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Original Scientific Paper

CATALOGUE OF DROUGHT RISK MANAGEMENT MEASURES: A VIEW FROM THE WATER SECTOR IN SERBIA

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Abstract. *Drought impacts are rising worldwide, mostly because of an increase in the severity, frequency and duration of drought events. Water scarcity is one of the direct consequences of drought. A proactive approach based on drought risk management is needed to successfully lessen the vulnerability to droughts. The source of measures selected for a particular river basin in its Drought Management Plan is a Catalogue of drought management measures. One such catalogue is proposed in this paper by extensive literature and documentation review, from the perspective of the water sector. Five groups of measures comprise the catalogue of twenty-six individual measures. The grouping of measures is done according to the tradition of organizing the water sector in Serbia: (1) water systems, (2) green solutions, (3) agriculture-oriented measures, (4) aquatic ecosystems, and (5) non-structural measures. The aim of the paper is to contribute to an existing list of drought risk management measures in the light of activities on the first National Drought Plan, and the next Action plan after 2023 for the implementation of the Water Management Strategy for the Territory of the Republic of Serbia until 2034.*

Key words: *drought risk management, water scarcity, drought risk management measures, water sector*

1. INTRODUCTION

Meteorological variables are changeable over space and time, hard to accurately predict for a shorter period like ten days or longer, while their long-term pattern defines climate. Drought primarily occurs as a consequence of natural climatic variability, but also other factors including human activities (deforestation, urbanization), land use change, global climate change, and water resources management interventions. As a natural hazard, drought is challenging to be prevented. It has a slow onset, can last a long time, covers a large area, and causes little structural damage, but affects weather-dependent industries and causes direct

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and/or indirect production losses. It is difficult to determine the beginning and end of the drought, mostly because of drought nature and the multiple consequences of its effects.

Droughts affected approximately 2.2 billion people in the world between 1950 and 2014 [1]. In the same period, drought damage in Europe is estimated to be 621 million euros on average per event. The drought hotspots in the 1990s and 2000s were the Mediterranean basin and the Carpathian region [2]. Recent droughts in Central Europe happened in 2003, 2015, 2018 and 2019. Meteorological drought affected approximately 15% (on average) of the EU territory, i.e., 17% of the population each year from 2006 to 2010 [3].

The territory of Serbia was exposed to several severe drought events in the last 20 years. The most pronounced droughts were in the years 2000, 2003, 2007, 2012, 2015 and 2017, accompanied by large economic losses [4]. There are expectations that future climate changes will increase the frequency and intensity of droughts in Serbia [5]. Drought consequences affect the economy, social relations and the environment. One of its specific characteristics is durability: the impacts may continue for years after it ends. One of the most obvious examples is the fruit growing segment where the impact of drought can be transferred to the next year, posing an additional problem to direct damage in agriculture. Serbia experiences great losses due to drought in the agricultural sector (especially in crop production), water supply sector and river transport [6].

The preventive measures taken before the drought can mitigate or eliminate the adverse drought effects. In order to successfully plan and implement measures for drought mitigation, it is necessary to analyze the previous droughts and their impacts, and also the future droughts. Carrão et al. [7] mapped projections of drought hazard changes obtained by five climate models under three representative concentration pathways (RCP). The results show an increase in the drought hazards between 1971-2000 and future periods. The first Global drought and flood catalogue (GDFC) for 1950 - 2016 was made by merging different types of data with hydrodynamic modelling [8]. The main aim was to provide a continuous and consistent estimate of the water cycle and weather extremes. Also, an integral part of the catalogue is different drought and flood analysis using univariate and multivariate risk assessment frameworks. He et al. [9] discussed existing state drought plans in the United States. Mitigative actions implemented by states are summarized and grouped into: Legislation / Public policy, Water supply augmentation / Development of new supplies, Public awareness / Education programs, Demand reduction / Water conservation programs, Technical assistance on water / Water conservation and other water-related activities, Water use conflict resolution.

Until the publication of the Drought initiative for the Republic of Serbia in the year 2020 [4], there was no single law, strategic or planning document in Serbia, exclusively dedicated to drought or drought management. The subject of drought is still compartmentalized in the legislative, mostly referring to it within the other themes including natural hazards, adaptation to climate change, risk management and emergency issues. In the Water Management Strategy for the Territory of the Republic of Serbia until 2034 [19] (WMS), drought is considered together with water scarcity, under the strategic goal of water-related risk reduction. Six measures are foreseen for the achievement of the only operational objective: 'Water management in drought and water scarcity conditions'. These measures are widely set, reflecting the current situation and the document type. Two of the measures directly deal with the development of measures to prevent and mitigate the effects of drought. However, in the Action plan [29] following the WMS, none of the drought-related measures is explicitly planned for implementation in the period 2021-2023.

This paper aims at proposing a catalogue of drought risk management measures appropriate for implementation in Serbia, from the perspective of the water sector. Following the long-term tradition of organizing specialized fields of public service (e.g., Ministry of Agriculture, Forestry, and Water Management), and bearing in mind a need for an interdisciplinary approach to the topic, the drought risk management measures are systematized here in five groups: (1) water systems, (2) green solutions, (3) agriculture-oriented measures, (4) aquatic ecosystems, and (5) non-structural measures.

2. Drought Risk and Vulnerability

The previous global approach to drought management, based on crisis management, proved unsuccessful [10]. The main aim of the drought measures was to mitigate the consequences, but not to reduce vulnerability, i.e., measures did little to strengthen natural infrastructure and to build integral management of land and water resources [10]. The new tendency in drought management, developed mostly as a result of the experience gained through understanding the drought risk, requires a proactive approach to risk management. Proactive and risk-based drought planning replaced the reactive and crisis management.

Risk, as a drought hazard with potential consequences during water scarcity, can be expressed as a functional relationship between the hazard and impact [11], i.e.,

$$\text{Risk} = \text{Hazard} \times \text{Impact}$$

The impact can be expressed as a product of exposure and vulnerability, and it represents the potential impact of drought on people, the environment, the economy and society.

Risk assessment is used in the decision-making processes of risk significance, i.e., whether any particular risk should be accepted or not. It is a direct comparison of risk analysis results with the risk criteria to conclude if the risk needs to be treated.

Like any other risk, the drought risk assessment should consist of three phases [12]:

1) Risk identification,
2) Risk analysis and
3) Risk evaluation.

Risk identification represents processes such as finding, recognizing and describing risks. It can be defined using the analysis of quantitative and qualitative indicators. Quantitative indicators include historical and statistical data, while qualitative indicators include expert opinions and panel discussions. For successful risk identification, it is important to identify all possible hazards, the possibility of risk occurrence and possible impacts.

Risk analysis is the process of understanding the risk process, assessing the probability of its occurrence and defining the potential impacts. It is crucial to determine the possible area affected by the drought. Risk analysis should be based on historical data, frequency assessment and spatial statistics.

In the risk evaluation or risk assessment phase, the risk criteria play an important role. They may include different types of criteria, like economic (costs and benefits), legal, social (concerns of stakeholders) and environmental.

According to Mishra and Singh [13], it is possible to identify and define the drought risk management measures for preparedness and mitigation, using an understanding of drought risk – knowledge of social, economic and ecologic drought impacts.

Meza et al. [30] point out that the vulnerability to droughts is complex to assess and strongly depends on the sectoral focus, together with the geographical context of the assessment. In their study [30], the drought vulnerability indicators are weighted according to their relevance for agricultural systems and domestic water supply, and grouped into four subcategories: social susceptibility, environmental susceptibility, lack of coping capacity and lack of adaptive capacity. According to the scale used, indicators range from 0 (low relevance) to 1 (high relevance). The results show that the most relevant indicators for drought vulnerability (relevance > 0.9) for water supply in Europe are in the category of lack of adaptive capacity: adaptation policies/plans, disaster prevention and preparedness, and disaster risk policies.

3. Setting the Drought Risk Management Measures Catalogue

Drought mitigation measures should help to avoid losses caused by drought, through reduction of the exposure and vulnerability, and to increase the resilience of society during future droughts. In order to achieve the success of planned measures, it is important that measures are developed and applied in normal conditions, the ones before the drought. Previous experience shows that individual measures against drought applied independently and unsystematically, do not give desired results [10].

A program of measures for drought management is an essential part of the preparation for the drought, and it is an integral element of the Drought Management Plan (DMP), that should be prepared as a part of the River basin management plans [11]. Selecting the drought mitigation measures using an understanding of relationships between climatological and hydrological parameters, i.e., the parameters that best characterize drought is necessary [14]. Therefore, the elements that precede the Program of measures in the DMP comprise: River basin characteristics, Historical drought events, Risk assessment, and Indicators and thresholds. The DMP element based on the Program of measures is Organizational structure. In order to achieve the implementation of the drought measures, establishing management mechanisms is required. When determining the action priorities and execution order, the multi-criteria analysis represents the special assistance in the decision-making process, while in synergy with probabilistic reasoning methods by focusing on Bayesian networks, analytical hierarchy processes, and geographic information systems, priority measures may be selected [27].

The drought risk management measures classification in the context of the EU water framework directive [11,15] is done according to three criteria:

1) organization
    a. strategic – long-term physical and institutional solutions,
    b. tactical – developed in advance for short-term water deficit, and
    c. emergency – response to a specific problem;
2) purpose
    a. preventive – to increase the drought resilience and to reduce the potential drought risk in conditions when there is no drought,
    b. operational – during the drought, before the alert,
    c. organizational – development of DMP and its implementation, and
    d. control – assessment of compliance with drought plan and the effects of its implementation;
3) general

a. structural – infrastructure reconstruction and modernization, and
b. non-structural – laws, regulations, economic instruments, etc.

In the WMS [19], the second criteria for (drought) risk management measures classification is used:

(i) preventive measures, for water retention in the river basin,
(ii) operational measures, for protection and controlled water use during the drought, and
(iii) organizational measures, referring to protocols for coordination of water sector and other water-use related bodies.

A grouping of measures found appropriate for this research resembles the general criteria (3) classification in the above list. Here, 'structural measures' are perceived widely, and grouped from the water sector perspective, according to predominant use in water, forestry, agricultural, and environmental sector: (1) water systems, (2) green solutions, (3) agricultural measures, (4) aquatic ecosystems, and (5) non-structural measures.

4. PROPOSED CATALOGUE OF DROUGHT RISK MANAGEMENT MEASURES

4.1. Water management systems

4.1.1. Multipurpose and small reservoirs

The goal of this measure is to increase water supply options for irrigation. It can be achieved through a) construction of new multipurpose reservoirs, b) increase of storage volume of existing reservoirs, and c) construction of small farm reservoirs (small lakes, ponds), in order to provide water supply during the drought [31].

In order to avoid known user conflict in multipurpose reservoirs, there are several models of water distribution from them, like the model of water distribution according to maximum requirements and final consumer rank or the model of distribution according to management rules [20].

Out of 25 potential reservoirs (volume >10 mil. m^3) included in the WMS [19], 12 are multipurpose with irrigation use included.

4.1.2. Water supply system efficiency improvement

The problems in the water supply systems (water losses, outdated equipment, uneconomic price of water), significantly increase drought effects, especially in the summer months, when there is a large gap between water demand and availability.

The measure that contributes to water supply system efficiency improvement consists of 1) the reduction of losses to the optimum level, 2) the introduction of an economic price for drinking water, and 3) organizational optimization of the water utility [23]. Among the three, the most efficient is the reduction of losses, specifically due to leakage. This measure is more effective than building a new water supply system or upgrading the capacity of existing systems [23], [28].

The measure is included in the WMS [19] under Operational objectives 3 and 4, Water Supply orientation. Moreover, in the actual Action plan [29] the measure 1.2.1. reads 'Acquire and use leak and loss detection devices', and comprises three activities.

4.1.3. Water abstraction control - Rationalization of supply and mandatory water restriction measures

The general restriction of water, which affects all consumers equally, in principle has low economic efficiency. It is always better and more cost-effective to introduce targeted restriction measures based on precise quantification of expected effects [33].

Water abstraction control is a crisis management measure that usually implies water use reduction for households, and issuing emergency permits for water use by a water management company and/or River Basin Authority [31]. The aim of this measure is to prevent conflicts between end users, and to ensure the functioning of a water supply system through better management and water abstraction control. Water management companies define the means for fulfilling their obligations according to DMP.

This measure has long been known and practiced in Serbia. A relevant Ministry may temporarily restrict the right to use of water if due to drought hazards, there is a water shortage or if water quality is endangered [21].

4.1.4. Reduction of drinking water use for industrial cooling

The measure generally refers to cooling in industrial plants, but mostly in thermal power plants, where the use of recycled water reduces the demand for drinking water. This measure thus contributes to the previous one (4.1.3) because a water management company and/or River Basin Authority become less sensitive to changes in water availability caused by drought. Reduction of the use of drinking water for industrial plants can be achieved by using water from alternative sources including treated wastewater, water from mining plants, leachate from agriculture, and atmospheric water [33].

4.1.5. Reuse of treated wastewater

The reuse of treated wastewater can be considered as a reliable way of water supply, independent of seasonal droughts [33]. There is the direct and indirect reuse of treated wastewater. In the direct use, wastewater is pumped directly into the water supply system, without prior return to the natural water features, while the indirect use implies mixing treated wastewater with clean water before use, by discharging it into watercourses or feeding it to groundwater.

This measure not only creates better conditions in the environment in quantitative terms by providing additional water supply, but in qualitative terms, it protects the environment from uncontrolled wastewater discharge, particularly important during the drought. Agriculture is considered to benefit most from the use of treated wastewater for irrigation due to the drought effects reduction on yields [33].

4.1.6. Groundwater recharge

The use of groundwater recharge systems contributes to controlling the excessive exhaustion of groundwater discharges and ensuring their balance [33]. These systems can be used in areas where changes in climatic conditions have led to lowering groundwater levels (most commonly in arid and semiarid areas), which is often the case in prolonged droughts.

A wide variety of techniques used to refill aquifers and thus preserve and secure groundwater reserves is considered here under the Groundwater recharge measure. The measure is also known as the Managed Aquifer Recharge (MAR), a planned renewal of natural reserves of groundwater released in order to restore them and achieve environmental benefits [33]. The choice of technique for groundwater recharge depends on many factors including the range, space/time scale, soil permeability and land availability. Treated wastewater, atmospheric water, and watercourses are sources of water for groundwater recharge. The main threat from any technique is groundwater quality deterioration, therefore special attention in the recharge study is dedicated to the evaluation of aquifer vulnerability to contamination [34].

There are three large groups of techniques for groundwater recharge, often presented as individual measures, depending on the method selected for recharge: 1) pumping water into the aquifer, 2) controlled infiltration from the land surface and/or by special structures, and 3) infiltration from a riverbed.

The Aquifer Storage and Recovery (ASR) technique is based on the direct pumping of water and recovering it through the same well, while Aquifer Storage, Transfer and Recovery (ASTR) techniques involve pumping water into one well and pumping it from another [33]. Both techniques represent the first group of recharge methods, where abandoned wells are often used for water injection.

Soil Aquifer Treatment (SAT) is a technique from the second group, where water is infiltrated into the aquifer through layers of soil under controlled conditions. The structures used for forcing infiltration from this group of techniques include infiltration basins, trenches/ditches, pits and shafts [35].

The infiltration from the riverbed is a natural way of feeding groundwater from the watercourse, when a water table in it is above the one in the groundwater. Modifications of the riverbed bottom and sides to increase water permeability, are considered techniques from the third group, often undertaken when re-naturalizing watercourses.

4.1.7. Construction of barriers in the riverbed

Built across the direction of water flow in shallow rivers, streams, intermittent and torrential watercourses, check dams or sills, barriers in the riverbed reduce the slope and velocity of a watercourse, and thus primarily prevent erosion [33, 35]. Slowing down flow velocity facilitates the infiltration of water from the riverbed and feeding groundwater. Although this measure may fall under the third group of techniques for groundwater recharge (4.1.6), it is shown as a separate one here because of its primary role – erosion prevention.

4.1.8. Inter-basin water transfer

The inter-basin water transfer is considered an extreme drought management measure for providing sufficient water quantities in the river basin from the neighboring or some other river basin. The measure involves large and costly water supply projects, usually at the national or even regional level [33]. Water transfer is not only expensive, but creates new and increases existing threats to the environment and food production in the donor basin during periods of drought.

4.2. Green solutions

The measures that are based on nature provide benefits to natural ecosystems and man-made systems. The measures considered here are based on vegetation. Blue-Green infrastructure is an approach to water management that protects, restores and mimics the natural water cycle [32]. This approach gives the opportunity to soil to absorb and infiltrate precipitation and provides water storage, thus enabling water reuse and groundwater recharge, both significant in drought mitigation.

4.2.1. Blue-Green urban infrastructure

This measure supports conventional rainwater drainage system in urban areas by including in it elements such as green roofs, infiltration trenches, bioswales, detention/retention basins, rain gardens, rain barrels for rainwater collection, and porous pavement [11]. From the drought aspect, these are decentralized systems, which retain precipitation that will later be locally used for drought mitigation. The reuse of water in urban areas usually includes irrigating landscape areas (cemeteries, parks), extinguishing fires, toilet water, and supplying fountains with water [33].

4.2.2. Blue-Green rural infrastructure

The systems envisaged in rural and natural areas are also referred to as Regional scale systems. This measure includes restoring floodplains and wetlands which can hold water in case of floods and enable its flooding [11], but also the construction of large-scale infiltration trenches and detention/retention basins. Small-scale technical interventions, such as tree removal and changes in land use in wetlands are illustrative of rural interventions.

The role of wetlands in water retention is significant, especially in areas where seasonal droughts occur. Wetlands store water and slowly release it, thus increasing the soil water retention capacity. Although this capacity depends on a wetland size, a network of ponds and wetlands is often created for retaining larger water volume.

From the environmental perspective, all these interventions can improve the hydrological regime of degraded wetlands and generally improve habitat quality [33].

4.2.3. Afforestation

Afforestation is primarily the forestry sector measure, but it plays an important role in the agriculture and water sector during drought. A recent study has found a positive relationship between drought conditions and soil loss, more pronounced with high variation in topography (slope length and steepness) across the study area in India [36].

When applied on agricultural land, this measure is recognized under Agroforestry [33]. Climatically resistant tree species planted on agricultural land in the form of protective belts around crops (stand of trees) provide multiple benefits: the tree root increases the water capacity of the soil, protects from erosion, prevents future soil degradation and provides shade during the drought [23]. Planting trees near crops also enables crop protection from solar radiation, wind, frost and flood, and in general, eases dealing with the effects of climate change.

4.3. Agricultural measures

4.3.1. Irrigation

Irrigation is the best and most effective measure for the drought mitigation serving the intensification of agricultural production [16]. This measure is one of the most expensive and requires certain technical conditions, i.e., it can be applied only if the irrigation water quality is good (salinity and alkalinity) and if the land is suitable for irrigation. The effect of irrigation depends on the applied irrigation method, schedule and irrigation norm.

The entirely structural sub-measures include reconstruction and modernization of the existing irrigation systems and building new ones, in order to increase and stabilize the yield, regardless of the time of occurrence, intensity and drought duration [17]. Irrigation is especially important for highly profitable intensive crops with short vegetation period.

Irrigation in Serbia covers an area of 52 441 ha, which is approximately 1.5 % of the total agricultural land in the year 2020 [18]. It is included in the WMS [19] where the development of irrigation systems is envisaged from 100 000 ha for existing systems to between 150 000 and 250 000 ha for new systems

4.3.2. Water-saving irrigation

Economical use of water for agricultural production also means increasing the efficiency of water use by crops. By the ”deficit irrigation” method, plants are irrigated with less amount of water than required for evapotranspiration [22]. This method allows plants to be exposed to moderate stress, but in such a way that the yield is not significantly reduced. There are two methods of proposed deficit irrigation which are most often used [22]: RDI – regulated deficit irrigation, and PRD – partial root drying. The RDI method implies that the root system is irrigated with approximately 50 % of the required amount of water. The PRD method defines which part of the plant root system will be irrigated. Both methods are used in order to provoke adaptive reactions of plants to drought (to reduce the drought effects and to select the genotype of plants).

4.3.3. Dual use of drainage channels

A drainage canal system may supply water for irrigation in the dry season by retaining water in the wet season and then only the water surplus should be drained [23]. By using this measure, retained water will increase in the soil and it can be used during the drought. The measure also enables the reduction of peak flow in the recipient and serves as a flood protection measure.

4.3.4. Soil water retention capacity increase

A range of sub-measures is available for the improvement of water retention capacity on undeveloped agricultural land. These, mainly structural interventions in its nature, include restoring wetlands, maintaining existing and building new drainage canal systems, establishing a variable water regime on rivers and irrigation canals, rehabilitation or adaptation of the morphological structure of the riverbed, optimization of land cultivation procedures in crop production, and setting up hydraulic structures for flood control [33]. The only solely agricultural measure here is an optimization of land cultivation procedures in crop production, while the others are already considered under measures 4.2.2., 4.3.1., 4.1.7. and 4.1.1.

4.3.5. Water sensitive agricultural practices

Compared to other sectors, agriculture is a large consumer of water. Because most of the expected negative impacts of climate change relate to the reduction of water availability, future policies and investments will have to be guided by increased water productivity in agriculture, reducing water losses, especially in irrigation infrastructure, and redesigning production systems and processes in agriculture to base them on the use of smaller amounts of water and water from alternative sources [33]. There are already initiatives in place for Water Sensitive Farming [46, 47] under the nature-based solutions umbrella, where the drought issue is one of many to deal with. A variety of measures listed here under previous groups, primarily in water systems, also serve as water sensitive agricultural practice measures.

4.4. Aquatic ecosystems

The protection of biological and social systems supported by rivers is the focus of hydrologic drought mitigation. Besides hydrologic drought, a concept of water management drought is introduced [49], where the former is a result of natural factors (rainfall, snowmelt, temperature, geological characteristics), and the latter is generated by artificial factors including operation of water control structures, water intakes and water discharges. The main measure for maintaining both hydrological and biological conditions i.e. water quantity and quality during drought, is a provision of environmental flow.

4.4.1. Environmental flow provision

There is a variety of methods for environmental flow assessment based on different criteria used to protect aquatic life from chronic and acute harmful effects of the pollutants [48]. Provision of the design flow in a river should be a part of the operational plans of the water management structures and systems, including water control structures (reservoirs and dams), water intakes (for population and industries), and water discharges (from industries, utilities and wastewater treatment plants).

4.5. Non-structural measures

4.5.1. Legislative framework

Legislation is an instrument that allows the government to implement the plans for drought mitigation. Legislative frameworks provide for applying the drought mitigation measures and establishing the links between different actors.

Drought is recognized as a phenomenon primarily related to water scarcity. Therefore, the legal basis for drought mitigation here is derived from the Law on Waters in Serbia [21]. In addition to the Law on Waters, Law on meteorological and hydrological activity [25] and Law on disaster risk reduction and management in emergency situations [26] stand out as legislative framework for drought risk management in Serbia in the water sector.

4.5.2. Water abstraction and saving planning

Water abstraction and saving plans are long-term plans that define how the authorities responsible for issuing permits for the abstraction and use of water resources will manage water at the river basin level [33]. The aim of these plans is to provide a framework for a future strategy for approving the use of water resources, which would ensure sustainable management of water resources at the river basin level. The measure 4.1.3 should rely upon this one.

4.5.3. Monitoring, forecasting, and early warning system

Forecasting the drought coverage is essential for drought mitigation. Forecasting cannot replace the drought early warning system (it is an integral part of the system), but it should be used to improve the drought monitoring system. According to Djurdjević [4], any improvement in drought monitoring and forecasting can be considered a drought mitigation measure. Monitoring and early warning systems should provide timely and reliable drought-related information for decision makers. Otherwise, proactive measures for drought risk management become reactive.

Within the Drought Management Centre for South East Europe Project, the Republic Hydrometeorological Service of Serbia (RHMSS) regularly publishes drought monitoring information. Operational procedures within the monitoring of wetness conditions carried out by the Department of Agrometeorology of the RHMSS include the estimation of Standardized Precipitation Index - SPI values based on the amount of precipitation gauged in the previous 30, 60 and 90 days. In addition to these calculations, the obtained results can be found and are regularly updated on the web page in the form of a map (Fig. 1) and in the form of tabular overview per meteorological station. Instead of numerous SPI values, as more suitable for use, qualitative assessments of wetness conditions are given according to criteria established for operational needs. The base for creating, issuing and delivering emergency meteorological and hydrological information and warnings in the period before, during and immediately after the end of meteorological and hydrological natural disasters is the Rulebook [51] in power since 2013.

4.5.4. Establishing the database of past (historical) droughts

Under the database of natural hazards, the records on past droughts should exist. Because the knowledge of past drought events is needed for successful forecasting and early warning of drought, the database of past droughts is sometimes considered a part of the Monitoring, forecasting and early warning system.

4.5.5. Agricultural insurance from drought damage

The goal of climate risk insurance is to financially compensate for the damage caused by extreme weather conditions. Ensuring crop production should enable crop protection from drought effects. These effects are manifested through yield fluctuation, final quality and price. The agricultural insurance provides financial security to the farmers by minimizing losses caused by drought.

One insurance company in Serbia explicitly provides agricultural insurance from drought damage [37], while many others advertise agricultural insurance [38, 39, 40, 41, 42, 43, 44], but from a detailed examination of their insurance packages, it is inconclusive if drought damage is included in special packages. According to the latest census of agriculture in Serbia, there are about 630,000 agricultural farms, of which only 3 % use insurance services at all [45].

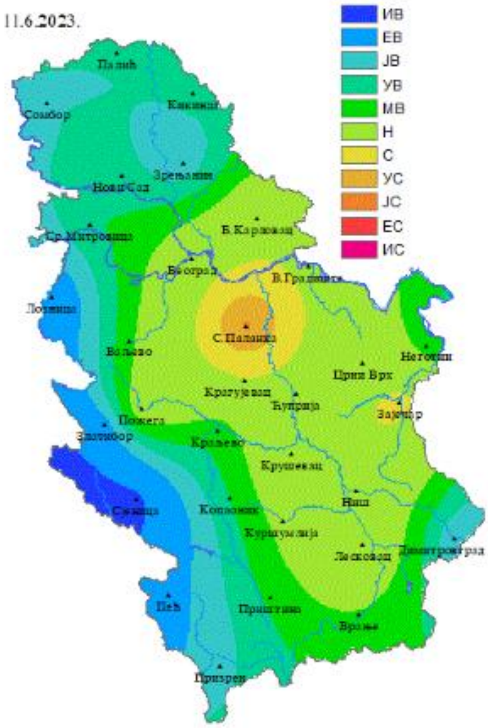

Fig. 1 Wetness conditions – drought monitoring based on the Standardized Precipitation Index (SPI) issued on 11 June 2023 by RHMSS [52]. SPI key shows 11 drought severity classes for wet (blue to green color variety), normal (green) and dry (yellow to red color variety) conditions.

4.5.6. Educational / awareness campaigns

There are two target audiences for education or awareness campaign: 1) public, and 2) local communities and farmers.

Public education for timely response to the drought event can be an effective measure for drought mitigation. The goal of education is to raise awareness of drought risk management by providing information on the Drought management plan and the program of measures. None of the public should be left out from education, especially not the vulnerable categories such as children. Education should be adapted to the participants through lectures, workshops and modern communication systems.

Local institutions can support local communities and farmers in two ways: 1) by generating and exchanging knowledge, and 2) by providing financial services and credit for awareness campaigns, educational or training purposes. There are several ways to achieve a successful knowledge exchange including field workshops, dissemination of information through local media, and organization of events where new knowledge will be presented (e.g. agricultural fairs).

4.5.7. Harmonize land use planning with water scarcity

The effects of drought can be prevented or reduced by such land use planning that will ensure well-adjusted water balance components at the regional level, influence the process of evapotranspiration and infiltration, enable better soil moisture, and control the flow rate in watercourses and floodplains [33].

As a regulatory instrument in land management and infrastructure planning in a given area, the key role is played by: 1) zoning the area within the scope of the planning document (e.g. designating protection zones); 2) prescribing specific conditions for the construction of facilities and infrastructure with increased drought risk; 3) procedures for proving resistance to drought influences when approving construction.

4.5.8. Land and water resources management programs

Development of policies, strategies, action plans and management programs focused on drought that encourage or discourage changes in land and water use, as well as management practices in agriculture improve adaptation to changing climate impacts in general.

The sub-measures involve the inclusion of different aspects of drought impact on agriculture in regulations related to sustainable land use, as well as in regulations concerning water conditions, water consents and water permits. The implementation of these programs requires an assessment of existing institutional and economic potentials at all levels of government and is often based on changes in existing legislation [33]. Resource management programs are sub-measures adopted and implemented by governments at various levels, but these programs have a direct impact on decision-making on adjustment at the micro level, i.e., at the level of agricultural farms.

4.5.9. Networking with scientific, research, and technical institutions

A proper approach to the selection of the conceptual needs to ensure the country's ability to respond to natural hazards (floods, droughts, etc.) and achieve objectives set in planning documents including necessary capital projects, can be achieved through increased capacity of technical, research, and scientific institutions and their more extensive networking with the administration and other relevant institutions.

The existence of a high-quality hub in scientific, research, planning, engineering and other fields in Serbia is recognized as an advantage for future water sector development [50]. However, there is insufficient involvement of scientific and research institutions in areas of special relevance to water management. Although numerous universities provide a satisfactory level of knowledge, their curricula and teaching methods should be updated, including those related to post-graduate studies [50]. Since 2018, Master Academic Study Program 'Natural disasters risk management and Engineering' exists at the University of Niš, Faculty of Civil Engineering and Architecture [53]. This is an example of updating post-graduate studies to accommodate the needs of water resources management in regard to research and engineering capacity.

5. Discussion and Conclusion

The Water Management Strategy for the Territory of the Republic of Serbia until 2034 [19], under the Operational objective 'Water management in the conditions of drought and water scarcity', recognizes the need for the development of the Drought management plans for the river basins. Drought mitigation, preparedness and response comprise the appropriate measures and actions aimed at reducing the vulnerability to drought and reducing the impacts of droughts [54]. The program of measures in the DMP for an actual river basin is selected from the wider set of measures, usually listed in the catalogue of measures. Through an extensive literature and documentation review, an attempt is made in this paper to identify appropriate measures that can be incorporated in the water sector planning (and action) documents, not only in Serbia, to combat the drought.

Twenty six measures, explained and classified in five groups, comprise the proposed catalogue of measures in Section 4 of the paper. An explanation is provided if the measure is already implemented or envisaged in Serbia. The Drought initiative for Serbia [4], lists 12 drought mitigation and preparedness measures. Therefore, this paper provides one step forward towards the future catalogue of measures that should be continuously developed to accommodate up-to-date scientific, research, and technical findings.

In the future catalogue update, attention should be paid to the measure definition. In the actual Action plan for the 2021-2023 period [29], more often than not, techniques are listed as measures. The hierarchy of objectives, sub-objectives, measures and activities in [29] should be observed, to come up with catalogue of drought risk management measures usable for the water sector.

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References

1. M. Zink, L. Samaniego, R. Kumar, S. Thober, J. Mai, D. Schäfer, A. Marx. 2016. The German drought monitor, Environmental research letters, 11, (1-9).
2. J. Spinoni, G. Naumann, J. Vogt, P. Barbosa. 2016. Meteorological droughts in Europe: events and impacts – past trends and future projections, Publications Office of the European Union, Luxembourg.
3. D. Guha-Sapir, P. Hoyois, R. Below. 2016. Annual disaster statistical review 2015 – the number and trends, Centre for research on the epidemiology of disasters, Institute of health and society, Université catholique de Louvain, Brussel, Belgium.
4. V. Djurdjevic. 2020. Drought initiative – Republic of Serbia: recommendations for development of the national drought plan of the Republic of Serbia, Ministry of environmental protection, Belgrade, Serbia.
5. V. Djurdjevic, A. Vukovic, M Vujadinovic Mandic. 2018. Climate changes observed in Serbia and future climate projections based on different scenarios of futures emissions, United Nations development programme.
6. G. Petrovic, M. Grujovic. 2015. The economic damage from natural disasters in Serbia and Sumadija district, Ekonomski signali, 10, 2, (99-107).
7. H. Carrão, G. Naumann, P. Barbosa. 2018. Global projections of drought hazard in a warming climate: a prime for disaster risk management, Climate Dynamics, 50, (2137-2155), 2018.
8. X. He, M. Pan, Z. Wei, E. Wood, J. Sheffield. 2020. A global drought and flood catalogue from 1950 to 2016, Bams article, (508-535).
9. D. A. Wilhite.1997. State actions to mitigate drought: lessons learned, Journal of the American Water Resources Association, 33, 5, (961-967), 1997.

10. D. A. Wilhite, M. J. Hayes, C. Knutson, K. H. Smith. 2001. Planning for drought: moving from crisis to risk management, Journal of the American Water Resources Association, 36, 4, (697-710).
11. Guidelines for preparation of the drought management plans, development and implementation of risk-based drought management plans in the context of the EU water framework directive – as a part of the river basin management plans. 2015. Global Water Partnership Central and Eastern Europe.
12. Risk assessment and mapping guidelines for disaster management. 2010. European Commission, Brussels.
13. A. K. Mishra, V. P. Singh. 2011. Drought modelling – a review, Journal of Hydrology, 403, (157-175).
14. A. K. Mishra, V. P. Singh. 2010. A review of drought concepts, Journal of Hydrology, 391, (202-216).
15. Water scarcity management in the context of WFD. 2006. Water scarcity drafting group, Brussel, Belgium.
16. Dj. Bosnjak. 2001. The problems of drought in the Vojvodina province and drought control measures, Zbornik radova, 35, (391-401).
17. S. Dragovic. 2001. Irrigation requirements and effects on yield increase and stabilization in agricultural regions in Serbia, Zbornik radova, 35, (445-456).
18. Statistical yearbook. 2021. Statistical Office of the Republic of Serbia, Belgrade, Serbia.
19. Water management strategy on the territory of the Republic of Serbia until 2034. 2017. Official gazette RS 3/17.
20. Dj. Markovic, M. Stanic, J. Plavsic, G. Sekulic. 2008. Optimization of water allocation from a multipurpose reservoir, Vodoprivreda, 40, (201-213).
21. Law on waters. 2018. Official gazette RS 95/18.
22. E. Fereres, M. A. Soriano. 2007. Deficit irrigation for reducing agricultural water use, Journal of Experimental Botany, 2, 58, (147-159).
23. Serbia's first national adaptation plan. 2015. Ministry of Agriculture and Environmental Protection, Belgrade, Serbia.
24. Climate change impacts on Serbian agriculture. 2019. United Nations development programme, Belgrade, Serbia.
25. Law on meteorological and hydrological activity. 2010. Official gazette RS 88/10.
26. Law on disaster risk reduction and management in emergency situations. 2018. Official gazette RS 87/18.
27. P. Vranić, S. Glišović, L. Velimirović. 2021. Decision Support for Integrated Management of Local-Level Adaptation to Climate Changes: The Case of Serbia, Int J Disaster Risk Sci (2021) 12:479–494.
28. Radivojević D., Blagojević B., A. Ilić. 2020. Water Supply System Performance Improvement in the Town of Pirot Using Water Balance IWA Methodology and Numerical Simulations, Technical Gazette, Vol. 27/No. 3 June 2020.
29. Action plan for implementation of the water management strategy on the territory of the Republic of Serbia for the period from 2021 to 2023. 2018. Official gazette RS 30/18.
30. Meza, I., Hagenlocher, M., Naumann, G., Vogt, J. and Frischen, J. 2019. Drought vulnerability indicators for global-scale drought risk assessments, EUR 29824 EN, Publications Office of the European Union, Luxembourg.
31. https://projects.iamz.ciheam.org/medroplan/guidelines/operational_defining_actions.html
32. S., Gordon-Walker, T., Harle, and I., Naismith: "Using science to create a better place: Cost-benefit of SUDS retrofit in urban areas", SC060024, Environment Agency, Bristol, 2007.
33. Milutinović S. Handbook for planning of adaptation to changed climate conditions in local communities in Serbia. Standing conference of the cities and municipalities. Belgrade.2018. http://www.skgo.org/storage/app/uploads/public/157/071/948/1570719485_Planiranje%20prilagodjavanja%20na%20izmenjene%20klimatske%20uslove-web.pdf
34. Scanlon, B.R., Healy, R.W. & Cook, P.G. Choosing appropriate techniques for quantifying groundwater recharge. Hydrogeology Journal 10, 18–39 (2002). https://doi.org/10.1007/s10040-001-0176-2
35. https://www.geographynotes.com/geology-2/rainwater-harvesting/top-9-methods-of-groundwater-recharge-geology/1573
36. Md Masroor, Haroon Sajjad, Sufia Rehman, Roshani Singh, Md Hibjur Rahaman, Mehebub Sahana, Raihan Ahmed, Ram Avtar, Analysing the relationship between drought and soil erosion using vegetation health index and RUSLE models in Godavari middle sub-basin, India, Geoscience Frontiers, Volume 13, Issue 2, 2022, 101312, ISSN 1674-9871, https://doi.org/10.1016/j.gsf.2021.101312 .
37. https://www.generali.rs/fizicka_lica/poljoprivreda_i_zivotinje/osiguranje_biljaka/osiguranje_useva_i_plodova.965.html
38. https://www.dunav.com/osiguranje/poljoprivreda/osiguranje-useva-i-plodova/
39. https://www.ddor.rs/stanovnistvo-proizvodi/osiguranje-useva-i-plodova/
40. https://wiener.co.rs/za-stanovnistvo/osiguranje-imovine/osiguranje-useva-i-plodova/
41. https://www.triglav.rs/osiguranja/fizicka-lica/poljoprivreda/vise-o-poljoprivrednom-osiguranju/usevi-i-plodovi

42. https://www.sava-osiguranje.rs/sr-rs/osiguranja/poljoprivreda/osiguranje-poljoprivrede/
43. https://centarzaosiguranje.com/upoznajte-osiguranje/koja-osiguranja-postoje/osiguranje-poljoprivrede/osiguranje-useva-i-plodova/
44. https://www.osiguranik.com/osiguranje/osiguranje-useva-i-plodova/online-osiguranje-useva-i-plodova/
45. https://www.psss.rs/index.php/forum/9/39121-ponuda-osiguranja-useva,-plodova-i-%C5%BEivotinja-u-srbiji.html
46. https://catchmentbasedapproach.org/learn/the-water-sensitive-farming-initiative-a-case-study/
47. https://norfolkriverstrust.org/our-work/water-sensitive-farming/
48. Blagojević, B., Mihailović, V., Blagojević, J., Radivojević, D. 2021. The hydrological and environmental aspect of low flow assessment in ungauged basins - A case study in the Južna Morava river basin. FACTA UNIVERSITATIS Series: Architecture and Civil Engineering Vol. 19, No 3, 2021, pp. 261-278 https://doi.org/10.2298/FUACE211219020B
49. EPA. 1986. Technical Guidance Manual for Performing Wasteload Allocation. Book IV: Design Conditions, Chapter 1.
50. https://rdvode.gov.rs/doc/dokumenta/javne-rasprave/strategija/Strategija%20SUMMARY.pdf
51. Rulebook on the methodology for making, issuing and delivering extraordinary meteorological and hydrological information and warnings (Official Gazette RS 96/13)
52. https://www.hidmet.gov.rs/ciril/meteorologija/uslovi_vlaznosti.php
53. http://www.gaf.ni.ac.rs/akreditacija2020/studijski/2021/index.php?dir=MAS%20Inzenjerski%20menadzment%20rizika%20od%20prirodnih%20katastrofa/
54. https://www.droughtmanagement.info/pillars/mitigation-preparedness-response/

KATALOG MERA ZA UPRAVLJANJE SUŠOM IZ PERSPEKTIVE SEKTORA VODA U SRBIJI

Uticaji suše se povećavaju širom sveta, uglavnom zbog povećanja jačine, učestalosti i trajanja sušnih događaja. Nedostatak vode je jedna od direktnih posledica suše. Proaktivan pristup zasnovan na upravljanju rizikom od suše neophodan je da bi se uspešno smanjila ranjivost na suše. Izvor mera odabranih za određeni rečni sliv u Planu upravljanja sušom je Katalog mera za upravljanje sušom. Takav katalog predložen je u ovom radu kroz obimni pregled literature i dokumentacije, a iz perspektive sektora voda. Pet grupa mera čine katalog od dvadeset šest pojedinačnih mera. Grupisanje mera je urađeno prema tradiciji organizovanja vodnog sektora u Srbiji: (1) vodni sistemi, (2) zelena rešenja, (3) mere usmerene na poljoprivredu, (4) vodni ekosistemi i (5) nestrukturne mere. Cilj rada je da doprinese postojećoj listi mera upravljanja rizikom od suša u svetlu aktivnosti na prvom Nacionalnom planu za borbu protiv suše, kao i narednom Akcionom planu nakon 2023. godine za sprovođenje Strategije upravljanja vodama na teritoriji Republike Srbije do 2034.

Ključne reči: *upravljanje rizikom od suša, nedostatak vode, mere za upravljanje rizikom od suša, sektor voda*