

Article

Monetary Assessment of Restored Habitats as a Support Tool for Sustainable Landscape Management in Lowland Cultural Landscapes

Jan Brus ^{1,*}, Jan Deutscher ², Aleš Bajer ³, Petr Kupec ² and Lucie Olišarová ²

¹ Department of Geoinformatics, Palacký University Olomouc, 17. listopadu 50, 771 46 Olomouc, Czech Republic

² Department of Landscape Management, FFWT MENDELU, Zemědělská 1665/1, 613 00 Brno, Czech Republic; jan.deutscher@mendelu.cz (J.D.); pkupec@seznam.cz (P.K.); lucie.olisarova@seznam.cz (L.O.)

³ Department of Geology and Pedology, FFWT MENDELU, Zemědělská 1665/1, 613 00 Brno, Czech Republic; bajer@mendelu.cz

* Correspondence: jan.brus@upol.cz

Received: 30 December 2019; Accepted: 10 February 2020; Published: 12 February 2020

Abstract: Surfaces directly influenced by mining and post-mining have risen to prominence in the field of restoration ecology. It is important to gain a better understanding of sustainable landscape management in lowland European cultural landscapes. Sand and gravel-pit areas were selected as study sites, where mining activities have been the main factor in land use over recent decades. The post-mining restoration of each area disturbed by mining processes was planned according to legally enforced technical and biological restoration protocols, as well as a specific document entitled the Biological Action Plan (BAP). The financial costs of BAPs for individual study sites were compared with the monetary value of habitats over three time periods. The economic evaluation was based on the assessment method of ecological harm to habitats carried out in Hesse (Germany). The results show that the restoration of target habitats after mining will establish and gradually develop new natural habitats with a higher monetary value than before mining, which become refuges of biodiversity in cultural landscapes. The results also indicate that the ecological restoration of post-mining areas can result in a higher monetary value of the restored natural habitats in comparison to the original habitats which were destroyed by mining.

Keywords: monetary assessment; NATURA2000; mining sites; financial assessment

1. Introduction

European landscapes have been managed by humans for centuries. European lowland landscapes along large rivers have been modified through agricultural use on a local scale since the Neolithic period [1]. Regional land-use changes in many European lowland landscapes started in the early Middle Ages, when traditional cultural landscapes were being established [2]. The socio-economic development of each society, related to strengthening production and residential, administrative, and cultural-societal functions, results in ever-increasing pressures on ecosystems and their individual components. The cultural landscape is a representative picture of the state and the development of society [3]. Land-use changes in lowland European cultural landscapes were the main negative drivers that influenced both biodiversity [4] and the provision of ecosystem services [5,6]. Currently, the impact of land-use changes on ecosystems is accelerated by global climate change [7] and various other human activities, such as agricultural intensification [8], forest management [9], ecosystem fragmentation [10] and mining [11].

The increasing area of land surface directly influenced by mining and post-mining activities (i.e., the depositing of ash and waste [12]), has given rise to the development of restoration ecology [13,14].

The ecological restoration of ecosystems disturbed by mining is essential for the overall restoration and future sustainable maintenance of ecosystem functions in lowland cultural European landscapes. This topic is an important challenge for us to gain a better understanding of sustainable landscape management in lowland cultural European landscapes [15].

Fundamental ecological principles are important when applying restoration ecology to the management of disturbed landscapes, and these principles have been generally defined [16], but some knowledge gaps still exist in relation to many problems in the application of ecological restoration to sustainable landscape management. Ecological restoration supports an increase in biodiversity and other ecosystem services [17]. In current studies, the ecosystem services approach was used to assess the impacts of mining activities and post-mining restoration processes [18–20]. Following restoration, these areas can benefit mainly from biodiversity, water regulation or aesthetic and recreation.

Biodiversity is commonly used as a criterion of ecosystem health and of the success of ecological restoration or protection [21,22]. Nevertheless, biodiversity must be carefully considered on different levels as it can be misleading in restoration ecology practice [23]. Selecting the biodiversity of species as indicators of restoration projects in post-mining areas must be related to a special focus on aspects that can be managed according to the locality [24]. In addition to the issues already discussed, uncertainty is another critical issue facing the valuation of ecosystem services and biodiversity. Actual problems with assessing the ecosystems include the uncertainty associated with the classification of land cover classes, and the categorization process of biotopes themselves [25].

New insights into restoration ecology in cultural landscapes have brought about the economic assessment of ecosystem services [26], because an econometric estimation of biodiversity supports public awareness of the importance of restoration projects in a generally clear way [27]. The restoration targets in the ecological restoration of post-mining areas are partly dependent on the values of the local stakeholders. Thus, knowledge of the monetary value of ecosystems is essential for sustainable landscape management planning and practice in cultural European landscapes [28]. We believe that the monetary assessment of both biodiversity and natural habitats can be considered as a key to the holistic evaluation of ecosystem services provided by restored ecosystems in mining areas. In this study, we aimed to evaluate the monetary value of habitats in three sandpit post-mining sites in lowland areas of the Czech Republic (Central Europe). We analyzed the differences in the monetary value of habitats before and after sand mining. We used an original, expert method [29] which has been widely used in the monetary assessment of natural habitats [30]. The aim of our study was to test a hypothesis based on the general assumption that mining activities decrease the monetary value of habitats in mining areas.

2. Study area and methods

All the study sites in this study (Fig. 1) are sand and gravel-pit areas, where mining activities have been the main force in land use over recent decades. The post-mining restoration of each area disturbed by mining processes was planned according to legally enforced technical and biological restoration protocols as well as the specific document entitled the Biological Action Plan (BAP). The Biodiversity Action Plan is a specific approach adopted by the mining company responsible for mining activities in these areas, with the aim to ensure ecological stability and the sustainable utilization of their post-mining sites [31]. The aim of the BAP is to provide support for the decision-making process and to encourage the implementation of effective management measures aimed at conserving and enhancing the biodiversity of the target areas, whilst also taking into account the ongoing technical and biological restoration legislation imposed by Czech mining law. At the same time, it also incorporates other landscape uses (recreation, agriculture, stakeholder visions, etc.) to ensure the long-term sustainability of the areas.

In the BAP, “target biotopes” are defined for the locality according to the NATURA 2000 systemization [32]. For these target biotopes, specific management measures for five years ahead are planned, and these incorporate the ecological and ethological demands of the expected important species which will inhabit them. The total financial cost of the designed measures is then calculated

according to national standardized costs. In this way, the document offers a basic idea of the expected financial cost, the work involved and the duration of the initial restoration process.



Figure 1. Localization of study sites.

2.1. Kluk study site

The mining site Kluk is located in the Elbe lowlands. It can be characterized as a floodplain area with flat morphology that originated from the erosive and sedimentation activities of the river Elbe and its tributaries. The geology consists of alluvial quaternary sediments in the form of gravel and sand from the river terrace, with enclaves of eolic loess and loam on the slopes of the surrounding hills. The area has interesting hydrogeology of cretaceous sea sediments with the occurrence of both permeable sandy sites (collectors) and marl and clay sites (isolators). In the studied locality, two different collectors of groundwater can be distinguished: a subsurface collector of quarterly sand and gravel sediments directly communicating with the river Elbe, and a deep underground collector of older waters accumulated in the cretaceous sandy sediments (local mineral water Podebradka). The soils in the area are relatively homogeneous with two main soil types: fluvisols and gleysols. The climate is warm relative to the other areas—one of the hottest in the Czech Republic with a mean annual temperature around 9°C and with mean annual precipitation around 600 mm. The mining site is located on the borders of a Special Area of Conservation, Natura 2000 (SAC Libické luhy). The vegetation can be characterized as a mosaic of floodplain forests and semi-natural cultivated meadows. The cultivated meadows are the result of the traditional management of cutting grass for bedding and food for livestock; a practice that has been abandoned for the most part in recent years. The semi-natural biotopes consist of the typical remnants of continental meadows and fragments of sedge meadows that form the local monocenosis.

Mining in this area has a long history. Up until 1976, mining was done in one lake in the northern parts of the mining site. In the following years, mining was extended, and more lakes were formed. There are five lakes currently. Before the mining started, the area was a mosaic of biotopes (Tab. A1, such as extensively managed fields of arable land and cultural meadows, semi-natural meadows and remnants of floodplain forests. The study areas where BAP was prepared covers the fifth post-mining lake and its close surroundings. Mining is not completely finished in the southern parts of the lake. However, technical restoration has already taken place on most of the other banks. According to a zoological survey, no critically endangered species were present in the locality. The highest ecological value is now present in the restored banks of the lake, both with vertical and gradual slopes, as they offer potential habitats for a several of specially protected amphibian species (*Bombina orientalis*, *Hyla arborea*, *Rana dalmatina*) that occur in the Libické luhy SAC. Close to the lake's banks, there are still

fragments of undamaged sedge meadows that could function as seed banks for the successful natural ecological restoration of neighboring sites designated for restoration.

The technical restoration consisted of stabilizing the lake banks, creating a littoral zone and soil conditioning on certain sites (adding a layer of topsoil rich with organic matter on the worst damaged areas). The banks beneath the expected water surface were shaped into a slope of 1:3.5 that, according to the soil characteristics, should ensure long-term stability. Some were left untouched in a vertical slope for natural abrasion processes to take place. The southern banks were shaped into gradual slopes of 1:10 to 1:15 by unsaleable fractions of sand and waste material from the mining. The bottom was shaped into a complex of different depths with humps and depressions to ensure a wider range of water habitats. The areas indirectly affected by mining such as manipulation sites, conveyor belt emplacements, associated areas, etc., were conditioned by a cover of humic topsoil 15 cm deep. The following biological restoration will consist mainly of the establishment of vegetated areas; woody sections and plant meadows.

According to the BAP, in five years the following target biotopes should be present in the locality: rich mesotrophic meadow, initial oligotrophic meadow, green vertical banks, green gradual banks, and reed. To reach the desired status, state-specific management measures were planned in the BAP (Tab A1.). During the mining process, the soils were either removed or the topsoil was heavily damaged by the transportation and mechanization and following quick nutrient leaching. This was reflected in the target biotopes, as most of them could be characterized as early succession or naturally oligotrophic ecosystems. Therefore, the management measures were primarily designed to streamline the natural ecological succession (such as the removal of ruderal vegetation and invasive species) with the utilization of the seed bank of naturally more stable neighboring biotopes from the Libické luhy SAC and to keep the low nutrient content and to protect against eutrophication (regular mowing, including disposal of mown material).

2.2. Zajecí study site

The mining site Zajecí is located in the floodplain of the river Dyje on the south-eastern border of the Dyje-Svratka valley. The area is characterized by a wide river valley bounded from the North by older river terraces and neogenic sediments originating in the Dyje-Moravian hills. It is one of the hottest areas in the Czech Republic (mean annual temperature approaching 10°C) with a mean annual rainfall of around 500 mm. The winds blow most of the year in a westerly or north-westerly direction; they carry dry air and cause desiccation. In recent decades, the local climate has been altered by a big artificial water body known as the Novomlýnský reservoirs. The soils in the floodplain are a mosaic of fluvisols, characterized by the alternation of different soil types (from alluvial coherent clay to permeable sand and gravel terraces). In the distant parts of the floodplain and the surrounding mild slopes, weathered sandy loam can often be found covered by overlays of loess sediments. On the loess sediments, a typical mosaic of fertile black and brown soils is formed. The evolution of natural biotopes is highly dependable on the water table level. The active mining of sandy gravel in close vicinity to the river channel and its natural deepening considerably decreases the water table level in the study area. Therefore, the current potential vegetation is mostly woody steppe with small enclaves of floodplain forest in local depressions. The biggest threats to these biotopes come in the form of invasive species such as acacia (*Robinia pseudoacacia*) and bush grass (*Calamagrostis epigejos*), eutrophication and following ruderalization.

Mining in the area dates back to many decades ago. In 1987, an old post-mining lake with an area around 1ha was located there. The modern mining era began in 1989 with a new mining permit. The studied area where the BAP was prepared is located in the eastern part of the mining site, around a new post-mining lake and its surroundings. Here, mining started in 2012. Up to that point, the locality was part of a huge block of arable land and, as such, it was intensively managed for plant production (Tab. A2). The targeted materials here were gravel and sand, and they were extracted from the open cast mine. Due to the vicinity of the Dyje River and the high-water table, a lake formed after the extraction of the mining material. Currently (in 2019), mining is finished, and technical restoration is in progress. In the current state, the highest biological value can be assigned to spatially

minor biotopes along the ragged shoreline of the post-mining lake and the waterlogged depressions formed on flat sandy littoral zones and beneath the vertical abrasion cliffs. These habitats have almost disappeared from the Czech landscape due to river straightening and stabilization [33].

The technical restoration consisted of the construction and stabilization of the lake banks in required slopes with the use of overburden material. The northern banks were modelled into three small peninsulas with steep slopes (1:2). The rest of the banks were modelled into changing slopes from 1:11 to 1:2. The peninsulas and parts of the lower slope banks were also overlaid by cultural topsoil. The following biological restoration consisted mainly of the establishment of vegetated areas; woody sections and plant meadows. Grass cover was sown on all flat areas; whereas steep slopes and littoral zones had no topsoil added and were left to natural ecological succession.

According to the BAP, in five years the following target biotopes should be present in the locality: woody steppe, green vertical banks, green gradual banks and open water bodies. To reach the desired status, state-specific management measures were planned in the BAP (Tab A2.). Most of the target biotopes could be characterized by early succession or low nutrient content. Therefore, the management measures are primarily designed to streamline the ecological succession (such as the removal of ruderal vegetation and invasive species) and to keep a low nutrient content and protect against eutrophication (regular movement, including disposal of mown material).

2.3. Napajedla study site

The mining site is situated on the northern border between the South-Moravian floodplain and the Carpathian uplands. The area is characterized by the wide floodplain of the River Morava and is in one of the hottest parts of the Czech Republic (mean annual temperature approaching 10°C) with slightly increased annual precipitation caused by the vicinity of the Vizovice uplands (mean annual precipitation around 500mm). Winds blow mostly in a northerly or north westerly direction and they carry dry air and cause desiccation. The typical mosaic of floodplain fluvisols is characterized by the occurrence of different soil types (from coherent clay to permeable sands and gravel). The evolution of biotopes is highly dependable on the water table level. The active mining of sandy gravel in close vicinity to the river channel and its natural deepening have considerably decreased the water table level in the study area. Consequently, the current natural biotopes can mostly be described as woody steppe and mesotrophic grassland, both of which are threatened by invasive ruderal species such as acacia (*Robinia pseudoacacia*) and bush grass (*Calamagrostis epigejos*).

The study area consists of the northernmost post-mining lake and its surroundings in the northern part of the mining site. Before mining started in 2009, this locality was part of a huge block of arable land and, as such, it was intensively managed for plant production (Tab. A3). The targeted materials here were gravel and sand and they were extracted from an open cast mine. Due to the vicinity of the Morava River and the high-water table, a lake formed after the extraction of the mining material and overburden. Currently (in 2019), mining has finished and the technical and following biological restorations are taking place. The highest biological value can be assigned to spatially minor biotopes along the rugged shoreline of post-mining lakes and waterlogged depressions formed either by flat sandy littoral zones or by steep vertical abrasion cliff sides. These kinds of biotopes have almost disappeared from the Czech landscape due to river straightening and stabilization.

The technical restoration mainly consists of the construction and stabilization of the lake banks in required slopes, the stabilization of the overburden at chosen sites and the overlay of some parts of the site by cultural topsoil. The following biological restoration mainly consists of the establishment of vegetated areas; woody sections and plant meadows.

According to the BAP, in five years the following target biotopes should be present in the locality: green vertical banks, extensive orchards, woody steppes, green gradual banks, rich mesotrophic meadow, open water bodies, green vertical banks and meadow beach. To reach the desired status, state-specific management measures were planned in the BAP (Tab A3.). Most of the target biotopes could be characterized as early succession or low nutrient content. Therefore, the management measures are primarily designed to streamline ecological succession (such as the

removal of ruderal vegetation or invasive species) or to keep the low nutrient content and protect against eutrophication (regular moving including disposal of the mown material).

2.4. Methods of monetary assessment of habitats

The financial costs of BAPs for individual study sites were compared with the monetary value of habitats at each site over three time periods: Before the start of mining activities, the current state and the target habitats after restoration. The biotopes were identified based on catalog of habitats in the Czech Republic, which is based on detailed terrain research done between 2001 and 2004 in order to create a network of the areas of European importance [32].

Economic assessment of the landscape draws on a modified Hessen biotope assessment method adjusted to the conditions of the Czech Republic [29]. Its detailed description which we followed was published in previous studies [30,34]. The method is based on a national list of habitat types and an expert evaluation of their point value (PV) in eight elementary evaluations of ecological criteria (maturity, naturalness, diversity of plant species, diversity of animal species, rarity of biotope, rarity of species, vulnerability, and threat to existence). A complete list of biotopes' point values is available at <http://fzp.ujep.cz/projekty/bvm/bvm.pdf>. For a specific type of habitat, the result of the point evaluation (related to 1 square meter of the habitat area) represents the relative ecological value of a specific habitat type in comparison with other habitat types. The final monetary value of an individual point for the Czech Republic amounted to EUR 0.592 in 2019.

3. Results

The results at each study site (Tab. 1–3) did not support the hypotheses being tested: mining activities decrease the monetary value of habitats in mining areas even after their restoration. At the study site Kluk, there was a very diverse spectrum of natural habitats (including habitat reed beds of eutrophic still waters, habitat mesic meadows and habitat of floodplain forest) before the start of mining activities (Tab. 1). After restoration, all these former habitats will be restored as target habitats in the post-mining area. The results of analyze (Tab. 1) reveal that the monetary value of target habitats after restoration will be increased by 18% in comparison to the monetary value of habitats before mining.

The results from the study site Zajeci indicated the same trend, but more significantly: Before the start of mining there were only anthropogenic habitats in the study area (Dominated by arable land and with an absence of natural habitats). After restoration, the restored post-mining area will be covered by a mosaic of natural habitats (reed beds of eutrophic still waters, the vegetation of exposed bottoms in warm areas, macrophyte vegetation of eutrophic still waters, mesic meadows, and willow scrub). The increase in the monetary value of habitats in this study area will reach 400 % of the former monetary value (Tab. 2).

Very similar results were identified at the study site Napajedla (Tab. 3), where the increase in the monetary value of the habitat will reach 380% of the habitat's monetary value before the start of mining. After restoration, the target habitats in this study site will contain the same habitat types as the study site Kluk (compare tab. 3 and tab. 1). Generally, in the three study sites, we identified similar trends: If the site was originally located on arable land, the mining process and the creation of artificial lakes already increased the monetary value of the biotopes compared to its initial value (Zaječí, Napajedla). In all cases, the restoration of target habitats after mining has the potential to establish and gradually develop new natural habitats with a higher monetary value than before mining.

Table 1. Biotope value in the locality Kluk.

	Biotope (Natura 2000)	Area (m2)	Value CZK
Before	X3 (100)	1186	216896
	T1.1 (100)	8800	4425696
	T1.7 (100)	10133	10192177

	T1.1 (100)	3401	1710431
	M1.7 (100)	12396	4911791
	X3 (100)	32541	5951098
	M1.7 (100)	10830	4291279
	M1.1 (100)	5049	2154509
	L3.1 (100)	1354	969843
	M1.7 (100)	5486	2173773
	T1.7 (100)	10881	10944545
	M1.1 (100)	5054	2156642
	L2.3B (100)	335	255270
	K1 (20), M1.1 (40), M1.7 (40)	512	218481
	T1.1 (100)	947	476265
	K1 (100)	1851	1015533
	M1.1 (100)	967	412638
	T1.1 (30), T1.9 (70)	8651	7119427
	T1.1 (50), T1.4 (50)	19640	11822887
	X3 (100)	17673	3232038
	T1.1 (100)	9740	4898441
	X14 (100)	12	2743
	M1.7 (100)	218	86380
	T1.4 (100)	9631	6751716
	M1.1 (100)	18541	7911816
	T1.1 (40), T1.4 (30), T1.9 (30)	6723	4702846
	L2.3B (80), M1.7 (20)	3893	2681685
	Total	206445	101686846
Current state	X7A 50, M1.1. 50	2748	942289
	X7A 50, M1.1. 50	9426	3232175
	X7A 30, T1.1. 40, M1.7. 30	1407	559654
	X7A 50, M1.1. 50	6833	2343036
	X6 70, T1.1. 20, M1.7. 10	10312	2875934
	X6	1500	297180
	X7A 30, T1.1. 40, M1.7. 30	36422	14487360
	X7A 30, T1.1. 40, M1.7. 30	19180	7629114
	X7A 50, M1.1. 50	10731	3679660
	X14	91124	20830946
	X14	6483	1482014
	Total	206445	58359363
Target biotopes	M1.1	2748	1172627
	M1.1	9426	4022263
	M1.1. 80, T1.7. 20	1407	763359

M1.1	6833	2915778
T1.1. 50, M1.7. 50	10312	4636069
M2.3. 80, L2.2. 10, M1.1. 10	1500	1019556
M1.1. 80, T1.7. 20	36422	19760538
M1.1. 80, T1.7. 20	19180	10405994
M1.1	10731	4579132
V1	91124	65270299
L2.2. 60, M2.3. 20, M1.1. 20	6483	3971797
T1.1. 50, M1.7. 50	10279	4621233
Total	206445	123138645

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to the national nomenclature of the Natura 2000 Biotopes [32]. The basic description of the so-called formation groups are as follows: X—Anthropogenic or heavily man-influenced biotopes; T—Secondary grasslands and heaths; M—Wetlands and coastal vegetation; L—Forests; K—Scrublands; V—Watercourses and water bodies. If numbers are present at the end of the description, for example, X7A 50, M1.1. 50, it corresponds to a mosaic of biotopes with an areal representation of 50% and 50%.

Table 2. Biotope value in the locality Zaječí.

	Biotope (Natura 2000)	Area (m2)	Value CZK
Before	211	121005	19916455
	Total	121005	19916455
Current state	X14	86658	19810019
	X14	1193	272720
	X6	5607	1110859
	X6	27547	5457612
	Total	121005	26651210
Target biotopes	M1.1 50, M2.3. 50	1193	681800
	V1	86658	62071392
	M2.3	5607	4016182
	T1.1. 60, K3 40	27547	13853937
	Total	121005	80623311

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to national nomenclature of the Natura 2000 Biotopes [32].

Table 3. Biotope value in the locality Napajedla.

	Biotope (Natura 2000)	Area (m2)	Value CZK
Before	211	242205	39865005
	231	189	38021
	Total	242394	39903026
Current state	X14	5434	1242212
	X6	1194	236555

	X7A 50, X6 30, L2.2. 20	67535	21408055
	X6 70, X7A 30	6632	1435218
	X7A	3906	1011966
	X14	136336	31166410
	X6 80, X7A20	19599	4121905
	Total	242394	60622321
Target biotopes	M1.1 50, M2.3 50	5434	3105531
	T1.1. 80, X3 20	1194	534979
	T1.1 50, K3 30, L2.2 20	67535	35817322
	M2.3	6632	4750369
	T1.1.	3906	1964406
	V1	136336	97654750
	M1.1 50, M2.3 50	1758	1004697
	X7A 60, T1.1 40	19599	6989317
	Total	242394	151821371

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to national nomenclature of the Natura 2000 Biotopes [32].

4. Discussion

Mining poses serious and highly specific threats to biodiversity [18]. Following this statement, we supposed that mining activities will lead to decreasing biodiversity and primarily expected that the monetary value of biotopes would be decreased. The results of this study indicated a higher monetary value for habitats in sandpit areas after the restoration of habitats following the end of mining activities in comparison with the monetary value of habitats before mining occurred (Tab. 1–3). This result can be explained because of the strict application of the principles of restoration ecology during the planning of restoration measures. In all study sites, the target of the restoration (exactly planned in the frame of Biological Action Plans) was to establish natural habitats with high biodiversity. The habitats in study sites that were destroyed by the excavation of sand were habitats with low biodiversity, and there were other habitats strongly altered by human activities (such as arable land). This is a clear explanation for the results of this study.

The results of this study cannot be generalized, because in Central Europe, technocratic approaches still prevail in the restoration of land degraded by mining, and the application of ecological principles to restoration projects has been rare [35]. Moreover, it is necessary to mention that restoration heavily depends on successfully documenting the 'restored' status of the biotopes with biological surveys or other monitoring methods over the long-term period. Furthermore, the monitoring methods used can have strong impact on the results. Even though the present method is widely accepted, there exist several other techniques which can bring other results, as recent academic and policy debates have highlighted a wider range of values (e.g., relational and intrinsic values), valuation methods (e.g., socio-cultural methods), and worldviews (e.g., indigenous and local knowledge (ILK) systems) [36].

Considering the results, we believe that five years of ecosystem management is needed to achieve the target habitats in restored study sites. Some types of restored habitats (e.g., Mesic meadows) will need management in order to maintain their biodiversity according to the basic characteristics of habitat type in the Natura 2000 habitat classification [37]. The target of establishing and maintaining open grassland habitats is also limited by the possibility of an invasion by an alien species, such as *Calamagrostis epigejos*, which can form a dense and very compact sward, and prevent the establishment of a grassland habitat. Thus, we believe that the management of grassland habitats

is necessary for long-term sustainability. The sustainable management of natural habitats which depend on human activities—such as the mowing of meadows—will be a very important factor in the effectiveness of conservation efforts and the maintenance of biodiversity in study sites. Spontaneous succession, in many large, disturbed and abandoned areas in this region, represents an interesting challenge in applying an ecological approach to future restoration in order to support biodiversity conservation [38] and ecosystem management should be an integral part of the ecosystem restoration process [39].

Some other target natural habitats (e.g., Willow scrub), which do not need management in order to be maintained in the long term, will be left to spontaneous vegetation succession. As mentioned above, spontaneous succession is currently considered to be a very useful tool in the restoration of areas disturbed by mining [40], including sandpits [41]. The authors of the study [42] found the highest cover of woody species in a sandpit—the wood succession ended in a sandpit close to the woods. This is in accordance with some of the targets (related to target forest habitats) of the restoration project in each of three sandpit areas in this study. In the succession of woody species, a whole array of different factors play important roles [43,44]. Thus, applying succession to restoration projects involves the manipulation of succession.

The restoration targets in the successful application of the principles of restoration ecology in disturbed areas need a definition of biodiversity indicators, although a consensus on a definition is difficult due to the complexity of biodiversity and local conditions [45]. We used the characteristics of the target habitats as described in the Czech national catalog of habitats under the Natura 2000 network [46]. The restoration targets are usually on a local scale and influenced by local stakeholders—who may be interested in the economic aspects of a restoration project. Information related to the monetary value of restored habitats (in comparison to the former state of the study areas before mining) can be important in raising the awareness of restoration targets. The monetary estimation of habitats can support the targets of restoration. Thus, this information can be considered as a decision support tool for both stakeholders and decision-makers in the frame of landscape management in cultural landscapes involving post-mining areas. We expect that the value of point value will be increased in time. This trend can be observed since 2003, when the point value was first determined. Possible negative influences on financial value can be determined by the material values placed by the stakeholders [47].

5. Conclusions

This study supports the emerging knowledge related to the ecological importance of post-mining areas as refuges of biodiversity in cultural landscapes. The study is in accordance with other studies and proved the importance of restoring areas affected by human activities. The results of the study indicate that the ecological restoration of post-mining areas (if the principles of restoration ecology have been applied) can result in a higher monetary value of the restored natural habitats in comparison to the original habitats which were destroyed by mining. We emphasized that these results cannot be generalized, and the interpretation is based on local conditions and the achievement of targets related to natural habitats. We also highlighted the importance of the management of the target open grassland habitats. Spontaneous succession must be involved in ecological restoration, especially if the target of restoration is a woodland habitat. For significant habitats corresponding to early succession stages (sandbanks, dry grasslands, oligotrophic wetlands), appropriate management should be ensured even after mining and recovery have been completed. Anthropogenic lakes created by gravel mining may be regionally important as a nesting place for water birds. Management interventions in favor of some vertebrate species also have a relatively good tradition in the Czech Republic. The sandpits were shown to be important for the regional persistence of some species, some of which were thought to be extinct in the Czech landscape [48].

Ecological restoration aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed. There are many examples in which mined land has been effectively rehabilitated for agricultural, forestry, conservational, urban or industrial land uses [49]. From this perspective, it is important to restore old mining places. Targeted recovery, to increase biodiversity and exploit the

full potential that the mining landscape can offer, is very meaningful. Well-managed restoration can contribute to enhancing biodiversity, but also to enhancing the recreational and aesthetic function of the landscape.

This study suggested some implications for sustainable landscape management in cultural landscapes. A comparison of the monetary value of habitats disturbed by mining and the monetary value of restored habitats is important for the successful achievement of restoration targets and, more generally, it can be used as a decision support tool for sustainable landscape management in cultural landscapes.

Supplementary Materials: Table A1: Biotope value in the locality Kluk. Table A2: Biotope value in the locality Zaječí and Table A3: Biotope value in the locality Napajedla.

Author Contributions: Conceptualization, J.B., J.D. and A.B.; Methodology, J.B., J.D. and P.K.; Investigation, J.D., P.K., L.O. and A.B.; Data Curation, J.D., L.O. and J.B.; Writing-Original Draft Preparation, J.B., J.D., A.B. and P.K.; Visualization, J.B.; Supervision, J.B., J.D., A.B., P.K., Writing-review and editing, J.B., J.D., L.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by project Significant Trees—Living Symbols of National and Cultural Identity DG18P02OVV027 financed by Ministry of Culture Czech Republic.

Acknowledgments: Authors would like to thank for the support by institutional plan of MENDELU 2019–2020 by strengthening and development of inventive activities at the FFWT MENDELU by creating of post-doc positions.

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

Appendix A:

Table A1. Biotope value in the locality Kluk.

	Biotope (Natura 2000)	Area (m ²)	Description	Point value/m ²	Value CZK	Value EUR (25.57 CZK)
Before mining	X3 (100)	1186	cultural meadows	12	216896	8459
	T1.1 (100)	8800	continental meadows	33	4425696	172602
	T1.7 (100)	10133	continental meadows	66	10192177	397495
	T1.1 (100)	3401	continental meadows	33	1710431	66707
	M1.7 (100)	12396	sedge meadows	26	4911791	191560
	X3 (100)	32541	cultural meadows	12	5951098	232093
	M1.7 (100)	10830	sedge meadows	26	4291279	167360
	M1.1 (100)	5049	reed	28	2154509	84026
	L3.1 (100)	1354	floodplain forest	47	969843	37824
	M1.7 (100)	5486	sedge meadows	26	2173773	84777
	T1.7 (100)	10881	continental meadows	66	10944545	426837
	M1.1 (100)	5054	reed	28	2156643	84109
	L2.3B (100)	335	floodplain forest	50	255270	9956

Current state after mining (2019)	K1 (20), M1.1 (40), M1.7 (40)	512	woody meadows	28	218481	8521
	T1.1 (100)	947	rich mesotrophic meadow	33	476265	18574
	K1 (100)	1851	brushland	36	1015533	39606
	M1.1 (100)	967	reed	28	412638	16093
	T1.1 (30), T1.9 (70)	8651	rich mesotrophic meadow	54	7119427	277658
	T1.1 (50), T1.4 (50)	19640	rich mesotrophic meadow	39.5	11822887	461093
	X3 (100)	17673	cultural meadows	12	3232038	126049
	T1.1 (100)	9740	rich mesotrophic meadow	33	4898441	191039
	X14 (100)	12	ruderal water body	15	2743	107
	M1.7 (100)	218	sedge meadows	26	86380	3369
	T1.4 (100)	9631	rich mesotrophic meadow	46	6751716	263317
	M1.1 (100)	18541	reed	28	7911816	308561
	T1.1 (40), T1.4 (30), T1.9 (30)	6723	rich mesotrophic meadow	45.9	4702846	183411
	L2.3B (80), M1.7 (20)	3893	floodplain forest	45.2	2681685	104586
	Total	206445			101686847	3965787
	X7A 50, M1.1. 50	2748	reed	22.5	942289	36749
	X7A 50, M1.1. 50	9426	reed	22.5	3232175	126055
	X7A 30, T1.1. 40, M1.7. 30	1407	meadows	26.1	559654	21827
	X7A 50, M1.1. 50	6833	reed	22.5	2343036	91378
	X6 70, T1.1. 20, M1.7. 10	10312	manipulation area	18.3	2875934	112161
	X6	1500	gradual banks	13	297180	11590
	X7A 30, T1.1. 40, M1.7. 30	36422	meadows	26.1	14487360	565007
	X7A 30, T1.1. 40, M1.7. 30	19180	meadows	26.1	7629114	297535

Target biotopes according to BAP in five years	X7A 50, M1.1. 50	10731	reed	22.5	3679660	143507
	X14	91124	open water body	15	20830946	812407
	X14	6483	vertical banks	15	1482014	57799
	X6 70, T1.1. 20, M1.7. 10	10279	manipulation area	18.3	2866731	111803
	Total	206445			61226093	2387818
	M1.1	2748	reed	28	1172627	45732
	M1.1	9426	reed	28	4022263	156868
	M1.1. 80, T1.7. 20	1407	rich mesotrophic meadow	35.6	763359	29771
	M1.1	6833	reed	28	2915778	113715
	T1.1. 50, M1.7. 50	10312	initial oligotrophic meadows	29.5	4636069	180807
	M2.3. 80, L2.2. 10, M1.1. 10	1500	vegetated gradual banks	44.6	1019556	39763
	M1.1. 80, T1.7. 20	36422	rich mesotrophic meadow	35.6	19760538	770661
	M1.1. 80, T1.7. 20	19180	rich mesotrophic meadow	35.6	10405994	405834
	M1.1	10731	reed	28	4579132	178586
	V1	91124	open water body	47	65270299	2545542
	L2.2. 60, M2.3. 20, M1.1. 20	6483	green vertical banks	40.2	3971797	154900
	T1.1. 50, M1.7. 50	10279	initial oligotrophic meadows	29.5	4621233	180228
	Total	206445			123138644	4802407

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to the national nomenclature of the Natura 2000 Biotopes [32]. The basic description of the so-called formation groups are as follows: X—Anthropogenic or heavily man-influenced biotopes; T—Secondary grasslands and heaths; M—Wetlands and coastal vegetation; L—Forests; K—Scrublands; V—Watercourses and water bodies. If numbers are present at the end of the description, for example, X7A 50, M1.1. 50, it corresponds to a mosaic of biotopes with an areal representation of 50 and 50%.

Table A2. Biotope value in the locality Zaječí.

	Biotope (Natura 2000)	Area (m ²)	Description	Point value/m ²	Value CZK	Value EUR (25.57 CZK)
Before mining	211	121005	arable land	10.8	19916455	776742
	Total	121005			19916455	776742

Current state after mining (2019)	X14	86658	open water body	15	19810019	772591
	X14	1193	vertical banks	15	272720	10636
	X6	5607	gradual banks	13	1110859	43323
	X6	27547	manipulation area	13	5457612	212847
	Total	121005			26651209	1039397
Target biotopes according to BAP in five years	M1.1 50, M2.3. 50	1193	vegetated vertical banks	37.5	681800	26590
	V1	86658	open water body	47	62071392	2420784
	M2.3	5607	vegetated gradual banks	47	4016182	156631
	T1.1. 60, K3 40	27547	woody steppe	33	13853937	540304
	Total	121005			80623311	3144309

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to the national nomenclature of the Natura 2000 Biotopes [32].

Table A3. Biotope value in the locality Napajedla.

	Biotope (Natura 2000)	Area (m2)	Description	Point value /m²	Value CZK	Value EUR (25.57 CZK)
Before mining	211	242205	arable land	10.8	39865005	1554735
	231	189	arable land	13.2	38021	1483
	Total	242394		10.8	39903026	1556218
Current state after mining (2019)	X14	5434	vertical banks	15	1242212	48446
	X6	1194	manipulation area	13	236555	9226
	X7A 50, X6 30, L2.2. 20	67535	associated area	20.8	21408055	834914
	X6 70, X7A 30	6632	gradual banks	14.2	1435218	55973
	X7A	3906	technical peninsula	17	1011966	39467
	X14	136336	open water body	15	31166410	1215490
	X14	1758	vertical banks	15	401879	15673
	X6 80, X7A20	19599	sown gradual banks	13.8	4121905	160754
	Total	242394			61024200	2379944
	M1.1 50, M2.3 50	5434	vegetated vertical banks	37.5	3105531	121116
Target biotopes according to BAP in five years	T1.1. 80, X3 20	1194	extensive orchard	29.4	534979	20864
	T1.1 50, K3 30, L2.2 20	67535	woody steppe	34.8	35817322	1396876
	M2.3	6632	vegetated gradual banks	47	4750369	185264

			rich			
T1.1.	3906		mesothrophic meadow	33	1964406	76612
V1	136336		open water body	47	97654750	3808535
M1.1 50, M2.3 50	1758		vegetated vertical banks	37.5	1004697	39183
X7A 60, T1.1 40	19599		meadow beach	23.4	6989317	272583
Total	242394				151821371	5921033

The column **Biotope (Natura 2000)** contains abbreviations describing the corresponding biotopes according to the national nomenclature of the Natura 2000 Biotopes [32].

References

- Kilianova, H.; Pechanec, V.; Brus, J.; Kirchner, K.; Machar, I. Analysis of the development of land use in the Morava River floodplain, with special emphasis on the landscape matrix. *Morav. Geogr. Rep.* **2017**, *25*, 46–59, doi:10.1515/mgr-2017-0005.
- Simon, J.; Machar, I.; Bucek, A. Linking the historical research with the growth simulation model of hardwood floodplain forests. *Pol. J. Ecol.* **2014**, *62*, 273–288.
- Farina, A. Landscape Ecology and the General Theory of Resources: Comparing Two Paradigms. *J. Landsc. Ecol.* **2011**, *4*, 18–29.
- Oprsal, Z.; Harmacek, J.; Pavlík, P.; Machar, I. What factors can influence the expansion of protected areas around the world in the context of international environmental and development goals. *Probl. Ekorozw.* **2018**, *13*, 145–157.
- Harrison, P.; Berry, P.; Simpson, G.; Haslett, J.; Blicharska, M.; Bucur, M.; Dunford, R.; Egoh, B.; Garcia-Llorente, M.; Geamănă, N. Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosyst. Serv.* **2014**, *9*, 191–203.
- Pechanec, V.; Vavra, A.; Hovorkova, M.; Brus, J.; Kilianova, H. Analyses of moisture parameters and biomass of vegetation cover in southeast Moravia. *Int. J. Remote Sens.* **2014**, *35*, 967–987.
- Machar, I.; Vozenilek, V.; Kirchner, K.; Vlckova, V.; Bucek, A. Biogeographic model of climate conditions for vegetation zones in Czechia. *Geogr. Prague* **2017**, *122*, 64–82.
- Sklenicka, P.; Zouhar, J.; Trpáková, I.; Vlasák, J. Trends in land ownership fragmentation during the last 230 years in Czechia, and a projection of future developments. *Land Use Policy* **2017**, *67*, 640–651.
- Simon, J.; Machar, I.; Brus, J.; Pechanec, V. Combining a growth-simulation model with acoustic-wood tomography as a decision-support tool for adaptive management and conservation of forest ecosystems. *Ecol. Inform.* **2015**, *30*, 309–312, doi:10.1016/j.ecoinf.2015.08.004.
- Sklenicka, P. Classification of farmland ownership fragmentation as a cause of land degradation: A review on typology, consequences, and remedies. *Land Use Policy* **2016**, *57*, 694–701.
- Macháček, J. Typology of Environmental Impacts of Artisanal and Small-Scale Mining in African Great Lakes Region. *Sustainability* **2019**, *11*, 3027.
- Walker, L.R. Integration of the study of natural and anthropogenic disturbances using severity gradients. *Austral Ecol.* **2011**, *36*, 916–922.
- Van Andel, J.; Aronson, J. *Restoration Ecology: The New Frontier*; John Wiley & Sons: Hoboken, NJ, USA, 2012.
- Palmer, M.A.; Zedler, J.B.; Falk, D.A. *Foundations of Restoration Ecology*; Island Press: Washington, DC, USA, 2016.
- Machar, I.; Vozenilek, V.; Simon, J.; Pechanec, V.; Brus, J.; Fulnecek, P.; Vitek, T. Joining of the historical research and future prediction as a support tool for the assessment of management strategy for European beech-dominated forests in protected areas. *Nat. Conserv.* **2017**, 51–78, doi:10.3897/natureconservation.22.12902.
- Clewell, A.F.; Aronson, J. *Ecological Restoration: Principles, Values, and Structure of an Emerging Profession*; Island Press: Washington, DC, USA, 2013.

17. Farber, S.; Costanza, R.; Childers, D.L.; Erickson, J.; Gross, K.; Grove, M.; Hopkinson, C.S.; Kahn, J.; Pincetl, S.; Troy, A. Linking ecology and economics for ecosystem management. *Bioscience* **2006**, *56*, 121–133.
18. Sonter, L.J.; Ali, S.H.; Watson, J.E. Mining and biodiversity: Key issues and research needs in conservation science. *Proc. R. Soc. B* **2018**, *285*, 20181926.
19. Larondelle, N.; Haase, D. Valuing post-mining landscapes using an ecosystem services approach—An example from Germany. *Ecol. Indic.* **2012**, *18*, 567–574.
20. Li, X.; Stainback, G.; Barton, C.; Yang, J. Valuing the environmental benefits from reforestation on reclaimed surface mines in Appalachia. *J. Am. Soc. Min. Reclam* **2018**, *7*, 1–29.
21. Pechanec, V.; Machar, I.; Pohanka, T.; Opršal, Z.; Petrovič, F.; Švajda, J.; Šálek, L.; Chobot, K.; Filippovová, J.; Cudlín, P. Effectiveness of Natura 2000 system for habitat types protection: A case study from the Czech Republic. *Nat. Conserv.* **2018**, *24*, 21–41.
22. Salekl, L.; Sivacioglu, A.; Topacoglu, O.; Zahradnile, D.; Jerabkova, L.; Machar, I. Crowns of old remnant oak standards. *Fresenius Environ. Bull.* **2017**, *26*, 4023–4032.
23. Prach, K.; Tolvanen, A. *How Can We Restore Biodiversity and Ecosystem Services in Mining and Industrial Sites*; Springer: Berlin/Heidelberg, Germany, 2016.
24. Pitz, C.; Mahy, G.; Vermeulen, C.; Marlet, C.; Séleck, M. Developing biodiversity indicators on a stakeholders' opinions basis: The gypsum industry Key Performance Indicators framework. *Environ. Sci. Pollut. Res.* **2016**, *23*, 13661–13671.
25. Brus, J.; Pechanec, V.; Machar, I. Depiction of uncertainty in the visually interpreted land cover data. *Ecol. Inform.* **2018**, *47*, 10–13, doi:10.1016/j.ecoinf.2017.10.015.
26. Whisenant, S. *Repairing Damaged Wildlands: A Process-Orientated, Landscape-Scale Approach*; Cambridge University Press: Cambridge, UK, 1999; Volume 1.
27. Helm, D.; Hepburn, C. The economic analysis of biodiversity: An assessment. *Oxf. Rev. Econ. Policy* **2012**, *28*, 1–21.
28. Machar, I.; Kulhavy, A.; Sejak, J.; Pechanec, V. Conservation effectiveness and monetary value of floodplain forests habitats in the Czech Republic. *Rep. For. Res. Zpravy Lesn. Vyzk.* **2018**, *63*, 206–213.
29. Sejak, J.; Dejmal, I.; Petricek, V.; Cudlin, P.; Michal, I.; Cerny, K.; Kucera, T.; Vyskot, I.; Strejcek, J.; Cudlinova, E. *Valuation and Pricing Biotopes of the Czech Republic*; Czech Environmental Institute: Prague, Czech Republic, 2003.
30. Pechanec, V.; Machar, I.; Sterbova, L.; Prokopova, M.; Kilianova, H.; Chobot, K.; Cudlin, P. Monetary valuation of natural forest habitats in protected areas. *Forests* **2017**, *8*, 427.
31. Deutscher, J.; Kupec, P.; Bajer, A. Biodiversity Action Plan as a means of sustaining ecological stability of opencast gravel mining sites. In Proceedings of the Public Recreation and Landscape Protection—With Nature Hand in Hand, Brno, Czech Republic, 1–3 May 2017.
32. Chytrý, M.; Kučera, T.; Kočí, M.; Grulich, V.; Lustyk, P. *Katalog Biotopů České Republiky (Habitat Catalogue of the Czech Republic)*; Agency of Nature Conservation and Landscape Protection: Prague, Czech Republic, 2010; Volume 2, 445p.
33. Cílek, V.; Gremlica, T.; Lepšová, A.; Volf, O.; Vrabec, V.; Zavadil, V. *Industriální Krajina a Její Přirozená Obnova: Právní Východiska a Rekultivační Metodika Oblastí Narušených Těžbou*; Novela Bohemica: Prague, Czech Republic, 2013; 110p.
34. Pechanec, V.; Brus, J.; Kilianova, H.; Machar, I. Decision support tool for the evaluation of landscapes. *Ecol. Inform.* **2015**, *30*, 305–308, doi:10.1016/j.ecoinf.2015.06.006.
35. Prach, K. Ecological Restoration: Principles, Values, and Structure of an Emerging Profession. *Restor. Ecol.* **2008**, *16*, 730–730.
36. Christie, M.; Martin-López, B.; Church, A.; Siwicka, E.; Szymonczyk, P.; Sauterel, J.M. Understanding the diversity of values of “Nature’s contributions to people”: Insights from the IPBES Assessment of Europe and Central Asia. *Sustain. Sci.* **2019**, *14*, 1267–1282.
37. Miko, L. Nature and landscape protection in the European context. In *Ochrana Přírody a Krajiny v České Republice, Vols I and II, Czech Republic*; Machar, I., Drobilova, L., Eds.; Palacky University Olomouc: Olomouc, Czech Republic, 2012; Volume 1, pp. 43–49.
38. Lacková, E.; Kasovská, K.; Cmielová, L. Concept of reclamation management of the ash pond trinec (The Czech Republic). *Int. Multidiscip. Sci. Geoconference Sgem Surv. Geol. Min. Ecol. Manag.* **2012**, *5*, 185–192.
39. Šebelíková, L.; Řehounková, K.; Prach, K. Spontaneous revegetation vs. forestry reclamation in post-mining sand pits. *Environ. Sci. Pollut. Res.* **2016**, *23*, 13598–13605.

40. Walker, L.R.; Hölzel, N.; Marrs, R.; del Moral, R.; Prach, K. Optimization of intervention levels in ecological restoration. *Appl. Veg. Sci.* **2014**, *17*, 187–192.
41. Prach, K.; Hobbs, R.J. Spontaneous succession versus technical reclamation in the restoration of disturbed sites. *Restor. Ecol.* **2008**, *16*, 363–366.
42. Prach, K.; Pyšek, P. Using spontaneous succession for restoration of human-disturbed habitats: Experience from Central Europe. *Ecol. Eng.* **2001**, *17*, 55–62.
43. De Steven, D. Experiments on mechanisms of tree establishment in old-field succession: Seedling emergence. *Ecology* **1991**, *72*, 1066–1075.
44. Pyšek, P. Dominant species exchange during succession in reclaimed habitats: A case study from areas deforested by air pollution. *For. Ecol. Manag.* **1992**, *54*, 27–44.
45. Řehounková, K.; Čížek, L.; Řehounek, J.; Šebelíková, L.; Tropek, R.; Lencová, K.; Bogusch, P.; Marhoul, P.; Máca, J. Additional disturbances as a beneficial tool for restoration of post-mining sites: A multi-taxa approach. *Environ. Sci. Pollut. Res.* **2016**, *23*, 13745–13753.
46. Cudlín, P.; Prokopová, M.; Francírková, T.; Buresová, R. System NATURA 2000 utilization for purposes of biotope valuation. *Ekológia* **2005**, *24*, 52–68.
47. Lorne, F.T.; Dilling, P. Creating values for sustainability: Stakeholders engagement, incentive alignment, and value currency. *Econ. Res. Int.* **2012**, *2012*, 142910.
48. Heneberg, P.; Bogusch, P.; Řehounek, J. Sandpits provide critical refuge for bees and wasps (Hymenoptera: Apocrita). *J. Insect Conserv.* **2013**, *17*, 473–490.
49. Laurence, D. Mine closure and the community. *Min. Environ. Manag.* **2001**, *9*, 10–12.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).