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EVALUATION OF CRITERIA OF THE EXTENT OF SOIL DEGRADATION IN THE VICINITY OF WORKINGS OF OPEN CAST BROWN COAL MINES SITUATED ON THE CENTRAL POLISH LOWLAND

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A b s t r a c t. In the result of geomechanical transformations associated with the activity of open cast brown coal mining, some changes in air-water relations may occur on arable land adjacent to these regions usually referred to as hydrological alterations. However, they do not always need to result in soil degradation, i.e. in the deterioration of their production potentials. This will often depend on the distance of fields from the workings, value of the arable land (soil quality class), type of water management, etc.

On the basis of long-term studies carried out in the area of operation of two brown coal mines - KWB "Konin" and "Adamów" - on arable land and grasslands of over 60 villages on the total area of 30 thousand hectares it was possible to develop evaluation criteria for the extent of soil degradation and work out principles for compensation payments for farmers.

Three zones and appropriate sub-zones of soil susceptibility to drainage were determined and clear and simple criteria for the estimation of the extent of arable land and grassland degradation were worked out. Furthermore, the authors proposed simple and readable systems to calculate compensatory payments to be paid to farmers taking into account the state of soil degradation, value of agricultural land (price of 1 ha of land of appropriate class) and the area of damaged land. The degree of soil degradation, both of arable land and grasslands, ranged from 10 to 30%. In the case of grasslands, additionally, an appropriate sum of money was allocated to compensate for sward recultivation.

K e y w o r d s: open cast mining, drainage, soil degradation.

INTRODUCTION

Open cast mining leads to drainage of areas adjacent to open workings often situated at quite considerable distances from them. The intensity of this type of drainage depends mainly on: quantities of waters stored in water-bearing layers, permeability of these layers, hydraulic gradient, length of the pathway of filtration, etc.

Drainage of surface layers is usually associated - especially by farmers - with a decline in yields, i.e. with a degradation in soil productivity. The establishment of actual results of this kind of drainage was the objective of numerous scientific papers, pedological studies and expert opinions [1,2,6,8,9].

A proper, appropriately precise and adequately accurate analysis and assessment of soil productivity degradation in areas adjacent to open cast mines depend primarily on methodological solutions, i.e. on the choice of properly developed and tested research methods or development of new solutions. In the past, the most frequently employed method was the only published scientific method, the so called "hydrogeological-soil method of estimation of damages on arable lands resulting from drainage caused by mining activities" [3].

In the result of long-term soil science investigations carried out by the Department of Soil Science of Poznań Agricultural University in regions affected by open cast mining (KWB "Adamów and "Konin) a wide range of methodological variants were applied which, ultimately, allowed to develop a complex method which portrays most objectively the influence of hydrological changes in the field and allows to determine soil zones characterised by different susceptibility to drainage degradation caused by mining activities. This study presents principles and criteria on which this method is based.

MATERIALS

Special pedological investigations concerning the problem of soil degradation in the result of brown coal open cast mining activities were focused on mining areas adjacent to two Brown Coal Mines (KWB), namely: KWB "Adamów and KWB "Konin. The examined area included five communes in the south and central-south part (KWB "Adamów) and five communes in the north-central part (KWB "Konin) of the former Konin voivodeship. Areas of the above mentioned communes and the area of investigations in these communes are shown in Table 1. The concerned areas constitute only 3.08% (in the case of KWB "Adamów") and 3.06% (in the case of KWB "Konin") of the area of that voivodeship, which in total makes only 6.14% of the voivodeship area.

In investigations carried out so far in this region, depending on their objectives, different methods of assessment of soil productivity degradation were applied which were referred to as: verification of soil class evaluation, two-stage studies, assessment of evolutionary soil changes, yield assessment and complex method. Their detailed characterisation was presented in a comprehensive monograph concerning

Table 1. Area of research in the range of "Adamów" and "Konin" quarries influence

Commune	Total area (ha)		Investigated area (%)	
	of the commune	investigated	in the commune	in the province
	"Adamów" Quarry			
Brudzew	11272	4878	43.28	0.95
Krzymów	9268	796	8.59	0.27
Przykona	11093	6073	54.75	1.18
Turek	10942	1394	12.74	0.27
Władysławów	9071	2688	29.63	0.52
Total	51646	15829	30.65	3.08
	"Konin" Quarry			
Golina	10372	629	6.06	0.12
Kazimierz Biskupi	10796	4529	39.45	0.88
Kleczew	11012	3859	35.04	0.75
Sompolno	13736	2013	14.65	0.39
Ślesin	14569	2335	16.03	0.45
Total	60485	15714	25.98	3.06
Total of "Adamów" and "Konin"	101759	31543	31.00	6.14
Total area:				
of the province of Konin	513 883 - 100.00%			
of arable lands	379 032 - 73.70%			

this problem [14]. The above mentioned methods of examination and estimation of the extent of drainage soil productivity degradation have their own advantages and disadvantages and their realisation requires different expenditures and degree of particularity of pedological studies.

The basic assumption of the most optimal complex method is that it has to have a two-stage character in order to identify ranges of 3 basic types of soil water regimes; rain, rain-ground (mixed), ground.

During the first stage of experiments the conformity of the evaluation classification was assessed and the existing evaluation changes exceeding the range of one land class were verified. Results of these studies were documented with field and laboratory profile analysis, soil samples, estimate method of yield and supplemented with photographs, etc.

The second stage comprised detailed pedological studies in regions characterised by mixed regime and ground-water regime. The aim of this stage was to identify and assess the extent of soil productivity degradation as well as possible degradation of meadow sward on grasslands. Pedological studies were supplemented with analysis and photographic documentation of yields. Also during this stage of investigations, soil water conditions were assessed in detail, in particular the depth of occurrence and seasonal variations in the level of ground waters.

RESULTS AND DISCUSSION

The most frequently occurring types of soils found in regions directly adjacent to open cast pits are: in particular, brown soils, rusty soils, arenosols and black earths (Table 2). They constitute the basic area of arable lands characterised by a relatively high evaluation class, i.e. nearly all of them belong to class IIIa and IIIb, IVa and IVb with local deviations to class II (black earths). On the other hand, rusty soils and arenosols are characterised by distinctly low productivity and evaluation classes. The above mentioned soils apart from the examined regions -

Table 2. Soils of the investigated area according to Systematics of Polish Soils [11]

Division and order	Type	Subtype	Soil order acc. to Soil Taxonomy
I. Lithogenic soils I.A. Noncarbonate soils, weakly developed	I.A.5. Soils weakly developed from loose materials (Arenosols)	a/ proper	
II. Autogenic soils			
II.B. Brown forest soils	II.B.1. Brown soils	a/ typical	Inceptisols
	II.B.3. Lessive soils	a/ typical d/ pseudogley	Alfisols
II.C. Podzol soils	II.C.1. Rusty soils	a/ proper	Entisols
III. Semi-hydrogenic soils III.B. Black earths	III.B.1. Black earths	a/ proper e/ degraded (grey)	Mollisols
IV. Hydrogenic soils			
IV.A. Bogged soils	IV.A.2. Peat soils	a/ low peat	Histosols
IV.B. Post-bog soils	IV.B.1. Muck soils	a/ peat-muck	Histosols
	IV.B.2. Mucky soils	a/ mineral-muck soils b/ proper c/ muckous	Inceptisols
V. Alluvial and deluvial soils			
V.A. Alluvial soils	V.A.1. River alluvial soils	a/ proper	Entisols
V.B. Deluvial soils	V.B.1. Deluvial soils	a/ proper	Entisols

are very common all over the Central Polish Lowland, especially in Wielkopolska (Great Poland) where they are very well recognised and characterised.

The above mentioned soils cannot undergo mining drainage because some of them (rusty soils and arenosols) have not had ground water within the reach of soil profile (arable soils - 1.5 m). On the other hand, the remaining soils: lessive soils, brown soils and black earths may, periodically, have ground water (early spring), in fact, a zone of full saturation which occurs in covering sands, usually at the depth of several dozens centimetres over moraine loam [10,14]. This kind of water can be effectively drained in the result of draining.

There are arable lands in the examined region which can undergo draining, namely hydrogenic soils: muck and mucky soils with the texture of sand soils or sands characterised by various degrees of silting. In general, they are arable lands derived from meadows which were ploughed under when meadow sward underwent natural or artificial degradation in the result of drainage.

Grasslands grow on hydrogenic soils: peats, muck and mucky soils. In the result of natural or artificial (including drainage caused by mining) drainage, especially when this process proceeds quickly and reaches deep into the soil, productivity degradation affects either both soil and sward or only sward.

Looking at drainage soil productivity degradation from the point of view of evaluation classes, it can be characterised as follows:

1. Classes I and II of arable lands cannot undergo drainage productivity degradation since they are characterised by well regulated water conditions - high water holding capacity, high porosity.

2. Classes IIIa, IIIb, IVa and most of class IVb of arable lands, in our physiographic conditions (soil, climate, topographic features, geological structure of top layers, etc.) occur almost exclusively as two-part soils, i.e. loamy sands formed on loams. These types of soils either have no ground water levelled - hence, cannot undergo drainage degradation or can have periodical (early spring) water stored over loam which can be drained. In the case of soil evaluation classes under permanent grasslands, drainage productivity degradation can occur in all six classes.

Looking at the problem of drainage productivity degradation from the point of view of soil agricultural usefulness complexes, the following complexes were subjected to analysis: complex 9 - cereal-fodder weak complex was analysed in detail, complex 8 - cereal-fodder strong complex was analysed partly as well as complex 6 - weak rye complex found in the neighbourhood of the two above. The following complexes from permanent grasslands were also analysed: 1z, 2z and 3z [13].

The performed investigations resulted in the development of relatively simple and unambiguous criteria of assessment of the degree of degradation of various soil formations in the vicinity of open cast workings [9,14]. The obtained results were presented on maps of land registration at 1:5000 scale in the form of separate soil units characterised by the same degree of susceptibility to changes of their water relations. Criteria which allowed such separation were elaborated in consecutive stages of investigations carried out on the above mentioned objects.

Below, we present detailed characterisation of soils included in appropriate zones and sub-zones drainage degradation associated with mining activities:

ZONE I - includes soils which did not and do not have ground water within the reach of soil profile. They cannot be drained and, therefore, undergo drainage soil productivity degradation. The yield in this zone depends on the evaluation class, agrotechnical operations and the course of climatic conditions.

ZONE II - includes soils which did not and do not have within the reach of soil profile the level of proper ground water but may exhibit periodical, usually early spring, easy to filter free water found over or between loam layers or a zone of local saturation with water in loamy sands formed on loam and in sand veins between loams. These soils are referred to as soils with rain water regime. The yield of these soils depends mainly on the evaluation class, agrotechnical treatments, climatic conditions and draining.

ZONE III - includes soils which have or had, during the last several years, ground water level within the reach of soil profile or this level was significantly lowered. The basic condition existence of ground water is fulfilled in these soils. Therefore, two cases were considered on which physical possibilities of soil drainage depend: appropriate contact and hydraulic gradient. Assuming this criterion, the following sub-zones were distinguished in the examined region: III-A, III-B, III-C and III-D.

Sub-zone III-A - includes soils which are characterised by the level of ground water but, because of the lack of contact or hydraulic gradient, drainage connected with mining activities or lowering of the level of ground water is impossible. These include primarily soils and agricultural wastes (marshes, overgrowing water reservoirs) occurring in glacial troughs found more than 1 km from open cast pits or deep mining canals as well as soils occurring in interior depressions surrounded by loamy moraine heights. In these areas ground water has remained unchanged for many years exhibiting seasonal annual or periodical variations depending, primarily, on atmospheric precipitations in the catchment area. So, there is ground water, there is no drainage associate with mining activities, there is no soil production degradation connected with drainage.

Sub-zone III-B - includes marshy soils developed in the result of drainage of marshy wastes associated with mining activities. They occupy very small areas and do not have practical significance. However, these wastes are important as, the so-called, ecological land which constitutes refuge and sanctuary for propagation of reptiles, amphibians, insects as well as special kinds of plants increasing in this way biodiversity of agricultural areas. Therefore, it should be mentioned here, their liquidation in the result of drainage was considered a negative environmental event, although no compensation can be paid in the light of the existing regulations.

Sub-zone III-C - includes muck and mucky soils, mainly derived from meadows of V and VI evaluation classes, damaged in various degrees, either in the result of natural [4] and open cast mining drainage, as well as by changes of water conditions connected with various canals, ditches, etc. The above mentioned soils are characterised by a conspicuously lowered level of ground waters causing aerobiotic processes in the mucky level and irreversible losses of biogenic constituents, primarily nitrogen, deterioration of air-water conditions, etc. This type of degradation progresses gradually and usually takes a few to several years - depending on drainage intensity, agrotechnical treatments, etc. [5,7,12]. Mean annual yield loss does not usually exceed 0.05 t/ha, therefore, it is impossible to notice in a short period of time, e.g. 1-2 years. Ultimately, the level of degradation reaches 1.5% of organic matter and it remains relatively stable for sandy soils [12,14].

Sub-zone III-D - includes soils under permanent grasslands, i.e. under meadows and pastures where the lowering of the ground waters level under the influence of natural and open cast mining drainage causes degradation of soil productivity as well as losses in sward. Degradation of soil productivity is similar to that recorded in arable lands of sub-zone III-C. However, in the examined region, such degradation comprises also soils of class IV and may occur also in soil characterised by a higher concentration of organic matter (peat, muck, mucky) than in arable land, but usually it does not reach the final stage since soils with far advanced natural degradation are commonly taken over by farmers as arable land. Most often, the extent of degradation of soil productivity does not exceed one evaluation class; it may, however, exceed one evaluation class in grasslands. The calculation of compensation for permanent productivity degradation Qtdp of arable lands - sub-zone III-C and grasslands - sub-zone III-D can be presented as a product of the following factors:

$$Qtdp = a*b*c$$

where: a - current price of 1 ha of land of a given evaluation class in a specific commune; b - % soil degradation given on the map of land registration (abstract number); c surface of the area in ha.

In grasslands - apart from permanent degradation of soil productivity - usually a very distinct, sometimes contrasting, degradation of meadow sward can occur as grasses respond very rapidly and quickly to even relatively small drops in ground water levels because they take place in sand soils. This results from the absence of adaptation to the existing species composition of the meadow sward to changing water conditions. When drainage of a given area caused by mining activities overlays with natural drainage, changes in water conditions occur relatively quickly, whereas natural regeneration of the species composition takes a very long time, usually several dozens years. In such conditions, cultivated grass species and appropriate leguminous plants should be introduced artificially, applying sub-sowing and suitable agronomic operations.

There is no doubt that the responsibility for drainage of permanent grasslands resulting in significant changes in water conditions and degradation of meadow sward associated with it can be put on the open cast mining. Therefore, appropriate mines should pay for the costs of sward regeneration, or generally speaking, all costs connected with land reclamation projects. The most optimal variant for the application to be recommended on the examined objects is the renovation of grasslands by means of undersowing supported by appropriate chemical weed control. The cost of such operations are estimated at the level of approximately 800 zl/ha [14]. Therefore, in the case of permanent grasslands the full compensation should consist of two parts: one part, for permanent degradation of soil and the second - for the reclamation of meadow sward.

Detailed criteria for the identification of the degradation of arable land together with the list of percentage degree of degradation for areas affected by activities of the Konin Brown Coal Mining Centre are given in Table 3. The table, together with the accompanying explanations concerning the applied symbols and abbreviations, presents in a simple and lucid way the most important conditions and the extent of soil productivity affected by drainage.

CONCLUSIONS

1. The most useful method for the evaluation of the effect of open cast mining on the degradation of arable lands is a complex method which comprises two

Table 3. Detailed principles of compensation establishment

Zones of soil degradation	Land capability unit	Types and sub-types of soils	Texture	Zone in relation to open cast pit	State of soil degradation
I	6,7	Bw	ps.pl ps:pl	irrespective of pit	without drainage degradation
		A	pl		
II	2,3,4	B	pgl./:gl		
		A	pgm./:gl		
III A	Different arable soils and grasslands far away from the pit - water conditions not changed by mining activities				without drainage degradation
III B (R)	8	D(Dz)	pgm:gl	over 300 (500) m from pit	amelioration drainage
	9	Dz	pgl:gl		
III B (Ł, Ps)	2z 3z	Dz	pgm:gl pgl:gl		amelioration drainage,sward degradation (compensation value - 800 zł/ha)
III C (R)	6.7 6 5	Bw Dz Dz	ps.pl ps.pl pgl:gl	in neighbourhood of grasslands (in depresions)	o-g-w→o-w 10% degradation
	4,5,6 8 (6)	Dz Dz (Bw)	pgl/pgm.gl pgl/pgm.gl (ps:pl)	up to 300 (500) m from pit or at pit boundary	10% degradation
	9 6	Dz M	pgl:gl pgl.pl(:gl) ps./:pl	in neighbourhood of grasslands (in depresions)	o-g-w→o-w 20% degradation

T a b l e 3. Continuation

Zones of soil degradation	Land capability unit	Types and sub-types of soils	Texture	Zone in relation to open cast pit	State of soil degradation
III D (Ł,Ps)	2z	Dz	pgm/pgl.gl	in glacial troughs	10% degradation + 800 zł/ha
	3z	Dz	pgl:gl pgl.pl		20% degradation + 800 zł/ha
	2z, 3z 2z	M, T Dz	- pgl.pl		30% degradation + 800 zł/ha
N, WN		M, T Etm	-	irrespective of pit	

a/ Land use: R-arable lands, Ł-meadows, Ps-pasture, N-barren land, WN-mashes and wet-lands.

b/ Land capability units: 4-very good rye, 5-good rye, 6-weak rye. 7-very weak rye, 8-cereal-follder strong, 9-cereeal-fodder weak, 2z-medium grasslands, 3z-weak grasslands.

c/ Types and sub-types of soils: A-arenosols or lessives soils, B-brown soils, Bw-rusty soils, D-proper black earths, Dz-degraded black earths, M-mucky soils, T-peat and peat-muck soils, Etm-peat-muck soils.

d/ Texture: pl,ps - sand, pgl, pgm - loamy sand, gl - loam.

e/ Change of texture: .- down to depth 50 cm, :- from 50-100 cm.

f/ Types of water management: 0-g-w - rain-ground water regime, o-w - rain water regime.

stages of pedological investigations which ought to be performed first before establishing the drainage barrier and then a few years later.

2. In order to estimate the degree of soil degradation, it is necessary to establish zones comprising soils which cannot undergo degradation (location, genesis, morphological structure, type of water management etc.) as well as soils which underwent various degrees of degradation. The latter ones should then be subjected to detailed investigations in order to ascertain their percentage degree of degradation.

3. The assessment of the value of compensation, mainly on the basis of yield drop is not very objective, as the yield is the resultant of many natural and agrotechnical factors. Therefore, the compensation to be paid should be determined on the basis of the value of the given piece of land and the degree of its degradation. In the case of grasslands, the compensation rate should, additionally, be increased by the cost of sward reclamation.

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