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WATER BALANCES IN THE SMALLER DRAINAGE AREAS OF THE TYWA RIVER BASIN (1961-1990)

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Abstract

The work presents water balance indexes for some smaller river basins in the Tywa river basin. The estimation of water balance indexes was worked out for months from IV to IX, half-years (X-III), (IV-IX) and year (X-IX), (period 1961-1990). The work presents also introductory analysis of precipitation's influence on retention index.

Key words: hydrology, water balance

INTRODUCTION

Correct water economy in the drainage area will be possible if its water resources (surface and underground) and the water balances are precisely determined. It is particularly essential for the small drainage areas, for which no water-gauge observations are provided.

The aim of this study was to estimate the water balance indexes for the selected smaller drainage areas of the Tywa river basin. The estimations were worked out for the months of the summer half-year (IV-IX), half-years: winter (X-III) and summer (IV-IX) and the year (X-IX) within the multiple-year period 1961-1990. The study also presents the preliminary analysis of the precipitation effect on the coefficient of changes in the retention states.

The water balance was estimated by means of the equation

$$P = H + V + \Delta R \text{ [mm]}$$

where:

P - precipitation index, H - run-off index, V - evaporation index,
ΔR - coefficient of changes in retention states

GENERAL CHARACTERISTICS OF THE TYWA BASIN

The Tywa river is a right tributary of the Eastern Odra (Fig.1). The area of the basin equals 256,4 km^2 (IMGW 1980, 1983). The Tywa basin abuts on the drainage areas of the Rurzyca, Myśla and Płonia. The Tywa river basin is located in the XXX hydrographic region, 57 and 73 subregions, within the Lower Odra area (PAN 1959).
The areas of the individual smaller basins for the adopted hydrometric cross sections equal: A_1 = 16,0 km^2, A_3 = 17,2 km^2, A_4 = 118,0 km^2, and A_5 = 252,0 km^2 (Duda et al 1991). This study takes no account of the smaller drainage area for the hydrometric cross section No 2, due to the joint studies of the surface water resources for the hydrometric cross sections No 2 located in the Tywa and Rurzyca river basins (no possibility of the separate indication of the smaller drainage areas for these cross sections due to the hydrological bifurcation occurring between them). Detailed discussion of the problem is contained in the work of Duda et al. (1991).

The Tywa basin is located in the climatic lands: IV - Pyrzyce-Goleniów and VI - Myslibórz Lake District. The length of vegetation period for these lands ranges between 215 and 220 days (Prawdzic 1961).

The mean yearly precipitation for the Tywa drainage area (1961-1990) equals 559 mm. Wheraes for the smaller drainage areas into the individual hydrometric cross sections: p.No 1 P = 576 mm, p. No 3 P = 576 mm, p. No 4 P = 573 mm and p. No 5 P = 559 mm (Table 1). Due to these values, the climate of the Tywa basin can be recognized as slightly humid (Lambor 1965).

Below are the physiographic parameters, soil kinds and the usage of the drainage area, according to the works of Duda et al (1979, 1991). The density of the water-courses in the Tywa basin equals 0,42 km/km^2, the longitudinal declivity of the river equals 2,2%, and the mean declivity of the drainage basin - 18%. The mean elevation of the drainage area equals H_{sr} = 57 m above sea level.

About 67% of the drainage area is covered with the podsolic soils which are located in the central and lower parts of the basin. Light brown and medium brown soils cover about 27% of the drainage area and occupy mainly its upper section. The lakes (Długie Bańskie, Długie, Strzeszowskie among others) - constitute about 3% of the basin.

Arable grounds occupy 68% of the area, forests and forest arable grounds about 8%. The utilization structure differs within the individual smaller drainage areas, i.e.

- permanent grasslands from 8% (p.4) to 31% (p.1 and 3)
- forests and forest arable grounds from 0.6% (p.3) to 21% (p.5)
- arable grounds from 67% (p.3) to 70% (p.4).

Pronczuk (1956) states that in order to provide forage basis, the minimum area of grass lands should equal 25%. Within the Tywa drainage system, this condition is met in the smaller drainage areas (p. 1 and 3) located in the upper part of the basin.

Table 1

Mean water balance indices (P, H, V, ΔR - mm), period 1961-1990, estimated for smaller river basins of Tywa river basin

Indexes of water balance	Months												Half-years	Year	
	X	**XI**	**XII**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X-III**	**IV-IX**	**X-IX**
Hydrometric cross section No 1															
P	41	46	50	38	31	35	42	53	71	63	56	50	241	335	576
H	6	7	10	12	13	15	15	12	7	6	6	6	63	52	115
V	22	9	5	5	8	18	49	69	74	80	72	50	67	394	461
ΔR	13	30	35	21	10	2	-22	-28	-10	-23	-22	-6	111	-111	0
Hydrometric cross section No 3															
P	41	46	50	38	31	35	42	53	71	63	56	50	241	335	576
H	6	8	12	15	16	19	19	15	8	6	6	6	76	60	136
V	21	9	4	5	8	17	47	66	71	76	69	47	64	376	440
ΔR	14	29	34	18	7	-1	-24	-28	-8	-19	-19	-3	101	-101	0
Hydrometric cross section No 4															
P	41	46	50	39	32	36	41	54	70	62	54	48	244	329	573
H	7	8	10	12	12	14	14	12	8	7	6	6	63	53	116
V	22	9	5	5	8	17	49	69	74	79	71	49	66	391	457
ΔR	12	29	35	22	12	5	-23	-27	-12	-24	-23	-7	115	-115	0
Hydrometric cross section No 5															
P	40	46	48	39	32	34	41	52	67	61	53	46	239	320	559
H	5	6	10	12	12	15	15	12	7	5	5	5	60	49	109
V	22	9	4	5	8	17	48	68	72	78	70	49	65	385	450
ΔR	13	31	34	22	12	2	-22	-28	-12	-22	-22	-8	114	-114	0

SOURCE MATERIALS

For the estimation of the water balance indexes by means of the correlates method the following materials were taken:

- mean monthly deficiency of the air humidity for the meteorological station in Lipki (archives of Chair of Agrometeorology, Agricultural University of Szczecin),
- precipitation index for the individual hydrometric cross sections for the years 1961-1985 was obtained from the work of Duda et al (1987), whereas for years 1986-1990 it was estimated by means of the method of equal precipitation polygons on the basis of the precipitation for the following stations: Gryfino, Linie, Trzcińsko Zdroj, Banie, Widuchowa (archives of IMGW)
- mean monthly, half-yearly and yearly discharge - archives of Agricultural Ameliorations Laboratory, Agricultural University of Szczecin.

Estimations of the water balance by means of the correlates method were made on the “Lambor 45” computer program (Jezierski 1992).

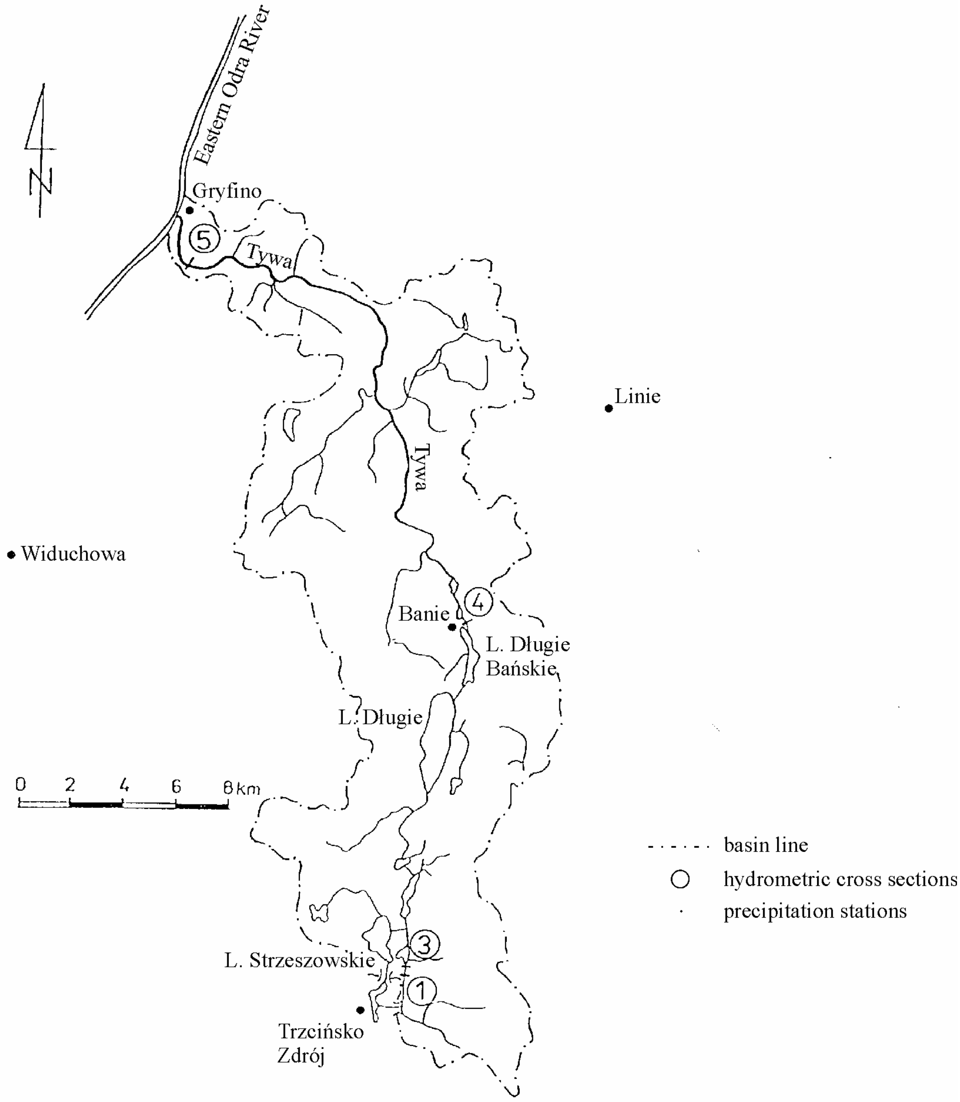

Fig. 1. Hydrographic map of Tywa river basin

Precipitation indices

The precipitation indices P [mm] were estimated by means of the method of equal precipitation polygons. In the multi-year period 1961-1990 the variability of the yearly precipitation $K_p = P_{max}/P_{min}$ for the individual cross sections equaled:

hydrometric cross section number	P_{max} [mm]	P_{min} [mm]	$K_p = P_{max}/P_{min}$
1	835	290	2,88
3	835	290	2,88
4	800	307	2,61
5	731	308	2,37

Run-off indices

There are no multi-year observation records (water state, discharge) for the Tywa basin, on which singular discharges and run-offs could be estimated. Therefore the estimations of the mean monthly, half-yearly and yearly singular run-offs are based on the method elaborated by Duda (1978).

The run-off indices H [mm] for the years 1961-1985 were estimated on the basis of the mean monthly singular run-offs from the work of Duda et al (1991), whereas for the years 1985-1990 the mean monthly singular run-offs Sq [$l/s \cdot km^2$] were estimated by the equations from Duda et al (1991), to be followed by the estimation of the run-off indexes which were matched in Table 1.

Evaporation indices

Evaporation indices (V) were estimated by means of the correlates method (Lambor, 1956). The correlates method consists in the estimation of the filed evaporation (evaporation from the soil and overgrowth together with transpiration) basing on the deficiency of air moisture.

The balance estimations were based on the hydrologic year from October 1 to September 30 (X-IX). The winter half-year comprises the period between October 1 and March 31 (X-III), and the summer one between April 1 and September 30 (IV-IX) respectively. This division differs considerably from the hydrologic year (XI-X), commonly assumed for the estimations due to the fact that April is a vegetation month in agriculture.

The field evaporation (V) estimated by means of the correlates method from the multi-year period 1961-1990 equals:

hydrometric cross		**V [mm]**	
section number	X-III	IV-IX	X-IX
1	67	394	461
3	64	376	440
4	66	391	457
5	65	385	450

The yearly field evaporation for the smaller drainage areas into each hydrometric cross section ranges from 440 mm (p.3) to 461 mm (p.1). Out of the total yearly evaporation, 14% (p.4 and 5) and/or 15% (p.1 and 3) occurs in the winter half-year (X-III), whereas 86% (p.4 and 5) and 85% (p.1 and 3) in the summer half-year (IV-IX), respectively.

Coefficients of changes in retention states

The coefficients of changes in retention states (ΔR) have resulted from the subtraction of the precipitation, run-off and field evaporation (ΔR = P - H - V). The values are shown in Table 1.

DISCUSSION ON THE INDICES OF WATER BALANCE DETERMINED FOR THE SMALLER DRAINAGE AREAS FOR THE ACCEPTED HYDROMETRIC CROSS SECTIONS OF THE TYWA RIVER BASIN (1961-1990).

Hydrometric cross section No 1

The mean yearly precipitation index (Table 1) equals 576 mm, out of which 241 mm (42%) is assigned to the winter half-year, and 335 mm (58%) to the summer one. The year with the heaviest precipitation was 1990 (P = 835 mm), whereas the heaviest drought occurred in 1963 (P = 290 mm). The maximum monthly precipitation index P = 174 mm was observed in August 1978, whereas the minimum one P = 3 mm in March 1984 (Table 1).

The mean yearly run-off index (Table 1) equals 115 mm, out of which 63 mm (55%) is assigned to the winter half-year, and 52 mm (45%) to the summer one. The maximum yearly run-off index occurred in 1988 (H = 191 mm), whereas the minimum one in 1990 (H = 62 mm). January 1975 was characterized by the maximum run-off (H = 30 mm), whereas the minimum run-off (H = 3 mm) occurred repeatedly (August and September 1976 and 1982, August, September and October 1983, October 1984, July, August, September 1989 and October and November 1990).

The mean evaporation index (Table 1) equals 461 mm, out of which 67 mm (14%) is assigned to the winter half-year, and 394 mm (86%) to the summer one. The maximum evaporation occurred in 1982 (V = 669,3 mm), and the minimum (V = 361,8 mm) in 1965. The maximum monthly evaporation index for the summer half-year occurred in September 1982 (V = 195 mm), whereas the minimum one (V = 31,8 mm) in September 1978 (Table 1).

The maximum retention increase (ΔR = 288,2 mm) was observed in 1965, whereas the maximum decrease (ΔR = -325,3 mm) in 1982. The maximum coefficient of the retention changes (ΔR = 103,4 mm) occurred in August 1978, whereas the minimum one (ΔR = -186 mm) in September 1982 within the summer half-year.

Hydrometric cross section No 3

The mean yearly precipitation index (Table 1) equals 576 mm, out of which 241 mm (42%) is assigned to the winter half-year, and 335 mm (58%) to the summer one. The year with the heaviest precipitation was 1990 (P = 835 mm), whereas the heaviest drought occurred in 1963 (P = 290 mm). The maximum monthly precipitation index (P = 213 mm) was observed in June 1990, whereas the minimum one (P = 6 mm) in June 1970.

The mean yearly run-off index (Table 1) equals 136 mm, out of which 76 mm (56 %) is assigned to the winter half-year, and 60 mm (44 %) to the summer one. The maximum yearly run-off index occurred in 1967 (H = 167 mm), whereas the minimum one in 1979 (H = 45 mm). September 1979 was characterized by the maximum run-off (H = 45 mm), whereas the minimum run-off (H = 2 mm) occurred repeatedly (September 1992, July, August, September 1989).

The mean evaporation index (Table 1) equals 440 mm, out of which 64 mm (14%) is assigned to the winter half-year, and 376 mm (86%) to the summer one. The maximum evaporation occurred in 1982 (V = 647,3 mm), and the minimum (V = 343.6 mm) in 1965. The maximum monthly evaporation index for the summer half-year occurred in September 1982 (V = 187,9 mm), whereas the minimum one (V = 30 mm) in September 1978.

The maximum retention increase (ΔR = 279,4 mm) was observed in 1965,whereas the maximum decrease (ΔR = -333,3 mm) in 1982. The maximum coefficient of the retention changes (ΔR = 107 mm) occurred in August 1978 for the summer half-year (IV-IX), and the minimum one (ΔR = -177,9 mm) in September 1982.

Hydrometric cross section No 4

The mean yearly precipitation index (Table1) equals 573 mm, out of which 244 mm (43%) is assigned to the winter half-year, and 329 mm (57%) to the summer one. The year with the heaviest precipitation was 1990 (P = 800 mm), whereas the heaviest drought occurred in 1963 (P = 307 mm). The maximum monthly precipitation coefficient (P = 206 mm) was observed in May 1990, whereas the minimum one (P = 3 mm) in March 1984.

The mean yearly run-off index (Table 1) equals 116 mm, out of which 63 mm (54%) is assigned to the winter half-year, and 53 mm (46%) to the summer one. The maximum yearly run-off index occurred in 1988 (H = 178 mm), whereas the minimum one in 1990 (H = 72 mm). April 1979 was characterized by the maximum run-off (H = 30 mm), whereas the minimum run-off (H = 4 mm) occurred repeatedly (August and September 1976, 1981 and 1982, October and November 1984, July, August, September 1989 and October and November 1990).

The mean evaporation index (Table 1) equals 457 mm, out of which 66 mm (14%) is assigned to the winter half-year, and 391 mm (86%) to the summer one. The maximum evaporation occurred in 1982 (V = 665,5 mm), and the minimum (V = 360,6 mm) in 1965. The maximum monthly evaporation index for the summer half-year occurred in September 1982 (V = 193 mm), whereas the minimum one (V = 31,7 mm) in September 1978.

The maximum retention increase (ΔR = 253,4 mm) was observed in 1965,whereas the maximum decrease (ΔR = -324,5 mm) in 1982. The maximum coefficient of the retention changes (ΔR = 93,2 mm) occurred in June 1990 for the summer half-year, and the minimum one (ΔR = -185 mm) in September 1982.

Hydrometric cross section No 5

The mean yearly precipitation index (Table 1) equals 559 mm, out of which 239 mm (43%) is assigned to the winter half-year, and 320 mm (57%) to the summer one. The year with the heaviest precipitation was 1961 (P = 731 mm), whereas the heaviest drought occurred in 1963 (P = 308 mm). The maximum monthly precipitation index P = 186 mm was observed in June 1990, whereas the minimum one P = 4 mm in April 1974.

The mean yearly run-off index (Table 1) equals 109 mm, out of which 60 mm (55%) is assigned to the winter half-year, and 49 mm (45%) to the summer one. The maximum yearly run-off index occurred in 1988 (H = 181 mm), whereas the minimum one in 1990 (H = 52 mm). April 1979 was characterized by the maximum run-off (H = 34 mm), whereas the minimum run-off (H = 2 mm) occurred repeatedly (August and September 1979, September 1982, August and September 1983 and July, August and September 1989).

The mean evaporation index (Table 1) equals 450 mm, out of which 65 mm (14%) is assigned to the winter half-year, and 385 mm (86%) to the summer one. The maximum evaporation occurred in 1982 (V = 657,1 mm), and the minimum (V = 354,2 mm) in 1965. The maximum month evaporation coefficient for the summer semi-year occurred in September 1982 (V = 189,9 mm), whereas the minimum one (V = 31,1 mm) in September 1978.

The maximum retention increase (ΔR = 245,8 mm) was observed in 1965, whereas the maximum decrease (ΔR = -338,1 mm) in 1982. The maximum coefficient of the retention changes (ΔR = 105,1 mm) occurred in June 1990 for the summer half-year (IV-IX), and the minimum one (ΔR = -177,9 mm) in September 1982.

Precipitation effect on the coefficients of changes in retention states

One of the factors which effects the coefficients of changes in retention states (ΔR) is the precipitation (P). In order to estimate this effect, the correlation coefficients (r) and the linear regression equations were estimated. The estimations were worked out for the winter half-year (X-III). The linear regression equations, correlation coefficients and the errors of standard estimation are matched in Table 2. The linear regression equations will allow the anticipation of the coefficient of changes of retention states for the day of April 1, i.e. the beginning of the vegetation season. The equations presented in this study constitute the preliminary to the further analysis of the effects of the climatic factors, physiographic parameters and soil genera, to be presented in another study by the authors. The analysis of the precipitation effect (from various periods) and the mean air temperature was presented in Duda and Żygas (1983) for the rivers of the northern part of Szczecin region. The values of the correlation coefficients between the coefficient of changes in retention states (ΔR_{X-III}) and the precipitation (P_{X-III}) presented in Duda and Żygas (1983) are very high-essential, at the essentiality level p = 0.1%, similarly to those obtained in this study.

CONCLUSIONS

1. The precipitation index for the Tywa basin from the multi-year period 1961-1990 equals P = 559 mm out of which 239 mm i.e. 43% is assigned to the winter half-year, and 320 mm, i.e. 57% to the summer one.
2. The coefficients of the yearly precipitation irregularity for the smaller drainage areas of Tywa range between 2,61 (p.4) and 2,88 (p.1 and p.3).
3. The mean run-off index from the multi-year period 1961-1990 equals H = 109 mm out of which 60 mm, i.e. 55% is assigned to the winter half-year, and 49 mm, i.e. 45% to the summer one.
4. The coefficients of the yearly run-off indexes irregularity for the individual smaller drainage areas of the Tywa range from 2,47 (p.4) to 4,39 (p.5)
5. The mean evaporation index from the multi-year period 1961-1990 equals V = 450 mm, out of which 65 mm, i.e. 14% is assigned to the winter half-year, and 385 mm, i.e. 86% to the summer one.
6. The correlations between the coefficient of retention changes from the winter half-year and the precipitation index of the winter half-year for the smaller drainage areas of the Tywa are very high-essential statistically, proven at the essentiality level p = 0.1%.

Table 2

Correlation coefficients r, linear regression equations, errors of standard estimations S_{yx} [mm] for relation between relation index DR [mm] and precipitation index P [mm] for some smaller river basins in the Tywa river basin

Number of hydrometric cross section	Correlation coefficient r	Linear regression equation	Error of standard estimation S_{yx} [mm]
1	0,94***	$DR_{X-III} = -79{,}272+0{,}789P_{X-III}$	18,3
3	0,87***	$DR_{X-III} = -65{,}957+0{,}696P_{X-III}$	24,9
4	0,96***	$DR_{X-III} = -78{,}495+0{,}795P_{X-III}$	14,6
5	0,93***	$DR_{X-III} = -62{,}899+0{,}742P_{X-III}$	17,5

explanation: *** - correlation with probability p = 0,1%

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BILANSE WODNE ZLEWNI CZĄSTKOWYCH DORZECZA RZEKI TYWA (1961 - 1990)

Streszczenie

W pracy przedstawiono wskaźniki bilansu wodnego dla wybranych zlewni cząstkowych dorzecza Tywy. Obliczenia wskaźników bilansu wodnego wykonano dla miesięcy półrocza letniego (IV-IX), półroczy: zimowego (X-III) i letniego (IV-IX) oraz roku (X-IX) wielolecia 1961-1990.

W pracy przedstawiono również wstępną analizę wpływu opadu na wskaźnik zmian stanów retencji.