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Sustainable Use of Organic Matter Obtained from the Bottom of a Post-Mining Pit Reservoir—A Case Study on the Creation of Raduszyn Lake in Poland

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Abstract: According to historical sources, a watermill existed in the valley of the Trojanka River on the north-western shore of Raduszyn Lake from the 15th century. Its dams lasted for centuries causing the water flow through the Raduszyn reservoir to slow down and deposit various mineral fractions in it. The aim of paper was to develop a scientific background for the sustainable management of organic matter extracted from the peat top and from deeper layers that are unsuitable for direct use, that is, decomposed peat. A SWOT (strengths, weaknesses, opportunities, threats) analysis was used to describe ways of restoration of the water reservoir alongside the characterization of organic matter and the financial condition of the studied enterprise. For the use of the studied material as a homogeneous substrate for plant cultivation, the contents of nitrogen, phosphorus, potassium, and copper were insufficient, whilst calcium was excessive. Microbiological analyses of the organic materials intended as an additive for horticultural substrates confirmed the presence of plant growth-promoting bacteria. The occurrence of such microorganisms in the substrate can limit the use of mineral fertilizers and chemical plant protection products. The results of the research can be an example for enterprises restoring or creating water reservoirs by extraction of organic matter, which is often considered as waste that generates costs and does not bring financial benefits. Such a measure can be used to improve the efficiency of water reservoir restoration enterprises and at the same time contribute to sustainable land development.

Keywords: organic matter; SWOT analysis; peat substrate; chemical composition; bacterial biodiversity; financial indexes

Citation: Czerwińska-Kayzer, D.; Kleiber, T.; Wolna-Maruwka, A.; Frankowski, P.; Staniszewski, R.; Kayzer, D. Sustainable Use of Organic Matter Obtained from the Bottom of a Post-Mining Pit Reservoir—A Case Study on the Creation of Raduszyn Lake in Poland. *Energies* **2023**, *16*, 2223. https://doi.org/10.3390/en16052223

Academic Editors: Jacek Grams and Agnieszka Ruppert

Received: 23 January 2023
Revised: 8 February 2023
Accepted: 16 February 2023
Published: 25 February 2023

1. Introduction

According to historical sources, in the year 1433 a watermill was built in the valley of the Trojanka River on the north-western shore of Raduszyn Lake [1]. Hydrographic conditions favored its location in the estuary of the river flowing through Raduszyn Lake. It was necessary to alter the Trojanka estuary to reach the water level necessary to start up the mill wheel, however no ponds were dug. The water needed to drive the wheel was used until the beginning of the 20th century. It can be assumed that the source of energy to drive the wheel was then changed from water to steam, which resulted in the backfilling of the culvert supplying water to the mill. The dam which had existed there for centuries thus caused the water flow through the reservoir to slow down and deposit various mineral solid fractions in it, including a fine fraction with a grain diameter smaller than 0.05 mm. Over time, the reservoir became covered by aquatic plants, which led to the filling of the reservoir with organic matter and extensive overgrowing of the lake.

Water resources conservation in central Europe is of high importance due to climate changes, inducing water shortage caused by hot summers and unpredictable distribution of precipitation during the year. Owing to the relatively low precipitation in Poland and long periods without rainfall, investments to increase the number of small and medium retention lakes have been undertaken throughout the country. The so-called small retention projects are particularly important in regions such as Greater Poland, where water shortages for agricultural purposes occur almost every year. In the years 1991–2021 the average temperature in Poznan (center of the region) was 9.7 °C and the average precipitation was equal to 649 mm [2]. The development of small retention capacity is based on regulations of the Water Framework Directive [3]. The need for water management at the catchment level is presented and there as a high requirement in Europe. The development of water retention capacity is carried out through the construction of water reservoirs, lake impoundments and the enhancement of water retention in river channels [4,5]. Water can also be stored in natural conditions other than in lakes or reservoirs, for example in river channels, peatlands, and bogs.

Wetlands, including peatlands areas are considered as a valuable factor in water retention, especially when peatlands are not degraded [6,7]. Peatlands can accumulate carbon dioxide, which makes them important components of the environment that have potential to regulate global processes shaping climatic conditions. For instance, the presence of peatlands in the Northern Hemisphere intensified the decline of air temperature during the ice ages. In contrast, under current conditions, ecosystems are exposed to negative effects of thermal and humidity factors leading to changes in their functioning. In the case of climate warming, it is expected that this situation can amplify net carbon dioxide emissions from peatlands into the atmosphere [7]. Peat is present in different geographical locations and is excavated in many countries due to its value as a fuel, an organic compound for mushroom cultivation, and for medical purposes. In Poland, the area of mined peatlands is 3300 hectares and 202,000 hectares are still accumulating [8,9]. It is important to consider that the emission of carbon dioxide from degraded peatlands is higher than its accumulation. In 2008, total emission of CO_2 from degraded peatlands was estimated to 24 million tons per year in Poland, 34 million tons per year in Germany, and 500 million tons per year in Indonesia (world highest) [10]. It was found that one hectare of drained peatland can emit 0.75 tons of CO_2 per year [11].

Recent studies have shown that after peat excavation, a post-mining pit lake can be created that will have a positive impact on the local landscape, water management, and recreation [12]. In the Greater Poland region, a unique lake was created in Nienawiszcz village (52°40′31.6′′ N, 16°59′05.0′′ E) with special attention paid to reconstruction of the shape of a former post glacial lake [12,13]. Similar procedures are planned for the degraded Raduszyn peatland, where in accordance with Polish legislation, a mine was established to conduct peat excavation in the year 2017. The former lake will be reconstructed simultaneously with the turf excavation. Most existing peat mine reservoirs in the World are cutaway lakes with almost vertical banks resulting from the excavation process, thus dangerous for the local community and for recreation [14–16]. Nevertheless, taking into account the concerns mentioned above, cutaway lakes can be perceived as a very interesting places for specific recreation purposes, such as angling and bird watching [17]. The conclusions formulated based on this study will be used in the reclamation of further reservoirs that will be created as a result of peat mining. The main point is to avoid problems observed in the Przebedowo reservoir, where the leaving of organic matter in the bottom layer led to rapid overgrowth of the water body [18]. The average discharge of the Trojanka River, which also flows through the Przebedowo reservoir, for the summer period in the years 1951–2005, was equal to 0.38 $m^3 \cdot s^{-1}$, and during winter it was equal to 0.54 $m^3 \cdot s^{-1}$ [18]. In the early years following the creation of the Przebedowo reservoir by the partial removal of peat, the physico-chemical parameters of water quality in the outflow showed that the reservoir acted as a settling pond for the river only to a limited extent [19]. This was visible for such parameters as sulphates and nitrates. For most water quality parameters, an increase of values was observed, i.e., biochemical oxygen demand, magnesium, chloride, soluble reactive phosphates, and electrolytic conductivity, thus the created reservoir caused a decrease in river water quality. This was a result of underlying sediments, organic matter remaining after excavation [17], and the impact of surrounding soils and groundwater. In view of the growing concern for the environment, the leading trend in the processing of organic matter, especially of plant origin, is for its management focused on closing the cycle of matter and energy. The rational recycling of organic matter of plant origin consists of processing it into growing substrates, thus allowing a product of high ecological utility to be obtained, and in addition, to save energy, the expense of which is several times higher in the process of storage of biodegradable organic matter [20].

The aim of this work was to develop the scientific background for the sustainable management of organic matter obtained both from the peat top and from the deeper layers containing strongly decomposed peat, which is unsuitable for direct use. In realizing the goal of the studies, the hypothesis that management of organic matter obtained both from the peat top and from profiles containing strongly decomposed peat will allow to improve the economic and financial situation of the mining company. It will contribute to the sustainable reconstruction of the water reservoir and the restoration of water resources.

A SWOT (strengths, weaknesses, opportunities, threats) analysis was used to describe the sustainable way of restoration of water reservoir along with determining of the characteristics of organic matter and financial condition of studied enterprise. Characteristics presented in the SWOT diagram concerned a specific enterprise restoring the Raduszyn water reservoir with the simultaneous recovery of the natural retention capacity of the Trojanka River basin.

2. Materials and Methods

2.1. The Study Site

2.1.1. Characteristics of Raduszyn Valley

The studied Raduszyn Lake (52°34′28′′ N, 16°59′31′′ E) is located in the town of Murowana Goślina in the province of Greater Poland. The area of Murowana Goślina consists of agricultural land (45%), forests (46%), and urbanized areas. Raduszyn reservoir, which is about 1 km in length and 300 m in width, divides Murowana Goślina into two parts: the southern—historical and the northern, associated with newly established residential areas (Figure 1). On the north-western border of the reservoir, sport facilities were built and this area was elevated by about two meters above the natural elevation of the valley using earth from local investments or debris.

Approximately 90% of the former lake area is a shallow water body covered by a reed bed. The rest of the area consists of abandoned lands and wetlands. The geology of the former lakebed is a mosaic; fluvial soils dominate, because of river transported sediments, alongside organic soils from the stagnation of nutrient rich waters. Organic matter covers about 79% of the valley area, including the area under the water body. The center of the valley has fine sands with organic and clay layers. On top of the sands and clay, a strongly decomposed peat layer of 0.2–5 m thickness is present. The main factor limiting its usefulness for horticulture is the presence of mud and sand layers within the peat. Only sparse areas with gyttja are found in the valley. The northern part is naturally dominated by sand, sand with clay, and sometimes clay, present in the area as 10–70 cm thick layers. The southern part of the area is covered by sands of different diameter, which have been mixed in preparation for investment (Figure 2).

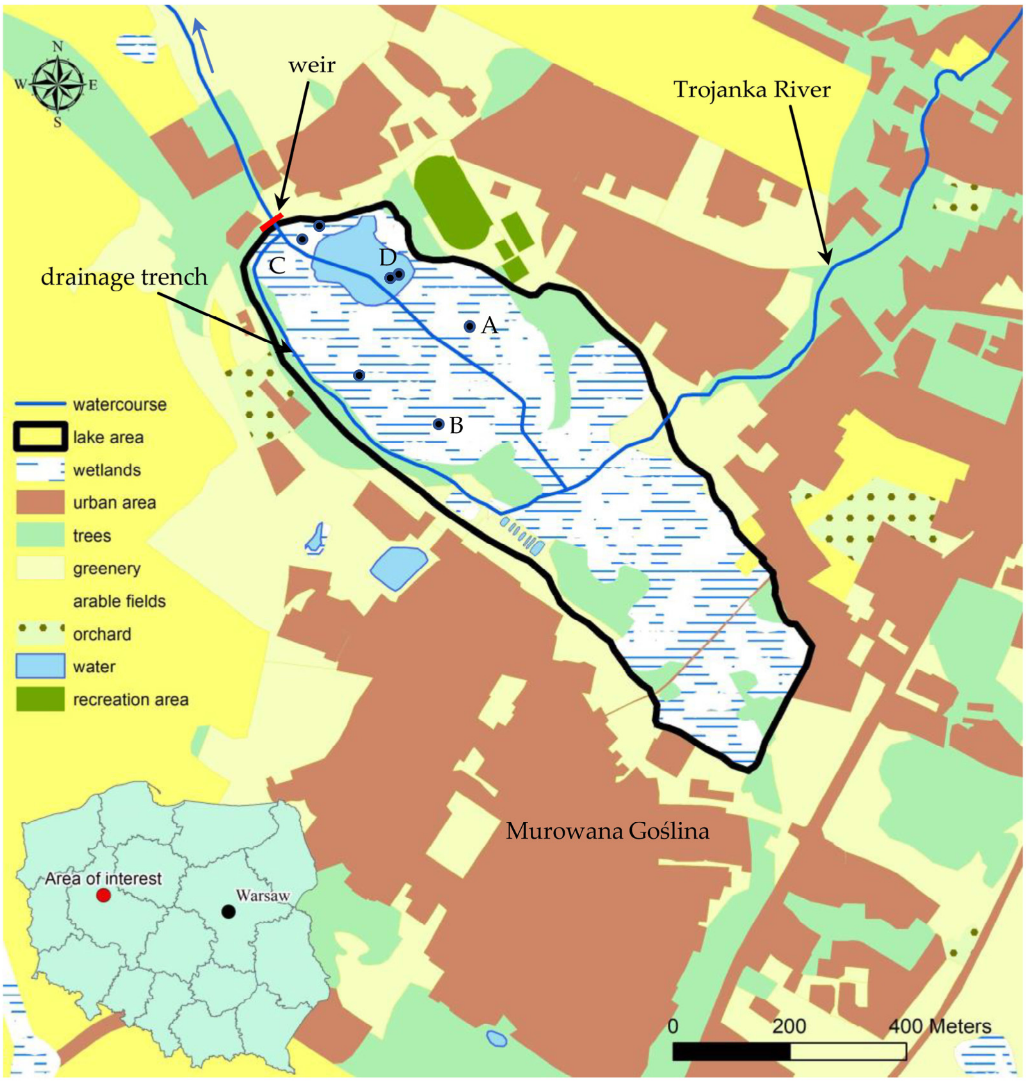

Figure 1. Location of the Raduszyn Lake. Explanation: A–D—sampling sites.

Samples of organic matter for microbiological and chemical analyses were taken from the northern part of the reservoir (samples A) and the southern part (samples B) from two depths (10–50 cm and 50–100 cm). Bulk samples taken from the overlay sediments (up to 0.7 m) stored for about 6 months at the Raduszyn peat mine location (samples C) were also analyzed (Figure 1). Organic material stored at point C in the form of a heap, was exposed to environmental factors such as temperature fluctuations, rainfall, as well as drying out due to wind. Moreover, the mineralization of organic matter occurring during the initial phase of storage may have contributed to quantitative and qualitative changes in its microbiome. However, long-term storage of organic substrate leads to stabilization of its chemical and microbiological parameters, which the study attempted to prove.

The peat, which is currently used as an ingredient in the production of an organic cover in mushroom cultivation, was sampled in the northern part of the reservoir in the depth range of 1–5 m (samples D) and examined. Subsequently, samples of organic matter considered as waste (samples E) and deposited in a heap at the mining company's yard for one month were studied. Samples of organic matter A, B, C and E were analyzed for their suitability as a potential raw material for a new product. Analysis of microbiological and chemical properties were performed for all samples. The methodology is discussed in Sections 2.3 and 2.4.

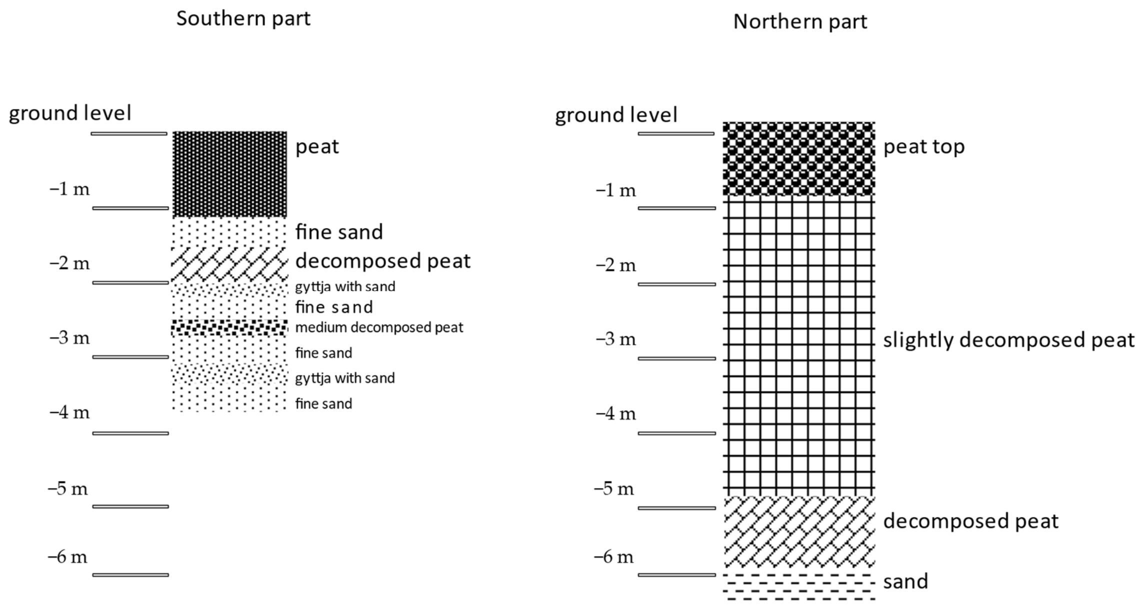

Figure 2. Stratigraphic column of the Raduszyn reservoir before peat excavation.

2.1.2. Plant Cover

Identification of plant species was made before peat quarrying, when summer characterized by very low precipitation and a significant decrease of groundwater level was observed. Most of the area was covered by common reed (*Phragmites australis*) forming a uniform plant cover. The peat in this area was never cut in recent history; thus the plants had become part of the turf. Smaller areas were covered by black alder (*Alnus glutinosa*), bird cherry (*Prunus padus*), willows (*Salix*) and sedges (*Carex*). In the areas dominated by sedges, about 30% was covered by reed canary grass (*Phalaris arundinacea*) with some patches of common nettle (*Urtica dioica*) and sway (*Acorus calamus*).

2.2. SWOT Analysis

In the research conducted on assessing the natural-economic aspects, the key method was a SWOT analysis, an acronym for Strengths, Weaknesses, Opportunities and Threats [21,22]. This method is the primary tool used for development decisions worldwide [23]. The SWOT analysis is more of a descriptive tool to conduct an overview of the environment, but it does not necessarily provide a guide to the strategic action [24]. For researchers, this tool is generally recognized as an effective method to understand the overall real situation [25], for example, from testing Nigeria's nuclear exploration agenda [26], Poland's management of municipal solid waste [22], or the sustainable forest policy and management in Greece [27]. The usefulness of SWOT analysis as a research method for identification and verification of project assumptions in various scientific areas has been confirmed by several authors, e.g., [28–31]. In its classic form, the method identifies and organizes internal conditions (strengths and weaknesses) and external circumstances (opportunities and threats) that have a significant impact when making a choice regarding the future implementation of a given project [32]. The analysis of internal determinants, also referred to as a resource analysis makes it possible to identify strengths i.e., all the features that are an asset, an advantage in a given activity, and weaknesses i.e., everything that constitutes a weakness or barrier to development. The analysis of external conditions, i.e., the analysis of the environment leads to the identification of opportunities, which provide potential opportunities for development, and favorable changes and threats, which represent the possible danger of unfavorable changes [33].

The SWOT analysis is increasingly being treated both as a method to help choose strategic directions for enterprises [34] and as a method for decision-making at the sector, regional and international levels [21]. In this study, a SWOT analysis was used to identify and juxtapose the characteristics of the organic matter extracted by the company with the future implications for the mining company and the environment from which the organic matter derives. The relationships occurring between the three elements are shown in Figure 3.

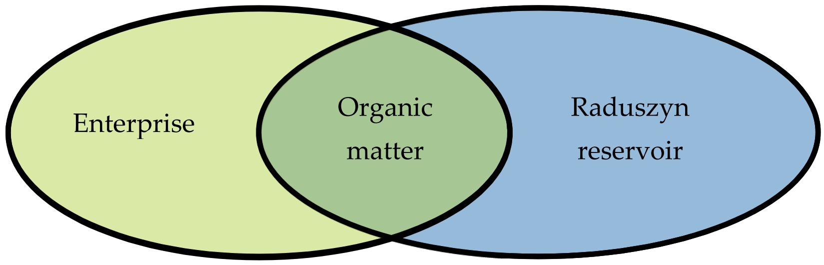

Figure 3. A Venn diagram showing the relationships between the enterprise and the Raduszyn reservoir.

The SWOT analysis in this research was conducted in three parts:

- the first part was concerned with identifying the positive and negative effects of the proposed activities on the environment including any suggestion of the possibility of using hydropower,
- the second part concerned a diagnosis of the positive and negative features of the proposed organic substrate and identifying opportunities and threats arising from its use in agri-horticultural crops,
- the third part involved a confronting of the assets and barriers as well as the potential opportunities and threats with the development of the company preparing organic substrates.

For the assessment of the company, the SWOT analysis allowed to identify the idea of the potential development of the company and the improvement of its economic and financial situation through the development of a new product produced from currently unexploited organic matter. On the other hand, concerning the environmental issues, the analysis allowed us to identify the strengths of the restored Raduszyn Lake including the possibility of using hydropower stored in the created reservoir and the potential adverse consequences of the investment.

Data for the development of the SWOT concept were collected during interviews with company executives and employees of scientific institutions. Research questions for this study were developed from the four basic aspects of SWOT analysis, as follows:

- What environmental benefits will occur after project implementation?
- What economic benefits can the company achieve from the management of the currently unused but mined organic matter?
- What environmental hazards may result from the implementation of the proposed project?
- What unfavorable consequences of implementing the project may arise for the enterprise?
- What are the chances of implementing the considered activities?
- What barriers can arise during implementation of the project?

2.3. Microbiological and Biochemical Analysis

The scope of the performed experiments comprised the determination (in five replications) of the total number of bacteria and molds (fungi), number of *Azotobacter* sp., *Bacillus subtilis* and *Pseudomonas fluorescens* as well as the number of cellulolytic bacteria. The examined groups of microorganisms were cultured by the plate method on solid substrates using the appropriate dilutions of substrate solutions and expressed in CFU·g^{-1} DM (dry matter). The total number of heterotrophic specific bacteria was determined using selective Standard Agar (Merck Millipore, Darmstadt, Germany) after 5 days of incubation at 25 °C whilst cellulolytic bacteria were determined using a medium prepared according to Rodina after 8 days of incubation at 28 °C [35]. The number of molds was determined using Rose Bengal Agar with aureomycin (Merck Millipore) after 7 days of incubation at 24 °C. Actinobacteria were isolated using a selective medium according to Pochon with the addition of nystatin [35]. They were determined after 5 days of incubation at 25 °C. *Bacillus subtilis* bacteria were isolated using Bacillus Chromoselected Agar (Sigma–Aldrich, Gillingham, UK) [36] after 24–48 h of incubation at 30 °C [37]. King B medium was used to determine the abundance of *P. fluorescens* bacteria after 48 h of incubation at 28 °C. Generic identification of *Pseudomonas* sp. and *Bacillus* sp. was performed on the basis of biochemical tests (*Pseudomonas* sp.; API 20 E system—BIOMÉRIEUX and *Bacillus* sp.; Microgen-®Bacillus–ID-GRASO Biotech, Waddinxveen, The Netherlands), microscopic analyses (OPTICAL MICROSCOPE; ZEISS PRIMO STAR) additionally employing Gram staining and in the case of fluorescence bacteria from the *Pseudomonas* genus using a fluorescence lamp of 365 nm wave length (Fluorescent Lamp; ULTRA LUM–UVAC 16) [37]. The isolates were characterized against the reference strains. Classification agreement for both species was obtained in about 90%. Numbers of *Azotobacter* sp. were determined by placing on a Petri dish 1 g of the soil sample which was mixed with a medium according to Jensen [38] after 5 days of incubation at 24 °C.

Dehydrogenase (DHA) activity was determined according to Camiña et al. [39] with some minor modifications. The substrate (1 g) was incubated for 24 h with 2,3,5-triphenyltetrazolium chloride (TTC) at 30 °C, pH 7.4. The produced triphenylformazan (TPF) was extracted with 96% ethanol and measured spectrophotometrically at 485 nm. Dehydrogenase activity was expressed as μmol TPF·g $^{-1}$ DM·24 h^{-1}.

Protease activity (PRO) was measured by means of the method developed by Ladd and Butler [40]. Enzyme activity was assessed by measuring the quantity of amino acids (tyrosine) formed, according to the following formula: μmol tyrosine·g^{-1} DM·h^{-1}. 1% sodium caseinate was used as a substrate. A sample of 5 cm^3 of the substrate was added to 2 g of medium and incubated for 1 h at 50 °C in a vortex mixer (120 rpm). Next, 2 cm^3 of 17.5% trichloroacetic acid (TCA) solution was added and the samples were cooled with ice to inhibit the activity of proteolytic bacteria. Then, the solution was filtered (90 mm paper filters-pore size: 8–12 μm) before 3 cm^3 of 1.4 M $NaCO_3$ (15.6% concentration) and 1 cm^3 of Folin's reagent (incubated for 10 min) were added, and the enzymatic activity was measured by spectrophotometry at a wavelength of 578 nm.

Urease activity (URE) was assayed as described by Hoffmann and Teicher [41]. Briefly, 1 g of moist medium was incubated with 0.15 cm^3 of toluene for 15 min at room temperature. Next, 1 cm^3 of a urea solution was added to the samples and they were incubated for 18 h at 37 °C. After the incubation, 5 cm^3 of 0.03 M acetic acid (0.18% concentration) was added and shaken for 20 min. The samples were then drained through 90 mm paper filters (Munktell Ahlstrom, Helsinki, Finland) before 0.4 cm^3 of 25% sodium potassium tartrate, 18 cm^3 of distilled water, and 0.4 cm^3 of Nessler's reagent were added. The urease activity wavelength was 410 nm and it was expressed as μg N-NH_4·g^{-1} DM·18 h^{-1}.

The activity of alkaline phosphatase (PAL) was assayed as described by Tabatabai and Bremner [42]. Briefly, 1 g of moist medium was incubated with 0.25 cm^3 of toluene for 15 min at room temperature. Next, 5 cm^3 of the buffer solution (60.5 g TRIS, 3.14 g boric acid, 7 g maleic acid, 244 cm^3, 1 M NaOH per 500 cm^3 distilled water, pH 7.5–8.0) was added to the samples. The pH of the buffer solution was 6.5 and it contained p-nitrophenylophosphate sodium substrate, which was solved in it. After the incubation 1 cm^3 of 0.5 M $CaCl_2$ (5.2% concentration) and 4 cm^3 of 0.5 M NaOH (2% concentration) were added to all the test tubes to stop the reaction. The solution was then drained through paper filters, Munktell Ahlstrom firm (90 mm), and the value was read on a spectrophotometer at a wavelength of 400 nm. The enzyme activity was expressed as μmol PNP·g^{-1} DM·h^{-1}.

2.4. Chemical Properties Analysis

Samples of materials were taken from selected places (Figure 1) from varied levels (10–50 cm; 50–100 cm) using a soil auger. Samples of excavated and stored material were also taken for analysis. The collected samples in actual humidity were chemically analyzed by the universal method [43]. Extraction of macronutrients (N-NH_4, N-NO_3, P, K, Ca, Mg, S-SO_4), Cl, and Na was carried out in 0.03 M CH_3COOH with a quantitative 1:10 proportion of medium to extraction solution (20 cm^3 of samples:200 cm^3 0.03 M CH_3COOH). After 30 min extraction, the following determinations were made: N-NH_4, N-NO_3—by microdistillation according to Bremer in Starck's modification; P—colorimetrically with ammonium vanadomolybdate; K, Ca, Na—photometrically; Mg—by atomic absorption spectrometry (ASA, on Carl Zeiss-Jena apparatus); S-SO_4—nephelometrically with $BaCl_2$; Cl—nephelometrically with $AgNO_3$. Micronutrients (Fe, Mn, Zn and Cu) were extracted from the samples with Lindsay's solution containing in 1 dm^3:5 g EDTA (ethylenediaminetetraacetic acid); 9 cm^3 of 25% NH_4 solution, 4 g citric acid; 2 g $Ca(CH_3COO)_2 \cdot 2H_2O$. Micronutrients were determined by the ASA method. Salinity was identified conductometrically as an electrolytic soil conductivity (EC in $mS \cdot cm^{-1}$), and pH—was determined by the potentiometric method (soil:distilled water = 1:2) [44].

2.5. Statistical Analysis

The arithmetic mean (mean) was used as a measure of central tendency for samples of organic matter from the analyzed peatland. The standard deviation (SD) was calculated as a measure of the amount of variation that shows how much the estimate depends on a particular sample taken from the population. The coefficient of variation (CV) is the percentage ratio of the standard deviation to the mean and shows the extent of variability in relation to the mean of organic matter from the peatland.

2.6. Assessment of Economic and Financial Situation of the Analyzed Peat Mining Company

A case study was used to assess the economic and financial situation. The research subject was the company extracting peat from the Raduszyn mine. The company operates under a license valid until 2054. The information necessary to present the financial situation of the audited entity was obtained from the individual annual financial statements of the company, available in the National Court Register [45]. The research on the company's financial situation covered the years 2017–2020. In order to compare the results achieved by the audited entity with the results of other companies from the organic minerals mining sector, information on sector financial indicators was collected. These datasets are prepared and published annually by the Financial Committee of The Accountants Association in Poland [46–48].

The main sources of information about financial achievements in an enterprise are financial indicators [49,50]. The literature collection includes a very wide set of indicators, which are classified differently depending on the analytical needs [51,52]. In this study, three groups of indicators were selected to assess the financial situation of the audited company, i.e., economic efficiency ratios, solvency ratios and liquidity ratios. The first group of ratios were used to examine the ability to generate profits and reflect success or failure. Amongst many efficiency indicators in this work, the profit margin ratio (y_1) and operating profitability of assets (y_2) were used. The profit margin ratio refers to the ability of sales to generate a profit from sales. This ratio is determined by dividing the profit from sales by the sales revenue [51]. A high ratio refers to high selling prices and low production costs. The high selling prices refer to the company's products having a competitive advantage. The competitive advantage of the product, either from cost or quality, helps the company increase profitability [53]. Operating profitability of assets (y_2) refers to the relationship between earnings before interest and taxes and involved total property [54]. This ratio measures the rate of return from the business on all existing assets [54]. A rise in the ratio refers to the effectiveness of the employment of assets by the company. The bigger the ratio, the better the financial condition [53].

Lenders, investors, and credit-rating agencies show great interest in the ability to meet all commitments [55]. Therefore, in the full assessment of payment capacity, companies should also use solvency ratios and liquidity ratios. One of the fundamental solvency ratios is the total debt (y_3)—leverage ratio that defines the share of short-term and long-term debt (total debt) relative to assets owned by a company [56]. Using this metric, one can compare a company's leverage with other companies in the same industry. This information can reflect financial stability. The higher the ratio, the higher the risk of financing and the worse security. From the group of liquidity ratios in this study, two fundamental ones were used, namely the current ratio (y_4) and the quick ratio (y_5). The current ratio is determined by dividing the total current assets by the total current liabilities (Table 1). The second provides a narrower focus and concerns only such items of current assets as accounts receivable, cash and marketable securities. This reduced amount is divided by total current liabilities [57].

Table 1. Name and construction of the indicators.

Name of the Indicator	Mark	The Formula of the Indicator
profit margin ratio (%)	y_1	$= \frac{PS \cdot 100}{S}$
operating profitability of assets (%)	y_2	$= \frac{EBIT \cdot 100}{TA}$
total debt ratio (%)	y_3	$= \frac{TD \cdot 100}{TA}$
current ratio	y_4	$= \frac{CA}{CL}$
quick ratio	y_5	$= \frac{CA - I - AC}{CL}$

Explanation: *CA*—total current assets, *CL*—total current liabilities, *I*—inventory, *AC*—accruals of costs, *TD*—total debt, *TA*—total assets, *S*—sales revenue, *PS*—profit on sales, *EBIT*—earnings before interest and taxes.

3. Results and Discussion

3.1. Economic and Financial Situation of the Analyzed Peat Mining Company

Sales revenues in the year 2019 amounted to PLN (Polish zloty) 5240 thousand and were 33% higher than in 2018 (Figure 4). Costs also increased during this year with a 55% growth in comparison to the increase in revenue. The cost rises followed an increase of production, which was linked to growing numbers of domestic and foreign orders. The positive change in revenue in 2019 followed the implementation of the basic objectives of the strategy for the development of production activities, the main direction of which was to improve the quality of the produced mushroom organic cover, reorganization of the production management, sales, and communication with contractors.

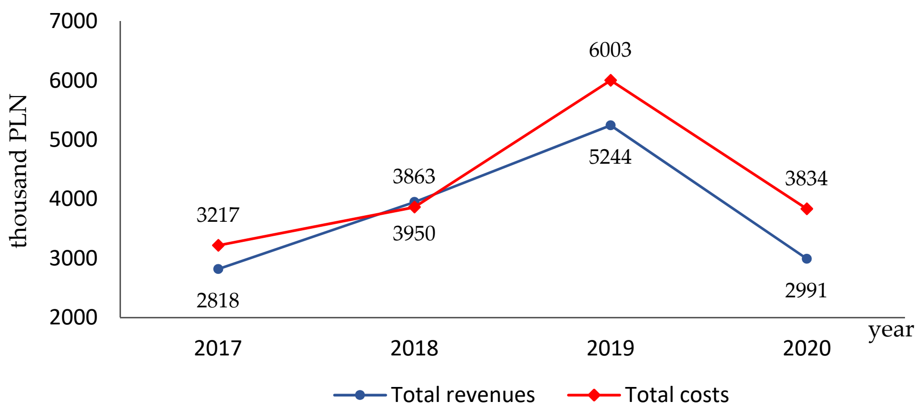

Figure 4. Total revenues and total costs in the enterprise in 2017–2020 (thousand PLN).

In the following year, which was the first year of the COVID-19 pandemic, revenues declined by 44% due to mushroom producers halting the supply of mushroom organic cover. A decrease in costs was also observed that year but it was smaller by eight percentage points in comparison to changes observed in the case of revenues. Changes in the year 2020 clearly worsened the already difficult financial situation of the analyzed company. In cost structure, the largest share was accounted for by operating expenses, including the costs of material and energy consumption, external services, and labor costs.

The excess of costs over revenues in the years 2017, 2019 and 2020 resulted in a production deficit, which increased in subsequent years (Figures 5 and 6). During the studied period the operations of company were only profitable in 2018. In that year, the profit margin (y_1) was 10.1%, and the operating profitability of assets (y_2) was equal to 9.4%.

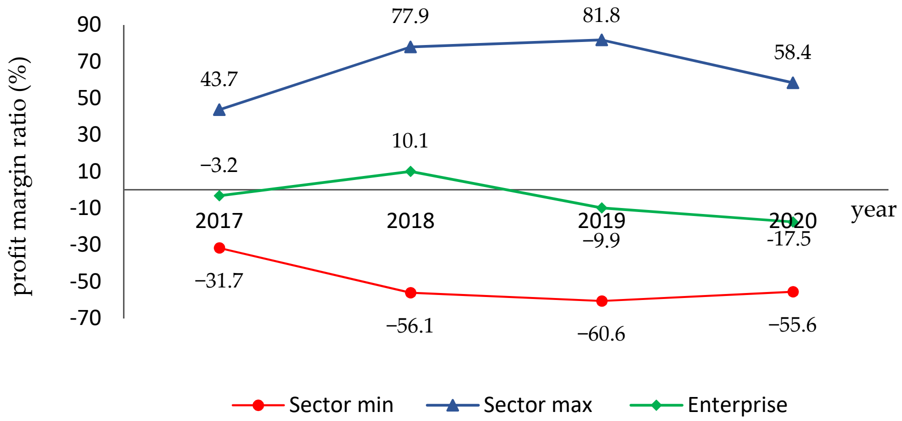

Figure 5. Profit margin ratio (y_1) in the enterprise and in the sector in 2017–2020 (%).

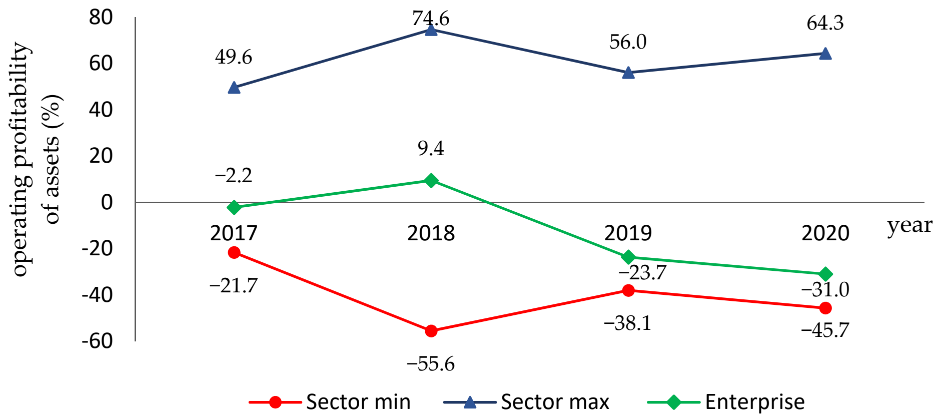

Figure 6. Operating profitability of assets (y_2) in the enterprise and in the sector in 2017–2020 (%).

The obtained results, in comparison with the values achieved in the entire sector, indicate that the studied company achieved relatively low profitability in the year 2018. The average profitability in the sector at that time was 6.2%. It is worth noting that profitability of entities in the sector was considerably varied. In the year 2018 the profit margin ranged from −56% to 78%, and operating profitability of assets ranged from −55% to 75% (Figures 5 and 6). This means that the surveyed company, despite the implementation of a strategy for the development of production activities, the main directions of which were the improvement of the quality of the mushroom organic cover (main product), and the restructuring of the management of production, sales, and communication with contractors, ranks among the companies with a poor financial condition. This conclusion was confirmed by results obtained in the years 2019 and 2020.

A total debt ratio (y_3) was also calculated for this case and shows the company's ability to pay back debt and helps assess financial risk [58]. The debt ratio represents a measure of the company's ability to pay back loans and the attached interest obligations when due. It also helps in assessing the financial risk of a company [59]. The values of this ratio indicate a very high level of foreign capital in the company. The total debt ratio (y_3) ranged from 84% in 2018 to 98% in 2019. This high value of the ratio indicates a poor financial condition and significant financial risk. It means that if the situation will not improve it could result in the shutting down of the company, with the consequent stoppage of peat extraction, halting of the construction of the reservoir and a loss of jobs.

The financial problems, including the high risk of doing business, were confirmed by the difficult situation around the ability to repay current liabilities. The current and quick liquidity ratios indicate low coverage of current liabilities with current assets. The literature states that the current ratio (y_4) should be within 1.2–2 and the quick ratio (y_5) should be in the range of 1–1.2 [52,53]. In the case of the surveyed company, obtained values of both indicators were below the reported ranges (Figures 7 and 8). The data also show that liquidity as measured by current and quick ratios was weaker than in other entities of the studied sector.

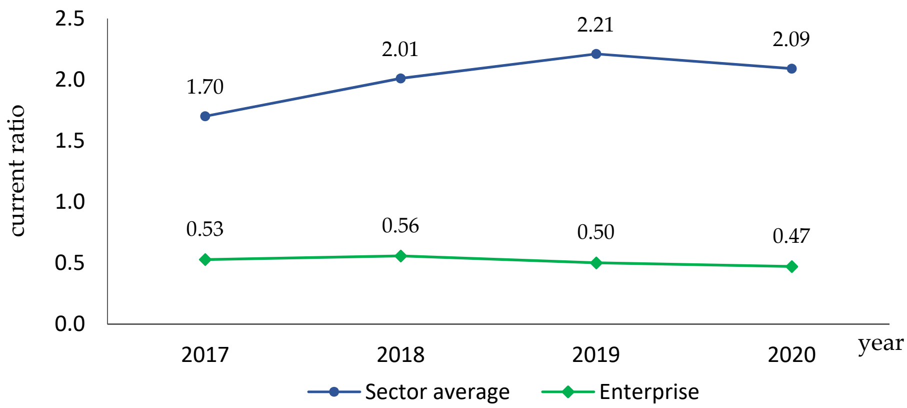

Figure 7. Current ratio (y_4) in the enterprise and in the sector in 2017–2019.

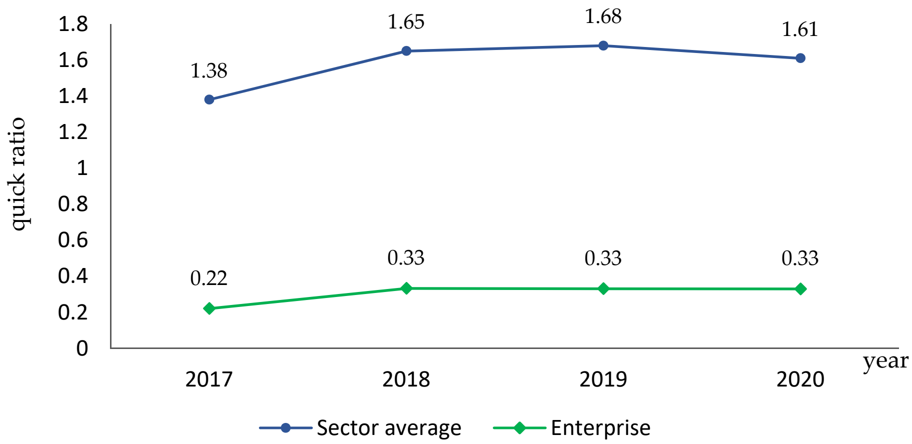

Figure 8. Quick ratio (y_5) in the enterprise and in the sector in 2017–2019.

According to Dudycz and Skoczylas [46–48], the values of the current ratio in the group of companies extracting other types of organic matter during the examined period were above 2.0, while in the studied company it did not exceed the value of 1.0. This means that current liabilities were not covered by the company's current assets. In addition, the ability to settle current liabilities in the following years was decreasing. The current ratio decreased from 0.56 to 0.47. This change was caused by a decrease in the value of stocks by more than 30%.

All the examined factors describing Opportunities, Strengths, Threats, and Weaknesses (Figure 9), which may be important for an enterprise, organic matter and environment are characterized below.

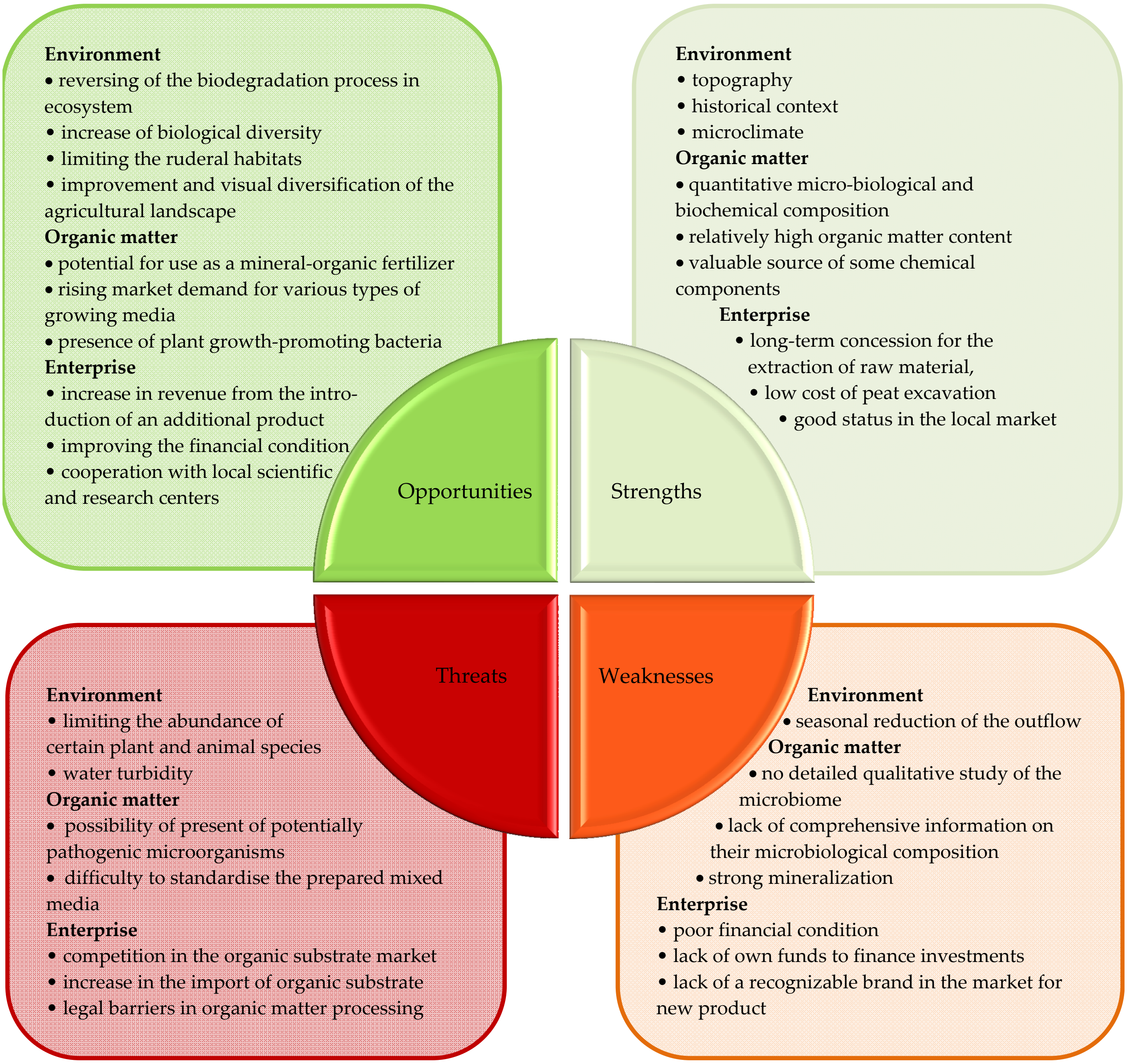

Figure 9. Strength, Weakness, Opportunity, and Threat (SWOT) analysis for the relationships between the environment, organic matter, and enterprise.

3.2. Opportunities

3.2.1. Environment

Currently, the analyzed area is the subject of continuous degradation due to decreasing water flow in the Trojanka River. The building of the reservoir will reverse the process of biodegradation and the ongoing mineralization observed in the studied area. As a result of the construction of the reservoir, aquatic species (macrophytes) will appear as well as new species of rush plants (helophytes), which could colonize the lake shore zone. In the case of macrophytes, 20–40 aquatic plant species typical of this part of Greater Poland could appear in the near future. These will most likely include hornwort (*Ceratophyllum demersum*), branched bur-reed (*Sparganium erectum*), common duckweed (*Lemna minor*), star duckweed (*Lemna trisulca*), and the common alien species pondweed (*Elodea canadensis*). In turn, sedges may appear among marsh plant species. Therefore, the objectives of the environmental policy on biodiversity, as well as on sustainable development, will be achieved. In the north-western part of the studied lake the presence of scattered sites with the invasive species, Himalayan balsam (*Impatiens glandulifera*) was observed. This taxon can pose a threat to native species due to its rapid spread, as experienced in other localities [60,61].

In regions dealing with the serious problem of proliferating Himalayan balsam, various methods of control have been tried, such as manual removal, use of chemicals or even boiling water [62,63]. The restored reservoir may be an effective method in controlling this species in the studied area. The reconstruction of the Nienawiszcz reservoir, which has similar functions to the Raduszyn reservoir [12] shows that water reservoirs can improve the visual aspect of landscape. Additionally, they create new ecological corridors with opportunities for increasing the populations of native animals found in suburban and rural areas.

3.2.2. Organic Matter

Microbiological Properties

A relatively poor range of organic substrates that contain naturally occurring, beneficial microorganisms promoting plant growth cannot follow strongly developing "bio" and "eco" trends in the horticultural as well as in the agri-food sector, which still represent an undeveloped market segment. Considering the growing demand for "bio" and "eco" plants, there is a successive increase in the need for organic matter-rich and beneficial microorganism-rich high-yield substrates for plant growth [64,65].

However, market analysis shows that there are a lack of substrates with a well-defined microbiological composition, containing naturally occurring plant growth promoting microorganisms, which additionally demonstrate phytosanitary properties. Currently, there are mainly offers of bioproducts that contain only isolates of the above-mentioned microorganisms, occurring in the form of lyophilizates, not being a component of the organic substrate, intended for plant cultivation. The presence of such microorganisms in the substrate may contribute to reducing the use of mineral fertilizers and, most importantly, chemical plant protection products [66]. The use of natural organic substrates, made entirely using plant matter, containing "beneficial" microorganisms, is in line with the trends of the European Biodiversity Strategy, whose main objective is to protect nature, reverse the process of ecosystem degradation and restore environmental biodiversity in Europe, by 2030 (Communication from the Commission to the European Parliament 2020 [67]).

The realized microbiological analysis of organic materials intended as an additive for horticultural substrates confirmed the presence of plant growth-promoting bacteria of the species *B. subtilis* and *P. fluorescens*, selected isolates of which show antagonistic properties against plant pathogens [68–71] (Table 2). The literature review shows that the above-mentioned microorganisms are included in the group of PGPR (Plant Growth Promoting Bacteria), which stimulate plant growth and development in two ways, by direct and indirect action. Direct promotion of plant growth consists mainly in supplementing nutrient deficiencies by, for example, mobilizing unavailable forms of mineral phosphorus or by enzymatic decomposition of phosphate and nitrogen organic matter. Indirect plant growth stimulation, in contrast, involves protecting the plant from the effects of fungal pathogens (e.g., *Fusarium* sp. and *Alternaria* sp.), as well as from the effects of abiotic stress, which may be low water content or excessive salinity of the substrate [72,73]. In addition, saprophytic bacteria of the genus *Azotobacter*, able to enrich the substrate with nitrogen by reducing atmospheric nitrogen to ammonium ion (NH_4^+) an easily available source of nitrogen for plants, were isolated from the tested experimental options [74].

Table 2. The number of selected microorganisms and the enzymes activity in the tested organic materials.

Microbiological and Biochemical Parameters	Samples A	Samples B	Samples C	Samples D	Samples E	Mean	SD	CV (%)
DHA (μmol TPF·g^{-1} DM·24 h^{-1})	0.005	0.012	0.002	0.019	0.003	0.008	0.007	87.69
PAL (μmol PNP·g^{-1} DM·h^{-1})	0.373	0.440	0.292	0.189	0.112	0.281	0.133	47.34
URE (μg N-NH$_4$·g^{-1} DM·18 h^{-1})	0.80	0.87	0.76	0.54	0.45	0.684	0.180	26.29
PRO (μmol tyrosine·g^{-1} DM·h^{-1})	0.056	0.133	0.041	0.029	0.035	0.059	0.043	72.58
Total bacteria number (CFU·g^{-1} DM)	67.04	87.65	57.59	100.49	57.25	74.00	19.28	26.05
Bacillus (CFU·g^{-1} DM)	53.63	85.92	30.35	146.02	105.15	84.21	44.99	53.43
Pseudomonas (CFU·g^{-1} DM)	0.37	0.00	2.15	1.35	0.34	0.842	0.888	105.4
Molds (CFU·g^{-1} DM)	32.03	26.03	36.58	81.65	70.10	49.28	24.90	50.54
Actinobacteria (CFU·g^{-1} DM)	20.11	23.43	16.34	28.26	17.53	21.13	4.824	22.82
Azotobacter sp. (CFU·g^{-1} DM)	0.00	0.00	0.00	3.14	0.00	0.628	1.404	223.6
Cellulolytic bacteria (CFU·g^{-1} DM)	8.94	10.41	10.90	14.13	16.36	12.15	3.022	24.88

Explanation: DHA—Dehydrogenase, PAL—Alkaline phosphatase, URE—Urease, PRO—Protease, SD—standard deviation, CV—coefficient of variation.

Chemical Properties

Extracted matter offers the potential for use as a valuable mineral-organic fertilizer (Table 3). Application of this type of fertilizer can have a positive impact on soil fertility considered as the outcome of diverse properties, either physical, biological, or chemical [75,76]. By applying them, especially to poor mineral soils with low humus and flowable content, it is possible to gradually increase the humus content of the soil. This increase in humus content, which is of course a complex process over time, improves the sorptive properties of soils and water retention, which is of importance especially in the light of ongoing climate change [77]. The sorption capacity of organic colloids is significantly greater than for mineral colloids. Due to the presence of 2-valent cations (Ca^{+2}, Mg^{+2}) and humus in the soil, a highly desirable tuberous structure for plants can be achieved, thus optimizing the physical properties including air-water relations. In addition, because of the presence of microbial life, transformations of some nutrients are possible, for example P where progressive transformations towards hardly soluble compounds occur [78]. Some phosphate fertilizers (e.g., bone powder, phosphate powder) contain P that is soluble in strong acids. Their use is ineffective on light soils without organic matter and rich biological life. It is worth noting that phosphate fertilizers can be used in organic farming and horticulture [79].

Table 3. Macronutrients and sodium content in extracted matter samples at selected sites (mg·dm^{-3}).

Samples	N-NH$_4$	N-NO$_3$	P	K	Ca	Mg	S-SO$_4$	Na
A (10–50 cm)	tr	tr	8	20	5539	177	74	31
A (50–100 cm)	tr	tr	14	9	5366	168	479	38
B (10–50 cm)	4	4	7	31	5408	155	110	46
B (50–100 cm)	4	7	3	27	5782	141	199	45
C	4	11	4	61	5412	178	266	43
D	4	tr	2	5	1668	128	58	39
E	4	7	0.5	17	6361	181	489	32
SD	2.0	2.9	4.6	18.6	1 543	20.5	182	6.0
Mean	2.9	7.3	5.5	24.3	5 076	161.1	239	39.1
CV (%)	68.3	39.6	83.5	76.6	30.4	12.7	76	15.3
Recommended range of content for plant growing	150–250		140–250	150–300	500–1500	130–250	50–150	<50

Explanation: tr—traces, SD—standard deviation, CV—coefficient of variation.

Due to its physical and chemical properties (including air-water relations and alkaline reaction), the extracted material could be used as an ingredient for mixed media (Table 4). The recommended ranges of nutrient contents are given in Tables 3 and 4. For example, the contents of N, P and K—regardless of the sampling location—were too low, while

Ca—excessively high. Media provide an anchorage for the root system, supply water and nutrients for plants and guarantee proper aeration in the root area [80]. The crops grown there are so-called soilless crops [81]. There is a rising market demand for various types of growing media. This trend is related to specialized substrates for the professional cultivation of herbs and vegetables under covers. The importance of substrates for amateur cultivation, whether of ornamental plants, vegetables or herbs is still increasing and this is also true for the growing urban horticulture industry [82]. One of the main arguments for the use of substrates is that they can be fully isolated from the soil, which among other things can reduce the possibility of infection by soil-borne diseases (e.g., fusarium diseases or *Pythium*) [83].

Table 4. Micronutrients (mg·dm^{-3}), pH reaction (in H_2O) and EC (mS·cm^{-1}) in samples collected at selected sites.

Samples	Fe	Mn	Zn	Cu	Cl	pH	EC
A (10–50 cm)	97.3	4.0	34.9	1.1	10.0	7.31	0.38
A (50–100 cm)	128.6	44.9	3.5	0.4	17.0	7.15	0.89
B (10–50 cm)	85.9	4.2	10.4	1.0	21.0	7.52	0.42
B (50–100 cm)	103.1	20.9	2.5	0.4	24.0	7.38	0.58
C	104.1	3.6	19.6	0.7	19.0	7.50	0.72
D	119.4	6.8	0.8	0.2	14.0	7.16	0.31
E	98.3	3.9	2.0	0.3	10.0	7.48	0.92
SD	14.4	15.5	12.6	0.4	5.4	0.16	0.25
Mean	105.2	12.6	10.5	0.6	16.4	7.36	0.60
CV (%)	13.6	123.1	120.0	60.3	32.8	2.12	40.7
Recommended range of content for plant growing	50–100	10–50	5–50	2–8	<60	5.5–6.5	<2.0

Explanation: SD—standard deviation, CV—coefficient of variation.

3.2.3. Enterprise

The company's strategy for developing its production activities has created an opportunity to increase sales revenues (Figure 4). The growth of revenue will be possible following the introduction of a new product prepared from high quality peat extracted from the northern part of the reservoir. This is supported by an increasing demand for various types of growing media. This invented product will be proposed for producers of herbs and vegetables grown under cover. The rise of sales revenue will make it possible to cover the costs of the company's operations and then restore the enterprise to efficient operation. The process of improving economic performance as assumed by the management is determined by the company's cooperation with scientists of research centers located in the region.

3.3. Strengths

3.3.1. Environment

The existence of a watermill that has been using the discharge of the Trojanka River and damming the water for hundreds of years suggests that the landform is naturally suitable for the creation of a reservoir. The restored lake will provide a valuable supply of water for the surrounding green areas and positively influence the microclimate. The microclimatic conditions can be modified by waters in several ways including cooling impact and outdoor thermal comfort [84]. The presence of an open water surface will increase evaporation in the close vicinity of the reservoir, therefore changing air humidity. This should be perceptible during the summer period, especially with the existence of tree canopies around reservoir.

3.3.2. Organic Matter

Microbiological Properties

The strengths of the tested organic materials clearly include their quantitative microbiological and biochemical composition (Table 2). Analyzing the results of our own studies shows that in all experimental organic materials the total number of heterotrophic proper bacteria, including cellulolytic bacteria, was at the low level from 57.59 to 100.49 CFU·g^{-1} DM (Table 2). Moreover, the level of dehydrogenase (DHA) activity in the analyzed objects reached low values compared to peat substrate [85], which may suggest biochemical stabilization of the tested substrates (Table 2). Dehydrogenase activity is recognized as one of the most reliable indicators for evaluating the biological activity of substrates [86]. Like PRO, URE and PAL, dehydrogenase actively participates in microbial metabolism and catalyze processes related to the processing of organic matter in a given substrate. Based on their activity levels, the rate of decomposition of a given substrate in a substrate and the degree of macro- and micronutrient release, as well as the stability of organic matter can be evaluated [87–89]. Analyzing our results showed that the highest activity of analyzed enzymes, indicating the highest content of easily degraded organic matter in relation to other test substrates, was characteristic of locations B and A. These locations were respectively, the active layer of the overburden of peat deposits additionally covered with reeds (sample B) and the top layer of the substrate by the drainage ditch (sample A).

The activity level of the enzymes studied, especially DHA, is a sensitive indicator of organic matter content, as confirmed by the studies of Hill et al. [90] and Barrena et al. [91]. The studies of the first authors show that the level of phosphatase activity analyzed in different types of peatlands was 0.65 µmol·g^{-1}·h^{-1}, while the DHA activity correlated positively with carbon content, reaching a value of 0.068 µmol·g^{-1}·h^{-1}. In turn, Barrena et al. [91] analyzed the level of DHA in composted organic waste, showed that at the beginning of the mineralization process of organic matter the activity of the enzymes tested was higher than 2.7 µmol TPF·g^{-1}.

The lowest level of enzymatic activity was found in sample E, the fresh assortment subjected to chemical disinfection, which indicates effective sanitation of this material. Similar observations were made when analyzing the microbiological status of the tested substrates (Table 2), however, in most cases no significant differences were observed between the numbers of microorganisms in the tested experimental materials. The highest level of the analyzed microorganisms was characterized by sample D, the lowest by object C. The conducted microbiological tests aimed at the quantitative and qualitative determination of bacteria, confirmed the presence of growth-promoting isolates of *B. subtilis*, *P. fluorescens* and *Azotobacter* sp., which makes the tested substrates suitable for plant cultivation. Bacterial species association, as described in Section 2 was determined using biochemical tests. Bacteria were isolated using selective media and then, after obtaining pure cultures their biochemical properties were determined. Biochemical identification of isolates was achieved by recording results visualized by the color changes after 24 and 48 h of incubation at 29–30 °C and addition of appropriate reagents. In these analyses, the ability of the bacteria to assimilate, ferment or degrade specific chemical compounds was assessed. These results were then analyzed using APIWEB™ (*P. fluorescens*) or Microgen Identification System (MID-60) (*B. subtilis*) software. Out of the 97 biochemically tested strains, 91% were identified as *B. subtilis*. In the case of *P. fluorescens* bacteria, out of the 69 strains analyzed, 94% were classified as this species.

Chemical Properties

The obtained material can contribute significantly to the improvement of various soil properties. For example, as the share of organic matter increases, the specific and bulk density of soils decreases, which clearly improves plant growth conditions [92]. An unquestionable advantage of extracted matter applied as an organic-mineral fertilizer, but also as a part of mixed substrates, is its high content of nutrients, mainly Ca, Mg, S, Fe and Mn (Table 4). Excavated peat has a high water holding capacity and good water retention.

However, to prepare the substrate, it is recommended to improve its air-water properties, for example by adding other organic materials such as sphagnum peat, coconut fiber or wood fiber. These materials have more favorable air-water properties and porosity that their mixture with the extracted matter can be used to cultivate plants [93]. According to Yeager et al. [94], an ideal growing media should have the following features: good mechanical properties to guarantee plant stability; low bulk density; high porosity (50–85%); stable and good water: air ratios, pH 5.0–6.5; low salinity level and also the absence of pathogens and pests. The prepared mixed media should ensure adequate dilution of the high content nutrients to optimal levels (especially Ca). For example, coconut fiber could be used as an additive in a mixture with the collected material in various proportions (e.g., V:V 30%:70%, 40%:60%, etc.). Once the initial analyses have been carried out, the fertilizers should be applied, bringing the nutrient content up to the levels recommended for plant cultivation. When planning to use the mentioned mixture as a substrate, ecotoxicity tests would be required using species with different characteristics, e.g., lettuce (short, approx. 30-day growing season) and tomato (long, many months' growing season) to determine the feasibility of using it for plant growth based on experimental results.

From the chemical point of view, the analyzed material is a valuable source of some components in the prepared mixtures e.g., Ca, Mg, S-SO_4, Fe (Table 4), which may reduce the costs of preparing compositions recommended for a given group of plants. A parameter which should be especially studied is the C:N ratio and the possibility of nitrogen immobilization [95]. An unquestionable advantage of organic or organic-mineral media is the ease of its utilization after plant cultivation. Therefore, after the completion of the plant cultivation cycle, the coconut fibers become valuable organic fertilizer exhibiting advantageous microbiological parameters, i.e., relatively high counts of fungi, bacteria and actinobacteria, as well as DHA activity, which may improve the fertility of the soil (especially with a low content of organic matter) on which they have been utilized [96]. In practice inert substrates (without sorption complex) e.g., rockwool are very often used in the large-scale cultivation of certain species, e.g., tomato. It has very favorable air-water relations for plant cultivation but requires the use of an excess of nutrient solution (water with dissolved fertilizers) the so-called overflow, which is supposed to offer protection against an increase of salinity in the root stress. Typically, the overflow is 20–40%, which amounts to huge quantities of nutrients moving directly into the soil (for systems without nutrient solution recirculation) creating a risk of environmental pollution. For example, in the cultivation of tomato, it is (in $kg \cdot month \cdot ha^{-1}$): N-$NO_3$ (up to 245), K (up to 402), Ca (up to 145) and S-SO_4 (up to 102) [97]. In crops grown in organic substrates, the overflow is not used or is distinctly less, hence the possible amounts of nutrients moving directly into the soil are as high as several to a dozen times.

3.3.3. Enterprise

An advantage of the company under study is the possession of a license for peat mining operations until the year 2054. It creates an opportunity to conduct long-term and planned business activities. The location of the peat workings at a short distance from the production works in Wojnowo (distance of 8 km) determines a low cost in the internal organization of the enterprise. An additional advantage of the location, as perceived by the local community, is that it is the site of the future water reservoir in the center of the settlement. Reclamation of Raduszyn valley will result in the construction of a recreation site in the center of the city where presently there is only undeveloped land overgrown with reeds and ruderal plant species.

3.4. Threats

3.4.1. Environment

After the removal of organic matter and peat, the population of organisms currently observed in the area will probably decrease. Species will not disappear entirely because part of the peat located in the upper region of the study area will remain intact. Due to the permit for peat extraction some of the sediments will be left in the restored reservoir, which may affect the increased fertility of the water body and a local reduction in species diversity. The water turbidity associated with trophic conditions can also limit light penetration to deeper parts of lake and may inhibit its colonization by vascular plants.

3.4.2. Organic Matter

Microbiological Properties

Risks associated with the use of tested organic materials for plant growth may be mainly related to the possibility of potentially pathogenic microorganisms in their composition or secondary contamination of materials with pathogens during the storage process. Air is a conveyor of pathogen cells and spores whose development is strongly influenced by environmental factors. Moist substrate and a high ambient temperature (25–37 °C) can promote the growth of pathogens that could penetrate it from the air. Therefore, systematic monitoring of the microbial composition of organic substrates is extremely important [98].

Chemical Properties

The chemical composition analyses of the sampled organic material showed a noticeable variation between the studied sites in term of CV values (Table 3). This high variability may make it difficult to standardize the prepared mixed media, both in terms of physical properties (i.e., air-water relations) and chemical properties (pH reaction, salinity, nutrient concentrations). Among macronutrients, P and K had the highest variability (CV 83.5 and 76.6%, respectively), while in the case of micronutrients, it was Mn and Zn (CV 123.1 and 120%, respectively). The analyzed material was characterized by a relatively high variability of EC (40.7%) but was very uniform in terms of pH reaction (CV 2.12%). As a homogeneous media the analyzed material is also unsuitable for use in plant cultivation due to its chemical composition (Table 4). The main reason for this is the excessive Ca content, which positively correlates with an alkaline reaction (pH > 7.0). Reaction plays an important role in plant substrates determining the availability of nutrients. With a Ca content of 500 to 1500 mg·dm^{-3} most substrates have a pH value of around 6.0–6.5, which is optimal for the cultivation of most plant species, especially foliage plants. Heath and coniferous plants prefer lower pH values. In the studied samples, Ca contents in most cases exceeded 5000 mg·dm^{-3}, which causes excessive alkalinization and antagonism in the uptake of P, K, Mg, and metallic micronutrients (Fe, Mn, Zn, Cu) [99–101]. For example, the determined low P content in the samples may have resulted from retrogradation (i.e., conversion to insoluble forms) caused by the excess of Ca (calcium phosphates).

3.4.3. Enterprise

One of the risks associated with the described business is the relatively large number of horticultural substrate producers. To find customers for a product based on organic matter from the southern part of the reservoir will require the development of specialized techniques for preparing such a substrate. Taking into account the size of lake and data of the stratigraphic column cross-section it will yield about 0.5 million m^3 of poor-quality raw material requiring further management. Additional competition for new products is the import of peat and different peat products to the amount of about 200 thousand tons per year, mainly from Belarus, Latvia, and Lithuania [102]. From the standardized interview it appears that an additional major problem in conducting mining and processing of the organic matter are changes in law. An example is the implementation of a limitation of the use of high volumes of peat sourced from outside recognized mining sites as an ingredient in horticultural substrates.

3.5. Weaknesses

3.5.1. Environment

In recent decades, decreasing water discharge in Europe's watercourses has been observed [103]. The construction of a reservoir may cause a seasonal reduction in the outflow from the Raduszyn Lake. Additionally, low water discharge can affect planned investments, e.g., the construction of a pico hydro-power plant, which would not have sufficient energy to generate electricity to illuminate the recreation and leisure areas.

3.5.2. Organic Matter

Microbiological Properties

The tested organic materials were characterized by low microbial abundance, although they were not analyzed for the stability of microbial species present in them (Table 2). The microbiological analysis of the substrates showed the presence of molds, which may indicate the likelihood of the presence of not only saprophytic, but also pathogenic species in substrates. Moreover, the tested organic materials were obtained from different places and additionally stored at different ambient temperatures depending on the season of the year, therefore they could differ significantly in terms of the species composition of microorganisms. Hence, it seems extremely important to conduct cyclic monitoring of their qualitative composition taking into account the culture methods, supplemented by modern genetic analyses, which would allow the provision of complete information on their microbiological composition [104].

The identification of the microbiome of substrates for plant cultivation was limited for a long time by the fact that most microorganisms cannot be cultured by traditional microbiological techniques. Only modern genomics and metagenomic tools allow their identification [105]. Although cost-intensive, these methods are very sensitive and effective, allowing a very precise determination of the quantitative and qualitative composition of the microorganisms of organic substrates, indicating their suitability, or eliminating their use in plant crops.

Chemical Properties

The collected material had attributes of strong mineralization (degree of decomposition H7-H9 as determined by the van Post scale) making it unsuitable for use as a homogeneous substratum and improvements in its air-water properties are required (Table 3) [81,106–108]. The optimum porosity of the substrate was usually 50–85% and bulk density 190–700 $kg \cdot m^{-3}$ [71]. To improve them it is necessary to add some other organic materials e.g., sphagnum peat, coir fiber, wood fiber or minerals, e.g., wood fiber has high porosity (>85%), high water capacity (60–80%) and air capacity (15–29%). Meanwhile coir fiber has good aeration and water-holding characteristics; a good porosity level: 98% and AFP (air-filled pore space) of around 70% [109].

3.5.3. Enterprise

The presented financial analysis revealed that the studied company that was processing mined peat was characterized by a lack of profitability (Figure 6), especially at the level of return on assets. This was caused by the relatively low level of its own finances. Such a condition reduces the company's ability to settle current liabilities (Figures 7 and 8) and leads to an increase of financial risk. Consequently, there is a shortage of funds to finance investments and to obtain capital from outside. An additional and significant obstacle requiring market research is the poor identification of demand for specialized substrates for professional herb and vegetable crops, as well as for amateur cultivation.

3.6. Sustainable Land Development

The building of Lake Raduszyn may be abandoned when the organic matter extraction company stops mining. Such a situation is possible because the entity's financial condition is relatively weak in comparison to entities with a similar business profile. Improving the efficiency of operations can be achieved by introducing a new product produced from organic matter extracted in Raduszyn. In the studied company, this issue can be approached in two ways. As the study shows, some of the material, both physically and chemically, is suitable for direct use. However, a significant part of the extracted organic matter could be used in production after its proper preparation by using additives with lower density and higher porosity. For this reason, the use of microorganisms should be considered in the preparation of organic substrates for growing plants. Their presence supports the growth of plants in organic substrates and increases their resistance to biotic and abiotic stresses, which results in a higher yield and affects the quality parameters of plants [110]. The biostimulatory potential of microorganisms present in the substrates is most often associated with the production of phytohormones and provision of nutrients to plants [111]. The bacterial capsule produced by some bacteria, in turn contributes to the formation of a tubercular substrate structure. Moreover, through the production of extracellular polysaccharides and other cellular metabolites, microorganisms influence the physical properties of the substrate, helping to stabilize its structure. In addition, some microorganisms exhibit antagonistic properties against pathogens, thus contributing to better plant yields [112]. Due to the above-mentioned properties of microorganisms, large-scale studies are currently being carried out on the targeted introduction of selected microbial strains into various types of organic substrates for plant cultivation [105,113,114]. The appropriateness of using organic matter as a potentially suitable substrate for environmental application in agriculture, horticulture or land reclamation was confirmed by a study on a mixture of bottom sediment and water treatment sediment [115].

Stopping the excavation of organic matter by the company under investigation will contribute to halting the restoration of the lake and will result in further degradation of the Trojanka River valley in Raduszyn. Excavation of organic matter, which can be used as a mixture in horticulture or land reclamation, should also have a positive impact on the attractiveness of the landscape and increase biodiversity [7], and turn neglected land into a recreational and tourist zone of the city. The construction of the reservoir and simultaneous afforestation could improve the diversification of the landscape and its functionality [12].

Upon completion of the mining and shaping of the reservoir canopy [12], it will be possible to achieve naturally stable water levels [13] despite increasingly low water flows in the watercourses [103]. This will create the possibility for the construction of a low-slope (<15 m) micro hydroelectric power plant at the site of the former mill. Micro-hydropower plants are characterized by small power (e.g., 5 to 50 kW in India, 5 to 100 kW in the US) and, like pico-hydropower plants (power up to 5 kW) are gaining popularity in various parts of the world supplying power mainly to facilities in suburban and rural areas [116–118]. Using a simplified Bernoulli equation [118], the power output of the planned hydropower plant was calculated at 7.5 kW with a water level difference of 3.95 m and a turbine efficiency of 50%. Even at the minimum flows observed at the Trojanka River site of 0.03–0.05 $m^3 \cdot s^{-1}$ [18], the power plant will generate energy at the level of a pico-power plant in the range of 0.59–0.99 kW. Considering the power generated at average flows, it could provide illumination for two sports fields (with a total area of 6730 m^2) and the walking paths surrounding the reservoir (2 km long, 2.5 m wide) with adequate illumination.

4. Conclusions and Recommendations

Results of studies on extraction of organic matter allowed to formulation following conclusions:

- the use of analyzed material as a homogeneous substrate for plant cultivation is possible despite insufficient contents of nitrogen, phosphorus, potassium and copper, and excessive presence of calcium,
- due to the presence of plant growth-promoting bacteria in the substrate, such as *Bacillus subtilis* and *Pseudomonas fluorescens*, the microbiological characteristics are suitable to limit the use of mineral fertilizers and chemical plant protection products in agricultural practice.

The management of organic matter and construction of the reservoir will cause several positive phenomena in the environment. Shaping of the reservoir banks will result in limitation of the area covered by the invasive species *Impatiens glandulifera*, which was identified in the study and if not eliminated, could cover a vast part of the adjacent area. The proposed solution can reduce the eutrophication rate and intensive overgrowth of restored lakes, which is a common problem in the Greater Poland region. After the excavation process and the final forming of the water reservoir and banks, a space for recreation will appear together with the possibility of obtaining green energy using the stream flow force of the outflow from reservoir. Additionally, open waters will positively affect the microclimate, thanks to higher evaporation and stabilization of local air humidity.

The lack of scientific publications on the possibility of building water reservoirs in accordance with sustainable development gives the study an exploratory character. The uniqueness of the work is given by the application of a SWOT analysis in three aspects, in the context of the environment, product, and enterprise. Such a solution made it possible to comprehensively describe the relationships between the management of organic matter and the sustainable maintenance of the natural system and the continuous functioning of the enterprise. Based on the SWOT analysis of the interactions between the creation of the reservoir and the operation of the enterprise, the following recommendations were developed:

- maintenance of peat excavation and simultaneous utilization of organic matter will allow the development of the enterprise, providing a balance between the natural environment and recreational functions of the restored lake,
- due to the presence of useful microorganisms belonging to the PGPB (Plant Growth Promoting Bacteria) group in the extracted organic matter, it can be used to produce horticultural substrates and land reclamation,
- microorganisms present in the substrates promoting plant growth can contribute to a reduction in the use of mineral fertilizers and pesticides applied in the cultivation of selected plants, which is part of the European Green Deal strategy,
- keeping the lake in good condition will promote the development of a recreational and tourist base and even make it possible to create hydropower by the construction of a micro hydropower plant.

The presented results of this research can be an example for enterprises restoring water reservoirs by extracting organic matter, whilst such a material is often considered a waste generating costs and not bringing any financial benefits. Adding of organic matter to horticultural substrates is a measure that can be used to improve the business efficiency of water reservoir restoration enterprises and at the same time contribute to sustainable land development.

Author Contributions: Conceptualization, D.K.; methodology, D.C.-K., T.K., A.W.-M. and R.S.; software, D.C.-K.; validation, D.C.-K., T.K., A.W.-M., P.F., R.S. and D.K.; formal analysis, D.C.-K., T.K., A.W.-M., R.S. and D.K.; investigation, D.C.-K., T.K., A.W.-M., P.F., R.S. and D.K.; resources, D.C.-K., T.K., A.W.-M. and R.S.; data curation, D.C.-K., T.K., A.W.-M. and R.S.; writing D.C.-K., T.K., A.W.-M., P.F., R.S. and D.K.; visualization, D.C.-K., R.S. and D.K.; supervision, D.K.; funding acquisition, D.C.-K., T.K., A.W.-M., P.F., R.S. and D.K. All authors have read and agreed to the published version of the manuscript.

Funding: The publication and research were co-financed by Faculty of Environmental and Mechanical Engineering (including research topic 506.868.06.00/UPP) and Faculty of Economics of Poznan University of Life Sciences.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thank Krzysztof Achtenberg for the help in the preparation of the Raduszyn reservoir map.

Conflicts of Interest: The authors declare no conflict of interest.

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