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EVALUATION OF BIOTECHNICAL CONSOLIDATION OF A WOODED GULLY IN OPOKA DUŻA

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Summary. The studies were carried out in a consolidated gully in Opoka Duża where an anti-erosion biotechnical structure was made in 1962–1964. On the basis of the studies it can be said that the settlement of the gully turned out to be efficient. The gully did not get any deeper or increase its size and the Sanna river bed did not require expensive dredging. Accumulation of soil material was mainly observed at the gully bottom. During 39 years, 123.5 m^3 of mud accumulated at the bottom. The hydrotechnical structures efficiently strengthened the erosion thresholds and the gully bottom against linear erosion as well as contributed to stopping the soil material.

Key words: water erosion, gully erosion, gully, biotechnical consolidation

INTRODUCTION

Gully erosion is the most destructive form of erosion and the presence of gullies in the landscape is an indicator of a given ecosystem degradation and it points out to the necessity of the area protection against gradual devastation [Ziemnicki *et al*. 1975, Józefaciuk and Józefaciuk 1992]. In general, the soil-protective function of plants is well known. However, the studies carried out in biologically fixed gullies proved that in some cases only such kind of settlement is not enough to stabilise them sufficiently [Buraczyński and Wojtanowicz 1971, Ziemnicki and Kudasiewicz 1975]. A similar example of an intensive secondary wooded gully development was observed in Opoka Duża near Annopol. Although before the gully settlement the wood covered 90% of its basin, intensive erosion processes occurred in the gully. Its bottom was washed out then lowered, and the slopes were cut, making them unstable. The soil material that was washed out from the gully formed at the outlet a deluvial cone of 40 m diameter and 1.5 m thickness, silting up the bottom of the Sanna river and forcing it to continuous dredging [Ziemnicki and Kucyper 1975]. Thus, there was a need to introduce additional technical fixing that, along with biological ones, would inhibit erosion processes and make the gully development impossible. Biotechnical settlement, according to Ziemnicki's conception [1966] was made in 1962–1964.

The evaluation of the anti-erosion biotechnical consolidation of a wooded gully in Opoka Duża after 45 years of project realisation is presented in the paper.

MATERIAL AND METHODS

Opoka Duża is situated in the western part of Lublin Region (physiographic area strongly branched due to gully erosion, ([Józefaciuk and Józefaciuk 1992], in the mesoregion of Urzędowskie Hills [Kondracki 2002]. Climatic division makes this area belong to the Opole-Puławy district with 520 mm of mean annual rainfall [Zinkiewicz and Zinkiewicz 1975].

The studied gully (Fig. 1) has a basin of 14.92 ha area. Its length is about 550 m, depth 12 m and mean width about 35 m. The bottom of the gully is narrow. The mean gully bottom width is 1.4 m and sometimes only 0.6 m. Mean bottom slope is 10.7% and maximum one – 16.7%. In an intersection, the gully is similar to V letter and has mainly steep slopes. The slope inclination at the bottom part of the gully achieves about 80% and at an upper one 30–50%. At the bottom, the slopes are cut and have almost vertical walls about 2.5 m high. At present, almost the whole basin along with the gully is wooded. Wood covers 14.65 ha, which makes 98.2% of the total basin area. The rest (0.27 ha) is occupied by ground roads and sod areas.

The studies in the gully were carried out in 2009. The erosion forms that can attest to the present-day denudation processes changing the sculpture of the gully have undergone detailed inventory-making. The structure of the gully basin use has been assessed. The measurements of tree breast-height diameter and a simplified description of floristic relations in accordance with the methodology of ecological research have been made [Faliński 2001]. The levelling measurements of the gully bottom in a relative system with reference to the working datums have been repeated. Comparing these results with those from 1970 allowed to evaluate the change of the bottom grade line, calculate the volume of relocated soil material and assess the performance of hydrotechnical structures that fixed the erosion thresholds. The technical state of the hydrotechnical structures was visually assessed.

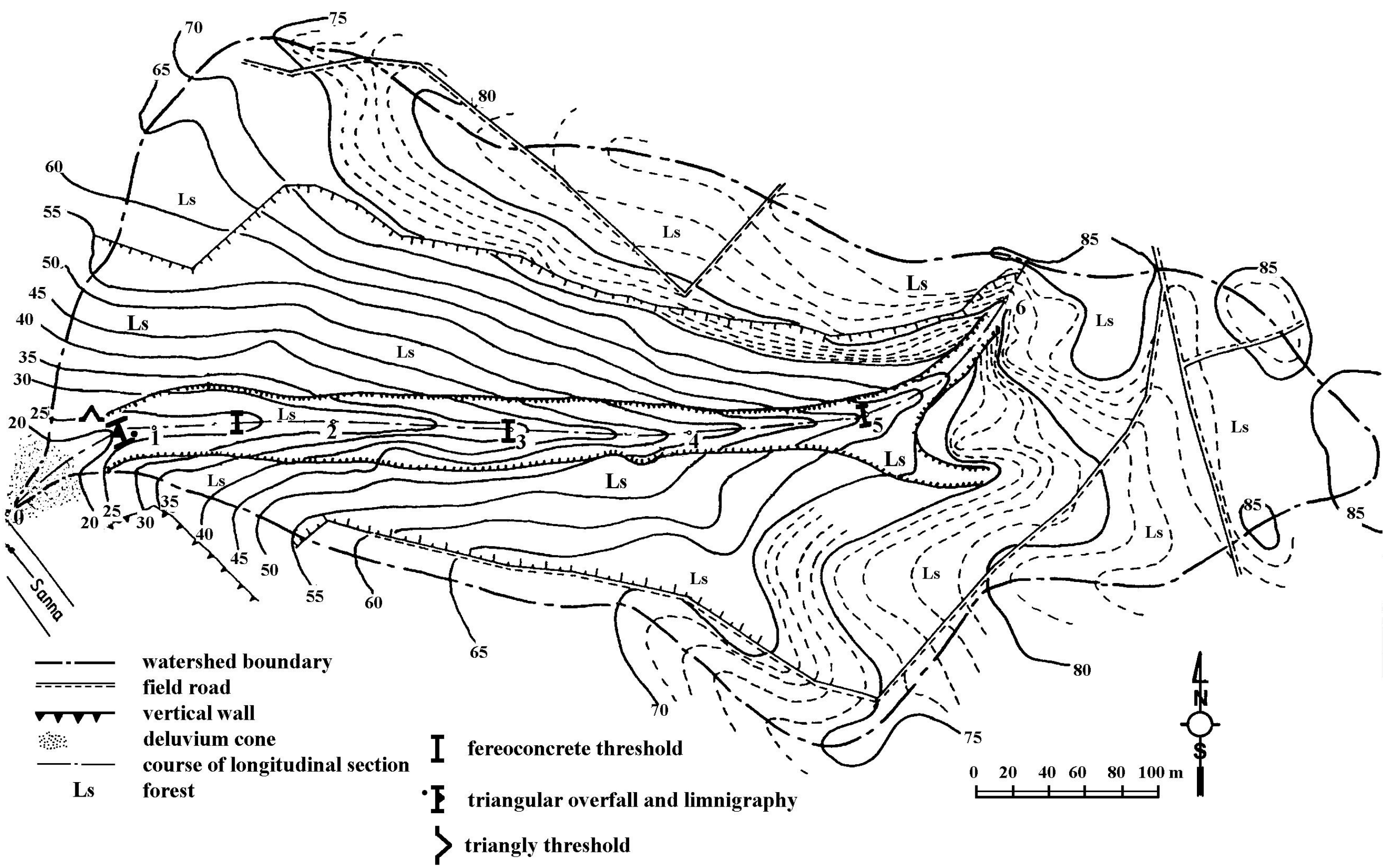

Fig. 1. Altitude scheme of the gully

RESULTS AND DISCUSSION

One-level stand consisting mainly of *Pinus sylvestris* L. and a slight share of *Quercus petraea* Liebl., *Betula pendula* Roth. and *Robinia pseudoacacia* L. dominates in the gully and its basin. *Pinus sylvestris* L., at the age of 80 years, achieved 21 m of height and mean breast height diameter of 43 cm (maximally 49 cm), but it grows in too loose density (coverage of 45%), thus its technical quality is very poor. Bolts are convergent and badly purified. Numerous branches occur up to about 2/3 of the tree height. The layer of saplings up to 10 m height and 33% coverage is distinguished under the trees. *Quercus petraea* Liebl. and sporadically growing *Betula pendula* Roth. and *Pinus sylvestris* L. as well as *Fraxinus excelsior* L. introduced during biological settlement making and growing at the bottom of cliffs. The quality of saplings is good and the underbrush is also well developed. Its coverage amounts to 50% and consists mainly of: *Quercus petraea* Liebl., *Pinus sylvestris* L., *Betula pendula* Roth., *Fraxinus excelsior* L., *Juniperus communis* L., *Corylus avellana* L., *Berberis vulgaris* L., *Euonymus europaeus* L. Ground cover occupies 45%. It consists mainly of: *Vaccinium myrtillus* L., *Fragaria vesca* L., *Urtica dioica* L., *Euonymus europaeus* L., *Dryopteris filixlmas* (L.), *Rubus caesius* L., *Cornus sanguinea* L., *Berberis vulgaris* L., *Junipera communis* L. and seedlings of various trees.

A forest built of all layers appeared in the gully. The existence of admixture and saplings of *Quercus petraea* Liebl. makes it possible to achieve mixed stands in the future.

The study of the present-day erosion forms showed that on the steep walls of the gully some isolated places with gravity processes can be found, but in general the degree of the biological enclosure of the walls is satisfactory. However, the bottom of the gully along which the local inhabitants drag the trees cut down there and lead cattle to meadows in the Sanna river valley is poorly grown with plants. *Alnus glutinosa* (L) Gaertn., that had been planted at the gully bottom during its settlement, was cut down. Generally, however, the bottom (especially in its lower and middle sections) is dominated by accumulation processes of the soil material. No clear signs of strong erosion processes invoked by surface water runoff, which could lead to instability of the gully, were observed in the gully and its basin during the studies.

Analysing the results of levelling measurements made in 1970 and 2009 (Fig. 2), it can be found that bottom elevation took place mainly at the lower part of the gully – from hectometre 0 + 82 to 2 + 96, where mean bottom inclination is about 6.5%. The bottom was elevated maximally by 0.71 m. In the upper part, the bottom of mean inclination 13.7% generally did not change – there are visible places where soil material accumulation occurred and places of it washing out. At the bottom of the gully, old erosion thresholds were efficiently fixed and new ones did not appear. All ferroconcrete thresholds and their water pillows are silted up, due to which the height of the erosion thresholds decreased. Only the water pillow of the threshold constructed in the gully outlet is not silted up, which demonstrates the lack of soil material transport and its effective stabilisation. The deluvial cone that was formed at the gully outlet did not increase its size and was well sodded. The mean thickness of mud deposited at the gully bottom is about 0.21 m. At mean bottom width of about 1.4 m and length of 415 m between extreme ferroconcrete thresholds consolidating erosion thresholds, 123.5 m^3 of soil material accumulated during 39 years at the bottom, including 80% at the lower part of the gully.

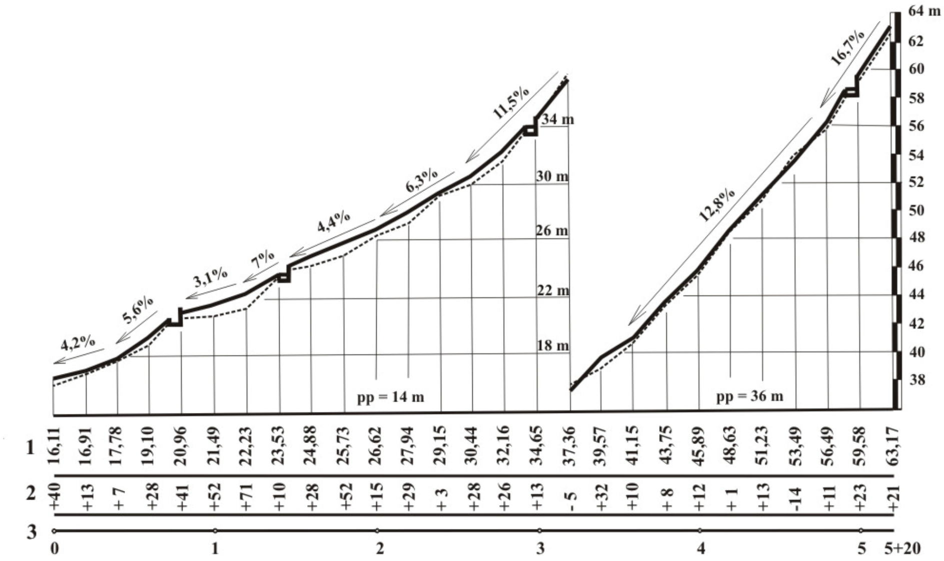

Fig. 2. The gully bottom profile: 1 – bottom ordinates in 2009, 2 – silting up (+) and washing out (-) in the period 1970–2009 in cm, 3 – hectometres

The technical condition of the structures set at the gully bottom is bad and raises serious concerns about their future normal functioning. In the first threshold made at the outlet of the gully, the notch wing is damaged and the side walls are bulging and cracked. In the second one the fore wall is damaged. The fourth threshold, the highest one, has cracked and damaged side walls. Extensive damage to the thresholds caused by logging and transport of wood were probably the reasons, which affected the increase of cliff ground pressure on the side walls and finally resulted in their bulging and cracking.

The shown direction of the gully settlement, in a view of protective efficiency, should be positively judged. After 45 years, the gully did not get deeper or change its size and the Sanna river bed did not require expensive dredging. Achieving such results was possible because of the introduction, at the first stage of the settlement, hydrotechnical buildings which strengthened the flow line. Ferroconcrete thresholds efficiently protected the bottom against linear erosion, not allowing further deepening of the gully, which gave the stable erosion base for slopes. Taking into account the fact that the gully was formed in a material very susceptible to water erosion processes (sandy and dusty) [Ziemnicki and Kucyper 1975], the lack of solid bottom stabilisation would make it impossible to achieve the state of balance of slopes, hindering the introduction of biological defences, which currently effectively protect the soil from water erosion. Besides, the ferroconcrete thresholds along with biological settlement contributed to mud stopping, which in turn led to diminishing and levelling of the bottom inclination. Bottom elevation around the structures combines the thresholds with surrounding plants, which is necessary for landscape aesthetics. The high efficiency and usefulness of biotechnical methods for stabilising gullies was also confirmed by Ziemnicki [1966] and Ziemnicki *et al.* [1977], Józefaciuk [1975], Józefaciuk and Józefaciuk [1995],.

CONCLUSIONS

1. The anti-erosion strengthening of the gully ought to be started with fixing the erosion base.
2. The ferroconcrete thresholds efficiently strengthen the erosion thresholds and gully bottom against linear erosion and contribute to stopping the soil material.
3. The hydraulic engineering structures strengthening the thresholds of erosion in the gullies require periodical inspections and regular maintenance, and the plants - proper cultivation.
4. The use of hydraulic structures in the gullies should be limited to a minimum considering the high costs of construction and maintenance of concrete structures, increasing with the age of the structure.
5. Vehicular and pedestrian traffic should be eliminated from flow lines in the fixed gullies.

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OCENA BIOTECHNICZNEJ ZABUDOWY ZALESIONEGO WĄWOZU W OPOCE DUŻEJ

Streszczenie. Badania prowadzono w umocnionym wąwozie w Opoce Dużej, gdzie w latach 1962–1964 wykonano przeciwerozyjną zabudowę biotechniczną. Na podstawie badań można stwierdzić, że umocnienie wąwozu okazało się skuteczne. Wąwóz nie pogłębił się i nie powiększył swoich rozmiarów, a koryto Sanny nie wymagało kosztownego bagrowania. Akumulację materiału glebowego zaobserwowano głównie w dolnej części dna wąwozu. W czasie 39 lat osadziło się około 123,5 m^3 namułów. Budowle hydrotechniczne skutecznie utrwaliły progi erozyjne i dno wąwozu przed erozją liniową, jak również przyczyniły się do zatrzymania materiału glebowego.

Słowa kluczowe: erozja wodna, erozja wąwozowa, wąwóz, zabudowa biotechniczna