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ADAPTATION OF BULGARIAN WATER SECTOR TO CLIMATE CHANGE EXTREMES

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INTRODUCTION

The aim of this research is to present implementation of DPSIR methodological approach for climate change vulnerability assessment of the water sector and to propose a Climate Change Vulnerability Index for water sector. It is estimated based on a set of indicators of the state of water resources, sensitivity to the regional climate change projections under different RCP scenarios, impact and the adaptive capacity.

The suggested index offers a comprehensive expert assessment of the level of vulnerability of the water sector to climate change. It also proposes a framework that can incorporate more accurate data from regional models for change in climate and hydrology and vary the precision of the included indicators to meet a desired level of detail.

METHODOLOGY

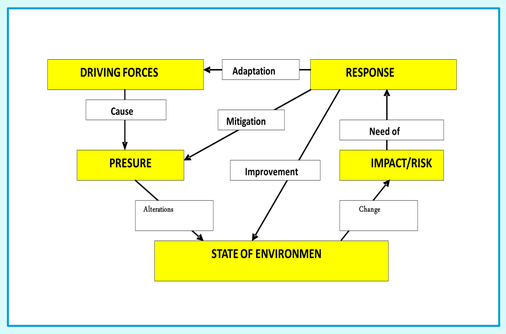
DPSIR Model for Climate Change Risk Analysis

Adaptation to climate change is a social process that takes place in conditions of significant uncertainty. This process is designed to reduce the risk from climate change for water sector. For this reason, the implementation of risk management mechanisms for adaptation to climate change seems an adequate approach.

A description of DPSIR model in this context is given by Holman et al. (2005):

- *Driving forces* at the regional level are examined and analyzed with respect to climate change, socio-economic systems and the national and European policy;
- *The pressure is* also estimated on regional level, analyzing variables that quantified the driving forces (temperature, rainfall, concentrations of carbon dioxide, extreme phenomena, GDP, regional development, etc.)
- *State* is characterized by indicators for the variables, which relate to the sensitivity of the systems or the sectors under pressure.
- *Impact* depends on what values are reached the system status indicators and how they are approaching critical levels.
- *The response* is expressed in the planned adaptation, mitigation and innovation models that aim to reduce the negative and enhance positive impacts of climate change. The results of these models are evaluated as a possible future adaptation policies. They must also be supported by business and non-governmental sector.

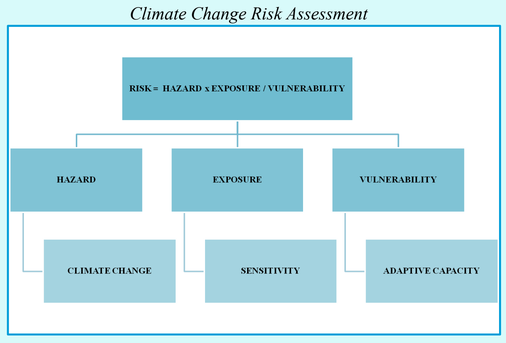
D P S I R Model for climate change risk analysis (after Holman et al., 2005)



Climate Change Risk Assessment

The hazard of climate change stems from the uncertainty of the realization of one or another scenario of climate change and is defined as the likelihood that a particular outcome and impact against sensitive systems. *Exposure* establishes which systems are exposed to the particular influence from climate change and how sensitive they are to it. *Sensitivity* depends on the combination of the likely outcome for realization of a scenario of climate change and the expected impact on the system. The impact of climate change depends on the exposure and sensitivity of socio-economic systems to it. *Vulnerability* in the context of the impact of climate change is "a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its *adaptive capacity*" (Parry et al 2007). *Adaptive capacity* measure the potential of the system to adapt to changes (Brooks, 2003).

Climate Change Risk Assessment



To assess the CCVI for Bulgarian water sector we use an indicator based approach. There are following main groups of indicators for:

- Climate change indicators: Temperature (C°) (1,5 -2,0); Precipitins (%) (0 – 10); Extremes (Max length of dry spell index) (0-4days) (drought) and Extreme wet days index (0-20 mm/y) (flood).
- Water indicators: Quantity of surface water; Quantity of underground water; Water quality; Drought; Flood; Raising the sea level.
- Adaptive capacity indicators: Structure of operators providing services in the water sector; Status of operators providing services in the water sector and how much they are vulnerable to changes in climate (SWOT); Directives, programs, strategies and other tools to improve adaptation capacity. Here it is measured using a simplified scoring in three levels scale: 1- high; 2 - sufficient and 3- insufficient (no action is taken to address the risk of climate change).
- Systems sensitivity indicators refers to the following groups of indicators for: 1) status of water resources; 2) impact on water resources and water sector and 3) sensitivity to climate change . Sensitivity is estimated for each system and each climate scenario individually by scoring as 1 - low, 2- moderate and 3- high.

On the base of the observed and projected changes, a scoring of indicators was implemented and integrated in a climate change vulnerability assessment matrix.

Climate Change Vulnerability Index (CCVI)

Vulnerability in the context of the impact of climate change is measured by the ratio between the sensitivity and adaptive capacity of the exposed systems by:

Climate Change Vulnerability Index (CCVI): CCVI = S/Ac

Where:
S – Sensitivity
S = ∑ Sn max scores/ ∑ Sn scores
Ac – Adaptive capacity

CCVI scale (*after Garcia et al. , 2012*)

CCVI Value	Vulnerability
0.80 – 1.00	Extremely vulnerable
0.50 – 0.79	Very vulnerable
0.20 – 0.49	Moderately vulnerable
0.01 – 0.19	Vulnerable

DATA

The analysis is based on information for the current status of precipitation, air temperature, quantity and quality of water resources in the country and related hydro-climatic risks, climate models and climate scenarios according to the IPCC AR4 (2007) and AR5 (2013) and their regional projections for the territory of Bulgaria from KMNI (2013). Additional data were obtained from the National strategy for the management and development of the water sector in Bulgaria (MEW 2012); the National Statistical Institute (NSI); the National Electric Company (NEC); data from the Ministry of Regional Development and Wellbeing (MRDW) and from the Ministry of Environment and Waters (MEW) on the state of environment and water management, water supply, sanitation and water purification, water resources and water use over the period 2007-2013; publications for the state of the environment from MEW, River Basin Directorates (RBD), National Institute of Meteorology and Hydrology, European Environmental Agency (EEA) and other sources of information.

RESULTS

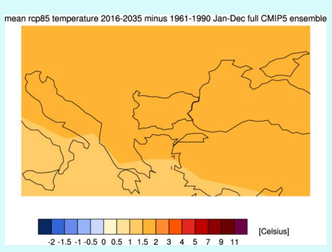
Identification of main actors in Bulgarian water sector

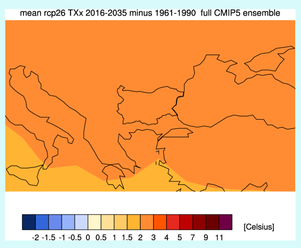
The analysis is mainly based on data for water resources, water use and management and water related extremes in the period after the accession of the country in EU in 2007. The long-term strategic objective of the water sector in Bulgaria is to ensure sustainable use of water resources and to secure the future needs for water of the population, economy and aquatic ecosystems. The summarized results show that the Water sector in Bulgaria operates in three main business areas: *plumbing* (supply, drainage and sanitation), *irrigation* (irrigation, drainage and protection from the harmful effects of water) and *hydropower systems and equipment* (dams and hydropower facilities). The operation of each one of these systems depends on the availability, quantity, and quality of water.

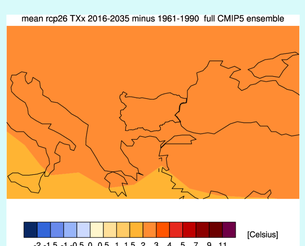
Assessment of climate change sensitivity and vulnerability of Bulgarian water sector

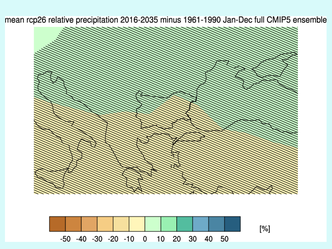
Projections of extreme weather phenomena on the basis of temperature and precipitation indices in AR5 show probable increase the number and intensity of dry and hot periods in the summer. Droughts and floods will occur with greater frequency, as well as torrential rainfall and related dangerous natural phenomena and processes. The values of some of the indices predict less frequent, but more intense rainfall. This is confirmed by the values of the indexes for Maximum 1-day precipitation amount (Rx1day), for Annual maximum consecutive 5 – day precipitation amount (Rx5day), as well as the values of the indexes for Very wet days (R95pTOT) and for Extreme wet days (R99pTOT) (IPCC 2013, MEW 2014).

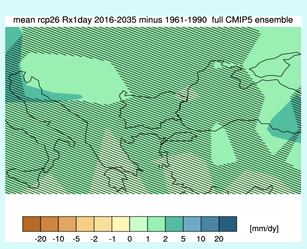
The sensitivity of water sector to climate change is evaluated in respect to the possible changes in time horizon 2016-2035, according to the *Representative Concentration Pathways* scenarios (RCP) in AR5 (IPCC 2013). Because the time period is relatively short, the differences in the estimated average values of changes in temperatures and precipitation and projected changes according to the four RCP scenarios (RCP8.5, RCP6, RCP4.5 and RCP2.6) are rather small and the likelihood of their realization is very high (MEW Analysis of ... 2014). Here we work with the projections for RCP 2.6. For the evaluation of susceptibility to drought and flood, we refer to the trends of projected changes of indices for extreme climatic phenomena according to the same RCP scenario in AR5 (IPCC 2013).

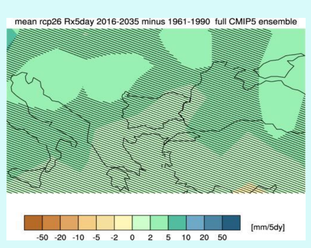












Indicators for assessment of sensitivity of water sector to climate change

Sensitivity Indicators	Trend
Status of water resources	
Fresh water resources	→
Fresh water resources per capita	→
Seized fresh leads on key economic activities	↑↓
Seized fresh water per capita	↑
Underground water resources	↑↓
Seized groundwater on key economic activities	↑↓
Seized marine water in basic economic activities	↓
Water Exploitation Index	↓
Impact on water resources and water sector	
Water use in different sectors of the economy	↑↓
Treatment of wastewater	↑
Share of population with public sewer and municipal wastewater treatment plants	↑
Share of population with water supply mode	↓
Physicochemical condition of surface water	↑↓
Groundwater chemical status	↑↓
Sensitivity to climate change	
Extreme temperatures	↑
Extreme rainfall	↑
Changes in the quantity and flow regime	↑↓
Changes in water quality	↓
Changes in sea level	↑

Indicators sensitive to the activities of operators in the water sector

Water Sector	Activity	Indicator	Trend
V&K	Delivery	Changes in the water amount and the flow regime Changes in water quality	↓↑ ↓
	Outlet	Extreme precipitations Changes in the water amount and the flow regime	↑ ↓↑
	Water Purification	Changes in water quality	↓
Hydro-meliorations	Irrigation	Changes in water quality Extreme temperature Changes in the water amount and the flow regime	↓ ↑ ↓↑
	Drainage	Changes in the water amount and the flow regime Extreme precipitations	↓↑ ↑
	Protection from the harmful impact of water	Changes in water quality Extreme precipitations	↓ ↑
Hydro-Power Systems and Equipment	Technical operation and maintenance of dams	Changes in the water amount and the flow regime Extreme temperature	↓↑ ↑
	Technical operation and maintenance of hydraulic systems and structures	Changes in the water amount and the flow regime Changes in sea level Extreme precipitations	↓↑ ↑ ↑

Assessment matrix for water sector sensitivity and vulnerability

Sector/indicator	Climate scenario IPCC AR5	Probability of output in time horizon 2016-2035			Expected impact: positive (+) minor or no (0) and negative (-)			Sensitivity 1- Low 2- Moderate 3- High		
1	2	3	4	5	7	8	9	10	11	12
Water	Scenario	Δ T ° C	Δ P%	Ex↓↑	ΔT °C	Δ P%	Δ Ex	ΔT °C	ΔP%	Δ Ex
Quantity of surface water	RCP2.6	1.5-2.0	0-10	↑↓	-	+	+/-	3	2	3
Quantity of underground water	RCP2.6	1.5-2.0	0-10	↑↓	-	+	+/-	3	2	2
Water quality	RCP2.6	1.5-2.0	0-10	↑↓	-	-	-	2	2	3
Drought	RCP2.6	1.5-2.0	0-10	↑	-	+	-	3	3	3
Flood	RCP2.6	1.5-2.0	0-10	↓↑	-	+	-	3	3	3
Sea level rise	RCP2.6	1.5-2.0	0-10	↑↓	-	+	-	3	3	2
Total scores Sensitivity (Sn)								17	15	14
Total maximum scores (Sn max)								15	9	12
Sensitivity (S)								0,88	0,60	0,85
Adaptive capacity (Ac)								3	3	3
Vulnerability								0,29	0,20	0,28

The assessment matrix shows that the change in precipitations will have negative impact on water quality. The negative impact from changes in water-related extremes relates to water quality, drought and flood risk and sea level change. The water sector is most sensitive to the projected changes in related extremes (drought and floods) and in temperature.

The index of the water sector's sensitivity to climate change in the time horizon 2016 - 2035, is estimated to: 0,88 for change in temperature, 0,6 for changes in precipitations and 0,85 for extreme events (drought and flood) under RCP 2.6 scenario.

Adaptive capacity of the main actors in Bulgarian water sector is assessed as "insufficient" and is scored with 3 points.

Climate Change Vulnerability Index (CCVI) for water sector in Bulgaria is estimated as „ *Moderately vulnerable* ". This result relates to the climate change in time horizon 2016-2035, RCP 2.6 and corresponds to the observed trends in most of the analyzed indicators over the last decade.

CONCLUSIONS

At present, the pressures (natural and human) on the quantity and quality of water resources is manageable by optimizing consumption; reducing water losses,; coverage of all waste water with treatment facilities; quality control; protection of ecosystems and increase of water sector resilience vis-a-vis possible climate change in the time horizon 2016 - 2035.

Implementation of the proposed CCVI provides a general notion about the level of vulnerability to climate change. It is very sensitive to the quality of indicator's data and expert assessment. More detailed assessment for each particular activity is necessary for better management of vulnerability and adaptation in water sector. The regional approach in this process will be essential due to the unequal distribution of water resources of the country, both in regions and seasons, and the expected increase of that inequality in the future. In the long-term perspective, to the end of this century and beyond, we'll need to develop more flexible and risk-responsive management of waters, build on the need for adaptation to climate change.

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