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SELECTED METHODS OF ESTIMATING WATER RETENTION CAPACITY – A COMPARATIVE STUDY WITH THE PIŃCZÓW REGION AS AN EXAMPLE

Abstract: Protection of areas with high retention capacities is crucial in sustaining the natural balance. This paper compares three methods used to identify such areas. The Pińczów region has been chosen as a tested area. The results obtained for selected groups of geocomplexes have been analysed.

Key words: landscape assessment, retention, Pińczów region.

INTRODUCTION

In physical geography, landscape is defined as a part of epigeosphere (external layer of the Earth), which is a spatial geocomplex with a structure and inner relations. Both the landscape as a whole and its separate units can be studied in the context of their usefulness for different forms of human activities. Retention control is one of the so-called landscape functions. Defined as the ability of the landscape to stop rainwater, retention contributes to lower quota of superficial outflow in the total water balance of a given terrain.

The aim of this paper is to asses the landscape retention control function for the Pińczów region. Two German approaches have been employed, viz.: 1) Marks, Müller, Leser & Klink method; 2) Röder & Beyer method, together with one Polish method – 3) Miler method, used for comparative purposes. The answer has been sought to the questions whether the results produced by the tree methods differ from each other, and, if so, what terrain types produce the widest differences. The amount of work necessarily involved in each method has also been compared.

RESEARCH AREA AND BASIC ASSESSMENT FIELDS

The selected methods have been used to asses the retention control function of the area south of the city of Pińczów (coordinates of the corner points for the area are the following: 50º33'30.87"N, 20º23'02.00"E; 50º22'44.60"N, 20º23'02.00"E; 50º22'44.60"N, 20º39'35.05"E; 50º33'30.87"N, 20º39'35.05"E). The tested area is of 400 km^2. The altitude varies between 173 and 340 metres above the sea level. In its largest part, the area is slightly sloping (0-3º).

The morphology is diversified by two distinct hills: the Wodzisławski and Pińczowski Humps located, respectively, in the south-western and north-eastern parts of the studied region. An important landmark is also an extensive valley of the Nida river, which is considered the largest watercourse in the region. As far as other natural watercours are concerned, their development level should be assessed as low.

The geological structure of the tested area is diversified. Loess dominates in the south-western sectors. Large parts are also covered with marl, marly limestones, and gaizes (north-western and south-eastern sectors). The Nida river valley and the north-eastern part of the region is dominated by sand of fluvial-glacial and periglacial origin. There are also gypsum, loam and clay residuals covering a significant part of the region.

The diversity in the geological structure is translated into the diversity of soil cover. The strip extending form the north-west to south-west shows a domination of Mollic Leptosols, while Eutric Cambisols, Endoeutric Cambisols, and Dystric Cambisols are particularly common in the south-western part, and Mollic Gleysols, Phaeozems in the southern part. In the north-eastern sector, there is a mosaic of different soils with a considerable share of Haplic Podzols, Haplic Luvisols, Sapric Histosols and also Histosols, Calcaric Cambisols, Mollic Leptosols, Mollic Gleysols, Phaeozems, and Stagnosols.

The largest part of the studied area is in agricultural use. Large forests are located in the south-western, central, and north-eastern parts of the region. Meadows represent the third form of the land cover, typical of the Nida river valley. Significant parts of the region are enclosed in the Kozubowski and Nadnidzianski Landscape Parks.

The following data has been collected for the region in question:

- digital elevation model in 20m resolution, used to generate a slope map;
- geological maps – fragments of sheets nos. 917, 916, 883, and 884;
- land cover map including natural watercourses, elaborated using the Corine Land Cover 2000 data base and itemised using data published by Geoportal[1];
- hydrogeological maps – fragments of sheets nos. 917, 916, 883, 884;

[1] www.geoportal.gov.pl

– soil agricultural map; and
– relevant details from habitat reports for forest areas[2].

Landscape units (partial geocomplex) have served as basic assessment fields. The units have been delimited based on the land cover (classes used in the Corine Land Cover program), slopes, and bedrock geology (with some information on their origin omitted). The geocomplex map (Fig. 1) has been generalised to eliminate units with surface areas too small to be mapped on the adopted scale of 1:50 000.

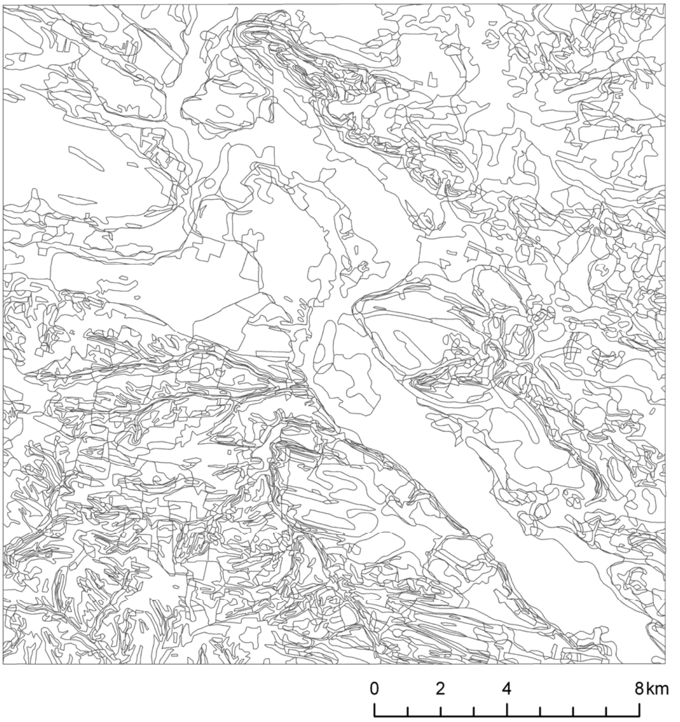

Fig. 1. Geocomplex map of the tested area

RETENTION CONTROL FUNCTION ASSESSMENT

The Marks, Müller, Leser, & Klink method

Developed by Marks, Müller, Leser, and Klink, the retention function assessment method is based on the following parameters: land cover, terrain slope, soil texture group, and effective field capacity. The authors assumed that the data necessary for the method to be applied would be taken from

[2] Data obtained from the Forest Inspectorate Pińczów.

a geoecological map on the 1: 25 000 scale, which was to be prepared for the entire German territory at that time. The relevant map instruction was developed by Leser and Klink (1988).

Values for the analysed parameters are arranged in five classes. The land cover classes include: vegetables cultivation areas; cereals cultivation areas (corn excluded); permanent crops and shrubs; bushes; orchards. Boundary values for the slope classes are as follows: 2º, 7º, 15 º, and 35º. The soil classification is based on the classification presented by Leser and Klink (1988), and supplemented by infiltration characteristics and soil skeleton quota. Where superficial underground waters (<2m) occur, combined with explicit hydrogenise characteristics of the soil, and marly-clayey primary bedrock with thickness exceeding 2 m, the classes need to be modified accordingly.

It was not possible to use the effective field capacity classification suggested by Marks, Müller, Leser, and Klink in this study because of the differences between the Polish and German particle size classification and soil textural classification (Ad-Hoc-Arbeitsgruppe Boden, 2005; Borek S., 2000). Therefore it was necessary to develop a simplified classification for the effective field capacity parameter (Table 1).

Table 1. Soil texture groups classified by effective field capacity

Soil texture group	Points
Peat, clay	5
From loamy sand to medium silt loam, heavy silt loam	4
Clay, heavy silt	3
Loose sand	2
Gravel	1

The final result in the retention capacity assessment is obtained by adding all partial point values, and then translating them into a corresponding retention control function class. According to this method, built-up areas are always in the lowest retention control function class, while the highest retention function control class is for forests.

As for the assessment results produced by the Marks, Müller, Leser & Klink method (Fig. 2), it is remarkable that the majority of the area belongs to the third class, generating mean retention capacity values. A substantial portion of the areas has a very high retention capacity (fifth class). Units categorised in the first class, i.e. lowest retention capacities class, represent a small percent of the analysed area.

The Röder & Beyer method

This method is developed for the 1:50 000 scale. The procedure may be divided into three steps. As the first step, the total outflow to the undersurface outflow ratio is determined, based on a terrain slope and hydrogenity level of the soil (A) (Table 2).

Table 2. Total outflow to undersurface outflow ratio – according to the Röder & Beyer method

Level of soil hydrogenity	Slope inclination					
	0-0.5°	>0.5-3°	> 3-7°	> 7-12°	>12-25°	> 25°
Lithogenic	0%	17%	33%	41%	50%	57%
	(1.0)	(1.2)	(1.5)	(1.7)	(2.0)	(2.3)
Semi-hydrogenic	50%	50%	50%	50%	57%	57%
	(2.0)	(2.0)	(2.0)	(2.0)	(2.3)	(2.3)
Hydrogenic	60%	60%	60%	60%	60%	60%
	(2.5)	(2.5)	(2.5)	(2.5)	(2.5)	(2.5)

The second step consists in establishing a point value for a given land cover form (B), based on Table 3 below.

Table 3. Point values for different land cover forms according to the Röder & Beyer method

Land cover form	Point value
Built-up areas	1
Cultivation fields and areas without vegetation	2
Permanent crops and uncultivated land	3
Shrubs and secondary succession areas	4
Forests and bushes	5

The third step is to calculate the point value of the retention control function, using the following equation:

retention control function point value = A x (6 – B).

The ultimate result produced by the method in question is the establishment of the retention control function class (1 of 5).

According to the Röder & Beyer method, the majority of the area has a high retention capacity (Fig. 2), with a prevalence of the fourth and fifth retention control function classes.

The Miler method

The method takes into account the following six parameters: forest area/total area ratio [Mforest, %], lake area/total area ratio [Mlake, %], density of the watercourse network [Mwater, km/km^2], average weighted soil filtration rate [Mfilter, mm/s], average terrain slope [Mslope ‰], and average thickness of the water permeable layer [Mthickness, m] (average difference between the terrain elevation value and the bottom of the water permeable layer). Each parameter value should be divided into 10 classes, each with a point value from 1 to 10. The classes from 1 to 3, from 4 to 7, and from 8 to 10 reflect low, middle, and high retention capacities, respectively. If two or more parameters for a given basic field are included in the classes of low or high retention capacities, the point value assigned to the unit is to be either decreased or increased as set forth in Table 4.

Table 4. Correction values in the Miler method

Number of parameters in the classes of low retention capacities	Correction value	Number of parameters in the classes of high retention capacities	Correction value
2	–1	2	1
3	–1.5	3	1.5
4	–2	4	2

The values (M) obtained in this way are then substituted for the relevant variables in the following equation, with due consideration for the weight parameters (W).

*ZWR (i,j) = Mforest (i,j) * Wforest + Mlake (i,j) * Wlake + Mwater(i,j) *Wwater + Mfilter (i,j) *Wfilter +Mslope (i,j) *Wslope + Mthicikness (i,j) *Wthickness*

Wforest – 0.41
Wlake – 0.25
Wwater – 0.02
Wfilter – 0.17
Wslope – 0.13
Wthickness – 0.02

For the purpose of this study, the Miler method has been modified to reflect the quality of the available cartographic materials. Instead of 10 classes suggested, there have been 6 classes created for each parameter. Such a reduction in the number of classes is aimed to reflect the number of filtration ratio classes on the hydrogeological maps.

The results obtained from using the Miler method (Fig. 2) vary from those obtained using the other methods. Units with low retention capacities are dominating. There are no areas categorised into any highest retention capacity class.

Assessment in the groups of geocomplexes

The graphical presentation of the results (Fig. 2) permits general conclusions only as regards similarities and differences among the three methods. To obtain an in-depth view, the results for particular groups of geocomplexes have been further analysed. Ground and land cover properties that are significant for retention control have served as criteria for grouping geocomplexes. The classification of terrain slopes has remained unchanged. Forms of land cover have been divided into: built-up areas, forests, orchards, plots and arable lands, meadows and rough grazing, marshes, water reservoirs, and quarry terrains. Geological ground types have been specified based on the general legend of the geological map. In the tested area, 400 of all possible 440 geocomplex groups occur. Further analysis has been limited to those groups that contain more than 1% of the total number of geocomplexes (Table 5). All the selected geocomplexes make up 72% of all geocomplexes of the tested area.

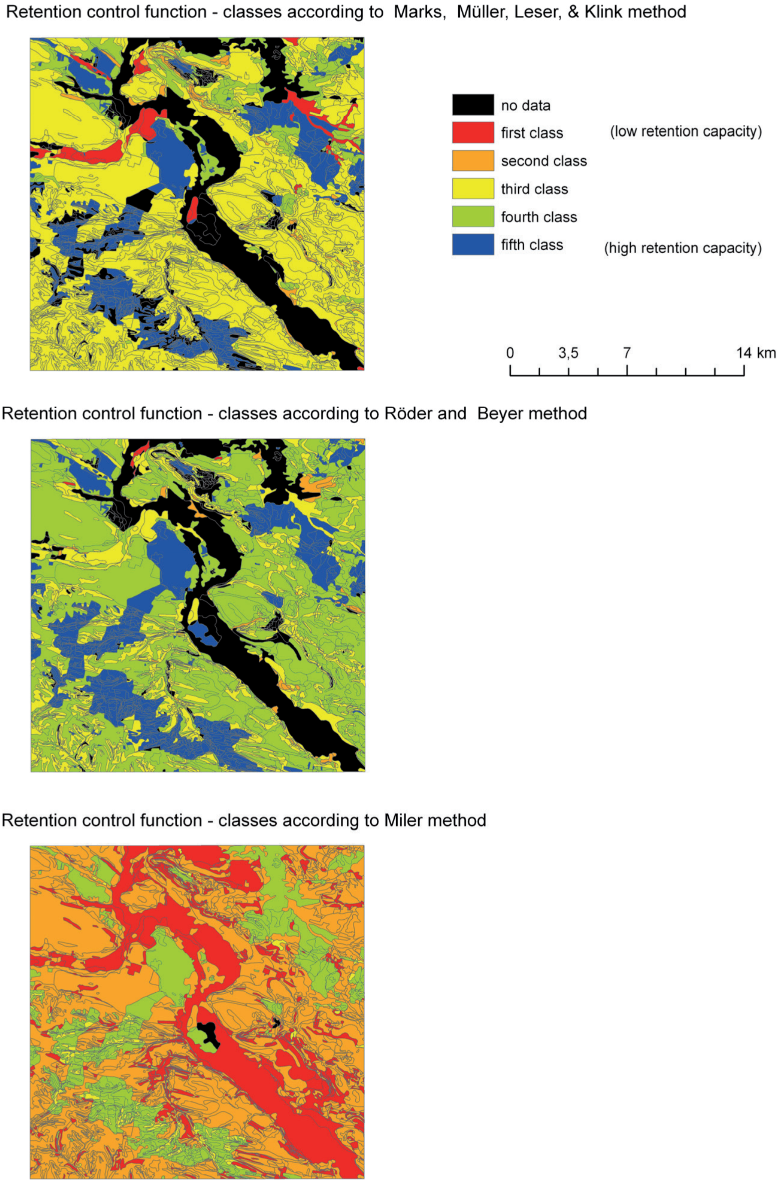

Fig. 2. Retention function assessment results by the three analysed methods

Table 5. Types of geocomplexes taken into account in the further analysis

Groups of geocomplexes	Mark, Müller, Leser, & Klink method (result in classes)	Röder &, Beyer method (result in classes)	Miler method (result in classes)	$Miler_2$ method (result in classes)	Slope class	Land cover	Bedrock geology	Filtration ratio class	Stream network density class	Effective field capacity class	Thickness of the water permeable layer – classes
1	3.4	4.0	1.9	3.2	1	plots and plants, arable areas	gravels, boulders, sands	2.5	1.0	2.9	2.2
2	3.0	4.0	2.0	3.2	1	plots and plants, arable areas	loess and fossil soils	2.1	1.0	2.1	3.5
4	3.3	3.8	1.9	3.1	1	plots and plants, arable areas	sands of different genesis	2.5	1.1	2.9	2.2
5	3.0	3.8	1.8	3.1	1	plots and plants, arable areas	aggradate mud and deluvial sediments	2.4	1.3	2.3	1.7
6	3.0	4.0	1.9	3.2	1	plots and plants, arable areas	gypsum, anhydrite, marl, loams of the gypsum level	2.4	1.0	2.7	1.9
8	3.2	4.0	1.9	3.1	1	plots and plants, arable areas	loams, clays, loesses and sands, gravels and small deluvial boulders	2.4	1.3	2.5	2.9
11	3.1	4.0	1.9	3.2	1	plots and plants, arable areas	marl, gaizes and marly limestones	2.2	1.1	2.8	2.3
13	5.0	5.0	4.0	5.2	1	forests	loess and fossil soils	2.0	1.0	1.2	4.3
15	5.0	5.0	3.9	5.2	1	forests	sands of different genesis	2.1	1.1	3.5	2.6
22	5.0	5.0	4.0	5.2	1	forests	marl, gaizes and marly limestones	2.0	1.0	2.5	3.1
48	3.1	2.8	1.4	2.7	1	buildup areas	sands of different genesis	3.8	1.0	3.0	1.5
55	2.9	3.0	1.4	2.6	1	buildup areas	marl, gaizes and marly limestones	3.8	1.0	2.9	1.9

Groups of geocomplexes	Mark, Müller, Leser, & Klink method (result in classes)	Röder &, Beyer method (result in classes)	Miler method (result in classes)	Miler$_2$ method (result in classes)	Slope class	Land cover	Bedrock geology	Filtration ratio class	Stream network density class	Effective field capacity class	Thickness of the water permeable layer – classes
70	2.6	3.4	1.6	2.9	1	meadows and permanent crops	sands of different genesis	2.9	1.1	2.2	2.0
90	3.0	3.1	1.8	3.0	2	plots and plants, arable areas	loess and fossil soils	2.0	1.0	2.0	4.0
92	3.1	3.0	1.4	2.7	2	plots and plants, arable areas	sands of different genesis	2.2	1.2	2.6	2.2
93	3.0	3.0	1.7	2.9	2	plots and plants, arable areas	aggradate mud and deluvial sediments	2.1	1.0	2.0	2.9
94	3.0	3.0	1.4	2.6	2	plots and plants, arable areas	gypsum, anhydrite, marl, loams of the gypsum level	2.4	1.0	2.7	2.1
99	3.1	3.0	1.4	2.7	2	plots and plants, arable areas	marl, gaizes and marly limestones	2.1	1.0	2.7	2.5
101	5.0	5.0	4.0	5.2	2	forests	loess and fossil soils	2.0	1.0	1.1	4.3
110	5.0	5.0	4.0	5.2	2	forests	marl, gaizes and marly limestones	2.0	1.0	1.4	4.3
178	3.0	3.0	1.9	3.1	3	plots and plants, arable areas	loess and fossil soils	2.0	1.0	2.0	3.8
187	2.7	3.0	1.4	2.6	3	plots and plants, arable areas	marl, gaizes and marly limestones	2.0	1.0	2.4	2.5
189	5.0	5.0	3.4	4.6	3	forests	loess and fossil soils	2.0	1.0	1.1	4.2
198	5.0	5.0	3.3	4.5	3	forests	marl, gaizes and marly limestones	2.0	1.0	1.7	3.8

Figure 3 presents the landscape function assessment results by the geocomplex groups. The X axis refers to the geocomplex group number, while the Y axis – to the results in classes. The numbers on the X axis denote the position in an ordered sequence only. To increase the clarity of the results, the curves are used on the graph; these, however, can be misleading by suggesting any continuity of the data and their functional interdependency.

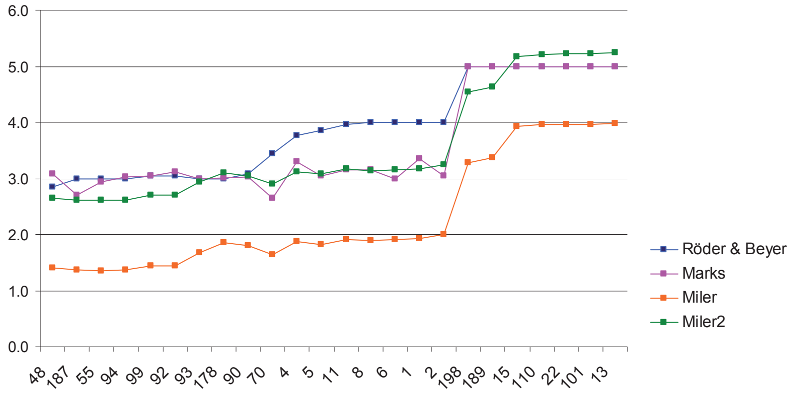

Fig. 3. Average results for particular groups of geocomplexes.
(Miler2 curve shows the results obtained using the Miler method and shifted by 1.25 class)

As illustrated above, the shapes of curves representing average results for the Marks, Müller, Leser & Klink method, the Röder & Beyer method, and the Miler method are similar. However, compared to the other two methods, the values produced by the Miler method are understated. Since all the methods are to yield relative values, the Miler curve may be shifted by 1.25 class along the Y axis (Miler2). When so shifted, three curves have very similar shapes, with small discrepancies in selected unit groups.

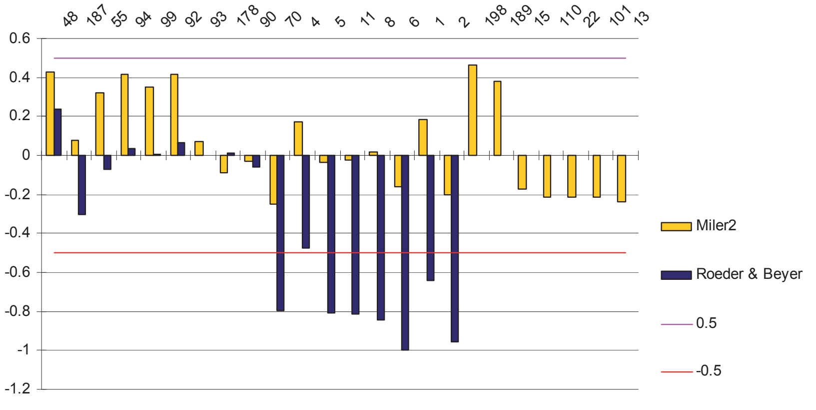

Fig. 4. Divergence between the Marks, Müller, Leser & Klink method and the other two methods. (Red line indicates negative deviations, while purple line indicates positive deviations).

In order to establish whether those discrepancies are significant, a column chart (Fig. 4) has been drawn up to more clearly illustrate differences between the Marks, Müller, Leser & Klink method (as a reference method) and the two other methods, with a significant discrepancy level set at 0.5 class. Any difference above the reference level can result in the change of class assigned to a given unit. There are no significant differences between the Miler method and the Marks, Müller, Leser & Klink method. Differences between the Röder & Beyer and the Marks, Müller, Leser & Klink approach that exceed the 0.5 class are visible in groups nos. 70, 4, 11, 8, 6, 1, and 2.

DISCUSSION OF RESULTS

There is a high level of similarity in the results obtained using the three methods for assessing the retention capacity. The shape of the curves is comparable; and the shift by 1.25 class of the Miler curve results in a fairly exact superposition of the curves. All the methods indicate the highest retention control capacities of the forests. Only the Miler method introduces a division of forests according to terrain slope ranges (unit groups nos. 189, 198).

Other land cover forms are assigned significantly lower values and are not divided into any sub-forms – built-up areas score similar to cultivation fields. When compared to the other two methods, significantly different results for those forms of land cover are obtained from the Röder and Beyer method for group nos. 70, 4, 5, 11, 8, 6, 1, and 2. These are non-forest, slightly sloping areas. Higher scores (in comparison to non-forest highly sloping areas) seem to be reasonable. The differences in the results for groups nos. 48, 187, 55, 94, 99, and 92 are insignificant. It is noticeable that, in contrast to the other methods, the Miler method assigns lower values to those groups. Compared to other unforested areas, those groups produce low values for the filtration rate, whose values are then translated into lower retention capacities.

CONCLUSIONS

The analysis discussed above shows a considerable similarity of the results obtained using these three methods. Except when applied to unforested low slope areas, all the methods are capable of providing equally valuable results. Hence, as far as their practical use is concerned, the selection of any particular method should be based upon available terrain related data.

There is yet another conclusion that can be drawn concerning the positive assessment of the comparative methodical approach employed. Since the results for the selected groups of geocomplexes well correspond with the results obtained for individual geocomplexes, it is possible to limit the comparative analysis to those groups only, and thus minimise the labour intensity required in the analysis.

REFERENCES

Ad-Hoc-Arbeitsgruppe Boden, 2005, *Bodenkundliche Kartieranleitung. 5. verbesserte und erweiterte Auflage*, Schweizerbart'sche Verlagsbuchhandlung, Hannover.

Borek S., 2000, *Przewodnik do ćwiczeń z gleboznawstwa melioracyjnego* [Guidebook for practice in land improvement pedology], Wydawnictwo SGGW, Warsaw.

Kondracki J., Richling A., 1983, Próba uporządkowania terminologii w zakresie geografii fizycznej kompleksowej [An attempt to organise terminology in complex physical geography], *Przegląd Geograficzny,* 55, no. 1.

Leser H., Klink H.-J., 1988, Handbuch und Kartieranleitung, Geookologische Karte 1:25 000 (KA GOK 25), *Forschungen zur Deutschen Landeskunde,* Band 228, Trier.

Marks R., Müller M.J., Leser H., Klink H-J., 1989, Anleitung zur Bewertung des Leistungsvermögens des Landschaftshaushaltes (BA LVL), *Forschungen zur Deutschen Landeskunde*, Band 229, Trier.

Miler A., 1998, *Modelowanie obszarowych zmienności różnych miar retencji* [Modelling of surface variability of different measurements of retention], Wydawnictwo Akademii Rolniczej w Poznaniu, Poznań.

Röder M., Beyer C., 2002, Abflussbildung und vorbeugender Hochwasserschutz in der Landes- und Reionalplanung. Dargestellt am Beispiel Sachsens. *Naturschutz und Landschaftsplanung,* 34 (7), 197-202.

Zawadzki S., 1999, *Gleboznawstwo* [Pedology], PWRiL, Warszawa.