EFFECT OF FOREST RECLAMATION ON THE KŘIVÝ DŮL SPOIL HEAP (UPPER SILESIA, CZECH REPUBLIC)

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Abstract: The contribution deals with the issue of social functions of forest woody plants on a reclaimed spoil heap Křivý Důl in the Stonava cadastral area. In the year 2010 the evaluation of real effects of functions of forest woody plants and their impact on the degree of coverage and abundances of species in the undergrowth was carried out here. There was verified the suitability of using the method: Quantification and Evalu-ation of Czech Forest Functions for anthropogenic substrates. There were evaluated the social func-tions, i.e. bioproduction, ecological-stabilization, hydric-water management, edaphic-soil-conservation, social-re-creation and sanitary-hygienic functions. On the basis of acquired results, the highest real effect was proved in the case of social hydric-water management function and the lowest one in the case of bioproduction function. Furthermore, the influence of woody plants on the character of the herb layer, the lowest species diversity in which was recorded in stand groups with allochthonous woody plant species, was proved. On the contrary, the highest species diversity was proved in stand groups with autochthonous species. On the basis of our results it can be stated that the used method can be applied also to the evaluation of anthropogenic areas (not only for natural soil conditions), but with emphasis put on the character of specific site; an integral part of the evaluation should also be herb layer evaluation.

Keywords: social functions of forests, effect of forest functions, reclamation, spoil heap Křivý Důl, degree of coverage and abundance of species.

1. INTRODUCTION

The area of Upper Silesia in the Czech Repub-lic is ranked among areas with a highly developed mining industry. Already for centuries, hard coal has been mined and processed here. An integral part of these activities is spoil heap construction. In spite of the fact that generally spoil heaps are regarded as undesirable, they can be, on the contrary, understood as very valuable habitats with a high potential. Spoil heaps become suitable safe sites for endangered, often even critically endangered species (above all animals). By studying the reclamation of spoil heaps and other mining-affected landscapes many authors, e.g. (Sklenička & Moldánová, 2010; Szarek-Łukaszewska, 2009; Andráš et al., 2007; Sádlo & Tichý, 2002; Bell, 2001, Štýs, 1998) have been con-cerned. Because spoil heaps occupy extensive areas, it is necessary to take them into account in the sub-sequent use and to interconnect them optimally with the surroundings so that resistant, species diverse,

fully functional and close-to-nature areas may be formed in an as short as possible period of time. Suitably performed forest reclamation and subse-quent tending of established stands are a basis for the creation of a high value functional forest ecosys-tem as stated by various authors in their works (e.g. Mauer, 2004). The classification of woody plants for anthropogenic soil reclamation was described by some authors (Dimitrovský & Vesecký, 1989; Štýs, 1981). Merely a stable ecosystem is capable to fulfil correctly all social functions of forest biotopes that develop on reclaimed areas. The social functions are, according to some authors (Fialová & Vyskot, 2009, Kupec 2004, Vyskot,I. 2003), the bioproduction function, edaphic-soil-conservation, hydric-water manage-ment, ecological-stabilization, social-recreation and sanitary-hygienic functions. On the inter-national level, e.g. Golos (2010), Führe (2000) or Bengtsson et al. (2000) are concerned with the forest functions and forest management. A precondi-tion for a successfully implemented reclamation pro-

ject is especially the knowledge of site conditions of area of interest, the utilisation of a suitable method of restoration, and the respecting of scenery and potential of the area. The least important aspect is the knowledge of succession stages of development of natural communities on a given site, because as stated by Prach & Hobbs (2008), the use of the method of controlled spontaneous succession is much more efficient and environment-friendly than restoration through technical reclamation. The success of vegetation development under unfavourable conditions in anthropogenic areas are described by various authors, e.g. (Mudrák et al., 2010; Damian & Damian, 2006; Kompala et al., 2004; Woryna & Rostanski, 2003; Marx et al., 2002; Strzyszcz & Heinkele, 2002; Prach & Pysek, 2001; Prach et al., 2001; Wali, 1999 etc.). The result of all works is the statement that vegetation has positive effects on soil substrate development and overall landscape restoration. For the purpose of evaluation of social functions of forests the following method is used in the Czech Republic: Quantification and Evaluation of Czech Forest Functions, henceforth referred to as Vyskot's method (Vyskot, 2003). The method deals with the comprehensive evaluation of capabilities of forests and their impacts on individual components of nature. These capabilities or functions can be categorized in a simplified manner into six basic social functions of forests:

1) Bioproduction function – henceforth referred to as BP, function ensuring the primary production and increase in ecosystem diversity.

2) Ecological-stabilization function – henceforth referred to as ES, the function the effects of which are ecological stability maintenance and ecological balance support.

3) Edaphic-soil-conservation function – henceforth referred to EC, the function the effects of which are soil forming, soil conservation and anti-erosion and anti-landslide effects.

4) Hydric-water management function – henceforth referred to as HW, the function the effect of which is the influence on water regime and total water balance of the given area.

5) Social-recreation function – henceforth referred to as SR, the function the effects of which affect the satisfaction of physical and psychical human needs and the production of natural substances utilized by people.

6) Sanitary-hygienic function – henceforth referred to as SH, the function ensuring the filtration of solid and gaseous substances, the mitigation of climate extremes, the ionization of air, and the sanitary-hygienic effect on the human organism.

The topical real effect of forest functions expresses the topical functional effectiveness of a forest ecosystem, it means a functional effect following from the topical condition. In percentage values it expresses the rate of a produced function with regard to its potential capabilities. The basis of its calculation is the determination of 3 determination criteria characterising the condition of stands: age, stocking and health condition. According to Vyskot's method (Vyskot, 2003), for the expression of age structure, the stand development stage, which represents the percentage expression of age from the total time of the supposed existence of a stand, i.e. rotation period, is used. For the expression of spatial structure, the criterion of stocking representing the reduced area of a woody plant is used. It is a case of indicator laid down in legislation, which expresses the degree of using the growth environment of a stand. Stocking must lie within the 1-10 interval; the value of 10 represents full stocking, i.e. the space of a forest stand is, from the point of view of growth processes, used optimally. The methodology for the expression of health condition rests on the procedures for evaluation according to the methodology ICP Forest (MZe et VÚLHM 2004), based on the evaluation of damage to particular trees and overall damage to a stand.

The goal of this contribution is to present achieved results of evaluation of the effect of forest reclamation performed on the Křivý Důl spoil heap using the method developed by Vyskot, (2003) and to verify thus the suitability of application of the given method not only to close-to-nature sites, for which the method was primarily designed, but also to man-made sites. The subgoal was to prove the positive or negative influence of woody plants on the character of herb layer.

2. MATERIALS AND METHODS

2.1. Křivý Důl Spoil Heap

The Křivý Důl spoil heap is situated in the Stonava cadastral area in the Moravian-Silesian Region. It is bounded by a class III hard surface road Solecka on the north and the west, by a hard surface tertiary road on the east, and the south part of the locality is bounded by a forest pass and a boundary of stand groups 806F and 806G. A class II road No. 747 allows access to the area. The total area under study is 13 ha and is divided into 5 stand groups (Fig. 1). Terrain characteristics of particular stand groups are given in table 1. The rotation period was according to forest economic taxation characteristics determined at 60 years. (Forestry projection F-M, 2008).
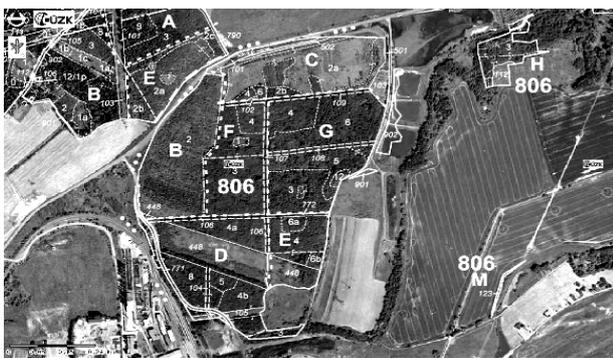
Figure 1. Spatial representation of stand groups 806C2a, 806C2b, 806C6, 806C4 and 806B2, (Source: www.uhul.cz)

Table 1. Terrain characteristics of stand groups

Stand group	Expo-sition	Angle of slope	Altitude [m a.s.l.]	Co-ordinates (S-JTSK)
806C2a	N	40°	260	454807;1105708
806C2b	-	-	260	454870;1105775
806C6	-	-	260	454927;1105778
806C4	-	-	260	454963;1105785
806B2	NW	27°	260	455148;1105974

2.2. Description of stand group

1. The stand group *806C2a* occupies an area of 6.06 ha; it is a case of young, 14-year-old, small pole-stage stand. Stocking is 9 full, health condition 0/1, i.e. stands slightly damaged, especially by browsing; in rather high parts of the slope, woody plants shrink due to increased runoff. The degree of total coverage of tree layer is 70%. The stand group consists of *Acer pseudoplatanus* (20%), *Tilia cordata* (20%), *Fraxinus excelsior* (20%) and an admixture of *Betula pendula*, *Alnus glutinosa* and *Quercus robur*. The degree of total coverage of spontaneous species is 90% in the under-growth. The abundances are as follows: *Betula pendula* juv. 1, *Calamagrostis epigejos* 1, *Daucus carota* 1, *Hieracium pilosella* 2, *Leontodon autumnalis 1, Quercus rubra* juv. +, *Salix caprea* juv. r, *Tanacetum vulgare* 1, *Tilia cordata* juv 2. (Braun – Blanqueta in Slavikova, 1986).

2. The stand group *806C2b* occupies an area of 0.29 ha. It is a case of 22-year-old, pole-stage stand (Fig. 2). Stocking is 9 full and health condition is 0, which represents a healthy stand. The degree of total coverage of tree layer is 60%. The stand group con-sists of *Betula pendula* (80%) and a mixture of *Alnus glutinosa* and *Quercus robur*. The degree of total coverage of spontaneous species is 95% in the under-growth. The abundances are as follows: *Betula pendula* juv. 1, *Cirsium arvense* 1, *Equisetum arvense* +, *Symphytum officinale* 1, *Tanacetum vulgare* 1*, Tilia cordata* juv. 2*, Urtica dioica* 1, and of species plant-ed: *Calamagrostis epigejos* 4.

3. The stand group *806C6* occupies an area of 0.15 ha; it is a case of 59 years old mature-stage stand. Stocking is 10 full and health condition is 0 – health stand. The degree of total coverage of tree lay-er is 70%. The stand group consists of *Quercus rubra* (50%), *Acer pseudoplatanus* (20%) and *Tilia cordata*. The degree of total coverage of spontaneous species is 20% in the undergrowth. The abundances are as follows: *Acer pseudoplatanus* juv. +, *Tilia cordata* juv. 2 (Fig. 3).

4. The stand group *806C4* occupies an area of 0.15 ha; it is a case of 34-year-old, high forest stand. Stocking is 10 full and health condition 0 – healthy stand. The degree of total coverage of tree layer is 80%. The stand group consists of *Tilia cordata* (60%), *Acer pseudoplatanus* (30%) and a mixture of *Betula pendula* and *Quercus rubra*. The degree of total cover-age of spontaneous species is 80% in the undergrowth. The abundances are as follows: *Carex brizoides* 4, *Rubus fruticosus* agg. 1, *Solidago canadensis* 1.

5. The stand group *806B2* occupies an area of 6.73 ha; it is a case of 17-year-old, pole stage stand. Stocking is 10 full and health condition is 0 – healthy stand. The degree of total coverage of tree layer is 80%. The stand group consists of a mixture of woody plants, namely *Larix decidua*, *Pinus sylvestris*, *Picea abies*, *Fraxinus excelsior*, *Acer pseudoplatanus*, *Betula pendula*, *Quercus petraea*.

Figure 2. Stand group 806C2b

Figure 3. Stand group 806C6

The degree of total coverage of spontaneous species is 90% in the undergrowth The abundances are as follows: *Acer pseudoplatanus* juv. 1, *Betula pendula* juv 2*., Hieracium pilosella* 2, *Leontodon autumnalis* +, *Populus* x *euroamericana* juv. 2, *Quercus rubra* juv. +, *Salix caprea* juv. 1, *Tanacetum vulgare* +, *Tilia cordata* juv. 2, and of species planted: *Medicago sativa* +, *Poa pratensis* 2, *Trifolium hybridum1*.

2.3. Methodological Procedure

The first step was in the framework of field examination the collection of data on site conditions (exposition, altitude, angle of slope, shape of spoil heap), dendrological characteristics of particular stands, abundances, degrees of coverage (phytocenological reléves) and representation of species in the herb layer. The real condition of woody plants was subsequently compared with forest economic and taxation characteristics. The data were collected altogether from 5 stand groups, in which always one partial study area was delimited for the determination of character of the herb undergrowth on the Křivý Důl spoil heap.

The second step was the evaluation of real effects, which were carried out on the basis of determination of three dominant criteria being capable to be evaluated. They characterise the condition of selected stands, their functional dynamics and effectiveness. It is a case of age, stocking and health condition of a stand.

The third step was the evaluation of herb layer from the point of view of abundances and degrees of coverage of particular species depending on a specific woody plant stand found and the determination of direct effect of planted woody species on spontaneously occurring species of herbs in the undergrowth. The sizes of partial areas of interest for the evaluation of topical herb condition were selected according to Mueller - Dombois et Ellenberg (Moravec, 1994). For stand stratification evaluation was used the scale by the method of Braun-Blanquet (Slavíková, 1986). Tthe following layers were determined: E3-tree layer, E2- shrub layer, E1 – herb layer (E0 – moss layer was not determined). To determine the abundances and degrees of coverage of particular plant species in the analyzed areas, the semi-quantitative combined scale of abundance and coverage by Braun-Blanquet (Slavíková, 1986) was used. The determination of plant species is made according to Rothmaler (1955).

3. RESULTS

In the locality there are not only plant species planted in the course of forest reclamation but also spontaneous species. Forest reclamation was performed at intervals of several years; stands established thus differ widely in age and species composition. The number of spontaneous and artificially introduced species is shown in figure 4. Particular functions of forest woody plants depending on age, stocking and health condition are stated in tables 2, 3 and 4. With reference to different ages of the stands, the results of particular social functions move in the range of 10-100% of the total real potential, which represents very variable values. The hypothesis that depending on age the values are lowest in those growth groups where the development stage of stand is the small pole stage or pole stage (Table 2) has been proved. This is evident above all in the bioproduction function – at low age, stands are not able to exhibit high values of the function. However, a direct connection between the increase in values of the bioproduction function with increasing stand age and the growing wood matter of the stands can be assumed. On the contrary, values of stocking represent homogeneous values because it is a case of fully stocked stands, which shows as a result high values of functions (Table 3). Fully stocked stands are capable to fulfil social functions much better than sparsely stocked or on the contrary, crowded stands, which would be endangered by a rather high risk of uprooting and/or a limited positive influence of any social functions. As for the health condition, the stands are healthy up to slightly damaged (0/I degree of damage) (Table 4). This degree of damage is caused especially by drought (drought spells) and browsing. However, damage is minimal and the health condition is very good. The influence of health condition on functional effects is identical in all the functions. Values of the functions are high, which represents stands fully functional.

In compliance with Vyskot's method (Vyskot, 2003), the real effects of forest functions are analytically evaluated according to particular function-reducing criteria. The criteria always act synergically and the character of synergy is determined by means of significance weights of actions of particular function-reducing criteria. With each function, for specific reducing criteria (age, stocking and health condition) a variation coefficient was calculated, as can be seen in table 5 for the hydric-water management function.

The average real effect is the weighted arithmetical average of values of real effects determined by particular function-reducing criteria. For its calculation, the determination of partial real effects according to the following relations is necessary:

Bioproduction function

$$RE_{BP} = T_1 * v_{T1} + Z_1 * v_{Z1} + ZS_1 * v_{ZS1}$$

Ecological-stabilization function

$RE_{ES} = T_2 * v_{T2} + Z_2 * v_{Z2} + ZS_2 * v_{ZS2}$

Hydric-water management function

$RE_{HV} = T_3 * v_{T3} + Z_3 * v_{Z3} + ZS_3 * v_{ZS3}$

Edaphic-soil-conservation function

$RE_{EP} = T_4 * v_{T4} + Z_4 * v_{Z4} + ZS_4 * v_{ZS4}$

Social-recreation function

$RE_{SR} = T_5 * v_{T5} + Z_5 * v_{Z5} + ZS_5 * v_{ZS5}$

Sanitary-hygienic function

$RE_{ZH} = T_6 * v_{T6} + Z_6 * v_{Z6} + ZS_6 * v_{ZS6}$

where:

T_1-T_6: value of the partial real effect of a given function depending on age;

Z_1-Z_6: value of the partial real effect of a given function depending on stocking;

ZS_1-ZS_6: value of the partial real effect of a given function depending on health condition;

v_{T1}-v_{T6} : weight of age for a given function in the stand development stage;

v_{Z1}-v_{Z6} : weight of stocking for a given function in the stand development stage;

v_{ZS1}-v_{ZS6}: weight of health condition for a given function in the stand development stage.

Calculation of the real effect of hydric-water management function of the stand group 806C4 is given below:

$RE_{HV} = T_3 * v_{T3} + Z_3 * v_{Z3} + ZS_3 * v_{ZS3}$

$RE_{HV} = 100*0.5 + 100*0.3 + 100*0.2$

$RE_{HV} = 50 + 30 + 20$

$RE_{HV} = 100\%$

The topical real effect of hydric-water management function of stand group 806C4 is extraordinary. The stand satisfies this function completely (100%), which is caused by good health condition, full stocking, and rather high stand age.

Table 2. Partial real effects depending on stand age

Stand group	Stand development stage	Functions of forest woody plants					
		BP	ES	HW	EC	SR	SH
806C2a	23	10	30	70	30	30	30
806C2b	37	30	50	100	50	50	50
806C6	98	100	100	90	100	100	100
806C4	57	50	70	100	70	70	70
806B2	28	30	50	100	50	50	50

Table 3. Partial real effects depending on stocking

Stand group	Stocking	Functions of forest woody plants					
		BP	ES	HW	EC	SR	SH
806C2a	9	100	100	100	100	70	100
806C2b	9	100	100	100	100	70	100
806C6	10	100	100	100	100	70	100
806C4	10	100	100	100	100	70	100
806B2	10	100	100	100	100	70	100

Table 4. Partial real effects depending on health condition

Stand group	Damage degree	Functions of forest woody plants					
		BP	ES	HW	EC	SR	SH
806C2a	0/1	100	100	100	100	100	100
806C2b	0	100	100	100	100	100	100
806C6	0	100	100	100	100	100	100
806C4	0	100	100	100	100	100	100
806B2	0	100	100	100	100	100	100

Table 5. Weights of reducing criteria of the hydric-water management function on the Křivý Důl spoil heap

Particular functions	Stand development stage	Weight of age	Weight of stocking	Weight of health condition
Hydric-water management	23	0.7	0.2	0.1
	37	0.7	0.2	0.1
	98	0.3	0.4	0.3
	57	0.5	0.3	0.2
	28	0.7	0.2	0.1

The stand is capable, by means of hydric effects, to form and modify maximally water balance and water regime, which is of high importance to the stand group itself and also to the surrounding ecosystems of the reclaimed spoil heap. Calculation of all real effects of social functions and average real effect of the study spoil heap is there in table 6.

Table 6. Real effects of particular functions and average real effect

Stand group	Real effects of social functions						Average real effect
	BP	ES	HV	EP	SR	ZH	
806C2a	28	58	79	51	41	44	50.2
806C2b	44	70	100	65	57	60	66.0
806C6	100	100	97	100	91	100	98.0
806C4	65	85	100	85	76	85	82.7
806B2	44	70	100	65	57	60	66.0
	Average real effect						72.6

The average real effect for the stand makes up 72.6% of real potential of forest woody plants, which represents relatively high values. Partial values move in the range of 28 – 100%. This indicates that it is a case of a very heterogeneous and dynamic whole especially from the point of view of age. The smallest real effect is characterised by young stands aged 14 years, when the average real effect of social functions is satisfied to 50.2%, and on the other hand, the highest values are associated with a stand aged 59 years, when its effectiveness is extremely high - 98%.

In the study locality, the hydric-water management social function has the highest values; on the contrary, the bioproduction function achieves the smallest effect. This smallest effect is a result of age structure of the study stands. It is possible to assume that in the future the effect of bioproduction function will increase proportionally to the growing age of the stands and tendencies in herb layer development.

For the purpose of evaluation of herb community, merely species in the undergrowth (i.e. species of the max. height of 0.10 – 1m) were classified from the point of view of abundance. Figure 4 shows that the lowest species diversity was found in the areas 3 and 4 (stand groups 806C6 and 806C4) and the highest one in the areas 1 and 5 (stand groups 806C2a and 806B2). The prevailing part of found plant species had been brought to the areas by spontaneous organisms. By research the By research the hypothesis that those stand groups the forest woody plant compositions of which contain *Quercus rubra* exhibit the smaller herb layer diversity than stand groups consisting of a mixture of autochthonous woody plants has been confirmed. Negative effects of *Quercus rubra* are caused by the insufficient and slow decomposition of leaf litter, its subsequent accumulation and thus suppression of development of herbs in the undergrowth. Research has confirmed the fact that the species composition of woody plants and their age have an unambiguous influence on the herb undergrowth. The positive and negative influences and the number of spontaneous species are given in table 7.

4. DISCUSSION

On the basis of achieved results it can be stated that it is the hydric-water management function that has the highest values; on the contrary, the bioproduction function reaches the smallest values. The low values of bioproduction function can be explained by the low age of examined stand groups. The used method for the calculation of real effects does not take the representation of forest woody plants into account; it was thus necessary to deal with the topical effect of woody plants on the herb component separately in the next step of research. The unit „average real effect" is not standardly used by Vyskot's method (Vyskot, 2003) the unit was named because of better quantification and comparison by autors.

The result of examination of plant communities was the determination of abundances of found species and the evaluation of influences of woody plant composition on undergrowth composition. The abundances of plants in the undergrowth ranged depending on the character of stand groups and the particular representation of specific woody plants.

Table 7. Real condition of woody plant layer and herb layer

Area	Influence of woody plants on herb layer	Composition of woody plants	Number of spontaneous species in herb layer
1	positive	Autochthonous species	9
2	positive	Autochthonous species	7
3	negative	Allochthonous species	2
4	negative	Allochthonous species	3
5	positive	Autochthonous species	9

Figure 4. Comparison of the total number of herb species and the number of spontaneous species in undergrowth on the Křivý Důl spoil heap
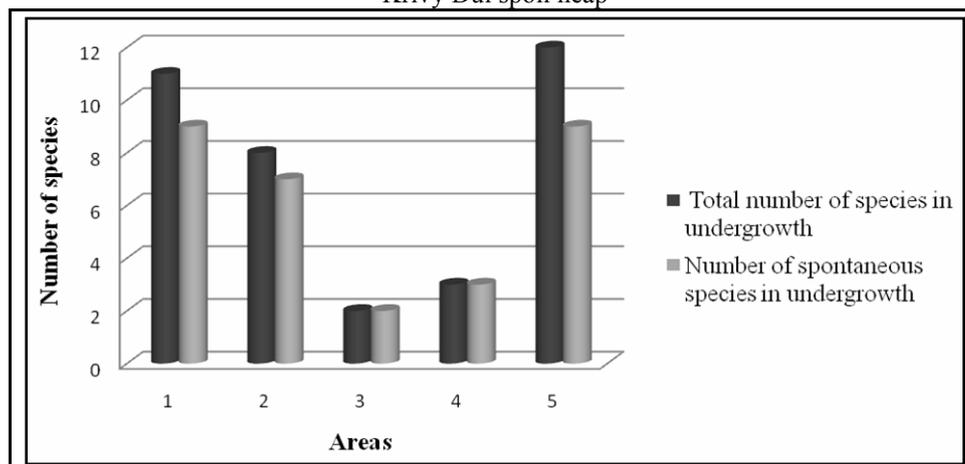
The vastest difference was observed in the case of the stand groups 806C6 and 806C4 with *Quercus rubra*. In the stand group 806C6, with reference to the negative effects of *Quercus rubra*, merely 2 spontaneous representatives of forest woody plants occurred (*Acer pseudoplatanus* juv., *Tilia cordata* juv.). In the stand group 806C4, representatives of herb undergrowth, namely 3 spontaneous species (*Carex brizoides, Rubus fruticosus, Solidago canadensis*) occurred; however, owing to the properties of strongly expansive *Carex brizoides,* in the herb undergrowth occur no other forest species than *Rubus fruticosus* and *Solidago canadensis.* The latter is an allochthonous ruderal species not desirable in the Czech landscape.

In comparison with the topical real effect of social functions, which was determined as the highest just in the case of stand group 806C6, it can be stated that any conclusions for the evaluation of influence on under-growth diversity cannot be drawn on the basis of calculations of real effect of forest woody plant functions. It is always necessary to verify the topical woody plant composition and real herb composition in the under-growth. From this research, it can be concluded that planted woody plants have positive effects on abundances of plant species in the undergrowth. Thus one can say that the correct selection of woody plant composition in the first stages of reclamation is of importance equal to that of subsequent tending of planted stand.

To the correct subsequent tending of established stands it is important to determine a value of the real effect of social functions, i.e. topical effect of forest ecosystem functions from the point of view of capabilities of the ecosystem to produce biomass, to influence runoff conditions in soil, to protect the soil surface, to eliminate erosion mechanisms, to produce oxygen, to filter solid and other substances, and also to evaluate the positive and negative influences of woody plants on herbs and organisms of a developing forest community. On the basis of our results it can be stated that the used method can be applied also to the evaluation of anthropogenic areas, but with emphasis put on the character of specific site; an integral part of the evaluation should also be herb layer evaluation. With the above-mentioned modifications, we recommend, in the framework of preparation of reclamation projects, subsequent tending plans and forest management plans, to use these characteristics as a basis and to make efforts to maintain balance between high topical effects and high species diversity in the herb undergrowth.

5. CONCLUSIONS

On the reclaimed Křivý Důl spoil heap in the Stonava cadastral area, research was carried out in the year 2010, which verified the suitability of using the method: Quantification and Evaluation of Czech Forest Functions (Vyskot, 2003) for anthropogenic substrates. In the study locality, effects of forest woody plants and their direct influence on plant communities were evaluated. Social functions were evaluated, i.e. bioproduction, ecological-stabilization, hydric-water management, edaphic-soil-conservation, social-recreation and sanitary-hygienic functions. For the purpose of function evaluation, variation coefficients for specific dominant criteria, namely age, stocking and health condition, partial real effects and average real effect of social functions of stands of forest woody plants on the spoil heap were determined.

purposes of evaluating the externalities of reclaimed and remediated areas of mining landscape and the project SP/2010100: Spoil heaps - recent habitats in the Upper Silesian mining landscape and their ecological potential.

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