# CLIMATE EFFECTS AND THE EXTENT OF DRYNESS IN REPUBLIC OF MOLDOVA

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***Abstract***

*The paper aims to present the relation between climate effects and the extend of dry lands due to desertification and draught. First of all moisture divides the country into wet sub humid and dry sub humid regionsbut in most partsthe extent of aridity tends to be regional or even local. Secondly huge portions of the country is under a high risk of land degradation this together with draught bring significant economic losses and distress. The main drought indexes are presented as well as proposing a new Drought and Aridity Index in the context of forecasting using a six month analysis of a twelve year time span. The conclusions reached made it obvious that reduced rainfall in the summer and autumn periods against a background of rising temperatures will cause a strong precipitation deficit and sequential increase of the potential evaporation. Furthermore, future prospect suggest that Moldovan climate is likely to be more arid with a higher drought incidence by the 2080s.*

**Key words:** dryness, drought, moisture, Drought and Aridity Index, precipitation

## INTRODUCTION

In the extent of drylands and Desertification/Drought Sensitive Areas (DDSAs) it is widely known that general dryness of climate is one of the main factors in developing desertification processes and drought phenomenon. In the dryland areas the balance of production and consumption often depends on moisture conditions and, at times, extreme water deficiency can have a dramatic impact reaching the scale of environmental and socio-economic disasters. One must have in mind that droughts can lead to natural disasters, due to the damages produced by them (Man et al., 2008).

## MATERIAL AND METHOD

The United Nations Convention to Combat Desertification's approach defines drylands as the areas with a dryness climate and with the ratio of annual precipitation to potential evapotranspiration (P/PE) between 0.05 and 0.65. According to the estimates (based on the average values within the landscape region), the Moldovan landscapes relate to two moisture zones: wet sub humid with P/PE>0.65 (The north of the country and part of elevated Codrii region) and wet dry sub-humid lands (Balti region and plain regions in the south and south-eastern part of Moldova) with the UNCCD index of 0.50-0.65 (Daradur et al., 2015). Furthermore, climatic data from the last century point out a progressive atmospheric warmth and a significant drop of rainfal quantities.

*Table 1*

The ratio between the accumulated precipitation and evapotranspiration estimates within landscape regions of the Republic of Moldova (Growing period, 1950-2012)

| Natural zone | Landscape region | Precipitation P, mm | Evaporation, E, mm | UNCCD Aridity Index/Class of lands |
|---|---|---|---|---|
| A. Forest-steppe zone | *I.Region of elevations and forest steppe* | *393* | *557* | *0.71 (Wet sub humid with AI > 0.65)* |
| | *II. Balti region of steppe elevations and plains* | *341* | *586* | *0.58 (Dry sub humid with AI =0.51- 0.65)* |
| | *III. Region of Codrii forest deviations* | *409* | *579* | *0.71 (Wet sub humid with AI > 0.65)* |
| B. Steppe Zone | *IV. Steppe plain region of the lower Nistru terraces* | *305* | *601* | *0.51 (Dry sub humid with AI =0.51- 0.65)* |
| | *V. Region of fragmentary plains of Bugeac steppe* | *315* | *605* | *0.52 (Dry sub humid with AI =0.51- 0.65)* |

At the same time, in the complex terrains of the Republic of Moldova the extent of aridity tends to be regional or even local, particularities of which are not accurately and uniquely captured by the observation network system (Daradur, 2001; Neadealcov et al., 2013). To produce accurate spatially-distributed estimates of the extent of drylands, quantified values of the geographical and topographical factors derived for a 90 m x 90 m gridded surface have been used. Statistical and spatial interpolation has been implemented to be effective in identifying and mapping *Desertification and Drought Sensitive Areas* (DDSAs) at high resolution

About three fourths - 75.5% (11.9% semi-arid and 63.6% dry sub-humid areas) of the Moldovan territory are under high risk of degradation processes. In accordance with the estimates at high resolution the biggest part of the Moldovan territory (63.6%) relates to the dry land category with the *dry sub-humid climate* (values of the P/PE=0.50-0.65). *Wet sub humid lands* (P/PE>0.65) with relatively favourable moisture conditions cover 24.5% of the Moldovan territory in the north and in the elevated areas in the central parts of Moldova. Spatially-distributed estimates at high resolution also delineate the areas with the UNCCD index of less than 0.50 which relate, according to the UNCCD classification, to the *semiarid land classes* with a highest risk of desertification processes and drought (Daradur et al., 2014). These lands cover 11.9% of the total area, located in the southern and south-eastern parts of the country predominantly with poor rural population and are the most vulnerable to desertification. Lengthy dry spells, combined with high temperatures, especially in late summer, create a great challenge for the environment and all development sectors in these regions.

Statistic says that 85.4% of population of Moldova dwell in the drylands. All administrative districts of the Republic of Moldova are sensitive to some extent (from 6% to 100%) to degradation processes. Taking into consideration high concentration of poor rural population and weak economic capacity of the most prone areas, improved climate risk monitoring and management is critical for supporting sustainable development and poverty reduction in the Republic of Moldova.

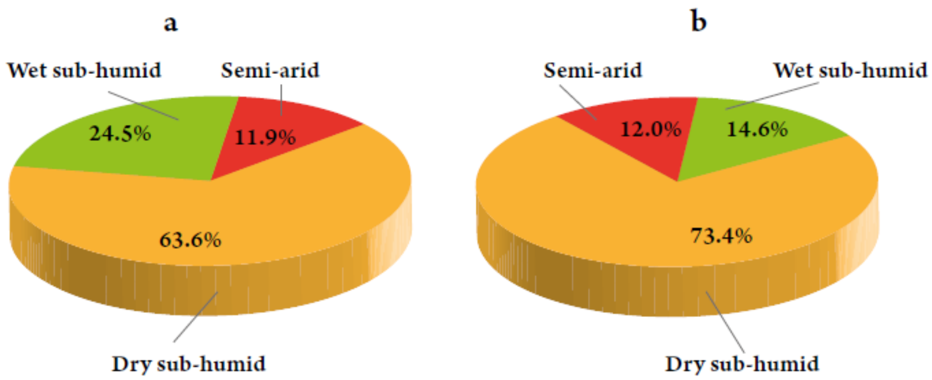


Fig. 1 Extent (%) of drylands (a) and population (в) of Moldova's drylands
(Source: Daradur et al., 2015)

Regarding drought: monitoring, early warning and data systems together with the reduction of their negative effect involves sustained efforts to monitor climatic phenomena (Sabau et al., 2015).

The natural and socio-economic subsystems of the Republic of Moldova are highly vulnerable to drought owing to the high level physical exposure to water related climate extremes, as well as insufficient capacity to manage risks. Accounting for 13% of the total number of hazards, droughts make up 67% of the economic losses from weather and climate related risks. The agricultural drought is recurrent to the meteorological drought and installs as a direct consequence for the lack of rainfall and evapo transpiration phenomena intensification (Armas et al., 2016b).

The State Hydrometeorological Service (SHS) of the Ministry of Environment (ME) is the main institution that carries out monitoring and provides most of the early warning services for drought risk planning in Moldova. Currently the monitoring of key meteorological parameters for drought assessment (precipitation, temperature, soil moisture, etc.) is carried out on 17 weather stations and 20 agrometeorological posts.

Several drought indices are applied in the Republic of Moldova: Hydrothermal Coefficient, HTC (Selyaninov, 1958), Standardized Precipitation Index, SPI (McKee et al., 1993), Standardized Temperature and Precipitation Index, STPI (Pedi, 1975), and Drought and Aridity Index, DAI (Daradur, 2001). However, lack of a consistent statistical basis to assess drought conditions, and of comparability of the drought categories among the indices make it challenging to achieve the desired monitoring and management goals (Daradur et al., 2015).

*Table 2*

Drought indicators used in the Republic of Moldova

| | Drought indicator name/abbreviation | Designing concept | Advantages | Disadvantages | Area of current applications |
|---|---|---|---|---|---|
| 1. | **Hydro-Thermal Coefficient, HTC (Selyninov, 1958)** | *Water supply and demand concept* | *Complex approach; Multi-scalar* | *No consideration of distributional aspects of precipitation; Inadequate assessment of extreme drought categories in a long time scale (6 month and more); Weak sensibility to climate change* | *Global, regional* |
| 2. | **Standardized Temperature and Precipitation Index,** STPI (Pedi, 1975) | *Water supply and demand concept* | *Complex approach; Easy to calculate Multi-scalar; High sensitivity to climate change; Relates to probability* | *Overestimation of temperature factor; Inadequate assessment of extreme drought categories in a short time scale (1-3 months); No consideration of distributional aspects of precipitation* | *Regional* |
| 3. | **Standardized Precipitation Index,** SPI (McKee et al., 1993) | *Precipitation based concept* | *Simplicity; Easy to calculate Standardized nature; Multi-scalar; Relates to probability* | *No consideration of evapotranspiration; No consideration of distributional aspects of precipitation; Inadequate assessment of extreme drought categories in a short time scale (1-3 months); Weak sensibility to climate change* | *Global, regional* |
| 4. | **Drought and Aridity Index (Daradur, 2001)** | *Water supply and demand concept* | *Complex approach; Incorporates distributional properties of precipitation; Easy to calculate Multi-scalar; High sensitivity to climate change; Relative, absolute and standardized form; Relates to probability* | *Requires calculation of variation of rainfalls within designed time scale* | *Regional* |

New drought products for drought risk assessment and management needs to be found and establishing a new Drought and Aridity Index (DAI) is a priority. Unlike the one already in use, the introduced Drought and Aridity Index (DAI) incorporates temporal properties of precipitation over designed time period that is one of the fundamental aspects of climate at any location, particularly in the dry areas with an uneven precipitation and high risk of drought (Daradur, et al., 2007).

The DAI is designed on the water balance concept with the original ratio:***DAI = ΣP*PDC /ΣPE,*** and a difference (Precipitation Deficiency, PD) form: ***PD =ΣP*PDC - ΣPE***, where ΣP is accumulated Precipitation; ΣPE – accumulated Potential Evapotranspiration; PDC – Precipitation; Distribution Coefficient. The resulting index, with its limits, permits climate classifications and therefore, it is a convenient tool for aridity and drought evaluation across locations. The DAI with the values:

- *close to 1* indicates water balanced climate conditions
- *DAI >1* meets wet climate conditions, and
- *DAI with the values <1* indicates dry climate conditions.

The obvious case of *how the DAI works* is given below in the tabulated form, where a comparative assessment of a response to distributional differences of hypothetical precipitation data is shown.

*Table 3*

How the DAI works (Comparative response of various drought indices to hypothetic drought conditions)*

| Month of the growing period | SCENARIOS Amount of precipitation, mm | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| April | *50* | *60* | *75* | *100* | *150* | *300* |
| May | *50* | *60* | *75* | *100* | *150* | - |
| June | *50* | *60* | *75* | *100* | - | - |
| July | *50* | *60* | *75* | - | - | - |
| August | *50* | *60* | - | - | - | - |
| September | *50* | - | - | - | - | - |
| | | | | | | |
| ΣP | *300* | *300* | *300* | *300* | *300* | *300* |
| ΣPE | *600* | *600* | *600* | *600* | *600* | *600* |
| HTC | *1.0* | *1.0* | *1.0* | *1.0* | *1.0* | *1.0* |
| SPI | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* |
| P/PE | *0.50* | *0.50* | *0.50* | *0.50* | *0.50* | *0.50* |
| DAI | *0.46* | *0.45* | *0.43* | *0.42* | *0.37* | *0.0* |

**Note:** * *The accumulated synthetic values* ΣP=*300 mm of precipitation and potential evapotranspiration* ΣPE *=600 mm have been chosen for calculating indices to be close to multiannual average in the most drought prone areas of Moldova.*

**Scenarios:** *A – precipitation distributed evenly during each month of growing period; B – one month no precipitation;C – two months no precipitation; D – three months no precipitation; E – four months no precipitation;F - five months no precipitation*

Accumulated values of precipitation (***ΣP*** =300 mm that is close to multiannual amount for the most prone areas of the Republic of Moldova) are equal for all scenario cases, starting from smooth monthly increments (scenario A) to the extreme monthly distribution (scenario F). Note that the UNCCD index (P/PE), as well as other indicators (HTC, and SPI) provide no insight into temporal differences with equal precipitation. Conversely, the DAI demonstrates a clear response to changing distributional properties of rainfalls, gradually indicating an increase of the intensity and lasting dryness conditions with a high monthly distribution.

Despite the lack of long term tendency toward progressive aridization it must not be neglected because in the recent decade the frequency and intensity of droughts in Moldova have already increased. Furthermore, the risk represents assuming the hazard by the system (Armas et al., 2016b).

**RESULTS AND DISCUSSION**

The system of drought risk assessment and management are based on return time concepts associated with given extreme drought event's intensity and includes (Daradur et al., 2014): average return time or average recurrence interval - over a long period of time such an event is expected to occur on average once in N years, but any separate individual events may occur closer or further apart in time. Confident return time – means that drought event will occur precisely once within this time period with 95% and higher confidence.

Finite severity level of drought - the severity level of drought in the particular location that cannot be overcome in the current climate conditions. Probability of occurrence in any given year (1 time in N years).

Chance of occurrence in any given year (%).

*Table 4*

System of risk estimates for recent 6-month time scale drought in the Republic of Moldova based on DAI time series*

| Drought | Average return time (F(t)=0.50), N years | Probability of occurrence in any given year (1 time in N years) | Chance of occurrence in any given year (%) | Confident (as-sured) return time (F(t)=0.95) period, N years** | Economic losses *Million Moldovan Lei(MDL)* | Economic losses *Million US $* |
|---|---|---|---|---|---|---|
| *2000* | *7* | *1 time in 7 years* | *13* | *21* | 2098, 1 | 169,7 |
| *2003* | *8* | *1 time in 8 years* | *12* | *24* | - | - |
| *2007* | *217* | *1 time in 217 years* | *0.04* | *651* | 11970,0 | 987,0 |
| *2009* | *11* | *1 time in 11years* | *9* | *33* | - | - |
| *2012* | *9* | *1 time in 9 years* | *11* | *27* | 2500,0 | 200,5 |

*Note: Average return time or average recurrence interval - this does not surely mean that drought event will occur precisely once every N years. Over a long period of time such an event is expected to occur on average once in N years, but any separate individual events may occur closer or further apart in time. **Confident return time – means that drought event will occur precisely once within this time period with 95% and higher confidence. Source: Daradur et al., 2014

The analysis of the drought indicator time series spanning from 1946 to 2012 did not identify significant (at 95% or higher confidence level) long-term trends toward progressive aridization of Moldovan climate. The exception is the STPI which reveals a relatively low (P=0.09) presumption against neutral hypothesis.

That is due to overestimation of the contribution of temperature factor in creating drought conditions inherent for this index (Daradur, 2001). The test results where the average air temperature over growing period (TG) is included along with the moisture indices, might serve as a confirmation of this statement. In particular, the TG also shows an increasing trend, even with the stronger significance (higher than 95% of confidence level). Thus, excepting STPI and air temperatures, there is no evidence of natural aridization of the territory of Moldova. To a first approximation, the provided estimates suggest a stationary of the long-term dynamics of dryness conditions in the Republic of Moldova.

However, it is widely known that on the described background the variability of Moldovan climate has increased during the recent decades, droughts being considered as temporary drops in available water average quantities (Halbac, 2011). The estimates show that the number of extreme events that go far beyond the average state of climate has considerably increased. First of all, the increase relates to the incidences of extremely hot days. The time-depended dynamics of drought frequency reveals an important feature of drought variability in Moldova, which consists of *considerable* increase in drought occurrence starting from the ‘80s.

The more detailed estimates of the dynamics of durable (6-month time scale) droughts in the Republic of Moldova show considerable increase in their frequency in the recent decade (2000-2012). This serves as an illustrative confirmation of the experts community assessments that suggest shortening of the return time of droughts in the Republic of Moldova in the last decade confirmed by government officials. Just during the recent decade (2000-2012) Moldova has already experienced several (2000, 2003, 2007, 2012) droughts that have had a dramatic effects on environmental and development sectors of Moldova.

The most severe drought took place in 2007. The 2007 drought was a very rare event with the average return time of about 200 years and most devastating in Moldova’s living memory (Daradur et al., 2014). It affected 80% of the country’s territory and included widespread crop failures and food shortages with the total losses of about 2.5 billion MDL (Ministry of Agriculture and Food, 2012).

**CONCLUSIONS**

Regarding projected assessment of aridity and drought trends in the Republic of Moldova, it is likely that the above described trends of the drought dynamics will last over the century. For all three SRES emission scenarios worsening of the humidity conditions is expected throughout the territory of the Republic of Moldova. Reduced rainfall in the summer and autumn periods against a background of rising temperatures will cause the strong precipitation deficit and sequential increase of the potential evaporation during the XXIth century (Ministry of Environment of the Republic of Moldova, 2013). Potential evaporation will likely increase by 9-13% during the growing season in the 2020s, reaching up to 40-45% under the high emission scenario A2. A little lower estimates are under the low emission scenario B1. The obtained results suggest that Moldovan climate is likely to be more arid with a higher drought incidence by the 2080s.

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