IOŚ-PIB OCHRONA ŚRODOWISKA I ZASOBÓW NATURALNYCH
ENVIRONMENTAL PROTECTION AND NATURAL RESOURCES 2014
DE GRUYTER OPEN
VOL. 25 NO 3(61): 9–13
DOI 10.2478/oszn-2014-0012

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Evaluation of influence of the Mine-Energetic Plant "Janina" in Libiąż activity on soil productivity index

Ocena wpływu działalności eksploatacyjnej Zakładu Górniczo-Energetycznego „Janina" w Libiążu na indeks produktywności gleb

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Keywords: hard coal mining, soil degradation, productivity index, soil reclamation need evaluation
Słowa kluczowe: górnictwo węgla kamiennego, degradacja gleb, indeks produktywności, ocena potrzeb rekultywacji

Abstract
The aim of the work was the determination of productivity index (PI) of soil in the area of exploitation activity of the Mine-Energetic Plant "Janina" in Libiąż using the Zhenqi Hu et al. [1992] method. Studies were carried out in mining subsidence basin in the Żarki village near Libiąż where two soil pits were realised and material for laboratory investigations was taken. Soil properties determined in laboratory used the Zhenqi Hu et al. [1992] algorithm method and values of PI were calculated. Mean value of PI amounted 0.67, which classifies the investigated area as one of the conditions for poor agricultural production. Changes of primary soil properties caused by mining activity of the Mine-Energetic Plant "Janina" had the highest influence on the calculated PIs. The determined PIs show the necessity of undertaking reclamation works for restoring primary properties of soil.

Streszczenie
Celem pracy było wyznaczenie indeksów produktywności gleb (PI) na obszarze działalności eksploatacyjnej Zakładu Górniczo-Energetycznego „Janina" w Libiążu z wykorzystaniem metody Zhengi Hu et al [1992]. Badania prowadzono na terenie niecki osiadań we wsi Żarki koło Libiąża, gdzie wykonano dwie odkrywki glebowe i pobrano materiał do badań laboratoryjnych. Wyznaczone w laboratorium właściwości gleb wprowadzono do algorytmu metody Zhengi Hu et al. [1992] i obliczono indeksy produktywności. Wartość średnia wyznaczonych PI wynosiła 0,67, co klasyfikuje badany obszar jako teren o słabych warunkach do produkcji rolniczej. Największy wpływ na poziom wyznaczonych indeksów PI wywiera zmiana pierwotnych właściwości gleb na skutek procesów degradacji spowodowanej działalnością wydobywczą ZGE „Janina". Wyznaczone indeksy wskazują także na konieczność podjęcia prac rekultywacyjnych w celu przywrócenia badanym glebom ich pierwotnych właściwości.

1. INTRODUCTION

Processes taking place on orogens and surface, caused by underground exploitation of coal mine, lead directly to settling and deformation of ground, obstructing cultivation or excluding soil from natural use [Dulewski, Wtorek 2000]. This phenomenon causes additionally hydrological degradation of soil, drying or water-logging [Chwastek et al. 1990]. High degree of soil moistness deteriorates plant vegetation conditions and intensifies expansion of hydrophilous plant. Rise of groundwater in arable lands may cause increase of agricultural production, but more often degradation of soil and decrease of soil quality class and productivity occur, necessitating change of arable land into meadow and pasture [Klatka et al. 2004]. According to Kaszowska [2007] who discuss the influence of mine activity on natural land elements, one cannot ignore the disadvantageous changes of soil structure caused by land drying or wetting. They may decrease soil productivity to a high degree.

The complexity of the problem of evaluation of environment conditions for land reclamation needs is testified by the quantity and variety of methods used [Boroń, Klatka 1997]. The productivity index (PI) method proposed by Zhenqi Hu et al. [1992], little known in Poland, enables the exact determination of current quality of soil degraded by coal mine exploitation from the point of view of future land reclamation needs. This method however does not include fertilisation and abundance of soil. That is why the obtained results cannot be compared with soil quality classes, but present land reclamation needs [Klatka 2002]. Taking into account validation methods classification, the presented method belongs to one-factor analysis [Koreleski 1979].

The aim of this work was to determine the PI of soils subjected to degradation in an area of chosen subsidence trough that came into being as a result of the Mine-Energetic Plant "Janina" in Libiąż activity using the Zhenqi Hu et al. method [1992].

2. MATERIAL AND METHODS

Negative influence of the Mine-Energetic Plant "Janina" in Libiąż on environment is connected mainly with ground surface deformations and changes of soil and groundwater conditions. The largest region of settlement covers the north-eastern part of mining area. Here several subsidence troughs of 3–5 m depth were raised [Klatka et al. 2004]. Field studies were carried out on one of subsidence troughs of 9.77 ha area in the Żarki village near Libiąż. Geomechanical deformations of land surface formed here flood land in an area of 2 ha and mean depth of 3 m. Soils in vicinity undergo high hydrological degradation. For characterisation of soil properties and evaluation of degradation degree, two soil pits with description of morphological properties were carried out and samples taken. Detailed location of soil pit is presented in Fig. 1.

In laboratory, determination of examined soils properties was carried out using standard soil science methods. Texture was determined by means of the aerometer Casagrande's in Prószyński modification method. Granular groups and subgroups were determined based on the PN-R-04033 standard [PKN 1998]. Solid phase density was determined using the pycnometer method in distilled water. Examination of bulk density in natural state and total porosity was determined using rings of 100 cm^3 volume. Reaction was analysed by means of potentiometer method in H_2O and 1 m KCL, while electric conductivity was determined in soil suspensions in soil:water ratio of 1:2.5 using conductometer. Content of organic matter was determined using the Tiurin's method. The determined texture and chosen physico-chemical properties of investigated soils are presented in Table 1, while physical properties are presented in Table 2.

The soil PI was calculated based on the method proposed by Zhengi Hu et al. [1992]. This method was elaborated for evaluation of soil quality, mainly on areas degraded by hard coal mining. It is based on the equation of dependence of the PI and physical, chemical and water properties of soil. In this method, the following properties of soil are taken into consideration: texture, bulk density [$Mg \cdot m^{-3}$], cohesion [MPa], saturated conductivity [$cm \cdot h^{-1}$], easily available water content [%], infiltration [$cm \cdot h^{-1}$], porosity [%], reaction, organic matter content [%], electric conductivity [$mS \cdot cm^{1}$], root zone depth [cm], aggregate stability [%], sodium content and stone content [%]. In calculations of the PI, all the above-mentioned or chosen parameters can be regarded, based on the following equation:

$$PI = \sum_{i=1}^{n} (w_i \times r_i)$$

where:
PI – soil productivity index,
n – following soil properties number,
w_i – weight coefficient for given soil parameter, but:

$$\sum_{i=1}^{n} w_i = 1$$

r_i – coefficient (0–1) for i-th soil parameter in a case of homogenous soil profile.

If soil profile consists of many layers, r_i coefficient is calculated according to the equation:

$$r_i = \sum_{j=1}^{L_i} (RL_{ij} \times WL_j)$$

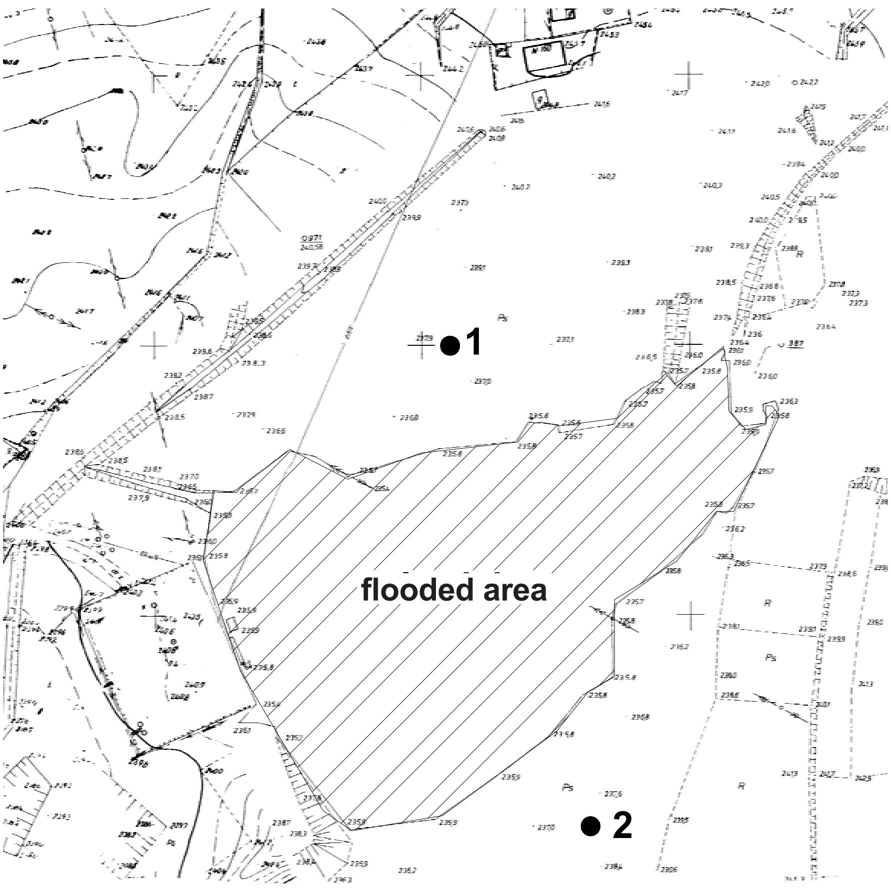

Fig. 1. Location of soil pit in the investigated area soil pit nos I and II

RL_{ij} – sufficiency coefficient (0–1) of i-th soil parameter in j-th layer,
WL_j – weight coefficient for j-th layer, and:

$$\sum_{j=1}^{m} WL_j = 1$$

L_j – number of following layer of soil profile,
m – number of layer.

For calculations of the PI, the original computer program was used. Input data composed properties of soil from material taken in openings and weight coefficients accepted at the same level for all of the regarded properties. Results of calculations are presented in Table 2.

3. RESULTS OF INVESTIGATIONS

Based on field and laboratory investigations, one can state that on the examined areas mineral-muck soils prevail. According to land classification map, soils were classified as IVb and V soil quality classes. In the latest guidelines, Systematics of Polish Soils [PTG 2011], soils belonging to type 7.6 are mucky soils and subtype 7.6.1 typical mucky soils. Regarding texture, only sand (S) and loamy sand (LS) occur. The material is of high permeability and low water retention [Boroń, Klatka 1997]. Solid phase density of investigated soils amounted on an average to 2.61 $g \cdot cm^{-3}$ and was similar to values occurring most often in Polish soils [Zawadzki 1999]. The determined values of bulk density amounted on an average to 1.51 $g \cdot cm^{-3}$ and were similar to values occurring most often in Polish soils [Zawadzki 1999] also. The lowest values of bulk density were observed in humus horizons of soils. In bottom layers, values increased as condensation grew. Total porosity of examined soils amounted on an average to 42.23% for the soil pit I and 43.37% for pit II. The value of about 50% is taken as the most optimal one [Zawadzki 1999]. The determined values were lower than the optimal ones. Reaction measured in H_2O and in 1 m KCl was shaped within the range occurring in soils of similar subtype. Specific electric conductivity does not exceed limitary value for non-irrigated soils [Boroń et al. 2001]. The high content of organic matter in top layer of investigated soils is worthy of notice. That is why in a case of future reclamation activity, possibility of removal and repeated use of humus horizon should be taken into consideration.

According to Zhenqi Hu et al. [1992], the maximum value of the PI can reach 1.0. Values of PI ≤ 0.5 testify high soil degradation and show the necessity of undertaking urgent reclamation treatments. In turn, values of PI > 0.8 point to inconsiderable intensification of degradation processes. The determined mean values of PI of investigated soils amount to 0.68 for soil pit no. I and 0.65 for soil pit no. II. The obtained values of the PI characterise the investigated area as having poor conditions for agricultural productivity and that it had a high level of degradation process. The main cause of low values of the PI is unfavourable change of soil properties as a result of rise of groundwater level, change of base types and subtypes of soil water management as well as hydrological degradation. Among others elements in determining the value of the PI, soil material (sand) occurring in bottom layers of examined profiles should be mentioned. This material is characterised by defective water management. Similar results were obtained for areas undergoing influence of the Hard Coal Mine "Szczygłowice" in Knurów [Klatka 2002]. At present, in the examined area, a common reality is stopping of cultivation and in many cases the ground is lying fallow. Meadows and pastures belonging to individual farmers are characterised by low level of crop production technique, which undoubtedly influences the quality and agricultural usefulness. In future, in case of lack of reclamation

Table 1. Texture and select physico-chemical properties of investigated soils

Soil pit no.	Layer [cm]	Soil particle content			Soil valuation item	Reaction in KCl	Reaction in H_2O	Electric conductivity [$mS \cdot cm^{-1}$]
		2–0.05 mm	0.05–0.002 mm	< 0.002 mm				
I	0–30	94	4	2	S*	6.62	7.12	0.13
	30–59	85	8	7	LS**	6.83	6.42	0.14
	59–102	99	4	0	S	6.86	6.43	0.06
II	0–40	89	6	5	S	6.15	6.24	0.07
	40–75	99	1	0	S	6.29	6.50	0.08
	75–110	98	2	0	S	6.33	6.75	0.11
	110–150	99	1	0	S	5.62	6.18	0.06

*S – Sand (Piasek), **LS – Loamy Sand (Piasek gliniasty)

Table 2. Physical properties and determined values of productivity index of investigated soils

Soil pit no.	Layer [cm]	Specific gravity [$Mg \cdot m^{-3}$]	Bulk density [$Mg \cdot m^{-3}$]	Total porosity [%]	Organic matter content [%]	Productivity index	Average productivity index
I	0–30	2.59	1.42	45.17	97.6	0.74	0.68
	30–59	2.60	1.54	40.77	-	0.68	
	59–102	2.65	1.57	40.75	-	0.62	
II	0–40	2.60	1.41	45.77	90.9	0.72	0.65
	40–75	2.65	1.52	40.75	-	0.66	
	75–110	2.63	1.57	40.30	-	0.62	
	110–150	2.55	1.57	46.67	-	0.61	

treatments, the area of wastelands will increase and values of the PI of investigated soils will also gradually decrease.

Among other elements influencing the PI indicators, soil material (sands) occurring in bottom layers of examined soil profiles should be mentioned. This material is characterised by incorrect water management. On mining areas, the ability of soil for rainfall water retention and its permeability decides to a high degree the extent and intensity of hydrological degradation [Klatka et al. 2010]. Soil productivity on areas of coal mine activity is usually measured in quantity categories (for example yield) [Reith, Charles 1982]. The criterion considered however does not always show actual soil productivity. As indicators of soil quality on mining areas, many morphological, physical, chemical, physical-chemical and biological properties are connected with prevailing conditions. The determined soil properties also give information of reclamation need [Potter et al.]. Depending upon the degree and scope of degradation for PI evaluation, various soil properties can be used. The determined soil PIs of reclaimed soil in the area of the Horse Creek Coal Mine contained in source elements apart from soil properties chosen, root layer height, aggregates stability and stones content [Chong et al. 1990]. The obtained results showed that essential elements influencing final evaluation result are proper recognition form of soil degradation and proper choice of properties for the PI algorithm. One of the most essential properties is texture [Chong et al. 1990]. Soil PIs determined by Klatka [2002] in the area of the Cola Mine "Szczygłowice" were similar to the ones obtained for the area in the Żarki village. They were also correlated with soil properties, including texture. The method proposed by Zhenqi Hu et al. [1992] allows a composite unity to evaluate soil PI in an area of coal mining activity. Additionally, it gives a possibility to eliminate elements influencing quantity evaluation of soil productivity (yield). For these elements, atmospheric conditions can be included [Zhenqi Hu et al. 1992]. At present, in the investigated area of the Żarki village near Libiąż, the common phenomenon is stoppage of cultivation and in many cases ground lying fallow. Meadows and pastures are characterised by low agrotechnics level, which undoubtedly influences their quantity and agricultural usefulness. The PIs of the examined soils show an urgent need to undertake reclamation works. Otherwise, an area of wastelands will decrease as a result of hydrological degradation.

4. CONCLUSIONS

1. The investigated area undergoes intensive influence of hard coal mining exploitation. Increasing geomechanical transformations of surface (settlements) led to creation of interior basin, flood land in central part of the area and global rise of groundwater. These factors caused hydrological degradation of soils.
2. Physical properties of investigated soils are similar to the ones occurring for Polish soils. The determined values of reaction and specific electric conductivity do not show chemical degradation of soils. The least advantageous property of examined soils is texture in a shape of sand. Such material on mining activity areas is characterised by high susceptibility on hydrological degradation.
3. Analysis of field and laboratory investigations shows that on the examined area soil material characterised by high susceptibility to hydrological degradation processes prevails. Physicochemical properties of soil do not indicate damages as a result of acidification, alkalisation or salinisation. High content of organic matter in upper layers of examined soils is worthy of notice. This is why in a case of future land reclamation activity, removing and repeated use of humus should be taken into consideration. Low values of the PI are influenced by changes of primary soil properties as a result of following hydrological degradation processes, connected with global groundwater rise caused by surface area settlement.
4. The obtained results allow to state that the PI method proposed by Zhegi Hu et al. [1992] may be a useful tool for the determination of current degree of soil degradation in areas of hard coal mining activity. This method however does not take into account current fertilisation and abundance of soil, which preclude comparison of obtained results with soil quality classification, but gives information of land reclamation needs. An essential element influencing the final result using the algorithm of this method is recognition of forms of soil degradation and proper choice of their properties. This method however does not regard actual fertility and abundance of soil, which does not enable comparison of obtained results with soil quality classification.

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