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VEGETATION AND LAND USE ANALYSIS FOR RUNOFF ESTIMATION IN SMALL FORESTED CATCHMENT: A CASE STUDY OF TAJOVSKÝ BROOK IN SLOVAKIA

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Abstract: Flash floods have been in the centre of attention for numerous hydrological studies recently and their magnitude and frequency are projected to increase due to the changing climate. This is especially important in small catchments where a local storm event can cause rapid increase in damage causing discharges. To estimate the possible impacts of a rainfall event, it is necessary to understand the precipitation/runoff conditions. Soil Conservation Service Curve Number (SCS CN) method is widely used and discussed to estimate the effect of land cover and soil moisture conditions on runoff. In this paper, we implement this standard method in the Tajovský brook catchment in Central Slovakia. The individual land cover classes were identified, and weighted CN numbers were established. Forest accounted for 67% of the entire area, grasslands for 19% and built-up areas for 10%. The final CN_{II} number was computed as 60.8. Seven initial abstraction ratio values were tested on a monthly hydrograph data and optimal value was set to 0.01. This suggests the possible most suited regional value of the abstraction ratio that could be used for this type of small (<50 km) forested catchments, but further testing on other catchments and precipitation events would be beneficial.

Keywords: vegetation structure, plant alliances, land cover, retention, runoff, extreme rainfall, Slovakia

1. INTRODUCTION

Flash floods in small catchments have been in the centre of attention for numerous studies and their magnitude and frequency is projected to increase due to the changing climate (Schröter et al., 2005; Faško et al., 2008; Lapin et al., 2009; Hlavčová et al., 2015; Maragno et al., 2018). Vegetation is one of the basic components of landscape and plays a vital role in the complex runoff conditions (Peel, 2009; Szolgay et al., 2010, Giri & Qui, 2016), providing a crucial water regulating ecosystem service (Fleischer et al., 2017; Pappalardo et al., 2017; Maragno et al., 2018). Further to rainfall regime, changes in land cover and land use (LCLU) are critical for the runoff characteristics of a catchment (Sajikumar, 2015; Shi et al., 2007). Conventional drainage network is often ineffective at managing runoff during the extreme events attributed to climate change (Ashley et al., 2007), therefore new approaches such as nature-based solutions (NBS) using green infrastructure (GI) are preferred (Haase et al., 2014; Mason & Montalto, 2014).

Detailed information about the vegetation structure and its management is necessary for deeper understanding its hydrological and mechanical functions (Bautista et al., 2007; Zhou et al., 2008). The components of plant species and vegetation patterns are also important factors in controlling soil erosion (Martin et al., 2010; Wang & Alimohammadi 2012; Wang et al., 2012, Zhang, 2014) and sediment delivery to fluvial systems (Van Dessel et al., 2008). A critical element in establishing the hydrological impact of climate change is the relationship between catchment vegetation and runoff, and this continues to be a very interesting area of research (Peel, 2009). First mentions about the impact of vegetation on runoff date as far back as the 1st century AD when initial estimations how forest removal increased streamflow were made by Pliny de Elder (Andréassian, 2004; Peel, 2009).

It has been observed that vegetation structures, including their canopies, litter layers and roots, influence the precipitation distribution and thus the hydrological processes which subsequently affects the production of runoff (Crockford & Richardson, 2000; Li et al., 2014). Vegetation properties such as species, age, condition or distribution are critical in controlling runoff (Bochet et al., 1998; Feng et al., 2012; Rišová & Škodová, 2017). Scale issues in combination with other environmental factors such as climate, topography or substrate complicate the effects of vegetation on runoff and soil loss (Bautista et al., 2007; Pannkuk & Robichaud, 2003).

It is also crucial to establish the natural or anthropogenic changes in land cover over time (Anstead & Balážovič, 2015; Žoncová, 2020; Žoncová et al., 2020). Numerous studies pinpoint flash flooding caused by the irrational land use (Ionita & Nagavciuc, 2021) and highlight the need for nature catchment restoration (Dixon et al., 2016, Doroszkiewicz & Romanowicz 2017, Ferreira et al., 2020). Intensive agriculture, deforestation, urbanisation or land dredging were shown to have a great impact on the hydrological processes in catchments such as infiltration, groundwater recharge, base flow or runoff (Sajikumar, 2015).

Around 200 of coupled catchment experiments were reviewed, observing changes in vegetation cover on runoff (e.g. Hibbert 1967; Bosch & Hewlett, 1982; Andréassian, 2004), which contributed to understanding of the complex relationships between vegetation and runoff. Some studies using simulated rainfall experiments were used to analyse the characteristics, regulation of, and correlation among the slope rainfall-infiltration-runoff, erosion and sediment under different vegetation types (Zhang et al., 2014). Study investigating how different tree species influence soil hydrological properties relevant for the runoff of a was performed by Jost et al., (2012).

Several models were developed to establish the effect vegetation may have on runoff (Neitsch et al., 2002; Gassman et al., 2007), using remote sensing data and high-resolution urban models (Maragno et al., 2018), or Soil and Water Analysis Tool (SWAT) model as part of GIS modules (Githui et al., 2009; Jayasree & Sajikumar, 2012; Wang et al., 2012; Sajikumar & Remya, 2015).

One of the most popular methods for direct runoff estimation is the SCS CN (Soils Conservation Service Curve Numbers) method (USDA, 2004). It was originally developed in 1950s for small agricultural catchments in the USA (USDA, 1972; 1986; Spál & Szolgay, 2013). The method was extensively used worldwide (Chow, 1964; Ponce & Hawkins, 1996; Hawkins et al., 2008; 2010; Woodward et al., 2003; Maragno et al., 2018), because its low demand on input data, versality and simplicity. However, number of drawbacks were identified with relation to different geographical settings, such as the initial abstraction ratio (λ) values (Spál et al., 2011; 2012; Spál & Szolgay, 2013; Vojtek & Vojteková, 2019; Shi et al., 2009; Lal et al., 2015), land cover structure and landform, the catchment's saturation etc. (Hawkins et al., 2008; Mishra, 2014). The CN values established on the precipitation/runoff conditions were also questioned as these were shown to vary between rain events (Shi et al., 2007; 2009). Various approaches were developed, for example two-CN system approach (Soulis & Valianzas, 2012; 2013). The problem of soil moisture accounting was first explored by Williams & LaSeur (1976), followed by Hawkins (1978) and improved by Mishra et al., (2004) introducing an enhanced SMA-based SCS CN model and furthermore the versatile model VSCS-CN. The model assumed that higher catchment saturation before a rainfall event will result in higher surface runoff. The third area of improvement was the landform becasue the original CN method referred to slope with 5% declination (USDA, 2004). Some studies modified the numbers for steeper slopes (e.g. Huang et al., 2006), but they require further testing (Mishra et al. 2004; 2018).

In this paper, we demonstrate the application of CN curve numbers for runoff estimation after detailed vegetation and land cover analysis of the Tajovský brook catchment in central Slovakia. Additionally, we aim to observe the effect the initial abstraction ratio has on the runoff volumes during on month precipitation events.

2. METHODS

SCS CN method combines the hydrological soil types, land use categories and previous catchment moisture conditions (Hawkins, 1979) and is described in detail in the NEH / 630 manual (USDA, 2004). Based on these conditions, corresponding CN number is determined and for a given rainfall amount, runoff height can be estimated (Bonta, 1997), using the water-balance equation and two basic relationships:

$$P = I_a + F + O; \qquad (1)$$

$$\frac{O}{P - I_a} = \frac{F}{S'} ; \; I_a = \lambda S; \qquad (2)$$

$$O = \frac{(P - I_a)^2}{P - I_a + S} = \frac{(P - \lambda S)^2}{P - S(\lambda - 1)}; \qquad (3)$$

$$for \; P < 0.2 * S; \; O = 0 \qquad (4)$$

Where O is the direct catchment runoff (mm); P is the precipitation (mm); I_a is the initial abstraction (mm) that has to be exceeded so that direct runoff can start to form; F is the cumulative infiltration (mm), not including I_a; S is maximum potential retention of a watershed after the start of the runoff and λ is initial abstraction ratio (Caletka et al., 2020). The runoff is set to zero when P < λ S. The maximum potential retention can be expressed as:

$$S = \frac{25400}{CN} - 254 = 25.4\left[\frac{100}{CN} - 10\right] \quad (5)$$

where *CN* is the curve number (with values from 0 to 100) derived from tables (USDA, 2004). For CN equal to 100 is that all rainfall turns into runoff, and when CN equals to 0, all rainfall infiltrates into the catchment (Antal, 1996). Depending on the catchment saturation condition (AMC), three values are used for CN. CN_{II} values are derived from the tables and these conversions are used:

$$CN_I = \frac{CN_{II}}{2.281 - 0.0128CN_{II}} \quad (6)$$

$$CN_{III} = \frac{CN_{II}}{0.427 + 0.00573CN_{II}} \quad (7)$$

Antecedent soil moisture content (AMC_I - AMC_{III}). accounts for the total daily rainfall during the previous five days (Jain et al., 2006; Ponce & Hawkins, 1996). It is classified based on precipitation intervals during dormant and growing season (Hjelmfelt et al., 1982) as dry, normal and wet condition, referring to 10, 50 and 90% cumulative probability of the exceedance of runoff depth for a given rainfall. High AMC will produce high CN number and high runoff. This approach is simple, easy to grasp and apply in field (Jain et al., 2006). However, the infiltration rate used in SCS methods is a function of the rainfall intensity (Morel-Seytoux & Verdin 1981). Extended CN procedure using infiltration theory was proposed and relationship of the CN to the hydraulic conductivity of the soil (K) and the storage suction factor (SJ) were established (Morel-Seytoux & Verdin 1981, Silveira et al., 2000).

One of the issues with CN numbers as mentioned earlier is the value of initial abstraction ratio λ (Caletka et al., 2020). In the original method, I_a was not part of the estimation (Plummer, 1998), later λ was set to 0.2. However, this value did not work for number of authors expressing that λ should be calibrated regionally and showed that reduced value produced more accurate results (Satheeshkumar et al., 2017). Karabová et al., (2012) approached the problem of regionalisation of CN curve through a new AMC categories and application of λ–P regression relationship, showing that using standard method for lower P over-estimated the runoff.

To establish the values for CN method similar to other works (e.g. Cronshey et al., 1986; Antal 1996; Antal, 2002; Halley et al., 2000; Vojtek, 2014), detailed land cover and vegetation analysis was undertaken in GIS and in the field to reconstruct the most accurate image of the current catchments' land cover and vegetation structure, using orthophoto maps with 20 cm resolution. The individual land cover classes (Table 1) were merged into groups according to the methodology by Pucherová et al., (2007), Table 2. For the identification of individual landscape categories, characteristics of morpho-structural and physiognomic features were used according to Feranec & Oťaheľ (1999).

3. STUDY AREA

The Tajovský brook catchment is situated in central Slovakia, in the Banskobystrický county, on the contact of geomorphologic units: Bystrická valley, Kordícka trough (lowered part of the Starohorské hills) and Kremnické hills. This results in high heterogeneity of the geological substrate, soil, geomorphology and other physical components. The elevation difference in the catchment is 945 m, with Vyhnatová (1283 m a.s.l.) being the highest point of the catchment and the confluence of the Tajovský brook and the River Hron (338 m a.s.l.) being the lowest.

Climate of the catchment is classified as temperate to cold (Lapin et al., 2002), with the mean annual temperature varying between 4-8 °C. In January, temperature can drop to -30 °C. Snow cover lasts between 60 to 100 days. Maximum precipitation occurs in June and July. Rainfall is increasing with altitude and mean precipitation is 1200 - 1600 mm on the hillsides and 600-800 mm in the lower lying valley (Lapin et al., 2002).

In the catchment, terrestric soils dominate over semiterrestric (Lukniš, 1972). Cambisols are most abundant (55 %) of the catchment, typical are also rendzic leptosols (28 %) and andosols (4.5 %). In terms of soils texture, loamy soils prevail (43 %) over sandy-loam (30 %). Cohesive clay loam accounts for 13 %) of the total catchment area.

Landform has significant impact on land cover. Exposed slopes are covered with forests, while low lying parts around villages are covered with a mosaic of woods, meadows, pastures, settlements, gardens and orchards, recreational areas, fields, line woody vegetation along watercourses or bushlands.

In terms of phytogeographical classification (Plesník, 2002), the area is part of the beech zone and within it the volcanic area (Kremnické hills and the northern sub-area of the Zvolen basin) and the Crystalline-Mesolithic area (Starohorské hills).

The current vegetation is significantly man influenced and original forests can be found rarely (e.g.

beech woods and rubble forests on Vyhnátová or yew growth on Tanečnica). Forests in the catchment were extensively felled for copper ores since the 13th century, mainly to be used for charcoal production (Škodová & Gajdoš, 2010; Gajdoš et al., 2012). In 1564, a forestry service was established, and the greater care was given to more sustainable forest management (Michal, 1979). Due to tree planting, besides the original deciduous species also conifers appeared, especially Norway spruce (*Picea abies*), white fir (*Abies alba*), Scots pine (*Pinus sylvestris*), black pine (*Pinus nigra*) and deciduous spruce (*Larix decidua*). At present, forests expand to less available permanent grasslands and abandoned orchards. Since 1980, forested area increased by almost 28 % and the proportion of non-forest woody vegetation also increased.

4. RESULTS AND DISCUSSION

4.1 Land use

The catchment's land cover is represented by a mosaic of habitats, from which each has a varied role in runoff conditions. Eight groups of land cover types were identified: (1) forest and non-forest woody vegetation, (2) permanent grasslands, (3) agricultural vegetation, (4) subsoil and substrate, (5) water streams and water areas, (6) residential and recreational zones, (7) technical areas and (8) transport related areas. These are listed in Table 1 below.

Forest vegetation covers most of the catchment area with mixed (54 %) and deciduous forests (6 %). Non-woody vegetation (tree lines, riparian vegetation etc.) creates 3 %. Meadows create 12 %, followed by grazelands, extensive grass-herbal and reedbed areas. Fields occupy only 2 % of the total catchment area. Built-up areas account for 12 %, from which towns are 7 % (Tables 1, 2).

4.2. Vegetation structure

Forested areas have a positive effect on water retention (Michalová, 1980; Minďáš et al., 2001; Holko et al., 2006). In the studied catchment, flood conditions can be caused by sudden short-term downpours, but forests would retain a great part of the precipitation to prevent fast runoff from the area.

On the slopes of the Vyhnátová ridge, forests with common beech (*Fagus sylvatica*), silver fir (*Abies alba*), sycamore maple (*Acer pseudoplatanus*) and small-leaved linden (*Tillia cordata*) occur. At the highest elevations, acid-loving beech forests with Norway spruce (*Picea abies*) occur. Frequent rock debris areas prevent plant colonisation and on steep slopes and rubble soils, in addition to beech, rubble trees such as linden, maple and rowan are present. Along the streams (Tajovský, Vyhnatovský, Kordícky and Mútňanský brook) fragmented natural communities of ash-alder foothill alluvial forests with grey alder (*Alnus incana*), crack willow (*Salix fragilis*), common ash (*Fraxinus excelsior*) or common hornbeam (*Carpinus betulus*) are present.

Grasslands have a mixed character: they serve as mowed meadows and as pastures. They are mowed twice a year, and mainly sheep are grazing them soon after mowing. Their existence depends on regular management, otherwise they are overgrown by trees. Compared to 1980 (Michalová, 1980), a decrease in their area by more than 46% is evident. Rare and endangered species growing here such as lady's-slipper orchid (*Cypripedium calceolus)*, twayblade (*Listera ovata)* and others are on retreat.

Andesite rocks, for example on the eastern slopes of Suchý vrch, are covered with the species of rocky steppes, represented mainly by northern spleenwort (*Asplenietum septentrionalis)* and hairy melic (*Melica ciliata*).

The mosaic of different types of plant communities is complemented by lines and stands of shrubs at the successively overgrown habitats and forest edges. In the colder part of the area, mountain hazel bushes (*Corylus avellana*) dominate. In warmer, lower-lying localities, blackthorn bushes (*Ligustro-Prunetum* association), hazel-blackthorn bushes (*Pruno-Coryletum association*) and common juniper stands (*Juniperus communis*) are particularly well developed.

From ruderal habitats, there are log cabins with a predominance of herbs and grasses or with a predominance of light-dependent woody plants in the Tajovský brook basin. Nitrophilous ruderal vegetation occurs near farms, fields or along watercourses. In several localities, abandoned fields had overgrown with weed vegetation.

4.3. Runoff numbers determination

For the purposes of establishing the SCN-CN numbers, the individual land cover categories were summed and joined into eight groups. Forests dominated and accounted for most of the area as mentioned earlier (2773 ha or 63.8 %), (Table 2). Prevailing soil hydrologic group was determined based on soil texture type, giving the loamy-sand soils B group and clay soils C group, built up areas were D group, and the CN II number was listed from the USDA table. Furthermore, weighted CN II number was calculated based on the proportion of the area for the given land cover type to total area of the whole catchment. The lowest CN II value was established for forest and non-forest woody vegetation (55 and 48 respectively).

Table 1. Land cover characteristics of the Tajovský brook catchment

Land cover group	Land cover type	Land cover class	Area (hectare)	Proportion of the total area (%)
Forest and non-forest woody vegetation	Forest woody vegetation	111 Deciduous forests	243.31	5.9596
		113 Mixed forests	2 333.19	53.6617
		114 Tree felling areas	71.46	1.6435
		130 Young tree growths	125.13	2.8779
	Non-forest woody vegetation	141 Groves	55.17	1.2688
		142 Groups of trees of shrubs	40.37	0.9285
		143 Solitaire trees	0.76	0.0175
		151 Linear woody vegetation - continuous	12.34	0.2838
		152 Linear woody vegetation - intermittent	3.91	0.0899
		153 Linear woody vegetation a – scattered	2.54	0.0584
		170 Areas of shrubs	30.50	0.7015
		181 Riparian tree lines and shore vegetation – continuous	1.59	0.0366
		190 Permanent intersections	0.73	0.0168
Permanent grassland	Pastures	211 Pastures - used	173.89	3.9994
		212 Pastures - unused	10.13	0.2329
	Meadows	221 Meadows - intensive	422.64	9.7204
		222 Meadows – extensive	55.50	1.2765
		223 Meadow barrens	22.89	0.5265
	Extensive grassland herbaceous vegetation	230 Extensive grassland herbaceous areas with low level of successive woody vegetation	78.92	1.8151
		240 Extensive grasslands herbaceous areas with high level of successive woody vegetation	45.53	1.0472
	Reed beds	252 Reed beds with low number of woody plants	7.28	0.1674
		253 Reed beds with high number of woody plants	0.24	0.0055
Agricultural crops	Fields	310 Large block fields	75.73	1.7417
		320 Small and narrow-band fields	4.90	0.1127
	Orchards and allotment sites	351 Orchards - large	6.15	0.1415
		352 Orchards - small	27.05	0.6221
		361 Allotment sites – without buildings	10.54	0.2424
		362 Allotment sites – with buildings	11.22	0.2581
		383 Mosaic structures (arable land, orchards)	1.89	0.0435
Subsoil and substrate	Subsoil excavations and quarries	410 Subsoil excavations	0.46	0.0106
		432 Quarries - closed	5.51	0.1267
Watercourses and water areas	Water streams and water areas	510 Water streams	7.73	0.1778
		562 Water reservoirs	1.64	0.0377
		570 Wet, waterlogged areas	0.001	0.00002
Residential and recreational areas	Urban build-up areas	600 Urban build-up areas with residential vegetation	281.55	6.4755
	Rural build-up areas	610 Terraced rural buildings with attached gardens	95.05	2.1861
	Isolated residence objects outside the urban area with home gardens	621 Scattered buildings	44.34	1.0200
		622 Remote settlements	1.08	0.0200
	Historical objects	641 Churches	0.02	0.0005
	Cemeteries	650 Cemeteries	2.13	0.0489
	Recreational areas	662 Sports fields	3.25	0.0748
		691 Cottage settlements with gardens	32.08	0.7378
Technical elements	Agricultural buildings	722 Farms, farmyards	12.91	0.2969
	Individual construction or technical objects	751 Used objects	4.41	0.1014
	Other technical elements	791 Paved surfaces	0.20	0.0046
Group of transport elements	Roads	800 Secondary and other roads	25.52	0.5869
Total			**4,347.96**	**100.00**

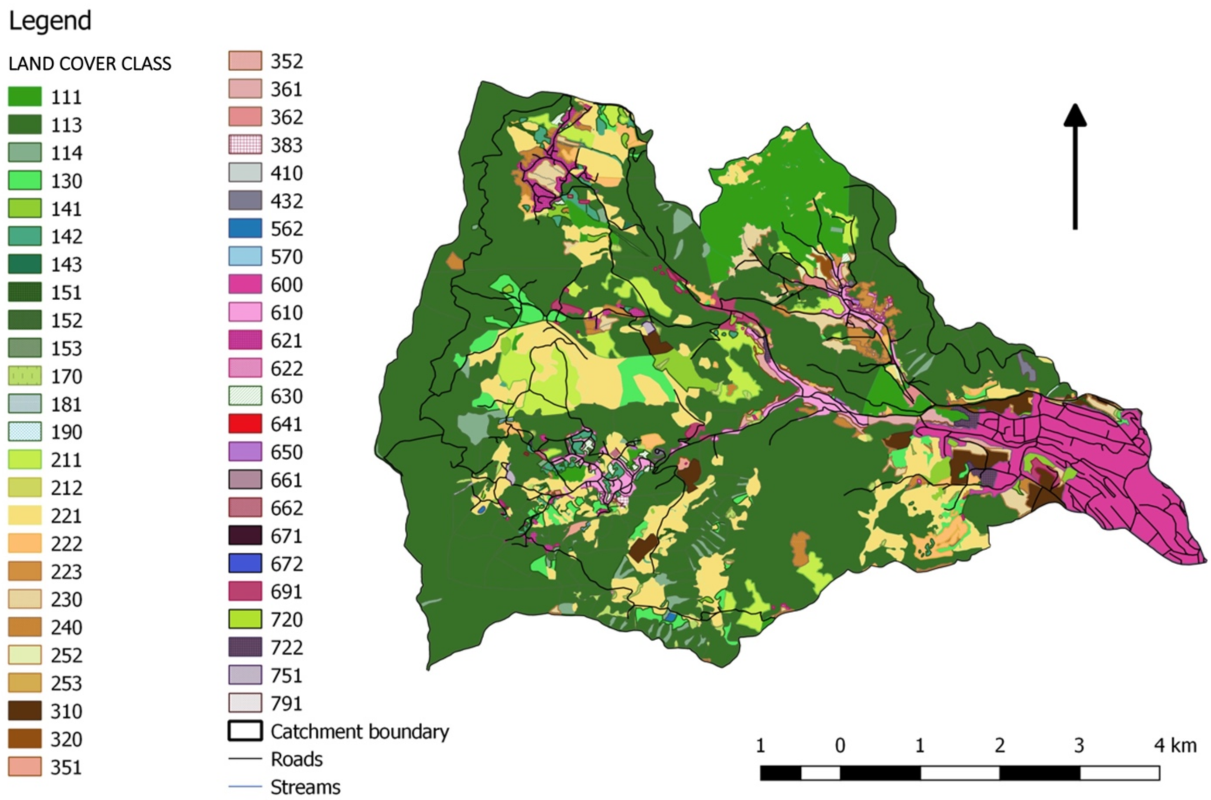

Figure 1. Land cover classes occurrence in the Tajovský brook basin. The codes from legend are listed in Table 1.

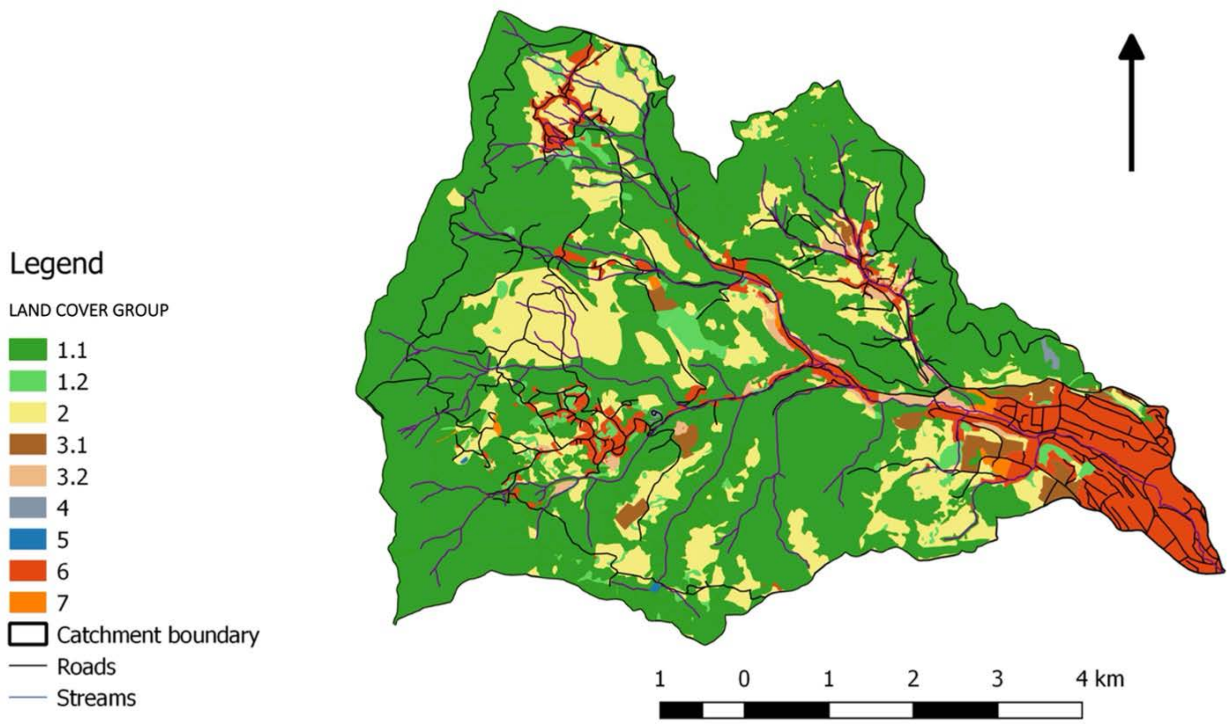

Figure 2. Land cover types in the Tajovský brook basin. The codes from legend are listed in Table 2.

The weighted mean was then calculated for each land cover type based on the partial area. The total CN II obtained for the catchment was 60.76. This is comparable with other studies, e.g. Spál & Szolgay (2013) who reported values 66 to 72 from three small catchments in western Slovakia.

Other studies reported on the effect that forest may have on decreasing runoff. Zhang (2014) showed

Table 2. Groups and their codes of land cover elements of the current landscape structure in the Tajovský brook catchment and the SCS CN curve numbers for four hydrologic soil group types. Highlighted are the prevailing soil types for each land cover type.

Land cover		Code	Area (ha)	Area (%)	HSGT	CN II	CN II*A(%)
Forest and non-forest tree vegetation		*1*	*2,920.99*	*67.18*			
	Forests	1.1	2,773.09	63.78	B	55	3,507.9
	Non-forest	1.2	147.90	3.40	B	48	163.2
Permanent grasslands		2	807.91	18.58	B	61	1,133.38
Agricultural		*3*	*137.47*	*3.16*			
	Fields	3.1	80.63	1.85	B	81	149.85
	Orchards, allotments	3.2	56.84	1.31	C	72	94.32
Subsoil and substrate		4	5.97	0.14	D	91	12.74
Watercourses and water areas		5	9.37	0.22	-	100	22
Residential and recreational		6	423.21	9.73	D	92	895.16
Technical		7	17.52	0.40	D	98	39.2
Transport		8	25.52	0.59	D	98	57.82
Total / Average			**4,347.96**	**100.00**		**79.6**	**60.76**

that runoff on wasteland was 11 times higher than under forest conditions, and forest also had the steadiest infiltration rates. The presence of vegetation with roots had positive effect on infiltration (Halley et al., 2000; Lin et al., 2005), not only trough root channel effects (Devitt & Smith 2002; Zhou et al., 2008) but also thanks to supplying organic or inorganic substances into the soil that increase water penetration and retention of soil (Hawes et al., 2000). Number of studies reported on the significant decrease of runoff after afforestation (Silveira & Alonso, 2009; Peel, 2009; Sajikumar & Remya; 2015) or increase after deforestation (Costa et al., 2003; Siriwardena et al., 2006).

In the original SCS CN model, the effect of individual tree species is not dealt with. But a study by Jost et al., (2011) showed a significant difference in retention response for spruce and beech forests due to different rooting systems. However, we have not noted any published data that would attribute CN number to a given dominant tree species, therefore some further experiments with regards to this would be very beneficial.

4.4 Runoff estimations using different initial abstraction ratio values

One month data were used from three precipitation stations and one river discharge station to observe the effect of the CN numbers on the runoff in the catchment (Figure 3). The total rainfall for this month was 132.7 mm. No rainfall was recorded for 10 days, the maximum precipitation occurred on 8th June (27 mm) and this was followed by week-long rains. The mean monthly discharge was 0.399 m^3/s and the peak discharge occurred on 11th June (1.16 m^3/s). The river flow reflected rainfall events but also the previous saturation of the catchment.

For each day, CN number was chosen, based on the AMC conditions (total rainfall during the last five days) during the growing season (Table 3). In 77% of cases, the AMC condition was I and only in 10% of days, AMC was III. CN II values were taken from the USDA table as reported earlier and CN I and III were calculated using relationships [6] and [7].

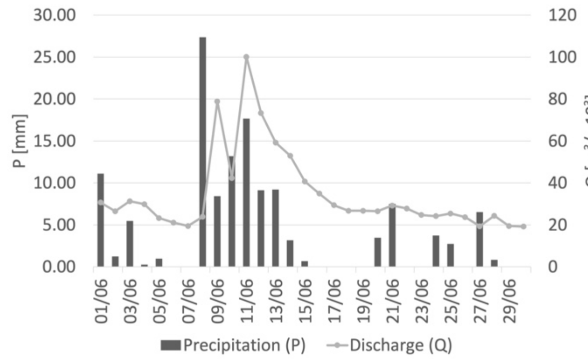

Figure 3. Combined mean catchment rainfall (P[mm]) and mean daily river discharge (Q m^3/s) during June 2012.

Table 3. AMC categories and the corresponding CN values based on the mean catchment rainfall during the last 5 days, for dormant and vegetation seasons.

	P (mm) dormant	P (mm) growing	CN type	CN value
AMC I (dry)	<13	<36	CN I	40.42
AMC II (normal)	13-28	36-53	CN II	60.76
AMC III (wet)	>28	>53	CN III	78.38

To establish the runoff value, *S*, the maximum potential retention was calculated using the equation [2]. Its values ranged from 374.04 to 74.6. For instances where P < λ*S, the runoff was set to zero, otherwise the equation [1] was used to calculate the runoff O [mm].

Number of values of initial abstraction coefficient λ were tested for the runoff calculations. The standard value for λ = 0.2 did not work with the chosen dataset and the total monthly runoff came to 0 mm, which is unlikely considering the 06/2012 hydrograph (Fig. 3). Other authors came to similar conclusions (Karabová et al., 2012; Spál & Szolgay, 2013; Satheeshkumar, 2017). Jain (2006) in a study of 307 catchments showed 90% of λ being less than 0.2. Further values of λ were tested and the results are summarized in Table 4. River discharge was summed to Q = 1.035 km^3 for the whole month. The base flow was also established, based on days with no rainfall to Q_b = 0.800 km^3. The difference gave a rough simplified estimate of possible amount of runoff O = 0.234 km^3. The total monthly runoff for each λ was subtracted from the total monthly river flow. The value of λ closest to possible estimated runoff was 0.01 which suggests that this value would be most suited for the runoff calculations for this catchment. Also λ = 0.005 provided reasonably good results, however λ = 0 was not suitable, providing significantly more runoff than there was in terms of total amount that was gaged at the end-point flow station. Figure 4 shows exponential curve fitting for the precipitation/runoff relationship for two most appropriate values of λ.

Table 4. The impact of initial abstraction ratio λ values on the runoff amount in mm and m^3.

λ	**O [mm]**	**O [m³]**	**O_{max} [m³]**	**D_{Q-O} [$m^3.10^6$]**
0.2	0.00	0.00	0.00	1.035
0.15	0.00	0.00	0.00	1.035
0.1	0.14	6.04	2.90	1.029
0.05	1.71	74.20	22.45	0.961
0.01	5.76	250.63	62.02	0.784
0.005	6.67	290.03	70.67	0.745
0	132.7	5,769.80	1,189.90	-4.735

Our findings do not comply with a study of 109 catchments by Cazier & Hawkings (1984) who showed that λ = 0 was the most common appropriate coefficient. Baltas et al., (2007) came to value of 0.014 which is similar to our result. Kohnová et al. (2020) in a study of Slovak and Polish catchments set the optimal value to 0.015.

This test complies with findings of other authors; however, these values should be tested on more hydrographs, considering hydrological extremes at both ends. Interesting would be also to compare other CN approaches to the original CN method as this was shown by Randusová et al., (2015) as the least accurate, highlighting the need for regional calibration not only of λ but also of CN values that are not constant but appear to be a function of regional rainfall-runoff processes, current land-use conditions, antecedent rainfall, relief, and soil moisture (Kohnová et al., 2020).

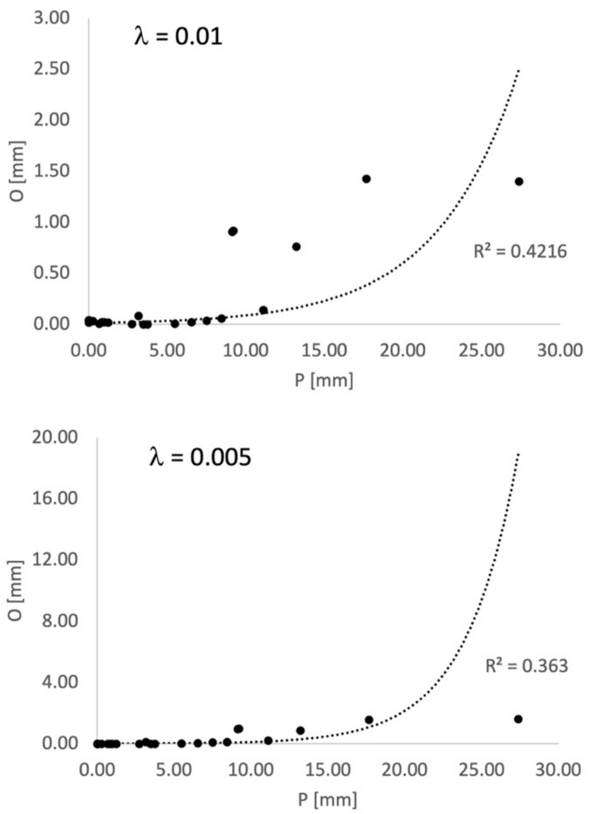

Figure 4. Mean daily precipitation P [mm] and computed runoff O [mm] based on λ = 0.01 and on λ=0.005 calculated using the SCS CN method for precipitation data during June 2012.

5. CONCLUSION

The processes of runoff in natural environment are very complex and their correct estimation despite numerous scientific studies remains a hydrological challenge. Runoff is a function of the heterogenic conditions of the environment; such as land use, diversity, condition and age of vegetation, root systems, hydrologic attributes of soils, geology, landform, rainfall, flow conditions etc. Furthermore, these attributes change in time and can differ from event to event.

What has been shown is that the good state of vegetation and land management as well as the overall land use are important to mitigate the effects of hydrological extremes. It is crucial to have a detailed picture about the land cover which can then be connected to various runoff estimations. In this paper we have presented results of detailed vegetation and landcover study in the Tajovský brook catchment, in the central Slovakia. GIS land cover analysis was accompanied by a field survey and the dominant species were described and quantified. Based on the landcover, dominant hydrologic soil groups were identified, and weighted curve numbers were added from standard USDA Soil Conservation Service methodology, widely used worldwide to estimate the catchment runoff. Tree cover occupied 29.2 km^2 (or 67%) of the entire catchment area and was attributed to the lowest CN values out of the all-land cover types.

The original CN method was based on empirical data only from US catchments, therefore number of studies identified issues with its accuracy, suggesting regional calibrations. In this paper, we have taken one variable to test. Seven different values of the initial abstraction ratio were selected for runoff calculations and the most appropriate value for the given hydrologic conditions in this was determined. Our findings comply with other studies, but more rainfall/runoff events should be tested to establish the most suitable parameter for this catchment with higher certainty. Appropriate initial abstraction ration could be than applied to other catchments with similar soils, vegetation, and land use properties. This is especially important in ungagged catchments with no data and in the context of increasing frequency and magnitude of hydrological extremes.

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