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FUNCTIONALITY ASSESSMENT OF SOIL TROPHY INDEX (ITGL) AND VASCULAR PLANT ECOLOGICAL INDICATOR FOR SITE QUALITY DIAGNOSIS IN A SAND MINE EXCAVATION

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Abstract. The aim of the study was a preliminary functionality assessment of soil quality index (ITGL) [Brożek 2001], ground water level and vascular plant ecological indicator presented as a site grid [Różański 1996] for site quality diagnosis in reclaimed areas and in areas left for succession in the Szczakowa sand mine excavation. A comparison of results of site quality assessment on the basis of soil quality and vascular plant ecological indicator shows the greatest compatibility of site quality diagnoses in non-reclaimed areas with succession communities. It confirms the current use of methods in this category based on vascular plant ecological indicator, co called phyto-sociological methods. The paper shows the need for further studies on the possibilities of using these methods for specific post-mining areas.

Key words: sand excavation, reclaim, site quality diagnosis, soil trophy index, ecological indicator

INTRODUCTION

In Poland 60% of the reclaimed post-mining sites are reforested [Krzaklewski 2001], and hence there is a need to develop reliable site quality assessment methods for post-mining areas. Detailed diagnoses which determine the process and effectiveness of biological reclaim [Krzaklewski 1977, 1979, 2005] are a crucial feature of reclamation treatment, apart from diagnoses of general reclaim conditions, discussed at length in numerous studies in this field [i.e. Greszta 1972, Skawina and Trafas 1971, Krzaklewski 1988, Krzaklewski 2005]. Mining produces open casts and waste dumps which present completely new conditions for the formation of soils and sites and for plant succession. Development of such sites and plant communities cannot be fully predicted and therefore site quality diagnosis methods used in “natural conditions” (timber forests and post-

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farming areas, etc.) are not suitable for post-mining areas as they do not reflect all the site quality conditions in such areas. In post-mining areas site quality diagnosis methods are divided into the so-called soil methods, phyto-sociological-soil methods and phyto-sociological methods [Krzaklewski 2005]. They are based on long experience and they have already been successfully used in reclamation treatment. They are not exhaustive but rather present models and the general course followed by diagnostic methods and they may be developed to suit conditions at a particular site under reforestation scheme.

Site quality diagnosis based on soil fertility and vascular plant ecological indicator

When studying sites it is crucial to express trophy in numerical form which allows to diagnose and compare it. Quantitative assessment of site trophy, often identified with "soil trophy" may be conducted directly as the notion of trophy is not only connected with abundance but also with general soil features and it is their biological resultant [Puchalski and Prusinkiewicz 1975]. Hence the selection of soil features which could serve as direct trophy indicators is disputable [Brożek 2001]. In the case of post-industrial wasteland, a scoring system to assess their functionality for reclamation was already developed in the early 1970's [Skawina 1969, Skawina and Trafas 1971]. This system comprises several features, presented as one indicator, the so-called LB quality number. Values of the quality number depend on the appropriately calculated indicators: litologic (showing granulometric composition), Ca (carbonate content), BM sorption (methylene blue) and soil density (calculated on the basis of plasticity index) [Skawina and Trafas 1971]. Krzaklewski [1977] suggested introducing a simplified soil fertility indicator ($W_ż$) showing soil fertility quantitatively as the product of soil abundance index Wz_g (calculated from an equation given by Puchalski and Prusinkiewicz [1975], on the basis of results of soil chemical analyses) and indicator of the so-called effective soil moisture (W_H – as amount of water accessible to plants). On such basis and keeping in mind the distribution of dominant vascular plant species from spontaneous succession, he prepared a soil fertility grid and potential site units. The method was applied on southern-eastern slopes of outdoor waste dumps at the "Adamów" mine (in the Turek--Konin lignite mining district).

In case of forestry Brożek [2001] suggested forest soil trophy index (ITGL), taking into account the results of assays of physical and chemical soil properties which constitute their trophy (dust fraction and floatable part content, pH, substitute alkaline cation content and C/N ratio for all horizons). Further studies indicated that four properties clearly differentiated B (coniferous forest), BM (coniferous mixed forest), LM (deciduous mixed forest) and L (deciduous forest) groups of sites in the classification of lowland and upland forest sites and they were: fraction content in diameter 0.1-0.02 mm and < 0.02 mm, pH in H_2O and readily mineralising Nitrogen content [Brożek et al. 2006].

It is impossible to list here all the studies connected with the use of plants and vegetation to assess site quality. Relations between soil and natural communities have been described and documented [including by Braun-Blanquet 1951, Adamczyk 1965, Zarzycki 1966]. Vegetation cover is a synthetic indicator of all site quality factors, and according to some researchers [Puchalski and Prusinkiewicz 1975] the number of vascular plant species growing on given soil may indicate its trophy. On the other hand though, when determining site trophy on the basis of the number of species, it was found that it does not only depend on trophy [Paczoski 1925 after Puchalski and Prusinkiewicz

1975]. It is known that floristic abundance (the number of species) in a given area depends on many factors including diversity of environmental conditions, local flora abundance and human impact [Falińska 1997]. Ellenberg [1950] provided theoretical and methodological foundations for site quality assessment using vascular plant species indicators (average ecological indicators). In Poland Zarzycki [1984] compiled the first list of ecological indicators for species fully adapted to Polish conditions. It generally follows the idea of grouping plants according to their relations with site quality factors. By contrast, a group of methods for the determination of site quality factor combinations using the so-called ecological groups of species originates from J. Iversen's studies (1936) [after Wójcik 1983] who described the relationship between the floristic composition of plant communities (of the seaside in Denmark), and the zonal humidity and soil salinity fluctuations. The forest site grid prepared by Różański [1996] and based on Zarzycki's [1984] ecological indicators is a practical example of using phyto-sociological studies in forest site quality diagnoses. Individual site units in this grid are assigned moisture index values (W) and soil trophy values (T) calculated for particular phyto-sociological surveys while keeping in mind the conversion of species abundance in Braun-Blanquet's scale into numerical values [Różański 1996, 2000].

In the light of these observations, the aim of this study was to compare site quality diagnosis methods based on soil features expressed as soil trophy index ITGL [Brożek 2001] and those based on ecological indicators of vascular plants as forest site grid [Różański 1996]. This comparison was based on results obtained during studies on reclaimed areas under reforestation schemes and on areas left for succession at "Szczakowa" sand mine excavation. The comparison is also based on a search for potential relations between soil substratum and vegetation in case of a particular post-mining site.

MATERIALS AND METHODS

Initial soils and plant communities in "Szczakowa" sand mine excavation, the largest open-cast sand mine in Poland were the object of the study. This sand mine excavation is located in the Great Starczynowska Desert. The "Szczakowa" sand mine deposits are made up of quaternary fluvioglacial sands [Lewandowski and Zieliński 1990].

In the 1970's and the 1980's parts of the open-cast were abandoned, to be mined again in 10 to 20 years' time. However, falling demand for sand filling meant that they were not mined later. Vegetation appeared there spontaneously and initial soil formation started under communities from succession as a natural process. Simultaneously, most of the open cast was reclaimed. This allowed to locate research areas and to compare site quality diagnoses in these two land types i.e. in reclaimed areas and in areas left for succession.

Initial soils, plants entering succession and ground water were studied. 20 research plots were set up for this purpose (10 in reclaimed areas and 10 in areas left for succession). In July 2003 phyto-sociological surveys were made in summer aspect using Braun-Blanquet's method (and inventory was made only of vegetation from succession). Topsoil was stripped, soil profile morphology was described and samples of identified horizons were taken for laboratory analysis as part of soil studies. Piezometers were installed on study sites and ground water level was checked once a month during hydrological year from November 2001 to October 2002.

Soil samples were prepared for analysis according to standard procedures and the following parameters were measured [Ostrowska et al. 1991]: particle size distribution [granulometric fractions and groups were distinguished according to PN-R-04033); pH in H_2O and 1 M KCl; carbon content [C_{org}] and total nitrogen content [N_{og}]; hydrolytic acidity [Y] and the sum of substitute alkaline cations using Kappen's methods, from which the sorption capacity was calculated [T] and the alkaline cation saturation level [V%].

On the basis of the obtained results soil trophy index was calculated (ITGL) [Brożek 2001] and later compared with the results of forest site quality assessments conducted according to Różański's method [1996, 2000] and based on ecological trophism and vascular plant moisture indicators [Zarzycki 1984]. A slight modification of this analysis was that in the soil trophy index (ITGL) the dust and clay fraction indicator was based on the division of dust into fractions of 0.05 to 0.002 and clay < 0.002 according to Polish standard PN-R-04033 and not according to PTG division [Systematyka gleb Polski 1989] used by Brożek [2001]. Depth of soil profile to 100 cm (initial soils forming on stripped floor of sand mine excavation) was considered in the calculations. Both diagnosis methods were implemented for the first time on post-mining sites.

RESULTS AND DISCUSSION

Soil description and site quality diagnoses based on soil trophy in Soil Trophy Index ITGL

The investigated soils from areas with succession [according to Forest Soil Classification 2000] were considered to belong to two sub-types i.e.: initial arenosols (with Ain-AC-C profile) and industrial-soils and urban-soils with undeveloped profile (Ainan-AC-C). In case of reclaimed areas they were considered to be one soil sub-type of industrial-soils and urban-soils with undeveloped profile [Pietrzykowski 2004]. A majority of non-reclaimed areas were considered to belong to a category in which ground water was accessible for root systems throughout the vegetation period (ground water levels from 1 to 2 m) [Greszta and Skawina 1965, Krzaklewski et al. 1999]. In case of reclaimed areas this category only included 3 areas, whereas in case of other reclaimed areas in the study period ground water occurred at a depth of more than 2.5 m (Table 1). In the study period fluctuations of ground water levels were reported, in some cases even up to 50 cm.

Values of Soil Trophy Index (ITGL) for all the investigated profiles in case of non-reclaimed areas varied from 13.2 do 18.7 (average 15.4), and in case of reclaimed areas they ranged from 10.7 to 20.3 (average 15.1), therefore the average values were similar. Higher ITGL Soil Trophy Index values were characteristic of areas where soil profiles included sandy clay and mellow clay insertions. According to Soil Trophy Index values ITGL the investigated soils were mostly (13 profiles) considered oligotraphentic soils from trophic group of BM (mixed coniferous forests sites), and some mesotraphentic from trophic group of mixed deciduous forests (LM) (7 profiles) (Table 1).

Description of vegetation and site quality diagnoses according to vascular plant ecological indicator

The results of phyto-sociological studies showed that vegetation from succession included groups of species which differed substantially in the sociological aspect. A total of 115 plant species were described in the research plots including a total of 106 vascular plant species, and about a dozen forest community species among them (13 in reclaimed areas and 15 in non-reclaimed areas). Ecological indicators calculated for species from succession representing particular areas were found to be from 2.4 to 3.5 in case of the soil moisture indicator (W), and soil trophy indicator (T) was from 2.4 to 3.4 (Table 1). According to a forest site grid prepared by Różański [1996] it was found that oligotraphentic sites prevailed in the investigated areas. These were sites corresponding to coniferous forests (B), where trophic indicators (T) were 2.4 (2 areas) and mixed coniferous forests (BM), where T was from 2.7 to 2.8 (11 areas), and in case of 5 transition areas i.e. coniferous forests / mixed coniferous forests (B/BM), where T was 2.5. In two reclaimed areas T was from 3.0 to 3.4 which indicated more fertile sites i.e. oligotraphentic mixed coniferous forests bordering on mesotraphentic mixed forests (BM/LM), or even mesotraphentic mixed forests (LM) (Table 1). Hence, units distinguished according to ecological indicators were slightly more fertile than those distinguished according to soil quality index ITGL.

As far as moisture was concerned, vascular plants from succession showed that fresh sites prevailed (10 areas), where W was from 2.7 to 3.1. Dry sites bordering fresh were reported in 3 areas (W was 2.6), and dry sites in 4 areas (mostly in reclaimed areas, with W from 2.3 to 2.5). Moist sites were found in 3 areas and only in areas left for succession (W from 3.4 to 3.5).

Comparison of results of site quality diagnoses according to soil trophy index ITGL and vascular plant ecological indicators taking ground water level into account

In case of areas left for succession there was more compatibility between diagnoses of site moisture according to moisture indicator of vascular plants (W) and ground water level. (Table 1). For instance, moisture sites diagnosed according to ecological indicators occurred with ground water level above 1 m (from 82 to 96 cm). Sometimes however, ecological indicators allowed to consider a site fresh, but ground water level was below 2.5 m. In case of reclaimed areas site moisture determined on the basis of ecological indicators did not show such a marked relationship with ground water level as in the case of areas with succession communities.

Comparison of site quality diagnoses according to forest soil trophy index (ITGL) and site grid prepared using vascular plant ecological indicators showed that in one half of the studied areas they were compatible or nearly compatible (i.e. 5 were fully compatible and 5 were similar out of 20 studied areas) (Table 1).

When considering compatibility of assessments in case of site trophic conditions according to these two criteria further subdivided into reclaimed areas and those left for succession, it becomes clearly visible that it was higher in areas left for succession (7 cases compatible or similar out of 10 areas located in sites with succession). With reclaimed areas incompatibility occurred in majority of the sites, i.e. 7 out of 10 studied sites. This means that with areas receiving some reclamation treatment, compatibility of

Table 1. The comparison of site quality diagnosis based on ITGL (soil trophy index) ground water level and ecological indicator values of vascular plants in reclaimed areas and in areas left for succession as exemplified by experimental plots in the "Szczakowa" sand mine excavation
Tabela 1. Porównanie diagnozy siedlisk na podstawie ITGL, głębokości lustra wód gruntowych i wskaźników ekologicznych roślin naczyniowych, na przykładzie powierzchni badawczych na terenach rekultywowanych i pozostawionych sukcesji na wyrobisku kopalni piasku „Szczakowa"

Experimental plots Powierzchnia badawcza	Values of ITGL Wartości ITGL	Diagnosis of site trophy groups based on ITGL Diagnoza grupy troficznej siedlisk na podstawie ITGL	Mean ground water level Średnia głębokość wód gruntowych (III-V 2002) cm	Moisture site groups based on ground water level (according to SPHL 2002) Grupa wilgotnościowa siedlisk na podstawie głębokości wód gruntowych (wg SPHL 2002)	Ecological indicators of vascular plants according to Zarzycki [1984, 2002] Wartości wskaźników ekologicznych wg Zarzyckiego [1984, 2002]		Site groups based on Zarzycki [1984] indicator of vascular plants presented as a forest site grid [Różański 1996] Grupy siedlisk na podstawie wskaźników ekologicznych wg Zarzyckiego [1984] wg siatki typologicznej lasów Różańskiego [1996]		Compatibility of site group diagnosis with used methods Zgodność diagnozy grup siedlisk według zastosowanych metod	
					T trophy trofizm	W moisture wilgotność	site trophy groups based on T grupa trof. siedlisk na podst. T	site moisture groups based on W grupa wilgotn. na podst. W	trophy based on ITGL and T trofizm na podst. ITGL i T	moisture based on ground water level and W wilgotność na podst. głęb. wód grunt. i W
1	2	3	4	5	6	7	8	9	10	11
Areas left for succession – Powierzchnie pozostawione sukcesji										
18 S	16.0	BM	<250	s	2.5	2.3	B/BM	d	s	c
7 S	15.4	BM	181	św	2.7	2.7	BM	f	c	c
8 S	14.4	BM	155	w	2.5	2.6	B/BM	d/f	s	n
9 S	14.1	BM	<250	s	2.6	2.8	BM	f	c	n
1 S	13.3	BM	96	w	2.6	3.4	BM	m	c	c
2 S	13.2	BM	95	w	2.5	3.5	B/BM	m	s	c
3 S	17.4	LM	82	w	2.7	3.5	BM	m	n	c
4 S	18.7	LM	<250	s	2.7	2.8	BM	f	n	n
5 S	11.9	BM	162	w	2.9	3.1	BM	f	c	n
6 S	18.0	LM	136	w	2.7	2.9	BM	f	n	n

Table 1 – cont.

1	2	3	4	5	6	7	8	9	10	11
Reclaimed areas – Powierzchnie rekultywowane										
19 R	18.4	LM	80	w	2.8	2.6	BM	f	n	n
16 R	20.3	LM	<250	s	2.5	2.4	B/BM	d	n	c
17 R	10.7	BM	<250	s	2.4	2.6	B	d/f	n	s
20 R	14.8	BM	<250	s	2.4	2.6	B	d/f	n	s
12 R	13.1	BM	<250	s	2.5	2.5	B/BM	d	s	c
13 R	18.2	LM	<250	s	2.7	2.3	BM	d	n	c
14 R	16.4	LM	<250	s	2.8	2.7	BM	f	n	n
10 R	13.7	BM	105	w	3.0	2.8	BM/LM	f	s	n
11 R	13.7	BM	131	w	3.4	2.9	LM	f	n	n
15 R	11.7	BM	96	w	2.8	2.7	BM	f	c	n

ITGL – soil trophy index.

B – coniferous forest, BM – coniferous mixed forest, LM – deciduous mixed forest, d – dry, f – fresh, m – moisture, c – compatible diagnosis, s – similar, n – incompatible.

ITGL – indeks trofizmu gleb leśnych.

B – bory, BM – bory mieszane, LM – lasy mieszane, d – suchy, f – świeży, m – wilgotny, c – diagnoza zgodna, s – zbliżona, n – niezgodna.

diagnoses obtained on the basis of ecological indicators of vascular plants from succession with soil trophy determined using soil quality index ITGL was clearly lower. It generally indicated less fertile site units that on the basis of soil trophy index ITGL. Similarly with areas left for succession in cases where diagnoses were incompatible it was possible to consider sites as belonging to higher trophic groups according to soil substratum features than according to vascular plant ecological indicators. This may be significant for scheduling species compositions in reclamation treatments particularly when introducing final species. On this basis it may be postulated that in reclaimed areas under discussion site quality diagnoses should be based primarily on soil properties and that indicative role of plants should be considered auxiliary. By contrast, in case of areas left for succession, methods using plants as indicators should be appropriate when conducting site unit quality diagnoses.

CONCLUSIONS

1. Comparison of site quality assessment according to soil properties as described in soil trophy index (ITGL) and ecological indicators shows that the biggest compatibility is obtained in case of non-reclaimed areas. These results proved the functionality of methods based on indicative value of plants from spontaneous succession for the purpose of site quality diagnosis of post-mining sites. In case of the studied sand excavation although the fraction of forest species in the communities was still relatively low, the application of site grid suggested by Różański [1996] gave positive results and significant compatibility with diagnoses based on soil properties as included in Soil Trophy Index ITGL.

2. The obtained results show that site quality diagnosis from "Forest Management Plant" prepared for the sand excavation which assumes the Bśw unit for the whole area, largely differs from the results presented in this study.

3. Generally, in the light of the obtained results the functionality of Brożek's [2001] Soil Trophy Index (ITGL) and Różański's [1996] vascular plant ecological indicators in forest site grid was proved for site quality diagnosis of the investigated sand excavation. Functionality assessment of these two diagnostic methods for post-mining areas under reforestation schemes should be the subject of further studies. It should also be adjusted to individual post-mining areas.

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OCENA PRZYDATNOŚCI INDEKSU TROFIZMU GLEB (ITGL) ORAZ EKOLOGICZNYCH LICZB WSKAŹNIKOWYCH W DIAGNOZIE SIEDLISK NA WYROBISKU PO KOPALNI PIASKU PODSADZKOWEGO

Streszczenie. Celem pracy była wstępna ocena przydatności dwóch metod diagnozowania siedliska na rekultywowanych dla leśnictwa oraz pozostawionych procesowi sukcesji terenach wyrobiska kopalni piasku podsadzkowego „Szczakowa”, na podstawie cech glebowych ujętych w indeks trofizmu gleb ITGL, z uwzględnieniem głębokości występowania lustra wód gruntowych oraz wskaźników ekologicznych roślin naczyniowych, ujętych w siatkę siedlisk leśnych. Stwierdzono, że największą zgodność wyników otrzymano w badaniach powierzchni terenów nierekultywowanych ze zbiorowiskami z sukcesji spontanicznej. Stosowane dotychczas w tej kategorii terenów metody oparte na wartości wskaźnikowej roślin, tzw. metody fitosocjologiczne, okazały się słuszne.

Słowa kluczowe: wyrobisko popiaskowe, rekultywacja, diagnoza siedliskowa, indeks trofizmu gleb, ekologiczne liczby wskaźnikowe

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