УДК: 556.532:551.57(497.72:282)

ESTIMATING ANNUAL SIMPLE WATER BALANCE ON KRIVA REKA CATCHMENT USING MULTIPLE LINEAR REGRESSION

Ivan RADEVSKI, Svemir GORIN, Ivica MILEVSKI,
Olgica DIMITROVSKA, Vladimir ZLATANOSKI
University Ss. Cyril and Methodius,
Faculty of Natural Sciences and Mathematics,
Institute of Geography; e-mail: radevskiivan@yahoo.com

ABSTRACT

Simple water balance contains four basic elements: precipitation, evapotranspiration, infiltration and runoff. For correct equation it is necessary to compare the basic elements in the measure unit (mm). The KrivaReka catchment is excellent area of research because there is no larger underground aquifer or differences between topographic and hydrological watershed (no karst relief or other rocks, where there is possibility of larger underground connection with near catchment). From basic data of Kriva Reka catchment, were obtained average annual precipitation sums of seven precipitation gauges, for the 1961-2000 period, and average discharge data of Kriva Reka for three gauges, for the same period. After calculation of annual average precipitation for Kriva Reka catchment using multiple linear regression in SPSS software package, new isohyetal grid was processed in raster calculator in ArcGIS software package. The other three elements were calculated with using empirical equations. The Kriva Reka catchment has an average annual water precipitation of 721 mm, of which 164 mm runoff, 473 mm evaporate and average annual infiltration is 84 mm.

Key words: simple water balance, precipitation, runoff, evapotranspiration, infiltration.

INTRODUCTION

Basin of Kriva Reka is located in the central part of the Balkan Peninsula, covering end-northeast parts of the Republic of Macedonia. It is situated between Osogovo Mountains on the south and lower German Mountain and Mount Kozjak on the north, a ridge Deve Bair on the east to the river confluence point near village Klechovce on the west in Kumanovska Valley. With this description of the confluence of the Kriva Reka takes the form of an irregular rectangle, suppresses quite significant in hydrological terms. With this form are obtained four natural boundaries of the Kriva Reka basin (Zikov & Radevski 2014).

In the precipitation regime, months with highest values of precipitation are May and November-December (Vasileski et al., 2012; Vasileski & Radevski, 2014). The Kriva Reka catchment is one of the areas with highest amount of precipitation in eastern part of Republic of Macedonia, and AAPS is close to amounts in western part of the country, for example catchment of Crna Reka (Vasileski & Radevski, 2011).

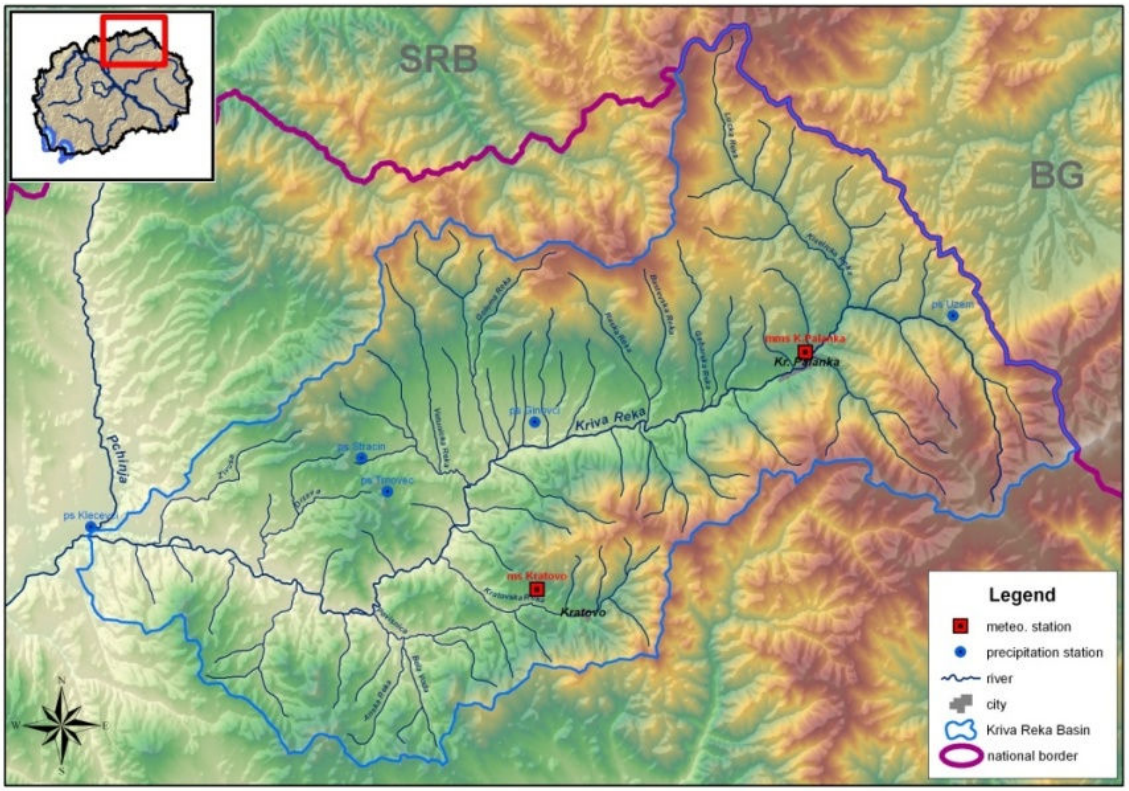

Figure 1: Precipitation gauges location in Kriva Reka catchment.

DATA AND METHODOLOGY

The basic data is average annual precipitation sum (AAPS) of each of seven precipitation gauges located in Kriva Reka catchment for period 1961-2000. There are necessarily for calculating AAPS for Kriva Reka catchment. This calculation was made with SPSS - multiple linear regression (Kay & Kutiel, 1994; Voudouris, 2006; Voudouris et al., 2007). After that GIS technique was used with raster calculator in ArcGIS to obtain new precipitation grid. Also there are average annual temperatures for the same period, necessary data for calculating evapotranspiration with using of Turc's equation, which was tested on 250 catschments (Turc, 1961). This empirical equation is one of the most often used formulas for calculating evapotranspiration (Fikos et al., 2005; Zhai et al., 2010) This technique of combination of statistics and GIS software makes correct interpolation of correct isohyetes GRID related to variables longitude, latitude and altitude (Kay & Kutiel, 1994). In addition for calculating runoff we have average annual runoff calculated by river discharges at confluence point of Kriva Reka - Klechovce. The infiltration was calculated like a difference between precipitation minus runoff and evapotranspiration.

Table 1. Annual precipitation sums at seven precipitation gauges in Kriva Reka catchment.

Gauge St.	Uzem	K. Palanka	Stracin	Kratovo	Trnovec	Ginovci	Klechovce
m.a.s.l.	880	691	680	640	520	470	300
mm	738	615	512	682	504	540	482
Longitude	22˚26’	22˚20’	22˚02’	22˚09’	22,03’	22˚09’	21˚51’
Latitude	42˚13’	42˚12’	42˚09’	42˚05’	42˚08’	41˚01’	42˚07’

Formula for calculating simple water balance is:

$$P = R+E+I \quad (1)$$

In the equation P is precipitation, R – runoff, E-evapotranspiration and I is infiltration. Isohyets method calculated with combination between multiple linear regression and GIS is most often used method for determining the average amount of precipitation in the watershed, information which is necessary for further calculation of the elements of the water balance of the Kriva Reka catchment. Besides this method which is the very often used for not uniform terrain as is the case with the Kriva Reka catchment, in watersheds with flat terrain (for example rivers in Poland or Hungary) used the method of Thiessen polygons (Berezovskaya et al., 2005).

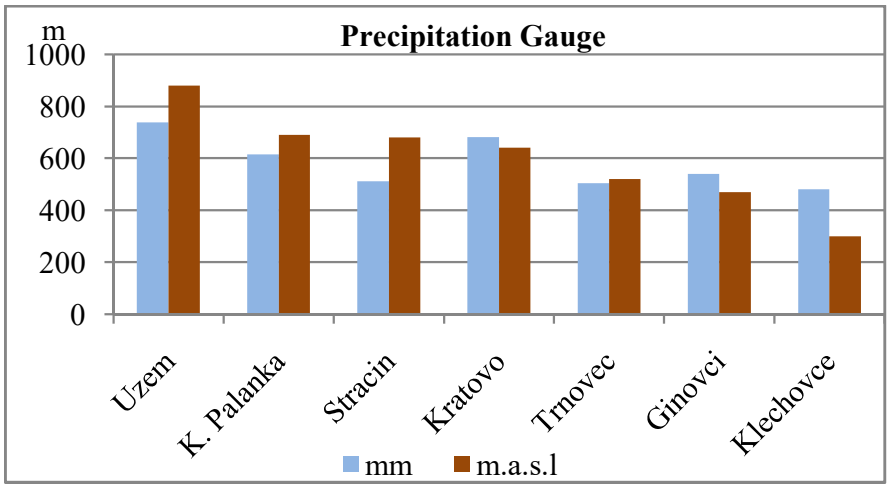

Figure 2: Relation between altitude and average annual precipitation sums in Kriva Reka basin.

RESULTS AND DISCUSSION

Average annual precipitation on Kriva Reka catchment was calculated by using multiple linear regression in SPSS, and geographical latitude, longitude and altitude are treated like a independent variables and precipitation is dependent variable, which allows more precise mak-

ing isohyetal map of the catchment of Kriva Reka. This procedure is required for grid composed of isohypses turn into appropriate isohyets through math.

$$P = 7453.1-79.435*\lambda-126.66\varphi+0.430h \quad (2)$$

Where P is average annual precipitation, λ is geographic longitude, φ is the geographic latitude and h is altitude above the sea level. Approximately for every 1km moving eastward the precipitation is decreasing for about 8 mm, and for every km movement northward, the precipitation is decreasing for around 13 mm. Every 100 meters altitude of Kriva Reka catchment, the precipitation is increasing for 43 mm, which is the precipitation gradient (Røhr & Killingtveit, 2003). According to the obtained grid with ArcGIS raster calculator, the AAPS for Kriva Reka catchment is 721 mm.

The processed isohyetal map is obtained using blue colored contours between isohyetes, the distance between isohyets is 100 mm. The west part of the catchment is arid and the east part of the catchment is wet. Spatial difference of annual average precipitation between mountainous eastern part and western lowland part of the catchment is 600 mm.

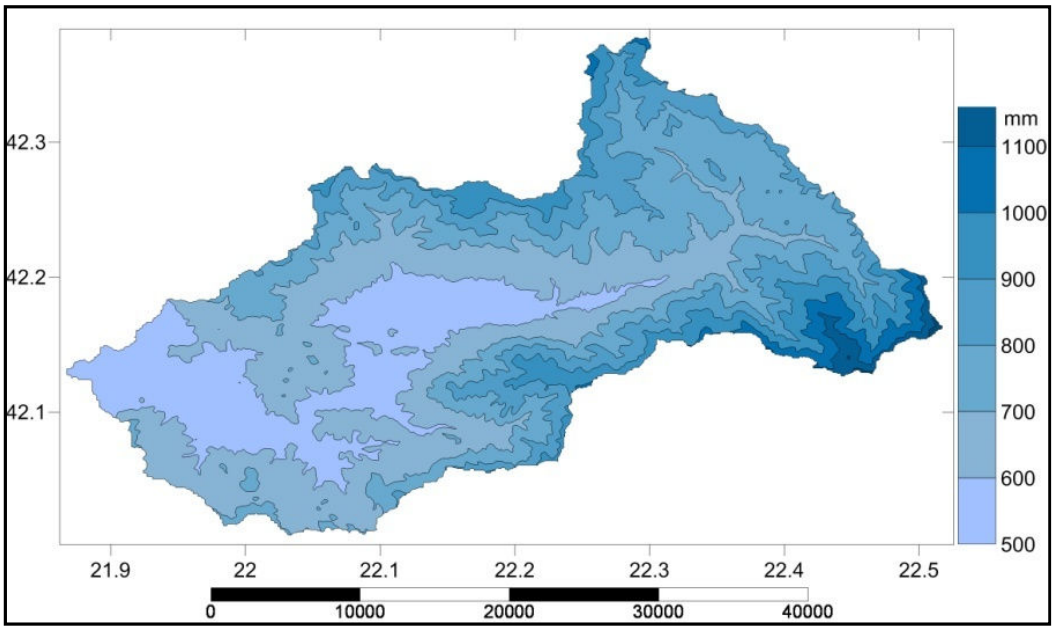

Figure 3: Isohyetal grid of Kriva Reka catchment.

Equation for calculating AAPS in Kriva Reka catchment:

$$P = \frac{\sum(f_1h_1+f_2h_2+\cdots+f_nh_n)}{A} \quad (3),$$

P = 721 mm

In the equation, f is area between two isohyets, h is average precipitation between same isohyets. The sign A means total catchment area. Average annual precipitation in Kriva Reka catchment is 721 mm.

The second main element of water balance is runoff (mm), which is opposite proportionality to precipitation. Besides, the specific runoff (q – l/s/km^2), which is calculated with equation (q = (Q*1000)/A), Q is average annual river discharge for period of 1961-2000. To convert specific runoff in runoff (mm), it is a multiplication with annual number of seconds^{-6}.

$$R = q * 31{,}56 \quad (4)$$

In the equation R is annual average runoff, q is specific runoff and number 31,56 means the seconds in a year 10^{-6}. The runoff is one of the most important elements in the water balance in the basin and has the same unit with precipitation and evaporation, which allows the easy relationship between these three variables. The average annual runoff in Kriva Reka catchment is 164 mm.

By entering the equation derived using a new grid of the runoff of the Kriva Reka basin. The map shows the contour lines that connect points of equal runoff. The color ranges from blue contours in higher average runoff to white with the lowest average runoff.

In the obtained average annual amount of precipitation and made created grids of isohyetal map and isolines runoff map is necessary to calculate the amount of evapotranspiration (E) of the Kriva Reka catchment (Turc, 1961).

$$E = \frac{P}{\sqrt{0{,}9+\frac{P^2}{L(t)^2}}} \quad (5)$$

$$L(t) = 300+25T+0{,}05T^3 \quad (6)$$

The P is average annual precipitation and the L(t) parameter is 581.9, T is average annual temperature, so the result for evapotranspiration (E) of Kriva Reka basin is 473 mm. The evapotranspiration value depends by precipitation amount, so how greater precipitation is, more water evaporates, for example Sava river catchment in Slovenia has 1594 mm AAPS and evapotranspiration of 716 mm (Frantar 2007).

In calculating the values of the four major water balance components of the Kriva Reka basin, i.e. precipitation P (721 mm), runoff R (164 mm), infiltration I (84 mm) and evapotranspiration E (473 mm), has determined the water balance of the basin on the basis of data from the annual amounts of precipitation for the period 1961-2000, the average annual flows, on which using the above regression equations determined grid height of the leak and evaporation from the confluence of the Kriva Reka.

Apart from the three main parameters P, R, I and E, and the obtained coefficient of runoff (C) which is the ratio between the runoff and AAPS is calculated according to the formula:

$$C(\%) = \frac{R}{P} * 100 \quad (7)$$

Table 2. Kriva Reka water balance: P - precipitations; R - runoff; E - evapotranspiration; I - infiltration; C - coefficient of runoff.

River/element	P (mm)	R (mm)	E (mm)	I (mm)	C(%)
Kriva Reka	721	164	473	84	23

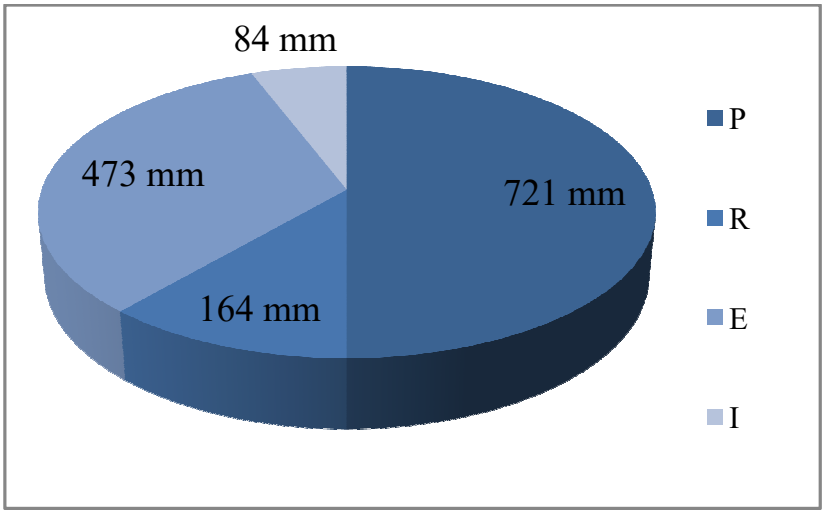

Figure 4: Graph of Kriva Reka water balance.

In the Kriva Reka catchment, the AAPS is 721 mm, of which 164 mm is runoff, 473 mm is evapotraspiration and average annual infiltration is 84 mm. Coefficient of runoff is 23%, 11% is water infiltration, while 66% evaporates from Kriva Reka catchment. In the higher gauge stations values of precipitation and the amount of runoff and runoff coefficient increases, while the evaporation is decreasing.

CONCLUSION

The Multiple Linear Regression and Raster Calculator in ArcGIS software were used to estimate the spatial distribution of precipitation. The relief of the Kriva River controls the annual precipitation distribution. The largest precipitation amounts occur in the Southeast part of the region, which is also with the highest elevation up to 2250 m.a.s.l. Precipitation decreases going to the western parts of the catchment. With Turc equation the evapotranspiration was calculated, which is the main element of water deficit in the catchment of Kriva River.

The large part of the precipitation evaporates, and the Coefficient of runoff by 23 % is typical for continental catchments, much lower from Word Average Runoff Coefficient – 36% (Schöniger & Dietrich, 2003).

The basic recommendation from this paper is optimizing the water management in the Kriva River catchment, according to the Water Framework Directive 2000/60/EC with lower water demands, particularly in summer, when the water level is lower and precipitation amounts also. This will be possible by building new dams, collect water sufficiency in spring and autumn and use it during the summer period.

REFERENCES

Berezovskaya, S., Yang, D.&Hinzman, L. (2005): Long-term annual water balance analysis of the Lena River. -In: Global and Planetary Change, 48(1), 84-95.

Fikos, I., Ziankas, G., Rizopoulou, A.&Famellos, S. (2005): Water balance estimation in Anthemountas river basin and correlation with underground water level. -In: Global nest. The international journal, 7(3), 354-359.

Frantar, P. (2007): Geographical overview of water balance of Slovenia 1971-2000 by main river basins. –In: ActaGeographicaSlovenica, 47, 25-45.

Kay, P.A., Kutiel, H. (1994): Some remarks on climatic maps of precipitation. -In: Clim. Res. 4, 233–241.

Røhr, P. C.&Killingtveit, Å. (2003): Rainfall distribution on the slopes of Mt Kilimanjaro. –In: Hydrological sciences journal, 48(1), 65-77.

Schöniger, M. &Dietrich, J. (2003): Hydrologie, Grundvorlesung mit Übungen. Hydroskript. TU Braunschweig.Braunschweig. Internet: www.hydroskript.de.

Turc L. (1961): Estimation of irrigation water requirements, potential evapotranspiration: a simple climatic formula evolved up to date. -In: Annals ofAgronomy, 12, 13–49.

Vasileski, D. & Radevski, I. (2011): Implementation of Gauss function in determing probability of floods at the gauge station 'Dolenci' on the CrnaReka in Republic of Macedonia. –In: Geographica Pannonica, 15(4), 113-118.

Vasileski, D. & Radevski, I. (2014): Analysis of high waters on the Kriva Reka River, Macedonia. Acta Geographica Slovenica, 54(2), 363-377. doi: http://dx.doi.org/10.3986/ AGS54209

Vasileski, D., Radevski, I., Milevski, J., Todorovska, S. (2012): Precipitation regime of water basin Kriva Reka. Proceedings from the Fifth International Scientific Conference - BALWOIS 2012, 28 May-2 June 2012, Ohrid, Republic of Macedonia.

Voudouris, K. S. (2006): Groundwater Balance and Safe Yield of the coastal aquifer system in NEasternKorinthia, Greece. –In: Applied Geography, 26(3), 291-311.

Voudouris, K., Mavrommatis, T. & Antonakos, A. (2007): Hydrologic balance estimation using GIS in Korinthia prefecture, Greece. –In: Advances in Science and Research, 1, 1-8.

Zhai, L., Feng, Q., Li, Q. & Xu, C. (2010): Comparison and modification of equations for calculating evapotranspiration (ET) with data from Gansu Province, Northwest China. –In: Irrigation and Drainage, 59(4), 477-490.

Zikov, M., Radevski, I. (2014): Water supply analysis of rural settlements in Kriva Reka watershed, Proceedings from Scientific Symposium “Problems and perspectives of hilly mountain areas”, Macedonian Geographical Society, pp 39-44, 12-15 September 2013, Ohrid, Republic of Macedonia.

ПРОЦЕНКА НА ГОДИШНИОТ ЕДНОСТАВЕН ГОДИШЕН БАЛАНС ВО СЛИВОТ НА КРИВА РЕКА СО КОРИСТЕЊЕ НА ПОВЕЌЕКРАТНА ЛИНЕАРНА РЕГРЕСИЈА

Иван РАДЕВСКИ, Свемир ГОРИН, Ивица Милевски,
Олгица ДИМИТРОВСКА, Владимир ЗЛАТАНОСКИ

Институт за географија-ПМФ, Универзитет „Св. Кирил и Методиј“, Скопје
e-mail: radevskiivan@yahoo.com

И З В О Д

Едноставниот воден баланс содржи четири основни елементи: врнежи, евапотранспирација, инфилтрација и површинско истекување. За поставување на соодветна равенка, неопходно е да се споредат основните елементи со иста мерна единица (mm). Сливот на Крива Река е одличен за истражување бидејќи овде нема голем подземен резервоар ниту пак големи разлики помеѓу топографскиот и хидролошкиот слив (нема карстен релјеф или други карпи каде би постоела можноста за подземни врски со соседните сливови). Од основните податоци за сливот на Крива Река анализирани се просечните суми на врнежи на седум дождомерни станици за периодот 1961-2000 година и просечниот протек на Крива Река на три водомерни станици за истиот период. По одредувањето на просечните годишни врнежи во сливот на Крива Река со користење на повеќекратна линеарна регресија во софтверскиот пакет SPSS добиен е нов изохиетски растерски грид преку растер калкулаторот во ArcGis. Останатите три елементи се пресметани со емпириски равенки. Сливот на Крива Река има просечни врнежи од 720 mm од кои 164 mm површински отекнува 473 mm испарува, а 84 mm понира во тлото.