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WATER EROSION OF AGRICULTURAL LOESS CATCHMENT IN TRZEBNICA HILLS

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A b s t r a c t. Catchment of the Mielnica Stream is situated in Trzebnica Hills area, covered with loess soils and under an intensive agricultural use. Bathometrical and hydrometrical measurements were taken in the hydrological years 1982/83-1993/94. Daily and periodical masses of a suspended load carried out through the hydrometrical cross-section, flow and unit run-off rates were analysed. The weight of total measured annual sediment ranged from 2.56 Mg to 295.94 Mg. Value of the mean annual flow rate, at the catchment closing cross-section, ranged from 8 to 19 l s^{-1} and the maximum daily values from 18 to 434 l s^{-1}. Additional analyses of water chemical composition were made in the years 1988-1990. Sixteen different chemical compounds and elements were investigated. Calculated chemical denudation indices were determined by the hydrometeorological conditions.

K e y w o r d s: water erosion, chemical denudation, unit run-off.

INRODUCTION

The Trzebnica Hills area is under intensive agricultural use as its soil cover is very fertile. Relation between anthropogenic factors and environmental elements gives rise to many negative processes e.g., water erosion. Problems of soils degradation, relief changes, silting-up of water reservoirs, irrigation systems exploitation can be met there. Chemical compounds dissolved in water and bound with suspended load are washed out from the soil profile and carried out from the catchment. Surface water pollution is the result. Because of that estimation of the quantity and dynamics of changes of erosion processes and localisation of eroded areas is a very important task. Investigation on the intensity of water erosion processes in the catchment is necessary in order to realise the task in question [2].

RESEARCH METHODS

The Trzebnica Hills are situated in the Low Silesia province in Trzebnica administrative district. The phenomena of erosion in this area has not been well investigated.

The erosion threat potential is determined by hilliness, loess soil cover which is very susceptible to erosion and the intensive agricultural use. The monitored catchment of the Mielnica Stream is situated in above mentioned region.

Investigations on erosion intensity were conducted both in the field and laboratory conditions. The following measurements were taken:

- daily measurements of water levels at the catchment closing cross-section;
- periodical flow rates measurements by the hydrometric current meter;
- daily bathometrical measurements and laboratory analysis;
- periodical analyses of chemical compositon of the water samples.

The aim of the investigation was to estimate intensity of erosion processes basing on the analysis of the sediment carried out and amounts of chemical compounds [1].

Site Description

The investigated catchment of the Mielnica Stream is situated in the Low Silesia province, in the Trzebnica administrative district. In the catchment there are such villages as: Boleścin, Głuchów Dolny and Głuchów Górny, Radłów, Skotniki, Piersno and Krakowiany. The stream supplies the Dobra River, which is the Widawa River tributary. The Widawa is a part of the Odra River system. The catchment area is 6.67 km^2. Elevation ranges from 171.25 m a.s.l. to 246.1 m a.s.l. Its length is 3.675 km (length of the stream 3.096 km), the mean width is 1.81 km and the density of hydrographical net is 0.84 km km^{-2}. Density of the hydrographical net rises to 1.25 km km^{-2} if we take into consideration streams periodically leading water. In the catchment area there is 0.364 km^2 of mostly stabilised gullies. The average slope inclination in the catchment is 2.9% as calculated on the basis of the slope map, the average slope gradient is 8%.

The catchment area of 667 ha is covered by the loess soil in 97%. Nearly 80% of the total area is under agricultural use (among this: cropland – 70%, meadows - 2%, pastures - 8%). Forests cover is only 6% of the total area in the studied catchment.

Knowledge of the local meteorological conditions is of the special importance in the erosion studies. Data on the meteorological conditions were collected at the Trzebnica and Chwałkowice IMGW meteorological stations.

During the period of investigation in the hydrological years 1982/83-1993/94, total annual precipitation (Table 1) ranged from 529.8 to 743.2 mm (the mean value during the study period was 637.6 mm), the mean annual temperature (Table 2) ranged from 7.2 to 9.8 °C (on the average - 8.7 °C). The study years were classified from dry to wet on the basis of precipitation values and in respect to thermal condition from cold to warm [3].

T a b l e 1. Monthly and periodical precipitations (mm) in hydrological years 1982/83-1993/94 from Trzebnica IMGW station

Years	Months												
	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI-X
1982/83	34.1	41.7	58.5	61.8	28.2	34.0	105.9	44.1	40.2	51.7	39.9	35.8	575.9
1983/84	40.9	27.8	23.2	15.9	20.9	33.0	113.5	113.7	70.0	48.7	97.3	34.2	639.1
1984/85	30.3	20.3	34.4	38.5	43.6	53.3	30.9	123.5	46.3	172.5	23.8	21.2	638.6
1985/86	39.3	69.7	62.6	18.0	32.2	36.8	96.6	70.4	108.0	99.3	54.9	39.5	727.3
1986/87	33.2	94.9	54.8	46.2	23.1	47.1	69.4	90.7	86.8	86.1	65.8	45.1	743.2
1987/88	85.2	39.1	38.9	62.6	80.8	19.5	9.4	79.1	104.7	102.0	81.9	18.1	721.3
1988/89	47.1	73.7	11.9	20.7	16.1	78.6	40.0	81.6	49.3	48.3	26.2	42.3	535.8
1989/90	65.3	32.6	19.4	34.9	23.5	42.4	10.0	112.4	16.1	72.3	71.5	36.4	536.8
1990/91	73.3	48.2	12.9	19.1	28.0	40.6	55.0	94.1	65.8	36.1	37.6	19.1	529.8
1991/92	62.7	64.2	37.0	49.2	108.7	28.4	33.5	67.4	75.2	52.3	23.4	44.0	646.0
1992/93	38.7	47.9	30.3	48.3	50.5	18.2	74.8	99.6	144.4	32.8	66.5	52.3	705.3
1993/94	35.9	102.6	43.8	21.7	79.0	70.4	72.3	32.5	47.7	93.4	27.5	26.0	652.8
1982/83-1993/94	48.8	55.2	35.6	36.4	44.6	41.9	59.3	84.1	71.2	74.6	51.4	34.5	637.6

RESULTS

The course and intensity of water erosion are mainly determined by the amount of the surface run-off. Estimation is very difficult in a practice, so our research was focused on the unit run-off (surface run-off is an element of the unit run-off). Basing on the obtained data, values of the periodical and maximum daily unit run-off were characterised. The mean monthly unit run-off ranged from 0.8 to 10.9 $l\ s^{-1}\ km^{-2}$, and the mean annual unit run-off from 1.2 to 2.9 $l\ s^{-1}\ km^{-2}$. The mean unit run-off during the research period was 2.1 $l\ s^{-1}\ km^{-2}$. During the winter half-year (XI-IV) run-off ranged from 1.5 to 3.3 $l\ s^{-1}\ km^{-2}$, but during the summer half-year (V-X) from 1.0 to 2.8 $l\ s^{-1}\ km^{-2}$. Everyday systematic observations allowed us to estimate variability in the maximum daily values. They ranged from 1.3 to 65.1 $l\ s^{-1}\ km^{-2}$ and showed strong similarity to meteorological conditions.

It was necessary to measure water flow rate in the stream in order to estimate total amount of soil and chemical material carried out. Mean monthly flow rates ranged from 5 to 73 $l\ s^{-1}$, and mean annual rates from 8 to 19 $l\ s^{-1}$. The scale of water erosion is determined mainly by maximum flows. Such discharges are caused by torrential summer rainfalls, midwinter and spring snow melting. The recorded maximum daily flow rates ranged from 9 to 434 $l\ s^{-1}$.

Daily suspended sediment concentration and discharge rates allowed us to estimate daily and periodical quantities of the soil material washed out through the bathometrical cross-section. Total monthly suspended sediment washed out from the catchment ranged from 37 kg to 110082 kg and total annual value was from 2561 kg to 295943 kg. These values depended on the existing hydrometeorological conditions.

The above mentioned values allow for the assessment of the erodibilitiy of the investigated catchment only. However, it is necessary to refer them to the surface unit for comparative analyses. Denudation indices calculated for the hydrological years 1983/84-1993/94 are presented in Table 3.

Monthly denudation indices ranged from 0,01 to 16.50 Mg km^{-2} and the annual indices from 0.38 to 44.37 Mg km^{-2}. Monthly values for the winter half-year ranged from 0.01 to 10.24 Mg km^{-2}. A wider range of monthly indices was observed during the summer half-year, i.e., from 0.01 to 16.50 Mg km^{-2}. Similar situation was found for the mean half-year indices. The winter half-year indices were from 0.27 to 15.23 Mg km^{-2}, and the summer indices ranged from 0.08 to 30.90 Mg km^{-2}. The highest soil loss during the whole research period was on 22 May 1987, when the biggest amount of washed material was measured. Referring

T a b l e 2. Mean monthly and periodical air temperatures (°C) in hydrological years 1982/83-1993/94 from Trzebnica IMGW station

Years	Months												
	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI-X
1982/83	5.7	1.3	3.4	-2.3	4.3	9.8	14.0	17.1	21.0	18.8	14.3	9.5	9.8
1983/84	3.6	-0.1	0.6	-1.1	1.5	7.4	12.2	14.4	15.4	17.3	12.4	10.8	7.9
1984/85	3.4	-0.6	-7.4	-5.9	2.9	8.1	14.6	13.9	17.7	17.2	12.9	8.5	7.2
1985/86	0.6	3.0	-0.9	-8.6	2.4	7.8	14.9	16.0	17.5	16.8	11.3	9.5	7.6
1986/87	5.8	1.0	-9.5	-0.9	-1.4	8.4	11.0	15.1	17.6	15.4	14.2	9.1	7.2
1987/88	4.7	1.3	2.5	2.2	1.6	8.1	14.7	16.0	18.7	17.5	13.7	8.6	9.1
1988/89	1.1	2.1	2.0	3.7	6.2	8.5	13.8	15.3	18.1	17.4	15.1	10.8	9.6
1989/90	2.3	1.9	2.8	5.6	7.4	8.1	14.7	16.0	17.1	18.4	11.4	10.0	9.7
1990/91	4.6	0.0	1.2	-3.5	5.8	7.8	9.3	14.3	19.2	18.0	15.0	8.1	9.4
1991/92	3.7	-0.4	0.1	2.6	4.1	8.4	14.0	18.7	20.2	21.5	14.2	6.6	9.5
1992/93	4.5	-0.8	1.1	-0.8	2.4	9.8	15.9	15.6	16.6	16.7	12.7	8.4	8.6
1993/94	-0.7	2.3	2.9	-1.9	5.2	9.1	12.8	16.5	22.3	18.5	14.3	7.1	9.1
1982/83-1993/94	3.3	0.9	-0.1	-0.9	3.5	8.4	13.5	15.7	18.4	17.8	13.5	8.9	8.7

T a b l e 3. Monthly and periodical denudation indices (Mg km^{-2}) in Mielnica Stream catchment in hydrological years 1982/83-1993/94

Years	Months												
	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI-X
1982/83	0.08	0.29	0.56	0.35	0.27	0.13	2.18	0.07	0.13	0.04	0.03	0.02	4.15
1983/84	0.03	0.04	0.03	0.04	0.07	0.08	0.31	0.34	0.10	0.10	0.35	0.14	1.61
1984/85	0.13	0.04	0.03	5.66	8.72	0.65	2.49	0.69	0.08	7.37	0.03	0.03	25.92
1985/86	0.07	0.22	0.62	0.01	0.50	0.08	0.10	4.71	0.64	0.24	0.11	0.10	7.38
1986/87	0.09	1.43	1.18	10.24	0.19	0.35	16.50	3.95	0.48	1.72	4.55	3.68	44.37
1987/88	0.36	0.11	0.14	0.21	2.94	0.34	0.05	0.03	0.07	0.54	0.46	0.07	5.31
1988/89	0.11	1.29	0.18	0.14	0.14	0.25	0.09	4.35	0.09	0.09	0.05	0.06	6.84
1989/90	0.07	0.08	0.03	0.03	0.03	0.04	0.01	0.68	0.01	0.02	0.01	0.01	1.00
1990/91	0.25	0.16	0.03	0.05	0.08	0.11	0.11	0.12	0.14	0.04	0.05	0.03	1.17
1991/92	0.07	0.07	0.04	0.04	0.07	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.38
1992/93	0.05	0.10	0.11	0.13	0.13	0.05	0.10	0.20	0.92	0.09	0.40	0.57	2.85
1993/94	0.15	1.91	1.10	0.39	-	-	-	-	1.12	1.20	0.26	0.27	-

it to the surface unit, about 16.15 Mg of the soil material was washed out from 1 km^2. This event was caused by a torrential rain with precipitation of 33 mm [5-7].

Investigations on erosion were supported by the analyses of chemical denudation in the years 1988-1990.

Chemical compounds carried out from the catchment with the stream flowing water are delivered to watercourses as a result of surface and underground flows. That phenomenon is closely related to hydrometerological conditions. Beside water factors, range of chemical denudation is determined by the chemical composition of the soil and the parent rock, fertilisation and environment pollution.

Chemical composition of the soil was analysed. With the respect to the type of land use, concentrations of the analysed chemical compounds were in the following ranges: P_2O_5 from 3.0 to 16.6 mg/100 g; K_2O 9.0–23.5 mg/100 g; Mg 2.7–8.5 mg/100 g; SO_4 1.2–2.5 mg/100 g; Ca 100.0–540.0 mg dm^{-3}; NO_3 10.0–59.0 mg dm^{-3}.

With the exception of arable lands the results obtained imply high soil acidity. The soils of the investigated area are rich in nutrients, but show high concentrations of zinc, copper and lead.

The mean mineral fertilisers use, basing on the questionnaires data, was below 100 kg NPK/ha on individual farms and about 220 kg NPK/ha in state farms.

The amounts of chemical compounds washed out from the catchment were calculated on the basis of water outflow rates and measured concentrations. The chemical denudation indices were received by referring the obtained results to the surface unit (Table 4).

Chemical denudation indices showed a considerable dependence on the meteorological conditions.

In the cases of ammonia, nitrites, nitrates, chlorides, sodium and calcium, an increase in the indices of chemical denudation was connected with the increase of precipitation and stream water discharge. Such a relationship was not found for other chemical compounds.

Water quality decreased during the periods of low flows because of higher concentrations of phosphorus, zinc, mercury, nitrogen, sulphur, copper and cadmium.

The compounds that were washed out from the catchment in the highes, amounts, were the compounds of calcium – 6331.5 kg km^{-2}; sulphate – 3945.9 kg km^{-2}; chloride – 1794.8 kg km^{-2} and of magnesium – 1484.5 kg km^{-2}. Then (in kg km^{-2}); sodium – 740.5; potassium - 580.8; nitrates - 38.8; ammonia – 31.5; iron – 15.4; nitrites – 7.9; zinc – 1.7; lead – 0.53; cadmium – 0.17; copper – 0.15, and mercury – 0.022 kg km^{-2} [4].

T a b l e 4. Mean monthly chemical denudation indices (kg km^{-2}) in Mielnica Stream catchment in years 1988-1990

Parameter	Months											
	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X
NH_3	1.78	3.37	3.26	3.46	6.91	3.96	2.34	2.24	1.47	0.98	0.69	1.02
NO_3	6.54	5.06	3.89	1.84	5.47	2.37	2.46	4.10	2.44	1.59	1.41	1.38
NO_2	0.50	0.70	0.92	0.45	0.38	0.48	0.90	1.54	0.55	0.55	0.49	0.40
Cl	116.48	158.29	157.65	165.65	210.24	151.68	140.02	218.30	132.12	130.50	115.54	98.33
SO_4	245.28	317.87	327.87	306.83	397.25	264.42	325.70	551.41	399.03	325.91	265.83	218.46
PO_4	1.46	2.27	1.31	0.96	1.23	0.84	0.73	1.38	0.77	1.21	1.68	1.55
K	39.65	65.91	50.35	47.73	73.57	47.39	47.08	68.09	43.06	32.82	33.92	31.20
Na	53.16	73.61	64.87	63.26	92.42	66.35	56.47	82.79	48.28	47.28	47.22	44.81
Ca	417.54	612.04	547.79	550.23	679.30	442.97	466.64	756.28	456.94	501.07	498.88	401.87
Mg	111.17	142.94	139.40	127.04	143.51	149.48	106.34	191.29	103.11	114.22	92.53	73.46
Fe	1.07	1.68	1.69	1.95	2.35	2.79	2.95	3.49	1.71	1.35	2.10	2.33
Zn	0.099	0.146	0.209	0.068	0.054	0.053	0.281	0.131	0.070	0.068	0.133	0.398
Pb	0.030	0.047	0.034	0.022	0.032	0.057	0.053	0.091	0.032	0.025	0.048	0.055
Cu	0.008	0.023	0.019	0.010	0.018	0.033	0.008	0.009	0.011	0.010	0.004	0.001
Cd	0.0003	0.0	0.0002	0.0004	0.0	0.0043	0.0074	0.0001	0.0	0.0002	0.1361	0.0198
Hg	0.0010	0.0016	0.0021	0.0035	0.0007	0.0006	0.0017	0.0038	0.0016	0.0013	0.0020	0.0022

CONCLUSIONS

Results of investigations on the erosion intensity in the catchent of the Mielnica Stream allow to assess erosion threats in this region. The mean index of the annual run-off denudation (ranging from 0.38 to 44.37 Mg km^{-2}) depended on the extreme values, especially the maximum daily levels. Values of the index indicate a serious threat from the phenomena of water erosion. The amount of the washed out soil material showed a strong relation with the unit flow values.

Investigations on the chemical denudation showed considerable differences between various amounts of washed out chemical compounds. The main factor that determines chemical denudation is the water factor. Human activity and the land use in the catchment have also had a serious influence on the described processes.

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