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Evaluation of sediment barriers in relation to the trap of soil particles

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Abstract: Water erosion and the subsequent sediment deposits can cause a number of environmental problems. The damage can be mitigated by means of sediment barriers. Their use is most often associated with the construction or protection of transport infrastructure. In some cases, they can also be used in forestry and agriculture. However, there is still a number of questions concerning sediment barriers regarding their proper function, efficiency and some implementation parameters. For these reasons, we decided to verify three types of sediment barriers. They were tested by simulated flooding at a flow of 5 and 10 L/s, always for a span of 25 min. All the tested barriers had a similar soil particle trap efficiency of about 90%. We assume that this result was due to some of our modifications to the sediment barriers and, above all, through the ensured run-off, where there were no structural failures within the barriers. Furthermore, it was also found, during the simulations, that the required sediment process of the eroded soil was not significantly affected by the size of the storage space. Therefore, it should be designed primarily with regard to the required amount of sediment and not to retain a significantly large volume of water.

Keywords: full-scale testing; silt-fence; soil bund; soil erosion; straw bale; trap efficiency

Land disturbances caused by human activities, such as construction, development, or agriculture, typically involve the removal of the vegetation cover and topsoil and cause soil disturbances. (Vitousek et al. 1997). As a result, the storm water run-off and erosion rates are significantly increased (Procházková et al. 2020). The subsequent erosion and sediment transport have both onsite and offsite economic effects. The erosion and soil loss, along with negative economic impacts, cause uncontrolled water and sediment run-off which degrades the surrounding environment. If the sediment gets off the site, watercourses, water ways and other objects can become clogged (Morgan 2009). The sediment-laden discharge can increase

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the turbidity (Kirk 1985; Ryan 1991), decrease the flow capacity, and provide a mode of transport for other pollutants (Alekseevskiy et al. 2008), which affects the amount of sunlight falling on aquatic plants (Isobe & Matsuno 2008) and deteriorates the living conditions of other aquatic animals (McDowell & Wilcock 2008).

In order to prevent soil wash-out outside the affected plot of land, sediment barriers have commonly been used abroad, which have become the basic protection measure most commonly used on construction sites (Schussler et al. 2021). However, they are also used in other sectors, such as protection in the transport infrastructure, in forestry after fire damage and in agriculture (Robichaud al. 2008; Donald et al. 2016). Sediment barriers have the character of a line barrier, which can be created from different types of materials: wheat straw, soil and stones, urethane foam or woven and non-woven geotextiles (Donald et al. 2013, Whitman et al. 2018). The main purpose of sediment barriers is to trap the washed-out sediment released by torrential rain (Schussler et al. 2021; Whitman et al. 2021) and to interrupt the surface run-off (Boardman et al. 2019). Due to the interruption of the run-off line, the flow velocity is reduced and the gravitational sedimentation is enhanced in front of the formed barrier (Donald et al. 2016).

However, some questions about the operation of sediment barriers still remain open. The issue of the efficiency and structural stability of barriers in operating conditions is still being addressed in expert publications (Bugg et al. 2017a; Whitman et al. 2018). Various shape installation methods on a plot have been designed and tested (Featherston et al. 2004; Zech et al. 2008). Moreover, the possibilities of burdening and draining sediment barriers have been determined, which should reduce the frequency of their failures (Donald et al. 2016; Whitman et al. 2021). Therefore, we have also focused on some of these issues, and the results and experience from our full-scale plot experiments are described in this article. The main objective of the study is to increase the awareness of mobile sedimentation barriers and to enrich this area with new information and knowledge gained during several years of research. The article is mainly focused on the ability of various sedimentation barriers to trap washed-out sediment. The size of the storage space has been modified over the years in order to test whether its extent affects the amount of sediment trapped. We do believe that the research focused on sedimentation barriers has a considerable potential and the information provided in the article can contribute to their greater use in practice.

MATERIAL AND METHODS

Tested barriers and their parameters. The testing of anti-erosion sediment barriers (Figure 1) was

Figure 1. Tested sediment barriers

1 – silt-fence; 2 – straw bale barrier; 3 – soil bund wit vegetation; 4 – trapped sediment

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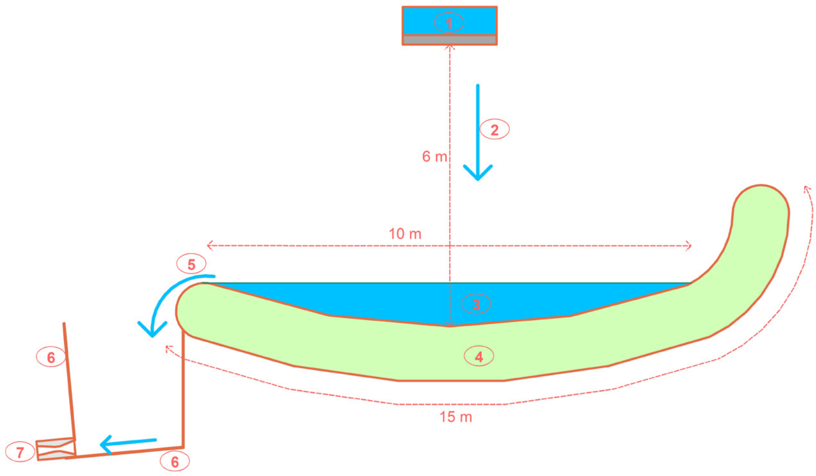

Figure 2. Testing method of sediment barriers

1 – overflow flume, 2 – direction of inflow onto the sediment barrier; 3 – storage space; 4 –sediment barrier; 5 – lateral run-off over the edge; 6 – plastic barriers directing run-off; 7 – Parshall flume

carried out from 2017 to 2021. More information is included in Electronic Supplementary Material (ESM). The first of the tested measures was a soil bundle with vegetation, which was created by building gradual levels of soil bunds and soil compaction. Its height reached 0.45 m and width in the foundations was 1.2 m. The soil bundle was made in a convex shape. In order to stabilise it, the entire surface was sown with a grass mixture, including a 1.5 m long space in front of it. The grass mixture consisted of perennial ryegrass (*Lolium perenne*), red fescue (*Festuca rubra rubra*) and Italian ryegrass (*Lolium multiflorum* Lam.) The second tested barrier was the silt-fence sediment barrier. The excavation depth for laying it was at least 0.15 m and the woven fabric was laid in a U-shape. Thus, approximately 0.4 m of fabric's length was anchored in the ground after backfilling and compaction of the soil. The remaining part of the fabric, above the ground, was 0.65 m long. The support posts were chosen to be made of wood having parameters 0.05 × 0.05 m and a length of 1.3 m. The fabric was attached to them using a stapling gun. The last of the verified measures was a straw bale barrier. The individual packages had a size of 0.4 × 0.5 × 0.6 m and were tightly placed in a trench. Its width corresponded to the size of the package and was set 0.1 m deep. Stabilisation was again carried out by means of a wooden post (0.05 × 0.05 m) with a length of 0.8 m, and only 0.1 m protruded after ploughing it into the package. To make the barrier work properly, the upstream side of the barrier was included up to the maximum height of the water level swell. The barrier made of straw bales, thus, became minimally permeable and no undercutting occurred. All the above-mentioned sediment barriers were built with a length of 15 m in the shape of the letter J. The storage space was created by the inclination of the barrier against the slope. The size of the storage space was then subject to an elevation between the centre and the edge of the sediment barrier. In the individual years, the elevation in the range of 0.0–0.2 m was verified. The burdening of the barrier by the water column itself was further increased by the height of 0.05–0.1 m to overcome the edge of the barrier by the run-off. Measurements took place twice a year in spring and autumn to test the barriers before and after the occurrence of erosion-prone precipitation. The data from the individual years were subjected to basic statistics – arithmetic mean, median, standard deviation. Subsequently, based on the normality of the data assessed by the Shapiro-Wilk test, the hypotheses were tested using a one-way analysis of variance (ANOVA) or a paired *t*-test. The significance level α was set to 0.05 in all the tests.

Testing method of sediment barriers. The testing of the mobile barriers (Figure 2) consisted in their controlled flooding with surface run-off with an intensity of 5 L/s and 10 L/s always for the time-span of 25 min. The intensity and duration of the simulation were chosen on the basis of the study by García et al. (2015), which, however, addressed other types of sediment barriers. The surface run-off itself was developed using sludge pumps with a known flow, which were drained into an irrigation trough with a volume of 224 L and an overflow edge length of 1.4 m. Its function was to direct the turbulent flow from the pumps to such an extent that the water flowed onto the soil surface. The distance of the irrigation trough from the tested sediment barrier was 6.0 m. After filling the defined storage space of the sediment barrier, a lateral run-off occurred over the edge of the barrier. This was guided into a Parshall flume

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by a system of plastic barriers with a slope of 1%, where the current value of the flow was read and recorded every fifteen seconds. The efficiency of the trapping eroded material by the individual sediment barriers was evaluated on the basis of a differential model determining the volume of the erosion furrows and deposited sediment. Surface measurements by 3D laser scanning were the basis used to create the difference model, which recorded the condition of the soil surface (between the irrigation trough and the sediment barrier) before flooding the sediment barriers, after simulating the flow of 5 L/s and after simulating the flow of 10 L/s. A Leica ScanStation P40 laser scanner (Leica Geosystems, Switzerland) was used for the scanning. It has a 360° × 270° field of view, whose accuracy of measuring the distance is 2 mm + 10 ppm and measuring angle is 8“. Maximum scanning range is up to 270 m (reflectance of 18%). The scanning rate is up to 1 million points per second. The scanner is equipped with a dual axis compensator with accuracy 1.5“. The scanning was carried out at 12 mm per 10 m resolution from one position.

Experimental area. The study area is located in Central Bohemia (Czech Republic) at the experimental station of Hovorčovice (226 m a.s.l.). The climate is warm and moderately dry, with an average annual temperature of 8.5 °C and annual precipitation of 500–600 mm. The geographical coordinate system is 50°10'56.520''N, 14°31'54.914''E (Figure 3). The soil type chernozem was classified on all the experimental plots – with a Main Soil Unit of MSU 01. Based on the soil survey, it can be stated that the basic physical-chemical properties are similar in terms of the soils for the individually tested plots and, therefore, the tested plots are comparable. The upper horizon of all the compared sites shows a texture type, a structure typical of silt loam soil. The basic soil properties: 1.72% total oxidisable carbon (C_{ox}); humus of 2.97%; total nitrogen (N_{tot}) of 0.21; C/N ratio of 8.4. The top soil layer is up to 30 cm (the soil texture: < 0.001 mm, 22.0%; 0.01–0.05 mm, 50.1%; 0.05–0.25 mm, 8.0%; 0.25–2.0 mm, 1.3%). The plots for the tested sediment barriers were selected particularly for their uniform slope of 8.5%.

RESULTS AND DISCUSSION

Despite the fact that sediment barriers have been used abroad for decades, their operational efficiency, proper function and other possible methods of installation and draining are still being addressed. Previously used laboratory and small-scale testing have failed to adequately simulate the surface run-off and to quantify the sediment retention efficiency in relation to structural stability of the barrier. Therefore, more and more experiments are currently beginning to appear that evaluate sediment barriers in operational and pilot conditions (Risse et al. 2008; Bugg et al. 2017b). These conditions were also simulated in our experiments. However, even this method had its limits due to the complexity and possibilities of the verification. Therefore, the results do not take into account the positive effect of the cascade installation of sediment barriers and the occurrence of further erosion on the plots of land located below the sediment barrier.

Sediment barrier efficiency in terms of trapping eroded soil. Within the first hypothesis, the

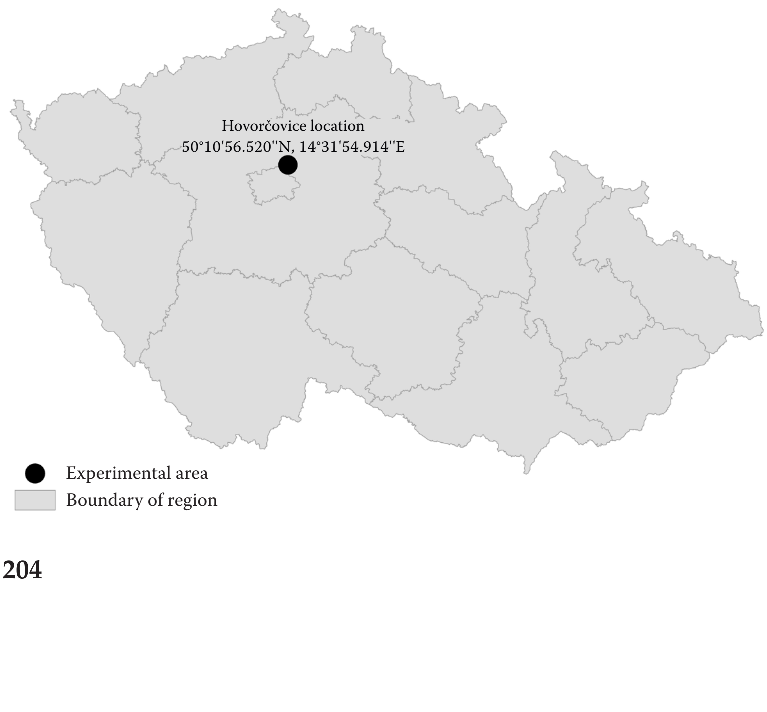

Figure 3. Location of the experimental area

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aim was to verify whether the results show a difference between the efficiency of the individual types of sediment barriers. That is, whether any barrier was demonstrably more efficient and trapped a relatively larger amount of soil particles. When running checks according to the Shapiro-Wilk test, the data were found to have a normal distribution. The arithmetic mean and median of all the sediment barriers were identical at around 90% efficient. The values of the standard deviations, which did not exceed 0.05, were also relatively low. The measured data were subjected to a statistical one-way ANOVA test, when the *P*-value reached 0.64. Therefore, no difference in efficiency was demonstrated between the individual types of sediment barriers (Table 1).

Silt-fence efficiency. Similar research with silt-fence sediment barrier was carried out by Bugg et al. (2017a), who verified and tested three possible installation methods. Our results it is possible to compare only with the two excavation methods of the silt-fence installation. The first type of installation, the ALDOT Trenched Silt Fence, trapped 86.6, 86.7 and 74.8% of the sediment in the individual experiments. Within the second type of installation, the AL-SWCC Trenched Silt Fence installation, the efficiency was even higher at 90.5, 91.0 and 90.0%. Another comparison is offered in the article by Robichaud and Braun (2002), who used a silt-fence as an economical option of measuring hill slope soil erosion. In the first year, the measures were evaluated after each precipitation-run-off event. The average efficiency value was found to be about 93%. In the second year, the individual precipitation-run-off events were no longer checked, only the total value for the season was checked. A 92% success rate was established in this case. Likewise, Kouwen (1990) states that a sediment trap efficiency of 90% and higher can be achieved. Our silt-fence barrier efficiency results, therefore, appear to be similar to these authors. Some authors state slightly lower values. Barrett et al. (1995) measured trap efficiencies in a range of 68–90% and Wishowski et al. (1998) measured trap efficiencies in a range of 69–81%. However, all the above-mentioned values are very favourable in terms of trapping wash-out sediment.

Straw bale barrier efficiency. On the other hand, in the case of another barrier from straw bales, our efficiency results were higher than for other authors. Robichaud et al. (2019) established that the straw bale barrier traps less than 50% of the total volume of eroded material. However, even this value is not considered stable either and its decline during the season is described. Therefore, the sediment barrier needs to be checked and repaired relatively more often. Poché and Sherwood (1976) also establish lower efficiencies, whose study evaluated sediment barriers in operating conditions, where a total of 9 barriers spaced 30.5 m apart were monitored. The straw bale barriers were efficient in a range of 28–98% within the first rainfall. On average, it reached 57%. Within the second rainfall, three measures were already damaged, the others were found to be in the range of 19–50%. Similarly, Johnson (2003) states that straw bales have an average efficiency of trapping medium and coarse sediment particles, and that they are generally not very effective in terms of trapping fine mud or clay particles in the run-off. The location of the barrier is undoubtedly reflected in the efficiency of trapping individual soil fractions. Therefore, the difference between our results and the results of other authors may arise due to the way the sediment barrier is implemented and the location during testing on the site, i.e., on the plot. During the installation, the upstream side was filled with loose soil and then subsequently compacted with a cylinder weighing 60 kg up to the maximum considered level in the

Table 1. Efficiency of the individual types of sediment barriers and the statistical evaluation

Type of sediment barrier		Arithmetic mean	Median	SD	Shapiro-Wilk test	One-way ANOVA test	Paired *t*-test
		(%)			*P* value α = 0.05		
Soil bund with vegetation	5 L/s	90.1	90.0	0.027	0.11	0.64	0.71
	10 L/s	90.3	90.5	0.028			
Silt-fence	5 L/s	91.2	90.5	0.030	0.16		0.63
	10 L/s	90.9	90.0	0.025			
Straw bale barrier	5 L/s	89.8	90.0	0.023	0.98		0.32
	10 L/s	91.1	91.5	0.041			

SD – standard deviation

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storage space. It is the mounding of excavated soils of the upstream side that proves to be a key factor. Without its implementation, there is significant flow leakage and the barrier partially loses its function. Undoubtedly, the different method of drainage also affected the results. After filling the storage space, the water did not flow over the barrier, but flowed out freely at its edge. This area was stabilised to prevent further erosion by the discharge from the sediment barrier. The possibility of lateral drainage was based on the different positioning of the sediment barrier. This was verified on a straight slope and not in a concentrated flow path as in the stated studies.

The efficiency of the soil bund with vegetation. Comparing the result for the anti-erosion soil bund with other studies is relatively complicated due to the different construction and soil-climatic conditions. Therefore, we consider the study of Amare et al. (2014) to be most relevant, as it assessed a soil bund with different types of vegetation cover. These were implemented on experimental plots with an area of 180 m^2 (6 × 30 m). They had a longitudinal slope for draining excess water of 2% and a 10 m interval was kept between the individual bunds. The highest anti-erosion efficiency was found to be in the combination of a soil bundle with elephant grass (*Pennisetum purpureum*), where the soil loss was reduced by 63.5%. For the other two barriers with vegetation cover, the soil loss was reported to be only slightly lower. The soil bund in combination with Vogel's tephrosia (*Tephrosia vogelii*) reduced the soil loss by 58.0% and jaraguá grass (*Hyparrhenia rufa*) by 56.5%. The main reason why our results are higher may be the different realization of the sediment barrier on the plot (contour versus with longitudinal slope). The question of how big this difference can be is addressed in the study by Wolka et al. (2018). It compared the efficiency of different types of sediment barriers due to their location on the plot of land. For a soil bund with a 1% longitudinal slope, an average value of 46% in terms of the reduction in the soil loss is stated, meanwhile, in a soil bund with a contour orientation, it is 60% on average. In another relatively similar sediment barrier, Fanya juu terraces, this difference was found to be even greater than 26%. In both cases, the soil barriers were without vegetation cover. We, therefore, assume that the combination of the contour location and vegetation cover had a positive effect on the efficiency of the barriers that we set.

Impact of the simulated flow in terms of trapping the eroded soil. Another hypothesis addressed whether the efficiency of the barriers would change with the size of the surface run-off, with the individual sediment barriers being flooded with flows of 5 and 10 L/s. A paired *t*-test was used for this purpose. A *P* value of 0.71 was set for the soil bund, 0.63 for the silt-fence and 0.32 for the straw bale barrier (Table 1). Thus, it was not possible to prove that the intensity of the surface run-off had a demonstrable effect on the efficiency of soil particle trapping for any of the sediment barriers (Table 1).

When compared to other studies, the flow rate chosen in our study was comparable. Bugg et al. (2017b) chose 6 L/s, García et al. (2015) chose 5, 7.5 and 10 L/s, Whitmann et al. (2019) chose 6.2 L/s. In some studies (Robichaud et al. 2008; Gogo-Abite & Chopra 2013), the authors used various rain simulators instead of pumps to create surface run-off, which is another way to verify sedimentation barriers. However, the disadvantage is usually a smaller experimental area.

We assume that, in our case, the main influence on this result is the position of the inflow on the sediment barrier and the amount of eroded material in the storage space. Within the measurement, the overflow trough and, thus, the inflow was directed to the centre of the sediment barrier. At this point, during the collision with the barrier and through the influence of the accumulated water, there was a significant reduction in the drag speed, at which the eroded soil sedimented. Even at an increased inflow of 10 L/s, the deposited material was not carried beyond the edge of the barrier to the discharge. This could only happen under two conditions. Firstly, if the storage space was significantly filled with eroded material and secondly, if the inflow was located closer to the edge where the discharge from the sediment barrier occurs.

A similar result is described by García et al. (2015), only on the parameter of the total solids concentration. In the verified sediment barriers, this study did not show a strong relationship between the flow and the total solids concentration under the tank.

Impact of the storage space in relation to the efficiency of the soil particle trapping. The third hypothesis assessed the effect of the size and volume of the storage space on the efficiency of the soil particle trapping regardless of the type of sediment barrier used. Whitmann et al. (2021) states that there are very few studies on design modifications. Therefore, we tried to verify different sizes of storage spaces by adjusting the elevation between the centre

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and the edge of the sedimentation barrier. Certain information and recommendations regarding the construction solution can be found in the manuals and publications of individual US states (TDEC 2012; AL-SWCC 2014; NCDOT 2015; Lake 2016).

In our case, the size of the storage space increased in the individual years in intervals of 5 cm. The determined values of the soil particle trapping efficiency had relatively the same arithmetic mean, median and standard deviation. Using the one-way ANOVA statistical test, a P value of 0.75 was calculated, thus no significant difference was found (Table 2).

The size and especially the volume of the storage space has a direct effect on the resulting run-off from the sediment barrier. Thus, the smaller the storage space, the sooner the run-off occurs at the edge of the sediment barrier. Surprisingly, in the case of the trapping and eroded material, the same principle was not confirmed during our measurements. The amount of eroded material was constant of around 90% regardless of the size of the accumulation. Even with a contour orientation (plane 0 cm), the sedimentation occurred at the moment when the inflow with the eroded material reached the barrier. We noticed a certain difference in terms of distribution only in the form of the sediment between the barrier of the soil bund with the vegetation and the other two barriers, i.e., silt-fence and straw bale barrier without vegetation. In the soil bund, the 1.5 m long storage space was covered with a grass mixture, where the sedimented soil particles had a rather elongated shape in the inflow direction. On the contrary, in the case of the silt-fence and the straw bale barrier, the sedimentation occurred only as a result of limiting the inflow and, therefore, had a longitudinal shape identical to the direction of the barrier. We therefore assume that the importance of the size of the storage space will only become apparent with a larger amount of eroded material and the number of erosion-runoff events. Even a relatively small storage space, on the condition that the sediment is regularly removed, can reliably fulfil the required anti-erosion function. At the same time, a lower probability of structural failures can be expected. However, we intentionally avoided determining the exact size of the storage space, this must depend on the conditions on the plot of land, the source area size (Bugg et al. 2017b), slope (Gogo-Abite & Chopra 2013), the requirement for the amount of soil trapped, etc.

The size of the storage space in relation to the drainage of the sediment barrier was addressed by the work of Donald et al. (2016) and Whitman et al. (2021). They evenly placed the overflow to a height of 0.46 m, which was to drain excess water and relieve the burdening of the sediment barrier silt-fence. In both studies, the sediment trap was more than 90%, i.e., approximately the same as in the case of the barrier without a weir. In our measurements, the sediment barriers were not burdened with such a high water column. To determine the height of the column at the lowest point of the barrier, it is necessary to add an increase in the range of another 5–10 cm to the basic height of the storage space (height between the centre and the edge). The flowing water had to overcome this height in order to flow freely from the edge of the sediment barrier.

Influence of the measurement terms regarding the soil particle trapping efficiency. The last hypothesis asked whether there is any influence concerning the verification term regardless of the type of the barrier. The effectiveness of sedimentation barriers is influenced by a number of indicators, such as the water retention time, barrier length, but also by the type of soil found in the given area or water temperature (Fennessey & Jarrett 1994; Waters 1995).

After having arranged the measured data, it was apparent that the values of the arithmetic mean and median are higher within the autumn verification

Table 2. Efficiency of the sediment barriers in relation to the size of the storage space

Years of measurements	Storage space (elevation between the centre and edge of the sediment barrier)	Arithmetic mean	Median	SD	Shapiro-Wilk test	One-way ANOVA test
		(%)			P value α = 0.05	
Y1	plane 0 cm	90.2	90.0	0.032	0.40	
Y2	height elevation 5 cm	91.5	91.5	0.035	0.36	
Y3	height elevation 10 cm	90.5	90.5	0.024	0.61	0.75
Y4	height elevation 15 cm	90.7	91.0	0.021	0.87	
Y5	height elevation 20 cm	90.0	90.0	0.032	0.65	

SD – standard deviation

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Table 3. Sediment barriers efficiency in relation to the term of the measurements

Term of measurements	Arithmetic mean	Median	SD	Shapiro-Wilk test	Paired *t*-test
	(%)			*P* value α = 0.05	
Spring measurement	88.7	89.0	0.019	0.05	2.79E-07
Autumn measurement	92.5	92.0	0.024		

SD – standard deviation

date. This did not apply to the standard deviations, which remained relatively low for both terms. The normality of the data distribution assessed by the Shapiro-Wilk test had a threshold value of 0.05. Nevertheless, a parametric paired *t*-test was used to assess the probability. The resulting value reached a *P* value of 2.79E-07, thus, the difference between the spring and autumn simulations was statistically significant (Table 3). The results of the efficiency of the individual terms are shown in Figure 4.

We assume that the main reason for the higher efficiency of the autumn term is generally the better tightness of the barriers. In the case of a silt-fence sediment barrier, the individual textile pores are clogged with eroded material during the season. This effect is also described by Whitman et al. (2021) and Bugg et al. (2017a). At the straw bale barrier, the higher tightness is due to the overall compaction of the embankment, on which a protective and less permeable soil crust is frequently formed. Moreover, the principle of compaction undoubtedly also applies in the case of soil bund, which is further supported by the higher quality and density of the grass in the autumn period. A favourable effect of grasses with fast growth and high biomass production is also confirmed by the study of Amare et al. (2014).

CONCLUSION

Sediment barriers have a specific position and use within anti-erosion protection. On plots threatened by erosion, they interrupt the surface run-off and trap soil sediments. Their use and exploitation are most often associated with construction sites, linear transport structures, but they are also beginning to find their application in the agriculture and forestry sectors. In the past, it was not recommended to place sediment barriers in places with more concentrated flow, where they are significantly burdened and there is a risk of damage. However, even in this direction, some changes can be expected thanks to new findings. Sediment barriers are beginning to be equipped with various types of discharge devices that regulate the amount of water retained. However, the parameters of the storage spaces and their efficiency

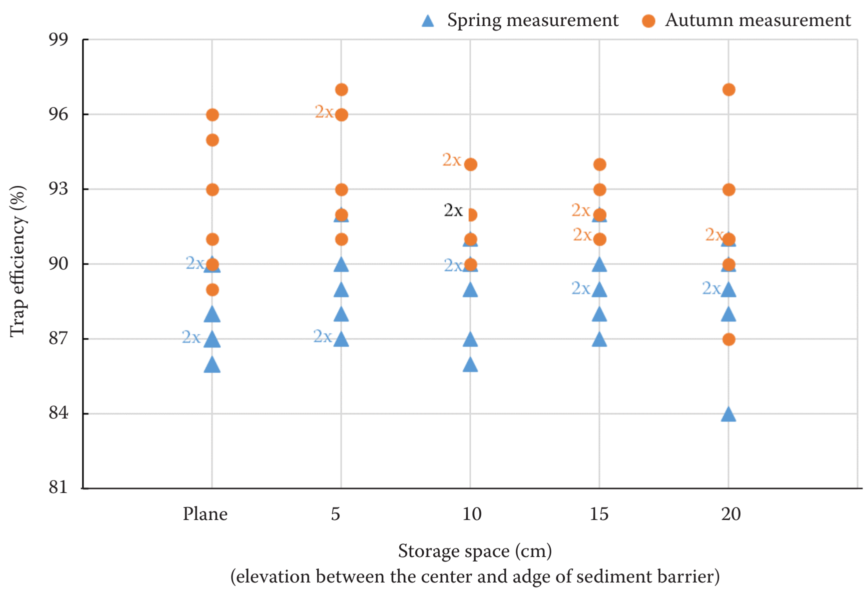

Figure 4. Soil particles trap efficiency in relation to the term of the simulation

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of trapping eroded soil particles are also closely related to this. Therefore, our research focused on verifying the anti-erosion efficiency of sediment barriers and their basic installation parameters.

The sediment process itself, with a high efficiency of about 90% was recorded for all types of barriers: silt-fence, straw bale barrier, soil bund with vegetation even with a minimum size of the storage space. On the contrary, the simulated inflow with a capacity of 5 L/s and 10 L/s had no effect on the resulting efficiency. The correct function of the barrier is therefore limited only at the moment when the trapped sediment begins to reach the edge into the run-off area. This can also speed up an inappropriately oriented concentrated inflow to the side where the sediment barrier is drained.

Surprisingly, the autumn simulation term was slightly better than the spring one in terms of the efficiency results. This is generally due to the lower permeability of the sediment barriers. However, this result would not be achieved without regular maintenance and repairs. The silt-fence barrier required relatively little maintenance work, and this is, in our opinion, one of the reasons why it is considered by most authors to be the most effective. On the contrary, barriers close to nature have a worse position in this respect, lasting approximately 1–2 years on the plot. The benefits of their use will only become apparent upon removal, when the material from which they are made usually remains on the place.

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