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INFLUENCE OF CLIMATE VARIABILITY ON WATER SOURCES OF EASTERN SLOVAKIA

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Assessing the impact of climate variability on water resources influence their sustainable development. During the last years, we have experienced some extreme hydrological but also climatic situations. Often we expose to flash floods or extreme hot dry periods that have been a rare phenomenon in the past. Extreme climatic events have strong influence to water resources. We contributed to the water resource assessment in eastern Slovakia. We compared the abstractions and discharges of water in the Hornád watershed in period 1999–2015; climatic and hydrological variables – precipitation, water temperature, water flow and water level in the station Stratená/Švedlár in period 1954–2015. In the Hornád catchment area at the Hnilec River at river station Stratená, we observed that the average annual water temperatures had risen. Air temperature could have an effect on it. We have observed the use of water in the Hornád basin, where water abstraction has been declining over the observed period, but water discharges have increased.

KEY WORDS: water resources, climatic variables, hydrological variables

VPLYV VARIABILITY KLÍMY NA VODNÉ ZDROJE VÝCHODNÉHO SLOVENSKA. Posudzovanie vplyvu variability klímy na vodné zdroje ma vplyv na praktizovanie udržateľného rozvoja. V období posledných rokov sme zažili niekoľko extrémnych hydrologických, ale aj klimatických situácií. Často sa stretávame z tzv. prívalovými povodňami či extrémne horúcimi, suchými obdobiami, ktoré v minulosti boli zriedkavým javom. Extrémne klimatické udalosti ovplyvňujú vodné zdroje. V príspevku sme sa venovali vodným zdrojom na východnom Slovensku. Porovnávali sme odbery a vypúšťanie vody v povodí Hornádu; klimatické a hydrologické veličiny – zrážky, teplota vody, prietok vody a stav vodnej hladiny vo vodomernej stanici Stratená. V povodí Hornádu na rieke Hnilec v stanici Stratená sme pozorovaním údajov zistili, že priemerné ročné teploty vody vzrástli. Vplyv na to mohla mať teplota ovzdušia. Zrážky tiež vzrástli, ale prietok vody klesol, z toho vyplýva že sa zvýšil výpar v danom povodí. Mohol to spôsobiť nadmerný výrub lesov. Pozorovali sme tiež využívanie vody v povodí Hornádu, kde odbery vody v pozorovanom období klesajú, ale vypúšťanie vody vzrástlo.

KĽÚČOVÉ SLOVÁ: vodné zdroje, klimatické veličiny, hydrologické veličiny

Introduction

The effects of climate change, occurring over the last few decades, intensify, and therefore have become an object of interest to governments, the international community, and science. Results of scientific research (Kundzewicz et al., 2006) indicate that the consequences of climate change pose a threat to the social and economic development of many countries worldwide. Changes in climate will have significant impact on local and regional hydrological regimes, which will in turn affect ecological, social and economic systems (IPCC, 2012). The study of the frequency development of the hydro-meteorological variables on the longest time series provides information on the hydro-meteorological characteristics and, consequently, the likelihood of their occurrence in the future (Huh et al. 2005; Szolgay et al., 2003; Shiau et al., 2003) e.g. by water management, the low flow period limits the use of surface water, the use of water for different purposes, the use of energy flows, navigation and so on (Pekárová et al., 2016).
Human activities, its impact on water resources and the problem of global warming due to increased carbon dioxide concentrations in the atmosphere and the

strengthening of "greenhouse" effects is unambiguous. An unexpected increase in air temperature and change in drainage impinges on renewable water resources and the nature of their economic use. However, the significant anthropogenic global climate change observed over the last decades is reflected in an estimations based on observations of water sources and water consumption.

As far as calculations for the future are concerned, we must say that the global warming forecasts for most of the regions currently available are very contradictory, especially with regard to the expected outflow changes. Therefore, these are not applicable to assessing water resource estimates and water consumption. Moreover, according to recent assessments for the future, the most important anthropogenic changes to the global climate are expected after 2030–40.

A quantitative estimation of global water resources over the past years and for the coming decades was based on the use of water for public and domestic needs, industrial production and agriculture (irrigation). Water surfaces have also been taken into account in connection with water reservoirs construction. All prospects for the future point to potential global anthropogenic climate change, it means to a stationary climate situation.

The contribution focuses on the assessment of climatelogical variables for the use of water resources in the conditions of eastern Slovakia, in Hornád river basin.

Study area

The sub-basin of Hornád is defined by a ridge switchboard from the Kráľova hoľa group, which continues in the southeast direction through the Slovak Paradise along the ridges of the Volovské vrchy and at the Kojšová hoľa 1246 m asl. is being turned into the Košice basin, where it leads as a valley substation at the highest points of the hilly part of the basin at the state border with Hungary. On the west side leads the Kráľová hoľa submarine through the Kozie chrbty, then it heads to the northeast and leads through the intersection between the Poprad and Hornád basin, continuing the ridges of Levočské hills towards the east on the Minčol at elevation 1157 m asl. in the Čergov Mountains. From thence it descends further east to the elevation of Šipotská hora 557 m asl. in Ondavská vrchovina. It takes south direction and through the ridge of Slanské vrchy the highest group Šimonka 1092 m asl. reaches the national border again with Hungary.

Hornád river basin is bounded at the west by the basin of Váh, in the southwest by the Hron river basin, the north of the Poprad river basin, the eastern Bodrog river basin, and the southern Bodva river basin. Part of the southern boundary of the basin forms the national border with Hungary. The area of Hornád catchment is 4414 km^2. River in the territory of a sub-basin with a surface catchment area greater than 1000 km^2 is: Torysa River. River in the territory of a sub-basin with a surface area greater than 500 km^2 is: Hnilec River. The long-term average of Hornád River in the state border profile is 28.9 $m3.s^{-1}$ (VÚVH, 2015).

The River Hornád is the largest tributary of Slaná, with which it forms the second largest river system in Eastern Slovakia, after Bodrog River. This river system creates an extensive veil with a center on Hungarian territory. Hydrological data of the Hornád basin are documented in Table 1 (VÚVH, 2015).

Table 1. Hydrological balance in the Hornád sub-basin (period: 1961–2000) (WÚVH, 2015)
Tabuľka 1. Hydrologická bilancia v čiastkovom povodí Hornádu (obdobie: 1961 – 2000) (VÚVH, 2015)

Territory	Area	Rainfall	Runoff	Rainfall-Runoff
	km^2	mm	mm	mm
Hornád river basin	4 414	701	210	491
Slovakia	49 014	743	236	506

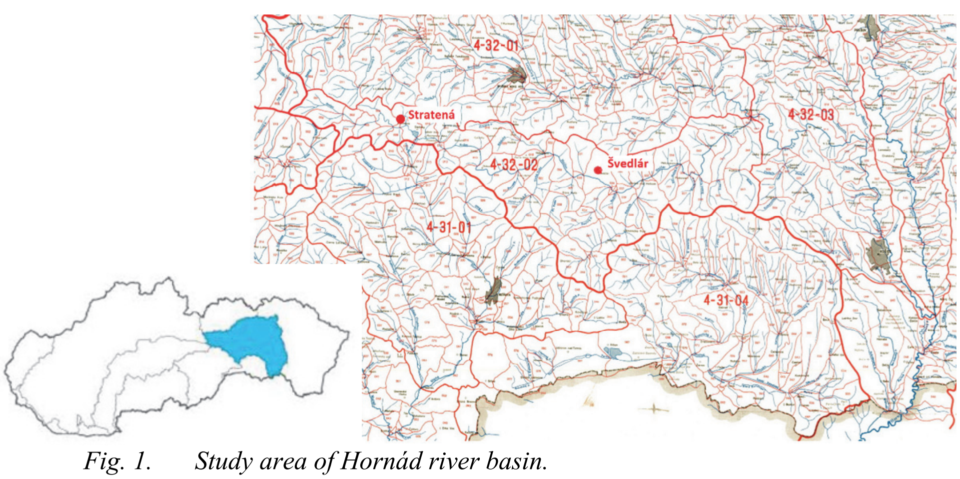

Fig. 1. Study area of Hornád river basin.
Obr. 1. Záujmové územie povodia Hornádu.

Results and discussion

The precipitation and runoff in the Hornád river basin during the period 1995 and 2000–2015 slightly increased as shown in Fig. 2.
The use of water in the Hornád river basin shows Fig. 3.

Water abstractions decreased in the observed period of 1999–2015, but the water discharged slightly increased over the observed period from 1999 to 2015.
Climatic station Stratená is located above the water reservoir Palcmanská Maša, in the cadastre village of Stratená (see Fig. 1).

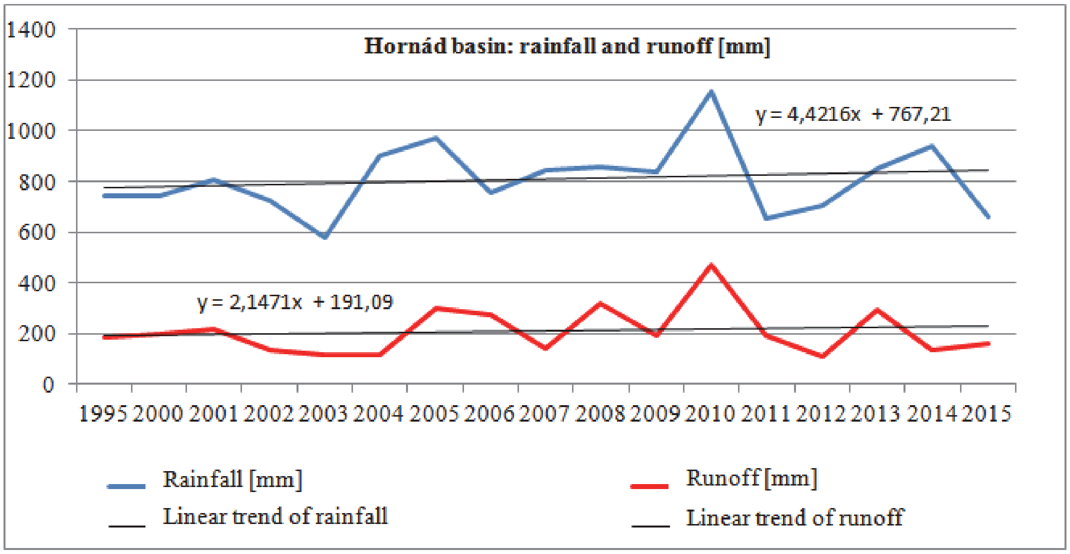

Fig. 2. Rainfall and runoff in Hornád river basin during years 1995 and 2000–2015 (SAŽP, SHMÚ).
Obr. 2. Zrážky a odtok v povodí Hornádu počas rokov 1995 a 2000 – 2015 (SAŽP, SHMÚ).

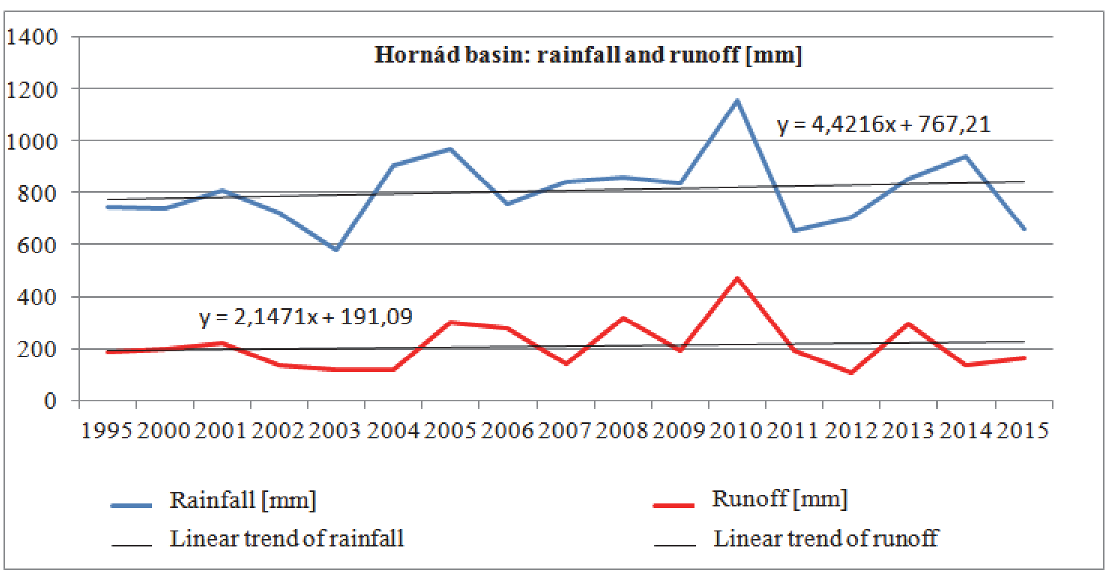

Fig. 3. Water abstraction and discharge in Hornád river basin during years 1999–2015 (SAŽP, SHMÚ).
Obr. 3. Odbery a vypúšťanie vody v povodí Hornádu počas rokov 1999 – 2015 (SAŽP, SHMÚ).

At the observed station, the average annual water temperature in the observed period 1954–2015, increased by about 1°C as shown in Fig. 4.
At the climatic station Švedlár (see Fig. 1) (the nearest climatic station to river station Stratená), in the observed period 1981–2010, the precipitations have increased by approximately 20 mm as shown in Fig. 5.
At the station Stratená, annual flows in the observed period 1954–1989 a 2001–2010, decrease as shown in Fig. 6.
At the station Stratená in the observation period 1954–1989 and 2001–2010 the height of the water level (in cm of watermeter) is decreasing, but in 1978 the station was transferred 1.5 km higher (and its position is higher), so the height of the water level has changed as is shown in Fig. 7.
The evaluation showed that the impact of climate variability on the water resources of eastern Slovakia is minimal, which results from the graphical evaluation of the data.

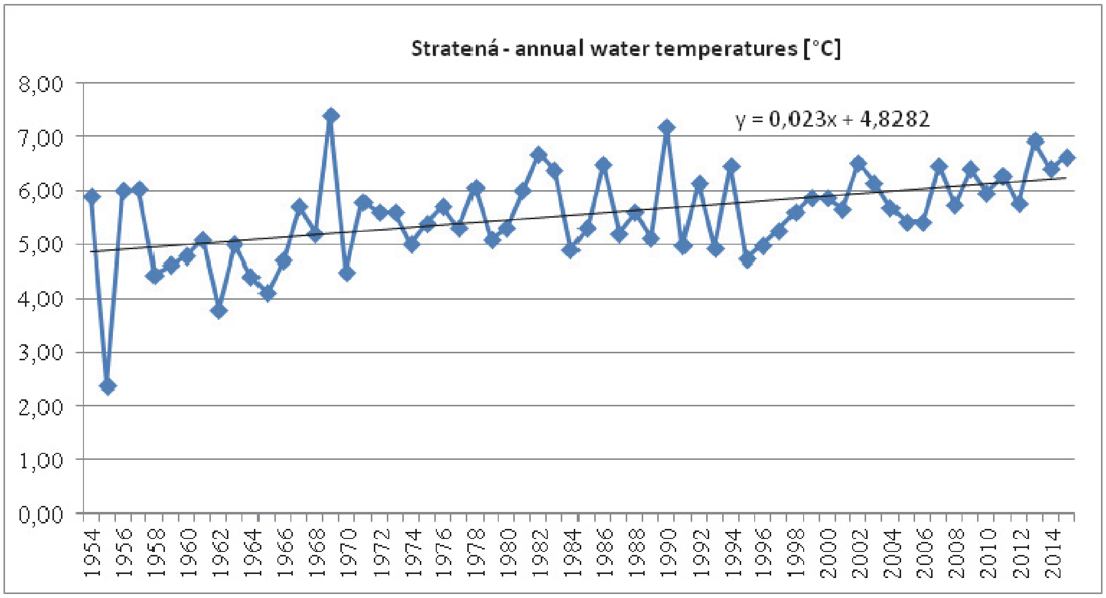

Fig. 4. Annual water temperatures in Stratená river station during years 1954–2015 (SHMÚ).
Obr. 4. Priemerné ročné teploty v stanici Startená počas rokov 1954 – 2015 (SHMÚ).

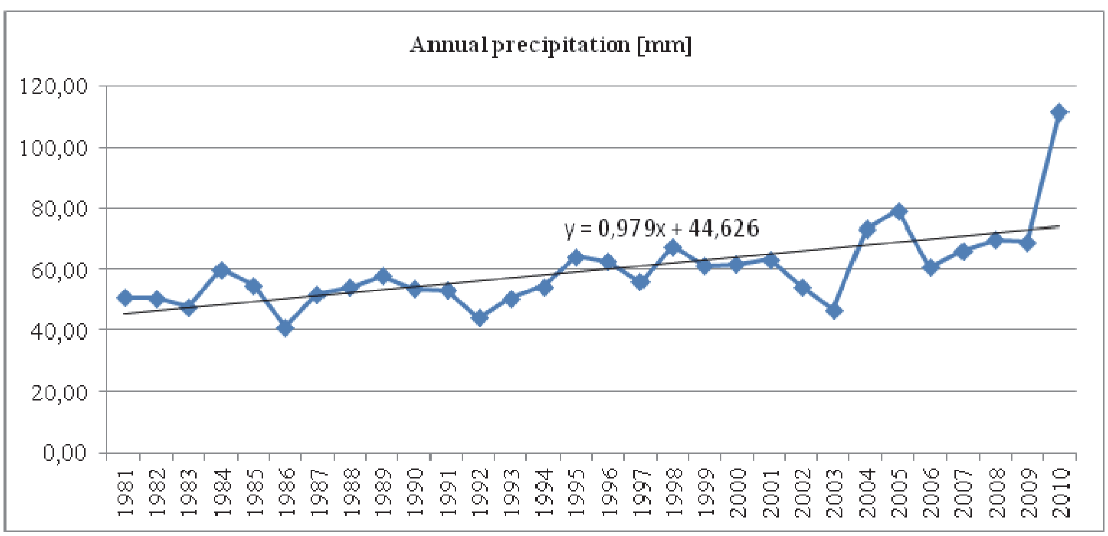

Fig. 5. Annual precipitation in station Švedlár during years 1981 – 2010 (SHMÚ).
Obr. 5. Ročný úhrn zrážok v stanici Švedlár počas rokov 1981 – 2010 (SHMÚ).

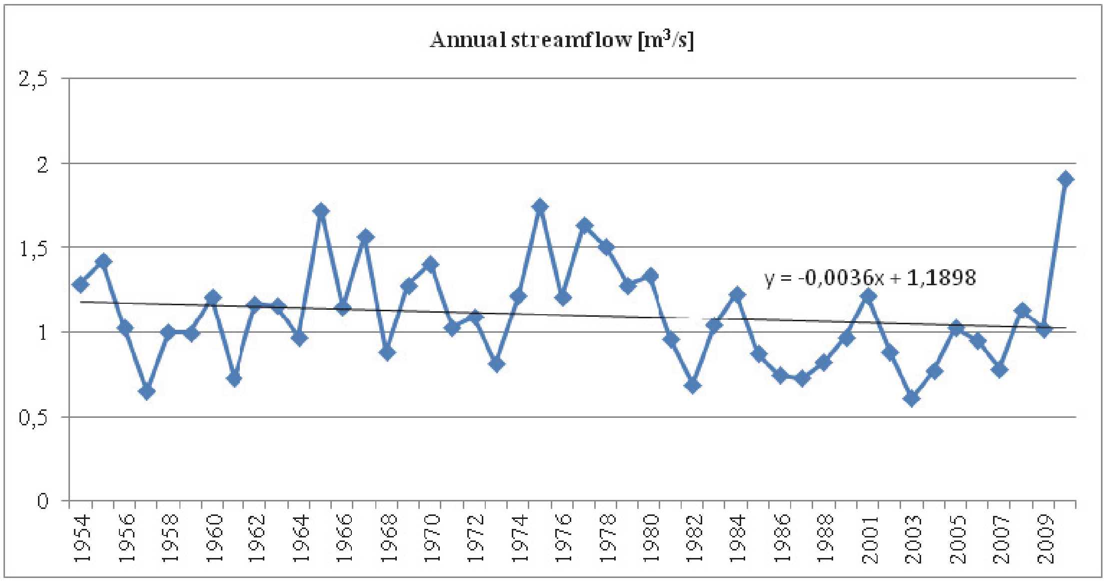

Fig. 6. Annual streamflows in station Stratená during years 1954–1989 and 2001–2010 (SHMÚ).
Obr. 6. Priemerné ročné prietoky v stanici Stratená počas rokov 1954 – 1989 a 2001 – 2010 (SHMÚ).

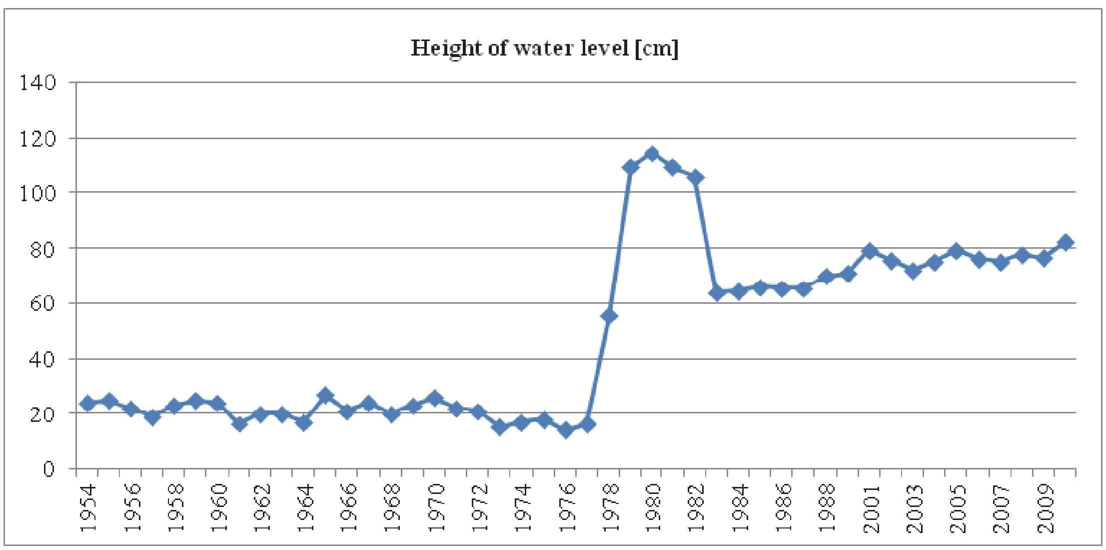

Fig. 7. Average water levels in Stratená during years 1954–1989 and 2001–2010 (SHMÚ).
Obr. 7. Priemerné vodné stavy v stanici Stratená rokov 1954 – 1989 a 2001 – 2010 (SHMÚ).

Conclusion

Water resource assessment provides the basis for a wide range of water-related activities. Without assessing water resources, it is impossible to plan, design, manage, operate and maintain projects for irrigation and drainage, flood mitigation, industrial and domestic water supply, urban drainage, energy production (including water), health, agriculture, fisheries, and the conservation of aquatic ecosystems and coastal waters.
The nature of decisions based on information on the assessment of water resources may include large capital investments with potentially massive environmental impacts. This demonstrates the value of water resource

assessment activities and their tangible and intangible benefits. To ensure sustainable development in the future, appropriate government policies and programs are needed. Therefore, greater knowledge is needed on the quantity and quality of surface and groundwater resources and extensive monitoring to guide the management of these resources.

In order to be able to reliably assess the future use of water resources and the current availability of water, it is not sufficient to rely only on volumetric data and natural changes in the runoff out of the river basin. In addition, changes due to human activity must be taken into account. In recent decades, natural changes in water runoff and the quantitative and qualitative characterristics of renewable water sources have been greatly influenced by the overall complexity of anthropogenic impacts. These include those directly related to water intake from river systems for irrigation, industrial and domestic water use. These include control of the reservoir, change of river basin use, such as afforestation and deforestation, land management, urbanization and drainage. All of these factors have a different effect on total water volumes, river drainage and water quality.

Estimating the real role of all anthropogenic factors is not easy. We should not overlook those factors that transform the morphology of the basin. Such factors can have a major impact on small and medium flows as well as on water quality. Under certain physiographic conditions, these types of human activities can even support an increase in renewable water resources simply by reducing the overall loss of vapours from the tank. Estimation of the global impacts of anthropogenic impacts on water resources is primarily based on consideration of the role of factors related to direct water intake from water courses and control of runoff from tanks. These factors, which cause unilateral reductions in runoff of surface and groundwater, are widely dispersed, most intensely developed and capable of exerting a significant impact on water resources in large regions.

Assessing water resources is to determine the quantity, quality and availability of water resources on which the assessment of the possibilities of their sustainable development, management and control is based. Assessment of the impact of climate variability on water resources is an important activity because we consider water as a strategic raw material. We have been working on the using of water in selected Slovak river basins, namely by water abstraction and water discharge. We have evaluated climatic and hydrological variables in selected river basins in the eastern Slovakia. We have compared the time series of observed variables over a period of about 60 years. The results of the work are the plots of observed variables, which we have evaluated. The impact of climate variability on water resources in eastern Slovakia is minimal.

Acknowledgement

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VPLYV VARIABILITY KLÍMY NA VODNÉ ZDROJE VÝCHODNÉHO SLOVENSKA

Hodnotenie vodných zdrojov poskytuje základ pre širokú škálu aktivít, ktoré sa týkajú vody. Bez posudzovania vodných zdrojov je nemožné dobre plánovať, navrhovať, spravovať, prevádzkovať a udržiavať projekty na zavlažovanie a odvodňovanie, zmierňovanie záplav, priemyselné a domáce zásobovanie vodou, mestské odvodnenie, výrobu energie (zahrňujúce vodnú energiu), zdravie, poľnohospodárstvo, rybolov, zmierňovanie sucha a zachovanie vodných ekosystémov a pobrežných vôd. Posudzovanie vodných zdrojov je určenie množstva, kvality a dostupnosti vodných zdrojov, na ktorých je založené hodnotenie možností ich udržateľného rozvoja, riadenia a kontroly. Hodnotenie dôsledkov zmeny klímy na vodné zdroje je dôležitou činnosťou, pretože vodu považujeme za strategickú surovinu. Príspevok sa zaoberá analýzou využívania vody vo vybraných povodiach Slovenska, a to najmä odberom vody a vypúšťaním vody. Hodnotili sme klimatické a hydrologické premenné vo vybraných povodiach na východnom Slovensku. Porovnávali sme časové rady sledovaných premenných počas obdobia približne 60 rokov. Výsledky práce sú grafom pozorovaných premenných, ktoré sme vyhodnotili. Vplyv variability klímy na vodné zdroje na východnom Slovensku je minimálny.

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