Social forest functions of reclaimed spoil heaps in the Ostrava-Karvina district

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ABSTRACT: The functional efficiency of forest stands planted on the heaps originated by black coal mining was resolved in the territory of the Moravian-Silesian region. The aim was to verify the possibility of applying the method of Quantification of Social Forest Functions for the purposes of evaluation of forest stands on anthropogenic substrates and the subsequent use of the method for quantification of social forest functions in the particular reclaimed localities. Potential functional capacities were evaluated as well as the current functional effect of the following functions: bioproduction, ecological, hydrological, soil-conservation, recreational and sanitary-hygienic on five afforested heaps of the Ostrava-Karvina coal-mining district. The obtained results were presented in tabular and graphic form. Based on the results, the highest potential capacity of the ex-amined stands to fulfil the sanitary-hygienic function was proved while their capacity to fulfil the recreational function was the lowest. The highest current functional effects were found for the hydrological function and the lowest effects for the bioproduction function.

Keywords: social forest functions; real potential and real effect of wood function; heap; Ostrava-Karvina coal-mining district

The primary goal of most reclamations and revitalizations is the reincorporation of the damaged or disturbed ecosystem into the surrounding landscape. The renewal and incorporation of post-mining landscape are usually solved as technically biological reclamation, which is performed mainly in the hydric or forestry manner. The territory of Upper Silesia belongs to the regions with highly developed extractive industry. Black coal has been mined and processed there for centuries. The integral part of these activities is the emergence of waste heaps as the side effects of mining activities or externalities. Although the heaps are generally considered as undesirable and belong to unnatural biotopes, they may be understood also as the very valuable sites with great potential and it is possible to see positive externalities in them (Polanská et al. 2011). Also the importance and economic value may be assigned to them for the needs of evaluation of nature's non-market services (Seják, Dejmal 2003). Therefore it is necessary to take into account the heaps forming extensive areas in the subsequent use of landscape and to interconnect them optimally with surroundings in such a manner that the resistant, stable and fully functional territories with species diversity will be created in the shortest possible period. The renewal of heaps and other landscapes affected by mining were studied for example by Dimitrovský and Vesecký (1989), Bell (2001), Prach and Pysek (2001), Sádlo and Tichý (2002), Simon et al. (2006), Prach and Hobbs (2008), Čermák and Ondráček (2009), Sklenička and Molnárová (2010). The high value of forestry reclamations and positive effect of forest stands on the formation of new soil substrates, microclimate improvement, creation of suitable habitats for fauna, etc. are known (Stalmachová 2006; Hendrychová et al. 2008; Čermák 2008). Appropriately implemented forestry reclamation and subsequent care of the planted vegetation are the basis for the creation of a fully functional forest ecosystem. In natural ecosystems at the international level the positive effects of forest stands were described for example by Führer (2000), Golos (2010) and their non-production functions for example by Scott et al. (2006). The economic value of ecosystems was described by Seják and Dejmal (2003). Specific effects of forest stands were also examined by the team led by prof. Vyskot at Mendel University in Brno (Vyskot et al. 2003). They classified these effects as social forest functions and they defined the calculation of the real current effect and real potential of particular functions for their evaluation. The method called Quantification and Evaluation of Forest Functions was primarily developed for the naturally formed soil of forest ecosystems and its application in the Czech Republic was described for example by Vyskot et al. (2003), Kupec (2004), Fialová and Vyskot (2010). According to these authors the social functions are understood to be the following ones: bioproduction, ecological, hydrological, soil conservation, recreational and sanitary-hygienic. The main aim of the project (that is described in this paper) was to verify whether it is possible to use the method, which was primarily developed for the purposes of evaluation of forests in natural ecosystem conditions, for the evaluation of forest reclamations on the spoil heaps of mining landscape and if so, to apply it on anthropogenic heaps. For these purposes Vyskot's et al. (2003) method Quantification and Evaluation of Czech Forest Functions was chosen for the reason of its complex processing and modern ecosystem conception.

MATERIALS AND METHODS

Within the project five reclaimed heaps of different age and different species composition were examined. The soil substrate is a slag coaly material deposited on the heaps for several years. Physical properties of sandstone, siltstone, claystone and clay shales are quite favourable for the development of vegetation cover. Effects of climate impacts and geomorphology have gradually formed the raw substrate with sufficient porosity, mineral content and sufficient moisture. Some of the examined heaps were overlaid with soil of different thickness, grassed and then afforested. Some heaps were afforested without soil overlaying and that is why the coaly substrate is still visible.

The heaps are located in the territory of the Ostrava-Karvina coal-mining district. Name, cadastral district, area and coordinate system of central points are shown in Table 1. Twenty-two examined areas classified in 22 stand groups were determined and the total area was 51.36 ha. Research areas are located in three oak-beech forest vegetation zones, they are mainly the mixed stands of pioneer species with target tree species. The species composition is mainly the result of biological reclamations, but also of spontaneously occurring species. The most frequent species are as follows: Silver birch (*Betula pendula*), Sycamore maple (*Acer pseudoplatanus*), European beech (*Fagus sylvatica*), Small-leaved linden (*Tilia cordata*), Pedunculate oak (*Quercus robur*) and coniferous trees – European larch (*Larix decidua*) and Scots pine (*Pinus sylvestris*). From the aspect of forest categorization (Section 2, Act No. 289/1995 of the Statute Book) all localities in consideration of their anthropogenic origin of mining heaps belong to the categories of exceptionally unfavourable sites with the complex of forest types 3Y of the skeletal oak beechwood.

From the aspect of nature conservation, in the territorial system of ecological stability (TSES) some examined areas are classified as local ecological centres (LEC) and local ecological corridors (LECo). The health state of forest stands was determined as good and in total the stands were evaluated as sound. Forest management plans (FMP) were elaborated for the planted stands and these plans are implemented by the State Enterprise Lesy České republiky, s. p. Currently, the management plans are elaborated for the period 2008–2017 (Lesnická Projekce Frýdek–Místek 2008).

To evaluate the forest stands of reclaimed heaps the method called Quantification and Evaluation of Czech Forest Functions (Vyskot et al. 2003),

Table 1. Characteristics of examined heaps

Heap No.	Name of heap	Cadastral district	Total area of examined areas (ha)	Coordinates (JTSK)
1	Křivý důl	Stonava	13.36	4°54'927''N, 11°05'778''E
2	Lidice	Lhotka u Ostravy	11.57	4°73'621''N, 10°98'266''E
3	Jan Maria	Slezská Ostrava	6.90	4°67'949''N, 11°02'560''E
4	Mokroš	Karviná-Doly	5.34	4°55'303''N, 11°04'229''E
5	Blastro	Radvanice	15.09	4°65'013''N, 11°02'830''E

Table 2. Basic characteristic of social functions and evaluation criteria

Social function	Abb.	Description of basic functional effects
Bioproduction	BP	Creation of primary production and diversity increasing (criteria: yield class of species, species composition)
Ecological-stabilization	ES	Maintaining and support of ecological balance (criteria: species diversity and degree of stand naturalness)
Edaphic-soil conservation	EC	Maintaining of soil-forming, soil protective, anti-erosive effects (criteria: atmospheric precipitation, infiltration, soil permeability, etc.)
Hydric-water management	HW	Affecting water regime and total water balance (criteria: slope inclination factor, soil depth, rain factor, humification intensity, etc.)
Social-recreation	SR	Satisfying physical and psychological needs of people and production nature products (criteria: altitude, terrain accessibility, herb layer, etc.)
Sanitary-hygienic	SH	Filtration of solid and fluid substances, moderating of climatic extremes, air ionization and sanitary-hygienic effect to the human organism (criteria: air pollution load, temperature, icy days, etc.)

hereinafter referred to as the method, was used. The method evaluates the capacities (potentials) of forests in a complex manner and their effects to produce the so called social forest functions. The social forest functions are understood as the socially implemented ecosystem forest effects. These social functions may be simply classified into 6 basic functions, the description of which is shown in Table 2.

The **real potential** of forest functions expresses the quantified functional forest capacities in the optimally possible ecosystem conditions. It is based on the analysis of complex natural conditions and subsequent determination of ecosystem functional forest units and site type (ST) within the forest management group (FMG).

The **real (current) effect** of forest functions expresses the current functional effectiveness of forest ecosystem, thus the functional effect arising from its current state. It expresses the degree of the produced function in consideration of its potential capacities in percentage. Its calculation is based on three determination criteria characterizing the stand state: age, stocking and health state. The next step is to set the value of the partial real effect of particular social functions. In accordance with the method the stand development stage is used for expressing the age structure, and it represents the age out of the total period of the supposed stand existence or rotation period in percent. To express the spatial structure the stocking criterion is used, which represents the ratio of the real stand stock to the table stock. It is the legislatively set indicator, which practically shows the degree of utilization of the stand growth environment. Stocking is given by the 1–10 range, the value 10 represents full stocking, i.e. the area of forest stand is optimally used from the aspect of growth processes. To express the health state the methodology is based on evaluation procedures in accordance with ICP Forest methodology (MZe et VÚLHM 2004) based on the evaluation of damage to individual trees and total stand damage. The criteria are of functionally "reduction" character, since they represent the full (potential) functional forest capacities only in optimum values. Due to the limited extent of the contribution Table 3 gives only calculations for the stand group 208A3a. The particular calculations are presented by means of final results in Table 4.

Methodical procedure

The methodical procedure consisted in the following steps based on the method (Vyskot et al. 2003):

The first step was, within the field research, to collect data on the site conditions (exposition, altitude, slope gradient) and dendrological characteristics of the stands (age, height, health state and stocking). Each locality was visited four times, central points, altitude and slope gradients were surveyed by GPS Garmin eTrex Vista Cx. The altitude was calculated as the average of ten measurements. The stand age was measured at the height of 1.3 m above the ground with an increment borer, the height was measured with the Blume-Leiss altimeter and stocking was calculated as the ratio of the real stock relascoped on the test areas and the table stock, health state was determined by visual estimate. The real state of forest cover was subsequently compared with forest management and mensurational characteristics from FMP Ostrava.

The second step was the evaluation of real potentials of forest stand functions. The method was developed for naturally formed soils and the stand types (ST) were determined on the basis of natural or planted compositions of forests most frequently present in

Table 3. Real potentials on chosen heaps of the Ostrava-Karvina district

Heap No.	Stand group	FMG	ST	Area (ha)	RP_{FF}						ΣRP_{FF}	Class
					BP	*ES*	*HW*	*EC*	*SR*	*SH*		
1	806C2a	1c	Z5Z6	6.06	3	4	3	4	2	4	20	III
	806C2b	45	D9x	0.29	3	3	3	4	3	3	19	III
	806C6	45	M5P6	0.13	5	4	2	3	3	5	22	IV
	806C4	45	M5P6	0.15	5	4	2	3	3	5	22	IV
	806B2	1c	Z3P6	6.73	3	2	3	3	4	5	20	III
	total real potential				4	3	3	3	3	4	20	III
2	208A3a	1c	Z5Z9x	10.77	3	4	3	4	2	4	20	III
	208A3b	1c	Z5Z9x	0.80	3	4	3	4	2	4	20	III
	total real potential				3	4	3	4	2	4	20	III
3	502E4a	1c	D9x	0.88	2	4	3	3	2	4	18	III
	502E5	1c	D9x	3.52	2	4	3	3	2	4	18	III
	502E2	1c	C7	1.23	3	2	3	3	2	4	17	III
	502E4b	1c	M5P6	0.82	1	2	3	5	2	4	17	III
	total real potential				2	3	3	3	2	4	17	III
4	804J2	1c	D8	1.86	3	3	4	2	3	4	19	III
	804J1	1c	M5P6	3.48	2	4	3	5	2	4	20	III
	total real potential				2	4	4	4	2	4	20	III
5	506J3c	1c	D9x	0.87	2	4	3	3	2	4	18	III
	506J4a	1c	D9x	1.05	2	4	3	3	2	4	18	III
	506F3	1c	D9x	0.24	2	4	3	3	2	4	18	III
	506F4	1c	Z7Z4	0.96	3	3	3	3	2	4	18	III
	506A4	1c	M5P6	2.87	2	4	3	5	2	4	20	III
	506C1	1c	C7	0.79	3	2	3	3	2	4	17	III
	506C2	1c	Z5Z6	1.37	3	4	3	4	2	4	20	III
	506C3	1c	D9x	0.91	2	4	3	3	2	4	18	III
	506D4	1c	D9x	2.00	2	4	3	3	2	4	18	III
	total real potential				2	4	3	3	2	4	18	III

FMG – forest management group, ST – stand type, RP_{FF} – real potentials of social functions, ΣRP_{FF} – total real potential of social forest function, *BP* – bioproduction function, *ES* – ecological-stabilization function, *HW* – hydric-water management function, *EC* – edaphic-soil conservation function, *SR* – social-recreation function, *SH* – sanitary-hygienic function

the territory of the Czech Republic. The examined heaps represent a non-standard environment from the aspect of both the man-made substrate and the non-standardized composition of stands that originated during forest reclamations with regard to local particularities of the given ecosystems. For this reason it was necessary to create new stand types. Their values for particular functions were substituted according to the standardized stand types or were newly created with regard to the dendrological characteristics of stands and substrate properties. For each stand group (SG) the real potential of BP, ES, HW, EC, SR and SH function was evaluated. It resulted in the determination of the total real potential of social forest functions (RP_{FF}) for each heap.

The third step was the evaluation of real current effects, which was implemented on the basis of determination of three valuable dominant criteria characterizing the state of the chosen stands, their functional dynamics and effectiveness (age, stocking and health state, see above). For each SG the real effect of BP, ES, HW, EC, SR and SH function was evaluated. It resulted in the determination of real effects of social forest functions (RE_{FF}). Field

Table 4. Example of calculating the values for setting of RE of stand group 208 A3

	Forest functions					
	BP	*ES*	*HW*	*EC*	*SR*	*SH*
Stand development stage (SDS)	48	48	48	48	48	48
Stocking	10	10	10	10	10	10
State of health (accidence)	0	0	0	0	0	0
Weight of age ($w_{T_1} - w_{T_6}$)	0.7	0.5	0.5	0.5	0.6	0.5
Weight of stocking ($w_{S_1} - w_{S_6}$)	0.1	0.2	0.3	0.3	0.2	0.2
Weight of state of health ($w_{SH_1} - w_{SH_6}$)	0.2	0.3	0.2	0.2	0.2	0.3
Partial RE – age ($T_1 - T_6$)	50	70	100	70	70	70
Partial RE – stocking ($S_1 - S_6$)	100	100	100	100	70	100
Partial RE – state of health ($SH_1 - SH_6$)	100	100	100	100	100	100
RE_{FF} (%)	65	85	100	85	76	85

BP – bioproduction function, *ES* – ecological-stabilization function, *HW* – hydric-water management function, *EC* – edaphic-soil conservation function, *SR* – social-recreation function, *SH* – sanitary-hygienic function

characteristics of particular stand groups are shown in Table 1. The rotation period of 60 years was set according to the forest management and mensurational characteristics (Lesnická projekce Frýdek-Místek 2008). All results presented in the text, their tabular and graphic forms were processed by Microsoft Office Professional 98 software.

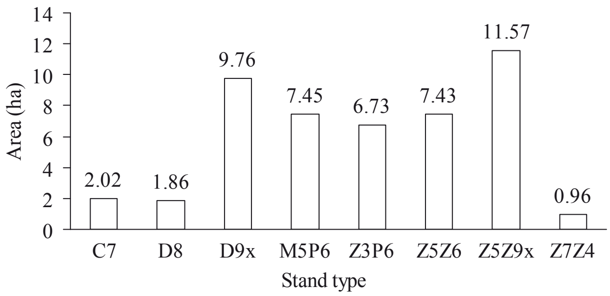

Fig. 1. Areal representation of stand types on heaps of the Ostrava-Karvina district

Proportions of tree species representation are as follows: monocultures P – pure stand type, where the tree species accounts for more than 90%, mixed stands D, M: D – dominant ST, representation 71–90%, M – majority ST, representation 51–70%, non-homogeneous stands B, A: B – basic ST, representation 31–50% and A – admixed ST, representation 11–30%. The tree species code is as follows: 3 – Scots pine (*Pinus sylvestris*), 4 – European larch (*Larix decidua*), 5 – group of broadleaved trees including: oaks (*Quercus* sp.), elms (*Ulmus* sp.) and limes (*Tilia* sp.), 6 – group of broadleaved trees including: European beech (*Fagus sylvatica*), maples (*Acer* sp.), 7 – ash trees (*Fraxinus* sp.), 8 – alders (*Alnus* sp.), 9x – group of broadleaved trees including among others for example Silver birch (*Betula pendula*), Common hornbeam (*Carpinus betulus*), etc.

RESULTS

Potential functional capacities

In total eight stand types for 22 stand groups were newly defined on the heaps for the needs of RP_{FF} evaluation. A scheme of individual stand types was created according to the method on the basis of proportions of tree species representation and tree species code. Created stand types according to the below-described scheme are shown for particular heaps in Table 5 in the 4th column under the abbreviation ST. The areal representation of the newly created stand types for all examined heaps is depicted in Fig. 1. It follows from the results that the most frequent stand type is Z5Z9x, which represents the non-homogeneous stand of broadleaved tree species with the percentage representation of 31–50% mainly of *Quercus* sp. and *Tilia* sp. and 31–50% of *Betula pendula.* Further it is possible to read the basic composition of forest from the created stand types. All the stand compositions consist of a certain percent of broadleaved tree species, in particular *Fagus sylvatica* and *Betula pendula*, while the coniferous tree species are represented by *Pinus sylvestris* and *Larix decidua.*

Values of the real potential provide information on values of produced social functions in optimally possible ecosystem conditions. According to the method the above-described stand types are used to stipulate these values. The resulting values of partial real potentials of social functions (RP_{FF}) are categorized in a 7-stage classification, where:
0 – functionally inconvenient,
1 – very low,

2 – low,
3 – average,
4 – high,
5 – very high,
6 – extraordinary.

The total real potential of stand functions ($\Sigma\ RP_{FF}$) is the sum of partial real potentials of evaluated functions, which reach the values (0–6) according to the 7-stage classification, thus the value of the total real potential reaches the values (0–36). This value is categorized in classes (I–VI), where:

Class I (0–11) – $\Sigma\ RP_{FF}$ very low,
Class II (12–16) – $\Sigma\ RP_{FF}$ low,
Class III (17–20) – $\Sigma\ RP_{FF}$ average [reduced (17), normal (18–19), increased (20)],
Class IV (21–26) – $\Sigma\ RP_{FF}$ high,
Class V (27–32) – $\Sigma\ RP_{FF}$ very high,
Class VI (33–36) – $\Sigma\ RP_{FF}$ extraordinary.

It follows from the results that in each heap the resulting values of the total $\Sigma\ RP_{FF}$ are in the range of the values 17–20, which belong to Class III and thus they represent the average stage of social functions. In heaps No. 1, 2 and 4 the functional potential is average-increased (Class III, value 20). In heap No. 3 the functional potential is average-reduced (Class III, value 17) and in heap No. 5 the functional potential is normal (Class III, value 18). The sanitary-hygienic function reached the highest values, stage 4 (high potential), while the lowest values were attributed to the recreational function with the average value 2 (low potential). The results also document that the extraordinary functional potential (stage 6) was not reached by any of the stand groups.

Current functional effectiveness

The evaluation of the real effect RE_{FF} provides primarily information on the current functional effectiveness of forest stands, and also on the current state of forest stands on the heaps. The real effect is expressed in percent in consideration of its potential capacities. In accordance with the used method the real effects of forest functions are analytically evaluated according to the particular functionally reduction criteria. The criteria always act synergically and the synergy character is determined by mean weights of the action of particular criteria

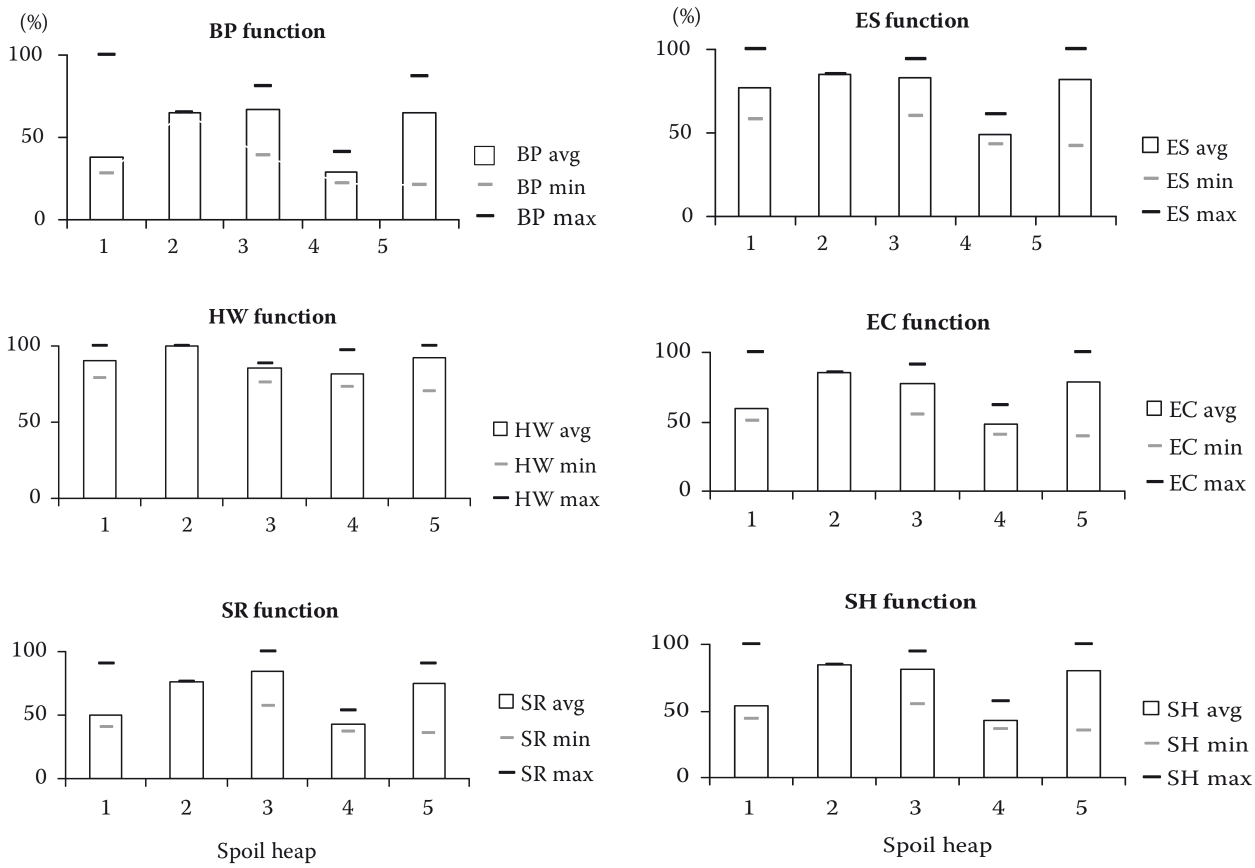

Fig. 2. Comparison of minimum, weighted average and maximum current functional effects of the social functions of particular heaps

(age, stocking and health state). The resulting real effect is the weighted arithmetic mean of the values of real effects determined by the particular functionally reduction criteria. For its calculation it is necessary to set the partial real effects shown for PG 208A3a in Table 4 and to use the formula:

Bioproduction function:

$$RE_{BP} = T_1 \times w_{T_1} + S_1 \times w_{S_1} + SH_1 \times w_{SH_1}$$

Ecological function:

$$RE_{ES} = T_2 \times w_{T_2} + S_2 \times w_{S_2} + SH_2 \times w_{SH_2}$$

Hydrological function:

$$RE_{HW} = T_3 \times w_{T_3} + S_3 \times w_{S_3} + SH_3 \times w_{SHS_3}$$

Soil conservation function:

$$RE_{EC} = T_4 \times w_{T_4} + S_4 \times w_{S_4} + SH_4 \times w_{SH_4}$$

Recreational function:

$$RE_{SR} = T_5 \times w_{T_5} + S_5 \times w_{S_5} + SH_5 \times w_{SH_5}$$

Sanitary-hygienic function:

$$RE_{SH} = T_6 \times w_{T_6} + S_6 \times w_{S_6} + SH_6 \times w_{SH_6}$$

where:

T_1–T_6 – the value of the partial real effect of the given function in dependence on age,

S_1–S_6 – the value of the partial real effect of the given function in dependence on stocking,

SH_1–SH_6 – the value of the partial real effect of the given function in dependence on the state of health,

w_{T_1}–w_{T_6} – the weight of age for the given function in stand development stage,

w_{S_1}–w_{S_6} – the weight of stocking for the given function in stand development stage,

w_{SH_1}–w_{SH_6} – the weight of the state of health for the given function in stand development stage.

Real current effects of forest social functions (RE_{FF}) on particular heaps reached the values from

Table 5. Real current functional effects in chosen heaps of the Ostrava-Karvina district

Heap No.	Stand group	Age/SDS	Stocking	State of health (Accidence)	RE_{FF} (%)					
					BP	*ES*	*HW*	*EC*	*SR*	*SH*
1	806C2a	14/23	9	0/1	28	58	79	51	41	44
	806C2b	22/37	9	0	44	70	100	65	57	60
	806C6	59/98	10	0	100	100	97	100	91	100
	806C4	34/57	10	0	65	85	100	85	76	85
	806B2	17/28	10	0	44	70	100	65	57	60
2	208A3a	29/48	10	0	65	85	100	85	76	85
	208A3b	29/48	9	0	65	85	100	85	76	85
3	502E4a	34/57	2	0	58	75	76	64	72	71
	502E5	45/75	8	0	81	94	88	91	100	94
	502E2	22/37	6	0	39	60	88	55	57	55
	502E4b	34/57	4	0	60	75	82	70	76	75
4	804J2	19/32	10	0	41	61	97	62	54	57
	804J1	12/20	8	0/1	22	43	73	41	37	36
5	506J3c	26/43	5	0/1	60	75	82	70	76	75
	506J4a	39/65	10	0/1	87	100	100	100	91	100
	506F3	26/43	5	0	60	75	82	70	76	75
	506F4	37/62	9	1	66	85	91	79	82	82
	506A4	36/60	10	0	65	85	100	85	76	85
	506C1	11/18	5	0	21	42	70	39	36	35
	506C2	17/28	6	0	46	65	88	55	57	55
	506C3	25/42	4	0	60	75	82	70	76	75
	506D4	37/62	9	0	87	100	100	100	91	100

SDS – stand development stage, RE_{FF} – Real current effects of stand social functions, *BP* – bioproduction function, *ES* – ecological-stabilization function, *HW* – hydric-water management function, *EC* – edaphic-soil conservation function, *SR* – social-recreation function, *SH* – sanitary-hygienic function

21% to 100% of the real potential, which documents the non-homogeneity and dynamics of the chosen heaps in particular from the aspect of age structure. Fig. 2 shows that the hydrological function was the best evaluated function on all heaps and, on the contrary, the bioproduction function produced the lowest effect. Fig. 2 also shows the remaining social functions which reached the mean values, as shown in Table 5.

DISCUSSION

To determine the functional effectiveness of reclaimed forest stands the method was chosen that was primarily developed for natural forest stands. Its practical use depends on deriving forestry parameters (parameters of forest management planning), which in the case of determining the real potentials are based on the setting of forest management groups and stand types and in the case of the current effects of forest functions on the criteria of age, stocking and health state. That is why the evaluation may be inaccurate in the case of man-made areas in the extreme sites for the reason of difficult deduction of the forestry parameters for anthropogenic localities.

The basic problem is the determination of stand conditions by means of forest type groups (FTG), or particularly by means of functional forest management groups. It is possible to specify the altitudinal vegetation group (AVG) on the basis of climatic parameters (proportion of downfall and temperatures, by means of bioindication or differentiation of the area into AVG) while soil conditions must be solved individually at each locality (analyses of the soil properties of reclamation made-up grounds are usually available). Another problem in using the method may be for example the fact that the stand age stage is important for defining the current effects of the forest functions and it is deduced from the current age and rotation period. In the case of reclaimed areas it is not primarily the forest-management use of the stand in most cases and the rotation period is shortened or prolonged, which may affect the final calculation, since the value of the stand age stage may be higher or lower. Therefore, when this method is used for anthropogenic localities, it would be more suitable to use the value of the average length of the stand life in hard growth conditions. A part of the evaluated heaps belongs to forest management group 45 (trophic sites of middle locations) and thus the highest real potentials are reached there from the aspect of the examined area (class 4 of the total real potential – high potential). The mentioned increase in the real potentials by including the stand in the functionally potentially superior forest management group is rather a controversial moment of evaluation by the chosen method, in particular when other stands are included in forest management group 1c (exceptionally unfavourable sites). Although other stand groups belong to forest management group 1c (exceptionally unfavourable sites), the real potential of forest stand functions was defined as average, which refers to the relatively functional ecosystem (originally anthropogenic) with the increasing ecosystem value with growing stand age. Resultant values document the positive side-effects of mining activities and thus the method may be used for the quantification of positive externalities in the territory affected by the exploitation of mineral resources.

The method of Quantification and Evaluation of Czech Forest Functions (Vyskot et al. 2003) considers the evaluation of forest ecosystems rather at the social level and the results do not describe directly the economic value of the territory of land evaluation, but it is possible to use them for a deep analysis of monitored areas from the aspect of the current and potential state of forest stand functions, creation of prognosis of utilizability of newly arisen areas or for the planning of the territorial systems of ecological stability. For the purposes of economic specification of the territory value it is possible to choose the method called Evaluation of the Czech Biotopes (Seják, Dejmal 2003), which defines in detail particular biotope types and gives them the point value, on the basis of which the price calculation is carried out. The disadvantage of using this method is that the man-made areas are evaluated by a relatively low point value in comparison with natural stands, although their potential is provably almost comparable with the average wood potential in natural stands. The method of biotope evaluation does not consider the rising point value of newly established biotopes in time and the variable characterizing the social need and requirements for the newly arisen territory is missing in calculations. Therefore it is not objective for the purposes of evaluation of man-made landscape. Another possibility is to use the method of geobiocoenological typification for the evaluation of functional effects of forests, which was used for the evaluation of the state of planting on the reclaimed areas of SD Bílina (Simon et al. 2006). The method evaluates the man-made sites in particular from the aspect of the condition and dynamics of forest stands. However, this method evaluates rather the state and development of natural environment of the reclaimed localities than their functional effectiveness in the sense of production of social functions.

In consideration of the presented results and the above-mentioned conclusions it may be stated that the used method of Quantification and Evaluation of Czech Forest Functions (Vyskot et al. 2003) was found to be a suitable instrument to evaluate the implemented reclamations on the Ostrava-Karvina heaps. After adaptation of the particular stand types it is possible to apply it also on other man-made areas, always in consideration of the current state of the species composition and stand conditions. For a more practical comparison of the localities within the evaluation of current effects of social functions we recommend to introduce the variable of average current effect for each solved locality (heap), which would better express the value of functional effectiveness on the given heaps and better compare the result of implemented reclamations.

CONCLUSIONS

The real potentials and real effects of social functions of forest cover were evaluated on five reclaimed heaps using the method (Vyskot et al. 2003).

Based on the results, the hypothesis was confirmed that in the examined conditions of the Ostrava-Karvina region the stands planted during forest reclamations composed of various tree species create the valuable communities with the average to increased potential to produce social forest functions in their optimally possible ecosystem conditions and their current effects reach even 100% in some cases. An important role is played by spontaneously occurring target tree species, which continue continuously the line, which was forwarded at reclamations by the planting of pioneer species.

The highest real potential of forest was proved for the sanitary-hygienic function. The lowest real potential was proved for the recreational function. By means of the forest capacity to produce hygienic effects the environment quality has improved in the given localities, further the positive effect on the microclimate is supposed and also the ionization and filtering capacity of forests is appreciable, where the trees bind dust particles, radioactive substances or heavy metals to their leaves. The stands reach higher values mainly by full stocking, higher density of treetops, higher ratio of broadleaved trees to coniferous ones and thick shrub level. The important feature is also the moderately warm microclimate of the Ostrava-Karvina basin. The low value of the total potential of the recreational function relates to the representation of pioneer species and their mixtures, and also to the low production of forest fruits (edible fruits), lower accessibility of the terrain, increased occurrence of allergens (e.g. the pollen of *Betula pendula*, *Solidago canadensis* and *Calamagrostis epigejos*) and increased number of terrain obstacles (fallen trees and unattended paths) or to the occurrence of forbidden waste dumps. This result confirms the hypothesis that the aim of the implemented reclamations was not to create recreational forests suitable for tourism or leisure time activities, but ecologically stable communities producing biomass and improving hydrological, pedological and climatic conditions in the territory affected by black coal mining. In future it would be possible to increase the potential of the recreational function by the appropriate care of planted stands and to make the localities accessible to visitors or to improve the environment attractiveness for example by adding of the restful and educational furniture. The lowest current effect was found out for the bioproduction function, which is probably caused by the middle age structure of the examined stands, where the stand development is in the small-pole or pole stage with the lower content of total biomass and lower production quality of heaps. An increase in the bioproduction function may be assumed in future with the growing age of the stand and its increasing wood substance.

It further follows from the results that from the aspect of successfulness and functionality of the implemented reclamation heaps No. 1, 2 and 4 were best evaluated, where the value of the total real potential was 20 and real current effects also reached high values, although for example on heap No. 2 relatively young (29 years old) stands from the biological reclamation are present. The heap reaches the good results in particular by the species composition, where the original older forests exist at its borders, which form the natural barrier from the surrounding lands. In the coppice, despite the lack of humus constituents in the soil, the seedlings in particular of *Quercus petraea*, *Carpinus betulus*, *Acer pseudoplatanus* may be seen. From the ecological aspect the part of the heap is defined as the local biological centre, which is functionally connected by the local ecological corridor with surrounding close-to-nature elements. From the aspect of recreation the heap is often used by visitors for walks and short-term recreation. Therefore we recommend effectively reclaiming the arisen heaps with regard to their future use, but in particular the long-term care of the planted stands in the same manner as at their planting. And further it is necessary to develop forest management plans for these localities or other care plans like for other ecologically valuable stands, since as Stalmachová (2006) stated, these areas may bring us in future unexpected refuges for species disappearing from the landscape.

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References

Bell L.C. (2001): Establishment of native ecosystems after mining – Australian experience across diverse biogeographic zones. Ecological Engineering, ***17***: 179–186.

Čermák P. (2008): Forest reclamation of dumpsites of coal combustion by products (CCB). Journal of Forest Science, ***55***: 137–144.

Čermák P., Ondráček V. (2009): Findings from the application of coal combustion by-products (CCB) for forest reclamation on spoil banks of the North Bohemian Brown Coal Basin. Journal of Forest Science, ***55***: 137–144.

Dimitrovský K., Vesecký J. (1989): Lesnická rekultivace antropogenních půdních substrátů. [The forest reclamation of anthropogenic soil substrates.] Prague, Agricultural Publishing House of the Czech Republic: 136.

Fialová J., Vyskot I. (2010): The changes in the values of ecological-stabilization functional potentials of forests in the model area Český les. Folia Oecologica, ***37***: 16–22.

Forestry Projection Frýdek-Místek (2008): Lesní hospodářský plán pro LHC Ostrava. [Forest Management Plan for the LHC of Ostrava.] Frýdek-Místek, Forestry Projection Frýdek-Místek.

Führer E. (2000): Forest functions, ecosystem stability and management. Forest Ecology and Management, ***132***: 29–38.

Golos P. (2010): Social importance of public forest functions – desirable for recreation model of tree stand and forest. Forest Research Papers, ***71***: 149–164.

Hendrychová M., Šálek M., Červenková A. (2008): Invertebrate communities in man-made and spontaneously developed forests on spoil heaps after coal mining. Journal of Landscape Studies, ***1***: 169–187.

Kupec P. (2004): Real potential of social forest function of selected forest stands at Židlochovice forest. Journal of Forest Science, ***50***: 190–198.

MZe et VÚLHM (2004): Monitoring stavu lesa v České republice 1984–2003. [Monitoring of forest conditions in the Czech Republic 1984–2003.] Prague, Forestry and Game Management Research Institute: 431.

Polanská J., Lacková E., Stalmachová B. (2011): Externality v krajině dlouhodobě ovlivněné těžbou nerostných surovin. [Externalities in the landscape affected by long-term mining operations.] Zpravodaj Hnědé uhlí, ***2***: 17–24.

Prach K., Pysek P. (2001): Using spontaneous succession for restoration of human-disturbed habitats: Experience from Central Europe. Ecological Engineering, ***17***: 55–62.

Prach K., Hobbs R.J. (2008): Spontaneous succession versus technical reclamation in the restoration of disturbed sites. Restoration Ecology, ***16***: 363–366.

Sádlo J., Tichý L. (2002): Sanace a rekultivace po lomové a důlní těžbě aneb tržné rány v krajině a jak je léčit. [Remediation and Reclamation of the Quarry and Mining: Gash in the Landscape and How to Treat Them.] Brno, Základní organizace Český svaz ochránců přírody, Land Trust Hády: 35.

Scott A.D., Burger J.A., Crane B. (2006): Expanding site productivity research to sustain non-timber forest functions. Forest Ecology and Management, ***227:*** 185–192.

Seják J., Dejmal I. (2003): Hodnocení a oceňování biotopů ČR. [Valuing and Pricing of Biotopes in the Czech Republic.] Praha, Český ekologický ústav: 450.

Simon J., Vacek S., Buček A. (2006): Růstová dynamika dřevin, stav lesních porostů a koncepce rekultivací v území SD Bílina. [Growth Dynamics of Tree Species, Condition of Forest Stands and the Conception of Reclamation in the Region of SD Bílina Mines.] Brno, Reklama směr plus CZ, s. r. o.: 125.

Sklenička P., Molnárová K. (2010): Visual perception of habitats adopted for post-mining landscape rehabilitation. Environmental Management, ***46:*** 424–435.

Stalmachová B. (2006): Restoration of the landscape of Ostravsko and Karvinsko post-mining landscape. Životní prostředí, ***40***: 195–199.

Vyskot I., Kapounek L., Krešl J., Kupec P., Macků J., Rožnovský J., Schneider J., Smítka D., Špaček F., Volný S. (2003): Kvantifikace a hodnocení funkcí lesů České republiky. [Quantification and Evaluation of Forest Functions of the Czech Republic.] Prague, Ministry of Environment of the Czech Republic: 218.

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