INFLUENCE OF LAND USE ON LOW FLOWS FORMATION (CASE STUDY OF TWO SMALL CATCHMENTS AT THE MALOPOLSKA UPLAND)

A. Kasprzyk, T. Biernat

Jan Kochanowski University of Humanities and Natural Sciences, Institute of Geography, Kielce, Poland
arturo@pu.kielce.pl

Introduction

The studies on hydrological effects of land use and catchment changes, especially in the periods of flood has been the subject of interest of many hydrologists. The results of their investigation are presented in the polish and foreign hydrology textbooks (Byczkowski, 1999; Chelmicki, 2001; Maidment, 1993). Relatively a few analyses deal with the role of forest areas in forming runoff during drought periods have been made so far. Some examples of the hydrologic consequences of plant cover changes in the catchments, including deforestation and reforestation in different climatic zones can be found in chapter 9 of the textbook Hydrological Drought (Tallaksen, Van Lanen, 2004).

Subject of the analysis

The aim of this study is to present the differences in hydrological drought development in two small catchments, based on precipitation and streamflow records for (1979–1992) carried out by Forest Research Institute in Warsaw.

Both catchments are situated in the northwest part of Malopolska region, they have similar areas, elevation and topography but they differ in land use (Table 1).

Table 1. The catchments characteristics and land use

Station	River	Physiographic parameters				Land use in % of total area			
		A	L	Hg	I	Forests	Arable lands	Meadows	Waste lands
		km^2	km	m a.s.l.	‰				
Wolka Kłucka	Lososinka	24.4	5.8	283	5.57	10.4	67.9	21.7	-
Oselkow	Jaslanka	21.3	8.5	359	8.82	50.9	30.3	10.8	8.0

A – basin area, L – length of the river, Hg – mean basin elevation, I – mean basin slope

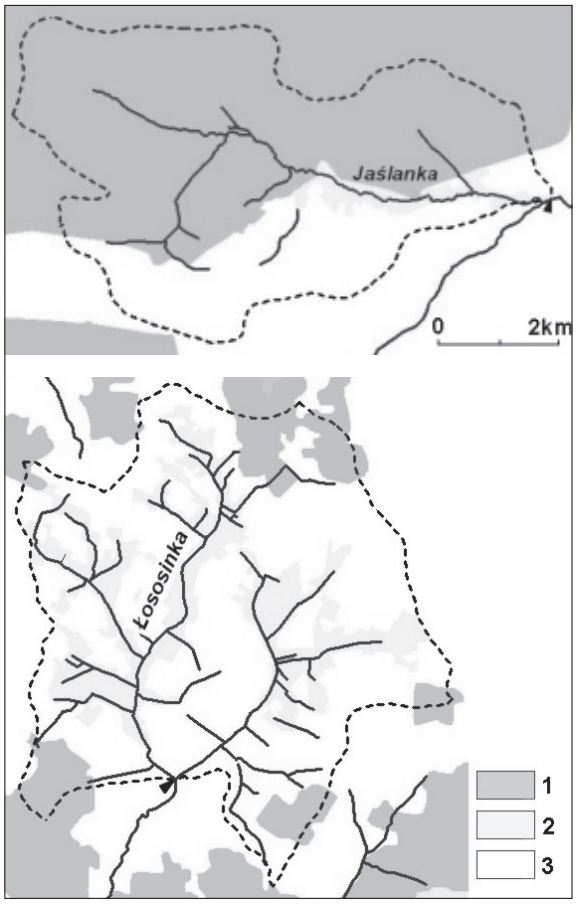

Figure 1. Jaslanka and Łososinka catchments1 – forests, 2 – meadows, 3 – arable lands

In the Jaslanka catchment, forests cover over 50% of the area and they constitute a densely mixed-forest complex which coat the whole upper and left part of the basin. The basin areas of the Lososinka are predominantly used as the farmlands and meadows (total covering nearly 90% of the whole area) and small forests are scattered over the whole basin (Figure 1). Meadows in Lososinka are located at wet lands which contribution to whole area is grater than at Jaslanka, also river network of this agricultural catchment is more dense.

Comparison of low flows parameters

In the comparative analysis of low flows, the following parameters were considered :

– The beginning and the end of low flow
– Duration of the low flows
– Frequency of low flow events
– Mean and minimal discharge of low flows
– Runoff deficit calculated from runoff hydrograph (area below threshold value $Q_{70\%}$) Deficit volume was standardized by the mean volume of annual runoff.

The analysis of the hydrograph, low flow events selection and runoff deficit computation have been made by using EXDEV program (Nowicki, Kasparek, 1994).

Table 2. Low flow parameters and discharge characteristic for low flow events in multi-year period 1979-1992

Characteristic		Lososinka	Jaslanka
Number of low flow		39	49
Maximum duration of low flow in days		201	65
Mean duration of low flow in days		33	20
Threshold discharge ($Q_{70\%}$) in $m^3 \cdot s^{-1}$		0.123	0.118
Minimum discharge of low flows in $m^3 \cdot s^{-1}$		0.011	0.000
Average from minimum discharge (specific runoff in $dm^3 \cdot s^{-1} \cdot km^{-2}$)		0.88	0.09
Classes of runoff deficit in % annual runoff	0.01-0.59	58	70
	0.60-1.00	16	16
	1.01-2.00	18	14
	2.01-3.00	0	0
	> 3.01	8	0

The comparison of the parameters (Table 2) shows, that the low flow more often occurs in the forested Jaslanka catchment. However, duration of low flows is higher in Lososinka and in consequence runoff deficit of Lososinka river appeared to be larger (8 cases of the deficit over 3% of mean annual runoff). In average, low flow minimal discharge (expressed by specific runoff) of Jaslanka is ten times lower than Lososinka and in some cases, during prolonging atmospheric droughts (1983-1985) Jaslanka river is drying up.

Recession curves characteristics

The baseflow recession model was used to describe decreasing portions of streamflow derived from of groundwater resources. It represents the lower part of falling limb of hydrograph, below the point Q_0 separating direct runoff from groundwater flow. Several methods have been elaborated for describing groundwater contribution to streamflow, during low flow (Anderson, Burt, 1980; Tallaksen,1995). In this study, method suggested by Radczuk and Szarska, 1989, (derived from Maillett's equation) was used to define recession curve equation.

$$Q_t = (Q_0 - Q_B)e^{-\alpha t} + Q_B$$

where:

Q_0 - initial baseflow discharge [$m^3 s^{-1}$], Q_B - base flow [$m^3 s^{-1}$],
t - time in days,
α - recession curve ratio

The recession parameters have been estimated by using the least squares method on the bases of the several summer streamflow recessions, separated from the hydrograph. Master baseflow curves illustrated in the Figure 2 show, that curve for forested catchment Jaslanka is more steeper and its base flow is lower than for Lososinka.

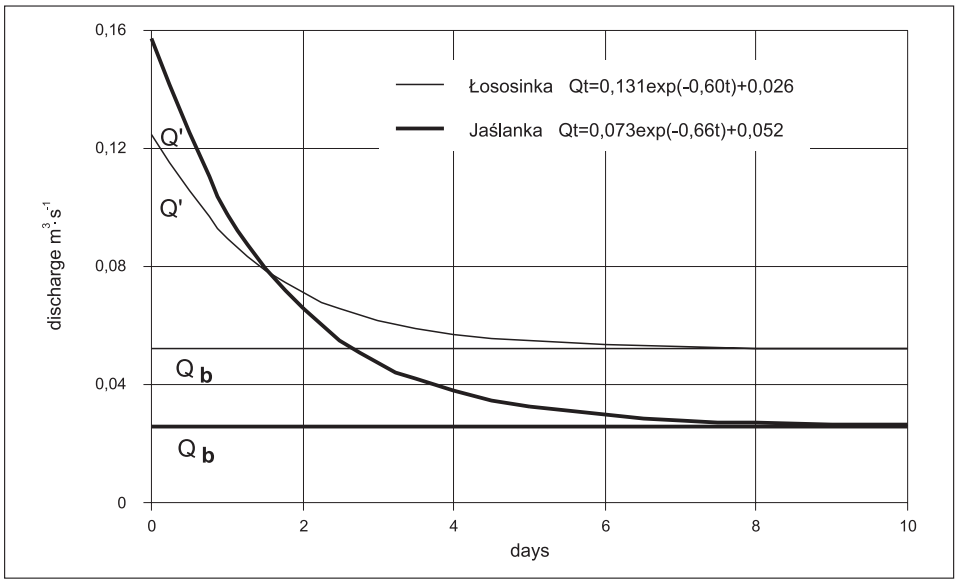

Figure 2. Recession curves of discharge for Łososinka and Jaslanka
Qb – base flow, $Q^{\cdot} = Q_0 + Q_b$, where Q_0 – initial discharge

Conclusions

The results of the comparative analysis of low flows characteristics can be composed as follows:

- Low flows occurred more often in the forested Jaslanka catchment, but duration of low flow events is much grater in Lososinka
- Minimal specific discharge during low flow periods is significantly lower for Jaslanka in comparison to Lososinka.
- The recession curves parameters showed that portion of streamflow derived from groundwater in the Jaslanka diminished to the lower level than in Lososinka. During the long dry periods streamflow of the Jaslanka river decay. It is probably the result of the intensive exhaustion of groundwater storage for the transpiration process in the forested area.

The role of forests in low flow creation is complex and not unidirectional for whole dry period. At the beginning of drought, plant cover retention and interflow from wooded area support river channels supply. During the phase when streamflow is mainly groundwater effluent, forest trees reduce water resources of the catchment.

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