of 0 to 100 cm (by 10 - 15%).

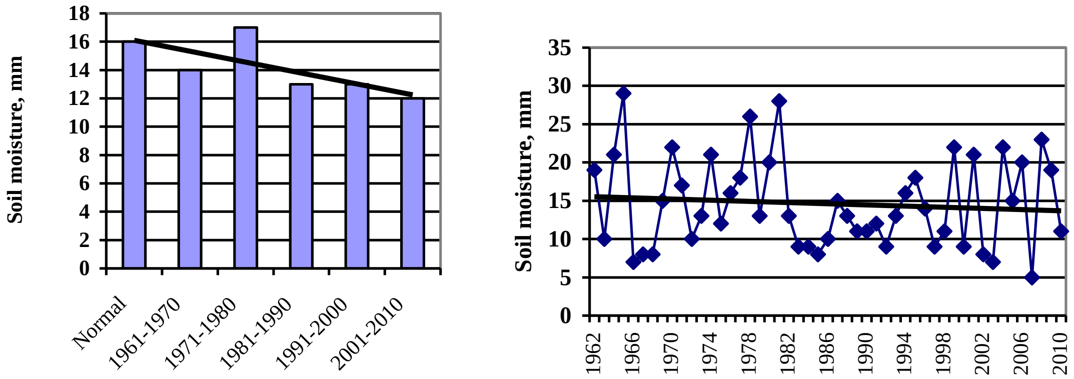


Fig. 13 Dynamics of soil moisture in steppe zone, by decades, in the soil layer from **0 to 20 cm**, by May 20. The trend to decrease by 15 - 20%.

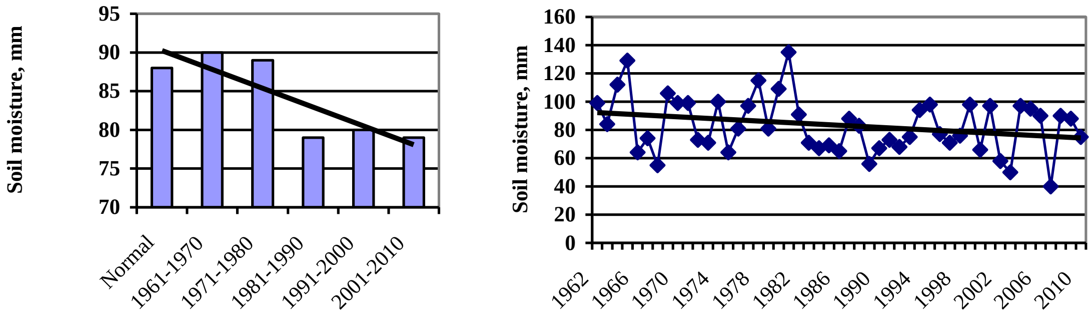
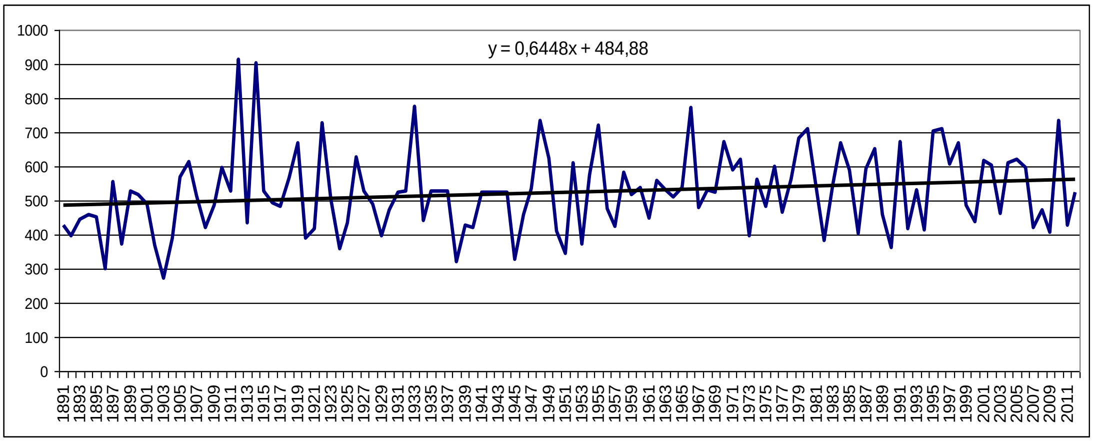


Fig. 14 Dynamics of soil moisture in steppe zone, by decades, in the soil layer from **0 to 100 cm**, by May 20

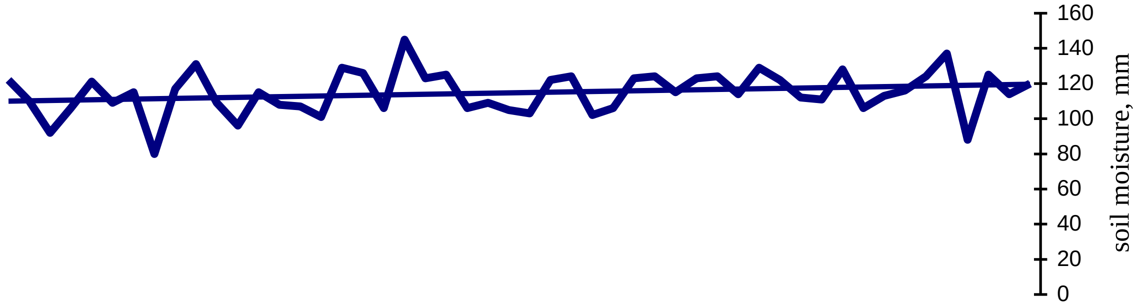
3.2 Moldova

Soil moisture data for the period from 1961 to 2010 in soil layer from 0 to 20 cm, including averages for spring/summer vegetation seasons and abnormal yearly rainfall data for Moldavian meteorological stations in the agricultural zone (7 stations) are shown at Fig. 3.1.1

Annual precipitation in the Dnester basin



Data on soil moisture are presented on fig 3.1.2. and refer for the period 1961 – 2011



Analysis of presented data shows slight growing of moisture content in soils in Moldavian part of the Dneste basin. At the same this trend is rather suspicious because of short period of observations time, more intensive agricultural practices, which are recently applied and changes of temperatures fro last 20 years (increasing for 1 degree and more than 1,5 degrees in the southern part of Moldova), especially in summer period.

3.2.2 Changes in soil moisture content in the Moldavian part of the Dniester basin

Recent climate change developments in Moldova show that droughts can cause serious damage to the agricultural crops in the spring period and also this phenomena is becoming more frequent for the beginning of the summer period thus affecting developing of crops, especially cereals and maize. Based on that some data on soil moisture content under these crops were collected and presented in the table 3.2.1.

Table 3.2.1. Moisture content in soils in different parts of Moldova (May-June)

		Decades

Meteorological stations	**Normal**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
	Soil moisture, mm					
Northern part of Moldova	41	39	46	47	41	38
Central part	38	39	42	44	39	35
Southern part	27	24	29	27	26	23

Analysis of averaged soil moisture data for the arable strata (0 - 20 cm) does not show significant changes for the period 1960-2010. Probably this is due to the increasing of annual level of precipitations for last 50 years. At the same time, integrated data on severe drought events in 2007 and 2012 are not available yet greater changes in soil moisture, especially for summer period. However decreasing soil moisture content in northern – southern direction in Moldova is obvious and temperature increasing in the south in recent years is more visible. This means that moisture content in arable lands in the southern part of Moldova will cause its deficit and additional measures for moisture conservation in this region of Moldova will be very urgent. At the same time soil moisture is a very variable value and more observations are needed for planning of relevant activities.

At the same period (2000-2012), moisture rezervs in soil at the depth of 20 cm could be estimated as optimal ones. The limit of 5 mm, is considered as a stress level for seeding of the winter wheat. Such level of moisture cotent was met only 5 times in the northern part of Moldova and 2 tmes in the south of the country (table 3.2.2)

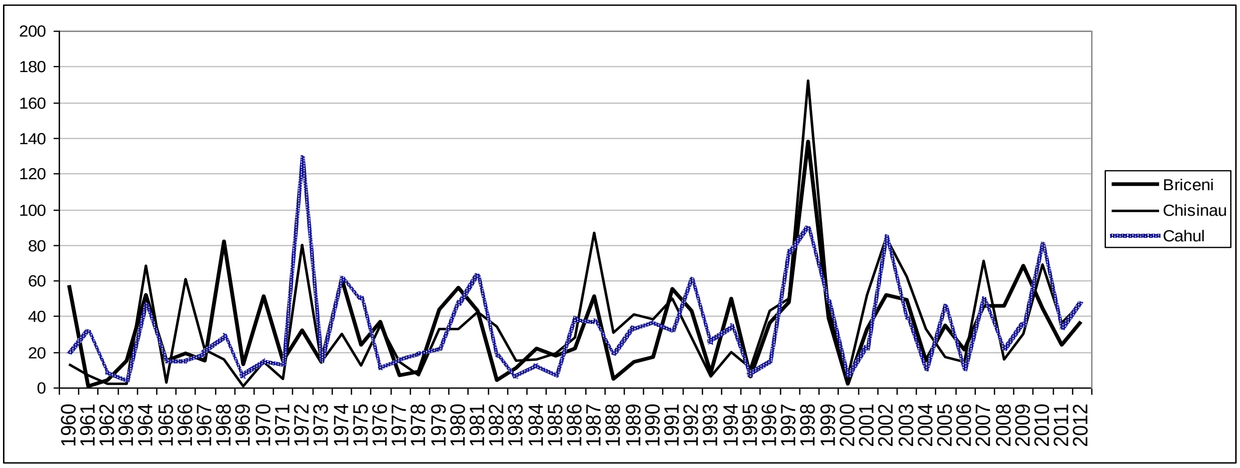
Tabel 3.2.2. Frecvency and limits of the variability of the moisture rezerves in soil in september at the depth of 20 cm in mm

Briceni (northern part of Moldova)		Cahul (southern part of Moldova)	
Limits of variabilityi	*Frecvency*	Limits of the variability	*Frecvency*
8,4 -19,8	14	8,6-17,1	6
19,8 -31,3	8	17,1-25,7	8
31,3-42,7	6	25,7-34,3	11
42,7 – 54,1	1	34,3-42,8	4
54,1	1	42,8-51,4	6

Data estimation on the soil moisture content in Ocotber is presented on fig. 3.2.1. based on data presented quantity of the atmospheric precipitations in the period 2000-2012 increased and moisture rezerves in soil are in optimal limits.

mm

a



b

mm

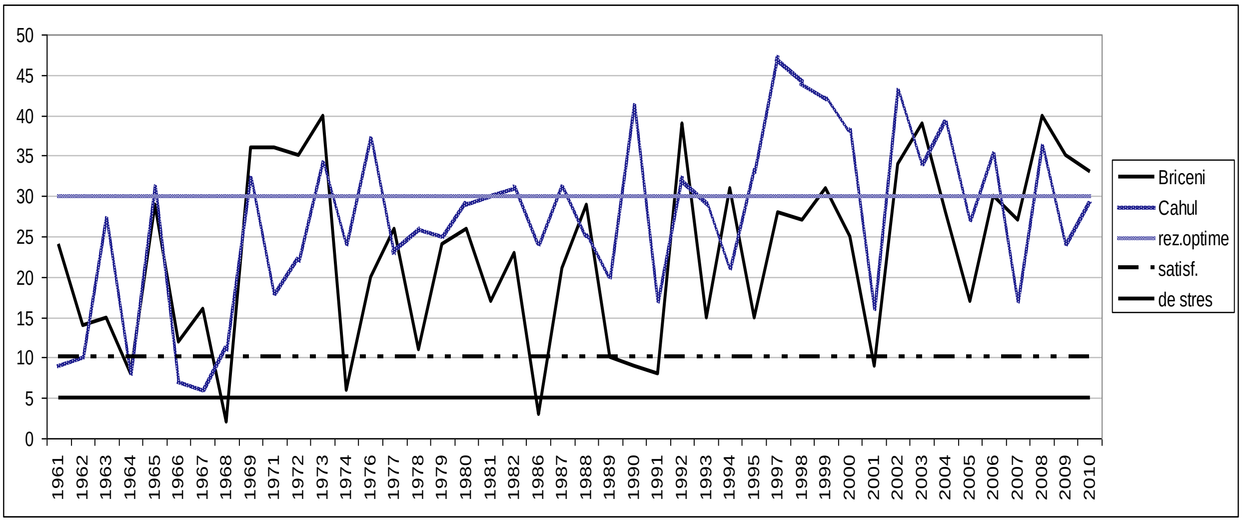


Fig.3.2.2. Evolution of the average monthly precipitations (a) and moisture rezerve in soils (b) under seeding of the winter wheat in october (o-20 cm)

Analysis of the variability of the soil moisture content at the depth 0-20 cm is presented in table 3.2.3

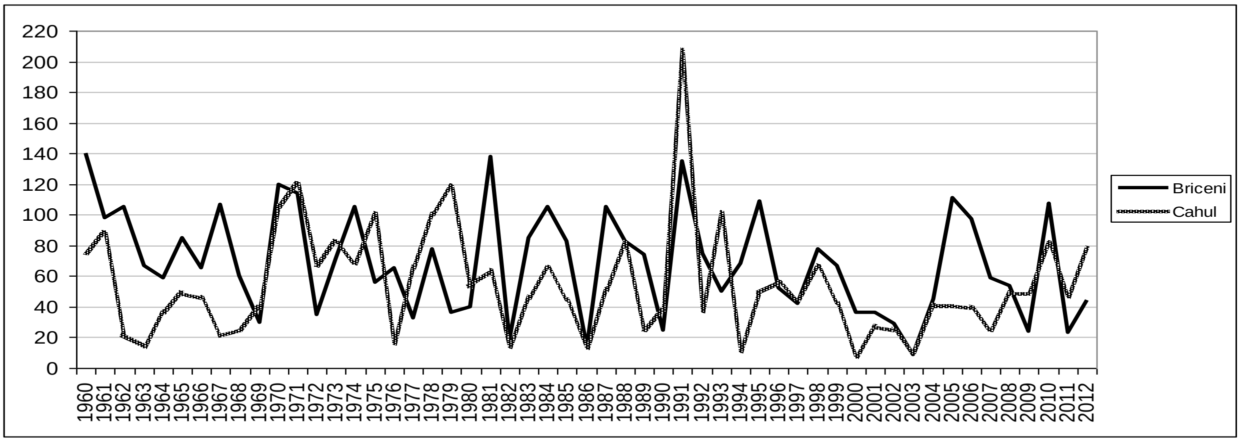
Tabel 3.2.3. Frecvency and limits of the variability of soil moisture in october at the depth of 0-20 cm

Briceni (northern part)		Cahul (southern part)	
Limits of variability in mm	*Frecvency*	Limits of variability in mm	*Frecvency*
7,1- 14,3	8	7,1 – 14,3	4
14,3- 21,4	8	14,3- 21,4	6
21,4 - 28,6	10	21,4 – 28,5	10
28,6- 35,7	9	28,5-35,7	13
35,7 - 42,8	6	35,7 – 42,8	6

Evolution of the monthly precipitation (a) and moisture rezervs in soils under wheat (b) at the epth of 100 cm in May is presented in fig 3.2.4. data obtained indicate decreasing of the moisture rezerves in soils in the southern part of Moldova in the period 2000-2012.

a

mm



b

mm

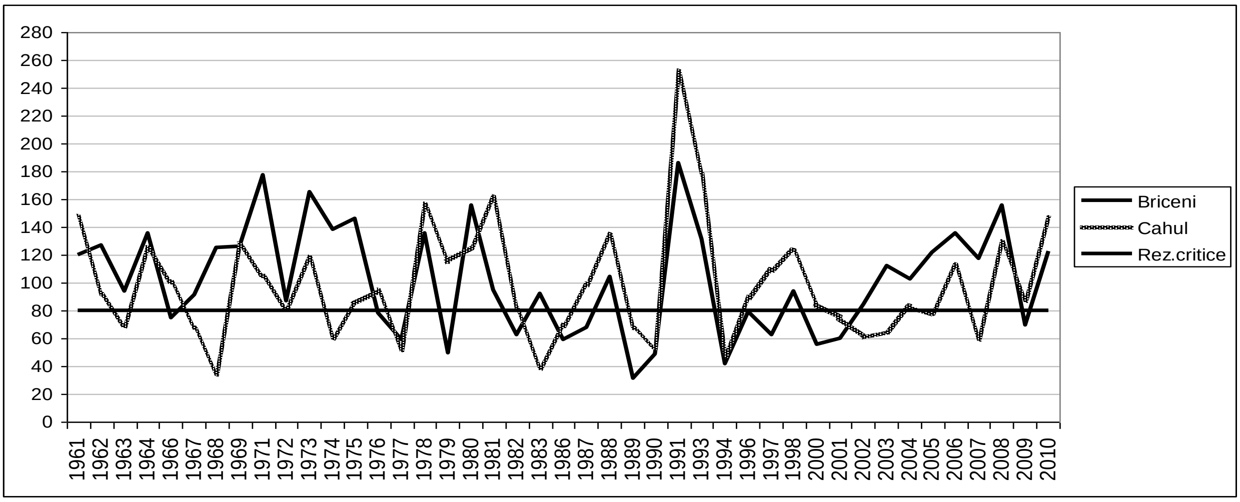


Fig. 3.2.4. Evolution of the monthly precipitations (a) and rezerves of moisture in soils under seeding of winter wheat (b) at the depth of 100 cm in May

Conclusions

4.1 Ukraine

The study was dedicated to review of changes in soil moisture with breakdown by meteorological stations, by agro-climate zones and for the whole territory of Ukraine. The analysis was conducted for the spring/summer season (April to June) and for the dates of crucial importance for crop yield.

The study results suggest that the process of soil moisture accumulation is of a complex pattern and directly depends on substantial variability of the main source of soil moisture - i.e. precipitation.

Notwithstanding that, some global warming models forecast summer soil desiccation; so far, results of observations in Ukraine do not provide evidence in their favour. At the whole territory of the country, a weak trend to increase of soil moisture in 1-metre soil layer was observed.

Notwithstanding that, the warming processes in Ukraine are more intensive comparatively to average parameters for the Northern hemisphere, in some regions of Ukraine a trend to growth of soil moisture is observed. Such developments may be attributed to falling solar insolation due to aerosol pollution in the troposphere (with associated direct and indirect impacts on short-wave radiation). As a result, trends to decrease of evaporation, to growth of the ground-level temperatures and soil moisture levels are observed.

Besides that, the study results do not confirm conclusions on growing aridity made at the base of Palmer indices [6] and cannot be attributed solely to changes in the ground-level air temperature and precipitation levels. The study results confirm the earlier made conclusions on soil moisture in Ukraine [8].

The observed changes in soil moisture in the course of drought development do not demonstrate a clear pattern. Growing air temperatures inevitably result in more intensive evaporation and - as a result - in higher soil moisture deficiency that may increase or decrease depending on precipitation levels. In 2 recent decades, some annual precipitation growth was observed in Ukraine. However, in temporal terms, the growth is not evenly distributed annually. Moreover, some growth of poorly efficient annual precipitation was observed.

In soil moisture time series for 0 - 20 cm (active layer) and 1-metre soil layers in woodlands/forest-steppe zones, a weak positive trend was observed, while in steppe zone a negative trend was revealed. According to data of the meteorological stations located nearby the Dniester basin, in the period from 1991 to 2010, soil moisture data for 1-metre soil layer were by 10 to 20% lower than the normal level (these developments may suggest climate change in the Dniester basin). Positive soil moisture change trends suggest that general soil moisture levels in forest-steppe and woodlands zones at least did not change. However, declining soil moisture levels in steppe zone reveal very negative aspects of climate change. Unless use of irrigation, the decline may result in adverse impacts on major cultivated land areas in Southern regions of the country.

Irrigation is the most efficient tool for addressing droughts-related problems, particularly in the case of soil droughts. However, irrigation is a fairly expensive option, as a result, it is impossible to implement irrigation at all territories of Ukraine prone to droughts. Besides that, a long-term application of irrigation results in soil degradation, secondary soil salination, loss of calcium and adverse soil structure changes. However, the most serious shortcoming of irrigation is associated with the facts that cannot guarantee complete protection on plant cultivation from droughts. In this connection, adaptation of agricultural practices to specific aridity conditions seems to be a more efficient option. Moreover, plant cultivation science and practices offer a broad range of agro-meteorological, biological and agro-technical methods allowing mitigating adverse impacts of droughts.

Notwithstanding that observation data for 50 years do not suggest a trend to a substantial decrease of soil moisture levels, droughts-related damages in Ukraine tend to increase gradually. It seems possible that an understanding of the on-going aridity changes would require application of well-developed models that might adequately account for multiple physical factors and their interactions. Besides that, it is necessary to analyse changes in length of warm seasons, dates of snow cover loss/formation and other parameters.

There are some uncertainties associated with forecasts of precipitation levels in Southern regions of Europe for the nearest decades, as noted in [8]. According to some scenarios, total annual precipitation levels at the territory of Ukraine are expected to grow in XXI century (particularly in winter seasons). In Southern regions, some minor decrease of precipitation levels may be expected in summer seasons.

The degree of uncertainty of forecasts of precipitation levels' decrease in the nearest decades is rather high. Less than two thirds of models predict changes at the level of one order of magnitude. In paper [9], computer GCM simulations for 100 years suggested that high precipitation periods are more easily predictable than droughts. In arid conditions, changes in soil moisture levels may result in higher changes of evaporation's intensity, comparatively to wet climate conditions. General atmosphere and ocean circulation models are main instruments that allow assessing changes in preconditions for development of droughts. Some climate change scenarios suggest that further climate warming would result in growth of convective precipitation levels and in reduction of precipitations from stratus clouds, these phenomena are of substantial importance for development of soil droughts [9].

In recent decades, satellite observations became rather commonly used for assessment of soil moisture levels in the topsoil layer. Satellite surveillance data allow registering changes in soil moisture with daily temporal resolution. Now, satellite surveillance data for more than 30 year have been already collected (http://www.ghcc.msfc.nasa.gov/landprocess). Application of satellite surveillance data for analysis of soil moisture regimes would require a joint review with parallel use of terrestrial observation results (e.g. ground level air humidity and temperature, vegetation parameters, precipitation levels and other variables).

4.2 Moldova

Presented data are based on the analysis of existed information on moisture content in soils for northern, central and southern parts of Moldova according to the agroclimatical zonation of the country.

The results of the study showed strong variability in the soil moisture content, which depends on the climatic patterns characteristics. Climate change issues significantly affect moisture content in soils and thus could affect social and economic development f the country.

Actual trends in soil moisture show slight increasing of its content. Anyway actual climate change trends can cause its reducing, especially in the summer period and in the periods crucial for crops development. Moisture content in soils is a very variable ingredient and depends on current conditions of precipitations and temperature. The most affected region in Moldova due to the climate change is southern part and additional data on moisture content in soils and surface soil temperature under different crops are needed for more relevant estimations, especially for the period of last 5-7 years. It is especially important due to the development of irrigation system in different parts of Moldova for the period until 2020.

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