UNCCD DROUGHT INITIATIVE

NATIONAL DROUGHT PLAN OF THE REPUBLIC OF MOLDOVA

Ministry of Agriculture, Regional Development and Environment

United Nations Convention to Combat Desertification

ecologistica

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CONTENT

LIST OF OBREVIATIONS

ACSA	National Agency for Rural Development
AEZ	Agro Ecological Zones
AI	Agricultural Insurance
AMP	Assistance Management Platform
CCAS	Climate Change Adaptation Strategy
CZI	China-Z Index
CIAT	International Center for Tropical Agriculture
SCPESD	State Civil Protection and Exceptional Situations Department
CRSI	Climate Risk Shift Index
CSA	Climate Smart Agriculture
CSOs	Civil Society Organizations
DAI	Drought and Aridity Index
DCRMP	Disaster and Climate Risk Management Project
DCRRP	Disaster and Climate Risk Reduction Project
DDSA	Desertification and Drought Sensitive Areas
DLDD	Desertification, Land Degradation and Drought
DRAs	Drought Risk Areas
DSAs	Drought Sensitive Areas
DSTs	Decision Support Tools
DRSI	Drought Risk Shift Index
EMS	Express Mail Service
ES	Environmental Strategy
FAO	Food and Agriculture Organization
GCM	General Circulation Model
GDP	Gross Domestic Product
GWP	Global Water Partnership
Ha	Hectare [unit of land]
HTC	Hydro Thermal Coefficient
IBI	Index Based Insurance
IDMP CEE	Integrated Drought Management Program for Central and Eastern Europe
IEG	Institute of Ecology and Geography
IPASP	Institute of Podology, Agro-chemistry and Soil Protection
IPPC	Intergovernmental Panel on Climate Change
LDN	Land Degradation Neutrality
LGP	Length of Growing Period
MARDE	Ministry of Agriculture, Rural Development and Environment

MDL	Moldovan Currency, Leu
ME	Ministry of Environment
MH	Ministry of Health
NAP	National Action Program
NAPs	National Adaptation Plans
NARDS	National Agricultural and Rural Department Strategy
NDCs	Nationally Determined Contributions
NDS	National Development Strategy
NDP	National Drought Plan
NGOs	Non-governmental Organizations
NFFM	National Farmer's Federation of Moldova
NPC	National Participation Council
P	Precipitations (mm)
PAs	Protected Areas
PD	Precipitation Deficit
PDSI	Palmer Drought Severity Index
SAPs	Sectoral Adaptation Plans
SBD	Strategy of Biological Diversity
SCPESS	State Service for Civil Protection and Exceptional Situations
SDGs	Strategic Development Goals
SEI	State Ecological Inspection
SHS	State Hydrometeorological Service
SMD	Soil Moisture Deficiency
SPI	Standardized Precipitation Index
STPI	Standardized Temperature and Precipitation Index
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WB	World Bank
WFD	Water Framework Directive

SUMMARY

The Republic of Moldova is a small-sized, landlocked country with a total land area of 33,846 km. sq. and a population of 3.5 mln. (as of January, 2018). Located in the South-Eastern part of Europe, Moldova has a temperate continental climate and high productivity agricultural soils. Most of the territory is a moderate hilly plateau with a 100-200 m average elevation, cut by many streams and rivers and semi-arid steppe plains in the south with the highest insufficient water conditions in the country. Having unique land resources and high productivity of soils, Moldova is characterized by high landscape utilization. Major human impact on Moldavian landscape is through agricultural activities covering about 74% of the landscape area. Wines, cereal grains, corn, fruit, vegetables, walnuts along with various other Moldavian agro-food products are well known in the world. Approximately 70% of the population from rural areas depends on agriculture for their livelihoods. Agro-food exports account for roughly 50% of the country's total exports.

High variability is an integral part of the overall pattern of the Moldavian weather and climate. It is a source of the greatest uncertainty in natural environment and vulnerable development sectors, in many respects, determining the lifestyle of people and their health. These uncertainties are greatly aggravated in a changing climate. In particular, one of a pivotal geographical consequences of climate change is an increase in the frequency of climate extremes. This in turn inevitably entails an increase in economic losses and social upheavals in the most regions of Moldova. Climate hazards, such as extreme temperatures, lasting droughts, late spring and early fall frosts, hail and heavy rain, have had significant impacts on productivity, incomes, and natural resources and are expected to generally increase in intensity and frequency in a changing climate.

Drought is one of the most common and devastating extreme climate events in Moldova. Moldova is located in a water insufficiency climate zone. A major part of Moldova (74.5%) relates to dry sub-humid ($UNCCD_{AI}$ = 0.50-0.65) and semiarid ($UNCCD_{AI} < 0.50$) lands. It is in dry lands the agricultural ecosystems are more vulnerable to climate and the balance of production and consumption often depends on water resources. Accounting for 13% of the total number of hazards, droughts in Moldova make up 67% of the economic losses from weather and climate related risks. Insufficiency and high variability of precipitation are the main drivers of drought and significant failure of water resources and agriculture production, creating a challenging environment for all sectors of human activity. In some years water deficiency acquires a national scale of socio-economic and environmental disaster.

The Government of Moldova has a strong commitment to enhance climate resiliency and reduce drought vulnerability. A number of strategies and programs have been approved recently in the Republic of Moldova intended to serve as an umbrella to create the enabling environment for specific sectors to 'mainstream' climate risks management through a series of National and Sectoral Adaptation Plans. In 2014 the Government approved the Climate Change Adaptation Strategy (CCAS), a national strategic framework with an overall goal to advance the resilience of the country's social and economic development processes. Submitting the First Nationally Determined Contributions (NDCs) in 2017 that prioritized adaptation activities in the most climate-sensitive sectors which are at particular risk, was a next programming document. Agriculture, water resources and forestry are among the sectors considered most at risk from climate variability/change impacts, as are human health, energy and infrastructure.

The subsequent steps (2018) was endorsing and transparently communicating at the national and international levels the voluntary Land Degradation Neutrality (LDN) target of Moldova "to achieve by 2030 no net loss of productive land/soils and increase drought resiliency, adaptation capacity and biodiversity services of agricultural ecosystems".

The endeavor to cope with climate risks and reduce drought vulnerability has been supported through several bilateral and multilateral climates risks mitigation projects. World Bank Disaster and Climate Risk Management Project (DCRMP) with the objective to strengthen the weather monitoring and early warnings of extreme weather and climate hazards to provide timely and accurate hydro-meteorological forecasts and services. UNDP Disaster and Climate Risk Reduction Project (DCRRP) with the overall goal to reduce extreme climate risks in Moldova through the development of national and local risk management capacities. The project contributed to increased national ownership and leadership for disaster and climate risks resiliency through better coordination, awareness and knowledge and innovative technology transfer.

Increased vulnerability and improved understanding of Moldova's climate impacts on droughts were likely to occur more often and be more severe, highlighted that existing drought policy and planning have not received the due recognition it should. Moldova did not have a policy document that would directly address the drought and related activities. Pre-existing policies related to drought response based mainly on a reactive (crisis management) approach and traditional hierarchical and command-and-control methods that makes for individuals and society reliant on government programs and often resulting in an increased vulnerability to drought events. The UNCCD Drought Initiative and related awareness and communication activities have promoted to an expert consultative process about the possible solutions with the intent of providing a strong proactive approach to drought management based on risk reduction principles. The overall goal of the debates were to contribute to raising awareness and engaging with the key stakeholders and decision-makers to create a participatory approach in establishing a resilient framework for drought planning in the Republic of Moldova.

The critical insight of the current plan is that a high level of variability in agricultural production is a normal part of a farmer's operating environment. High climate variability in many respects determines a greatest uncertainty in many other development sectors and should be managed as any business risk. So, as a major contribution to improved understanding of climate variability impacts on regional environment and vulnerable development sectors, the plan focuses on incentives for primary producers to adopt a more self-reliant approach to their farming operations, including drought preparedness. In this respect the Plan provide for shifting the drought policy and intervention programs be restructured from a reactive, crisis management approach and traditional hierarchical and command-and-control management methods to creating an overall environment to facilitate affected stakeholders be prepared for drought.

An imperative of the Plan is that human and economic capital will be directed towards the implementation of mitigation/adaptation strategies that are relevant, targeted and effective. Despite there are many field-ready innovations with significant benefits to productivity, climate resiliency and drought mitigation objectives, limited financial resources at the farm level is a considerable barrier to utilizing these innovations. In limited funding it is important that mitigation and adaptation options are developed so that they specifically address the climate risks challenges that local rural communities face. So, mitigation options which offer the greatest return on investment from an economic, social and environmental perspective be prioritized and implemented to improve the resilience of agricultural systems and rural livelihoods.

The overall goal of the National Drought Plan (NDP) is to create a conducive environment and to develop a coordinated and consistent framework for integrated actions to reduce drought risk and to improve preparedness to drought based on an adaptive, resilience perspectives. Based on resilience and systems design approach and supported by comprehensive biophysical information, the NDP is a critical input for developing drought related policy initiatives at all management levels. The plan identifies key responsibilities for data collection and analysis to establish a consistent basis for evaluating the drought severity and impacts to make a sound decision. It also contemplates the concept of exceptional circumstances to cover drought events of a greatest severity that go beyond the scope of good drought risk assessment and management. This component aims to strengthening the capacity of national and regional civil protection authorities and modernizing and upgrading to international standards regional Emergency Command Centers and providing preparedness and response equipment and training.

The National Drought Plan integrates global obligations of the Republic of Moldova and ensures a high relevance to the policies and planning initiatives, capitalizing the previous country climate risks mitigation and adaptation planning efforts to boost sustainability in drought resiliency. The document is prepared under the UNCCD' Drought Initiative. Guidelines and model plans of the UNCCD' Drought Initiative team and the regional science inputs and elements are already in place on how to respond to drought in specific conditions of Moldova (Government decisions, programs and other policy documents), served as the background documents.

Moldova has a coherent legal framework for institutional regulation addressing drought preparedness and response. This legal framework has been implemented into national legal framework through *the Water Law* (Parliament of Moldova, Law Nr. 272) is aiming to protect water resources and to establish environmental quality standards according to the European Water Framework Directive (WFD, 2000/60/EC) principles. The Law and its by-laws provide mechanisms for managing water resources to promote effective actions for preventing damage, preserving, protecting and restoring surface and underground water resources. Nationwide declaration of drought emergency is regulated by Article 48 of the Water Law. Regulation on drought management planning (Government Decision no. 779 of 04.10.2013) has been issued also to meet the provisions of the Water Law.

The Plan introduces the main institutions, their subordinated agencies, scientific and civil society organizations are involved in drought response and describes their main responsibilities. Moldova has several key institutions aimed at supporting and increasing mitigation capacity and resiliency to drought whose main activities relate to one or more or three drought management pillars (monitoring and early warning, vulnerability and risk assessment, actions to reduce drought impacts). *The Republican Commission for Emergency Situations* is the main entity responsible for managing major emergencies, including drought. The Head of the Commission is the Prime Minister; the deputy head is the Director of the State Civil Protection and Exceptional Situations Department (SCPESD), which is responsible for disaster prevention, response, relief and recovery. *The Ministry of Agriculture, Rural Development and Environment (MARDE)*, former Ministry of Environment (ME) of the Republic of Moldova, is the central public authority responsible for the development of legal and regulatory framework in the field of environmental protection and land policy formulation, rational use of natural resources and biodiversity conservation. Representatives of the MARDE perform the function of the UNCCD Focal Point. On behalf of the Government of the Republic of Moldova, the MARDE is responsible for the implementation of UNCCD. *The State Civil Protection and Exceptional Situations Department (SCPESD)*, which is a part of the Ministry of Internal Affairs with a clear role and responsibilities for issuance of water–related hazard warnings, disaster prevention, response, relief and recovery. *The State Hydro meteorological Service (SHS)* is an institution subordinated to the MARDE. The State Hydrometeorological Service is the main institution that carries out monitoring and provides most of the early warning services for drought risk management in Moldova and provides critical support in the drought preparedness and prevention.

The NDP is also to serving as a compendium of comprehensive drought-related policy, biophysical and socio-economical information. The drought planning process has initiated a wide national consultative process for sustainability in drought resiliency and was an opportunity to analyze climate effects on drought variability, the current water and land resource use/planning and prioritizing actions with regard to scientific and technical data, capacity building, resources, awareness raising, needs in terms of policy coherence and coordination to ensure an effective implementation UNCCD drought initiative in the Republic of Moldova. The Plan investigates climate effects on drought trends and statistics, susceptibility and key drought vulnerabilities at high resolution. It promotes extended and new services in improving accessibility of the drought risk assessment and management design information to make a sound decision.

The plan indicates that current regional climate may have a greater negative potential impact assuming a corresponding "risk shift" of the large environmental and development failures due to extreme droughts. Despite the long-term changing of the average climate has no indication any significant trend toward progressive aridization of Moldavian climate, the plan has revealed an important feature of the regional climate variability effects on drought dynamics that consists in increasing frequency of drought that go far beyond from the average climate. Drought of 2007 drought was the driest year in the history of Moldova with a return period more than 200 years. The top 10 driest years also include the recent droughts of 2000, 2009 and 2012. Thus, the last decades 2000 to 2016 was one of the driest for the period from 1946 to 2016.

Global challenges such as climate change are a key factor of increased drought vulnerability affecting both environmental and socio-economical subsystems. Increased drought risk of recent years due to climate change suggests that the country remains highly vulnerable to global environmental challenges. Just for period from 2000 to 2016 Moldova has already experienced several (2000, 2003, 2007, 2012) droughts that have had a dramatic effect, acquiring the scale of a nationwide environmental and socioeconomic catastrophe. A range of recent studies indicates the continuing increase of historical trend of temperature in Moldova in the near future having even a more dramatic impact on drought conditions.

High risk of drought hazard in a changing climate is aggravated by unsustainable agricultural practices and ineffective risk governance. Since the proclamation of independence (1991) Moldova has gone through an unprecedented economic transformation which, due to the rapid and often dramatic transition process, has accelerated environmental degradation and has been associated with increasing poverty and rural vulnerability. Expansive overexploitation of land resources and poor adaptability of applied agricultural practices along with an ineffective drought risk governance have created an increased and wide-ranging impact on natural environment with a reduction in resiliency and functional integrity of the agro-ecosystems.

Increased exposure to drought hazard is translating into a great risk for the Republic of Moldova can be attributed to poverty and high rural vulnerability. Drought impacts directly hit small holder farmers and agricultural workers whose income is 40-70% weather depended and comes from agriculture. Droughts reduce their savings considerably and worsen both the overall quantity and the composition of their nutrition. In addition, in rural areas, where 45% of the population rely on wells as their main source of drinking water, negative social effect of droughts are exacerbated by reduced access to potable water. Taking into consideration high concentration of rural population and weak economic capacity of the most prone areas, improved drought risk assessment and management are critical for supporting sustainable development and poverty reduction in the Republic of Moldova.

The plan has established the national drought indicators system. An examination of the most common drought indices that are in use for the operational purposes in Moldova indicates that all of the indicators are closely related to each other (R^2 = 0.96-0.98). Showing generally similar behaviour in the drought detection, the drought indices, however, reveal discrepancies related to the drought triggers and categories that determine timing and management actions, as well as to the key vulnerable sectors. The complex indicators based on water balance approach are more responsive to an increase drought frequency associated with an increase of the air temperatures and warming of regional climate.

Identifying of areas and key sectors that are vulnerable to drought impacts is an issue in the Republic of Moldova due to the variations in microclimates and impact sectors. Although Moldova is relatively small, it has a number of distinct areas that experience significantly different weather patterns, topography, and runoff characteristics. The extent of drought tends to be regional or even local and different responses are required. The plan recognize areas at risk (Drought Sensitive Areas, DSAs) to promote implementing specific response strategies prior to the onset of a drought to mitigate potential impacts, and, therefore, to assist in a more proactive drought management strategies. Drought risk ratings focus on the traditional framework using the return level and return time concept. The concept is a byproduct of the extreme value analysis and it is considered as a convenient tool for drought risks assessment and planning.

The Plan has identified the priority mitigation activities and investments across the vulnerable sectors for implementation in the near to mid-term future. Much of the current as well as predicted drought impacts are concentrated in agricultural sector and rural areas. So, the biggest challenges and investment opportunities are in sustainability of agriculture and rural development. Regeneration of irrigation systems along with the rehabilitation and modernization of drainage infrastructure are a vital input to improving drought resilience and agricultural productivity as well as to mitigate expected extreme climate impacts. Other options include small-scale on-farm irrigation systems, soil management and climate risk management technologies which are more resilient to climate variability and change.

Water resources that provide challenges both related to quality and quantity have been deteriorating rapidly, with severe consequences for natural environment and key development sectors. Improvements of local supply systems to reduce losses, and building a small-scale storage reservoir on the main rivers, present immediate, modest investment opportunities with high returns.

Ecological rehabilitation and expansion of forests and forest belts are expected to have high returns and to have a high poverty and gender impact. Forests and biodiversity degradation is also a major issue and is well recognized that helping to improve forest sector performance and increasing the forest cover promote to reducing poverty and increasing the wealth of the population. Restoration of degraded forests and pasture lands also promotes agricultural productivity through improved watershed function and protection from drought and related extreme climate events.

Drought impacts on public health are mostly indirect because of its link to other mediating circumstances like loss of livelihoods, population migration from rural areas to cities and out of the country and increasing tension over water resources associated with inadequate sanitation and low-quality drink water supply. Although there is uncertainty around the scale of drought and climate related health impacts, modest investments in heat warning systems and public health campaigns are expected to have high returns effects.

Improvements for drought prevention and preparedness, including training facilities and emergency response capabilities are also key gains for public safety as well as substantial economic returns. These actions aim to strengthen the capacity of national and regional civil protection authorities to prepare for and respond to drought and other extreme weather events, including disaster management systems to support a wide range of sectors with risk management planning and response to extreme climate events.

1. CONTRY CONTEXT

1.1. General remarks

The Republic of Moldova is a landlocked country (except for a 200 m direct river-sea exit in the south of the country where the Danube forms part of the border). Located in the South-Eastern part of Europe, Moldova has a temperate continental climate and high productivity agricultural soils. It spans 350 km from North to South, and 120 km from West to East. Most of the terri- tory is a moderate hilly plateau with a 100-200 m average elevation cut by many streams and rivers and semi-arid steppe plains in the south with the highest insufficient water conditions in the country. The Republic of Moldova has 37 first tier units: 1 autonomous territorial unit (Gagauzia),

1 territorial unit (Transnistria); 3 municipalities (Chisinau, Balti, Bender) and 32 districts (“rayons”).

The Republic of Moldova, having unique land resources and high productivity of soils, is characterized by high landscape utilization. Major human impact on Moldavian landscape is through agricultural activities covering about 74% of the landscape area. Wines, cereal grains, corn, fruit, vegetables, walnuts along with various other Moldovan agro-food products are well known in the world.

European integration has anchored the Government’s policy reform agenda, but reforms that are good on paper have yet to materialize. A vulnerable political system, polarized society, adverse external environment, and skills mismatch in the labor market, as well as climate-related shocks, are Moldova’s biggest economic challenges (The World Bank in Moldova Country Snapshot, 2018).

1.2. Demographic and macro-economic context

Population and poverty. As of January 2018, the population of the Republic of Moldova 3.5 million people. The density is approximately 119.1 persons per square kilometer. Females predominate with 52.2% in the total population. 57% of Moldova lives in rural areas and about a quarter is employed in agriculture with low levels of productivity. The Republic of Moldova has made significant gains in reducing poverty. However, Moldova remains one of the poorest countries in Europe.

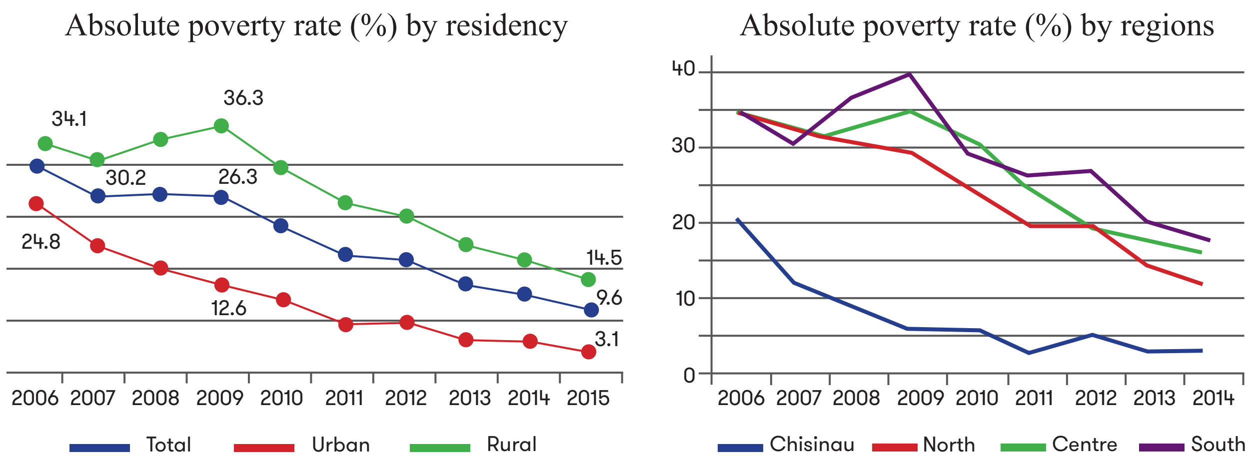


Figure 1.1. Poverty rate by residency and regions (Republic of Moldova)
Source: NBS, National Development Report, 2016

Poverty is concentrated in rural areas where livelihoods depend on agriculture and natural resources that are increasingly at climate risks. With 57 percent of the population living in rural areas, 84 percent of the poor are concentrated there. Those in rural areas, poor and non-poor, rely more on agriculture and remittances for income sources than their urban counterparts who derive more income from non-agricultural employment.

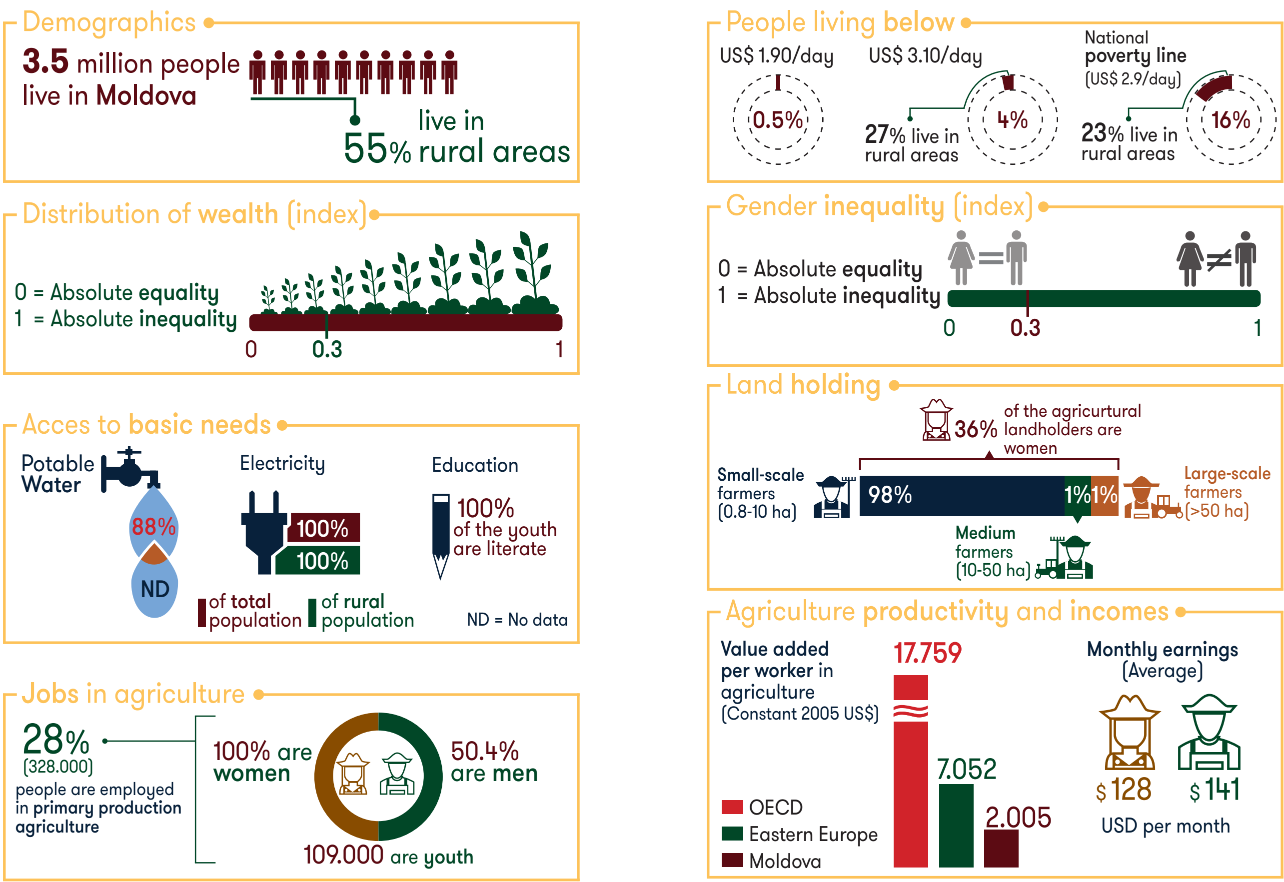
Migration. Weak governance and associated low economical growth have led to the emigration of almost one third of the working age population, depriving rural areas of a key productive group. Low pay and lack of employment opportunities, wage discrepancies between rural and urban areas, as well as relatively easy access to European and Russian labor markets, indicate that Moldova is seriously affected by emigration, with an estimated 600,000 people (at least 25% of the workforce) working abroad (National Development Report, 2016).

Gender issues. The economically active population in Moldova make up of 1.35 mln., with an employed population in 2015 of 1.31 mln. Out of this, 55.2% live in rural and 44.8% in urban areas. Moldova suffers considerable gender disparities with only 37% of women employed compared to 42% of men, women earning only 87% of the male wage on average (UNDP, 2014). In the rural areas, women make 36% of the total agricultural holders in the country, but they manage only 19% of the land covered by agricultural holdings.

Macro-economic context. Moldova has an agro-industrial economy with high reliance on remittances. Agriculture in Moldova is dominated by private businesses but the sector is the least productive in the economy, yet employs the largest proportion of the workforce. Most farmers (98%) are small-scale, with farm sizes ranging between 0.85 and 10 ha. Many of them lease the land to private or corporate entities or leave it as fallow.

The agriculture is crucial for all development sectors. Since 2000 the economy has expanded by an average of 5% annually, driven by consumption fueled by remittances. A great part of migration was from rural areas and remittances, therefore, predominantly benefitted the poorest segments of society, who used the money for consumption purposes mainly of imported goods (National Development Report, 2016). Remittances as a share of GDP peaked high up to 31% in 2008 and gradually declined to 22% and in 2016. The role of agriculture has also changed and its value-added share of GDP dropped from 30% in 2000 to only 10% in 2009, after which it accounted for 14% of GDP, 32% of employment, and 31% of exports in 2017.

Population, agriculture and livelihoods in Moldova



Source: Adapted from World Bank and CIAT, 2016.

The dependence of Moldova's economy on agriculture means that annual GDP growth is disproportionately affected by the agricultural productivity in any given year. However, agriculture is inherently dependent on weather and other risks. About 90% of agricultural production is rain feed. Bumper harvests are often followed by droughts. The negative output growth in agriculture in 2007, 2009, 2012 and 2015 dragged the economy each time into recession (World Bank, CIAT, 2016).

1.3. Environmental context

Land use and change. Moldova is divided into 2 major natural zones: forest-steppe zone and steppe zone that include 5 distinct landscape regions with an insufficient precipitation, dry winds and drought (Figure 1.2). Moldova's lands have undergone considerable alteration over the past last 200 years with the most striking feature of an increase in agricultural lands. This modification of natural land cover has resulted in a great mosaic of land cover patterns (Leah, 2016a; 2016b).

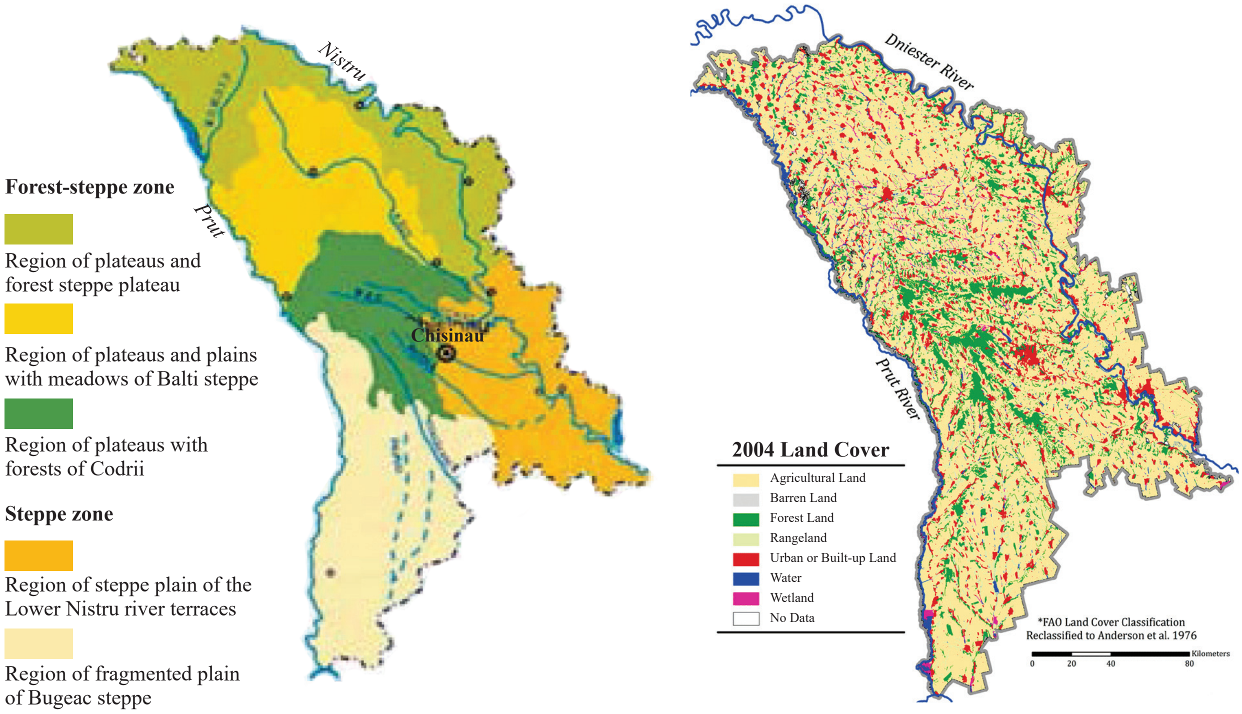


Figure 1.2. Natural zones and current land cover patterns of the Republic of Moldova
Source: Daradur et al., 2015b; Shaker, R.R. 2018

Moldavian predominant land cover remains overwhelmingly agricultural, while farming is the dominant land use activity. The most noted changes in recent land cover/use structure (1990-2015) is an increase of forest areas (+42.7 th. ha or by 12%), artificial lands (+8.3%) and wetlands and water bodies (+8.1%).

Table 1.1. Land cover/land use change, th. ha (1990-2015)

Land Category	Indicator, th. ha				Difference, 2000-2010		Difference, 2000-2015	
	1990	2000	2010	2015	th. ha	proportion, %	th. ha	proportion, %
1. Forest	371,4	372.30	411.07	414,1	+38.77	+10.41	+42,7	+11,5
2. Grasslands	390,7	412.80	380.92	373,9	-14.74	-0.67	-16,8	-4,3
3. Croplands	2258,4	2212.50	2197.76	2203,6	-31.88	-7.72	-54,8	-2,4
4. Wetlands and water bodies	89,4	96.60	99.64	96,7	+3.04	+3.15	+7,3	+8,1
5. Artificial areas	218,4	236.10	233.64	236,5	-2.46	-1.04	+18,1	+8,3
6. Bare land and other areas	56,3	54.33	61.60	59,9	+7.27	+13.38	+3,6	+6,4
TOTAL	3384,6	3384.63		3384,6			–	–

Source: Leah, 2012; 2016a; 2016b; Talmaci, 2017

Forests, natural protected areas and biological degradation. Natural and semi-natural ecosystems cover approximately 15% of Moldova. The main natural ecosystems of Moldova are: forests (10.8% of total area), steppe (1.9%), rocky habitats (0.68%), and aquatic (2.8%). Country's natural ecosystems and forests provide a critical support for biodiversity services and other environmental benefits and services such as soil protection, water regulation and carbon sequestration.

The forests are mainly broadleaved – oak, ash, hornbeam, black locust and poplar being the most significant species. Protective forest belts have a long tradition dating back to 1947 when shelterbelts were first established to reduce soil erosion on agricultural land, and as riparian buffers for water sources. Currently the total extent of forest belts is 30,300 ha.

The forest fund is highly fragmented. Spatial distribution of the forest areas is uneven and varies from less than 6% in the Balti region of steppe elevations and plains to 24% and more in the most afforested central Codrii region. About 5,000 existing woodland areas, with the extent ranging from 5 ha to 15,000 ha, are dispersed and isolated. There are no interconnecting forest corridors that are of major importance both for the viability of the forestry fund and for maintaining biological diversity, conserving soils and providing hydrologic protection (Ministry of Environment of the Republic of Moldova, 2009; UNDP & Ministry Environment of the Republic of Moldova, 2013).

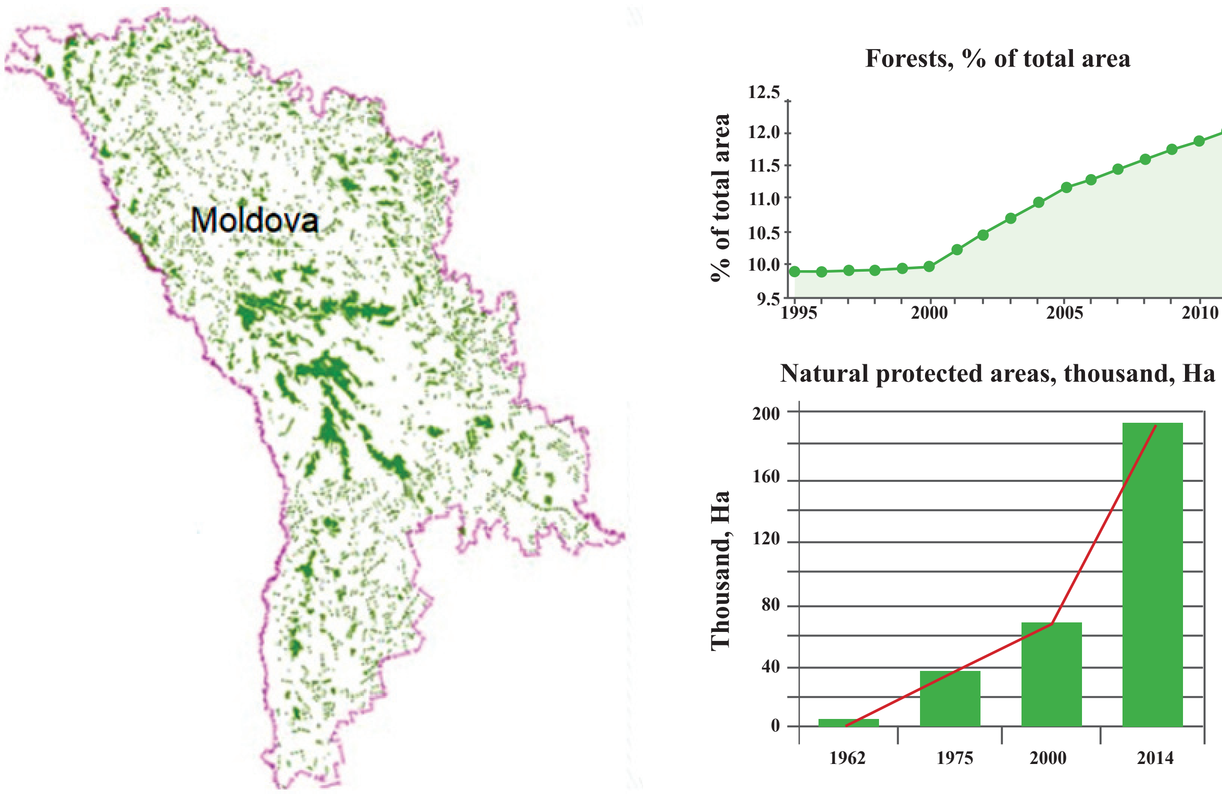


Figure 1.3. Forests ecosystems and natural protected areas (Republic of Moldova)

Source: Adapted from: Daradur et al., 2015b; United Nations Development Program, 2016; Forth National Communication, 2018

A considerable extension of the protected natural areas in the Republic of Moldova in the recent years is an important result in the environment protection. Currently there are 312 protected areas in the country, covering 191,000 ha or 5.68% of its territory (Ministry of Environment, 2013). However, biodiversity degradation, and, in particular of country's forests is a major problem and is well recognized. Total afforested area (forests land fund) is about 14% while for European countries is about 30% (Capcelea, 2016). Respectively the rate of the forestry sector in GDP is about 0,27% while in other Eastern European countries is at the level of 1.2-1.6%.

Climate variability and change. Moldova has a temperate continental climate with short winters (-2.8°C to -5.3°C and extremes of -30°C), long warm summers (averaging 20°C, and extremes in the high 30-s °C) and limited precipitation ranging from around 600 mm in the northwest to 450 mm in the southeast (Fourth National Communication, 2018). Most precipitation occurs as rain in the warmer months, with highly variable rainfall events in time and space. The annual volume of precipitation is evaluated at 15.3 km3 per year (Climate adaptation strategy, 2014).

The main driver of the spatial variability of the climate over Moldova is the geographical zonality. However Moldavian complex orography gives a specific response to spatial extent of the climate characteristics that can overlap the impact of main zonal factors (solar radiation). For example, spatial variability of the average annual air temperature under zonal factors ranges from 8.0°C to 11.0 °C, i.e., within 3.0°C (Daradur et al., 2007), whereas due to microclimate particularities, the geographical patterns of average temperatures can vary from 8.0°C to more than 14.0 °C (Figure 1.4).

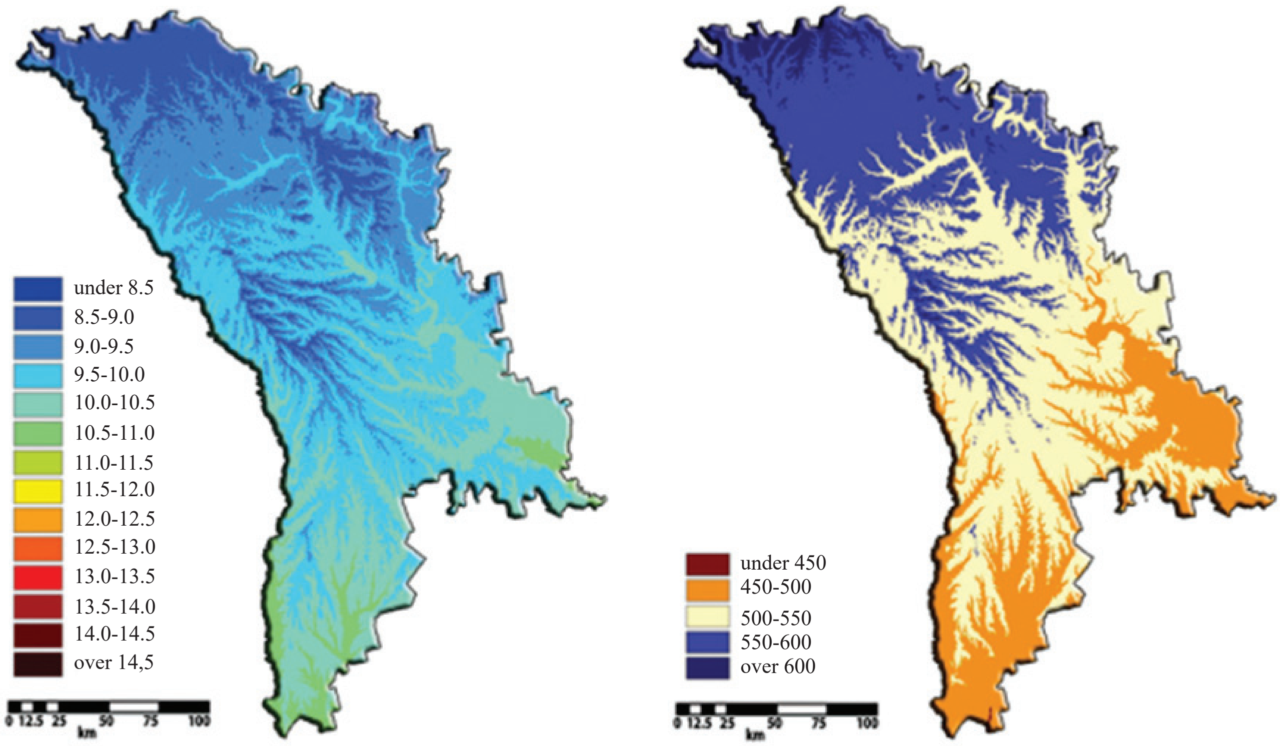


Figure 1.4. Annual temperatures and precipitation (Republic of Moldova, 1986-2005)
Source: Taranu et al., 2018

High climate variability is a source of an uncertainty in all sector of development and, in many respects determining the lifestyle of people and their health. These uncertainties are greatly aggravated in a changing climate. In particular, one of a pivotal geographical consequences of regional climate change is an increase in the frequency of climate extremes. Climate hazards, such as extreme temperatures, lasting droughts, late spring and early fall frosts, hail and heavy rain, have had significant impacts on productivity, incomes, and natural resources and are expected to generally increase in intensity and frequency in a changing climate.

The present total cost of inaction on climate adaptation in Moldova is estimated at US $ 600 Mln., equivalent to 6.5% of GDP (International Bank for Reconstruction and Development and World Bank, 2016). This value is expected to more than double in real terms by 2050 to around USD 1.3 billion.

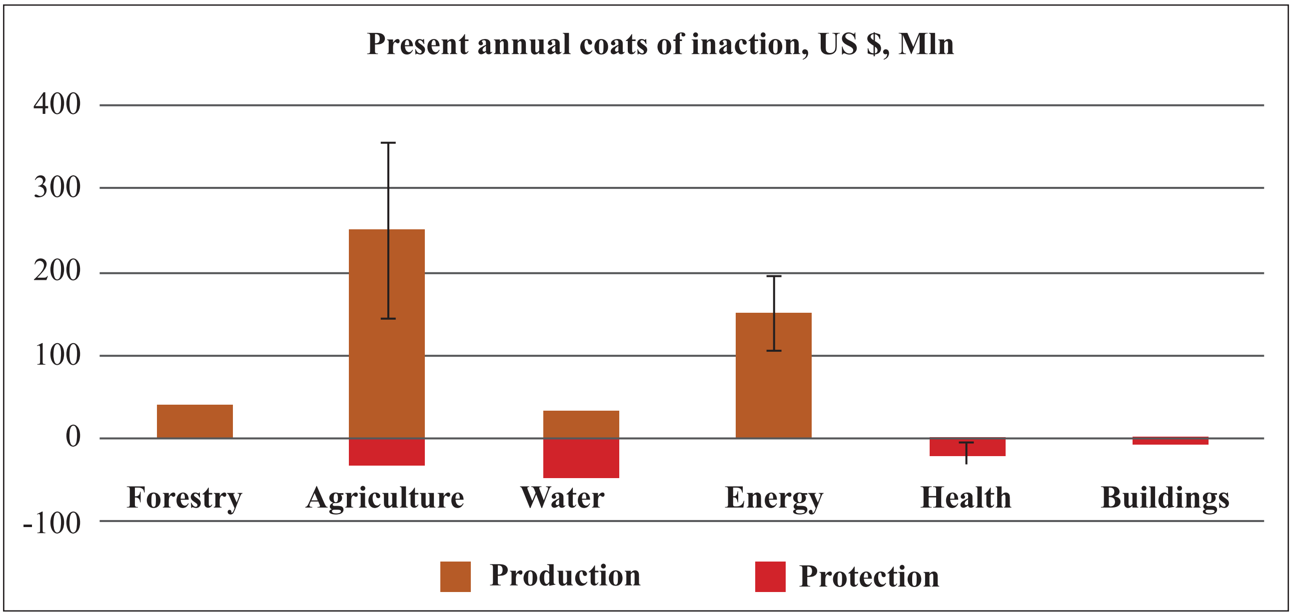


Figure 1.5. Present annual costs of inaction across assessed sectors (presented in 2015 dollars).

Costs of inaction related to potential gains from enhancing climate dependent production are represented as positive values (brown). Costs of inaction related to potential savings from reducing harmful effects of climate and the costs of protecting against them are represented as negative values (red). The total cost of inaction in each sector is the sum of the magnitudes of both potential gains and savings (i.e. the combined height of the orange and blue bars). The confidence limits represent the range of values obtained from the climate, price, and shared socioeconomic pathways (SSP) scenarios used in the analysis. They do not encompass all sources of uncertainty.

Source: International Bank for Reconstruction and Development and The World Bank, 2016

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Agro-climate. Moldova's territory is divided into three agro-ecological zones (AEZs) with similar physical and geographical particularities in terms of terrain, climate, soil type, and water availability (National Agriculture and rural development strategy, 2014; World Bank; CIAT, 2016.

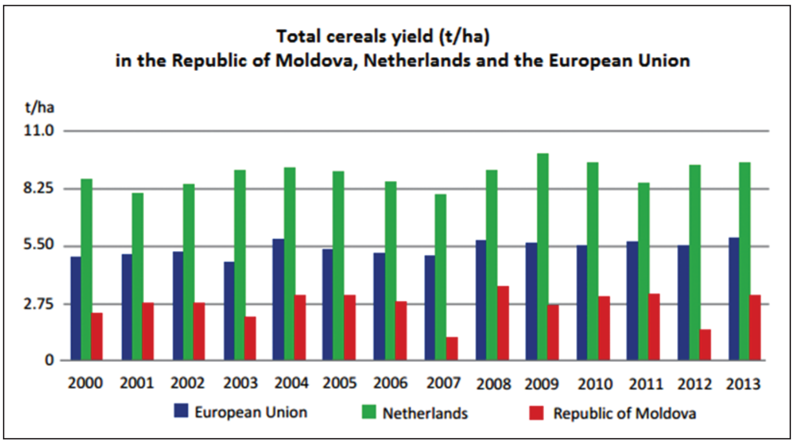


Figure 1.6. Afro-ecological zones
Source: Adapted from Daradur et al. 2015; USAID, 2017

1. The Northern AEZ is a hilly zone with forests, steppe and meadow vegetation and high productivity rates for forages, pastures, livestock and crops. It has the most fertile soil with a high-water holding capacity, which makes this zone the most suitable of the three zones for field crops.
2. The Central AEZ is hilly and has deep valleys, has less fertile soil, and is best for perennial crops like orchards and vineyards.
3. The Southern AEZ with a mix of hilly steppe and meadow terrain and both highly fertile and not as fertile types of soils. Due to higher temperatures and insufficient precipitation is less suitable for agricultural production.

At present, despite the high level of natural soil fertility and favorable climate for the main crops, productivity of agricultural ecosystems in Moldova is very low. Compared to European Union (EU) countries total cereals yield in Moldova is approximately 2 times lower of the average EU and 3 or even more times lower that on Netherlands.

Water resources. Moldova located within two major river basins: the Dniester and the Prut. There are also 60 natural lakes and more than 3.5 thousand water storage reservoirs. The natural water regime has been changed both by the construction of dams and reservoirs, designed to prevent floods, trap sediment, and to provide water for agricultural, industrial and household consumption as well as for fish farming.

The sub-surface water grid includes circa 112,000 springs and wells (public and private) and more than 3,000 functional artesian wells. Sub-surface waters are the main source of potable water supply in the Republic of Moldova, for 100 percent of the rural population and 30 percent of the urban population, or 65% of the total population of the country. The remaining 35% of the population use surface waters as a source of potable water. Approximately 44% of the population in the country does not have access to safe drinking water.

Extent of dry lands and land degradation. There is no single agreed definition of the term dry lands. Two of the most widely accepted definitions are those of FAO and the United Nations Convention to Combat Desertification (FAO, 2008). FAO has defined dry lands as those areas with a length of growing period (LGP) of 1–179 days; this includes regions classified climatically as arid, semi-arid and dry sub-humid.

The UNCCD classification employs a ratio of annual precipitation to potential evapotranspiration (P/PET). This value indicates relation between the availability of water resources and the maximum quantity of water capable of being lost, proceed from thermal recourses in a given climate. It includes evaporation from the soil and transpiration from the vegetation from a specific region in a given time interval. Under the UNCCD classification, dry lands are characterized by a P/PET of between 0.05 and 0.65.

In arid and semi-arid areas water resources are the most important element of the complex of natural factors that determine the ecosystems productivity and form the natural basis of production and, above all, in the agriculture. For Moldova, sufficiently provided with heat and fertile soils, water availability is of paramount importance, largely determining the efficiency of the development efforts of the Government Moldova. Insufficient of precipitation, aggravated by their uneven distribution over time, result in water stress for the most sectors of human activity, occasionally having a dramatic impact with environmental and socio-economical consequences.

About three fourths – 75.5% (11.9% semi-arid and 63.6% dry sub-humid areas) of the Moldovan territory under high risk of degradation processes (Daradur, 2015). The biggest part of the Moldavian 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. 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. 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. Most of population (> 85%) of population of Moldova dwell in the dry lands.

Land resources are degrading at an alarming rate with an average annual values of 0.22% year^{-1} or 7,400 ha year^{-1} (Land degradation neutrality targets of the Republic of Moldova, 2018). Degraded lands have increased from 27.6% (2000) up to 31.3% (2015) mainly caused by: (1) use of inappropriate soil cultivation technologies; (2) allocation of land without taking into account the soil conservation and fertility maintaining needs; (3) failure in crop rotation; (4) lack of funding at all levels; and (5) unauthorized deforestation on agricultural lands. Increasing of the frequency of very intense precipitation and extreme droughts also contribute to the intensification of degradation processes (landslides, linear and surface soil erosion, etc.) on agricultural lands mostly (80%) located on sloppy areas. The impacts are is estimated at MDL 3.1 billion annual losses (Leah, 2012; 2016a; 2016b).

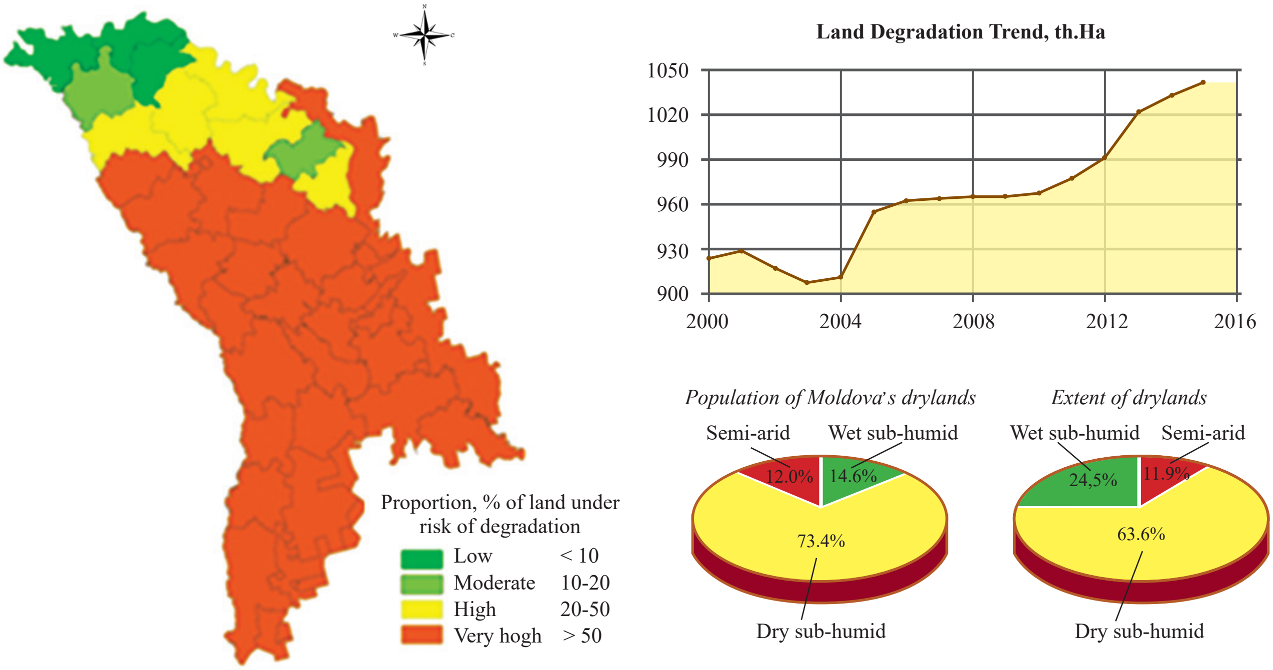


Figure 1.7. Extent of dry lands areas and land degradation trends (Republic of Moldova)

Adapted from: Daradur et al., 2015; Leah, 2012; 2016a

To respond to this serious challenge, the Republic of Moldova has joined the Land Degradation Neutrality (LDN) global initiative of the United Nations Convention to Combat Desertification (May, 2016) with an objective to prioritize effective policy interventions *"to achieve by 2030 no net loss of productive land/soils and increase drought resiliency, adaptation capacity and biodiversity services of agricultural ecosystems."* With a high concentration of rural population, both poor and dependent on income from agriculture, the LDN target is a highest priority for the Government of Moldova.

2. DROUGHT IN THE NATIONAL DEVELOPMENT CONTEXT

2.1. Key drivers, impacts and vulnerabilities

Drought is one of the common and devastating extreme climate events that has a wide range of impacts across all sectors of development the Republic of Moldova. The increased vulnerability to drought and associated risks is substantial, with significant and frequent adverse impacts and high volatility of both social and economical subsystems. Agriculture, water resources and forestry are among the sectors considered most at risk, as are human health, energy and infrastructure. Agriculture sector, which is of vital importance to Moldova is the most vulnerable to drought. Drought leads to wide spread failures of agro-ecosystem production and food shortages. Agricultural small holders are particularly vulnerable to drought and related climate risks as they have limited access to information and few resources to invest in mitigation/adaptation measures.

Global challenges such as climate variability and change are a key factor of an increase of drought vulnerability affecting both environmental and socio-economical subsystems in the Republic of Moldova. Increased drought risk of recent years due to climate change suggests that the country remains highly vulnerable to global environmental challenges. Moldova has already experienced several (2000, 2003, 2007, 2012) droughts that had a dramatic environmental and socio-economic effects. One of the most severe droughts on record occurred in 2007, affecting over 75% of the population and resulting in significant damage to the economy.

Risk of drought hazards in a changing climate is aggravated by unsustainable agricultural practices and weak drought risk governance. Since the proclamation of independence (1991) Moldova has gone through an unprecedented economic transformation which, due to the rapid and often dramatic transition process, has accelerated land degradation. Expansive overexploitation of land resources and poor adaptability of applied agricultural practices along with ineffective drought risk governance have created an increased and wide-ranging drought impact with a reduction in resiliency and functional integrity of the agro-ecosystems.

Increased exposure to drought hazard translating into a great risk for the Republic of Moldova can be attributed also to poverty and high rural vulnerability. Poorest households are the most vulnerable groups of population. Drought impacts directly hit small holder farmers and agricultural workers whose income is 40-70% weather depended and comes from agriculture. Droughts reduce their savings considerably and worsen both the overall quantity and the composition of their nutrition. Taking into consideration high concentration of rural population and weak economic capacity in the most prone areas, improved drought risk monitoring and management are critical for supporting sustainable development and poverty reduction in the Republic of Moldova.

2.2. National Development Strategy and drought agenda

The National Development Strategy (NDS), known as “Moldova 2020: eight solutions for economic growth and poverty reduction” (approved by the Parliament of the Republic of Moldova on July 11, 2012), served as basis for the Government activity and a series of sectoral strategies. The Strategy presents the country’s overall development policy and describes the country’s medium-term development priorities. It replaced a medium-term National Development Strategy (NDS) for the period 2008–2011 (known as "Re-think Moldova"), which had as one of its aims moving the country toward environmentally sustainable development.

The new medium-term NDS for the period 2012-2020 unified the government's poverty reduction strategy and development vision in one document. With the objective of "... ensuring qualitative economic growth and poverty reduction...", it lists eight national priorities: (a) aligning education with labor markets; (b) increasing public investment in roads; (c) promoting financial sector competition; (d) improving the business climate; (e) raising energy efficiency, including the use of renewable sources; (f) ensuring fiscal sustainability of the pension system; (g) enhancing the efficiency and quality of justice, including combating corruption; and (h) fostering the competitiveness of agro-food products and sustainable rural development. This development and reform agenda is broadly consistent with the Sustainable Development Goals (SDGs).

For a better sectoral governance, climate risks mitigation was streamlined into **Biological Diversity Strategy for 2015-2020, National Environmental Strategy 2014-2023, Strategy for Water Supply and Sanitation for 2014-2028**. The Environmental Strategy contemplates a wide environmental sector reform and contains specific objectives for the implementation of the system of hydrological basins management. The water supply and sanitation strategy aim is to improve the institutional capacities in the water supply and sanitation sector, including the regionalization of services.

In 2014 the Government approved the **Climate Change Adaptation Strategy** (CCAS), its first national strategic framework aiming to advance the climate resiliency of social and economic development processes. It is intended to serve as an umbrella strategy which creates the enabling environment for specific sectors and ministries to mainstream climate risks management into country's strategies through a series of National and Sectoral Adaptation Plans. This initiative is supported by a long-term financial strategy which includes national resources and international support.

The draft Moldova Development Strategy 2030 is currently being finalized. Among the specific objectives of the Strategy project is contemplated a significant increase in the area of wooded and reforested land to assure climate resiliency and reducing the climate risks and drought impacts.

The Sustainable Development Goal 15 (SDG 15) "Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss" includes 9 targets (the target 15.4 on the conservation of the mountain eco-systems are not relevant to country). SDG 15.1, 15.3 and 15.5 refer to the sustainability of ecosystems and biodiversity services, land degradation and drought, and biodiversity conservation that respectively strongly relate to the global UNCCD's LDN principle and the Biodiversity Targets adopted by the Convention on Biological Diversity.

The SDGs Target 15.3 "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world" is under the mandate of the newly established *Ministry of Agriculture, Rural Development and Environment (MARDE)* – key institution to be engaged in aligning the target with the national policy and strategies, as well as for the achievement of downscaled targets. With the majority of the rural population, both poor and dependent on the agricultural sector for their livelihood, land sector sustainability and increased drought resiliency are the highest priority for the Government of Moldova.

As the result of the consultative process, the National voluntary LDN target have been endorsed and communicated at the national and international levels and formulated as **"to achieve by 2030 no net loss of productive land/soils and increase drought resiliency, adaptation capacity and biodiversity services of agricultural ecosystems"**. The National LDN agenda integrates global obligations of the Republic of Moldova and ensures a high relevance and clear policy implications to government land-sector priorities, capitalizing the previous country land sector target-setting efforts.

3. OVERVIEW OF DROUGHT IN MOLDOVA

3.1. What is a drought?

Drought is a principal perceived risk in Moldova. Nevertheless, it is a phenomenon that is very difficult to qualify and describe since the concept of drought usually has no generally accepted definition. As a complex natural phenomenon with important environmental and socio-economic impacts, drought provides room for different interpretations. For more clarity, it can be distinguished by a conceptual and an operational definition of drought.

The conceptual definition of drought helps to understand drought, which is treated as a lack of or little precipitation over a dry period. In this sense, deviation of precipitation from the average climate (precipitation anomalies) is considered, as it is associated with a large-scale or general circulation of the atmosphere (Willeke et al, 1994; Pandey and Ramasastri, 2001; Daradur, 2001, Dai, 2012). Short periods of time, when some area receives little or no rain at all, usually are not considered.

The more general approach defines drought as a "period of abnormally dry weather long enough to cause a serious hydrological imbalance" (IPCC, 2012, p.167). Consequently, drought is treated as a relative term and should not be mixed with aridity, which describes the general dryness of a climate. As a recurring event, drought can be inherent to any climate and it is defined with respect to the average climate of the given region (Daradur, 2001, Heim Jr., 2002; Dai, 2012).

However, the relative concept of drought cannot be applied to describe drought conditions of a location with specific moisture conditions. For example, the question arises whether it is possible to consider any combination of these weather conditions as a drought. Anyway, for the wet zone with sufficient or even excess precipitation it is not obvious (Koster et al., 2004; Daradur et al., 2007; Seneviratne et al., 2010). Application of the relative approach to the dry lands with an uneven and insufficient of precipitation, where the timing and distribution of the rainfall events is an important drought impact factor, can also lead to misleadingly estimations in the form of unreasonable values of the indices (Daradur, 2001; Lloyd-Haghes and Suanders, 2002).

Operational understanding of droughts determines drought conditions (the time of onset and end, its intensity, spatial extent, impacts, etc.) and is described by drought indexes and indicators. Large diversity in the approaches to the functional definition of a drought has made it very difficult to establish an unique and comprehensive drought index (Daradur, 2001; Heim, 2002, Crossman, 2018).

Identification of drought by precipitation anomalies or some form of standardization related to the long-term average climate (usually 30 years or more) is one of the common approaches. Herewith, the thresholds or triggers for drought identification are usually chosen empirically and often lack statistical basis, which prevent an objective estimation of drought and defining optimal management strategies (Daradur et al., 2007; Vicente-Serano et al., 2010). Drought indices may emphasize different aspects of drought and should be carefully selected with respect to the drought characteristic in mind. Thus, in spite of availability of numerous techniques for the operational definition of drought, selecting indicators and quantifying drought conditions, which is imperative for drought planning, represents a challenge.

The choice of indicators for drought monitoring and risk assessment in a specific location is usually based on the ability of the index to consistently detect spatial and temporal variations during a drought event and the quantity of climate data available (Crossman, 2018). The use of a multiple indicators approach is often more effective in detecting drought onset and its intensity.

3.2. Drought classification

There exist a number of techniques for a drought classification. The most common is distinguishing a meteorological, agricultural, hydrological, socio-economic droughts (Daradur et al, 2007; Van Loon, 2015; Grossman, 2018). The recent generational advances in spatial data processing and remote sensing put also a synthesis of multiple (composite) indices (meteorological, agricultural, hydrological) in relatively easy reach for drought monitoring and early warning (Crossman, 2018).

Meteorological drought is a lack of or little precipitation over a given period of time. In this sense, deviation of precipitation from the average climate (precipitation anomalies) is considered, as it is associated with a large-scale or general atmospheric circulation (Willeke et al, 1994; Daradur, 2001, Dai, 2012). Another approach is based on more complex, supply and demand concept, when quantifying the drought is a measurement of misbalance between precipitation and the radiation potential expressed by evaporation.

Hydrological drought typically is associated with a long (months and years) period of shortage of river stream flow and a low water level or volume in the natural and artificial reservoirs due to effects of lasting periods of low precipitation (Van Loon, 2015). Being a natural phenomenon, hydrological drought, at the same time, can be greatly aggravated by human activities, since intensive land use and degradation processes can affect the intensity and frequency of hydrological droughts (Crossman, 2018). Identification of drought through a volume of river stream flow (or in some form of standardization relatively to the long-term climate values) which is a critical component for the environment and various development sectors are the common approach.

Agricultural drought reflects the influence of drought conditions on agricultural production and usually is characterized by deficiency of precipitation and soil moisture, differences between actual and potential evaporation, etc. (Daradur et al, 2007; Van Loon, 2015; Crossman, 2018). Determination of agricultural drought involves an impact assessment on crop production at different stage of growing period and crop failure due to droughty conditions.

Agricultural droughts often coincided with meteorological droughts, identified through rainfall deficits, but the severity and duration of agricultural drought depended very much on soil moisture derived from rainfall that is commonly the factor that is most limiting to plant growth (Mangul, 1998; Daradur et al., 2007; White and Walcott, 2009).

The timing and distribution of the rainfall events is another impact factor (see the section 6) that define the severity and duration of agricultural drought that means a minor rainfall deficiency could also have major consequences in terms of agricultural production, whereas a moderate rainfall deficiency may not always seriously reduce crops production (Daradur, 2001; White and Walcott, 2009). For example, the same quantity of precipitation can be accumulated whit a high monthly concentration indicating on the increase of intensity and lasting dryness conditions or evenly distributed during the period, that indicates on better climate conditions (see figure below).

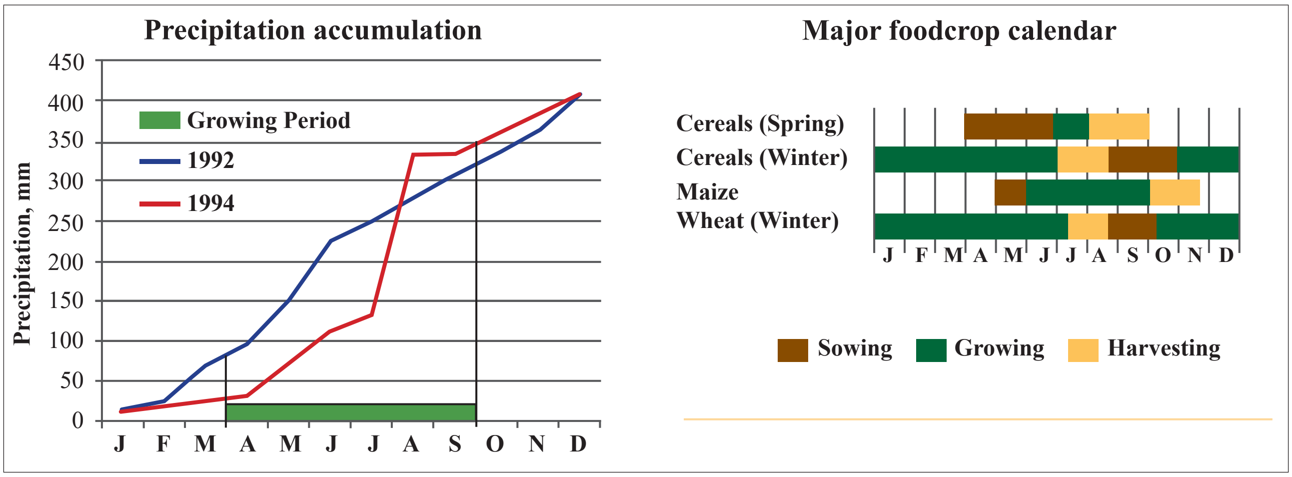


Figure 3.1. Effects of intra-annual accumulation of precipitation on agricultural drought (Chisinau meteorological station records)
Source: Adapted from Daradur et al., 2015; FAO Moldova, 2018

There exists also a technique for agricultural drought identification in terms of crops production that appeal to final crops yield as an integral indicator of climate conditions of growing period. In this regard, the yield reducing to certain limits, as compared with the average long-term value or the dynamic average (trend), is taken as a criteria for evaluating drought severity (Daradur, 2001). The thresholds are usually established based on the level of variability (for example the standard error of the trend component) of a crops yield in a given area.

Socio-economic drought differs from the types of droughts given above and involves an impacts droughty meteorological conditions on various development sectors. It is determined, for example, by the demand and supply of various goods and services (such as water, feed, food grains, hydropower production, etc.), depending on the weather and climate indicators. Due to climate variability and drought, both their excess and deficiency can be observed.

Composite is often most effective for detecting drought onset and end, its intensity, spatial extent, impacts, etc. and involves a synthesis of multiple indices that combines and describes the major types of drought (Crossman, 2018). As an example – the U.S. Drought Monitor – an operational drought monitoring tool based on a multiple indices approach and produced through a partnership with the National Drought Mitigation Center and the University of Nebraska Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration.

3.3. Drought severity indices

Quantitative index-based values that robustly identify drought severity, onset and duration is essential for drought monitoring/risk assessment and policy planning. Selecting indicators is a trial and error process and can take time to test indicator suitability given the unique characteristics of the location (Crossman, 2018). The choice of indexes for the operational assessment of drought in a specific location is usually based on the ability of the index to consistently detect spatial and temporal variations during a drought event and the quantity of climate data available. The use of a multiple indicators approach is often more effective in detecting drought onset and severity (Daradur et al., 2007; IPCC, 2012; Crossman, 2018).

Most current drought assessment techniques use a monthly or longer (3, 6 and 12 months) time scale accumulation of precipitation to characterize drought in terms of intensity and spatial/temporal variability. Since drought is characterized, above all, by a deficit of precipitation, an important aspect of drought identification is the deviation of precipitation from the average climate (precipitation anomalies, % or some standardized form). These indicators are readily calculated, easy to determine and to understand by a wide range of stakeholders of climate and drought information.

However, the same values of precipitation anomalies related to average may have specific consequences for a specific area. For example, a precipitation deficit of 20-30% for the Moscow region with an average precipitation exceeds the optimal values, may be optimal for the crops yield. At the same time, the same value of anomaly for Moldova would significantly strength a water stress for crops as Moldova located in the dry lands with an insufficient precipitation (Daradur, 2001). Thus, this technique is a rather simplified expression of precipitation deficit, which is typical of drought and, in this regard, it has repeatedly been subjected to serious criticism (Crossman. 2018).

At present, perhaps the most widely accepted drought Index is the SPI which is based on precipitation data only, considerably facilitating calculations and promotes extension of the geography of its practical implication. By this, the SPI eliminates the weaknesses of many indices which have a complicated calculation mode and require extended volume of data. Practical applications of the SPI have been wide lately, ranging from studies related to agriculture, drought and climate monitoring (Daradur et al., 2007; Dai, 2012), to assessing water resources, hydrologic conditions (Shahabfar and Eitzinger, 2013) and ecosystems services (Capra et al., 2013). At the same time, simplicity and reliance just on precipitation constitute major shortcoming of the SPI (see detailed examination of the SPI, as well as other common indices used to assess drought severity in Moldova in the section 6 of this plan).

With a view of improving drought monitoring, some efforts have been undertaken in the recent decade to establish new multi-period indicators and triggers (Daradur, 2001; Gonza´lez and Valde´s 2006; Keyantash and Dracup 2004; Tsakiris et al. 2007; Vicente-Serano et al., 2010) or to improve the existing ones (Wells et al. 2004). Some research has attempted to compare drought monitoring by single and multiple indicators (Morid and Paimozd, 2007). The results showed that the sensitivity of the multiple indicators method to drought severity and onset is more significant.

The design concept and the advantages, as well as disadvantages of the indicators and indices that are in use for the operational identification of drought have been assessed in several investigations. An investigation of the World Meteorological Organization and Global Water Partnership (2016), for example, has defined the most common indicators by meaning the indicator is relatively easy to obtain and use (Crossman, 2018). An examination, based on drought events and categories in time and space to reveal a "behavior" of the common indices are in use in specific conditions of Moldova has been performed by Daradur et al., 2015. Comparative analysis of drought indicators and indices has enabled identifying their disadvantages, as well as their strong properties and perspectives of using in a specific condition of Moldova.

At present, of all the indicators, Selyaninov's Hydrothermal Coefficient (HTC) of (1958), the Palmer Drought Severity Index, PDSI (Palmer, 1965), the Standardized Precipitation Index, SPI (McKee et al., 1993), the China-Z index (CZI, Wu et al., 2001) are well known. The listed indices are in a different degree of practical application and are used for drought monitoring and risk assessment in many countries.

The HTC is one the most common indicator used in the current drought and agro-meteorological monitoring systems of Russia and other countries of the post-Soviet area, including the Republic of Moldova. This index has been the base for the drought assessment and variability analysis in the twentieth century in the country (Sofroni, 2000; Daradur et al., 2001). In recent years the SPI, Drought and Aridity Index, DAI (Daradur, 2001) have been applied in the context of drought variability/risk assessment as well as for regional climate monitoring.

3.4. Climate effects

Approach. Climate as a statistical term reflects a relative stability of weather characteristics in the given (but limited) historical time period. Determination of this time period is related to the variability of climate parameters, but it is usually defined within 30 years (Climate Change, 2012). In other words, climate is an average state of the weather conditions at a given location within a limited time period that substantially may change. An investigation of the effects of these change (for example, on aridization and drought) has often been concerned also with averages of climate depended factors which often are less climate sensitive than their extremes. A comprehensive information on the behavior of these factors can be obtained by incorporation of all spectrum values of climate dependent variables.

Herewith the issue of climate change effects on drought variability could be seen as comparing the probability distribution P'(X) and P''(X) related to different time periods of climate evolution and (or) climate projections (Daradur, 2001). *The main inference that confirms informational content of the probabilistic approach to climate depended variables is that any climate change impacts not only the average state of the depended factor, but also other distribution characteristics which are often more climate sensitive and, what is important, may have a greater environmental and development impacts* (Daradur, 2001; IPCC, 2012). Therefore, the particularities of a dynamics of unusual climate phenomena that go far beyond the average weather have come to close attention of the climate risks assessment studies.

To quantify the changes of the mean and the other distributional characteristics of climate depended factors we make use of Climate Risk Shift Index (CRSI) – a non-dimensional parameter that represents the ratio of the numerical distributional characteristics calculated for the compared samples of climate (Daradur, 2001):

$$CRSI = CL'i / CL''i$$

where under CLi the mean, variance, quintiles and other numerical distribution characteristics calculated for the compared samples of climate are understood.

This index was introduced for an assessment of effects of climate variability and change for climate depended factors and allows express monitor ongoing or expected changes at all of spectrum of climate variability/change impacts on depended variables (Daradur et al., 2015). If the value of this index equals or close to:

- 1 – it states that no any changes in the current climate characteristics related to drought;
- The value more or less than 1 states respectively on an increase or decrease in the recurrences for drought event of specific categories.

A demonstrative technique which illustrates the expediency and the informational context of the approach for drought examination under climate variability and change is represented in the figure below.

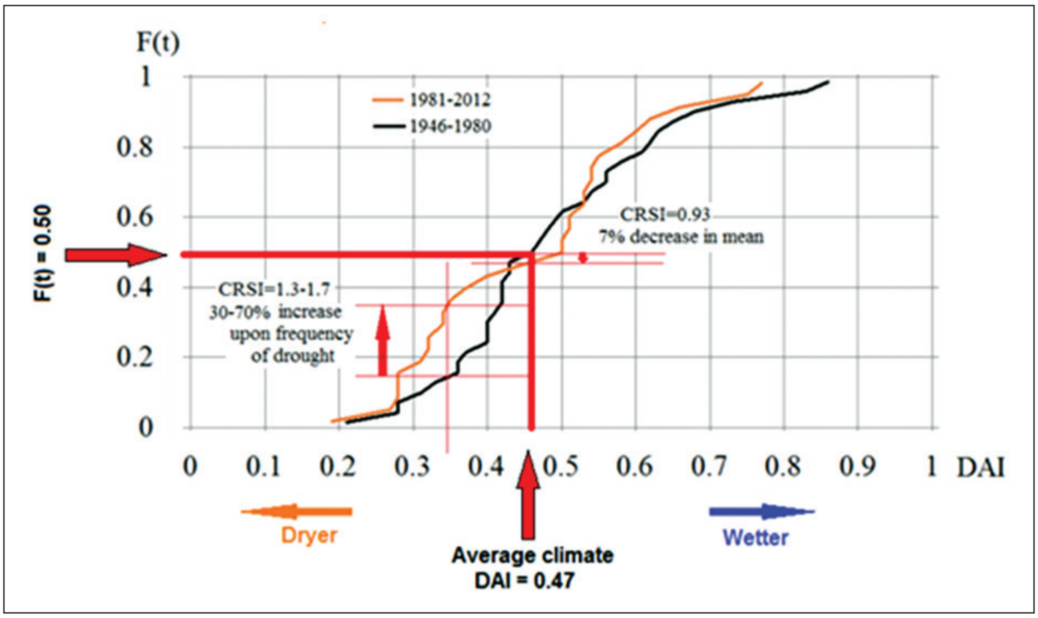


Figure 3.2. Empirical cumulative distribution functions for two non-overlapping periods as an illustrative example of the assessment of changes in the mean and in the intensity of drought by using Climate Risk Shift Index (CRSI)

Note: The values of the CRSI >1 indicate an increase in the occurrence of the event. CRSI <1 points out a decrease in the event frequency in a given climate.

Source: Adapted from Daradur et al., 2015a.

The figure illustrates comparing variability all of spectrum values of drought indices based on the characteristics a of the current climate (1980-2012) and the previous historical climate data (1946-1979). Comparing all of spectrum values of drought indices in pairs reveals much more pronounced changes in the frequency of extreme values that go far beyond the average than the related changes of the mean ($F(t) = 0.50$) that may result *in corresponding "risk shift" of the large environmental and socio-economic failures*.

What has changed. Long-term (1887-2014) examination of the average climate indicates that climate of Moldova has became warmer and wetter: over the last 127 years (1887-2014) the trend component of mean annual air temperature to increase greater than 1.0°C. Accumulated precipitation that are the main driver of drought variability and, therefore, often are used for drought identification, shows an increase on 54.7 mm. Thus, long-term changing of the average climate has no indication any significant trend toward progressive aridization of Moldavian climate.

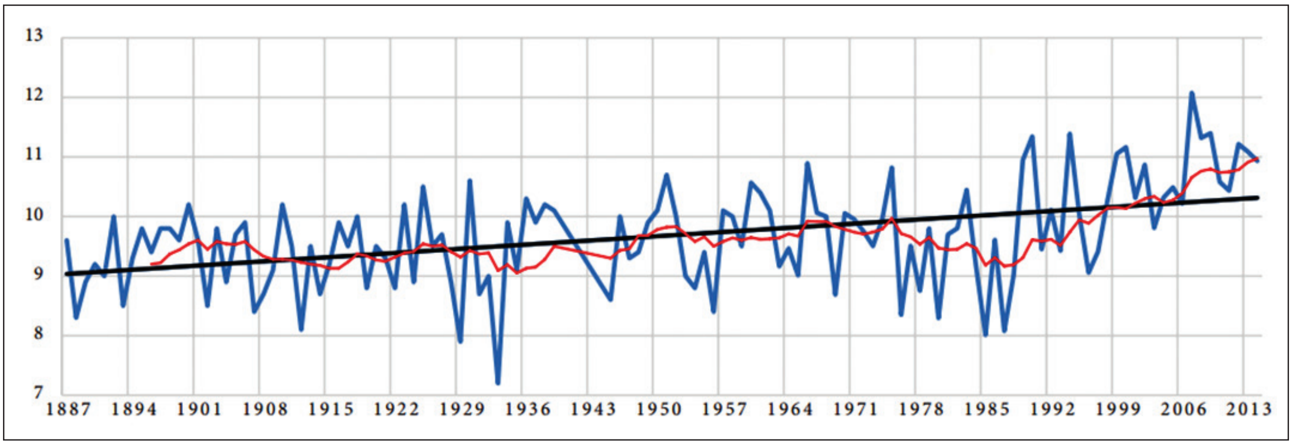


Figure 3.3. Long term trends of annual average air temperature (°C) for 1887-2014: blue (actual course trend), black solid line (long term linear trend) and red line (10-year moving average) at the meteorological station Chisinau.

Source: State Hydro-meteorological Service; Forth National Communication.

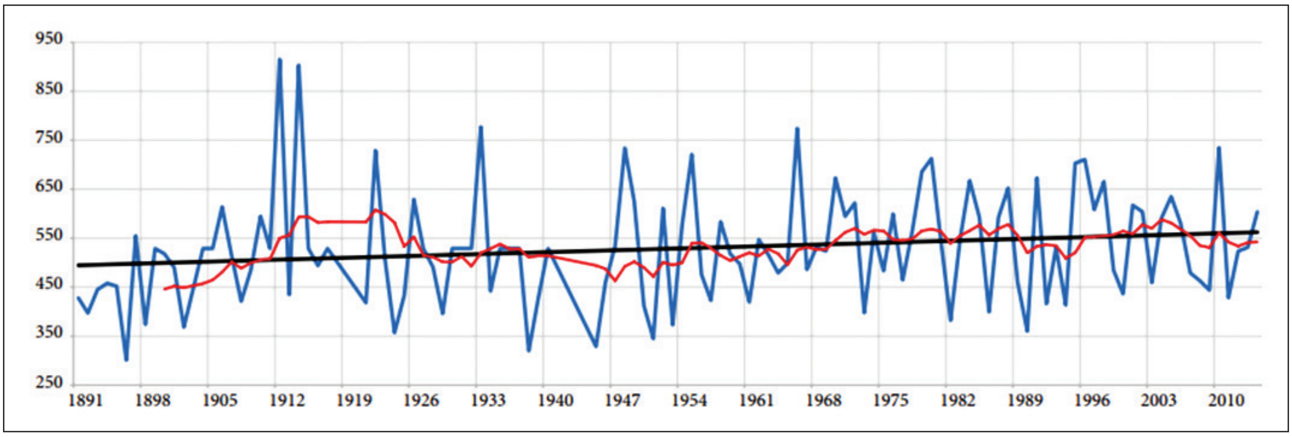


Figure 3.4. Long term trends of annual average precipitation (mm) for 1891-2014: blue (actual course trend), black solid line (long term linear trend) and red line (10-year moving average) at the meteorological station Chisinau.

Source: State Hydro-meteorological Service; Forth National Communication.

The tests are given below in the table include wider set of climate and drought indicators and indices also reveals no indication any significant trend toward progressive dryness of regional climate. The average air temperature over growing period, - T_G C^O, which reveals a relatively high (significant at 95% and higher confidence level) presumption against neutral hypothesis and indicates on real warming of regional climate.

Table 3.1. Long term dynamics of moisture and temperature indicators in the Republic of Moldova (1946-2012)

Climate and drought/aridity index	Yearly average rate (1 year^{-1})	Changes for the period 1946-2012	P-Value
Precipitation, P mm	-0.288	-18.71	0.30
Hydro-Thermal Coefficient, HTC	-0.002	-013	0.30
Standardized Precipitation Index, SPI	-0.005	-0/32	0.48
Drought and Aridity Index, DAI	-0.0008	-0.052	0.43
Precipitation Deficit, PD mm	-0.70	45.0	0.30
Average Air Temperature over growing period, $T_{G,}$ C°	0.014	0.91	0.03*

Note: * Significant at 95% and higher confidence level

Meanwhile, despite the lack of a long-term progressing tends toward aridization of average climate, an important feature of the climate effect on regional droughts is an increase their frequency and severity. For example, comparing all of spectrum values of drought indices in pairs within the historical (1946-1979) and current climate (1980-2012) indicates that the Drought Risk Shift Index (DRSI) values for the mean and near normal drought conditions are equal or close or to 1 that indicates no any or no significant effect of observed climate change to average drought conditions. However, the DRSI increases with drought severity ranging from 1.3 to 1.7 (depending on indicator). *All of indicators expressly show this important particularity of drought variability in the current climate of Moldova.*

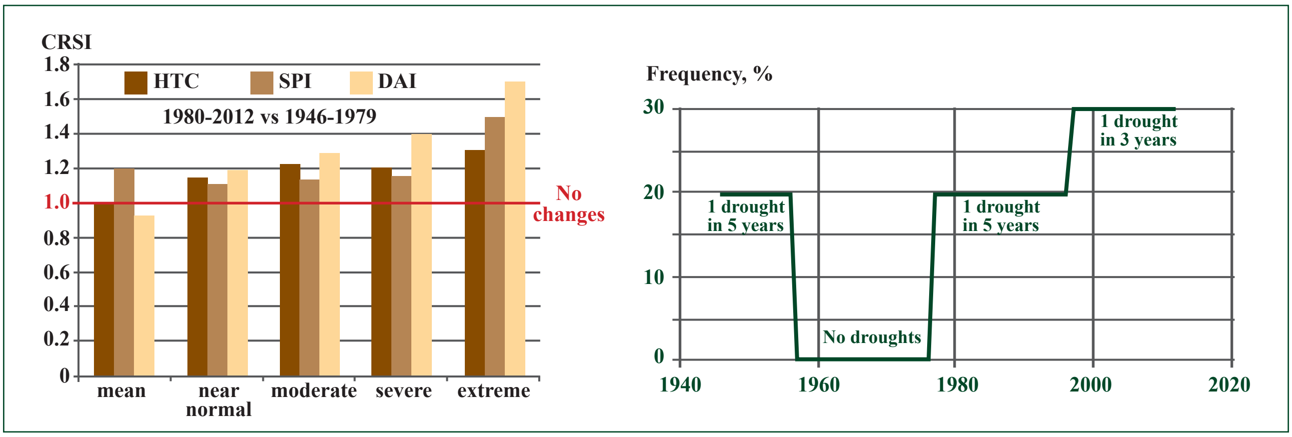


Figure 3.5. Drought Risk Shift Index for selected drought categories and means in (Current climate 1981-2012 vs historical drought data, 1946-1980) and frequency (proportion, % of years) of the 6-month time scale drought (DAI time series, 1946-2012) in the Republic of Moldova.
Source: Adapted from Daradur et al., 2015.

This results in shortening the return time of droughts with an increase of their frequency: in the 50s, 70s and 80s one long term extreme drought was registered on average in 5 years, whereas in the recent years, they are registered on average once every 3 years (*Figure 3.5.*). This assumes that current climate has greater negative potential with corresponding "risk shift" of the large environmental and socio-economic failures due to droughts. The driest year (for the period 1946-2012) in Moldova was the drought of 2007. The top 10 driest years also include the recent droughts of 2000, 2009 and 2012. Thus, the last decades 2000 to 2016 was one of the driest in the last 70 years (1946-2016).

Table 3.2. Top 10 of the driest years (6-month time scale, April-September) identified by different indicators (Chisinau, Republic of Moldova, 1946-2012)*

Rank	SPI		HTC		DAI		PD	
1	2007	-2.57	2007	0.4	2007	0.19	2007	-554
2	1951	-2.32	1951	0.5	1951	0.21	1951	-516
3	1973	-1.66	2009	0.6	2009	0.27	1946	-490
4	1990	-1.61	1999	0.6	1946	0.28	2009	-483
5	2009	-1.56	1946	0.6	1973	0.28	2012	-483
6	1999	-1.54	1973	0.6	1986	0.28	1999	-468
7	1981	-1.30	1990	0.6	1990	0.28	1986	-458
8	1946	-1.27	1986	0.6	1999	0.28	1990	-442
9	1953	-1.23	2012	0.7	1953	0.31	1973	-439
10	1986	-1.22	1953	0.7	2000	0.31	2000	-433

* *HTC* – Hydrothermal Coefficient (Selyaninov, 1958); *SPI* – Standardized Precipitation Index (McKee et al., 1993); *DAI* – Drought and Aridity Index (Daradur, 2001); *PD* – Precipitation Deficit (Daradur, 2001)

**Note:* Full list of the 6-month time scale (April-September) time series of the climate parameters and drought indices at the Chisinau meteorological station (1946-2012) is given in the Annex of this Plan.

What is expected to change. An assessment of drought variability under climate change requires an exceptional competence and responsibility, because it entails important implications in the environmental and development policy context. Although the overall warming trend is evident, the uncertainty of the degree of warming, however, remains very high. Precipitation trends, as the main driver of drought variability, have the greatest uncertainty than change of air temperature, since they are the most volatile and, very likely, the most sensitive component of the climate system.

Despite the wide range of often controversial estimates in the Moldovan scientific and expert society, there are no doubts that at present the climate of Moldova is changing at accelerating rate. A range of recent studies indicates the continuing increase of historical trend of temperature in Moldova in the near future having even a more dramatic impact on drought conditions (Daradur, 2001, Sutton et al., Forth National Communication, 2018; Taranu et al., 2018).

Climate models predict future mean temperature rises exceeding 2 °C by mid-century, and a significant decline or slight increase in precipitation by 2050, depending on the region and overall decline in precipitation after 2050. Climate change is expected to increase the frequency and intensity of most climate extreme events and natural disasters (e.g. droughts and floods, as well as other severe weather events such as hailstorms, torrential rains, late frosts, heavy winds). This will have important implications for natural environment and development, especially for the rural poor, who are more dependent on natural resources and vulnerable to climate-related shocks with fewer resources to cope with climate hazards (Forth National Communication, 2018).

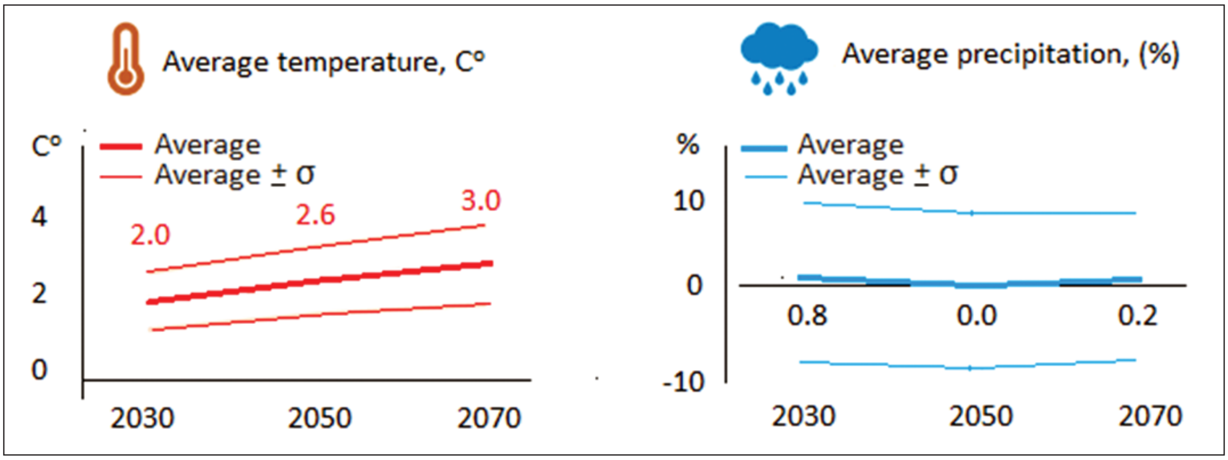


Figure 3.6. Projected climate of Moldova.

Source: Adapted from World Bank and CIAT, 2016; USAID, 20017; Forth National Communication, 2018

It is expected reduced rainfall in the summer and autumn period with an increased their variability. In combination of rising temperatures this precipitation trend will cause increase of the potential evaporation and a strong water deficit to promote conditions for a drought as a climate phenomenon (Daradur et al., 2007; Forth National Communication, 2018).

Potential evaporation is likely to increase by 7-11% during the growing season (April- September) over the 2016-2035 period, and run up to 42-47 % the 2081-2100 period and make from 1022 mm for Northern to 1312 mm in Southern AEZs under the high emission scenarios. Te lowest projected emission scenarios predict rising the potential evaporation by 10-11% cent, from 779 mm for Northern, to 990 mm in Southern AEZs, as compared to the baseline climate (1986-2005).

Under the climate change impact the whole territory of the Republic of Moldova will meet the dryness conditions (HTC ≤ 0.7) by 2080, whereas in the current climate the HTC index ranges from 1.4 to 0.7.

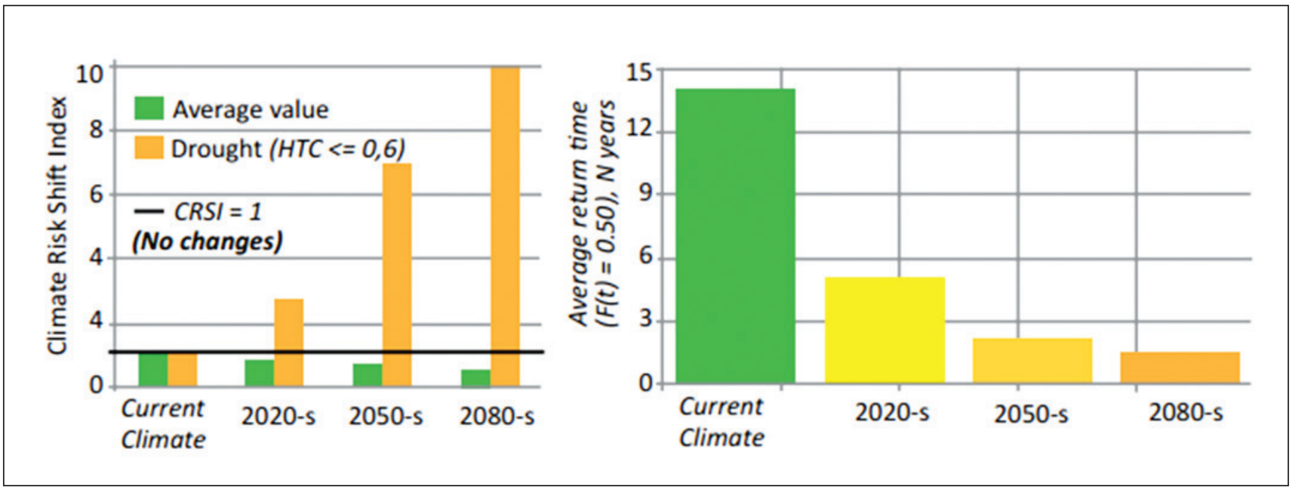


Figure 3.7. Projected drought in Moldova (Trend of the Drought Shift Index and the average return time for the lasting 6 month drought (with HTC $\leq$ 0.6) in a changing climate (Republic of Moldova)

Source: Adapted from Daradur et al., 2015

This distinguishing aridization trend of Moldavian climate will lead to increase in the drought incidences and corresponding shift of large environmental and socio-economic failures (Daradur et al., 2007). For example, the frequency of durable, six-month droughts (April-September) with the HTC < 0.6. In the current climate is about one drought incidence in 12-14 years where as in the new climate of the 2030-s, the frequency of lasting droughts may increase more than two times (one drought in 5 years).

Agriculture, water resources and forestry are among the sectors considered most at risk from climate change impacts, as are human health, energy and infrastructure. Agricultural productivity will significantly decrease due to increasing water stress on crops, even without accounting for the increasing impact of extreme weather events. Increasing the vulnerability of population and assets to the impact of natural hazards may also have significantly challenge the ability of a country to mitigate, prepare and respond to natural disasters (Forth National Communication, 2018).

4. NATIONAL DROUGHT PLANNING

4.1. NDP design concept

The 13-th Conference of Parties (COP) of the United Nations Convention to Combat Desertification requested its institution and bodies (Decision 29/COP13) implement a drought initiative in the biennium 2018-2019. Countries, that have expressed interest in developing a national drought plan were provided with a national expert and with *a model of national drought plan* to facilitate the development of their national drought plans (Crossman, 2018).

The model establishes some preconditions and institutional arrangements required to develop a national drought plan and specify the process needed to address drought and drought related activities. The guiding document requires the national drought plan to contain some essential elements for a country's preparedness to drought that include the following: (i) early warning and prediction, (ii) vulnerability mapping, (iii) preparedness and mitigation, (iv) response, and (v) communications.

The current National Drought Plan (NDP) has been designed under UNCCD Drought Initiative with an adjustment on the country specifics. Developing the plan has initiated a wide national consultative process and has provided an opportunity to analyze the current status of the drought risk assessment and management, land/water resource use/planning and prioritizing actions with regard to scientific and technical data, capacity building, resources, awareness raising, needs in terms of drought policy coherence and coordination to ensure an effective implementation UNCCD drought initiatives in the Republic of Moldova. Based on the systems design approach and supported by the comprehensive biophysical baseline information, the plan is a critical input for developing climate and land sector related policy initiatives at all management levels.

The Republic of Moldova did not have a policy document that would directly address the drought and related activities. Pre-existing policies related to drought response based mainly on a reactive (crisis management) approach and traditional hierarchical and command-and-control methods that makes for individuals and society reliant on government programs and often resulting in an increased vulnerability to drought events.

The critical insight of the current National Drought Plan (NDP) is that drought and high level of variability in agricultural production is a normal part of a farmer's operating process and should be managed as any other business risks. So, as a major advance in a policy, the Plan provided that the drought management is about for risk reduction involved in carrying out any vulnerable human activity in a changing climate (Wilhite, 2005; Daradur et al., 2007). In this respect the plan seeks an approach to shift drought policy and restructured intervention programs for creating an overall environment to facilitate be prepared for drought.

An imperative of the Plan is also that human and economic capital will be directed towards the implementation of mitigation/adaptation strategies that are relevant, targeted and effective. Despite there are many field-ready innovations with significant benefits to productivity, climate resiliency and drought mitigation objectives, limited financial resources at the community level is a considerable barrier to utilizing these innovations. In limited funding it is important that mitigation and adaptation options are developed so that they specifically address the climate risks challenges that local rural communities face. The current plan, pursuing a critical stocktaking of ongoing and promising interventions which offer the greatest return on investment from an economic, social and environmental perspective have been prioritized and implemented to improve the resilience of agricultural systems and rural livelihoods.

The NDP is also as a compendium of comprehensive drought-related biophysical information, identifying key responsibilities for information collection needed to establish a consistent basis for evaluating the drought severity to make informed decisions. This Plan describes which agencies or organizations can be relied upon to provide information for use in assessing the severity of drought conditions and impacts to the social and economic viability and natural environment of Moldova.

This plan is an open structured document and has been designed in such a way that it can be further developed and updated to reflect changing conditions, new information, and an evolving leadership structure encompassing government agencies, stakeholders, and the general public to achieve the desired management goals and objectives on mitigation of drought impacts. It is contemplated that the plan has to be updated every six years.

4.2. Overall goal and key planning objectives

The overall goal of the National Drought Plan (NDP) is to create a conducive environment and to develop a coordinated and consistent framework for integrated actions to reduce risk and to improve preparedness to drought based on an adaptive, resilience perspectives. The current plan have sought providing the incentives and so assist preparedness for drought and creating the overall environment facilitating drought risk reduction approach. It provides for a new policy principles within the 3-key components in effective drought risk reduction strategy development, summarized as follows (Wilhite, 2005, Crossman, 2018):

- **Preparedness** (the availability of timely and reliable information to make an informed decisions; communication, and application of that information). Transforming climate variability/change information for primary agricultural producers seeks to increase the drought resiliency of agricultural businesses by providing stakeholders with better decision support tools (DSTs), such as predictive information, delivered in a more effectively and usable manner with integrating comprehensive guide information. Promoting an extended and new services and facilitate planning process to make a sound decision;
- **Protection** (an appropriate risk management measures for all key decision makers). Policies and institutional arrangements that encouraged assessment; actions by decision makers that were effective and consistent; Governance and Coordination;
- **Prevention** (Implementing measures to reduce drought impacts of drought and better respond to drought). Preventive options include awareness campaigns, to optimize public behavior, improved forecasting capabilities, early drought warning systems, provisions of subsidies or matching grants to encourage and assist farmers to invest in good practices, such as control prevention land degradation through afforestation or other land use change etc.

This plan also contemplates the concept of "exceptional circumstances" to cover events of greatest severity that they would be considered beyond the scope of good drought risk assessment and management (Wilhite, 2005). The component aims to strengthening the capacity of national and regional civil protection and emergency response authorities and modernizing and upgrading to international standards regional Emergency Command Centers by providing preparedness and response equipment and training.

4.3. Science input and analytical studies

The potential value of the science information on climate variability and change for various practical applications is supported by significant body of climate and social science research. A range of governmental and civil society organizations related to climate risks are also actively recognizing the role climate science in making an informed decision. Over the past several decades regional climate science has provided a major contribution to improved understanding drought variability with advances in drought risk assessment and management research that would lead to transforming national policy formulation towards more proactive drought response.

In particular, effective mapping predisposed to drought areas at high spatial resolution has been suggested. Drought risk assessment at high resolution is an innovative task that is required by a variety of models and decision support tools that are essential for designing resilience for coping with this climate hazard at community level. Identification of areas that are vulnerable to drought impacts is an issue in the Republic of Moldova due to the variations in microclimates and impact sectors. Understanding the threats from potential drought hazards on population and natural environment along with understanding the vulnerabilities of drought allows for improved nationwide planning in advance of drought scenarios.

Transforming climate science information for primary agricultural producers seeks to increase the drought resiliency of agricultural businesses by providing stakeholders with better decision support tools (DSTs), such as predictive and impact information, delivered in a more effectively and usable manner with integrating comprehensive guide information (Daradur et al, 2007; 2015).

A number of studies and reports have been written on a wide range of subjects associated with drought and related climate risks, reducing drought impact and fostering capacity to deal with the issue. Some of the most important studies are outlined in this section.

Rural Productivity in Moldova – Managing Natural Vulnerability. World Bank, 2007. This study outlines the key opportunities and considerations for the mitigation of natural hazards, mainly for the highly exposed and vulnerable agricultural sector. Within the report, climate risks and drought impact is broadly incorporated within a number of key threats. An analysis of the occurrence, impact and potential mitigation options for a range of natural hazards affecting Moldova is undertaken within this report, with a focus on reducing risk through natural hazard mitigation or by addressing vulnerability.

Climate Monitoring and Droughts. Ministry of Ecology and Natural Resources and State Hydro-Meteorological Service, 2007. This comprehensive study covers both theoretical and practical aspects of climate variability/change and drought monitoring. It is based on the country-level climate data, including historic observations from local meteorological stations going back over 150 years. The study also includes detailed analysis of the impacts of projected future changes in climate on agricultural systems in the country, including the impact of extreme events.

National Human Development Report: 2009, Socio-Economic Impact of Climate Change in Moldova and Policy Options to Adapt. UNDP & The Expert Group, 2009. This report undertakes a comprehensive assessment of climate variability/change vulnerabilities, impact assessments and adaptation measures at the sectoral level for Moldova. Sectors included in the analysis in this work include agriculture, water resources, energy, transport, human health and natural systems. Existing policies, laws and regulatory systems are assessed in relation to their effects on climate-induced vulnerabilities for a number of sectors including agriculture, forestry, disaster management and water.

New Drought Products: Transforming Drought Information to Facilitate Decision Making. Ministry of Environment of the Republic of Moldova, Research and Project Centre, 2015. The study introduces new drought products to facilitate an informed policy decision. In particular, effective mapping of climatically predisposed to drought risk areas (DRAs) at high spatial resolution has been suggested. The findings promote extended and new services in improving accessibility of the management design information related to drought decision making. The investigation has also ensured more effective use of the climate data in terms of aligning with drought management design information and decision support tools that are essential for preparedness planning and response strategies.

Aligned with UNCCD 10-Year Strategy National Action Plan to Combat Desertification, Land Degradation and Reduce Drought Impact in the Republic of Moldova through Using Integrated Financial Strategy. 2015. Ministry of Environment of the Republic of Moldova; State Hydro-meteorological Service; CCP "Eco Logistica". The aligned NAP was an opportunity to analyze the existing situation and identify a set of needed actions with regard to scientific and technical data, capacity building, resources, awareness raising, needs in terms of policy coherence and coordination to ensure effective implementation of the UNCCD in the Republic of Moldova and strengthen monitoring and reporting process.

This document has become a strategic country document outlining actions and measurable targets with a set of indicators to assess the overall progress in implementation of the UNCCD in the Republic of Moldova. Based on the multi-disciplinary approach and scientific inputs to developing policies and strategies that are highly dependent on human behavior and environmental parameters, and supported by the comprehensive biophysical and socio-economic baseline information, this document established a DLDD resilient framework for addressing the increased environmental risks at all management levels.

However, In October 2015 at COP 12 in Ankara, Turkey, UNCCD country Parties reached a breakthrough agreement on **Land Degradation Neutrality** (LDN) as a guiding principle and agreed that Parties would play an important role in the follow-up on the new United Nations 2030 Agenda for Sustainable Development. The agreement acknowledged that SDG target 15.3 is a strong vehicle for driving implementation of the UNCCD that leveled the previous programming documents of the convention, including the 10-Year UNCCD Strategy.

National land degradation targets (Republic of Moldova). Daradur M., Cazac V., Mosoi Iu., Leah T., Shaker R., Josu V., Talmaci I., 2018. Chisinau, State Hydrometeorological Service. The overall goal of this document is to present the results of downscaling the Sustainable Developments Goals (SDGs) target 15.3 "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation-neutral world" and to contribute to raising awareness and engaging with the key stakeholders and decision-makers to create a participatory approach in establishing a resilient framework for land sector sustainability in the Republic of Moldova.

The Republic of Moldova has joined the Land Degradation Neutrality (LDN) global initiative of the United Nations Convention to Combat Desertification (UNCCD) with an objective to prioritize effective policy interventions *"to achieve by 2030 no net loss of productive land/soils and increase drought resiliency, adaptation capacity and biodiversity services of agricultural ecosystems."* Tracking progress towards LDN has been communicated in terms of increased productivity, vegetative cover, biodiversity and ecosystem services, and the resulting socio-economic benefits. The minimum set of the indicators has been recommended for monitoring progress towards LDN includes *land cover, land productivity and soil organic carbon stock*.

Vulnerability Assessment and Climate Change Impacts in the Republic of Moldova: Researches, Studies, Solutions. Taranu, L et al., 2018. This study presents an indicator-based assessment of past and projected climate, impacts and the associated vulnerabilities and risks to ecosystems, agriculture, water recourses, forestry, bioclimatic conditions, human health. It identifies regions that are particularly at risk of climate change impacts. The indicators included in this study are based on various sources covering past and future time periods, and presented at various levels of spatial aggregation.

National Communications are the primary policy documents that assesses the potential impacts of climate variability and change and outlines adaptation options to respond to projected extreme weather and climate. The latest is a Forth National Communication. This document includes climate projections for Moldova to 2100 and undertakes a preliminary vulnerability assessment of sectors including those are at particular risk – agriculture, water resources, forestry and public health. This assessment includes an analysis of climate change impacts using three separate GCM's and time periods, as well as broad recommendations and potential adaptation and mitigation options for each sector. To assess the economics of mitigation and adaptation actions, the report also includes valuation or prioritization of the adaptation options and cost benefit analysis.

4.4. Governance and coordination

Moldova has a coherent framework for institutional regulation addressing climate risks preparedness and response. Emergency situations governance is split among several ministries and state departments, local public authorities, and economic entities. Although overall coordination is provided by the Emergency Commissions, and vertical lines of authority within the system in most instances work adequately, there is little feedback up the chain of command, and horizontal linkages among many institutions appear to be inadequate in many instances (World Bank, 2017).

Coordination and activity between and for future drought. Due to the system nature of drought hazard the multiple government levels are involved for drought risk assessment and management. Moldova has several key institutions aiming at increasing mitigation capacity and resiliency to drought whose main activities relate to one or more or three drought management pillars (monitoring and early warning, vulnerability and risk assessment, actions to reduce drought impacts).

Ministry of Agriculture, Rural Development and Environment (MARDE) of the Republic of Moldova is the central public authority responsible for the development of legal and regulatory framework in the field of environmental protection, rational use of natural resources and biodiversity conservation. The MARDE is entrusted with developing and promoting policies and strategies addressing environment protection, identifying priorities, elaborating and promoting national programs and action plans which address priorities, coordinating relevant actions and monitoring their implementation in the best way; integrating environment protection policies in the social-economic processes and corresponding parts of sector policies based on the principles of sustainable development. Establishment of an information management system and development of the relevant databases is also included in its tasks.

On behalf of the Government of the Republic of Moldova, the MARDE is responsible for the implementation of international environment treaties to which the Republic of Moldova is a part, including the UNCCD, signed by the Republic of Moldova in 1998. Representatives of the MARDE also perform the function of the UNCCD Focal Point.

The State Hydro meteorological Service (SHS) is an institution subordinated to the MARDE. The State Hydro-meteorological Service is the main institution that carries out monitoring and pro- vides most of the early warning services for drought risk management in Moldova and provides criti- cal support in disaster drought preparedness and prevention. The SHS provides government agencies with timely forecasts of weather and climate emergencies and covers a wide sector related to drought response activities.

The Institute of Ecology and Geography (IEG) of the Academy of Sciences of Moldova, which is under double subordination (MARDE and Academy of Sciences) undertakes integral monitoring of environment and elaborates GIS tools for extreme weather and climate risks management. The IEG is in charge of the study of the dynamics and trends in geo- and ecosystems' components under the influence of natural and anthropogenic factors, evaluation of the factors which determine the occurrence of unfavourable geo-ecologic risks and establishment of the integrated information base for monitoring.

The "Apele Moldovei" State Agency is subordinated to the MARDE, its main responsibilities include development and implementation of water management policies, hydro-amelioration and irrigation, supply and sewage system services in Moldova. The Agency is responsible for the collection and processing of data on water use for statistical reports.

Under the conventions, excepting UNCCD, corresponding offices have been established to support the ME in implementation of the National Strategies and Action Plans and to facilitate the fundraising. Their work is project-based and beside their support activities, they are tasked with coordinating information holders and users, and establishing and maintaining relevant databases.

The State Forestry Agency "Moldsilva" is responsible for implementing the state policy on forestry, as well as cooperating with the MARDE on the implementation of the UN Convention to Combat Desertification and the UN Convention on Biological Diversity.

The Ministry of Health (MH) implements a state policy on public health, including drinking water quality management, and carries out monitoring of environmental health, including air monitoring in residential areas. Territorial centers for preventive medicine of the MH monitor quality of drinking and bathing water.

Local Public Authorities. Drought response activities are to a large degree a private sector activity and the decisions on land and drought management are often a prerogative of the private actors at the local level. So, wide involvement of the local Public Authorities and agricultural producers is, therefore, highly critical for the effective implementing drought mitigation measures.

National Working Group (NWG) for coordination and guidance of the NDP. Moldova is a small size country and the National drought planning process has been interoperated into the existing country's disaster risk management institutional arrangement. To avoid creating parallel structures, drought planning process has been implemented under the coordination and supervision of the *National Working Group (NWG)*, created in November, 2016 by the Government Decision No. 120. The NWG includes 20 members delegated to the established body by various public and scientific institutions, as well as by the economic and rural organizations, given their knowledge and experience in the drought and land degradation issues. According to the decision, WG carries out overall monitoring and coordination of the NDP implementation and organize producing and presenting reports to Government agencies and to public on the NDP implementation. The activity of the NWG and implementation of its decisions is coordinated by the MARDE and National and Focal Point to the UNCCD.

The list of involved institutions and subordinated agencies in drought monitoring, risk assessment and management with the main their responsibilities in given the table below.

Table 4.1. Institutional arrangements for climate risks mitigation/adaptation (Republic of Moldova)

	Institution	*Subordinated subdivisions*	*Main responsibilities*
1.	National (headed by PM) and local (headed by mayors) Commissions on emergency situations	Governmental Commission on emergency situations Local commissions on emergency situations	- preparing recommendations on emergency planning and; preparedness, development of national/local policies and legislation; institutional strengthening, budgeting, etc; - elaborating and coordinating of urgent measures and actions in case of emergency situations; - organization and coordinating post-recovery activities; - review of the status of preparedness to emergency situations
2.	Ministry of Agriculture, Rural Development and Environment	Republican Water Management Concern "Apele Moldovei"/ Acvaproject Institute	- developing water policy, programs and action plans; - flood protection measures and projects; - elaboration of urgent measures in case of floods; - irrigation and drainage projects; - water reservoirs and water courses dams and dykes safety control; - participation in liquidation of relevant natural hazards consequences
		Institute of Soil and Agro chemistry (partially subordinated also to the Academy of Sciences)	- soil investigations; - preparing methodologies and methods for preventing land degradation and soil improvements (including gullies erosion, landslides and surface erosion); - preparing national programs and action plans in the domain; - extension of best agricultural practices on soil conservation through training and demonstrational activities;
		State Hydro-meteorological Service	- weather and natural hazards monitoring, meteorological (droughts, hail, frost, heavy rains, strong winds, etc.) hydrological (floods), agro-meteorological forecasts; - natural hazards warning; - dissemination of hydro-meteorological information among key stakeholders; - maintaining of National Fund of hydro-meteorological data;

		State Geological Agency AgeOM/ State Enterprise Moldovan Hydro-geological Expedition	- monitoring of environmental pollution; - surface water resources monitoring, including water level and quantity; - underground water resources monitoring (quality and water level); - monitoring and data collection on groundwater; - implementing research projects in hydrogeology; - publishing the annual scientific bulletin on human activity impact on groundwater; - maintaining of the National Geological Archive;
		Institute of Geography and Ecology	- mapping of climate conditions and dangerous geological processes; - micro-zoning studies
		State Ecological Inspectorate	- ecological control and enforcement, including on implementation of preventive land degradation measures and action plans
3.	Ministry of Internal Affairs	Department of Exceptional Situations and its territorial sub-divisions	- national legislation, policy and programs development in the area of emergency response and mitigation of natural and man-caused hazards; - emergency response planning and implementation; - search and rescue; - developing and operating warning systems; - emergency preparedness and training; - post-disaster recovery and reconstruction; - monitoring of radioactivity safety; - disasters damage assessment
4.	State Forestry Agency MoldSilva	Forestry Design and Research Institute Territorial Forest Enterprises	- developing national forestry policy, legislation, guiding materials, programs and action plans in forestry sector; - preparing Forestry Management Plans; - designing afforestation and forestry biodiversity improvement projects; - implementing on the ground afforestation and other forestry activities, including afforestation of agricultural field protective belts.
5.	Academy of Sciences (subordinated to the GoM)	Institute of Geography and Ecology	- monitoring of seismic activity; - vulnerability assessment; - maps design; - developing seismic, landslides and gullies erosion mapping methodologies; - dangerous geological processes mapping (gullies and landslides); - carrying out micro-zonation studies; - development of methodologies for micro-climatic zoning
6.	Agency for Land Relations and Cadastre (subordinated to the GoM)	Land Improvement Institute State Soil Protection Association and its territorial sub-divisions	- designing national, regional and local soil improvements schemes; - implementing soil conservation measures.
7.	Local public authorities	Rayon Councils Village Administrations (Primarias)	- hazards records; - emergency situations preparedness planning and training; - planning and coordinating post-disaster recovery activities; - public warning and public awareness; - hazards reporting to central authorities

Source: Adapted from Ministry of Environment et al., 2015; World Bank, 2012; Land degradation neutrality, 2018

Institutional arrangements for exceptional circumstances. The plan also contemplates the concept of exceptional circumstances to cover drought events of such severity that they would be considered beyond the scope of good drought risk assessment and management. Institutional arrangements for exceptional drought response, relief and recovery are key functions within the mandate of the *State Civil Protection and Exceptional Situations Department (SCPESD)*, which has been part of the Ministry of Internal Affairs since 2004. The Law on Civil Protection provides clear roles and responsibilities for the office for the issuance of water – related hazard warnings. The central departments of the CPESD are organized into: operations, civil protection, fire and rescue services, finance, and judicial affairs (*Figure 4.1*).

The Commission for Emergency Situations is the main entity responsible for managing major emergencies, including drought. The Head of the Commission is the Prime Minister; the deputy head is the Director of the State Civil Protection and of Exceptional Situations Department (SCPESD), which is responsible for disaster prevention, response, relief and recovery. The Commission meets semiannually and includes representatives from all line ministries and executive branches. District and local emergency commissions have a similar structure and include heads of local governments and relevant public services.

HAZAR MANAGEMENT INSTITUTIONS

Structure of Official Hazar Management Agencies in Moldova

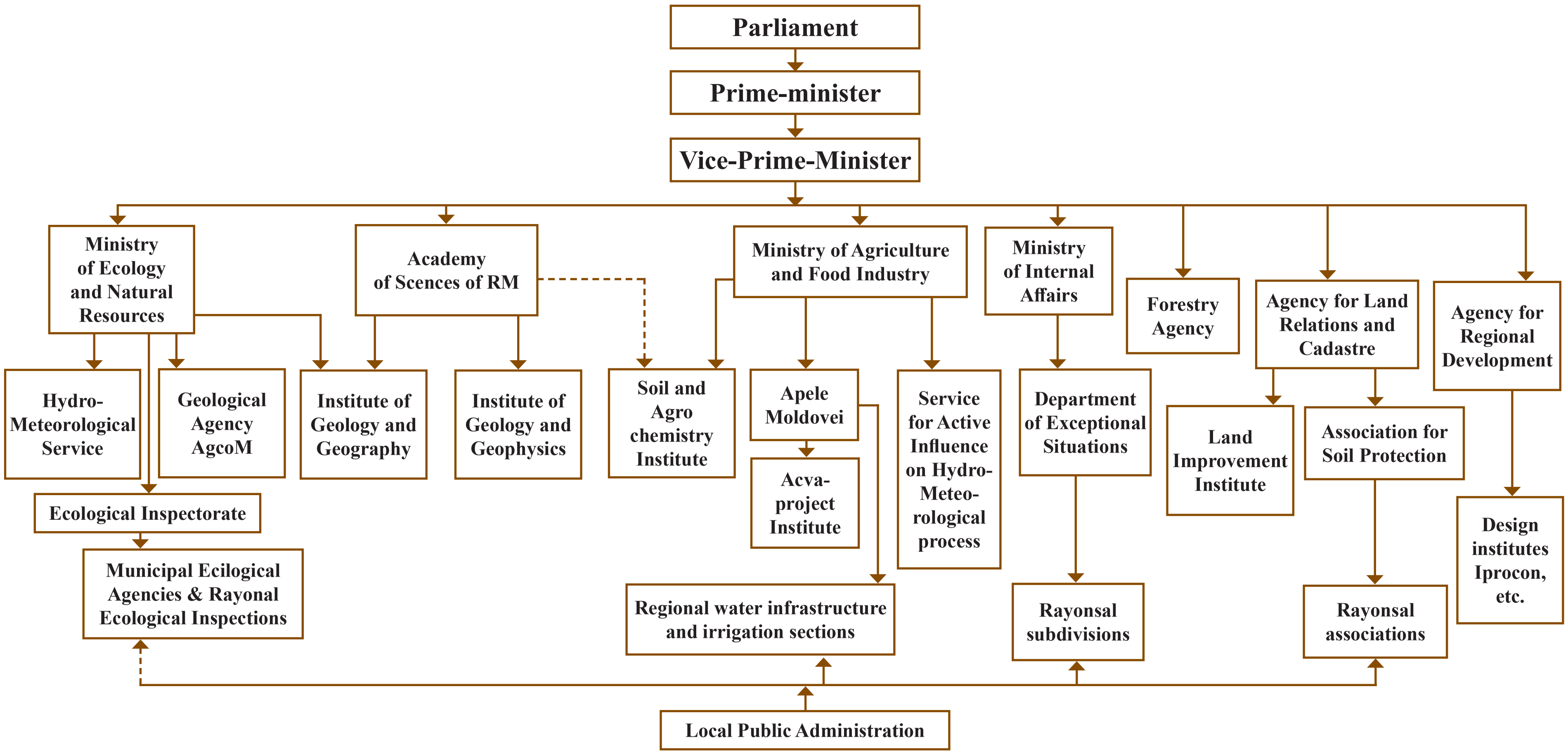


Figure 4.1. Natural Hazard Management Institutions (Republic of Moldova)

During emergencies, members are notified immediately and meet to evaluate the level of threat to people, the economy, and infrastructure and agree on responses. The emergency commissions and the SCPESD create five-year preparedness and response plans, and hold regular meetings to discuss, update, and ratify these plans. District and local-level emergency planning is updated annually; as are sector plans, for example, for flood protection. The SCPESD – coordinated emergency response exercises are carried out on average every five years,

Following the protocols for an issuance of water–related hazard warnings from MARDE agencies, the SCPESD communicates and coordinates with their own and other central, regional and local civil protection agencies as appropriate for prevention, mitigation, rescue and relief operations. There are no express provisions related to risk assessment.

The Emergency Commissions create emergency preparedness and response plans for a period of five years, which are discussed, regularly updated, and ratified in its meetings. Emergency planning at the district and local level is updated on a yearly basis, based upon public consultations and data collected by the authorities. There are also a number of sector plans, such as drought protection. These plans could be improved as follows:

- Include measures for drought management and mitigation that are not confined to rapid-onset disaster response measures;
- Recognize and specify inter-sectoral linkages and coordination mechanisms;
- Conduct cost-benefit analysis to prioritize among plans and operational measures; and

Involve all agencies, especially front-end ones such as Hydro-meteorological Service, in the planning process.

54 SCPESD sub-units are deployed in all rayons (districts) and individual municipalities. To respond to major disasters, the SCPESD has two army brigades at its disposal, and required personal to maintain a response team, usually comprising 10 to 12 persons with basic emergency response training.

4.5. Civil society, agriculture stakeholders and gender context in drought planning

Civil Society Organizations (CSOs) bring valuable efforts to achieve awareness of the population and contribute to the implementation of planned interventions to reduce drought impact in the prone areas. Legal framework on public participation in the environmental decision process was improved after the ratification of the *Convention on the Access to Information, Justice and Public participation* (Aarhus, 1998) within the *Adoption of Environmental Decisions*, ratified in conformity with the Republic of Moldova Parliament Decision No. 346-XIV of 07.04.1999.

Currently in Moldova more than 400 non-governmental environmental organizations are registered. Collaboration of the Government with NGOs is based on a memorandum which regulates cooperation between the parties, signed in 1996 and updated in 2003. At present NGOs are represented in the management boards of the National Environmental Fund and local funds, in working groups to implement international conventions and in the country's official delegations to the international environmental forums.

Public authorities use various forms and techniques of public enrolment in decision making: social soundings and referendums, public inquests, etc. Funding related to public consulting process is provided by the interested initiators' institutions. In the case of national programs consultations, the expenditures can be drawn from the resources of the National Ecological Fund (Ministry of Environment, 2013).

Establishment of the National Council for Participation (Government Decision No. 11 of January, 2010) is an example of action taken by public authorities to develop participatory approach and mechanisms to increase civil society's environmental related initiatives in the country. National Participation Council (NPC) is created at the initiative of the Government of Moldova as an advisory body. The Council consists of 30 members, representatives of organized Civil Society Organizations and groups. National Participation Council intends to facilitate involvement of all interested stakeholders in designing, implementing, monitoring, evaluating and updating of strategic planning documents, including in the field of environment and education. The Council aims to develop and promote strategic partnership between public authorities, civil society and private sector to strengthen participatory democracy in Moldova, by facilitating stakeholders' communication and participation in identifying and achieving strategic priorities for country development at all stages and by creating institutional framework and capacities to ensure full involvement of stakeholders in the decision-making process. In order to achieve the established goals, during the NPC mandate four working groups were created related to four focal point areas:

- Justice and Human Rights
- Economic Development
- Foreign, Security and Defence policy
- Social, Education, Environment and Youth policies

An important role in the development of agriculture as well as rural development in Moldova is held by extension and farmer's organizations at the national level, through the policies and programs established to support the population engaged in agricultural activities (Ministry of Environment, 2013; FAO, 2013; 2018).

The National Agency for Rural Development (ACSA) is a nationwide farmers' organization. The mission is to ensuring sustainable development of rural communities through establishing and developing a professional network of information, consultancy and training service providers for agricultural producers and rural entrepreneurs (for more detailed information see http://www.acsa.md/index.php?l=en).

The National Union of Agricultural Producers Association (UniAgroProtect) which comprises 17 Agricultural Associations, reuniting 2,238 medium enterprises and 24,307 small farmers, labouring 800,903 ha altogether (50% of the farmland in Moldova). The UniAgroProtect's objective is to provide information and consultations to its members, attract investment and implement new technologies, promote the image of the members in relation with potential investors, develop marketing, and strengthen efforts to negotiate product prices.

Overall goal of the National Farmers' Federation of Moldova (NFFM) is to improve the welfare of the rural population, through realization and protection of civil, economic, social and cultural rights of all landowners and people practicing agricultural businesses and services. At present, the NFFM encompasses 11 regional organizations, 9 Centres for Information and Consultancy and over 700 local organizations that include over 27,000 farmers.

The National AGROinform Federation is a network of regional non-governmental organizations aimed to support the private agricultural producers from Moldova by providing informational assistance and professional advisory services. At present, the National AGROinform Federation comprises 27 regional non-governmental member organizations.

The Research and Project Center "Eco-Logistica" provides support to the governmental institutions and scientific society, central and local public authorities, private actors in research and project development activities on land sector sustainability in a changing climate. The overall goal of the Center is to promote new services and decision support tools for developing new design products for drought and related climate risks planning.

4.6. Instruments in place for how to respond to drought

At present, legislative framework of the Republic of Moldova contains a set of laws related to water resources regulation and managing of drought. Among the adopted legislation the following can be mentioned:

1. The National Strategy for Water Supply and Sanitation for 2014-2028 (Law on water supply and sanitation no. 303 of 13.12.2013);
2. Environmental Strategy for 2014-2023 and its action plan (April, 2014);
3. Association agreement with the EU;
4. National Strategy for the Adaptation to the Climate Change till 2020 (October, 2014);
5. Targets and Target Dates to implement the Protocol on Water and Health in the Republic of Moldova (May, 2011).

The Action Plan for the harmonization of the legislation with the European Union has triggered a substantial reform of the entire environmental legal framework towards a more integrated approach to environmental protection. This legal framework has been implemented into national law by the Water Law (Parliament of Moldova, Law Nr. 272) and is aiming to protect water against pollution and establish environmental quality standards according to the European Water Framework Directive (WFD, 2000/60/EC) principles. The Law and its by-laws provides mechanisms for managing water resources within the river basins that contribute to effective action on preventing further damage, preserving, protecting and restoring surface and underground water resources and also sets the legal base for the water cadastre and WIS

Nationwide declaration of drought emergency also is regulated by Water Law (Article 48). Declaration is issued for purposes of seeking appropriate Government assistance to impacted stakeholders and according to the Water Law declaring drought.

The Law on Civil Protection establishes the designated national authority (State Civil Protection and Exceptional Situations Department subordinated to the Ministry of Internal Affairs) and provides clear roles and responsibilities for the office for an issuance of water – related hazard warnings. Following warning the State Civil Protection and Exceptional Situations Department communicates and coordinates with their own and other central, regional and local civil defense agencies as appropriate for prevention, mitigation, rescue and relief operations. There are no express provisions related to risk assessment.

The Regulation on drought management planning (Government Decision no. 779 of 04.10.2013) was approved in order to achieve the provisions of the Water Law the Regulation aims to regulate drought management planning and contains provisions on:

- elaboration of individual drought management plans for each river basin district or sub-basin;
- specification of the indicators that allow the identification of drought conditions;
- establishing specific monitoring systems to identify drought conditions;

- identifying management objectives and measures to mitigate the effects of drought, including measures to rationalize water demand, setting priorities for water use, support basic human needs, including food, protect ecosystems water;
- public participation in the development and implementation of drought management plans, including information measures;
- creation of water reserves for drought.

4.7. Regional cooperation

Managing drought and related climate extreme events, emergency and mitigation response requires institutional coordination and collaboration among neighboring countries. Regional strategies is crucial for drought early warning and preparedness to reduce drought risk in Moldova. Government has pursued regional cooperation through activities in the Integrated Drought Management Program for Central and Eastern Europe (IDMP CEE) that supports the governments of Bulgaria, the Czech Republic, Hungary, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia and Ukraine in the development of drought management policies and plans. IDMP CEE regional program is coordinated by the Global Water Partnership Central and Eastern Europe. One of the main outcome of the IDMP CEE is the Guidelines for preparation of the Drought Management Plan (based on the global Guidelines) served as a one of background document on designing the current plan (Global Water Partnership Central and Easter Europe, 2015). Within the IDMP CEE there was also a demonstration project between Ukraine and Moldova on Dniester river basin where: the new agro-climatic zoning Dniester River Basin was done; recommendations for improving drought monitoring prepared; upgraded forecasting models and good practices for increasing soil moisture retention developed.

Republic of Moldova is a member of the Drought Management Centre for Central and Eastern Europe (coordinated by the Slovenian Environmental Agency) and promotes a feasible contribution to developing an effective use and aligning of the drought related data with drought management design information and decision support tools. Currently, for the outputs leading to more improved accessibility and increased awareness to be more sustained, the efforts are underway to form a partnership with the key stakeholders in developing new design products based on real-time web-based services with integrating comprehensive guide information.

4.8. Policy and programs

A number of policy documents, refer to facilitate conductive environment to increase resiliency and adaptation capacity to climate risks and minimize extreme climate impacts. Moldova joined the global community in its efforts to combat Desertification, Land Degradation and Drought (DLDD) by signing the United Nations Convention to Combat Desertification (UNCCD) in 1998. To meet obligations under the Convention the Ministry of the Environment (ME), currently the Ministry of Agriculture, Rural Development and Environment (MARDE) of the Republic of Moldova, **created the National Action Program (NAP) to Combat Desertification and Drought in 2000** (approved by Government Decision no. 367 of 13.04.2000). The NAP 2000 was a primary policy document that assessed the potential impacts of land degradation, outlined response measures to prevent degradation processes and ensure drought impact mitigation. The program also aimed to consolidate institutional cooperation among donors, Moldavian government, local administration and general public and NGOs.

The NAP 2000 was repealed in 2012 (Government Decision no.796 of 25.10.2012) and had been revised. Revision of the NAP has been conditioned by the limited impact of the previous NAP and the need to increase coherence with the 10-Year UNCCD Strategy and a number of national policies and strategies closely related to DLDD, rural development and poverty reduction recently adopted by the Government of Moldova.

The Aligned with UNCCD 10-Year Strategy National Action Plan to Combat Desertification, Land Degradation and Reduce Drought Impact in the Republic of Moldova through Using Integrated Financial Strategy (2015) was a critical input for developing national drought related policy initiatives and planning. However, in October 2015 at COP 12 in Ankara, Turkey, UNCCD country Parties reached a breakthrough agreement on *Land Degradation Neutrality* as a guiding principle and agreed that Parties would play an important role in the follow-up on the new United Nations 2030 Agenda for Sustainable Development. The agreement acknowledged that SDG target 15.3 is a strong vehicle for driving implementation of the UNCCD that leveled the previous programming documents of the convention, including the 10-Year UNCCD Strategy.

The Program of Soil Fertility Preservation and Enhancement for the period 2011-2020 (Government Decision no. 626 of 20.08.2011) provides for halting the degradation of the active forms of soil cover degradation the area of about 877 thousand hectares of arable land (about 50% of the surface of arable lands) and undertaking actions for soil fertility conservation on the area of 1.7 million ha by 2020. Financial coverage of the program is insufficient (about 18 miln. MDL).

The Program on the development of water management and hydro-melioration in the Republic of Moldova for 2011-2020 and the Action Plan for its implementation (Government Decision nr. 751/2011). The specific objectives of the Program with respect to reducing drought impact contemplate an increase of irrigated land areas up to 300 thousand hectares, both rehabilitated and newly constructed – by the end of 2020 to increase sustainability of the agriculture production.

The National Agricultural and Rural Development Strategy (NARDS) was added to the NDS "Moldova 2020" in 2014 (Government Decision no. 409 from June 4, 2014) and recognizing the importance of the agro-food sector and rural development for the country. The strategy outlined the major problems and identified optimal solutions in the sector and serves as a framework for rural development planning and securing financial sources from internal development partners, international financial institutions and donors to support activities for implementation of the proposed agenda.

Reducing drought impact has been addressed under the second goal and related to the supporting:

- farming and water management practices;
- environment-friendly production technologies, organic products, including biodiversity services;
- adaptation and mitigation of climate change impacts on agricultural production.

According to the NARDS, total investments provided for 37,948,684 MDL, the implementation period – 2014-2020.

The National Plan for the extension of the areas with forest vegetation for the years 2014-2018 (Government Decision no.101 of 10.02.2014), which stipulated the afforestation of the degraded lands, increase the forest strips areas along the rivers, as well as a forestry green belts to protect agricultural lands on an area of at least 13,000 ha. however, due to the lack of financial sources the plan has implemented only by the 20%.

In 2014 the Government approved the Climate Change Adaptation Strategy by 2020 (Government Decision no. 1009 of 10.12.2014) a national strategic framework with a overall goal to advance the resilience of the country's social and economic development processes to climate variability and change. The strategy recognized the six sectors considered most vulnerable: agriculture, water resources, forestry, human health, energy and infrastructure.

The strategy includes an Action Plan to 2020, at an estimated budget of US$155 million, based on institutional and investment activities recommended within each sector. Intended to serve as an umbrella strategy that creates the enabling environment for specific sectors and ministries to “mainstream” climate change adaptation and risk management in their existing and future strategies.

Other national strategies to enhance climate change adaptation and mitigate extreme climate impacts is **the Environmental Strategy** for 2014-2023 (approved by the Government Decision no. 301/2014) has set out the target to expand the forests area up to 15%. In order to achieve this objective, it is planned to create and restore riparian protection stripes and watersheds on the area of 30 thousand ha, forests on degraded lands, green spaces – on the area of 150,000 ha. The overall objective of the Strategy is to create an effective environmental management system that will help to improve the quality of environment and ensure the right to a clean, healthy and sustainable natural environment

The subsequent steps were submitting **First Nationally Determined Contributions (NDCs)** in 2017 of Moldova, which outline adaptation priorities for six climate-sensitive sectors: agriculture, health, water resources, energy, forestry and transport. These strategic documents are intended to serve as an umbrella strategy which creates the enabling environment for specific sectors and ministries to ‘mainstream’ climate change adaptation and risk management into existing and future strategies through a series of National Adaptation Plans (NAPs) and Sectoral Adaptation Plans (SAPs).

In 2018 the voluntary Land Degradation Neutrality target of Moldova “to achieve by 2030 no net loss of productive land/soils and increase drought resiliency, adaptation capacity and biodiversity services of agricultural ecosystems” was established. The target was endorsed and transparently communicated at the national and international levels. The National LDN agenda integrates global obligations of the Republic of Moldova and ensures a high relevance and clear policy implications to government land-sector priorities, capitalizing the previous country land sector and climate variability/change mitigation and adaptation planning efforts.

The National Strategy on Gender Equality 2016-2020 is crosscutting with rural development, especially in the implementation of the article 14 of the Convention on the Elimination of all forms of Discrimination Against Women (CEDAW) on the rights of rural women.

4.9. A SWOT analysis

Despite of existing a number of programming documents related to drought, the scientific/expert society and subsequent contribution to the understanding the relationships between the high variability of a climate and droughts over Moldova suggests that the currently existing drought policy has not received the due recognition that it should. The UNCCD Drought Initiative in Moldova and related communication activities contributed to facilitating an expert consultative process on the possible solutions with the intent of providing a strong proactive approach based on risk reduction principles.

An analysis, represented below in the text form as well as in a shorter form of a matrix, used a strategic planning approach to evaluate the Strengths, Weaknesses, Opportunities, and Threats (SWOT) related to legal and institutional framework in relation the country level drought plan. The SWOT analysis aimed at identifying and assigning factors, either positive or negative, to develop a structured comprehensive understanding of the main factors that determine the implementation of the drought risk reduction in the specific country conditions of the Republic of Moldova.

Strengths:	Weaknesses:
Environmental - *Fertile soils and the favorable temperate climate.* Institutional - *Commitments to the promotion of green economic development, including sustainable agriculture;* - *Land degradation issues in line with the recent sectoral development strategies and programs;* - *Numerous programs and projects to promote afforestation and reforestation, land restoration and carbon sequestration.* Policy, Legal and Regulatory - *Medium and long term strategic vision to accelerate environmental protection with European standards;* - *The priority attention of land use regulation to the land/soil protection issues.* Economical and financial - *Introduction of the Medium-Term Expenditure Framework (MTEF) and improving coherence environmental protection policy and allocating finance.*	Institutional - *Weak governance and institutional capacity;* - *Limited experience in strategic planning;* - *Limited availability of technical and business management skills;* - *Poor coordination at the institutional level;* - *Lack of effective coordination of donors.* Policy, Legal and Regulatory - *Sector-based approach;* - *Lack of incentives for private investors;* - *Unclear regulatory framework on the roles of Local authorities in the land protection;* - *Ineffective market-based instruments for pursue green, clean or low-carbon investments.* Economical and financial - *lacking of clear environmental priorities in budget process;* - *Reduced availability of financial resources.*
Opportunities: Institutional - *Avoiding narrow sector-focused strategies that lead in a fragmented policy framework, unclear priorities and dispersed public budgets;* - *contributing to the resilience agriculture and rural sustainable development.* Policy, Legal and Regulatory - *Improving policy coherence;* - *Enforcing SLM and rural development sound policies;* - *Striving participatory approach with involving individuals and stakeholders;* - *Moving away from narrow sector-focused strategies.* Economical and financial - *Developing linkages between planning and financing;* - *Improving the investment and business climate.*	**Threats** Environmental - *Global environmental challenges in a changing climate.* Institutional - *A complex, multi-dimensional system challenge of land degradation issues;* - *Lack of coordination and synchronization of policies and activities;* - *High upfront capital costs, long investment timelines, and difficulties to access loans;* - *Insufficient financial support.* Policy, Legal and Regulatory - *Lack of clear Local authorities' responsibilities in solving land degradation issues;* - *Unfavorable business and investment climate;* - *Political uncertainty regarding consistency of policy and strategy.* Social, information and awareness - *Climate risks not seen as a shared social responsibility;* - *Lack of political clout of the environmental authorities;* - *Inadequate information by the private actors at the local level;* - *Fragmented land ownership;* - *Significant rural depopulation.*

5. DROUGHT MONITORING AND EARLY WARNING

5.1. Drought and regional climate monitoring

In the Moldavian natural environment there are few factors that could be as important to human as the weather and climate have. However, we know that the weather and climate may deviate from their averages, often quite significantly. These deviations (or anomalies) are the source of the greatest uncertainty in many development sectors. Recurrence from time to time of catastrophic droughts, heavy rains, extreme heat and cold, other climate extremes initiate a great interest to assessing these variations and their impact to the environment and human activity. How far can we look into the future variability of the climate extremes? Can we predict their behavior with sufficient accuracy for practical needs? These questions naturally arise when it comes to reducing the vulnerability and economic shocks from the climate variability and change.

Assessment of natural and anthropogenic climate variability and change in Moldova is a task of regional climate monitoring. Monitoring of the regional climate has the following three basic objectives (Daradur, 2001):

- Regular monitoring of the state of the regional climate system;
- Probabilistic assessment of the anomaly state of the current climate of Moldova; and
- Identification of natural and anthropogenic drivers of its observed changes.

The basic requirements to the monitoring systems of the regional climate of Moldova may be reduced to its rhythmic functioning and adequate describing of weather and climate throughout all territory of Moldova and any scale of their variability in time. Since the main issue of perception of the current climate is related to an increased variability, the essential requirement of the monitoring system is an assessment of the degree of the anomalies and "behavior" of climate extremes.

Climate hazards in Moldova (that, in essence, are extreme demonstration of climate variability since they usually go far beyond of averages) prove to be more sensitive to the changes than the average state of regional climate or even its average dispersion (Daradur, 2001; Daradur et al., 2007). This feature of the atmospheric dynamics in the region has became very important, both for a cognition of the climate patterns and their drivers, as well as for understanding negative environmental and socio-economic consequences of extreme climate events. In particular, we can assert that a significant change in extreme climate will lead to a corresponding shift of "major economic failures" resulting in environmental degradation and development instability. In this respect, an analysis and interpretation of drought phenomena, that go far beyond average climate would be a very useful element to monitor the regional climate systems.

An availability of information about the drought and related climate risks is, therefore, a prerequisite for substantiating and subsequently to making an informed policy decision. Such information, along with the data of the existing observational network, serves as an important component of the climate monitoring at the regional scale. An attempt of the practical application of the given approach has been undertaken in this plan. Based on the findings obtained, a number of drought variability particularities and stochastic properties have been identified to be useful for regional climate variability and change risk assessment and management.

5.2. National drought indicator systems

The most common indices that are in use for drought severity assessment in the Republic of Moldova are listed in the table below. The design concept and the advantages, as well as disadvantages of the indicators that are in use for the operational purposes in Moldova are also summarized in the given table.

Table 5.1. Drought indexes are in use for operational purposes in the Republic of Moldova

	Drought indicator name/ Abbreviation	Designing concept	Advantages	Disadvantages	Area of current applications
1.	*Percent of Normal Rainfall Index*	*Precipitation based concept*	*Simplicity; Easy to calculate; Standardized nature; Most effective when used for a single region or a single season.*	*No consideration of evapotranspiration and 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*
2.	*Hydro-Thermal Coefficient, HTC (Selyaninov, 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*
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 and 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*

5.	*Soil moisture at a series of depth*	*Integral approach*	*Effective for agro meteorological service*	*Limited data base*	*Global, Regional*
6.	*The Stream flow Index (Q)*		*Based on the number of consecutive months that streamflow levels are below normal*	*Limited data base*	*Global, Regional*

Source: Adapted from Daradur et al., 2015

Lack of a consistent statistical basis to assess drought conditions and of comparability of the drought categories among the indices challenge achieving the desired monitoring and management goals (Daradur et al., 2007). An examination of the most common convential drought indices that are in use for the operational purposes in Moldova indicates that all of the indicators are closely related to each other ($R^2 = 0.96$-0.98). Showing generally similar behaviour in the drought detection, the drought indices reveal discrepancies related to the drought triggers and categories that determine timing and management actions, as well as to the key vulnerable sectors. The complex indicators based on water balance approach are more responsive to an increase drought frequency associated with accelerating increase of the air temperatures and warming of regional climate.

Hydro-Thermal Coefficient, HTC is one of the main indicators used in the current drought and agrometeorological monitoring systems of Russia and other countries of the post-Soviet area, including the Republic of Moldova. This index has been the base of the drought variability analysis of the twentieth century in Moldova (Sofroni, 2000; Daradur et al. 2007). The HTC is calculated as (Selyaninov, 1958):

$$HTC = P/\,0.1\Sigma T \geq 10°\ \mathrm{C},$$

where P and T mean the consecutive daily precipitation and air temperature above 10 °C respectively. HTC discerns four severity levels of drought (see the Section 6.2).

Standardized Precipitation Index (SPI) is based on precipitation alone, and it represents the standardized anomaly, equivalent to the statistical Z-score, for a multiple time scale (3, 6, 9 or 12 months), relative to climatology (McKee *et al.*, 1993). Calculation of the SPI is based on the transformation of a long-term record of precipitation data to a standard normal distribution. Usually the procedure consists in fitting gamma or other distribution to data and then transforming them to an equivalent SPI value based on the standard normal distribution (Guttman, 1999). In this study it was assumed that SPI comes from lognormal distribution with 95% and higher confidence level:

$$SPI_i = Z = (x_i - \hat{\mu})/\hat{\sigma},$$

where $\hat{\mu}$ and $\hat{\sigma}$ are sample estimates of the population mean and standard deviation respectively.

To assess how well a given distribution describes the data, it is possible to compare the empirical cumulative probability distribution with the corresponding theoretical cumulative probability distribution. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. SPI also discerns four severity levels of drought.

The Drought and Aridity Index (DAI) is designed on the water balance concept and is calculated as a ratio of accumulated precipitation, adjusted by timing ($\sum p^{*}PDC$, mm), mm and radiation resources expressed by potential evapotranspiration, E_0 mm (Daradur, 2001). *The DAI incorporates temporal properties of precipitation over the designed time period, that is one of the fundamental aspects of drought detection at any location:*

$$DAI = \sum p^{*}PDC / \sum E_0$$

where: $\sum P$ – accumulated precipitation; PDC – Precipitation Distribution Coefficient – $PDC = 1 - \sum Pi^2 / (\sum Pi)^2$; $\sum E_0$ – accumulated potential evapotranspiration.

The resulting index, with its limits, permits climate classifications and, therefore, is a convenient tool for aridity and drought evaluation across locations. The DAI within 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

5.3. Monitoring, data collection and early warning systems

Hydro-meteorological and agro-meteorological monitoring. Monitoring trends and collecting pertinent weather and climate data is vital to making timely and informed decisions. In the Republic of Moldova the State Hydro-meteorological Service (SHS) of the Ministry of Agriculture, Rural Development and Environment (MARDE) is the main institution that carries out monitoring and provides most of the early warning services for drought risk assessment and management. Currently the monitoring of key meteorological parameters for a drought assessment (precipitation, temperature, soil moisture, etc.) is carried out on 13 weather stations and 19 agro-meteorological posts.

The State Hydro-meteorological Service carried out different types of operations, such as agro-meteorological analysis of weather conditions, forecasts and yearly warnings are used to determine planting and harvesting periods, productivity assessments, planning of economic policy measures and other types of short- and long-term planning in agriculture. Historical agro-meteorological data and agro-climate information, findings on regional climate change applied research represent a basis for the of long-term policy and planning in agriculture. The materials of the agro-meteorological observations are published since 1955 in terms of agro-meteorological directories and agro-climatic guidance.

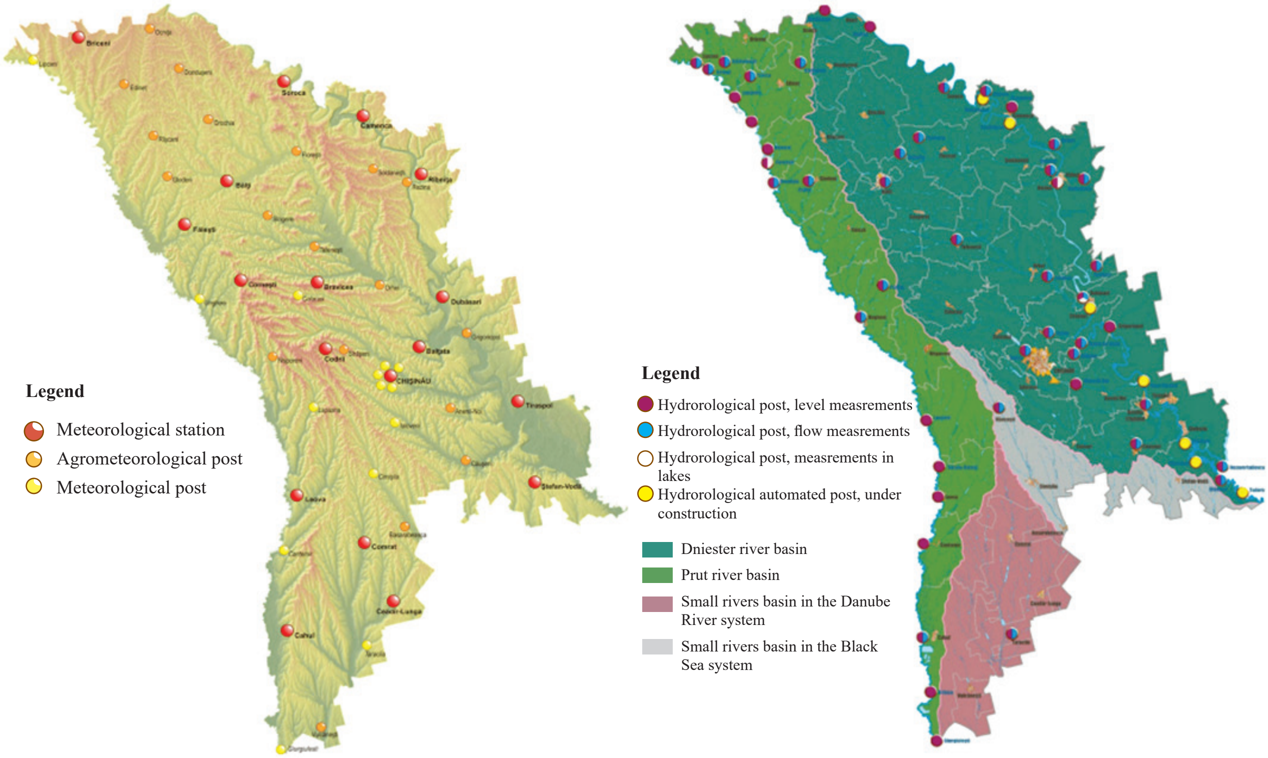


Figure 5.1. Meteorological and hydrological network of the Republic of Moldova

Information services provided by the SHS:

- Decadal and annual agro-meteorological bulletins;
- Monthly and annual agro-meteorological data (soil temperature on agricultural lands, soil temperature, soil moisture, freezing and thaw depth, phenological observations, crop production);
- Multiannual average agro-meteorological data.;
- Agro-meteorological characterization during the year after each seasons;
- Information on the influence of weather conditions on agricultural crops and farming operations;
- Information on the unfavourable phenomena (drought and dry wind, frosts in the vegetation period, hail, sunshine, wind, frosting of sowing) and damage for agricultural production;
- Information on timing of the onset air temperature of 0, 5, 10, 15 °C and the Crop Heat Units for various agricultural crops;
- Data on reserves of productive moisture in the soil layers for any periods of agricultural crop vegetation;
- Forecasting information on beginning dates of the stages of crop's vegetation, on Crop Heat Units (sums of the active and effective air temperatures).

Yearly warning information systems

The SHS analyzes, prepares meteorological and climate information and provides following forecasting information:

- Soil moisture content by the beginning of spring field works;
- Main phases of vegetation and maturation of agricultural crops;
- Country crop production on main agricultural crops (wheat, maize, sunflower, sugar beet) with anticipation from 1 to 3 months;
- Winter conditions and possible damage fruit and vine crops;
- Information on climate hazards and potential damage assessment for agricultural production.

Socioeconomic indicators that are used to asses drought and associated risks currently are also under responsibility of the Ministry of Agriculture, Rural Development and Environment (MARDE). Data is sent in from districts for compiling and analyzing by the Department of Crops of the ministry. MARDE is also promoting crop insurance against drought and other natural hazards (frost, hail), matching compensation by the insurance companies.

Monitoring of ground waters. For monitoring and data collection on groundwater levels is carried out by the state entity "Hydro-Geological Expedition" subordinated to the Ministry of Agriculture, Regional Development and Environment. Monitoring includes measurement of ground waters level, temperature, and quality. Te Institute of Geology and Seismology of the ASM also implements research projects in hydrogeology, with ground water monitoring component included. Ground water monitoring results are published in the annual scientific bulletins, in which the analysis of information on changing the ground waters level and quality as a result of human activities and natural processes, is provided. Te results of ground water quality monitoring are also transmitted to the State Geological Fund.

The primary resource for soil information is the Institute of Pedology, Agro-chemistry and Soil Protection (IPASP). Research area of the IPASP spans to the genesis, physical, chemical, biological and geographical particularities of soils, aims studying and creating the informational database to contribute implementing advanced technologies in agriculture, developing concepts, strategies and programs in soil science and agro-chemistry and promoting efficient practices to combat land degradation, land recovery and soil protection.

Integral monitoring of environment. The Institute of Ecology and Geography (IEG) of the Academy of Sciences of Moldova, which is under double subordination (Ministry of Agriculture, Rural Development and Environment and Academy of Sciences), undertakes integral monitoring of environment and elaborates GIS tools for extreme weather and climate risks assessment.

The national forest monitoring network of the Republic of Moldova was created within "Moldsilva" Agency. The State Agency "Moldsilva" is the central public authority (subordinated directly to Government) and is responsible for implementing state policy in forestry. The institution has 25 subdivisions encompassing including the Forest Research and Management Institute (ICAS). "Moldsilva" manages 83% of the National Forest Fund (NFF – forest, land for afforestation and land designated in the national cadaster as forest), other state institutions (e.g. Botanical Garden etc.) manage a further 4%, with the balance being owned and managed by Local Public Authorities (LPAs).

Transforming sophisticated drought and related climate risks information into simple and, at the same time, effective decision support tools (DST) to promote designing a more proactive drought planning is the mission of the Research and Project Center "Eco-Logistica".

The Center seeks new services for more effective use and reduce a missing link between climate science information and the stakeholders' skills that is essential for drought preparedness planning and response strategies. The center promotes also extended and new services to improve accessibility of the drought management design information and to increase awareness. Currently the efforts are underway to form a partnership with the key stakeholders in developing new design products based on real-time web-based services combined with integrating guide information.

5.4. Remote sensing and GIS data application for drought monitoring and yearly warning.

Drought monitoring and impact assessment with conventional methods has been laborious and time consuming. Recently developments in the satellite imagery integrated with geo-spatial technologies assist in initial threatening indication and near real time destruction valuation of drought hazard.

To monitor of drought and to assess the current drought situation with the objective of providing near real time information to manage emerging crop losses or water shortages and prevent or mitigate possible drought impacts, the NDP contemplates to incorporates the latest remote sensing data integrated with GIS-technologies sourced from the Flood and Drought Portal (www.flooddrought-monitor.com). The Flood and Drought Portal is the outcome of the Flood and Drought Management Tools (FDMT) project (http://fdmt.iwlearn.org/) financed by the Global Environment Facility (GEF), International Waters (IW) and implemented by UN Environment, with the International Water Association (IWA) and DHI as executing agencies. The project is developing a methodology for basin organizations and local users, which uses tools that allow the integration of information on climate variability and change, including floods and droughts, into planning across scales: Integrated Water Resources Management (IWRM) planning, Water Safety Planning (WSP) and Transboundary Diagnostic Analyses (TDA) and Strategic Action Plans (SAP). The outcome will enable stakeholders at the transboundary and national basin to local levels, to compile information, from models, indicators and existing planning approaches, so as to develop future planning scenarios to make a sound decision (Flood and drought management tools, 2018).

Portal uses the latest remotely sensed data to monitor precipitation, soil moisture, and vegetation health in order to support drought early warning systems (Flood and Drought Management Tools, 2019). Based on the latest available climate data as well as downscaled seasonal forecast assessment of drought status is carried out with interpretation of different types of drought hazards:

- Climate status based on observation and forecast of rainfall, as well as observation of temperature day temperature;
- Soil moisture status based on the observation of soil moisture content in the top layer of the soil;
- Vegetation status based on the observation of the Normalized Difference Vegetation Index (NDVI) providing information about the vegetation canopy greenness.

The methodology is based on an online approach providing users access to a series of web based technical tools to incorporate information about droughts and likely climatic scenarios into planning across scales to address impacts. The tools enable users to carry out baseline assessments using readily available satellite data, impact assessments through the analysis of the data, planning options and a means for disseminating information to relevant groups or individuals.

6. DROUGHT DECISION SUPPORT SYSTEMS IN THE REPUBLIC OF MOLDOVA

6.1. Operational assessment of drought risks

Risk assessment is an important component of the management process of natural hazards that identifies risks and evaluates the magnitude of their consequences and the likelihood that they occur (Leigh and Kuhnel, 2001; Smith, 2001; Daradur, 2001; 2015; Dalezius et al., 2014). The overall goal of the drought risk assessment is to promote an informed decision resulting in designing resilient drought plans. Hence, the risk of drought disaster integrates of both the frequency and severity of drought and the corresponding vulnerability where drought risk is considered as a hazard (a potential threat, that is with an additional implication of the chance of a particular hazard actually occurring).

An essential steps of the drought risk assessment is an operational identification of drought to reveal the probability (frequency) and severity of drought as well as ability to manage that risk of a drought. The Global Water Partnership Central and Eastern Europe (IDMP CEE, 2015), for example, defines following steps for identifying the operational drought risk assessment:

- Identifying the drought hazard with regard to its spatial extends, frequency, and severity;
- Identifying and quantify drought vulnerability, e. g., people, economy, and structure exposed to the drought hazard;
- Computing drought risk pattern from drought hazard and vulnerability.

Identifying of areas and key sectors that are vulnerable to drought impacts is an issue in the Republic of Moldova due to the variations in microclimates and impact sectors. The plan recognize areas at risk (Drought Sensitive Areas, DSAs) to promote implementing specific response strategies prior to the onset of a drought to mitigate potential impacts, and, therefore, to assist in a more proactive drought management strategies.

In this plan the operational identification of drought risk and its ratings focus on the traditional framework using the return level and return time concept (Daradur et al, 2007; 2015). The concept is a byproduct of the extreme value analysis and it is considered as a convenient tool for climate risks assessment and planning (Daradur, 2001; Vicente-Serrano, 2010; Salinger and Porteous, 2013). Wherein, qualitative assessments of the risk level proceeds from relationships of the frequency of a drought and associated probability of its occurrence. In practice, quantification of a drought risk and potential damages are based on probabilistic estimates of a drought event (hazard) with the potential adverse impacts on key vulnerable sectors – for people, the natural environment, and economic actives etc. (Daradur et al., 2007; IDMP CEE, 2014; Crossman, 2018).

Table 6.1. Qualitative assessments of the risk level based on relationships of the frequency of a drought and associated probability

Drought frequency (λ, 1 year^{-1})	Average return time, years	Risk level	Description
$\lambda > 0.2$	< 5	Frequent	Frequent and high risks of drought damage
$0.1 < \lambda < 0.2$	5-10	Probable	Relatively frequent and damaging medium drought
$0.01 < \lambda < 0.1$	10-100	Rare	Rarely experience and low damaging drought
$0.001 < \lambda < 0.01$	100-1000	Very rare	Very rarely experience and damaging drought
$\lambda < 0.001$	> 1000	improbable	No experience and damaging drought

Source: Constantinova et al., 2006; Daradur et al., 2007

The plan has established a system for quantifying drought risk to represent the overall sensitivity of a particular location to drought risk and provides for:

- *An average return time.* Average return time does not mean for sure that the 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;
- *A practically assured return time* means that the drought event will occur precisely once within this time period (at 95% and higher confidence level);
- *Finite severity level of drought* – the severity level of drought in the particular location that cannot be overcome in the current climate.

The Precipitation Deficiency (PD) is used as a proxy indicator of the potential threat drought hazards. The accumulated values of the Precipitation Deficits ($\sum PD$) are an equivalent to the amount of water that is necessary to be added to reach water balanced climate, and it is considered an important tool for drought risk management (Daradur, 2001; Vincente, 2010; Salinger and Porteous, 2013). Areas with the strong precipitation deficit are challenging for farming operations making a non-profitable market aggravated by the limited water resources. Agricultural producers need more investments to reach water balanced conditions for maintaining a sustainable productivity of agro-ecosystems. Optimum water levels, for example, to obtain the potential of agro ecosystems productivity, can be reached by irrigation.

A better understanding of areas that are at risk promote to a sound decision and determination of a drought insurance rates throughout the country. Although Moldova is relatively small, it has a number of distinct areas that experience significantly different weather patterns, topography, and runoff characteristics. The extent of drought tends to be regional or even local and different responses may be needed (Daradur, 2001; Daradur et al., 2007). Therefore, this plan provides for an assessment of drought and its key sector impacts and vulnerabilities on a regional and, even, local basis, rather than using a single nationwide or regional approach.

6.2. Establishing triggers and categorization of drought conditions

Drought triggers are interpreted as threshold values of the drought indicator that differentiate drought conditions into severity categories. Determination of drought indicators and triggers is an important issue of drought planning, since they define the timing and type of management actions, such as granting relief from the required measures. Since each of index was established for a specific geographical area, distinguishing drought into categories often lacks a consistent statistical basis and is not comparable among indicators. (Karl et al., 1992; Lohani et al., 1998, Daradur, 2001; Steinemann, 2015).

Drought conditions in Moldova are described using a certain combination of the simple and practical drought severity thresholds of the U.S. Drought Monitor and recommendations on the defining drought stages of the Global Water Partnership Central and Eastern Europe (IDMP CEE). Keeping the abbreviation of the drought categories of the U.S. Drought Monitor, however, in Moldova, following the designations of the GWP guideline, 4 drought categories are defined (the US Drought Monitor classifes areas into 5 drought categories) that are D0 (Abnormally Dry) to D4 (Exceptional Drought).

Table 6.2. Drought support decision systems: Drought triggers and categories (Meteorological drought)

Identified by HTC			
Values of indicators	**Drought severity**	**Chance of occurrence in any given year (%)**	**Occurrence in any given year (1 time in N years)**
0.71 to 9.00	*Abnormally dry*	30	1 in 3
0.61 to 0.70	*Moderate Drought*	15	1 in 7
0.51 to 0.60	*Severe Drought*	5	1 in 14
0.50 or less	*Extreme Drought*	2.5	1 in 50
Identified by SPI*			
0 to -0.99	*Abnormally dry*	30	1 in 3
-1.00 to -1.49	*Moderate Drought*	15	1 in 7
-1.50 to -1.99	*Severe Drought*	5	1 in 14
-2.00 or less	*Extreme Drought*	2.3	1 in 44
Identified by DAI*			
0.41 to 0.50	*Abnormally dry*	30	1 in 3
0.31 to 0.40	*Moderate Drought*	15	1 in 7
0.21 to 0.30	*Severe Drought*	5	1 in 14
0.20 or less	*Extreme Drought*	2.3	1 in 44

Note: HTC – Hydro-thermal Coefficient (Selyaninov, 1958); SPI – Standardized Precipitation Index (McKee et al., 1993); DAI – Drought and Aridity Index (Daradur, 200).

**Note:* based on empirical data

The primary meteorological indicators of drought which provide no insight of the specific regional/local drought impacts may be overridden with other relevant indices. For example, the SPI as one of the primary index, relied on measurements of total rainfall has a weak responsive to warming of regional climate (Daradur et al., 2007; 2015) can be overridden with other relevant impacts to assess the triggers and select an indicator to activate drought mitigation response, rather than follow the formal provisions. These regional an sector specific drought indices should factor in both climate conditions and system specific responses to those conditions at the regional and local level.

6.3. Assessment of the drought indices from climate variability/change perspectives

Comparing in pairs of the primary meteorological indices to reveal the sensitivity to regional climate variability, shows a weak response of the SPI, as an indicator based solely on precipitation. From the climate change perspective, an attempt to define a drought as a period of below-average precipitation (indicators based on precipitation) that results in prolonged water stress is obviously not enough since an increase in temperatures can also cause water stress by increasing evapotranspiration. The HTC is also less responsive to climate variations than DAI (Figure 6.1). According to the estimates the SPI and HTC are characterized by large probability values in the near normal conditions and conversely by small values in a greater drought category, especially on the unprecedented level.

The sensitivity of the DAI is even and at the same time high. It is explained by the designing concepts of the DAI, as it is based on water balance principles with incorporating the temporal properties of precipitation over the designed time period, which is one of the fundamental aspects of regional climate.

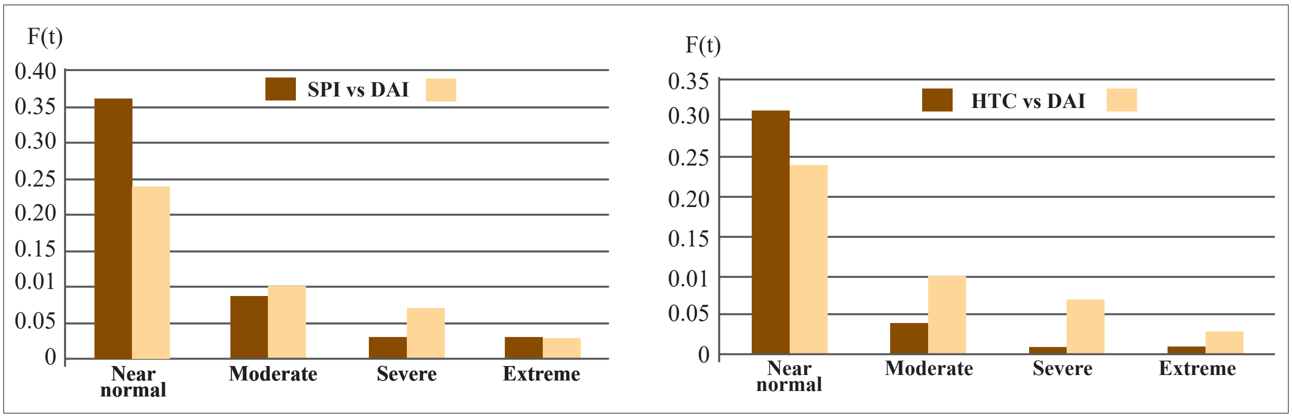


Figure 6.1. Comparative assessment of drought frequency $F(t)$ by categories (Semiarid lands, Republic of Moldova, 1946-2012)

Increased drought risks, induced by recent regional climate warming, is believed to be one of the main causes of decreasing agricultural production and wide range of environmental impacts in Moldova (Daradur et al., 2015; Forth National Communication, 2018). The ability of drought indicators to detect climate variability and change effects is considered an important advantage of the drought indices in the highly variable climate of Moldova.

To reveal drought indices response to climate change trends, we have used the time depended function $F(\tau)$ of the accumulated drought events identified by the set of primary indicators. An analysis represented in the figures below shows that the main feature of the drought events accumulated function $F(\tau)$ is a stair-step character of its dynamics. This indicates on strengthening and weakening of "failures" of the atmospheric processes contributing to the drought as a climatic phenomenon. At the same time, gradation curve $F(\tau)$ is pronouncedly irregular, which indicates on a weak "organization" of the original function and the random nature of the drought variability in time in the region.

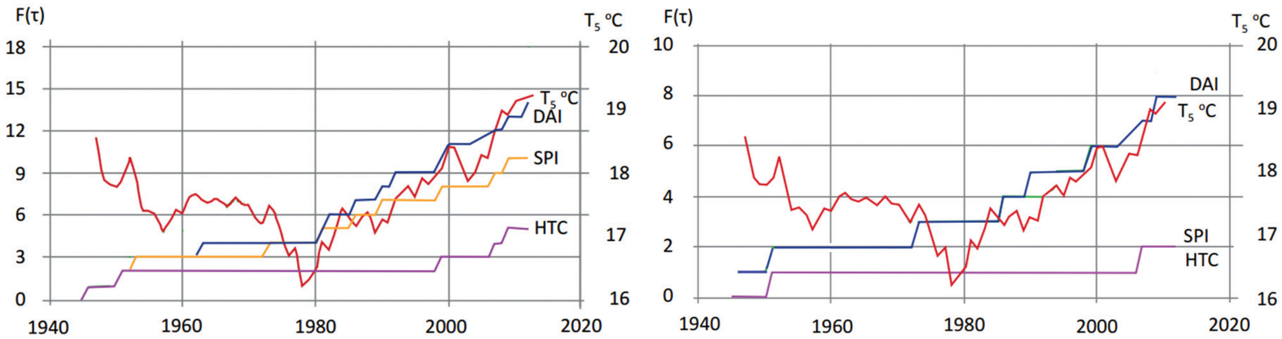


Figure 6.2. Time-depended aggregated function $F(\tau)$ of the abnormally dry and moderate intensity drought (Republic of Moldova, 1946-2012) (red line: the 5-year running mean of the 6 months (April-September) average temperature, T_5 °C)
Source: Daradur et al., 2015

In the graphs the ratio of function increment with the time of observation ($\Delta F/\Delta\tau$) is none other than *the frequency rate* of drought (Daradur, 2001). So, selecting of sufficiently small sub-time scale of time ($\Delta\tau$) enables us to analyze the drought frequency and its variations over the specific time periods of climate evolution.

The historical climate (1946-1980) is characterized by a relatively low increasing the accumulated function F(τ) with an average 1-2 drought events for a decade (for moderate droughts), where as the current climate (1981-2016), on the background of accelerated overall trend, the frequency of drought has increased to an average 3-4 moderate drought incidences per decade.

A rapid increase in the F(τ) values starting from *the 1980s* suggests an increased drought frequency as an active response of the indices to the warming regional climate: last decades the average temperature over the growing period (April-September) has increased by 2 °C (from 17 °C to 19 °C). *The analysis reveals an important feature of F(τ) dynamics over time which consists in the distinction response of the indicators on the intensification rate of original function F(τ) starting from the 1980-s.* This means that drought indices give a distinct response to warming of regional climate. A weak response is a characteristic of the HTC and the SPI. Compared to those, the DAI have a high sensitivity of a response to the changing climate. The distinction in this response between the two groups of indicators rises with an increase of drought severity.

6.4. Relevance of drought indices for agricultural sector

Drought causes significant yield reductions in rain fed agricultural systems of Moldova. Calculations carried out, per example, for winter wheat, indicate that yield may decrease by an average of 46-56% across the agro-ecological zones of Moldova (Daradur et al., 2007). In this respect a relevance of the established meteorological indicators for most vulnerable sectors is also considered as a great advantage for understanding the resilience of existing cropping systems to drought hazard and for effectively planning to mitigate its impacts.

In order to determine the effects of drought on agricultural production, and to exploit the temporal attributes of yield dataset, we developed nonlinear regression models for total crops production using the SPI and the DAI as explanatory variables. These indicators express different approach for drought risk identification: the SPI is an indicator of drought has been a measurement of total rainfall, where as the DAI uses a complex, supply (precipitation) and demand (evapotranspiration) concept.

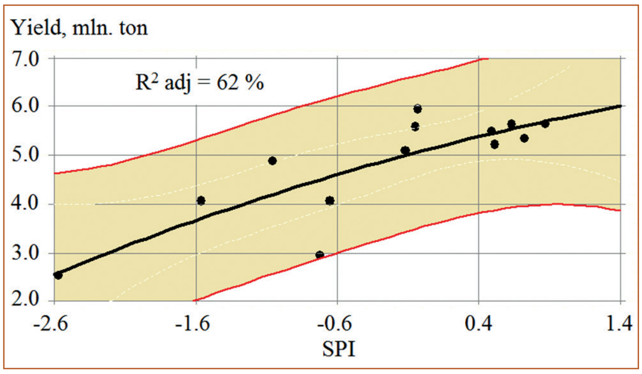
The quantified values of the explanatory variables were used to develop a statistical model to address the applicability of the selected indices for existing cropping systems in Moldova. The analytical function obtained was then used to assess the sensitivity and climate resiliency of existing cropping systems and to quantify the effects of droughts on crop production.

An assessment of an applicability of the SPI, based solely on historic records of average precipitation, shows that this indicator describes 62 % of total crop production variability in Moldova. Applying the DAI leads to obtaining a great improvement of the estimates. A graphical illustration of the relations (red lines – 95% confidence intervals) indicates that the DAI has improved the estimates of drought impact on crop production by 10% (72% from total variability of yield) that evidences of a higher relevance of this indicator for agricultural sector in specific climate conditions of Moldova.

Table 6.3. Attribution of crop production variability to climate using non linear regression statistics

Drought indicator	Attribution (R^2 adj, %) of yield variability to drought	Standard Error, mln. t	P-Value
SPI	62%	0.7	0.0032*
DAI	72%	0.6	0.0007*

Note: * Significant at 99% and higher confidence level



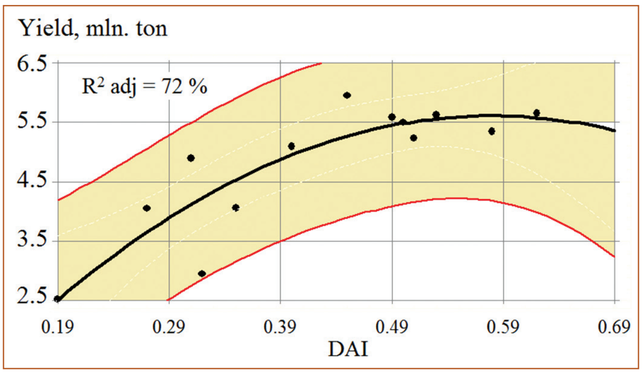


Figure 6.3. Relation of Moldova's total crops production and selected drought indices (red lines – 95% confidence intervals)

Table 6.4. Climate induced variability on crops yield and drought impacts (Republic of Moldova, 2000-2016)

Year	Crop yield, th. tons	Total anomaly of crop yields		Climate induced variability		Climate conditions
		σ, th. tons	%	σ, th. tons	%	
2000	4885.5	-65.2	-1.3	-46.9	-0.9	Near normal
2001	5621.8	671.1	13.6	483.2	9.8	Mild wet
2002	5495.6	544.9	11.0	392.3	7.9	Mild wet
2003	4057.6	-893.1	-18.0	-643.0	-13.0	Mild drought
2004	5579.8	629.2	12.7	452.0	9.2	Mild wet
2005	5640.9	690.3	13.9	496.0	10.0	Mild wet
2006	5345.6	395.0	8.0	284.4	5.7	Near normal
2007	2534.6	-2416.1	-48.8	-1739.6	-35.1	Extreme drought
2008	5948.6	998.0	20.2	718.5	14.5	Mild wet
2009	4054.3	-896.4	-18.1	-645.4	-13.0	Mild drought
2010	5223.8	273.1	5.5	196.6	4.0	Near normal
2011	5088.3	137.7	2.8	99.1	2.0	Near normal
2012	2955.0	-1995.6	-40.3	-1436.8	-29.0	Severe drought
2013	5596.1	645.4	13.0	464.7	9.4	Mild wet
2014	6348.4	1397.8	28.2	1006.4	20.3	Moderate wet
2015	4187.8	-762.9	-15.4	-549.3	-11.1	Mild drought
2016	5597.5	646.8	13.1	465.7	9.4	Mild wet

Source: Yield data – Bureau of Statistics of the Republic of Moldova: http://www.statistica.md/pageview.php?l=ro&idc=315&id=2279

6.5. How the DAI works?

An examination of the drought indices is given above indicates discrepancies in a response between drought indicators related to the drought triggers and categories as well as in relevance to the most vulnerable sectors. Comparative analysis has also revealed an important feature of indicators in response to an accelerating increase of the air temperatures, associated with warming of regional climate. The investigation shows that the response of DAI, constructed for specific climate conditions of Moldova, in every described cases is even and at the same time high.

The design concept of the DAI includes an important aspects associated with rainfall effectiveness in rainfed crops systems – the timing of rainfall events during the drought period. Usually, agricultural droughts coincided with meteorological droughts, identified through rainfall deficits, but the severity and duration of agricultural drought depended very much on the timing and distribution of the rainfall events (Daradur, 2001; Luis and Gonz´alez-Hidalgo, 2011; White and Walcott, 2009). This means that a total accumulated precipitation is not ambiguous and minor rainfall deficiency could also have major consequences in terms of agricultural production, whereas a moderate rainfall deficiency may not always seriously reduce crops yield.

An illustrative example of how the DAI works is given in the following table and graph, where a response of a set of indicators to hypothetical precipitation data is examined. The example considers six similar amount of precipitation (300 mm) with varying the timing of rainfall that can be accumulated whit a high monthly concentration indicating on the increase of intensity and lasting dryness conditions or evenly distributed during the period, that indicates on better climate conditions. This example is exaggerated to illustrate the importance the timing of precipitation.

DROGHT AND ARIDITY INDEX (DAI) and HOW IT WORKS

The Drought and Aridity Index (DAI) is designed on the water balance concept and is calculated as a ratio of accumulated precipitation, adjusted with timing and distribution of the rainfall events (∑P‘ mm), and radiation resources expressed by potential evapotranspiration (E_0 mm). The resulting index, with its limits, permits climate classifications and, therefore, is a convenient tool for aridity and drought evaluation across locations. The DAI within the values (Daradur et al., 2015):

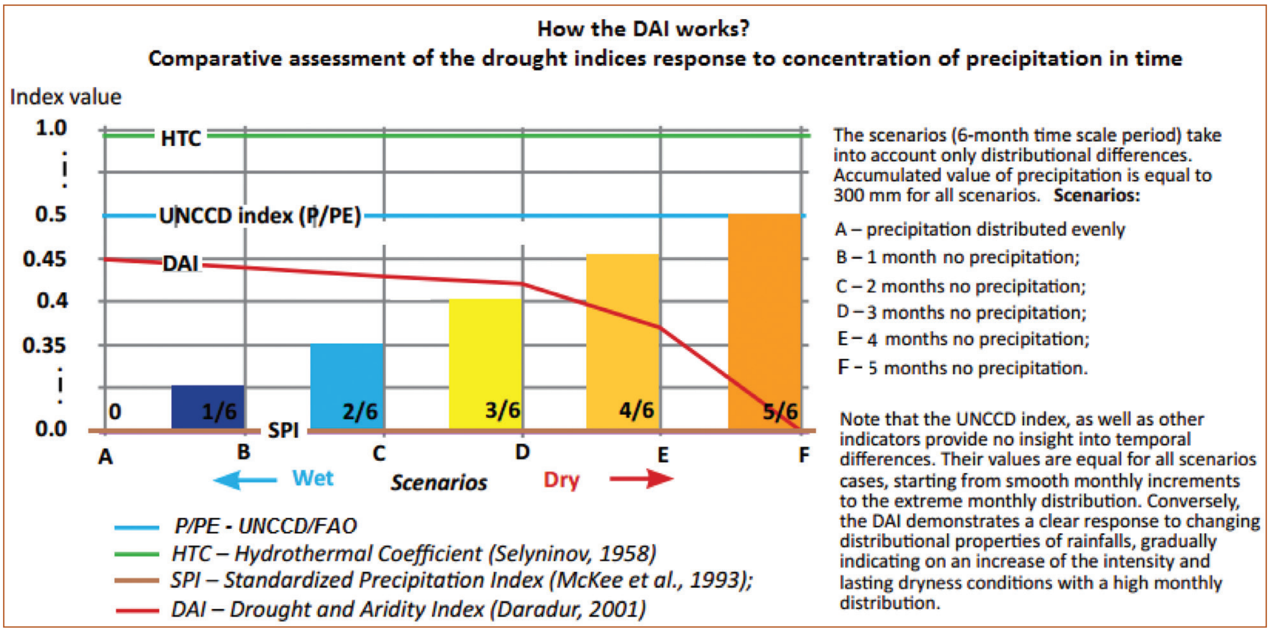
- *close to 1* indicates water balanced climate conditions;
- *DAI >1* meets wet climate conditions, and;
- *DAI with the values <1* indicates dry climate conditions.

Accumulated values of precipitation (∑***P*** = 300 mm, which is close to multiannual amount for the most prone areas 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 rainfalls distribution.

Response of drought indices to precipitation timing and distribution

Scenario / Month	A Evenly distributed	B 1 month no precipitation	C 2 month no precipitation	D 3 month no precipitation	E 4 month no precipitation	F 5 month no precipitation	Insight
	Precipitation, mm						
April	50	No precip	No precip	No precip	No precip	No precip	
May	50	60	No precip	No precip	No precip	No precip	
June	50	60	75	No precip	No precip	No precip	
July	50	60	75	100	No precip	No precip	
August	50	60	75	100	150	No precip	
September	50	60	75	100	150	300	
Total, ∑*P*	300	300	300	300	300	300	No
HTC	1.0	1.0	1.0	1.0	1.0	1.0	No
SPI	0.0	0.0	0.0	0.0	0.0	0.0	No
P/PE	0.50	0.50	0.50	0.50	0.50	0.50	No
DAI	0.46	0.45	0.43	0.42	0.37	0.0	Yes

Note: * The accumulated synthetic values of precipitation (∑*P* = 300 mm) and the indices were calculated based on datasets chosen close to the multiannual average in the most drought prone areas of Moldova. Shading and color change from yellow to orange-brown-red indicate greater uneven precipitation and increasing dryness.



Source: Daradur et al., 2015

6.6. Hydrological drought

Hydrological drought typically is associated with a long (months and years) period of shortage of river stream flow and with a low level or volume in the natural and artificial water reservoirs due to effects of lasting periods of low precipitation (Van Loon, 2015). Being a natural phenomenon, hydrological drought, at the same time, can be greatly aggravated by human activities, since intensive land use and degradation processes can affect the intensity and frequency of hydrological droughts (Crossman, 2018). Identification of drought through a volume of river stream flow (or in some form of its standardization relatively to the long-term climate values) is the common approach.

Table 6.5. Drought support decision systems: Drought triggers and categories (Hydrological drought)

Stream flow, Q m^3/s Dniester	*Stream flow, Q m^3/s Prut*	*Drought severity*	*Probability of occurrence in any given year (1 time in N years)*	*Chance of occurrence in any given year (%)*
250	64	Abnormally dry	30	1 in 3
200	46	Moderate Drought	10	1 in10
170	38	Severe Drought	5	1 in 20
150	35	Extreme Drought	2.5	1 in 50

Source: State Hydrometeorological Service of the Republic of Moldova

6.7. Agricultural drought and attribution of agro-ecosystems productivity to drought

Soil moisture deficit (SMD) represents a greatest interest for agricultural drought identification to provide early warning estimates and potential failures of crops yield. This is an integrated parameter considering soil moisture, the amount of use of precipitation, its filtration beyond the root zone, evaporation and transpiration, surface runoff and feeding of soil by groundwater to robustly describe the water conditions in the active crop growing period (Mangul, 1998; Daradur, 2001; Grossman, 2018).

The plan suggests a ratio form of the SMD:

$$W = W_i / W_0$$

where Wi is the actual, and W0 optimal values of productive moisture in the given soil layer, 0-100 sm (Mangul, 1998).

Optimum values of soil moisture (in mm of productive water) is established at 85% from the maximum moisture capacity content of soils (Mangul, 1998). The values of the indicator ranged from 0.9 to 1.1 meet the optimal conditions of soil moisture. The intensity of agricultural drought increases with decreasing the values of this indicator (Table 6.6).

The plan also appeals to final crops yield, Yi as an integral indicator of climate conditions of yield forming to identify agricultural drought. In this regard, the fact of reducing yields to certain limits, as compared with the average long-term value or the dynamic average (trend, Y_i (T), is taken as a criteria for evaluating drought severity (Daradur, 2001; Taranu et al., 2018). The thresholds is usually established based on the variability level (for example the standard error of the trend component) of a crops yield in a given area.

The deviation crop production from the trend, $\Delta Y_i\ (T)$ is controlled by climate. Herewith, it is assumed that in case of positive values of $\Delta Y_i\ (T)$ there is no significant negative climate impact on crop productivity, and, on the contrary, decreased (negative values), exceeding the certain level, is conditioned by excessive or insufficient quantity of the main climate factors. Since the Republic of Moldova is sufficiently provided by heat resources and fertile soils, significant failure of the agro-ecosystem productivity is due to water deficiency and drought (Daradur et al, 2007). To evaluate the climate component of crops yield $\Delta Y_i(T)$ is used a standardized form (Daradur, 2001):

$$\Delta Y_i(T) = Y_i - Y_i\ (T) / \ Y_i\ (T)$$

Table 6.6. Drought support decision systems: Drought triggers and categories (Agricultural drought)

Soil Moisture Deficit	*Climate component of yield, σ*	*Drought severity*	*Probability of occurrence in any given year (1 time in N years)*	*Chance of occurrence in any given year (%)*
0.71 to 0,90	-0.50-0.99	Abnormally dry	33	1 in 3
0,51 to 0,70	-1.00 to -1.49	Moderate Drought	10	1 in 10
0,41 to 0,50	--1.50 to -1.99	Severe Drought	5	1 in 20
< 0,4	-2.00 or less	Extreme Drought	2.5	1 in 50

Source: State Hydrometeorological Service of the Republic of Moldova

6.8. Drought Sensitive Areas (DSAs)

Approach. Due to high variability and geographical patterns of precipitation, drought conditions may significantly vary and areas under risk need to be adjusted based on the conditions in any particular drought situation. A regional, even local approach allows customization of drought actions and conservation measures to address particular situations in each specific location.

Drought risk assessment at high resolution is an innovative task and is required by a variety of models and decision support tools that are essential for designing resilience for coping with this climate hazard at farm level (Daradur et al., 2007; Crossman, 2018). For example, Index-based insurance (IBI) products allow farmers to insure against drought and related hazards measured at the regional, even local level. However, IBI must be well designed to avoid the problem of basis risk (i.e. when an individual farmer's crop losses are weakly correlated with the regional-level insurance trigger).

Drought risk estimates at high resolution is also essential for designing smart agriculture that provides an effective approach for rational use of the limited water resources with intensive agriculture (small farm irrigation).

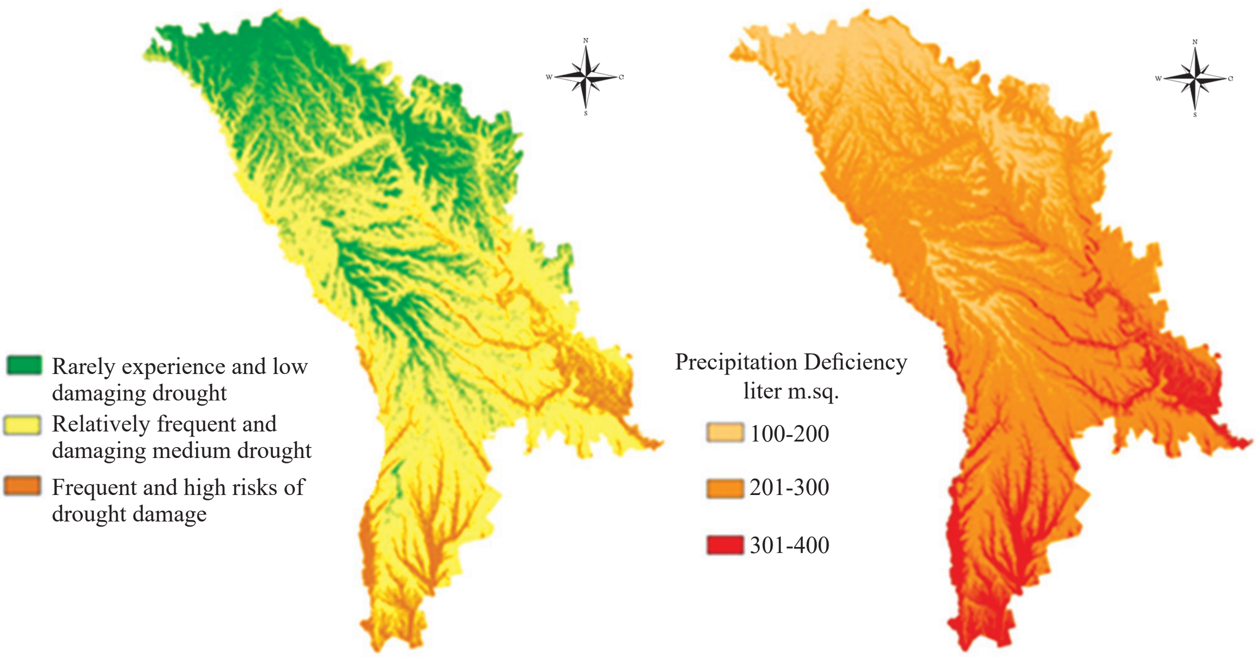


Figure 6.4. Drought support decision systems: Drought Sensitive Areas (DSA) and Precipitation Deficiency (PD) at high resolution (Republic of Moldova)
Source: Daradur et al., 2015

**Note:* The accumulated values of precipitation deficiency (PD) are equivalent to the amount of water that needs to be added (by irrigation) to reach agro-ecosystem potential productivity (in essence, the irrigation rate). The PD estimates are, therefore, essential for designing smart agriculture that provides an effective approach for rational use of the limited water resources of dry lands with an intensive agriculture. They are given in liters per square meter and, therefore, meet the stakeholder's skills and are usable for practical implementation.

This plan incorporates geographical and local topographic factors into geo-statistical approach to produce accurate spatially-distributed estimates of drought conditions in the Republic of Moldova by using a multivariate nonlinear regression approach. Seven geographical factors (latitude (φ) and longitude (λ) and meso- and micro-scale topographical factors (altitude (h), relative altitude (Δh), rugosity (r), slope (s) and aspect (a)) have been used as explanatory variables. The quantified values of the explanatory variables were derived from a digital elevation model (DEM) at 90 m x 90 m resolution grid. The analytical function obtained was then used to produce spatially-distributed estimates of drought risks at high resolution (see the figure 6.4).

Precipitation Deficiency (PD) and irrigation rates. The accumulated values of the Precipitation Deficits (∑PD) are an equivalent to the amount of water that is necessary to be added to reach water balanced climate, and it is considered an important tool for drought risk management (Daradur, 2001; Vincente, 2010; Salinger and Porteous, 2013). Optimum water levels, for example, to obtain the potential of agro ecosystems productivity, can be reached by irrigation. These estimates averaged over 63 years for the 90 m x 90 m gridded data and are given at high resolution since Moldavian complex orography gives specific climate response to spatial extent of the PD values. They are given in liters per square meter that is usable for and to meet the stakeholder's skills.

Overall, the South and South-East (semi-arid lands) have experiencing the strong precipitation deficit up to 400 liters per sq. m. These areas, due to their environmental feature and intensive loads, potentially are highly vulnerable to drought. These conditions are challenging for farming operations making a non-profitable market aggravated by the limited water resources. Agricultural producers need more investments to reach water balanced conditions for maintaining a sustainable productivity of agro-ecosystems. In these areas the risk of precipitation deficiency exceeds 80 % of years (8 years out of 10 are dryness with insufficient precipitation). Where as in the northern part and elevated central part of Moldova (so named Codri area) only 2-3 years out of 10 (20%-30% of probability) climate features promote to droughty conditions (Daradur, 2001).

In the wettest regions (wet sub humid lands in the Northern part of the country and elevated areas in the Central part), the PD values are lower than 100 liters/ sq. m. The most of the country experiences the deficit of 100-300 liters sq. m. range.

Average waiting time of seasonal drought events that is given in the table below is an average value calculated over the period 1950-2015 and is based on the DAI index. These estimates relates to each identified DSAs.

Table 6.7. Drought support decision systems: Return levels for selected return times of seasonal drought based on the DAI index (Republic of Moldova)

DSA	Return period, years	Return level of the DAI	Lower bound	Upper bound	Finite Level (FL)
Low, with rarely experience and low risk of damaging drought	2	0.35	0.34	0.30	0.13
	5	0.23	0.24	0.21	
	10	0.18	0.20	0.17	
	20	0.15	0.17	0.14	
	50	0.12	0.15	0.11	
	100	0.11	0.14	0.09	
Medium, with relatively frequent and medium risk of damaging drought	2	0.35	0.33	0.37	0.09
	5	0.23	0.22	0.27	
	10	0.18	0.17	0.23	
	20	0.15	0.14	0.20	
	50	0.12	0.11	0.17	
	100	0.11	0.09	0.16	
High, with frequent and high risks of drought damage	2	0.50	0.44	0.53	0.15
	5	0.35	0.31	0.37	
	10	0.29	0.24	0.31	
	20	0.25	0.18	0.27	
	50	0.21	0.13	0.25	
	100	0.19	0.10	0.22	

6.9. Near real time web-based decision system to support drought planning

The Flood and Drought Portal. The Flood and Drought Portal is the key output of the Flood and Drought Management Tools (FDMT) project aiming at responding to a need for improved capacity of managers operating in transboundary river basins to recognize and address the implications of changing climatic scenarios and land-use on water resource management. Through the portal users can access technical applications relevant in supporting their planning for flood and drought events.

The methodology is based on an online approach providing stakeholders access to a series of web based technical tools which can be used individually or collectively to incorporate information about floods and droughts and likely climatic scenarios into planning across scales to address impacts. The tools enable users to carry out baseline assessments using readily available satellite data, impact assessments through the analysis of the data, planning options and a means for disseminating information to relevant groups or individuals. The project's tools are integrated in a single workflow and can be used anywhere in the world to support drought planning. The product enables stakeholders to compile information, from models, indicators and existing planning approaches, so as to develop future planning scenarios for making a sound decision.

Near real time web-based decision system. *Climate status* assessment based on comparing the rainfall with previous years to asses rainfall deviation and to detect any signs of meteorological drought. The observation of rainfall provides a long-term historical data set (see figure below).

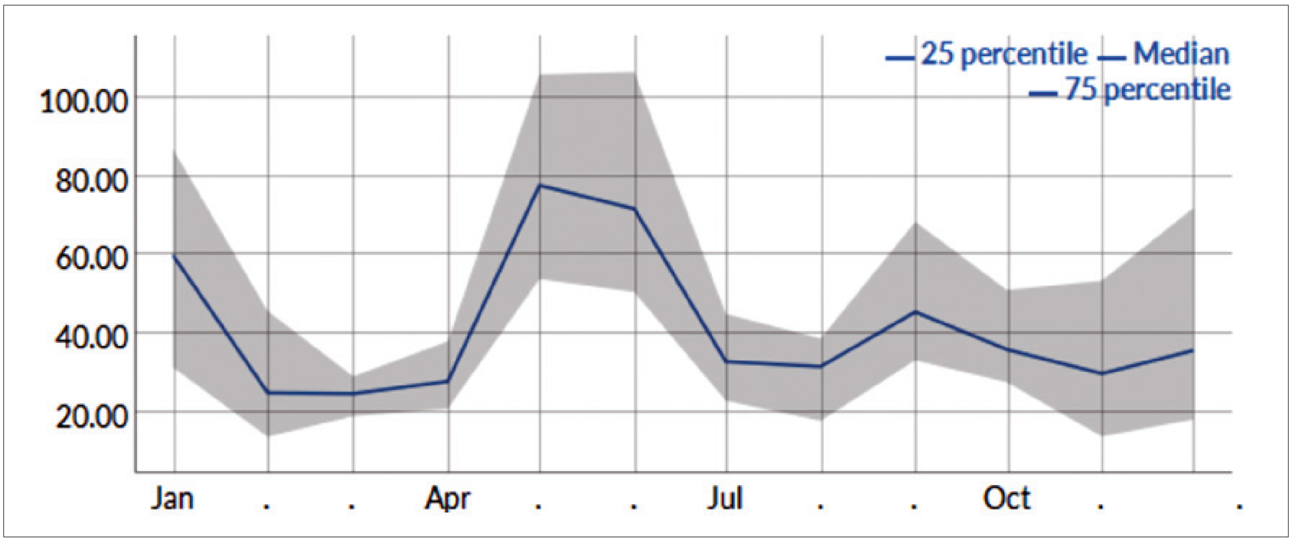


Figure 6.5. Historical precipitation* (mm) averaged for the Republic of Moldova (Shaded areas – 25 and 75 percentile)

**Note:* Rainfall observation is based on the Tropical Rainfall Measuring Mission (TRMM) product with a spatial resolution of 0.25 degree and on the daily basis aggregation from 2000 to present.

Source: Adapted from Flood and Drought Data Portal, 2019

The rainfall deviation indicates how the current seasonal deviates from climate averages from 2000. The following maps indicate the monthly rainfall deviation for the latest month of observations. Meteorological drought is characterized using the *Effective Drought Index (EPI)*. Unlike other rainfall-based drought index (SPI), EDI does not need to be specified for a specific time range. The EDI can be compared across regions with different climates. A drought event occurs any time if the EDI is continuously negative and reaches an intensity of - 1.0 or less. The drought event ends when the EDI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues.

The positive sum of the SPI for all the months within a drought event can be defined the drought's "magnitude". The map uses five classifications: abnormally dry (D0), showing areas that may be going into or are coming out of drought, and four levels of drought: moderate (D1), severe (D2), extreme (D3) and exceptional (D4).

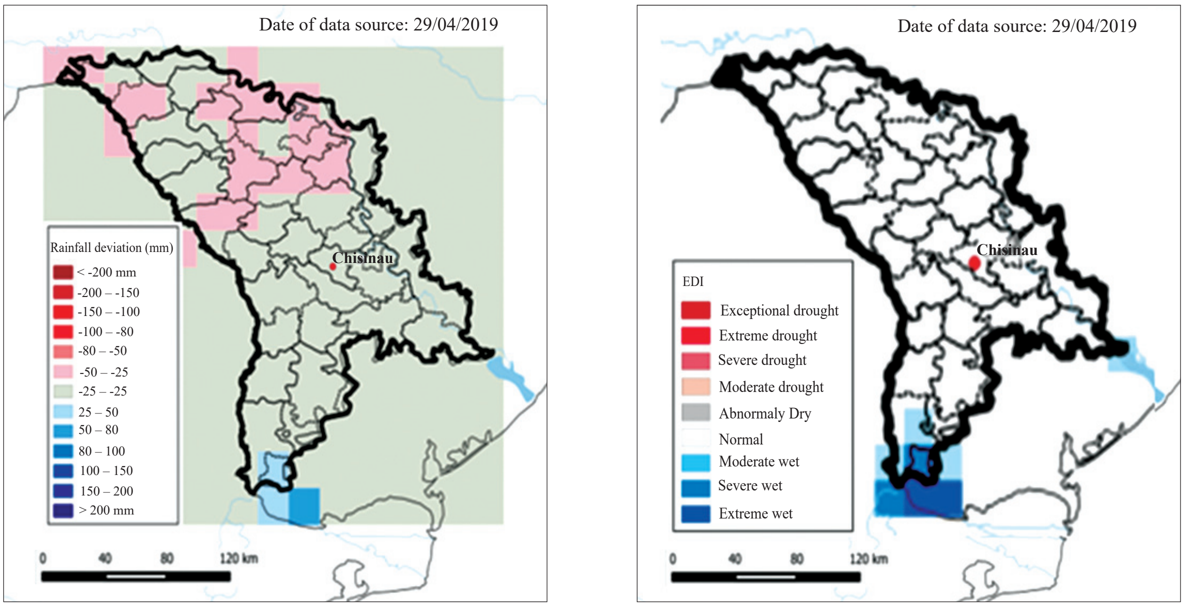


Figure 6.6. Deviation of the precipitation, (mm) from the long term mean (2000-2019) and values of the EDI during the last month (April, 2019).

Source: Adapted from Flood and Drought Data Portal, 2019

Soil Water Index (SWI) is used to monitor to detect agricultural drought. SWI is daily synthesis of Soil Water Index derived from ASCAT SSM data at 25 km resolution (then resampled to 0.1 degree). Soil moisture content is calculated as the percentile value in the same period for each year of the entire record. A larger value of the SWI percentile (close to 100) indicates that similar SWI value have already occurred for the same day in the past. On the contrary, a low value of the percentile indicates that the current value deviates significantly from what is normally observed, the latter could be a sign of drought. A drought or water scarcity is often defined when the soil moisture percentile drops below 30 or 20 % (Flood and Drought Data Portal, 2019).

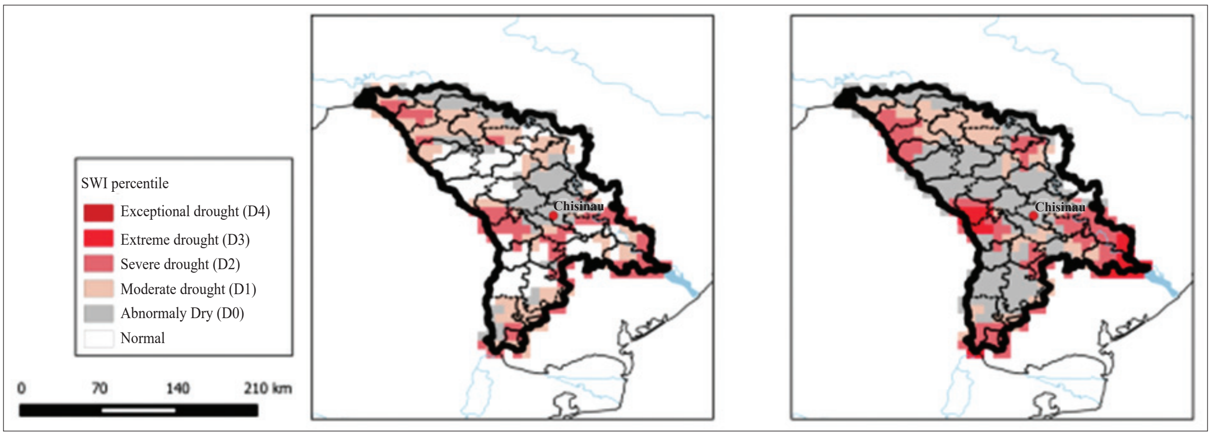


Figure 6.7. Maps of the SWI* during the two consecutive months.

**Note:* assessments based on a daily synthesis of Soil Water Index derived from ASCAT SSM data at 25 km resolution (then resampled to 0.1 degree).

Source: Flood and Drought Data Portal, 2019

Vegetation status is monitored using the Normalized Difference Vegetation Index (NDVI) and Vegetation Condition Index (VCI) based on a MODIS vegetation index produced on 16-day intervals and at multiple spatial resolutions.

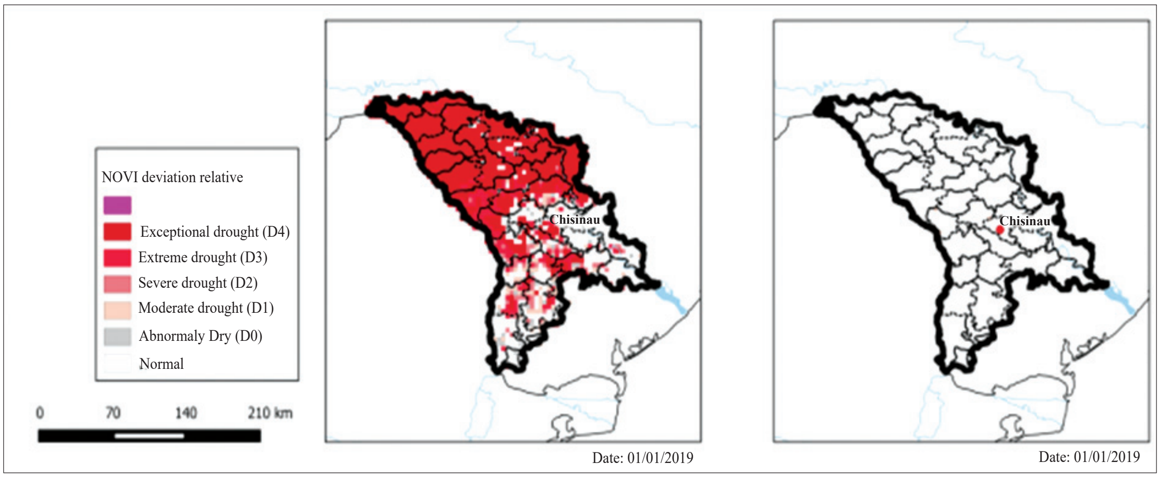


Figure 6.8. Maps of the VCI* during the two consecutive months

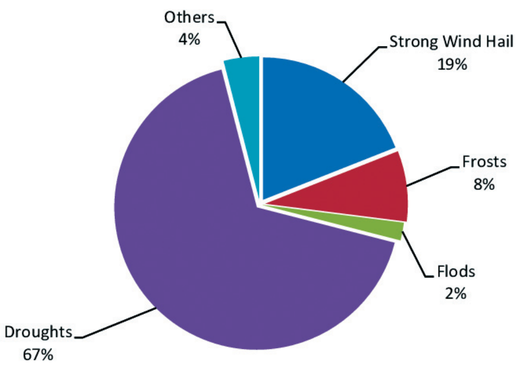
**Note:* assessments based on a MODIS vegetation index produced on 16-day intervals and at multiple spatial resolutions.

Source: Flood and Drought Data Portal, 2019

The (NDVI) provides consistent spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure. The (VCI) evaluates the current vegetation health in comparison to the historical trends. The VCI relates current NDVI value to its long-term minimum and maximum. The VCI is used as a drought index to describe the deviation from the long-term mean.

6.10. Key sector impacts and vulnerabilities

Accounting for 13% of the total number of climate hazards, droughts make up 67% of the economic losses from weather and climate related risks (Daradur et al., 2015). In some years, such as 1994, 2007, 2012 the negative impact of drought may acquire the scales of a nationwide environmental and socioeconomic catastrophe. In monetary terms the losses for the agricultural sector may be estimated at close to US $1 billion (2007). The greatest losses were experienced by fruit and vegetable growers (US $550 million), livestock producers (US $305 million) and cereal growers (US $132 million).



Drought of year	Affected area, %	Duration, seasons	Economic losses	
			Million lei (MDL)	Million $ USA
2000	75	spring-autumn	2098,1	169,7
2003*	86	summer-autumn	-	-
2007	78	summer-autumn	11970,0	987,0
2012	80	summer-autumn	2500,0	200,5

Figure 6.9. Attribution (%) of the economic losses to weather and climate related hazards in the Republic of Moldova. Source: Daradur et al., 2015

* No data

With the majority of the rural population both poor and dependent on the agricultural sector for their livelihood, the drought impact is of particular concern among the poorest rural households in the Central and South regions, where intensity of droughts usually more severe and poverty rates is still very high. Drought impacts directly hit small holder farmers and agricultural workers whose income is 40-70% weather depended and comes from agriculture. Droughts reduce their savings considerably and worsen both the overall quantity and the composition of their nutrition.

A range of recent studies indicates the continuing and even accelerating historical trend of temperature in Moldova in the near future having even more dramatic impact on drought conditions in Moldova (Daradur et al., 2015; Forth National Communications, 2018). Agriculture, water resources and forestry are among the sectors considered most at risk. Particularly profound droughts impact on agricultural sector and water resources, which are essential to human and economic development in Moldova.

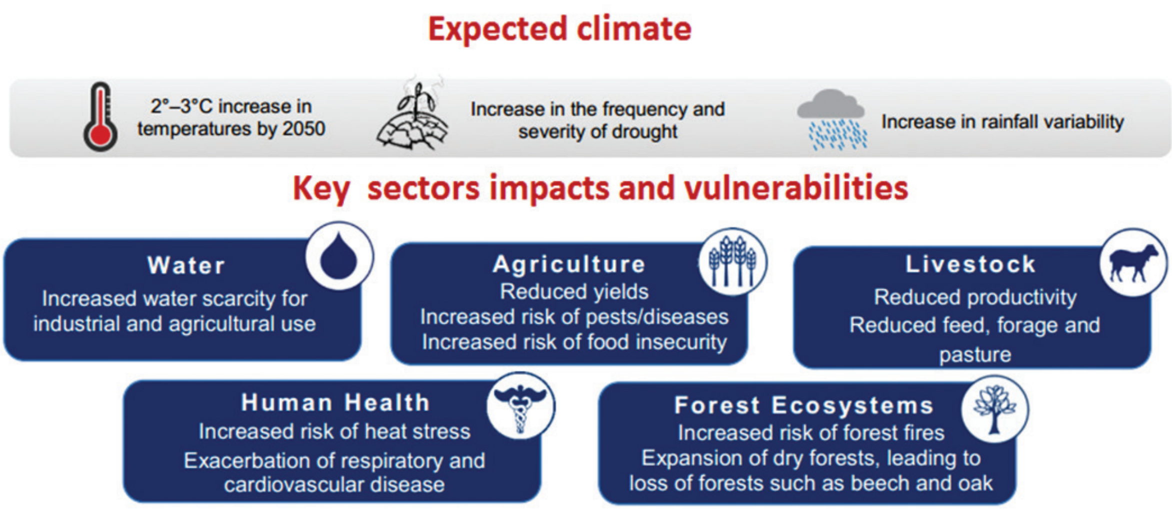


Figure 6.10. Expected climate and key sector impacts and vulnerabilities (Republic of Moldova)

Source: Adapted from USAID, 2017

Agriculture sector. Drought leads to wide spread failures of agro-ecosystem production and food shortages leading to a high volatility of both social and economical subsystems and to instability of rural development. A dramatic decline in agricultural output in recent time is, in a large part, conditioned also degradation and a lack of irrigation infrastructure, change in the subsidies and access to markets, as well as by land reform and farming structure (National Agriculture and Rural Development Strategy, 2014).

Since the proclamation of independence (1991) Moldova has gone through an unprecedented economic transformation which, due to the rapid and often chaotic transition process, has accelerated environmental degradation and has been associated with increasing poverty and rural vulnerability. The post-Soviet land reform has cardinally changed the agriculture land ownership and tenure pattern form. Transition to the new forms of management in agriculture has negatively affected the sector by promoting expansive overexploitation of the land resources and the unsustainable land use.

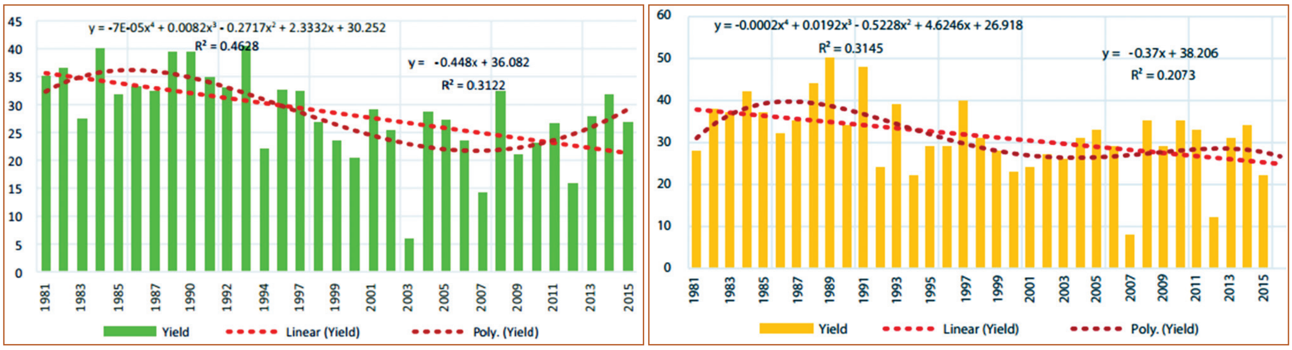


Figure 6.11. Yield variability of the major food crops (Republic of Moldova, 1981-2016)

Source: Forth national communication, 2018; Taranu et al. 2018

Expansive overexploitation of land resources and poor adaptability of agricultural practices along with ineffective climate risks governance have created an increased and wide-ranging drought impacts with a reduction in resiliency and functional integrity of the agro-ecosystems. Owing extreme droughts in the past decades the declining of selected crops yield has acquired a catastrophic scale with a significantly reducing food security of the country. At the same time, variability of the climate component of crops yield has increased making an instability as a main issue of crop production systems and rural development in Moldova.

Existing cropping systems of Moldova is very vulnerability to drought and related climate risks. The following graphic and tables present an assessment of drought severity with ranked drought impacts for the period from 2000 to 2016. As a criteria for evaluating drought severity is used an assessment of climate component of crops yields is presented in the section 6 of the plan. The estimates reveals the strongest drought of 2007 with the average return time more than 200 years (Daradur et al., 2015).

An assessment has revealed that drought, such as drought 2007 causes may decrease reduction of total crops yield of crops yield by 35%. In the absolute values the losses are – 1,7 mln. tons.

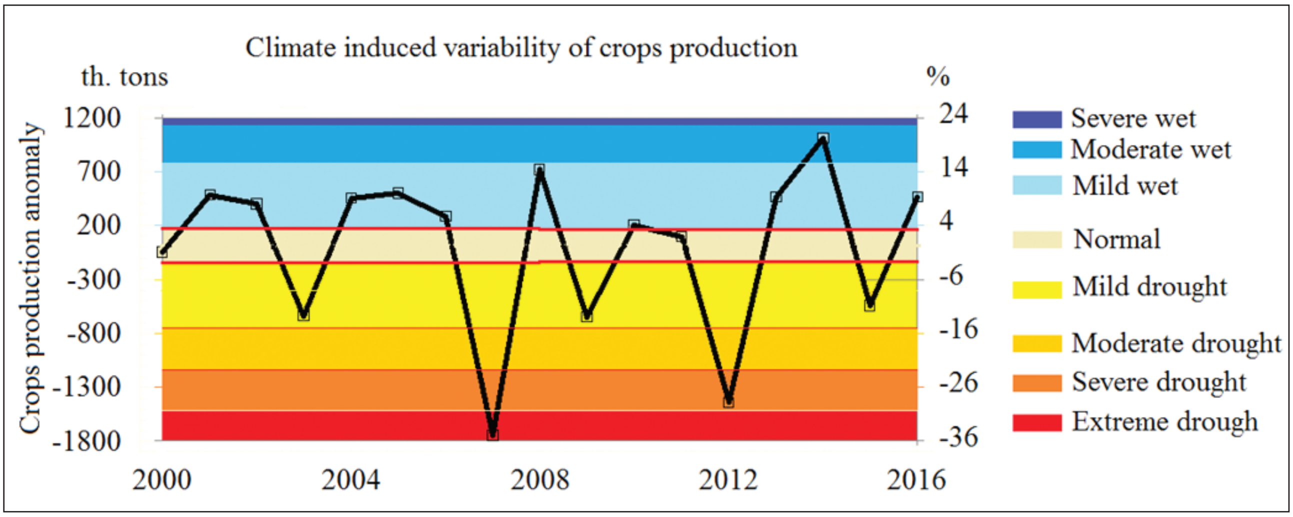


Figure 6.12. Climate induced variability of yield production and an assessment of water conditions for recent decades (Republic of Moldova, 2000-2016)

Underperformance of crop systems during the last decades sector can be attributed to a set of drivers resulting from launching the land reform, increased severe drought frequency as well as week capacity to manage climate risks (Environmental Strategy, 2014; Daradur et al., 2015; World Bank, 2017).

Table 6.8. Drought decision support systems: Drought induced crops failure (Republic of Moldova, 2000-2016)

Year	*Total Crops yield*	*Total losses of crop yields relative to average climate*		*Drought induced losses*		*Drought severity*
	Mln. ton	*Mln. ton*	*%*	*Mln. ton*	*%*	
2007	2,535	-2,416	-48.8	-1,740	-35.1	Extreme drought
2012	2,955	-0,200	-40.3	-1,437	-29.0	Severe drought
2009	4,054	-0.896	-18.1	-0,645	-13.0	Mild drought
2003	4,058	-0,893	-18.0	-0.643	-13.0	Mild drought
2015	4,189	-0,763	-15.4	-0.549	-11.1	Mild drought
2000	4,886	-0.065	-1.3	-0.047	-0.9	Mild drought
Total	17,789	-6,964	-28.12	-5,014	-20.24	

Table 6.9. Drought decision support systems: Return time and impacts of recent droughts (6-month time scale based on DAI time series)*

Drought	*Chance of occurrence in any given year (%)*	*Drought severity, 1 in N years*	*Confident return time period, N years***	*losses Mln. Lei MDL*	*losses Mln. $ USA*
2000	13	1 in 7 years	21	2098, 1	169,7
2003	12	1 time in 8 years	24	-	-
2007	0.04	1 in 217 years	651	11970,0	987,0
2009	9	1 in 11 years	33	-	-
2012	11	1 time in 9 years	27	2500,0	200,5

**Note: Average return time or average recurrence interval* – this does not mean for sure that the 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. ***Assured return time* means that the drought event will occur precisely once within this time period at 95% and higher confidence level.

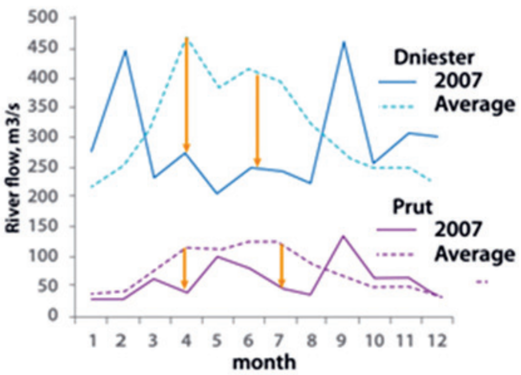
Water recourses. Water resources provide challenges both related to quality and quantity have been deteriorating rapidly, with severe consequences for natural environment and development sectors. Water availability has already become a major issue in the country, especially in the dry seasons and during drought periods, which occur more frequently and is expected fall below total demand within a couple of decades with implications for many development sectors (World Bank, 2016; Forth National Communication, 2018).

Droughts in Moldova considerably decrease water resources and lead to serious water shortage, increasingly affecting rural livelihoods. Climate modeling and projections suggests that climate change will only increase the risk of the weather/climate and water-related hazards in Moldova.

The Dniester and the Prut rivers constitute the main source of water in the Republic of Moldova. Access to water resource is unequal. The greatest distance between a settlement and the closest water body is about 6 km. The area includes one fifth of the total area of Moldova and 23% of the settlements. The rest of the country and population (about 3 million people) have to rely on various supply systems designed to transfer water from these rivers, or rely on local resources of poorer quality.

Local surface water resources in the south (and, less frequently, in the central part of the country) are at high risk of depletion in droughty years. The area of water scarcity, as it extends northwards, has already reached the most populated areas in the central part of Moldova.

The drought of 2007 may serve as a case study when assessing the impact of droughts on surface water. Reduced precipitation and high temperature, in combination with increased water demand, caused a reduced flow in the main rivers, which was up to 50% below the average level. The 2007 drought affected a rural population of about 1.2 million persons in Moldova, mostly in the rural poor areas.



Drought Impact	
Water Resources	Development sector
Annual runoff decrease;	Reduced water availability and an
Increased water shortages;.	increased risk of desertification;.
Ggroundwater level low;	Increase in demand for irrigation;
Impact on water quality.	Conflicts among water users;
Reduced the dilution	Increased water pollution;
capacity; Reduced dissolved	High requirement for water treatment;
oxygen.	Health impacts;
	Increased risk of soil salinisation;

Figure 6.13. Drought impact on water resources and development sectors

Source: State Hydrometeorological Service

Among major of drought impacts on natural environment and population in Moldova with serious health implications, is a surface water and ground water pollution. The situation is deteriorating due to many factors and, in particular, due to lack of investments in sanitation sector and discharges of not treated or poorly treated waste water.

Droughts is considered as an exacerbating factor of other stressors on water quality, in particular, by increasing negative social effects and reducing an access to potable water. In rural area 45% of the population rely on wells as their main source of drinking water. While drought the shallowness of the leads to total drying out and thus to an acute shortage of water for many rural areas. In case of extreme drought (2003, 2007, 2012) water table may fall more than 5 m below normal average, which led to drying out of lots of wells.

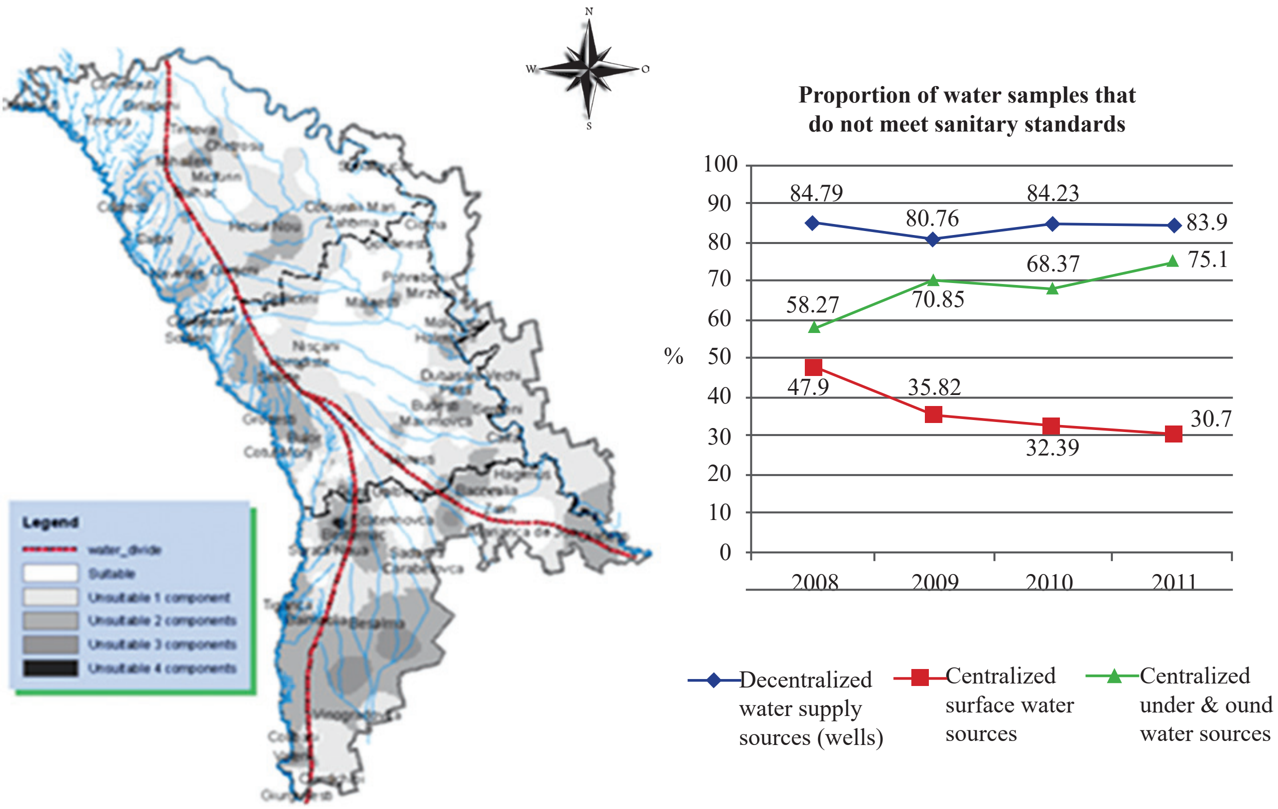


Figure 6.14. Water quality suitability for shallow aquifers

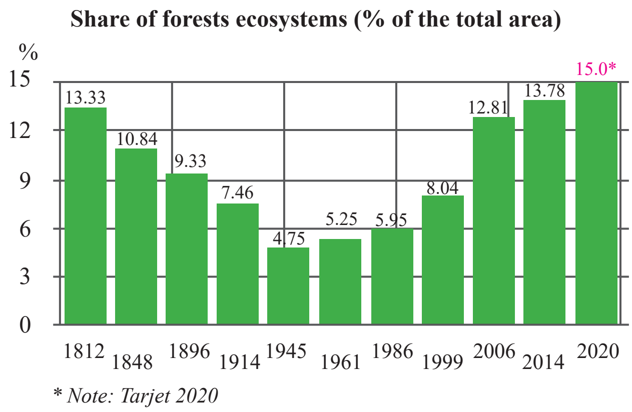
Source: Adapted from: Bajureanu & Budestianu, 2008. Environmental assessment for selected rural areas for National Water Supply and Sanitation Program – Rehabilitation of water supply services in selected rural communities", European Union & Government of the Republic of Moldova, 2013; National Centre of Public Health, 2012 annual report; European Union & Government of the Republic of Moldova, 2013.

The sanitary situation of the decentralized water sources has stayed at the disappointing level of 83.9% of the samples failing to meet standards. (European Union & Government of the Republic of Moldova, 2013). For shallow ground water the major problem is the concentration of nitrates and microbiological contamination, which is most likely caused by infiltration of untreated waste water from pit latrines, poor sewer systems and from livestock farming.

Impact of drought on natural ecosystems and forest vegetation. The main natural ecosystems of Moldova are forests which play an important role in environmental protection and provide a number of direct and indirect benefits in terms of rural development (Popa & Borz, 2014; World Bank, 2016).

Natural ecosystems and forests of Moldova are very sensitive to droughty conditions. A number of studies and documents (see for example, UNDP & Ministry Environment of the Republic of Moldova, 2013; Climate Change Adaptation Strategy of the Republic of Moldova, 2014) identifies a series of effects of drought and related climate risks on the forestry sector.

Increased temperatures and lack of precipitation with consequent drought are a major constraint on forest growth and productivity and greatly affect forests survival. The most vulnerable areas are forest ecosystem margins and thresholds (Clima East Project, 2013). High temperatures with precipitation deficit in a summer time are also the main factors predisposing forest ecosystems to pests and fungal diseases.



Forest Lands fund:	▶ 462.7 thousand ha (13.7%)
Forested areas:	▶ 366 thousand ha (10.8%)
	▶ true forests are, probabily 7-8%
Forest Lands Management:	▶ 89% by State Agency ”Moldsilva”
	▶ 11% by others (incl. 0.8% private)
Arable land:	▶ 71% (vineyards, orchards etc.)
Pastures:	▶ 14%

Figure 6.15. Chare of forests ecosystems (% of the total land area) in the Republic of Moldova

* *Note:* 2020 goal – 15% of total area (Strategy on Sustainable Development of the Forest Sector in the Republic of Moldova), 2001

Source: ICAS; Daradur et al., 2015

Droughty conditions reduce the productivity of natural forests due to a decrease in water availability and increase the areas affected by pests (15 %), the areas subject to drying (25 %) and fire risk (30 %), and soil erosion due to high temperatures, lack of precipitation and a reduction of water availability. The greatest impact is in the in the Southern, semi-arid areas of Moldova (with the lowest forest cover – 8% of land area). Drought of 2007, for example, damaged 5.5% of the national forests affecting about 20 native and non-native forest species (Forth national communication, 2018).

The condition of forests is aggravated by irrational and extensive use of natural ecosystems. Currently almost all forestry ecosystems are affected by human impact, expressed by destroyed biotopes, and unregulated harvesting of biological resources or inappropriate ecosystem management (Botnari, 2011). Cutting of floodplain forests and shelterbelts, wetlands drainage and channelization of small rivers, damage to the integrity of natural ecosystems, pollute the natural and agricultural ecosystems has acquired a threatening scale in the last few decades.

Climate change with an increase drought frequency could lead to a decrease of beech, durmast and oak forests in favor of semi-arid forests and drylands and pastures more suitable to hot and drier conditions (Forth National communication, 2018). By 2040, 15-25% of trees in the northern region will likely be water stressed. Hornbeam and ash will be the most vulnerable, with ash biomass growth estimated to decrease by 20-40 percent by mid-century (World Bank, 2015).

Table 6.10. Major drought/climate risks impact factors on forests and mitigation/adaptation opportunities (Republic of Moldova, Forestry sector)

Drought/Climate risks	*Mitigation/adaptation opportunities*
Changing forest composition due to distinct sensitivity of species to temperature and precipitation	*Stimulating research on the relationship between adaptability of native tree species to climate change. Reconsider forestry practices in adaptation context*
Changes in the competitiveness of species	*Stimulating research on the relationship between adaptability of native tree species and climate change. Reconsider forestry practices for their adaptation*
Degradation of forest density and stand structure	*Reconsider forestry practices for their adaptation*
Changes in species peculiarities with regard to regeneration	*Adapting forest regeneration practices to the needs of climate change*
High rate of drying due to an increased risk of diseases and pests	*By continually investigating, identifying interactions related to climate change, alternative species, and appropriate attack management strategies*
Spread of pathogenic pathogens from other geographic regions that adapt to climate change	*Take immediate action in case of relevant alerts. Hold regular meetings with specialists, amending if necessary import or domestic phytosanitary regulations*
Increasing the survival capacity and fecundity of game species that can affect forest plantations	*Adoption of local level strategies for the management of herds*
Spreading of invasive plant species, new or existing	*Collaboration with regulators, agricultural, forestry, local authorities, etc.* *Planning collaborative control strategies and eradication where impact shows signs of being significant*
Mass drying phenomena	*Adopt management measures to eliminate severely affected stands without compromising regeneration capacity.* *Adoption of appropriate regeneration compositions. Continue research into adapting species to climate change*

Source: USAID, 2007; Ministry of Environment, 2009; Forth National Communication, 2018

Impact on public health. The negative effects of drought have been well defined and explored in the environmental and economic context but less studied on its impact on public health. Most health impacts of drought are indirect because of its link to other mediating circumstances like loss of livelihoods, migration from rural areas to cities and out of the country and increasing tension over water resources associated with inadequate sanitation and low-quality drink water supply.

Given the complexity in assigning and because of effects tend to accumulate over time, documentation of the health effects of drought is a challenge. However, rising awareness on the regional climate variability/change and the need to manage its wide-ranging social effects, has promoted to a great interest to explore the impacts of extreme conditions of drought on the public health in Moldova (Corobov et al., 2013).

The population of the Republic of Moldova have already experienced an impact of high temperatures heat waves, associated with drought. The health impacts of heat waves of drought 2007 has been documented, for example, in Chisinau. In 2007, 200 deaths (6.5% increase in mortality) were attributed to drought and accompanying high temperatures (Corobov et al., 2013).

Some of the approaches are summarized also in the Fourth National Communication of the Republic of Moldova (Forth National Communication, 2018). In particular an attempt to explore of the drought of 2007 impacts on public health was undertaken based the number of deaths and Emergency Medical Service (EMS) calls in Chisinau municipality. Te study provides an analysis of periods with extremely hot days and related variables and indicates on the correlation of an increase of number of deaths and Emergency Medical Service (EMS) calls in Chisinau municipality with drought stress in 2007.

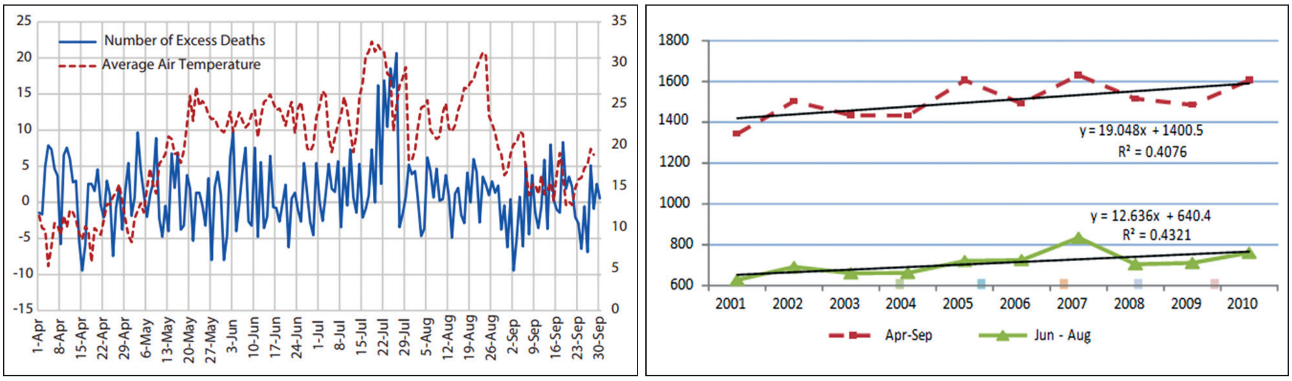


Figure 6.16. Dynamics of the number of excess deaths and average air temperatures (April -September, 2007; Chisinau, Republic of Moldova)

Source: Forth National Communication, 2018

The negative effects arising from the drought impact on agriculture, forestry and water resources, thus causing food security, water shortage and poor water sanitation problems, which, in their turn, can indirectly promote to serious impact on public health in the short and long term.

Public health response to the issues caused by the climate variability and change is formulated in the sector specific document Climate Change Adaptation Strategy in Health Sector and Related Plan of Actions till 2020 (Government Decision No. 1032, 20.12.2013). The vision of the strategy is to ensure protection of population by increasing resilience and capacity of health to climate variability and change. However, the strategy has many gaps related to specific health strategies to be implemented to reduce drought impact on public health (see the annex).

7. DROUGHT COMMUNICATION AND RESPONSE ACTION LEVELS

7.1. Communications and establishing knowledge sharing systems

Successful implementation of the National Drought Plan depends on the timely dissemination of usable drought information that meet stakeholders' needs and skills to make an informed decision. Government of Moldova, The State Hydro-meteorological Service and Agency for Geology and Mineral Resources under the Ministry of Agriculture, Rural Development and Environment (MARDE), the State Service for Civil Protection and Exceptional Situations (SCPESS) are the entities that has a key communication responsibilities during all drought action levels.

Dissemination drought information is executed by several ways, including television, radio, print and online media. Civil Society Organizations (CSOs) bring valuable efforts to achieve public awareness and contribute to the implementation of planned interventions to reduce drought impact in the prone areas. For example, the National Federation of Farmers in Moldova AGROinform (http://www.agroinform.md) with a network of 15 regional organizations oriented towards to providing assistance in business development, marketing, application of advanced technologies, and representing the interests of its members, play an important role on dissemination of drought information to agencies, agricultural producers, and the general public.

Within the recommended communication protocol, The State Hydrometeorological Service issues warnings on weather-related hazards. State Service for Civil Protection and Exceptional Situations (SCPESS) assists with dissemination of these warnings, as they may entail mobilization for possible intervention and relief effort where needed.

Warnings for low-onset hazard categories require extensive data analysis and prediction capability. Therefore, for the activities on dissemination of drought information to agencies, stakeholders, and the general public, the main responsibilities fall on the State Hydrometeoro-logical Service. In case of atmospheric, hydrological or agricultural droughts, information bulletins are issued daily through radio and television, which include recommendations on the actions to be taken to reduce the effects of drought.

Starting with a normal situation the data are routinely collected and distributed, moving to heightened alertness and increased data collection with each of following drought alert status. Water restrictions are appropriate at the pre-alert warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which mandatory water restrictions or use of emergency supplies is necessary.

The communication activities and drought action levels, set forth for the interagency coordination and dissemination information to public, are described in the table 7.1 below. The action levels specified in the table are a general plan of action to coordinate nationwide response to drought situations. However, numerous individual agencies have particular responsibilities that they are responsible for implementing on an ongoing basis. Regional and local plans may have a range of actions they can take to manage their systems during droughts. Thus, regional/local level of a drought management plan may also define local drought indices should factor in both water resource conditions and system specific responses to those conditions at the local level. The system specific drought management plans might contemplate the differ terminology for drought conditions and action levels.

7.2. Drought action levels

Unlike many other emergency situations, drought severity of droughts develops over time and, therefore, allows for a graduated implementation of appropriate measures. Following table defines the drought categories along with appropriate levels of response, given the severity of the drought. The levels provide a basic framework from which to take actions to assess, communicate, and respond to drought conditions mitigate drought impacts.

Table 7.1. Drought action levels (Republic of Moldova)

Category	*Drought conditions*	*Consumers actions*	*Water suppliers actions*	*Management actions*
D0	Abnormally dry	D0.1 - Technologies for efficient water use in industry D0.2 - Water efficient Technologies for Agriculture D0.3 - Continuous water leakage control Strategy	S0.1 - Improved rural water supply infrastructure	M0.1 - State Hydrometeorological Service Submits Quarterly Drought Bulletin M0.2 - The State Hydrometeorological Service publishes monthly hydrometeorological data on the official service page M0.3 - Educational Water Management Program
D1	Attention do drought	D1.1 - Reducing Insignificant Use	S1.1. - Restriction of water use	M1.1 - State Hydrometeorological Service informs the Ministry of the Environment and interested stakeholdrs M1.2 - The State Hydrometeorological Service presents a monthly drought bulletin M1.3 - Media campaign on voluntary water use reduction
D2	Drought warning	D2.1 - Termination of unimportant use D2.2 - Reducing the pressure in the water supply for drinking water D2.3 - Phased reduction of water for agriculture D2.4 - Phased reduction of water for industry D2.5 - Intensive Leak Reduction Program D2.6 - Preliminary reduction of water supply to the public	S2.1 - Increasing levels of water supplies S2.2 - Restriction of water use S2.3 - Reduced groundwater abstraction	M2.1 - The State Hydrometeorological Service and the Agency for Geology and Mineral Resources informs the Ministry of the Environment and interested parties M2.2 - Establishment of a drought management working group M2.3 - Media campaign regarding mandatory reduction of water use

D3	Critical drought conditions	D3.1 - Termination of water use for agriculture D3.2 - Cessation of water use for industry D3.3 - Significant reduction in water volumes for public water supply	S3.1 - Termination of the release of any volumes of water from reservoirs S3.2 - Renewing the use of previously unused water sources S3.3 - Supplementing the supply of water to people from underground sources S3.4 - Addition of minimum ecological flow from groundwater S3.5 - Water use in tanks S3.6 - Urgent distribution of bottled water in crisis centers	M3.1 - The State Hydrometeorological Service and the Agency for Geology and Mineral Resources informs the Ministry of the Environment and interested parties. M3.2 - The State Hydrometeorological Service presents a monthly drought bulletin M3.3 - Government issues decree declaring critical drought condition
D4	End of drought	D4.1 - Full restoration of water supply to the population D4.2 - Gradual increase in the provision of industrial water D4.3 - Gradual increase in water supply for agriculture D4.4 - Gradual increase in provision of water for secondary needs	S4.1 - Minimum ecological channels are restored as a matter of urgency through additional measures	M4.1 - the State Hydrometeorological Service and the Agency for Geology and Mineral Resources inform the Ministry of Environment and interested parties M4.2 - The State Hydrometeorological Service resumes submission of the quarterly drought bulletin

7.3. Nationwide declaration of drought emergency

National wide drought declaration have been rare and are issued in case of extraordinary drought conditions that create significant economic loss likewise the drought of 2007. In the Republic of Moldova, nationwide declaration of drought emergency is regulated by Water Law, Article 48 (Parliament of Moldova, Law Nr. 272 of 23.12.2011).

The issuance of a nationwide declaration of drought shall be based upon a recommendation from the Ministry of Agriculture, Rural Development and Environment (MARDE). The declaration is preceded by the evaluation of current and foreseen weather and climate, and other drought related conditions. Exceptional situations in the country are managed by the State Civil Protection and Exceptional Situations Department (SCPESD) subordinated to the Ministry of Internal Affairs. The SCPESD informs the population also about the fires hazards since during the drought triggering spontaneous fires of vegetation is extremely high.

Declaration is issued for purposes of seeking appropriate Government assistance to impacted stakeholders and according to the Water Law provisions on declaring drought:

1. The Ministry of Agriculture, Rural Development and Environment (MARDE) recommends and the Government approve a Decree on Proclamation of Drought. The decree indicates the application of decree provisions at the national, level of the basin district or sub-basin;
2. The decree on declaring a drought may provide for:
   a) restrictions on some or all of the activities, providing for water use;
   b) restrictions or prohibitions for water use under the special environmental permits;
   c) restrictions or prohibitions on general water use;
   d) new priorities for water use in the zone affected by drought and water scarcity;
   e) use of water reserves.

Government agencies communicate by telephone, fax, and mobile phone, and via limited use of radio communications. The SCPESD staff has access to dedicated radio communication channels but most of the technology is outdated. Each response organization has its own internal radio frequency, and inter-agency communication among medical units, police and fire brigades can be established over a standard frequency, activated during emergencies. In practice, mobile phones dominate communication among disaster response units. Emergency communication and disaster management information systems are deficient; The SCPESD has no emergency management center or modern information technology to facilitate coordination during emergencies (World Bank, 2017).

7.4. Determination of the end and post drought evaluation

Determinations regarding the end of a drought or reduction of the drought level focus on key meteorological and hydrological indicators such as precipitation which is the overall driver of drought conditions (Government provision Nr. 779 from 04.10.2013 on approval of the Regulations on Drought Planning, Part V). Groundwater levels as well as other depended factors from precipitation such as stream flow, water supply, reservoir levels, soil moisture that respond more slowly to improving conditions are good indicators of medium- and long-term recovery to normal conditions.

Post-drought evaluations include a drought impact assessment on environment and development sectors as well as an examination of the effectiveness and identifying deficiencies of proactive drought mitigation actions and good practices when drought mitigation and response were effective and successful.

7.5. Emergency relief

Drought relief and recovery options are the mandate of the State Civil Protection and Exceptional Situations Department of (SCPESD), which has been part of the Ministry of Internal Affairs. The declaration of drought helps provide relief assistance for those suffering from drought conditions. Recent droughts have been followed by emergency interventions of the Government of Moldova, often supported by international organizations. As example: emergency procurement and distribution of vegetable seedlings and maize seeds, emergency supply of winter wheat seeds, allocations to cover the costs incurred by farmers to tillage and sowing of winter crops etc.

The scale of relief assistance based on the social assistance tools tested by social protection program that address the needs of rural households severely impacted by drought. The specific issue for Moldova is lack of flexibility of these social assistance tools. In particular, potential income of land holdings is uses as part of the tools testing formula is calculated based on pre-drought data (Environmental Strategy, 2014).

8. RECOMENDATIONS AND IMPLEMENTATION ACTIONS

8.1. Drought risk reduction strategies

Drought risk reduction can be defined as measures or activities for mitigating the overall risk to drought with a goal to reduce the severity of drought impacts. Risk management strategies to cope with drought and related climate risks are large. However, despite the significant benefits to productivity, climate resiliency and drought mitigation objectives, many small-scale farmers are disinclined to such investments. Limited access to relevant technical assistance and to adequate financial resources, insufficient water resources and technologies for irrigation are some of the main barriers (World Bank, CIAT, 2016).

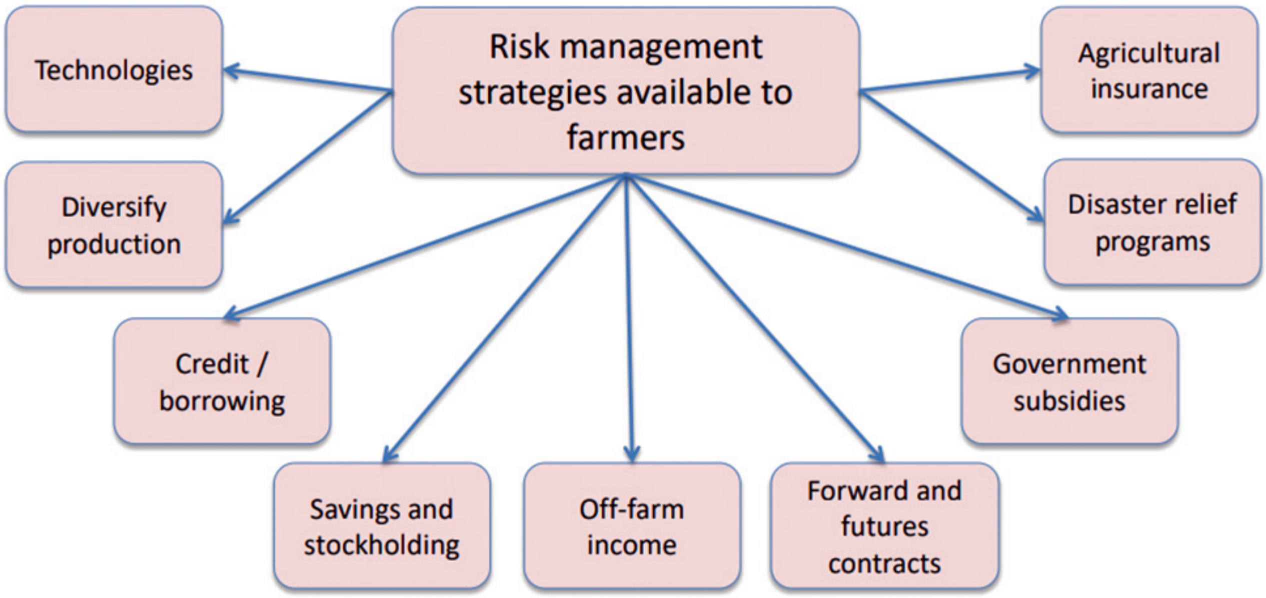


Figure 8.1. Drought rick management strategies available to agricultural producers

Source: Adapted from World Bank, CIAT, 2016; Cramon-Taubadel and Walter, 2018

To mitigate and adapt to high climate variability and to increased drought frequency Moldavian farmers sought options aiming mainly to facilitate the conservation of water in soils, since the major threat to agriculture production in the country is water stress and drought (Leah, 2016; Daradur et al., 2015; World Bank, CIAT, 2016). They also include introduction of drought-resistant crop varieties, optimization of sowing and planting time in accordance with agro-meteorological information. The stood out primary response options for reducing drought impacts in Moldova mainly focused on “win-win” which have brought about short-term benefits on their livelihoods. This approach, however, is not effective from medium and long-term perspective for the rain fed cropping and livestock systems across various natural and socioeconomic conditions of Moldova.

8.2. How does Moldova cope with a drought?

Climate smart agriculture (CSA) practices. The climate-smart agriculture initiatives sustainably increase productivity, benefits climate resiliency and drought mitigation objectives and address tradeoffs and synergies between three CSA pillars: productivity, adaptation, and mitigation (FAO, 2010). The following graphic presents a selected of practices with high climate smartness scores according to expert evaluations. The average climate smartness score is calculated based on eight climate smartness dimensions that relate to listed above CSA pillars. An option can have a negative/ positive/ zero impact on a selected CSA indicator, with +/-10 indicating a 100% change (positive/ negative), and 0 indicating no change (World Bank, CIAT, 2016).

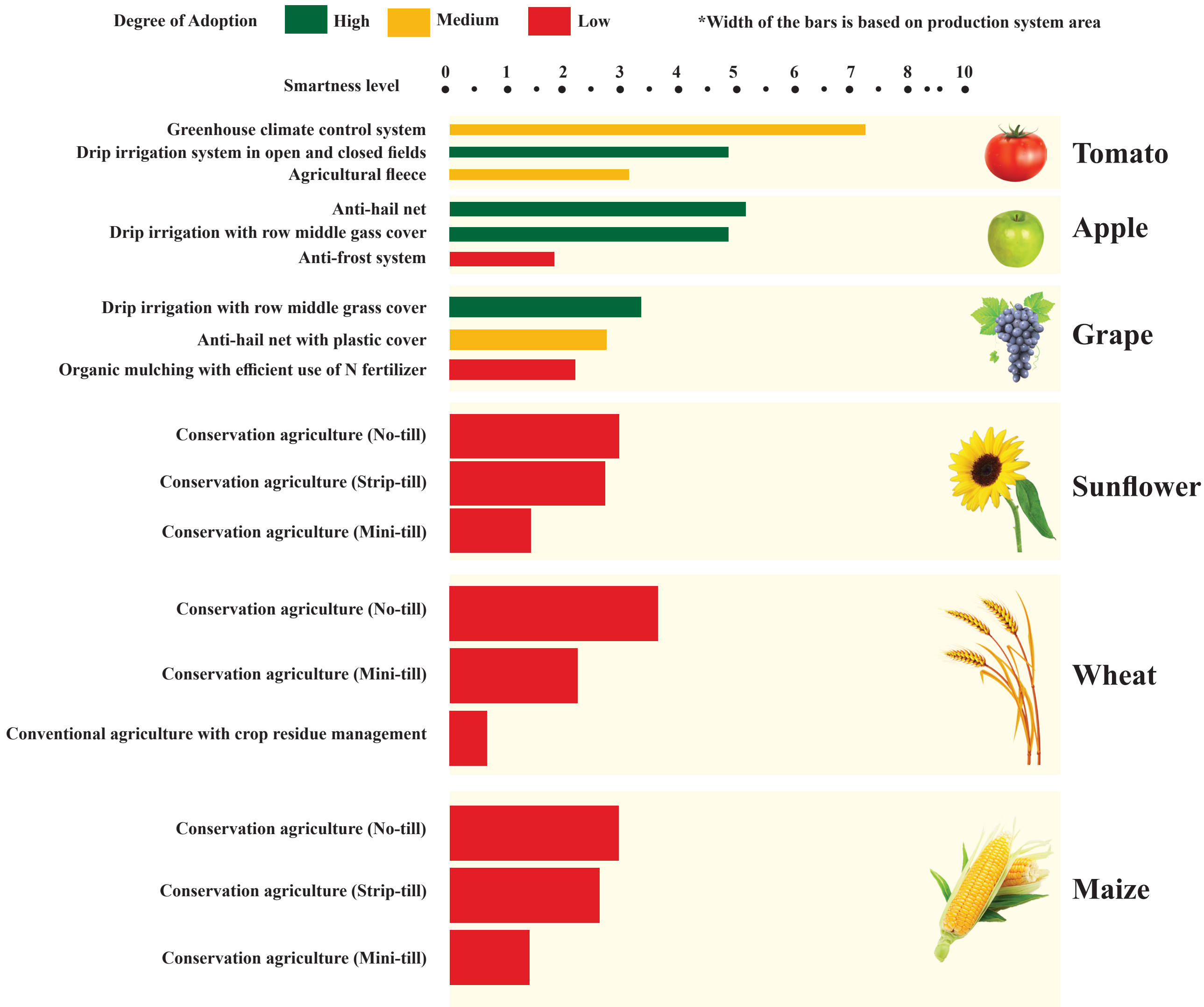


Figure 8.2. Selected CSA practices and technologies for crop production systems of Moldova

Source: Adapted from World Bank and CIAT, 2016

Irrigation and conservation agriculture are an example in this sense as a water-use efficiency options with high potential to help mitigate drought and related climate risks impact on the crop systems and land degradation. Irrigation brings multiple benefits to adaptation and productivity: increases soil fertility; reduces heat stress, soil erosion and pests and diseases; increases yields and decreases post-harvest loss, and consequently enhances food availability and incomes.

No-till and Strip-till conservation options for maize, sunflower, and wheat production, stood out as a CSA practice with high potential for adapting the crop systems to climate risks and soil erosion. The total area under conservation agriculture has increased from 40,000 to 250,000 ha, whereas the potential area could increase to at least 900,000 ha (Ignat A; Moroz V. 2014, World Bank, CIAT, 2016). The advantages of greater soil health, productive capacity and lower cost of production leads to higher crop yields and greater profit margins and competitiveness from implementing the practice. Within the IDMP CEE Demonstration project also a special guide on best practices on soil conservation in Moldova was developed (https://www.gwp.org/globalassets/global/gwp-cee_files/regional/idmp-guide-moldova-ro.pdf).

Green economy initiatives. The fragmented agriculture lands in the Republic of Moldova substantially limit the implementation of sustainable approach and effective business models in line with greening land use and management. Despite the undertaken efforts, coherent or comprehensive strategies for "greening" the economy are still scarce in Moldova. High upfront capital costs, low-returns and long investment timelines, and difficulties to access loans are the main barriers to develop green economy infrastructure (UNDP, 2012; Ministry of Environment, 2013). Lack of transparency and costly use of natural resources are the main barriers to improve incentives for the resource efficiency or pursue green or low-carbon investments.

Organic agriculture is a new approach to agricultural production that focuses on products quality and their nutritional value, without affecting the environment during production process. In organic farming plant cultivation, livestock and food production are achieved by use of environment-friendly technologies that respect the ecosystems natural cycle and apply the traditional agricultural practices having positive impact on the environment.

The efforts of the NGOs and private investors, along with the promotion of the Government of Moldova have led to developing the organic agricultural sector. Currently the area of certified organic land represents almost 2% of the total arable area providing 11% of total agricultural exports of the Republic of Moldova (Wingqvist and Wolf, 2013; United Nations Economic Commission for Europe, 2014).

Agricultural insurance. The Government of Moldova has enacted Law no 243-XV, of 8th July, 2004, entitled "Subsidy Insurance against Production Risks in the Farming Sector". However, the options for encouraging the development of agricultural insurance to reduce the impacts drought impacts, should be further explored (World Bank, 2016; Cramon-Taubadel and Walter, 2018). In general, insurance means that one party (the insured) transfers the risk of a large, potentially devastating loss to another party (the insurer) in exchange for a predictable and quantifiable small loss (the premium). Agricultural insurance (AI) is a specialized form of insurance most commonly takes the form of crop insurance, but it can also apply to livestock, greenhouses, aquaculture and forests. There exist three main types of agricultural insurance (Cramon-Taubadel and Walter, 2018):

1. Specific peril products provide insurance against a farm's losses from a specific peril or named risk. The most common example is hail. Specific peril insurance is often offered by private insurance companies without government support on a purely commercial basis.

2. Multiple peril products provide insurance against a wide range of generally un-named perils. They typically insure yields, revenues or incomes, and experience in Moldova shows that they require government support (i.e. are not offered by private insurance companies on a purely commercial basis).
3. Index-based insurance (IBI) products allow farmers to insure against events measured at the regional level, such as (lack of) rainfall or extreme temperatures. If, for example, rainfall in a region falls below a certain level, farmers in the region who have purchased rainfall IBI receive indemnities. Today, IBI products have also depended heavily on government support.

Based on strong and objective regional-level even local drought assessment, the IBI may reduce of the incentive problems that challenge traditional AI products (Cramon-Taubadel and Walter, 2018). However, the IBI must be well designed to avoid the problem of basis risk. The IBIs therefore depend heavily on high-resolution drought risk assessment, and research on the links between climate and agricultural outcomes that matter to farmers.

Currently 9 companies (2017) with licenses to provide agricultural insurance, but high market share of 2-3 companies that have experts. The market penetration is quiet low (2-3%) of total agricultural lands with a Premium rate reported to be quite high, e.g. 5-6% premiums for hail, 1.5-3% for frost, 7-9% for drought, if insured separately. Subsidies for AI account for roughly 1% of total agricultural subsidies.

Direct payment system. A simple direct payment system may also be considered as alternative to stabilize farmers' incomes while avoids associated insurance incentive problems. However, this approach, relying on a reactive, crisis management approach and traditional hierarchical and command-and-control management methods makes farmers and societies more reliant on government programs and, often on external assistance from donor organizations, result in increased vulnerability to drought events (Daradur et al., 2007; Cazac and Daradur, 2014).

Mutual funds. Mutual funds also are considered as an alternatives to AI (German Economic Team Moldova, 2018). Mutual funds are non-profit risk-sharing tools based on private agreement among farmers/members, who contribute to a stabilization fund that is used to compensate losses according to agreed-upon rules. The main advantage: members know one another – solidarity and moral suasion can reduce moral hazard and adverse selection. A disadvantage: danger that most or all members of a regionally organized mutual fund incur losses simultaneously.

Watershed Management. Improvements in watershed management can address erosion, drought and flood hazards. Its economic viability is solid. Since benefits may take many years to materialize, and may accrue to downstream beneficiaries and/or the global commons, there is a strong argument for state contribution toward costs. Planning and improvements can be undertaken on a watershed basis drawing on community mobilization and readiness to embark on long-term interventions.

Large-Scale Infrastructure. Drought mitigation options would entail investment in infrastructure include rehabilitation of irrigation. Starting with the land reform (1991), irrigation facilities were destroyed in more than half of the irrigated areas. Currently less than 1% of the total area of arable lands is irrigated with 15 systems are still functional. Decrease of irrigated areas continues due to economic volatility (*Figure 8.3.*).

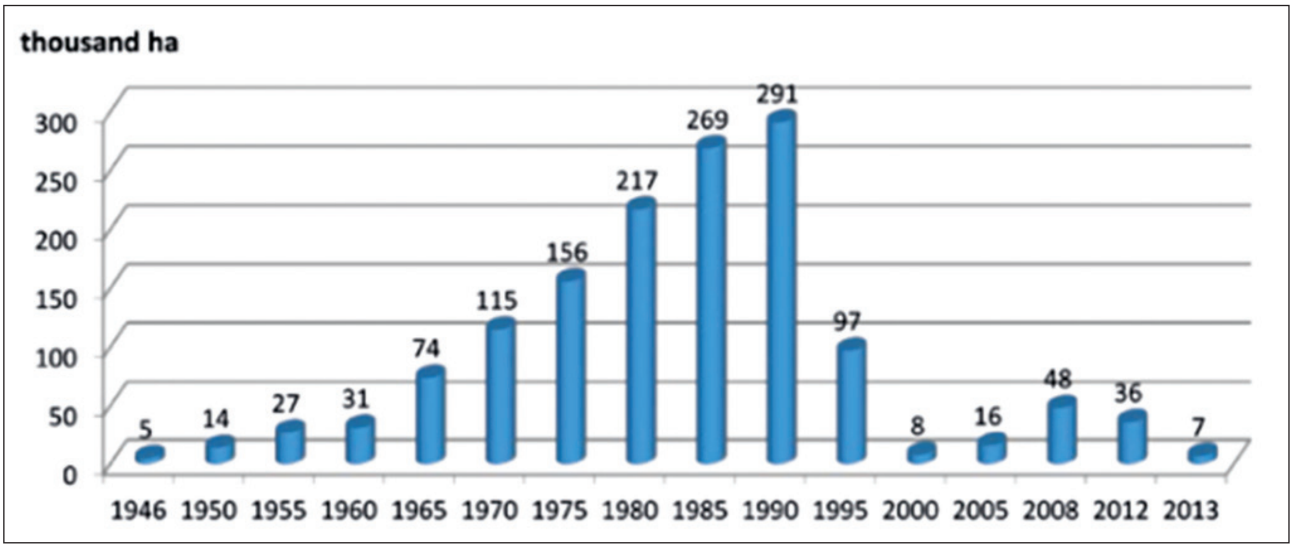


Figure 8.3. Trend of irrigated lands (Republic of Moldova, 1946-2013)

Source: Leah, 2012; 2016a; Daradur et al., 2015b

The Government has developed but not yet financed a major irrigation rehabilitation program. The estimated cost per hectare is relatively high (US$500-1200), but economic returns can justify the investments. In normal years irrigation promotes to increasing yield by 25%-50% while in drought conditions it considerable averts losses (World Bank, 2010). Canals and sprinklers irrigation are the most widespread irrigation systems in Moldova. Resent years *small-scale modern on-farm irrigation technologies based* on CSA approach (dripping method combining with fertilization on farm levels) have introduced. Dripping method is well accepted at all farm level and most effective in the limited water resource of Moldova. However, it is not widespread yet in Moldova owing high investments requirements.

Investment in irrigation should be undertaken on a demand basis and financing should draw primarily on private sources, with the role of the State focused on support for feasibility assessments to help targeting, and possibly rehabilitation of major inter-farm structures, such as pumping stations, that may be needed to establish privately financed sub-projects (World Bank, 2010; 2016).

8.3. Short and midterm preventive interventions and investments

Planning strategy. The critical insight of the current plan is that high level of variability in agricultural production is a normal part operating environment in agriculture and consequent of the overall pattern of regional weather and climate. Climate variability in many respects determines a greatest uncertainty in many other sectors of development and, the lifestyle of people and their health. As a major contribution to improved understanding of climate variability impacts on regional environment and vulnerable development the plan focus incentives for primary producers to adopt a more self-reliant approach to their farming operations, including drought preparedness. In this respect the Plan provide for shifting the drought policy and intervention programs be restructured from a reactive, crisis management approach and traditional hierarchical and command-and-control management methods to creating an overall environment to facilitate affected stakeholders be prepared for drought.

Preventive options include awareness campaigns, to optimize public behavior, improved forecasting capabilities, early drought warning systems, provisions of subsidies or matching grants to encourage and assist farmers to invest in good practices, such as control prevention land degradation through afforestation or other land use change etc. (Crossman, 2018). A list of preventive drought mitigation/adaptation options for agriculture and water resources, by no means an exhaustive, is recommended in the number of Moldavian publications are displayed in *Table 8.1*.

Table 8.1. Mitigation/adaptation options for agriculture and water resources

Sector	*Mitigation/adaptation strategies*
General	*Invest in research and extension services to enhance the capacity and delivery of information to the agricultural sector, with particular reference to climate change and the implementation of adaptation options.*
	Improve the early warning and weather information systems, including the publication and distribution of agriculture-specific weather forecasts on a frequent basis (e.g. short-term and seasonal forecasts, the monitoring of drought, etc.).
	Invest in the monitoring and detection of new pests and diseases for the crop, livestock and forestry sectors through improvements in the sanitary and phito-sanitary regime.
Rain fed cropping	*Development of new genetic varieties with higher resilience to increased temperatures and lower precipitation, with the potential of increased production via carbon fertilization.*
	Increase farming system water-use efficiency and reduce soil erosion via improved surface management techniques, including the adoption of minimum and zero tillage practices.
	Development and adoption of improved agronomy and risk management techniques.
	Improved plant protection, through enhanced monitoring of pests and diseases and improved education of farmers via extension services.
Irrigation	*Rehabilitation of economically viable irrigation and delivery schemes to improve access and system water-use efficiency.*
	Developing water recycling schemes that use treated waters from communal waste water treatment plants. Modernization of on-farm distribution systems.
	Introduction of new irrigation techniques and improvement of existing techniques to enhance field level water use efficiency.
	Small scale irrigation development and creation and rehabilitation of local water storage and associated infrastructure.

Source: World Bank, 2010; 2016; World Bank and CIAT, 2016; Climate Change Adaptation Project, 2017; Forth National Communication, 2018

However, mainstreaming many of them into policy and planning process requires critical stocktaking of ongoing and promising interventions for the future, and of institutional and financial enablers for their implementation (Daradur et al., 2007; World Bank, CIAT, 2016; Cramon-Taubadel and Walter, 2018).

Since finances are limited, it is an imperative that adaptation options which offer the greatest return on investment from an economic, social and environmental perspective be prioritized and implemented to improve the resilience of agricultural systems and rural livelihoods. It is important that mitigation and adaptation options are developed not only at the national scale, but at the agro-ecological zone scale, so that they specifically address the climate risks that local communities face (World Bank, 2017). This will ensure that human and economic capital is directed towards the development and implementation of adaptation strategies that are relevant, targeted and effective. Although there are many field-ready innovations that could improve the resilience of agricultural systems in Moldova, the lack of financial resources at the farm level is a considerable barrier to utilizing these innovations. Additionally, significant investments will be required by the state and development partners to build the infrastructure, knowledge and policy systems that can support and develop an array of adaptation options to increase the resilience of the farm sector into the future.

Drought mitigation activities should be ongoing and continually funded to fully realize benefits from undertaken efforts and to reach desired management goals. A critical changing in Moldavian climate and drought policy has started last decade with the shift to an adaptive, resilience perspectives based on drought risk reduction principles that are consistent with the UNCCD approach. A number of strategies and programs have been approved recently are closely related to climate risks and to increase drought resiliency, land degradation and biodiversity services of agricultural ecosystems. This endeavor was also highly supported by the international community through several bilateral and multilateral adaptation projects of diverse sizes and scopes, targeting the country's priority sectors project-based assistance.

Forth National Communications, as well as other documents (Smart agriculture project of Moldova, UNCCD bank of good practices etc.), propose a range of mitigation/adaptation strategies for the agricultural and water resources sector. Despite the significant benefits to productivity, climate resiliency and drought mitigation objectives, many small-scale farmers are disinclined to such investments because of constraints associated with a variety of economic and social factors (World Bank, 2010; 2017). Limited access to relevant technical assistance and to adequate financial resources, insufficient water resources and technologies for irrigation are some of the main barriers (World Bank, CIAT, 2016). Moldova, with poor rural population, low levels of agricultural productivity, a highly variable climate and a high reliance on rain-fed crop systems has significant food sustainability and food security risks.

High climate variability is a source of the uncertainties in all sector of development and, in many respects, determines the lifestyle of people and their health. These uncertainties are greatly aggravated in a changing climate that dictate robustly evaluation of the adaptation strategies under a range of different future climate scenarios. In particular, one of a pivotal geographical consequences of climate change is an increase in the frequency of drought and related climate risks. This in turn inevitably entails an increase in economic losses and social upheavals in the most regions of Moldova. It is likely that the climate risks downside to the environment and development sectors outweigh potential benefits. So, the interested stakeholders should focus on reducing the adaptation deficit by increasing the efficiency, productivity and adaptive capacity of agriculture to the present climate, while simultaneously developing effective medium and long-term adaptation options for the dominant farming and livestock systems across the three agro-ecological zones of Moldova (World Bank, 2017).

Priority mitigation interventions and investments. A set of priority mitigation activities and investments have been identified (see the table below) across the target sectors for implementation in the near to mid-term future (Climate Adaptation Strategy, 2014; World Bank, 2016; Forth National Communication, 2018). The overall goal of actions is reducing climate risks in a changing climate. Much of the drought and related climate extreme impacts are concentrated in agricultural and rural areas. Agricultural sector significantly decreases due to water stress on crops production (Climate Adaptation Strategy, 2014; Land degradation neutrality program, 2018: Forth National Communication, 2018).

Table 8.2. Short and midterm priority interventions and investments (Republic of Moldova)

Sector	*Actions for priority investment*	*Investment period*	*Cost, US $, mln.*
Agriculture Water Management	*Rehabilitate/modernize centralized irrigation systems*	2017 to 2040	975.0
	Rehabilitation/modernization of drainage infrastructure in irrigated areas	2017 to 2026	120.0
	Institutional reforms/capacity building	2017 to 2024	140.0
Forestry	*Ecological reconstruction of forests*	2020 to 2029	91.3
	Ecological reconstruction of forest belts	2020 to 2029	4.9
Health	*Heat health warning system*	2017+	0.4
Water Supply	*Improving municipal & industrial water system efficiency by 10% reduction in losses*	2017+	2.8-5.5
	Water storage in Lower Dniester)	2030+	18.4
	Water storage in Raut	2020	0.3
	Non-Structural measures	2020-2040	136.6
Disaster Response Management	*Improved training facilities;* *Create N&S Emergency Command Centers;* *Improved emergency response capabilities*	2020	11

Source: Adapted from: Climate Change Adaptation Strategy, 2014; Environmental strategy, 2014; World Bank, 2016; World Bank, CIAT. 2016; Climate Change Adaptation Project, 2017; Forth National Communication, 2018

The biggest challenges and investment opportunities are in sustainability of agriculture and rural development. Regeneration of irrigation systems is a vital input to improving drought resilience and agricultural productivity (Climate Adaptation Strategy, 2014; World Bank, 2016; Forth National Communication, 2018). Along with the rehabilitation and modernization of drainage infrastructure will make a major contribution to increasing current productivity as well as to mitigate expected extreme climate impacts. These are expected to have good rates of return as long as they can be combined with successful institutional capacity-building for management of irrigation systems. Other options include small-scale on-farm irrigation systems, soil management and climate risk management technologies (e.g., anti-hail nets), and the potential for changes in crop mix towards perennial crops (i.e., grapes and fruit trees), which will be more resilient to climate change.

Water resources that provide challenges both related to quality and quantity have been deteriorating rapidly, with severe consequences for environment and all development sectors. Water availability will fall below total demand within a couple of decades with implications for irrigation. Improvements of local supply systems to reduce losses, and building a small-scale storage reservoir on the main rivers, present immediate, modest investment opportunities with high returns. In coming decades, larger-scale storage infrastructure will be needed. The ideal size and timing of these requires more analysis, and the institutional capacity to effectively manage a variety of water investments would also need to be strengthened.

Ecological rehabilitation and expansion of forests and complementing Moldova's greenbelts plans are expected to have high returns and to have a high poverty and gender impact. Forests and biodiversity degradation are major problems and are well recognized that helping to improve forest sector (Environmental Strategy, Climate Change Adaptation Strategy, Capcelea, 2016; World Bank, 2016; Daradur et al., 2018; Forth National Communication, 2018). Increasing the forest cover promote to land performance, environmental sustainability and reducing poverty and increasing the wealth of the population. Restoration of degraded forests and pasture lands, complementing Moldova's greenbelts plans that protect valuable farmland areas promotes agricultural productivity through improved watershed function and protection from drought and related extreme climate events.

Improvements for drought prevention and preparedness, including training facilities and emergency response capabilities are also key gains for public safety as well as substantial economic returns. These actions aims to strengthen the capacity of national and regional civil protection authorities to prepare for and respond to drought and other extreme weather events, including disaster management systems to support a wide range of sectors with risk management planning and response to extreme climate events (Environmental Strategy, Climate Change Adaptation Strategy, Capcelea, 2016; World Bank, 2016; Climate Change Adaptation Project, 2017).

Drought impacts on public health are mostly indirect because of its link to other mediating circumstances like loss of livelihoods, population migration from rural areas to cities and out of the country and increasing tension over water resources associated with inadequate sanitation and low quality drink water supply. Although there is uncertainty around the scale of climate-related health impacts, modest investments in heat warning systems and public health campaigns are expected to have high returns.

Drought risk response management actions. Within the country's framework of Disaster Risk Reduction (DRR) there have already been efforts to integrate it in the national disaster risk management response to climate risks (Forth National Communication, 2018). This priority area is highly supported by the international community through project-based assistance to promote national ownership and leadership for disaster resilience through better coordination capacities, awareness and knowledge and innovative technology transfer. World Bank Disaster and Climate Risk Management Project (DCRMP) with the objective to strengthen the State weather monitoring and early warnings of extreme weather and climate hazards to provide timely and accurate hydro-meteorological forecasts and services; manage and coordinate responses to natural and man-made disasters; and help end users, particularly farmers, be aware of, and adapt to climate variability and extremes.

UNDP Disaster and Climate Risk Reduction Project (DCRRP) with the overall goal to reduce extreme climate risks in Moldova through the development of national and local risk management capacities. The project contributed to increased national ownership and leadership for disaster and climate resilience through better coordination, awareness and knowledge and innovative technology transfer.

9. FINANCING OPPORTUNITIES

9.1. Domestic funds

In 2014, the Government of Moldova with support of United Nations Development Program (UNDP) and the Government of Austria, developed and approved a National Climate Change Adaptation Strategy, reviewing climate risks vulnerabilities in the six sectors considered most vulnerable: agriculture, water resources, forestry, human health, energy and infrastructure. The strategy includes an Action Plan to 2020, at an estimated budget of US$155 million, based on institutional and investment activities recommended within each sector (Climate adaptation strategy, 2014). Both, domestic and international funding of the country drought and related climate risks reduction initiatives are contemplated. Domestic financing is usually modest and planned to be secured both from the state budget and from other financial mechanisms (special funds).

National Ecological Fund (NEF) and local ecological funds are the basic institutions for allocation of the revenues generated by the use of economic tools in the Republic of Moldova. The NEF, established in 1998, is a key instrument for financing the implementation of environmental policies in Moldova. *The NEF is under direct supervision of the MARDE, it is not a separate legal entity.* The NEF is administered by a management board, which is chaired by the Minister and includes representatives of line government institutions and environmental NGOs. The latter is elected by an assembly of environmental NGOs, and the post rotates on an annual basis. Environmental pollution charges earmarked in the Law on Payment for Environmental Pollution are the main revenue source of the NEF and local environmental funds (mobilize yearly approximately $16 mln; United Nations Economic Commission for Europe, 2014). Compared to the investment needs in the sectors these sources are rather limited and do not allow for the implementation of national and local environmental policies.

The general mandate of the NEF is to provide grants for environmental protection projects and environmental research, as well as support environmental NGOs. Resources of the NEF are distributed on a competitive basis, providing grants to local authorities, businesses and the civil society. *Grants constitute the basic NEF financing form; no other types (subsidizing the interest rate, credits without interest rate or with bonus rate, guarantees for loans) have been used before*.

The local environmental funds *are closely integrated with the territorial units of the State Ecological Inspectorate (SEI).* Each fund is administered by a management board that is chaired by the head of the territorial environmental inspectorate. There are four other members: the deputy mayor or deputy district president (vice-chair); a municipal council member in charge of environmental protection; a representative of the local centre for preventive health; and a representative of a local environmental NGO (Ministry of Environment, 2013).

The local environmental funds is very limited and an average annual expenditures amounted to 2.5% of NEF expenditure or 0.01% of total government expenditure (United Nations Economic Commission for Europe, 2014). On average, each of the 36 local environmental funds spent some 111,000 lei (€7,325) per annum during (Environmental Performance Review, 2014).

Despite some modifications being made in the regulatory framework of the Fund, an extensive reform of its governance structure and management practices is required in order to increase transparency and participation in the decision making process and ensure a better collaboration with other state institutions, as well as to improve the operational procedures and project management cycle in order to ensure targeted and efficient use of the available financial resources.

The National Fund for Regional Development (NFRD) was established in 2010 and became operational in 2011. It is the major domestic source for the financing of regional development priority projects. Among the priority areas are: *the rehabilitation of physical infrastructure, including water supply and sewerage networks, and environmental protection*.

The revenues of the Fund originate from the State budget and should, as officially stipulated, amount to at least 1% of total annual State budget (approximately €1.5 million per month) revenues (Environmental Performance Review, 2014). However, the Fund receives an average 130-160 mln. lei (€8-11.0 mln.) strongly relies on foreign assistance for making a noteworthy contribution to regional development.

The National Fund for Agricultural and Rural Development (NFARD) established in 2017 on the basis of the Law on the Principles of Subsidies in Agriculture and Rural Development (No. 276 of December 16, 2016). The law is intended to stimulate the modernization of the agro-industrial complex and rural areas by increasing their competitiveness, modernizing and restructuring the market, ensuring sustainable management of natural resources in agriculture, and raising the standard of living in rural areas. The NFARD created support measures included in the National Strategy for the Development of Agriculture and Rural Areas. The funds are formed from annual budget allocations as a separate provision for agriculture and rural development and , as well as from sources within the programs of the European Commission.

Overall annual allocations from the state funds with foreign sources for the NFARD is planned to be at least 2% of the of the state budget revenues in respective year. About 50% of the sources will be used for direct payments. As part of support measures, investments in construction and reconstruction of greenhouses, agricultural equipment, building and reconstruction of livestock farms, installing irrigation systems, machines and equipment for the introduction of modern soil treatment technologies with low environmental impact etc.

In May, 2018, the Government has approved a set of amendments regarding the allocation of funds from the NFARD (Government Decision No. 507). The document provides for the annual allocation of at least 5% of the total amount of the Fund to finance small start-up projects initiated by young farmers and women. According to the new regulations, the subsidy for insured farmers in agriculture increases from MDL 300,000 to 400,000, which is a unique ceiling for all farmers in Moldova.

The amount of the subsidy granted to a farmer for three years will not exceed MDL 9 million, including a one-year break after three consecutive subsidy years. Farmers who practice conservative agriculture to receive financial support from the state will assume their commitment to continue their business for at least 5 years. Starting 2019, the farmers will be able to submit their online grant applications.

The Fund for Food Security among others refers to alcohol beverages control, livestock traceability, vineyard and wine electronic registers, the Agricultural Information Centre.

The Fund for Biotechnology Research, the Fund for Horticulture and Field Crops is aimed at supporting the testing of plant varieties (including drought-resistant ones), the conservation and development of plant genetic resources, rural extension, hail service, co-financing contribution of Moldavian government in international projects implemented in Moldova.

The National Fund for Credit Guarantee offers solutions for small and medium enterprises that do not have collateral to access credit lines from banks.

9.2. External financing

External financing plays a particularly important role in the climate risks agenda of the Republic of Moldova. An integrated database of the external assistance on direct budget support and projects is managed by the Aid Coordination Unit of the State Chancellery. Funding is mostly mobilized from external development partners by means of Official Development Assistance (ODA). From 2005 to 2015 total official development assistance to the Republic of Moldova increased from 112 million EUR to 331.6 million EUR. Foreign funds are allocated to the State budget under program Environment protection and hydrometeorology (including the water supply and sanitation sector). Among the major potential donors (2015) in Moldova are the United States of America (USA), the European Union (EU), the World Bank (WB), United Nations Agencies (UN), the European Investment Bank (EIB) and Romania.

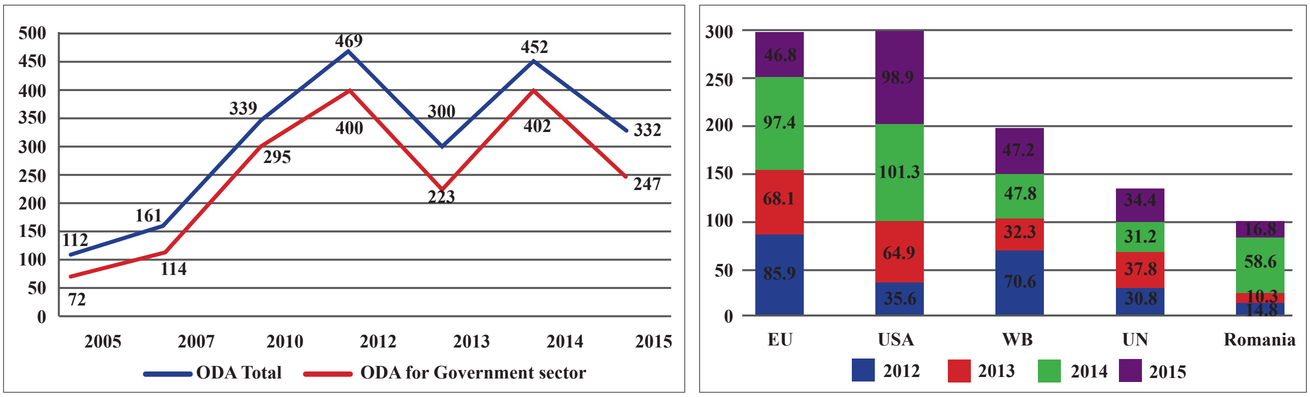


Figure 9.1. ODA disbursements (EUR, mln.) trends (2005-2013) and major external donors (2012-2015) for climate risks initiatives of Moldova

Source: Forth Communication Report (2018) based on AMP data

Drought and related climate risks mitigation initiatives are supported through several bilateral and multilateral adaptation projects of diverse sizes and scopes, targeting the topics:

- Climate risk reduction (International Development Association, UNDP);
- Rural economic development and climate resilience (International Fund for Agricultural Development, IFAD; Austrian Development Cooperation);
- Reducing small-holder farmers' vulnerability (Japan International Cooperation Agency, JICA);
- Soil conservation and rehabilitation of Soviet irrigation systems (World Bank, WB), Millennium Challenge Corporation, MCC);
- Sustainable management of pastures (European Commission);
- low emissions development Australian Agency for International Development);
- Information and communication technology to improve forest governance (Government of Korea).

The table below highlights existing and potential financing opportunities for drought and related climate risks reduction initiatives in Moldova.

Table 9.1. Funding opportunities for drought and related climate risks reduction initiatives in Moldova

Funds accessed	Focal area	Access
Adaptation Fund (AF)	*Climate variability/change*	*Not accessed*
(Australian Agency for International Development (AAID)	*Low emissions development*	*Accessed*
Austrian Development Association (ADA)	*Sustainable management of water resources, climate resilience*	*Accessed*
International Development Association	*Disaster and climate risk reduction*	*Accessed*
(International Fund for Agricultural Development (IFAD)	*Rural development and climate resilience*	*Accessed*
Japan International Cooperation Agency (JICA)	*reducing small-holder farmers' vulnerability*	*Accessed*
European Commission	*Sustainable management of natural resources*	*Accessed*
European Bank for Reconstruction and Development (EBRD)	*Agriculture and rural development*	*Accessed*
EU Neighborhood Info Centre, an ENPI project	*Sustainable development*	*Accessed*
Environment and Sustainable Management of Natural Resources (NTR)	*Sustainable management of natural resources*	*Accessed*
European Neighbourhood and Partnership Instrument (ENPI)	*Agriculture and rural development*	*Accessed*
European Regional Development Fund (ERDF)	*Agriculture and rural development*	*Accessed*
French Global Environment Facility (FFEM)	*Sustainable management of natural resources*	*Not accessed*
Global Environment Facility (GEF)	*Land degradation*	*Accessed*
International Fund for Agricultural Development, IFAD;	*Agriculture and rural development*	*Accessed*
Austrian Development Cooperation	*Water resources*	*Accessed*
Reducing small-holder farmers' vulnerability (Japan International Cooperation Agency, JICA);	*Agriculture and rural development*	*Accessed*
World Bank, WB	*Climate risks, rural development, soil conservation and rehabilitation of irrigation systems*	*Accessed*
Millennium Challenge Corporation (MCC)	*Soil conservation and rehabilitation of irrigation systems*	*Accessed*

Source: Adapted from UNCCD and CEF, 2013; Daradur et al., 2015; World Bank, 2016; World Bank, CIAT. 2016; Climate Change Adaptation Project, 2017; Forth National Communication, 2018

9.3. Market incentives and innovative funding

Incentive and market mechanisms refer to approaches that rely on economic incentives, market forces or financial mechanisms to encourage regulated entities to improve environmental performance (GEF, 2013; Wingqvist and Wolf, 2013). Creating a conducive environment and encouraging the private actors to improve preparedness to drought based on an adaptive, resilience perspectives can have a crucial contribution to drought and related climate risk issues, including poverty reduction and environmental protection. In the recent years the Moldovan authorities have pursued an ambitious reform program aimed at achieving sustainable growth led by the private sector (World Bank, 2014).

The main components of the legal framework adopted for this purpose are the 2008 Law No. 179-XVI on Public-Private Partnerships and the 1995 Law No. 534-XIII on Concessions. The role of these PPPs, however, is still quite small, but could grow, depending on the extent to which tariffs for these services allow for full cost recovery on a sustainable basis (United Nations Economic Commission for Europe, 2014).

Other components of the legal framework on Public Private-Partnerships include:

- *Regulations and composition of the National Council for Public and Private Partnership*, Decision of the National Council for Public and Private Partnership No. 245 of April 19, 2012.
- *Preliminary Matrix of the Project Risk Distribution Preliminary Matrix* (Ministry of Economy Order No. 143, August 2, 2013) is an indicative model of sharing risks in public and private partnership projects.

As example an incentive and market mechanisms is the Program on Attracting Remittances into the Economy (PARE “1+1”). The program operates under the rule of “1+1” when every MDL invested from remittances is complemented with a MDL in the form of a grant. Grant financing can amount to up to 50% of the investment, but not exceed 200,000 MDL. The state policies targeting the channeling of remittance funds towards small businesses, however, are not supported by sufficient financial means and it is not clear yet how they could be used to finance the program projects.

However, the market-based instruments addressing drought risk reduction and sustainable land management are still not adequately considered in the Republic of Moldova. In combination with weak or partial environmental policy there are low incentives to improve resource efficiency or pursue green, clean investments.

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ANNEXES

Annex 1.

The National Working Group on the implementation of the UNCCD provisions in the Republic of Moldova (Government decision No. 120, 2016)

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Annex 2.

Six-month time scale (April-September) time series of the climate parameters and drought indices (Chisinau meteorological station, 1946-2012)*

Year	*P*	*P'*	*PDI*	*HTC*	*SPI*	*DAI*
1946	216	194	0.9	0.6	-1.27	0.28
1947	298	256	0.86	0.91	-0.18	0.41
1948	628	515	0.82	1.99	2.34	0.86
1949	485	427	0.88	1.6	1.47	0.73
1950	269	231	0.86	0.8	-0.52	0.37
1951	158	141	0.89	0.45	-2.32	0.21
1952	342	260	0.76	1.05	0.29	0.42
1953	218	194	0.89	0.67	-1.23	0.31
1954	408	355	0.87	1.22	0.88	0.56
1955	526	479	0.91	1.76	1.74	0.83
1956	287	255	0.89	0.93	-0.31	0.43
1957	255	230	0.9	0.77	-0.71	0.36
1958	382	336	0.88	1.21	0.66	0.54
1959	270	243	0.9	0.86	-0.51	0.4
1960	277	247	0.89	0.89	-0.43	0.42
1961	281	250	0.89	0.86	-0.38	0.4
1962	292	266	0.91	0.9	-0.25	0.43
1963	238	209	0.88	0.7	-0.94	0.33
1964	329	290	0.88	1.04	0.16	0.47
1965	325	296	0.91	1.08	0.11	0.5
1966	321	286	0.89	0.99	0.07	0.46
1967	257	226	0.88	0.78	-0.68	0.36
1968	310	264	0.85	0.93	-0.05	0.42
1969	272	242	0.89	0.87	-0.49	0.4
1970	411	370	0.9	1.3	0.91	0.61
1971	362	319	0.88	1.17	0.48	0.53
1972	438	394	0.9	1.32	1.12	0.63
1973	192	167	0.87	0.61	-1.66	0.28
1974	423	381	0.9	1.39	1	0.65
1975	352	306	0.87	1.02	0.38	0.48
1976	358	311	0.87	1.2	0.44	0.56
1977	314	283	0.9	1.06	0	0.49
1978	386	347	0.9	1.35	0.7	0.62
1979	388	353	0.91	1.22	0.71	0.58
1980	425	383	0.9	1.49	1.02	0.68

1981	214	193	0.9	0.7	-1.30	0.32
1982	235	204	0.87	0.75	-0.98	0.34
1983	462	407	0.88	1.41	1.30	0.66
1984	401	361	0.9	1.33	0.82	0.62
1985	422	363	0.86	1.34	1.00	0.6
1986	219	177	0.81	0.65	-1.22	0.28
1987	349	314	0.9	1.15	0.35	0.54
1988	365	329	0.9	1.16	0.51	0.55
1989	360	320	0.89	1.13	0.46	0.53
1990	195	176	0.9	0.61	-1.61	0.28
1991	505	444	0.88	1.63	1.60	0.75
1992	232	209	0.9	0.72	-1.02	0.34
1993	353	321	0.91	1.15	0.39	0.54
1994	314	245	0.78	0.89	0.00	0.37
1995	527	474	0.9	1.62	1.75	0.77
1996	380	312	0.82	1.18	0.64	0.51
1997	387	344	0.89	1.26	0.70	0.58
1998	344	313	0.91	1.02	0.31	0.5
1999	199	179	0.9	0.58	-1.54	0.28
2000	230	198	0.86	0.68	-1.05	0.31
2001	379	334	0.88	1.14	0.63	0.53
2002	363	319	0.88	1.07	0.49	0.5
2003	259	223	0.86	0.77	-0.65	0.35
2004	310	273	0.88	1.06	-0.05	0.49
2005	407	354	0.87	1.35	0.87	0.62
2006	389	354	0.91	1.22	0.72	0.58
2007	147	132	0.9	0.4	-2.57	0.19
2008	311	283	0.91	0.93	-0.03	0.45
2009	198	176	0.89	0.56	-1.56	0.27
2010	365	332	0.91	1.06	0.51	0.51
2011	303	255	0.84	0.89	-0.12	0.4
2012	254	224	0.88	0.67	-0.72	0.32

*P – precipitation; P’ – Effective Precipitatin; PDI – Precipitation Distribution Index (Daradur, 2001); HTC – Hydrothermal Coefficient (Selyaninov, 1958); SPI – Standardized Precipitation Index (McKee et al., 1993); DAI – Drought and Aridity Index (Daradur, 2001)

Annex 3.

Sectors policy gaps related to climate risks mitigation/adaptation

Agriculture

Policy document	*Overall goal*	*Gaps related to climate risks*
National Strategy for Agricultural and Rural Development for the years 2014-2020	To address multi-functional character of agriculture. Te objective is based on the achievement of synergies among economic, agricultural resource management and social areas: To ensure that the agri-food sector contributes to the sustainable achievement of the national economic and social development goals.	Climate change adaptation is considered under the specific objective 2.3. Support to adaptation and mitigation of climate challenges effects on agricultural production. Te objective is an overall one lacking distinct actions to reach it. Other aspects of adaptation are mentioned under the specifc objec tives Support sustainable agricultural land and water management practices; Support environmentally friendly production technologies, organic production and products ensuring biodiversity. Agriculture industry is not recognized as a strategic one within the constraints of economic, social and global energy, focus on employ ability of rural population in agriculture to reduce poverty and lack ing an action plan to protect the environment in the context of agricultural sector to reduce the impacts of climate change is mis.
National Strategy for Sustainable Development of the agro-industrial complex of the Republic of Moldova (2008-2015)	Ensuring sustainable le growth of agro-industrial sector, increasing the quality of life in rural areas by increasing the productivity and competitiveness of the sector.	Te strategy focuses on technological modernization of the agricultural sector without adequate attention to systemic and environmental change or linkages to other sectors
Food safety strategy for 2011-2015	Orientation towards protection of human health and safety food.	A comprehensive analysis of the link between product quality and climate change, especially the broad connection between food securi ty and food safety in terms of global warming is missing.
Strategic Development Programme of the Ministry of Agriculture for the period 2012-2014	Serves as the Ministry's short term (3 year) planning and management tool and as the instrument for communication of sectoral goals.	Te priority medium-term policy reorientation is missing and there is a need for a model farm for sustainable development and for the ability to track environmental impact and climate change.
Program for Conservation and Increase of Soil Fertility 2011-2020	It is oriented toward improving soil fertility through stopping the active degradation of arable 887,000 ha by 2020 ha and implement measures for soil conservation and fertility improvement on 1.7 million ha.	Te proposed actions do not refer specifcally to adaptation to climate change, whereas the link between improved soil fertility and sector resilience to climate change is missing.

Water sector

Policy document	*Overall goal*	*Gaps related to climate risks*
Water Supply and Sanitation Strategy in communities of Moldova, for the years 2007-2025	Environmental protection and environmental management, including water.	Does not address or contain any condition or principles for climate change adaptation.
Regulation on flood protection levees (2012)	Establishes the requirements for the design, construction, reconstruction, repair and operation of dams, their operations and monitoring of status, as well as enforcement responsibilities	Tough dams are considered essential flood protection for localities, climate adaptation issues are missing because responsibilities for their functions and duties are not articulated.
Program for the Development of Water Management and Hydro-amelioration in the Republic of Moldova for 2011-2020	Te Program aims at increasing water use efficiency across sectors.	Refers to water use only in agriculture sector.
Water supply and sanitation Regional Sector Program 2014	Focuses on strengthening the WSS sector planning and programming process at regional and local level in order to optimize investments and develop sustainable projects in the specific sector. Establishes the directions of water supply and sanitation in the regional context, in the communities of 3 RDs.	Does not address climate change adaptation into a programmatic way, with specific measures to address climate risks at the regional level.
National Water Supply and Sanita tion Strategy for 2014-2028	Aims at implementing water safety plan at high quality of water for human consumption. Strategy prioritizes interventions in the development of the sector and sets out medium and long-term reform objectives, which include inter alia: decentralization of the public WSS services to the LPAs of level 1; extension of central piped water supply and sewage systems andincrease of rate of access for population. Te strategy also promotes sustainable development measures and environmental protection of water resources by harmonizing the national legal framework with the EU Acquis.	Te Strategy does include adaptation action, such as use of surface water management, but the action plan foresees the development of the group water mains from the Dniester and the Prut rivers, while for remote communities, the strategy refers to groundwater, which is known being of high heterogeneity.
National Program for the Implementation of the Protocol on Water and Health for 2016-2020	Set the actions to reach national target indicators on human health and welfare, sustainable management of water resources, protection of aquatic ecosystems; preventing and reducing the spread of water-related disease.	Te program does not prioritise actions that would directly support the need of sector under the threat of changing climate.

Forestry sector

Policy document	*Overall goal*	*Gaps related to climate risks*
Plan of action for implementation of the Strategy for Sustainable Development of the national forest (2004-2020)	Includes specific actions to implement the strategy of sustainable development of the forestry sector in Moldova.	The plan provides for the options to mitigate the climate risks impact, indicates responsible agencies, however, due to legal challenges has not been implemented.
Environmental Strategy for the years 2014-2023	Provides the integration of sustainable development and climate change adaptation in the forestry sector.	Addresses climate change in an indirect manner only.
Te National Program for expansion of the areas covered with forest vegetation for the years 2014-2018	Technical-oriented document, conceived to slow down the soils degradation processes by extending the areas covered with forest vegetation. It also provides regionally disaggregated indicators regarding the areas to be recovered.	Does not refer to a programmatic approach building and maintaining stable diversified forests adapted to climate change.

Health sector

Policy document	*Overall goal*	*Gaps related to climate risks*
National Health Policy 2007-2021	To develop a legal framework to strengthen preventive health care and ensure high quality medical services.	Adaptation measures for preventive healthcare, primaryhospital under extreme weather event was not a specific purpose of these policies.
National Strategy for Public Health 2014-2020	To set objectives of the surveillance and control of communicable and non-communicable diseases and principal activities of the state in pursuing these.	Does not refer specifically to climate risks issues, does not set adaptation goals and targets.
National Program for the Implementation of the Protocol on Water and Health 2016-2020	To set the actions to reach national target indicators on human health and welfare, sustainable management of water resources, protection of aquatic ecosystems; preventing and reducing the spread of water-related disease.	No prioritized actions to mitigate climate risks impacts that would directly support the.

Source: Adapted from World Bank, 2010; 2016; Forth National Communication, 2018

Annex 4.

Key intervention for the implementation of the National Drought Plan

No.	Activities	Institution in charge	Time frame	Estimated costs, MDL, mln	Sources of funding	Monitoring Indicators	Strategy, Program, Project
1	2	3	4	5	6	7	8
The Forestry Sector							
1.	Enhance the process of scaling-up territories covered with forest vegetation and ecological restoration of forests, create interconnection corridors between forested massives	"Moldsilva" Agency; Ministry of Environment	2020	10,0	State Budget, the National Ecological Fund, external financial assistance	130,000 ha of woodland, green islands created	Change Adaptation Strategy by 2020
2.	Create forest bands for agricultural land, roads and water protection	"Moldsilva" Agency; Ministry of Environment; Ministry of Transport and Road Infrastructure; Ministry of Agriculture and Food Industry	2020	10,0	State Budget, the National Ecological Fund, external financial assistance	30,000 ha of forest bands restored/created	Climate Change Adaptation Strategy by 2020
3.	Create forest plantations for industrial and energy needs (planting energy forest to meet the population's needs)	Ministry of Economy; Ministry of Environment; "Moldsilva" Agency	2020	380,0	State Budget, the National Ecological Fund, external financial assistance	Forest plantations created (ha)	Climate Change Adaptation Strategy by 2020
4.	Creating accountability mechanism for beneficiaries of woodlands, haylands, wetlands and creating incentives and economic tools in order to ensure their sustainable management and protection	Ministry of Environment; Ministry of Agriculture and Food Industry	2020	0,045	State budget	Projects approved; economic tools implemented	Environmental Strategy for the years 2014-2023 and of the Action Plan for its implementation entation

5.	*Creation and restoration of riparian and water basins protection strips, of forests on degraded lands and of green spaces*	*„Moldsilva" Agency; Ministry of Environment*	*2023*	*80,0*	*State budget; National Ecological Fund; foreign sources*	*30,000 ha of riparian protection strips – restored/ created; 150,000 ha of forest plantations, green areas – created*	*Environmental Strategy for the years 2014-2023*
6.	*Expansion of forest covered areas*	*Ministry of Environment*	*2030*		*External financial assistance*		*Development strategies with low emissions of the Republic of Moldova until 2030*
			The Agriculture sector				
7.	*Developing of a monitoring system for quality of soil, air, water (including drinking water), biodiversity, state protected natural areas and wetlands*	*Ministry of Environment*	*2023*	*800,0*	*State budget; foreign assistance; National Ecological Fund*	*Stations, monitoring posts - created*	*Environmental Strategy for the years 2014-2023*
8.	*Ecological restoration of degraded lands subject to landslides and used for the extraction of minerals*	*Ministry of Environment; Ministry of Agriculture and Food Industry*	*2023*	*100,0*	*State budget; National Ecological Fund; foreign assistance*	*880,000 ha degraded land – restored, reforested; 21 500 ha of land subject to landslides - reconstructed*	*Environmental Strategy for the years 2014-2023*
9.	*Restoring farmland buffer strips and creating natural carcass of soil conservation by linking them to existing forest massive*	*„Moldsilva" Agency; Ministry of Environment; Ministry of Agriculture and Food Industry*	*2020*	*4,0*	*National Ecological Fund; foreign sources*	*30,000 ha of buffer strips – restored; natural carcass created*	*Environmental Strategy for the years 2014-2023*
10.	*Mitigating the impact of soil desertification by implementation of resource productivity technologies*	*Ministry of Environment; Ministry of Agriculture and Food Industry*	*2023*	*0,5*	*State budget; National Ecological Fund; foreign sources*	*New technologies used*	*Environmental Strategy for the years 2014-2023*

11.	*Introduction of a conservative no-till tillage system in a crop rotation with five fields of green manure (spring peas) once every 5 years*	*Ministry of Agriculture and Food Industry*	*2030*	*6 400,00*	*State budget, external financial assistance, foreign sources*	*320 thousand hectares / year for which no-till tillage is implemented*	*Development strategies with low emissions of the Republic of Moldova until 2030*
12.	*Introduction of a conservative mini-till tillage system using green fertilizers as intermediate crops and / or secondary products*	*Ministry of Agriculture and Food Industry*	*2030*	*7 680,00*	*State budget, external financial assistance, foreign sources*	*320 thousand hectares / year, on which the processing of soil "mini-till" is implemented*	*Development strategies with low emissions of the Republic of Moldova until 2030*
13.	*Support agricultural land and water management practices*	*Ministry of Agriculture and Food Industry; Ministry of Environment Intervention and Agriculture Payments Agency*	*2020*			*Reduction in the number of agricultural land parcels (land consolidation), ha Area of agricultural land under irrigation, ha*	*National strategy on agriculture and rural development for the period 2014-2020*
14.	*Restore shelterbelts of agricultural fields*	*Ministry of Agriculture, Regional Development and Environment, "Moldsilva" Agency, Ministry of Environment, Academy of Sciences of Moldova*	*2020*	*376,20*	*State budget, external sources*	*Shelterbelts with a surface area of 3000 ha restored*	*Biological Diversity Strategy of the Republic of Moldova for the years 2015-2020*
15.	*Promote organic farming elements and environment friendly practices (lynchets, wicker fences, anti-erosion embankments/belts etc.)*	*Ministry of Agriculture, Regional Development and Environment, Land Relations and Cadaster Agency, Academy of Sciences of Moldova*	*2020*	*1039,72*	*State budget, external sources*	*Actions implemented in 3 pilot farms*	*Biological Diversity Strategy of the Republic of Moldova for the years 2015-2020*

16.	*Establish forest plantations on degraded lands and promote domestic species*	*"Moldsilva" Agency, Academy of Sciences of Moldova, Land Relations and Cadaster Agency, Ministry of Agriculture, Regional Development and Environment*	*2020*	*3380,00*	*State budget, external sources,*	*500 ha of new plantations established (in the northern and central part of the country)*	*Biological Diversity Strategy of the Republic of Moldova for the years 2015-2020*
The Water Resources Sector							
17.	*Undertake measures to combat drought/ water scarcity*	*Ministry of Environment; Ministry of Agriculture and Food Industry*	*2020*	*60 000 000*	*State Budget, the National Ecological Fund, external financial assistance*	*Monitoring and warning services provided, leakages in water networks reduced, mapping and drought thresholds established, water storage capacity created*	*Climate Change Adaptation Strategy by 2020 and of the Action Plan for its implementation*
18.	*Restore riparian protection belts for rivers and water basins*	*Ministry of Agriculture, Regional Development and Environment, "Apele Moldovei" Agency*	*2020*	*3792,00*	*State budget, external sources*	*Belts restored on a surface area of 3 thousand ha*	*Biological Diversity Strategy of the Republic of Moldova for the years 2015-2020*