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Article

The frequency occurrence of the drought in Montenegro from the 1981-2017, vulnerability and impacts

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Abstract: The purpose of the article is to analyze the drought frequency in Montenegro in the period from 1981-2017 due to the climate change. The analysis is based on statistical methods, climate projections, available remote sensing data and drought impact analysis. Analysis show that drought has become more frequent since the beginning of the 21st century, and in particular, 2000, 2003, 2007, 2008, 2011, 2012, 2017 and 2018. Such situation is in line with national projections and IPCC projections for the region of Southeast Europe. According to the investigated historical effects of droughts on economy, environment and society in Montenegro, it has been confirmed that in recent decades its consequences have been increasing more than in the 20th century, followed by higher temperature than in the last century. Considering that the risk is high, the sectors of agriculture, forestry and water supply should be in the center of attention.

Keywords: climate change 1; drought more frequent 2; risk 3, attention 4.

1. Introduction

Institute of Hydrometeorology and Seismology, hereafter IHMS till 2010 did not have permanent drought monitoring. There were documentations about analyses of droughts mainly from meteorological point of view, published in public journals or scientific papers.

Before the project "Drought Management Centre in South East Europe" (DMCSEE), sparse information about the droughts could be found in IHMS's archive, such as: drought reports for specific towns, meteorological outputs that define onset and duration of the drought made for the purpose of Conferences, Media and customer's requests, outputs from the project "Extreme Atmospheric Conditions in Montenegro - AEN" based on the aridity index of De Morton.

Detailed vulnerability assessment did not exist before the project DMCSEE. An initiative in 2003 to calculate SPI index was unsuccessful as it was evident the lack of the staff and a great demand of disposable experts to be trained.

Those very important actions were implemented in IHMS through the project DMCSEE since 2010 and ongoing project DriDanube[1] since 2017. The innovative approaches, tools, uniform data collection, risk assessment, online GIS and dissemination to end beneficiaries brought drought monitoring and reporting to a new level than before.

2. Materials and Methods

Based on electronic archive of newspapers, web sites of state institutions, local governments, enterprises as well as statistical yearbooks, data on the drought effects since 2000 were classified per years and selected in three categories: economic, environmental and social, with emphasis on those which according to available material most frequently affected society. Some of the consequences could be classified in more than one category (e.g. forest fires can be classified in each of these categories). Special attention was dedicated to the drought in 2000, 2003, 2007 and 2011 when its significant impact occurred.

Following set of indicators that are mostly in use to monitor and characterize drought magnitude in IHMS are presented in the table 1:

Table 1. Set of indicators that are mostly use to characterize drought magnitude are as follows:

Elements	Indicators
Temperature	Anomalies in ^{0}C /percentiles, HWD[2], number of days with temperature over 90th percentile
Water	Percentiles,SPI, CDD,water level, outlooks for accumulated water balance relative to percentile classes
Soil	Near real time soil water state in areas of agriculture, forest, viticulture, fruits and olives, SWDI, SWI[3]
Remote sensing data	FVC, LAI, NDVI,
Socioeconomic	Air quality assessment, losses in agriculture, losses in electro-distribution, yield prediction

From the aspect of data availability it should be noted that the density of the stations in Montenegro was 6.88/1000 km2 up to 2010. The network was consisted of 94 active stations. From them 9 are main, 18 were climatological while 67 were rainfall stations. From the 2011 rapid decrease of precipitation stations is evident mainly due to financial problems. About 20 precipitation stations

[1] DriDanube – Drought risk in the Danube region

[2] HWD - Heat Wave Duration

[3] SWI – Soil Water Index

are currently in use. It is important to stress that in nowadays IHMS faces the problems of rapid reduce of precipitation stations with decrease in density less than 6 /1000 km2 what will reduce the quality of analysis timely and spatially as well. The table 2 represent the meteorological stations till 2011 categorized by their quality.

Table 2. The number of all active stations till 2011 sorted by altitude and assessed by categories from bad to very good

Altitude categories	Number of all active meteorological stations	Representativity of the category (very good, good, acceptable, bad)
0-200	22	Very good
200-500	4	Acceptable
500-1000	45	Good
1000-1500	24	Acceptable

Network of hydrological stations has 51 stations that measures water level. Certain number of them are automatic for the main rivers in the Adriatic and Black Sea catchment. Data are available on-line over the web site of IHMS (www.meteo.co.me).

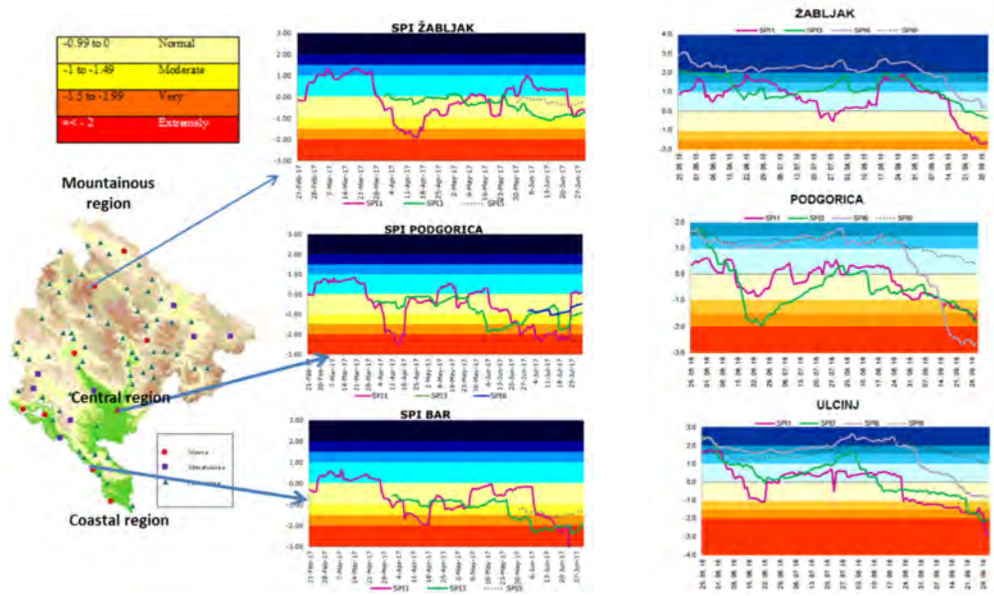
(a) **(b)**

Figure 1. Network of automatic hydrological stations on Adriatic (a) and Black Sea (b)

3. Results

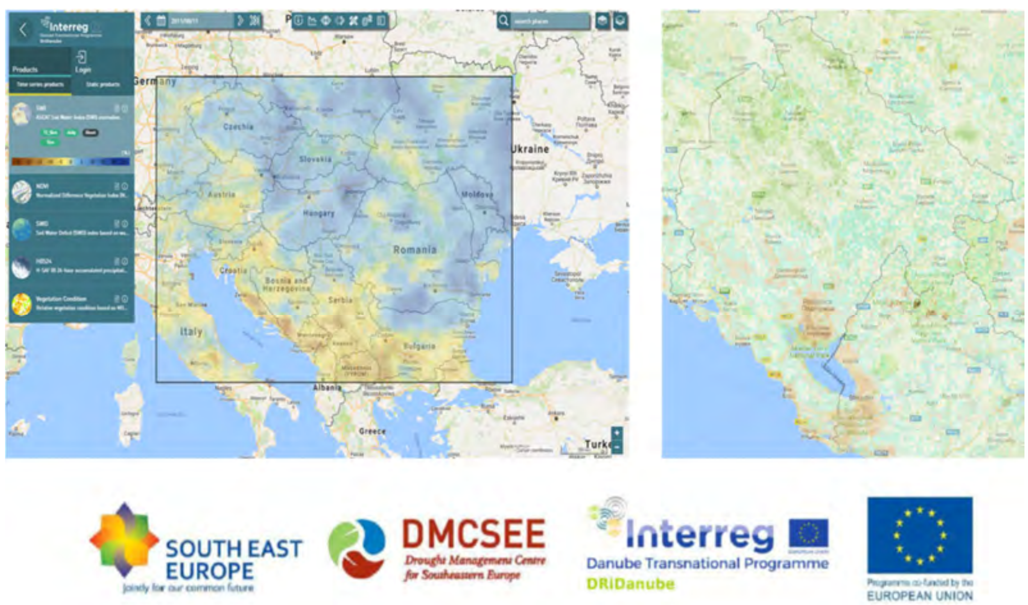
The monitoring of the drought is presented in several figures below, and ongoing project INTERREG DriDanube (Drought risk in the Danube Region). Two projects of EU were crucial that IHMS increased capacity and became able to monitor the drought permanently. That was IPA DMCESEE (Drought Management Centre for South East hosted by ARSO in Ljubljana, Slovenia

Figure 2 presents the drought intensity in 2017 and 2018, while the figure 3 present the state of the soil water index and NDVI on the 11th August 2018. Both are in brownish color emphasizing soil water deficit and dry vegetation.



(a) (b) (c)

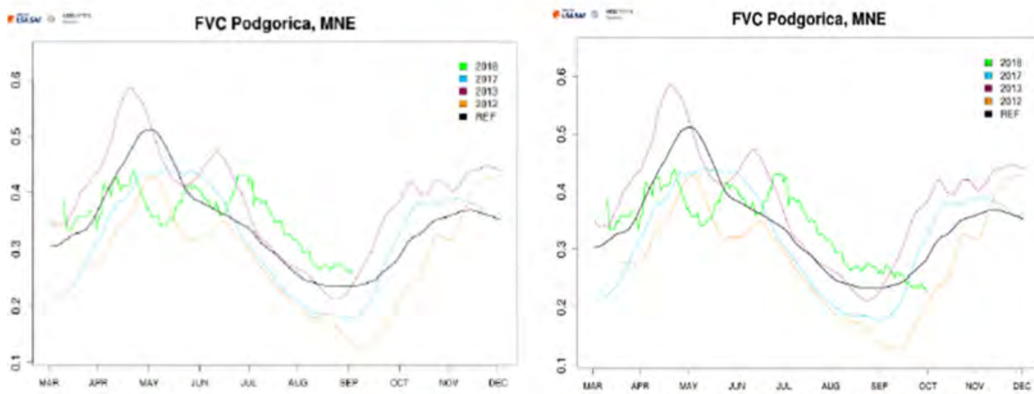
Figure 2. Network of meteorological stations till 2010 and the examples of moderate (a) agricultural and hydrological drought in 2017 monitoring by SPI3 and SPI 6 index and moderate to extreme **(b)** hydrological drought in 2018 in Ulcinj and Podgorica respectively (Source: IHMS)



(a) (b)

Figure 3. The state of the soil water index (a) and NDVI (b) on the 11th August 2018

Comparison of satellite indices for the 2012, 2013, 2017 and 2018 relative to the referent period 2007-2013 is presented on the figure 4. The development of FVC index in 2018 during the Autumn is presented till September on the picture (a) and October (b).



(a) (b)

Figure 4. Comparison of satellite indices for the 2012, 2013, 2017 and 2018 relative to the referent period 2007-2013. Development of FVC till September 2018 (a) and October 2018 (b) is marked in green

It could be concluded that in the 2012 the drought was lasted almost whole year with all 4 phases well developed: meteorological, agicultural, hydrological and socioeconomic. The values of FVC index were low in April indicated that vegetation was very dry, while in July and August was unusually high what means that in those months was enough moisture in the soil. The situation is changing in September and October when the values of the FVC index started to sharply decrease. That coincides with the development of hydrological drought based on SPI indexes and hydrological monitoring.

Identification and categorization of the drought impacts in Montenegro show that the drought affected mostly economy with direct (e.g crop yield reduction) or indirect consequences in agriculture (e.g. increase price for crops on the market), livestock, forestry and water supply.

Focusing on water resources shortage and their impacts, the most vulnerable sectors in economy are:

- agriculture, food and milk production
- water supply
- electricity production
- environment.

The most vulnerable groups of the society are small farmers (wheat, ray, barley, oats and maize producers), producers of fruits and vegetables (olives, figs, citrus, raspberries and grapes, potatoes, cabbage and pepper), ranchers and milk producers.

Regarding the public health, the most vulnerable groups are those with respiratory problems, heart disease as well as children who suffer the most effects of forest fires smoke.There is insufficient data and information on drought and damages caused by drought in previous years. Drought in Montenegro were not permanently analyzed and monitored in the past. There is no archive on the damages dedicated particularly to the drought.

Drought impact archive was created during the project DMCSEE and updated in 2018 within the project DriDanube. Collected data on economic impact of the drought on annual basis show that during the dry years maximum losses in electricity production are in range from 3 – 3.5 million Euros. Total hydropower potential of Montenegro is about 9900GWh annually. In the period 1999-2008. deficit was 14121GWh or 620million EUR.

Collected data on water supply show that in Podgorica, capital town of Montenegro, water supply uses about 2.000lit/s, with a daily injection into water supply system of about 130.000m3 . The daily loss of profit during the drought ranges from 15.000EUR to 85.000EUR.

Impact of the drought in December 2011 reflected in unprecedented lowest water level in Montenegro. In agricultural sector during the, crop production was suffered the greatest damage (the damages are estimated from 30 to 60 percent of expected yield). Throughout the crop production great impact was on livestock.

Milk production was second ranked as extremely affected by the drought. An urgent measures such as subsidies for the import of cattle's food necessary for production of milk, was sought by the Agriculture Union of Montenegro. They addressed to the Government with the strong need for support of the milk production.

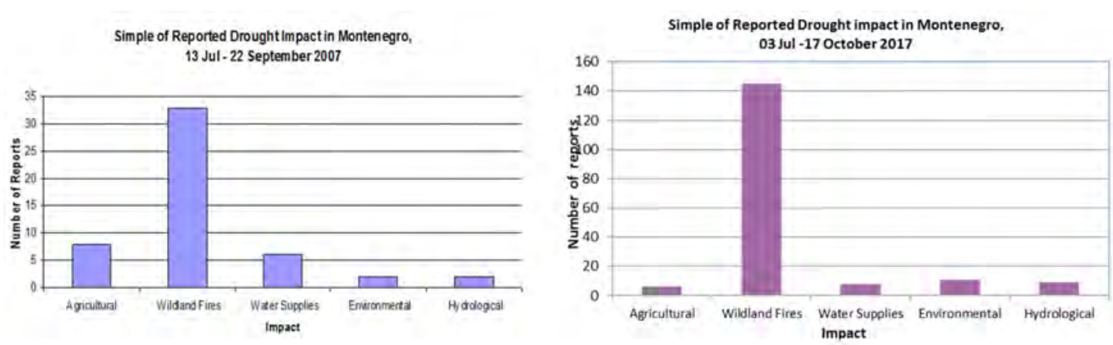


Figure 5. Comparison between the number of reports on the effects of drought in July to September and July to October 2017 (source: Montenegrin newspaper archive)

North parts of Montenegro were exposed to below normal height of snow cover in 2017 in January and February, and to seasonal deficit in precipitation from April to June. Although January was extremely high, from February to June was warm, very warm and even extremely warm. The consequences of such climate situation were: minimum water level 2 months earlier than usual (i.e. in August instead in October), accumulations close to minimum, suitable conditions for forest fires, one month earlier grape harvest (i.e. in September instead in October), less honey and tomatoes, but excellent conditions for the olives. The government promised to support the construction of the irrigation system as on of the adaptation measures (http://www.privredniportal.me/portal/poljoprivrednici-pretrpjeli-ogromnu-stetu-zbog-suse-rod-gotovo-prepolovljen/).

4. Discussion

The increase trend of temperature, more frequent extreme events such as heatwaves, droughts and heavy rainfall, affect Montenegro too. Decade 2001-2010 is the hottest decade since the beginning of the measurement what coincide with the warmest decade in the world (WMO, 2013).

The highest changes in the temperature anomalies was detected on the north (e.g. in Zabljak + 1.4 0C in that period).

Followed by higher temperature, drought has become more frequent since the beginning of the 21st century, and in particular, 2000, 2003, 2007, 2008, 2011, 2012, 2017 and 2018. Such a situation is in line with national projections and IPCC projections as well for the region of Southeast Europe.

According to national climate projections, the biggest changes can be expected in the northern regions in winter, spring and summer, by + 0.9C, + 1.1C and + 1.3C respectively in the period from 2001-2030 for the A1B scenario. Then, decrease in precipitation for 10% in the winter and spring in all parts of Montenegro, the increase in intensity of extreme events such as heavy precipitation, droughts, heat waves and less days with frosts.

The establishment of an archive with identified and categorized consequences of the drought was the basis for further research. Therefore, in 2018 within the project DriDanube, the networks of reporter were established for weekly reporting from the field about the condition of soil moisture agricultural crops and forest vegetation. Reporters' network consists of agricultural producers, employees of NP Durmitor, Biogradska Gora and Lovćen, meteorological technicians, as well as agricultural engineers (the focus of interest is on agriculture and forestry).

Starting with information on the current condition of soil and plant moisture, weekly reports are basis for several types of maps for the territory of Montenegro: a map of the current state of soil moisture (per week), the state of the soil moisture status (after weeks) and the impact maps (current and backward after the weeks) based on the methodology implemented within the INTERREG DriDanube project.

According to specific needs, the same maps can be made especially for forest, crop and fruit crops. The significance of the existence of the reporter network in the field, its reporting and the mapping of soil moisture and the effects of drought, is reflected in the improvement of the existing monitoring and early warning of drought and its consequences in Montenegro.

5. Conclusions

Based on aforementioned results and considering observations and projections of climate change in on national, regional and global level, there is an urgent need for skills in drought management both on individual and institutional levels, establishment of drought authority and organized drought management, implementation of irrigation scheduling system (e.g. WINISAREG which was applied in IPA DMCSEE resulted in Montenegro as an efficient and very precise tool in agricultural water management).

Regarding the irrigation, higher portions of water required each year, comparing to the past. The intensity of this problem is evident not only in southern part of Montenegro but also in the hilly and mountainous region under cold continental climate where irrigation traditionally was not used in the past.

In Montenegro does not exist a national policy or strategy related to the drought. There are only a few strategic documents such as: Montenegro Spatial Plan until 2020. (http://www.gov.me/files/117498935.pdf), and Montenegro Water Law, 2007).

Montenegro Water Law from 2007 is an important document in combat the drought and its mitigation (http://www.gov.me/files/1246958897.pdf). This Law regulates the water management.

Montenegro ratified in 2007 the EU Convention to Combat Desertification (UNCCD) (http://www.ncsa-montenegro.com/index.php?jezik=0&opcija=0&id=5). By approaching to UNCCD and adopting obligations, it is expected to produce own national strategies directly involved in combating the droughts. Ratifying and approaching the Convention Montenegro has the obligation of Development and implementation of programs for sustainable irrigation, like necessary condition for agricultural development in rural and arid areas. Program has to be a part of existing and future agro-ecological programmes on local and national level. Realization of this plan is expected to have numerous positive effects on agricultural production, in combating the drought and drought mitigation.

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