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ASSESSMENT OF THE DEGREE OF SODDING AND FLORISTIC COMPOSITION OF THE SLOPES OF THE RACIBÓRZ DOLNY DRY RESERVOIR

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ABSTRACT

Background. The Racibórz Dolny reservoir is a polder located in the Odra Valley in the Silesian Province. It covers area of 26.3 km² and its capacity is estimated to reach 185 million m³. It was under construction between 2013 and 2020, when it became operational. It currently operates as part of the passive and active flood protection system. An important part of flood control reservoirs is the slope, the reinforcement of which can be of a biological nature. It then takes the form of turf, built mainly by plant species from the *Poaceae* and *Fabaceae* families.
Material and methods. Projective cover was calculated for individual species that occur in the turf on the reservoir slopes. This made it possible to determine the percentage composition, and then to quantify vascular plant species. The COBORU methodology was applied to assess the scale of sodding, which includes a 9-grade rating scale.
Results. On the slopes, sodding was found which was created by sowing grass mixtures, mainly *Festuca rubra* L. and *Lolium perenne* L. They demonstrated ground cover from about 25%–75% (quantity 3–4) to 75.1%–100% (quantity 5). They were accompanied by *Trifolium repens* L., *Vicia hirsuta* L.S.F. Gray, and *Festuca arundinacea* (Schreb.). Many other vascular plant species with low cover were also found. Density of turf on slopes was diversified and reached from 45% in the lower part of the slope in part ZC, to 100% in the upper parts of the slope in sections ZC, ZP, and ZL.
Conclusion. In less than two years after the slopes of the Racibórz Dolny dry reservoir were managed by sowing grass mixtures, it was found that their sodding was diversified. The lower parts of the slopes on both the dehydration and vent side were more poorly sodded. It appears that grass species more predisposed to sowing in such artificial communities could be *Poa pratensis* L., *Agrostis capillaris* L., and *Festuca ovina* L. This may serve to achieve proper sodding, which, as a result, is expected to strengthen and protect the slopes against erosion.

Key words: degree of slope sodding, dry reservoir, optimal grass species

INTRODUCTION

The function of dry reservoirs is to reduce the flood wave while maintaining the natural flow in the riverbed during non-flood periods. In Poland, most of the existing facilities of this type are located in the Sudety Mountains, in the Opolskie and Lower Silesian Voivodships. They were built between 1905 and 1929,

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on the tributaries of the Oder River. Flooded areas are often left in their natural state, and retain a mosaic pattern of habitats. These places are characterised by a high diversity of flora and fauna, especially species of birds, amphibians, and fish. This indicates that such facilities are of little harmfulness to nature, and even create good conditions for the development of many of its components (Lenar-Matyas *et al.*, 2009). This may therefore represent an added value of their construction and maintenance (Breil, 2008). Furthermore, some dry reservoirs are also located in agricultural areas used as pastures. Racibórz Dolny is a dry flood control reservoir (polder) located in the Silesian Voivodship, in the Odra valley. It covers the area of 26.3 km² and has an estimated capacity of 185 million m³. It was built between 2013 and 2020, and became operational in 2020. Two villages in the district of Wodzisław, namely Nieboczowy and Ligota Tworkowska (https://pl.wikipedia.org/wiki/Racib%C3%B3rz_Dolny), were closed down for the construction of the facility. The reservoir was built within the *Programme for the Oder River 2006*, as an element of the system of passive and active flood protection (Dz.U. 2001.98.1067 art. 2).

An important element of all flood control reservoirs is the slope, which is a structural element of earthen structures. The slope can be reinforced artificially, for example with concrete, or biologically, where turf is most commonly used (Głażewski and Piechowicz, 2009). Also, the low, creeping shrubs can be used to strengthen the slopes. However, due to the significant costs, this solution is used only on small sections of embankments, and slopes. Therefore, the most often practice is sowing some mixtures of grasses and legumes, in order to strengthen the slopes and protect them against erosion. In this way, specific plant reinforcements are created (Coopin and Richards, 1990; Begemann and Schiechtl, 1999). The way in which a slope is fortified depends on its intended use and also on the environment in which it will be located. This includes the frequency of precipitation and exposure to surface runoff, and the type and properties of the soils (Makowski, 1976).

The aim of the study was to determine the degree of sodding and the floristic composition of the slopes of the newly created dry Racibórz Dolny reservoir, along with finding the optimum grass species for the use on these particular slopes.

MATERIAL AND METHODS

The slopes of the Racibórz Dolny reservoir dams have the total length of 22.4 km, the height of the embankments ranges from about 6.0 m to 17.0 m, and the width of the slopes varies from about 6 m to 20 m (Fig. 1). The shortest slopes are those with the slope of 1:6 (lowest on the dehydration side). Floristic inventory, and the assessment of the degree of slope sodding of the Racibórz Dolny reservoir was made in 2021, along its entire length, divided into the upper and lower parts of the slope. The research included the head dam (ZC), the right-bank dam (ZP) and the left-bank dam (ZL), assessed from the dehydration and vent side. The head dam extends in the northern part of the Racibórz Dolny reservoir over the length of 4 km (mileage ZC 0+000 – ZC 4+000). The right-bank (ZP) dam is 8.8 km long and is situated in the eastern part of the reservoir, at the mileage ZP 0+000 – ZP 8+800. The left-bank dam (ZL) is 9.6 km long and extends in the western part of the reservoir, at the mileage ZL 0+000 – ZL 9+600.

Fig. 1. Research area – slopes of the Racibórz Dolny reservoir (with marked locations of soil sampling)
Source: Own study based on *google maps*

The soil on the slopes of the reservoir, which was of medium compactness, comes from the immediately adjacent areas and was previously used for agricultural crops, and permanent grasslands. It forms a 15 cm thick layer, with a protective layer made of asphalt underneath. In addition, on the dehydration side, a reinforcement structure was applied to the top soil layer in the form of a 10 cm thick humus layer, an anti-erosion grid, and a 5 cm thick humus layer, on which grass mixtures were sown. Chemical analysis of the soil indicated its very acid reaction, very low content of total nitrogen, and medium and high content of organic matter (Table 1). Moreover, in the vast majority of soil samples, high contents of the assimilable forms of phosphorus, and potassium were found. The exception in this respect was the soil on the slopes of ZP, on the dehydration side, where the very high content of those macroelements was found. According to PN-R-04023:1996 and PN-R-04022: 1996+Az1:2002, for the above-mentioned components, those were content classes III and II. In soil samples ZC and ZL, at the mileages 4+500 (from both sides), and 9+500 (from the vent side), very low content of assimilable magnesium was found. On the other hand, on ZP and ZL at the mileage 9+500 (from the dehydration side), low Mg content in the soil was found. According to PN-R-04020:1994+Az1:2004, those were Mg content classes V and IV.

Table 1. Chemical properties of the soil on the slopes of the Racibórz Dolny reservoir

Specification		pH		Content				
				$g \cdot kg^{-1}$ soil		Available, $g \cdot kg^{-1}$ soil		
		H_2O	KCl	Org. matter	N – total	P_20_5	K_20	Mg
ZC 0+000	dehydration	5.26	4.12	22.3	3.1	0.125	0.162	0.028
	vent	4.97	4.09	19.4	3.0	0.107	0.148	0.027
ZC 4+000	dehydration	5.32	4.25	25.1	3.2	0.139	0.171	0.030
	vent	5.04	4.11	23.7	2.9	0.112	0.135	0.029
ZP 4+400	dehydration	5.27	4.03	21.3	3.5	0.159	0.203	0.031
	vent	5.13	4.22	20.6	3.0	0.123	0.189	0.031
ZP 8+400	dehydration	5.20	4.16	19.8	3.4	0.161	0.213	0.032
	vent	4.96	4.01	18.9	2.9	0.145	0.194	0.034
ZL 4+500	dehydration	5.41	4.26	20.5	3.2	0.136	0.196	0.030
	vent	4.89	4.20	17.1	2.6	0.118	0.157	0.028
ZL 9+500	dehydration	5.03	4.07	18.4	3.0	0.150	0.181	0.031
	vent	5.18	4.23	15.7	2.8	0.142	0.176	0.029

Source: own study (2021)

Grass mixtures were sown on the slopes of the Racibórz Dolny dam in 2019 and in the spring of 2020. Two mixtures were used, the first of which was ‘*Universalna S*’ with the composition: *Festuca rubra* (3 cultivars Adio 10%, Areta 20%, and Reda 30%), and *Lolium perenne* (2 cultivars Naki 30% and Boxer 10%). The second mixture was *'Skarpowa II type A1'*, with the following composition: *Festuca rubra* (3 cultivars Reda 10%, Maxima 1 10%, and Rapsodia 10%), *Lolium perenne* (2 cultivars Naki 15% and

Boxer – 15%), and *Festuca arundinacea* (2 cultivars Tomahawk 20% and Escalante 20%). In 2021, the floristic composition of the slopes was determined. For individual species that occurred in the sward, the so-called projective cover was calculated (Braun-Blanquet, 1964). The COBORU methodology was applied to assess the sodding, with a 9-degree rating scale (Table 2), (Domański, 1992 and 1998). The Latin nomenclature is given according to Mirek *et al*. (2002).

Table 2. Projective cover of plants in the sward and the degree of sodding

Degree of quantitativeness	Site coverage by given species	Rating scale		% of sodding
5	75.1%–100%	(1). bad	no plants	0–5
4	50.1%–75%	(2). bad to poor		6–15
3	25.1%–50%	(3). poor		16–25
2	5.1%–25%	(4). poor to sufficient		26-40
1	1%–5%	(5). sufficient	average density	41-60
+	<1%	(6). sufficient to good		61-75
r!	1–2 specimens	(7). good		76-85
		(8). good to very good	total density	86-95
		(9). very good		96-100

Source: own study based on: Braun-Blanquet (1964) and Domański (1992; 1998)

RESULTS AND DISCUSSION

The drainage structure used on the slopes of the Racibórz Dolny reservoir with a humus layer of about 10-15 cm should be conducive to sodding. Problems with rooting may occur in the case of some plant species. Therefore, grass species that do well in a habitat with a thin layer of humus are best suited there. On the slopes, sodding was found that resulted from the sowing of the applied grass mixtures. Those were mainly *Festuca rubra* L. and *Lolium perenne* L. Both of those species demonstrated ground cover ranging from about 25%–75% (quantity 3–4) to 75.1%–100% (quantity 5), and are dominant there. They were accompanied by *Trifolium repens* L., and *Vicia hirsuta* L.S.F. Gray. In addition, many other vascular plant species with low or very low cover were found in the slope sward (Table 3). *Festuca rubra* used in the sodding mixture is a grass with a wide ecological amplitude, occurring in various soil types. It does not have high requirements concerning soil abundance in nutrients, which makes it suitable also for worse habitat conditions (Balcerkiewicz, 2007). The other main component of the mixture, *Lolium perenne* is one of the basic grasses used for perennial and short-term, intensively used pastures. After sowing, it develops very quickly, flourishes intensively, and in the first year often dominates the sward. However, it is sensitive to unfavourable habitat conditions (Grabowski *et al*., 2003). Its desirable traits also include tolerance to insufficient or excessive water in the soil, lack or excess of nutrients, and high competitiveness towards accompanying species (Broda *et al*., 2003; Trąba and Grzegorczyk, 2003; Starczewski and Affek-Starczewska, 2011).

Table 3. Floristic composition and quantity according to Braun-Blanquet (1964) of vascular plant species on the slopes of the Racibórz Dolny reservoir

Species name	Quantity			Species name	Quantity		
	ZC	ZP	ZL		ZC	ZP	ZL
Festuca rubra L.	3–5	3–5	3–5	*Lotus corniculatus* L.	·	·	+
Lolium perenne L.	3–5	3–5	3–5	*Lupinus polyphyllus* Lindl.	·	·	+
Trifolium repens L.	2–3	2–3	2–3	*Medicago lupulina* L.	1	1	1
Vicia hirsuta (L.) S. F. Gray	1–2	1–2	1–2	*Myosotis arvensis*(L.) Hill	+	+	+
Festuca arundinacea (Schreb.)	1	1	1	*Oxalis stricta* L.	+	+	+
Achillea millefolium L.	+	+	+	*Papaver dubium* L.	+	+	+
Agrostis capillaris L.	+	+	+	*Papaver rhoeas* L.	+	·	+
Alopecurus geniculatus L.	+	·	·	*Plantago lanceolata* L.	1	+	+
Alopecurus pratensis L.	+	+	+	*Poa annua* L.	+	+	+
Anagalis arvensis L.	r!	·	·	*Poa pratensis* L.	1	1	1
Anthemis arvensis L.	+	+	+	*Poa trivialis* L.	1	1	1
Anthoxanthum odoratum L.	+	+	+	*Potentilla anserina* L.	+	+	+
Anhusa officinalis L.	·	·	+	*Ranunculus acris* L.	+	+	+
Arrhenatherum elatius (L.) P. Beauv	1	1	1	*Reynoutria* sp.	+	+	+
Artemisia vulgaris L.	+	+	+	*Rubus* sp.	+	+	+
Bromus mollis L.	+	+	+	*Rumex acetosella* L.	+	+	+
Capsella bursa pastoris (L.) Medik.	+	+	+	*Rumex acetosa* L.	+	+	+
Cerastium arvense L.	+	+	+	*Senecio vulgaris* L.	·	+	·
Cirsium arvense (L.) Scop.	+	+	+	*Sinapis arvensis* L.	+	·	+
Conyza canadensis L.	+	+	+	*Sisymbrium officinale* (L.) Scop.	+	+	+
Convolvulus arvensis L.	+	+	1	*Solidago canadensis* L.	+	+	+
Dactylis glomerata L.	1	1	1	*Stellaria graminea* L.	+	+	+
Elymus repens (L.) Gould	+	+	+	*Symphytum officinale* L.	+	+	+
Equisetum arvense L.	+	+	+	*Taraxacum officinale* Web.	+	+	+
Erigeron annuus (L.) Pers	+	+	+	*Teesdalea nudicaulis* (L.) R. Br.	+	+	+
Erodium cicutarium (L.) L`Her.	+	+	+	*Thlaspi arvense* L.	+	+	+
Erysimum cheiranthooides L.	+	+	+	*Trifolium campestre* Schreb.	+	1	1
Euphorbia cyparissias L.	+	+	+	*Trifolium hybridum* L.	1	1	1
Festuca pratensis Huds.	1	1	1	*Tussilago farfara* L.	+	+	1
Geranium pratense L.	+	+	+	*Urtica dioica* L.	+	+	+
Heralcleum sosnowskyi Manden.	+	·	·	*Veronica chamaedrys* L.	+	+	+
*Holcus lanatus*L.	1	1	1	*Vicia angustifolia* L.	+	+	+
Holcus mollis L.	1	1	1	*Vicia cracca* L.	+	+	+
Lamium amplexicaule L.	·	·	r!	*Viola arvensis* Murray	+	+	+

Source: Own study (2021); explanations to the table: ZC – head dam, ZP – right-bank dam, ZL – left-bank dam

On the slopes located on the head dam (ZC), both on the dehydration and vent side, in the upper part of the slope, main grass species occurred in similar proportions. In the lower part, *Festuca rubra* was more abundant. The best quality of sodding was in the upper part of the slope – vent side, the mileage ZC 0+000 – ZC 4+000. In such places occurred *Trifolium repens*, which was observed, in the form of patches about 1–1.5 m in diameter, where the sodding reached up to 100% (Table 4). Other vascular plant species were also present, showing low cover. Single specimens of *Reynoutria* sp., an invasive species, reaching up to several centimetres in height, as well as *Rubus* sp. were found. In places with some deficiencies in sodding, grass seeds, including *Festuca rubra*, were visible. Mechanical damage was also visible, in the form of stripes from several centimetres to several metres long, as an effect of cross motorbikes riding on the slopes, which was also observed during the natural inventory of the area. Sodding density on the slopes at the mileage ZC 0+000 – ZC 4+000 was clearly diversified. It ranged from approximately 45% in the lower part of the slope on the dehydration site, which indicates sufficient sodding (number 5 on the rating scale). In the upper layers of the slope, on the dehydration and vent side, the sodding ranged between 60 and 100%. That characterize the turf density from sufficient and good, to a very good. Mown patches of grasses were predominated there, but also there were patches of plants that had not been mown before, which were interspersed with them.

Table 4. Head dam (ZC) – sodding of the slopes of the Racibórz Dolny reservoir from the dehydration and vent side

Mileage	ZC – head dam – sodding density on the slopes (%)			
	Dehydration		Vent	
	Lower part of the slope	Upper part of the slope	Lower part of the slope	Upper part of the slope
ZC 0+000 – ZC 1+400	65–90	85–100	65–90	80–100
ZC 1+500 – ZC 1+900	65–80	60–100	60–90	70–100
ZC 2+000 – ZC 2+400	45–75	70–95	60–90	70–100
ZC 2+500 – ZC 4+000	65–80	75–95	70–90	80–100
Dominating species in the sward	*Festuca rubra*	*Lolium perenne*, *Festuca rubra* – similar proportions	*Festuca rubra*	clusters of *Trifolium repens* up to 100%; *Lolium perenne*, *Festuca rubra* – similar proportions

Source: Own study (2021)

On the right-bank dam (ZP), in the upper part of the slope, both grass species occurred in similar proportions (Table 5). In the lower part, *Festuca rubra* showed a higher degree of coverage. There were many patches of *Trifolium repens*, in the form of irregular circles with the diameter of about 1.4 m, and similar clusters of *Vicia hirsuta* as well. In those places, the sodding reached up to 100%, so it was very good. Other vascular plant species were also found, with low cover in patches. Similarly to the head dam (ZC), single specimens of *Reynoutria* sp. and *Rubus* sp. were found, as well as some single specimens of *Solidago canadensis*. In places where gaps in the sodding were visible, reseeding with grass seeds was observed.

Mechanical damage was also observed, in the form of strips several metres, and over a dozen centimetres long. In this part of the dam, mown patches of grasses were clearly predominant. In such parts, where the turf was mown, there was also more biomass. This is beneficial, as it will contribute to the further soil fertilisation. In the lower part of the slope, gaps in the sward were visible - average area of such gaps of about 2–3 m², and proper grass seeds were reseeded.

Table 5. Right-bank dam (ZP) – sodding of the slopes of the Racibórz Dolny reservoir from the dehydration and vent side

Mileage	ZP – right-bank dam – sodding density on the slopes (%)			
	Dehydration		Vent	
	Lower part of the slope	Upper part of the slope	Lower part of the slope	Upper part of the slope
ZP 0+000 – ZP 3+900	70–85	80–95	65–90	60–95
ZP 4+000 – ZP 6+000	60–85	75–100	60-85	80–100
ZP 6+100 – ZP 8+800	65–85	75–100	75–85	85–100
Dominating species in the sward	*Festuca rubra*	*Lolium perenne*	*Festuca rubra*	*Lolium perenne,* clusters of *Trifolium repens* up to 100%

Source: own study (2021)

The left-bank dam (ZL) extends in the western part of the polder, at the mileage ZL 0+000 – ZL 9+600, thus its length is 9.6 km. Grass reseeding was evident in several bare areas of up to 3 m². Both on the dehydration and vent side, in the upper part of the slope, both grass species used in the mixture occurred in similar proportions. In the lower part of the slope, *Festuca rubra* was more abundant. Many clusters of *Trifolium repens* were found, in the form of patches 1–1.5 m in diameter, along the entire height of the embankment. In those areas, the sodding reached up to 100%, and was therefore very good. Numerous other vascular plant species were also present, which demonstrated low cover in patches (Table 3). Single specimens of *Reynoutria* sp. (plants reached up to several centimetres in height), *Rubus* sp., and *Solidago canadensis* were found. However, the latter species was rarely recorded on the vent side, which may also be related to the fact that it was slightly drier there, than on the dehydration side. Seed sowing was found in patches that were not sodded. The density of sward on the slopes at the mileage ZL 0+000 – ZL 9+600 is presented in Table 6. The predominant patches were grasses, which were already mown in the 2021 vegetation season, but there were also patches with visible sward regrowth.

On the slopes of the Racibórz Dolny reservoir, overdrying of soil was observed, which often shows a skeletal character. A structure made of non-cohesive, easily permeable material called a protective layer of sandy gravel, located directly under the layer of fertile soil, may exacerbate periodic water deficits in the substrate, as liquid is not retained but drained away by this structure. This is particularly important for plant species that are sensitive to stress conditions that result from water deficits in the substrate. In the case of the embankments, on such long and sloping stretches, sprinkler irrigation, as is done for example on sports fields, is not possible, so in this situation a suitable selection of species for the substrate is necessary.

Table 6. Left-bank dam (ZL) – sodding of the slopes of the Racibórz Dolny reservoir from the dehydration and vent side

Mileage	ZL – left-bank dam – sodding density on the slopes (%)			
	Dehydration		Vent	
	Lower part of the slope	Upper part of the slope	Lower part of the slope	Upper part of the slope
ZL 0+100 – ZL 5+000	80-95	70-100	60-95	75-95
ZL 5+100 – ZL 7+400	60-85	80-100	65-85	70-95
ZL 7+500 – ZL 9+500	60-85	85-100	50-85	60-95
Dominating species in the sward	*Festuca rubra*	*Lolium perenne*, *Festuca rubra* – similar proportions	*Festuca rubra*	*Lolium perenne*, clusters of *Trifolium repens* up to 100%

Source: own study (2021)

Observations and experience described by Głażewski (2003) demonstrate that when carrying out finishing and recultivation works, the scope of works related to the removal of erosion damage can be minimised by using a mixture of grass seeds and legumes with the addition of mulch. In Poland, the evaluation of the functional traits of lawn grasses is most often made on a nine-point scale (Prończuk, 1993; 1998; Prończuk and Prończuk, 1994). However, most of such traits are not measurable, but based on visual assessment, and especially important is the assessment of sward cover. The quality of sodding is conditioned by many variables, among others the habitat conditions and the weather course during the growth period: temperature, amount of precipitation, length of day, and degree of sunshine. It also appears very important to correctly select grass species and cultivars for sowing (Domański, 1999; Czarnecki and Harkot, 2002; Prończuk, 2002; Jankowski *et al.*, 2003; Starczewski and Affek-Starczewska, 2011). In order to achieve proper sodding on special surfaces, such as embankments, a selection of preferably several plant species and within them also several different cultivars should be applied. For reservoirs such as Racibórz Dolny, this increases the chances of good sodding, taking into account the different trophicity and soil moisture in the 22.4 km long area.

Due to the sloping terrain, species with loose-tuft and stoloniferous root systems should be sown on slopes to protect the soil. Grasses that reinforce the ground cover with vegetative shoots are ideal for this. In areas with pronounced slopes, water deficit in the subsoil also becomes a problem, especially on the top and on the slopes. This is reflected in the sodding and the harvested biomass. Therefore, species with low sensitivity to such stress conditions should be selected for those sites. *Lolium perenne*, due to its very high moisture and soil nutrient requirements, appears to be less predisposed to this type of site. In such an artificial habitat, *Poa pratensis* L., a species with loose-tuft and stoloniferous tillering, such as its forms *Poa pratensis* var. *latifolia* or *Poa pratensis* var. *angnustifolia*, may perform better. The loose-tuft and stoloniferous root system is assessed as a very advantageous characteristic, as the development of new plants takes place by means of stems, which enable fast regeneration after damage caused by, for example, biotic and abiotic stresses (Prończuk and Prończuk, 2008). The advantage of this species with competitiveness group III is also the variability of forms and the effects of good sodding regardless of soil richness and moisture (Martyniak, 2003). It should be sown as a substitute for *Lolium perenne* where soils show low abundance and are periodically dry, with a high amount of skeletal fractions.

Another species adapted to the environmental conditions of slopes is *Agrostis capillaris* L. In Poland, it is a very common grass, predisposed to sowing on periodically dry and moderately fertile or barren soils with deficiencies of nutrients and water. On slopes characterised by high insolation and low trophicity, *Festuca ovina* L., a short grass with a wide ecological amplitude, included in competitiveness group III, will also prove useful. It develops well on soils poor in phosphorus, especially acidic, in well-sunlit positions (Kwietniewski, 2006; Prończuk *et al*., 1997). Currently, its use for sodding various types of surfaces, including the so-called difficult areas, is increasing. Other alternative species for sowing in particularly dry places can be *Festuca filiformis* Pourr., *Festuca capillata* Lam., and *Festuca trachyphylla* (Hack.) Krajina, as well as *Festuca ovina* sp. *duriscull*a (L). Koch. They do not require frequent mowing and, in mixtures, can be easily outgrown by accompanying species due to poor competitiveness (group III).

On such an extensive area as the slopes of the Racibórz Dolny reservoir, where the trophicity and humidity of the substrate are highly diversified, it may not be possible to achieve an overall cover of 95–100%, while the current cover is satisfactory. In places with lower plant density, grass seeds are sown on a regular basis. The sodding also protects the embankments from erosion. On the embankments of the dam, regular mowing of the turf was observed, which, after being shredded, is left on the mown plants. This is a very good solution, as the shredded and left over biomass contributes to soil fertilisation. In addition, the shredded plants fill any gaps in the turf, effectively protecting it from water and wind erosion. Mowing, on the other hand, stimulates especially some grasses to grow even more vigorously. Mowing also effectively reduces undesirable dicotyledonous plants, especially the so-called invasive species, such as *Solidago canadensis* and *Reynoutria* sp. The shredded plants left behind are also not indifferent to the growth and development of certain species, such as *Solidago* sp. and contribute to reducing their populations without harming the grasses.

However, it should be noted that intensive mowing of the reservoir slopes may weaken the persistence of the species in the mix. With the current state of sodding on the vast majority of embankment areas, it is possible to achieve plant densities above 85% by regular mowing, shredding the plants, and leaving them on the mowing site. Mineral NPK fertilisation should also be applied, as it stimulates grass growth and development, increases tillering, and contributes to the formation of more biomass (Grygierzec *et al*., 2020). However, N fertilisation causes the disappearance of species from the *Fabaceae* family, so the contribution of, among others, *Trifolium* sp. and *Vicia* sp. is limited. Also reseeding with *Trifolium repens* seems to be a good alternative in this area. This has a beneficial effect on soil richness through the assimilation of atmospheric nitrogen by *Rhizobium* sp. It should be added that of all the elements known in the world, plants react most strongly to a deficit of nitrogen in the soil, which manifests itself, depending on the species, with for example poor rooting, yellowing of leaves, and stiffness of tissues (Łyszcz and Gałązka, 2016). The above-mentioned factors affect the quality and speed of surface sodding by plants. In Poland, nitrogen deficiencies are often observed, which can be supplemented chemically, by applying synthetic fertilizers. However, such a method requires high energy inputs, is expensive, and negatively affects the environment (Napora *et al*., 2015). It is estimated that the amount of N_2 bound by microorganisms exceeds the amount of nitrogen produced with industrial methods by about four times (King, 2006). In the natural environment, it is the process of biological nitrogen fixation that is one of the best methods of introducing into the soil reduced nitrogen compounds that are available to plants. Therefore, reseeding with species from the *Fabaceae* family, especially *Trifolium repens*, is beneficial.

CONCLUSIONS

In less than two years after the slopes of the Racibórz Dolny dry reservoir were managed by sowing grass mixtures, it was found that their sodding varied. The lower part of the slopes, both on the dehydration and vent side, was less well sodded. In the upper parts of the slopes, included in sections HD, RD, and LD, the sodding was much more favourable, sometimes even reaching 100%. The dominant species in the sward were *Festuca rubra* and *Lolium perenne*, with cover ranging from about 25%–75% to 75.1%–100%. Due to the slope of the terrain, species with a loose-tuft and stoloniferous root systems should be sown on the slopes in order to protect the soil. Grasses with vegetative shoots, such as *Poa pratensis*, *Agrostis capillaris*, or *Festuca ovina*, are ideal for this. On the other hand, *Lolium perenne*, due to its very high moisture and soil requirements, appears to be less suited for this type of site. On such an extensive area, with the observed large trophic diversity, it may not be possible to achieve the sodding of 95%–100%.

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OCENA STOPNIA ZADARNIENIA I SKŁADU FLORYSTYCZNEGO SKARP SUCHEGO ZBIORNIKA RACIBÓRZ DOLNY

Streszczenie

Zbiornik Racibórz Dolny to polder położony w dolinie Odry, na obszarze woj. śląskiego. Zajmuje powierzchnię 26,3 km², a jego pojemność określa się na 185 milionów m³. Powstawał od 2013 do 2020 roku, kiedy został uruchomiony. Obecnie działa jako element systemu biernego i czynnego zabezpieczenia przeciwpowodziowego. Istotną częścią zbiorników przeciwpowodziowych jest skarpa, której umocnienie może być o charakterze biologicznym. Ma wówczas postać darni, budowanej głównie przez gatunki roślin z rodzin *Poaceae* oraz *Fabaceae*. Dla poszczególnych gatunków występujących w darni na skarpach zbiornika obliczono pokrycie projektywne, co pozwoliło określić skład procentowy i następnie wyznaczyć ilościowości dla gatunków roślin naczyniowych. Do oceny skali zadarnienia zastosowano metodykę COBORU, obejmującą 9-stopniową skalę bonitacyjną. Na skarpach stwierdzono zadarnienie, które powstało w wyniku wysiewu mieszanek traw, głównie *Festuca rubra* L. oraz *Lolium perenne* L. Wykazują one pokrycie terenu od około 25–75% (ilościowość 3–4) do 75,1–100% (5). Towarzyszą im *Trifolium repens* L., *Vicia hirsuta* L.S.F. Gray oraz *Festuca arundinacea* (Schreb.). Stwierdzono także występowanie wielu innych gatunków roślin naczyniowych z niskim pokryciem. Zwarcie darni na skarpach było zróżnicowane i wynosiło od 45% w dolnej części skarpy ZC – do 100 % w górnych częściach skarpy na odcinkach ZC, ZP oraz ZL. W okresie niespełna dwóch lat od zagospodarowania skarp suchego zbiornika Racibórz Dolny poprzez wysiew mieszanek traw stwierdzono, że ich zadarnienie było zróżnicowane. Dolne część skarp od strony zarówno odwodnej, jak i odpowietrznej były słabiej zadarnione. Wydaje się, że gatunkami traw bardziej predysponowanymi do wysiewu w takich sztucznych zbiorowiskach mogą być: *Poa pratensis* L., *Agrostis capillaris* L. oraz *Festuca ovina* L. Może to posłużyć do uzyskania prawidłowego zadarnienia, co w rezultacie ma umocnić i zabezpieczyć skarpy przed erozją.

Słowa kluczowe: optymalne gatunki traw, stopień zadarnienia skarp, suchy zbiornik