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Influence of in-field retention reservoirs on soil outflow from a catchment

MAGDALENA PATRO

Department of Land Reclamation and Agricultural Buildings University of Life Sciences in Lublin

Abstract: *Influence of in-field retention reservoirs on soil outflow from a catchment.* Rainfalls, topographic features, and catchment management are the main factors that affect the amounts of soil denudation. Studies carried out within loess catchment, being ploughed and covered with orchards, were aimed at evaluating the water erosion intensity and assessing the anti-erosion efficiency of in-field retention reservoirs. After intensive rainfalls in 2001/2002–2003/2004, the quantity of erosion damages was assessed on a base of recorded erosion landforms and capacity of the soil material sedimented in reservoirs. Analysis of translocated soil quantities in micro-catchments of particular reservoirs confirmed the influence of catchment management on water erosion processes. Great importance of in-field water reservoirs in retention of the eroded soil material was proved.

Key words: water erosion, retention reservoir, soil denudation.

INTRODUCTION

Lubelska Uplands along with the Rozto-cze are very threatened by water erosion, which is the consequence of diversified topographic features, great susceptibility of loess soils towards washing out and intensive agricultural management [Ziemnicki 1978]. Moreover according to Chomicz [1951], Lubelska Uplands is characterized by intensified frequency of

heavy rainfalls. The heavy rainfalls had negative effect on degradation of soil environment resulting in soil washing out up to completely washed out subsoil [Turski and Słowińska-Jurkiewicz 1994]. Depending on local conditions, washed out material is translocated within a catchment or removed out of it. Thus, there is a need to apply works that would protect against erosion process or minimizing its consequences within an agricultural catchment and around it. Various barriers reducing the water outflow and maximizing catchment's water retention are proposed as methods for preventing against soil washing out by surface run-offs [Józefaciuk and Józefaciuk 1999; Orlik 1998; Ziemnicki 1968].

Study was aimed at evaluating the water erosion effects due to intensive rainfalls as well as the role of retention reservoirs in reducing the soil washing out from the loess catchment.

MATERIAL AND METHODS

Studies were carried out in loess catchment of 7.6 ha area in Orchard Farm Euro-East, Olszanka, Lublin region in hydrological years 2002/2003–2003/2004. Results from study performed in 2001/2002 season were used for interpreting the

erosion phenomena and soil material transport processes [Patro 2004]. In five micro-catchments: No 14, 15, 16, 17, and 18, retention reservoirs were installed on outflow lines from that catchments (Fig. 1). Marking of the reservoirs is the same as the respective micro-catchments.

Reservoirs parameters in studied micro-catchments were determined by leveling measurements, which were made at the beginning of vegetation periods 2002, 2003, and 2004. Ranges of water rise heads, reservoir capacities, and their surface areas within three-year period

FIGURE 1. Way of land use in micro-catchments and erosion landforms after heavy rainfall on May 26th, 2002

were respectively: 0.3–1.6 m, 8–192 m³, and 32–272 m², whereas the lowest values were recorded in May 2002 (Tab. 1). In autumn 2002 every reservoir, and in autumn 2003 reservoirs No 14 and 15 were cleaned from deposited soil material. This material was used to raise the tops of the ground barriers or put on their wind-blowing sides.

The areas of micro-catchments are from 1.19 ha (No 17) to 2.06 ha (No 14). They have been characterized by different topographic features, indicator of which can be the percentage of distinguished land inclination classes (Tab. 2). The areas of land inclination which are less than 6% make 42.5% of the whole catchment, while remaining 57.5% of area had inclination in range 6–15%. In the individual micro-catchments the land

inclination characteristic is more diversified. Over 71% of the micro-catchment area No 18 has inclination < 6%, while in the micro-catchment No 15, the areas with inclination 6–15% make up to 81%. In the micro-catchments No 14, 16, and 17, the percentage of land inclination < 6% is about 1.5-times lower than that of 6–15%.

Studied catchment was ploughed and orchards were cultivated. Fruit trees in north-south directed rows were set in upper part of the catchment (micro-catchments No 16, 17, and 18) in autumn 2001. Lower part of the catchment was performed as ploughing fields (almost whole micro-catchments No 14 and 15) (Fig. 1). The orchard was set in spring 2003 in all micro-catchments No 14 and 15, and beetroots were grown in inter-

TABLE 1. Parameters of retention reservoirs

Reservoir No	2001/2002			2002/2003			2003/2004		
	Water rise head [m]	Pondage [m ³]	Reservoir area [m ²]	Water rise head [m]	Pondage [m ³]	Reservoir area [m ²]	Water rise head [m]	Pondage [m ³]	Reservoir area [m ²]
14	0.4	52	245	1.2	92	227	1.6	192	272
15	0.9	49	182	1.1	86	211	1.4	72	128
16	0.3	8	32	1.2	26	75	1.1	29	62
17	0.6	52	223	1.6	97	234	1.4	83	164
18	0.5	33	201	1.2	54	205	1.0	49	128

TABLE 2. Areas and land inclinations in micro-catchments

Micro-catchment	Area		Land inclinations					
			< 6%		6–15%		> 15%	
	ha	%	ha	%	ha	%	ha	%
14	2.06	100	0.83	40.3	1.23	59.7	–	–
15	1.21	100	0.23	19.03	0.98	81.0	–	–
16	1.91	100	0.87	45.5	1.04	54.5	–	–
17	1.19	100	0.42	35.3	0.77	64.7	–	–
18	1.23	100	0.88	71.5	0.35	28.5	–	–
Σ	7.60	100	3.23	42.5	4.37	57.5	–	–

spaces. Interspaces of the orchard set in autumn 2001 were covered with a sod in 2003, and herbicidal bands were kept among tree rows. In the third study year, the whole catchment was utilized as an orchard in 100%, including 60% of sodded tree settings made in 2001 and less sod-covered in 2003.

The precipitation sum was 627 mm in 2001/2002 hydrological season, 500 mm in 2002/2003, and 628 mm in 2003/2004. In that period two heavy rains occurred: on 26th May 2002 and on 24th July 2003, and one long-lasting rain on 26th – 27th July 2004. Total amount and mean intensity of the rainfall in May 2002 were 43 mm and $0.44 \text{ mm} \cdot \text{min}^{-1}$, respectively. The rainfall in July 2003 reached the quantity of 36 mm, and its intensity was $0.40 \text{ mm} \cdot \text{min}^{-1}$. Rain recorded in July 2004 was of 70 mm amount, but due to its duration (15 hours), its average intensity was only $0.10 \text{ mm} \cdot \text{min}^{-1}$. The rainfalls caused surface run-offs and flute wash-outs.

The transport of soil material within the catchment was assessed in accordance to methodology worked out by Mazur and Pałys [1991]. Directly after the sur-

face run-offs, records and measurements were made for determination of capacity $[\text{m}^3]$: flutes erosion, mud depositions (out of the reservoirs), and estimation of surface erosion. The capacity of soil material sedimented in retention reservoirs $[\text{m}^3]$ was also estimated on a base of their leveling measurements (Tab. 3).

RESULTS AND DISCUSSION

The rainfall occurring on 26th May 2002, formed 4 flutes in micro-catchments No 14 and 15 that were ploughed (Fig. 1). On areas covered with young orchard (micro-catchment No 17), 8 flutes were recorded. The flute washing-outs were in general directed along the flow lines of the micro-catchment. Total capacity of the soil transferred out by flute erosion was almost 40 m^3 (Tab. 3). Also surface wash-outs of total capacity over 28 m^3 were recorded (Fig. 1); they were present on wind-blowing side of the ground barriers (no-sodded yet) as well as below orchard's boundary (Fig. 1). Muddled regions, area of which was 10% of their capacity (Tab. 3), were observed in the flute's outlet and below washed-out areas

TABLE 3. The erosion damages scale after run-offs in the vegetation seasons, in particular micro-catchments

Micro-catchment	Vegetation season 2002				Vegetation season 2003			Vegetation season 2004	
	26th May 2002			Mud deposition in reservoir [m³]	24th July 2003		Mud deposition in reservoir [m³]	26th – 27th July 2004	Mud deposition in reservoir [m³]
	Flute erosion [m³]	Surface soil wash-out [m²]	Mud deposition out of reservoir [m³]		Flute erosion [m³]	Surface soil wash-out [m²]		Flute erosion [m³]	
14	28.5	18.0	7.0	52.0	41.3	–	84.0	9.5	23.0
15	8.6	10.5	–	37.0	21.8	2.0	76.0	1.5	–
16	–	–	–	4.0	–	–	15.0	–	–
17	2.4	–	–	9.0	–	–	13.0	0.3	–
18	–	–	–	4.0	–	–	5.0	–	–
Σ	39.5	28.5	7.0	106.0	63.1	2.0	193.0	11.3	23.0

(Fig. 1). The flute and run-off material volumes were subjected to calculation of erosion index, of which value was from 0.8 (micro-catchment No 17) to $21.9 \text{ m}^3 \cdot \text{ha}^{-1}$ (micro-catchment No 14).

The run-off after heavy rain in July 2003 caused the formation of 5 flutes situated in the orchard set in spring 2003, while no damages were found in sod-covered orchard set in 2001. The beetroot was cultivated in interspace of former orchard. The surface soil wash-out also occurred on wind-blowing side of the ground barrier No 17. Total capacity of the soil eroded due to fluting and washing-out processes reached value similar to that estimated after rainfall in May 2002 in reference to the amount and intensity (Tab. 3). Mean erosion index in micro-catchments No 14 and 15 (eroded micro-catchments) was similar amounting to about $20 \text{ m}^3 \cdot \text{ha}^{-1}$. The study results confirm anti-erosion role of interspace sodding – no washing-outs were found in orchard set in autumn 2001. However, using the interspace for root crops cultivation, which is parallel to the slope inclination, intensified the fluting processes (Tab. 3). It may be indicated by the flutes volume (micro-catchments No 14 and 15), that after the run-off in July 2003, was 1.7-times larger then after rainfall in May 2002.

Four flutes localized along the young trees lines growing in herbicidal bands, were formed after two-day rainfall in July 2004. Total capacity of the soil material transferred due to flute erosion was 11 m^3 (Tab. 3), which was much lower than in the case of heavy rainfalls in 2002 and 2003. The erosion index for studied micro-catchments was the lowest for the whole study period and it amounted

from 0.3 (micro-catchment No 17) to $4.5 \text{ m}^3 \cdot \text{ha}^{-1}$ (micro-catchment No 14).

In micro-catchments No 16, 17 and 18, which are in upper, top part of the catchment, large erosion landforms were not found (Tab. 3). Only in micro-catchment No 17, whose almost 65% of area has inclination 6–15%, flute washing-outs were recorded in herbicidal bands (Tabs 2, 3). After the rainfall in May 2002, capacity of erosion landforms in micro-catchment No 14 was 2.4-times larger than in micro-catchment No 15, and after the rainfall in July 2003 – 1.9-times higher. Despite over 80% of area of micro-catchment No 15 has inclination 6–15%, the fact that area of micro-catchment No 14 is about 70% larger than micro-catchment No 15 has the main impact on erosion damages quantity (Tabs 2, 3).

The soil material transferred from the flute erosion and surface soil wash-out was mainly sedimented in reservoirs. In 2002, 106 m^3 of soil material was deposited, in 2003 – 193 m^3 , and in 2004 – 23 m^3 (Tab. 3). In general, the sediment amounts in all reservoirs were much higher than volumes of erosion landforms in their micro-catchments. Such discrepancy may result from the under-estimation of the surface wash-out, which is particularly difficult or even impossible to be measured when the process occurs on the whole area and washed-out material cannot be found on the slopes and their bottoms. It also concerns flute washing-outs in the case, when their sizes are small, and their locations are difficult to notice among vigorously growing cultivated plants. The discrepancy between the capacity of mud depositions in reservoirs and erosion landforms may be

effect of occurring erosion processes after rainfalls that did not cause distinct erosion landforms. Comparison of the mud volume in reservoirs that close micro-catchments with the capacity of erosion forms in those micro-catchments proves the intensive surface run-offs, mainly just after heavy rainfalls.

Accepting the quantity of deposited material in the reservoirs as more reliable erosion proofs in micro-catchments, soil erosion after heavy rainfall in 2002 were from 2.1 (micro-catchment No 16) up to 30.8 m³·ha⁻¹ (micro-catchment No 15), whereas in 2003 – from 4.2 (No 18) up to 63.3 m³·ha⁻¹ (No 15). Despite similarity between total amount and mean intensity of rainfalls in May 2002 and in July 2003 the capacity of mud deposition in reservoirs No 14 and 15 in 2003 was 1.8-times larger than in 2002. It indicates occurring intensive flute washing-outs along tree rows and beetroot ridges, whose direction was, additionally, parallel to land inclination. In 2004, except from micro-catchment No 14, for which erosion index reached 11.0 m³·ha⁻¹, while in other reservoirs, no material accumulation was recorded at the level possible to be measured using commonly applied geodetic methods.

CONCLUSIONS

- Rainfalls in 2002 and 2003 caused the transfer of similar amounts of soil material in consideration to capacity of flutes and surface soil wash-outs. However, in the case of rainfall in July 2003, the flute washing-out was the main erosion process.
- The catchment erosion intensity, determined on the base of measured flute's volume and surface soil wash-out esti-

mations, is lower than calculated on the base of mud capacity deposited in the reservoirs. Such discrepancy may result from the under-estimation of capacity of flute erosion and surface wash-out in the case, when erosion landforms were small, they occurred in vigorously growing cultivated plants and the lack of washed-out material deposition on the slopes.

- Despite similarity between intensity of rainfalls in May 2002 and in July 2003, the volume of mud deposition in reservoirs in 2003 was almost 2-times larger than in 2002. It indicates occurring intensive erosion processes closely connected with plant cover.
- Study results confirm the significant influence of agricultural catchment performance on erosion damages scale. The anti-erosion role of the orchard with sodded interspaces was found. However, herbicidal bands, root crops cultivation and cultivation parallel to slope inclination increase the erosion processes.
- The ground barriers along the flow lines within a micro-catchment are quite good obstacle for washed-out soil material. Besides mud retention, they also decreased the water run-off value.

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Streszczenie: *Wpływ śródpolnych zbiorników retencyjnych na odpływ gleby ze zlewni.* Głównymi czynnikami wpływającymi na ilość zmywanej

gleby są opady deszczu, ukształtowanie terenu i sposób zagospodarowania zlewni. Badania przeprowadzone w zlewni lessowej, będącej w użytkowaniu orno-sadowniczym, miały na celu określenie natężenia erozji wodnej i ocenę przeciwoerozyjnego działania śródpolnych zbiorników retencyjnych. Po intensywnych opadach deszczu w latach 2001/2002–2003/2004 określono wielkość szkód erozyjnych na podstawie zarejestrowanych form erozyjnych oraz kubatury materiału glebowego osadzonego w czasach zbiorników. Analiza wielkości przemieszczonej gleby w mikrozlewniach poszczególnych zbiorników potwierdziła znaczenie użytkowania zlewni na przebieg procesów erozji wodnej. Stwierdzono duże znaczenie śródpolnych zbiorników wodnych w zatrzymywaniu wyerodowanego materiału glebowego.

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Author's address:
Katedra Melioracji i Budownictwa Rolniczego
Uniwersytet Przyrodniczy w Lublinie
ul. S. Leszczyńskiego 7, 20-069 Lublin
Poland
e-mail: magdalenapatro@wp.pl