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KAROLINA WOŹNICA*, AGNIESZKA JÓZEFOWSKA*,
JUSTYNA SOKOŁOWSKA*, RYSZARD MAZUREK*,
TOMASZ ZALESKI*

CLASSIFICATION OF BROWN EARTHS BASED ON FIELD AND LABORATORY PROPERTIES: PROBLEMATIC ISSUES AND PROPOSITION OF THEIR SOLUTION

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Abstract. In this paper, the current problems associated with the classification of brown earths are presented. According to the Polish Soil Classification (PSC) (1989, 2011), base saturation is the main parameter for identifying eutrophic and dystrophic brown soils. However, in practice it is not possible to determine the base saturation value in the field. Therefore, the aim of this study was to estimate the base saturation using a regression equation and create a field guide for brown earths, based on the pH value measured using a Hellige indicator, and the calcium carbonate content. Determination of the pH ranges enabled the classification of brown earth types in the field. These results suggest that pH can be used as a proxy for base saturation, especially in the field. A change in the hierarchy of soil (sub)types is proposed for the new Polish Soil Classification.

Keywords: brown earths, Polish Soil Classification, field guide, cambisols

INTRODUCTION

Brown earths are one of the most common soil types in Poland. They occupy large areas, especially in mountainous regions and in southern and south-eastern Poland (Skiba *et al.* 2003, Skłodowski and Bielska 2009). In the Polish Soil

* University of Agriculture in Kraków, Department of Soil Science and Soil Protection, Al. Mickiewicza 21, 31-120 Kraków, Poland. Corresponding author's e-mail: karolinawoznica@o2.pl

Classification (PSC 2011), brown earths have been divided into four main types – eutrophic brown soils, dystrophic brown soils, brown alluvial soils, and brown rendzinas. In the previous edition of the PSC (1989), the types were typical brown soils (in Polish, *brunatne właściwe*), acidic brown soils (*brunatne kwaśne*) and leached proper brown soils (*brunatne wylugowane*). Both editions of the PSC (1989, 2011) classified brown earths according to a diagnostic cambic horizon, base saturation (BS) at a depth of 25–75 cm and content of CaCO_3 . Along with the change in the classification from 1989 to 2011, a BS limit value was also changed. Brown earths are classified into particular types and subtypes based on their BS value and the content of CaCO_3 . The change in BS limit value from 30% (PSC 1989) to 60% (PSC 2011) for eutrophic brown soils (typical brown soils) and dystrophic brown soils (brown soils) is misleading. According to botany and forest science, habitats such as *Galio odorati-Fagetum*, *Melico-Fagetum* (*żywna buczyna niżowa*) and *Dentario glandulosae-Fagetum* (*żywna buczyna góraska*) are very fertile habitats that cannot grow on dystrophic soils (Brożek 2012).

The main aim of this paper was to estimate the BS value in the field based on the pH value, measured by a Hellige indicator. To establish the range of pH values that correspond to a range of BS, a linear regression was performed in order to estimate the BS value limit for typical eutrophic brown soils (BEt) and typical dystrophic brown soils (BD). The secondary aim was to create a guide for the classification of BEt, leached eutrophic brown soils (BEw) and BD in the field.

MATERIALS AND METHODS

The study was conducted on 79 soil profiles. The soils in the database came from the Polish mountainsides located in the Carpathian and Sudety Mts., and include: Little and Silesian Beskids, the Ciężkowickie and Silesian Foothills (Miechówka *et al.* 2009, 2011, 2012), the Pieniny (Zaleski *et al.* 2016), and Bieszczady (Wanic unpublished data) Mountains, Babiogórski National Park (Brożek *et al.* 2013), and the Giant (Kabała *et al.* 2010) and, Stołowe (Kabała *et al.* 2015) Mountains. All of them were classified as brown earths (according to the PSC 2011), divided into two types – BD (28 soil profiles) and BEt (26 soil profiles) – and one subtype – BEw (23 soil profiles). The analyses focused on the horizons at the depth from 25 to 75 cm, because this is the depth which is used for classifying brown earths (PSC 2011). The soils were analysed both in the field and in the laboratory. The fieldwork included obtaining a description of the soil morphology and a measurement of pH using a Hellige indicator. Soil properties, such as the CaCO_3 content (using the volumetric Scheibler method) and the texture (organoleptic method), were determined in the laboratory. BS was calculated according to the equation:

$$BS = 100 \times S / (S + Hh) [\%] \quad (1)$$

Where: S is the sum of the exchangeable bases (Ca^{2+} , Mg^{2+} , K^+ , Na^+) extracted using 1M NH_4Cl at pH 8.2 and measured by the ICP-OES (Optima 7300 DV) method, and Hh is the total potential acidity (in Poland known as “hydrolytic acidity”). Hh was extracted with 1M $(\text{CH}_3\text{COO})_2\text{Ca}$ at pH 8.2 and titrated by using 0.1M NaOH (Kappen method). The hydrolytic saturation (HS) was calculated according to the equation:

$$HS = 100\% - BS [\%] \quad (2)$$

Using equations 1 and 2, we plotted a scatter diagram based on the Hellige pH and BS values for each specific soil type. Statistical analyses, including a Pearson linear correlation between Hellige pH and BS, a scatter diagram of Hellige pH vs. BS and HS, a regression equation and principal component analysis (PCA), were performed using Statistica 12.0 and Canoco 5 software.

RESULTS

According to Polskie Towarzystwo Gleboznawcze (2009), the soil texture of the BEt belonged to: sandy loam, sandy clay loam, loam, clay loam, silty clay loam, silt loam, silt, silty clay and clay. The pH of the BEt ranged from 5.1 to 8.6. The BS values ranged from 63.3% to 97.6%, with a mean value of 88.9%, whereas the HS values ranged from 2.4% to 36.7%, with a mean of 11.1%. The CaCO_3 content was within the range from 0.03% to 14.5%. The soil texture of the BEw belonged to: loam, clay loam, silty clay loam, silt loam, silt, sandy clay, clay. The BEw were characterised as slightly acid to alkaline (pH 5.6–7.7). Their BS values ranged from 63.3% to 98.1% (mean 85.1%), HS from 1.9% to 36.7% (mean 14.9%) and the CaCO_3 content was 0.0% (Table 1). The BD did not contain carbonates. The soil texture of the BD were characterised as: loamy sand, sandy loam, loam, silty clay loam, silt loam. Their pH ranged from 3.7 to 6.1. The BD had the lowest BS among the studied soils, lying between 2.6% and 58.9% (mean 28.8%). The HS values ranged from 41.1% to 97.4% (mean 71.2%). The soil that was not included in either type or subtype (Exception I) was assigned as clay loam. In this soil, the pH was slightly acid (pH 6.1). The BS was 56.0% and the HS was 44.0%. The CaCO_3 content was 0.48% (Table 1).

Statistical analysis of the results (Fig. 1) indicated a positive correlation between the pH measured in the field (Hellige pH) and the BS for each investigated soil type. The mean pH value for the BD was 5.0, correlating with a mean BS value of less than 40%. The mean Hellige pH and BS in the BD (mean of Hellige pH 5.0) were different than the same parameters in the BEt (mean of Hellige pH 7.5) and BEw (mean of Hellige pH 7.3). The mean values of BS and Hellige pH did not differ significantly between the BEw and BEt (Fig. 1). PCA

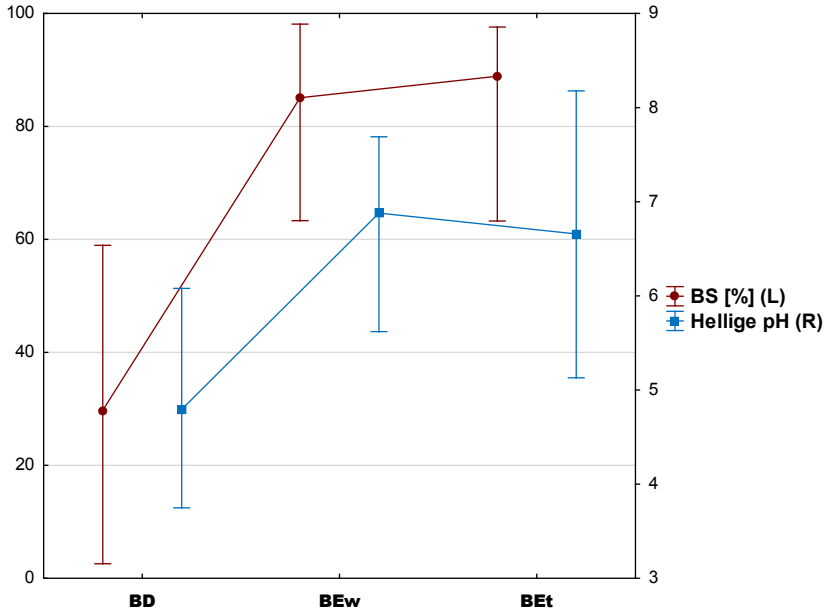


Fig. 1. Mean values of base saturation BS and Hellige pH

BD – typical dystrophic brown soils (*gleby brunatne dystroficzne typowe*), BEw – leached eutrophic brown soils (*gleby brunatne eutroficzne wylugowane*), BEt – typical eutrophic brown soils (*gleby brunatne eutroficzne typowe*), BS – base saturation.

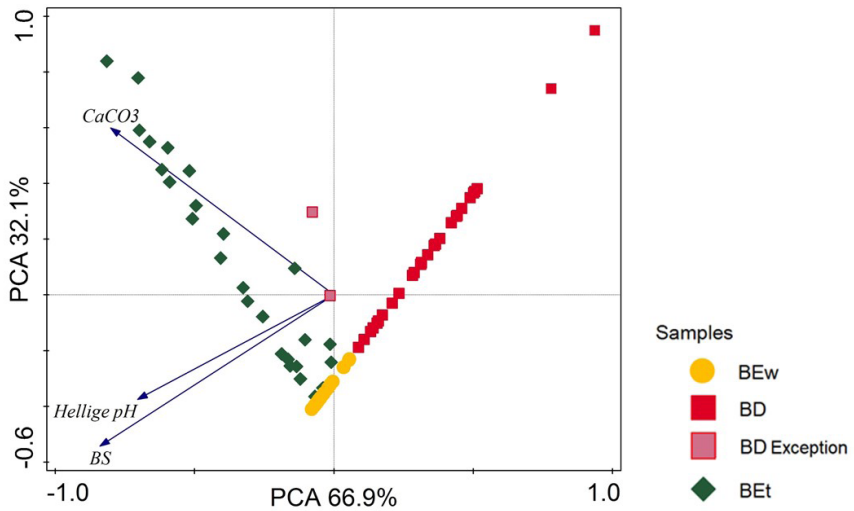


Fig. 2. Principal component analysis (PCA) for brown earths

BD – typical dystrophic brown soils (*gleby brunatne dystroficzne typowe*), BEw – leached eutrophic brown soils (*gleby brunatne eutroficzne wylugowane*), BEt – typical eutrophic brown soils (*gleby brunatne eutroficzne typowe*), BS – base saturation.

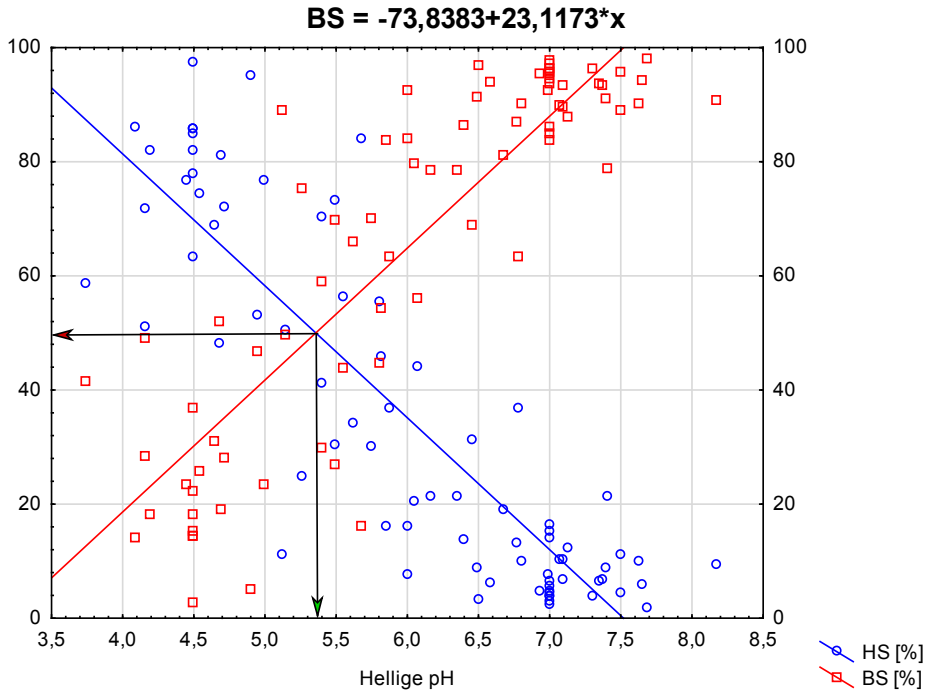


Fig. 3. Scatter diagram Hellige pH vs. BS, HS

BS – base saturation, HS – hydrolytic saturation.

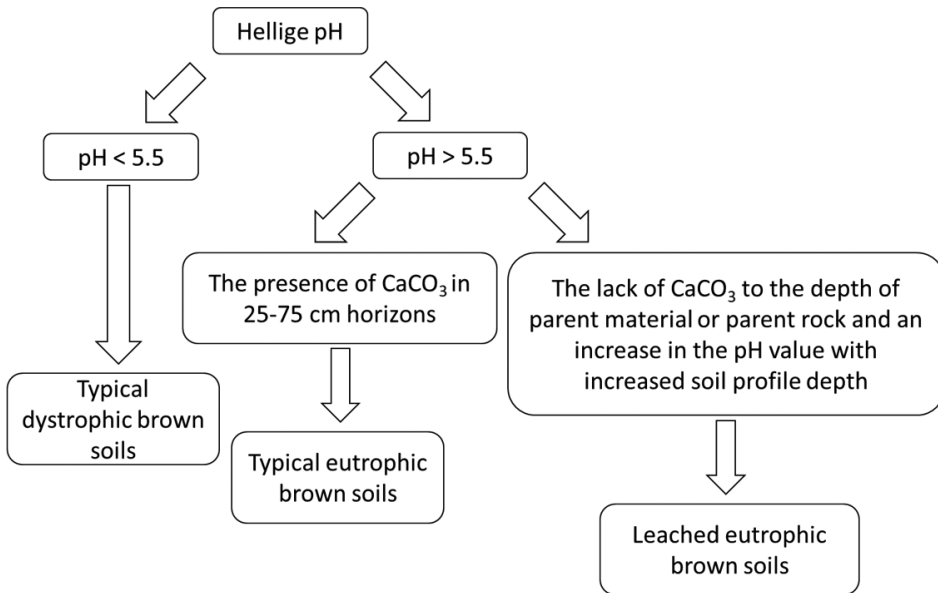


Fig. 4. The field guide for identifying brown earths

showed that the soils from the BEt group were closely connected to CaCO_3 (Fig. 2). In addition, the PCA confirmed the strong correlation between Hellige pH and BS. Based on PCA, it was noted that BEt and BD varied, with the exception of one typical dystrophic soil, which occurred in a different place in the ordination space. This soil was characterised by a BS of less than 60% and had CaCO_3 (0.48%) in the horizons at the depth of 25–75 cm. The scatter diagram (Fig. 3), showing Hellige pH vs. BS and HS, indicates that a pH of 5.5 and a BS of 50% are the threshold values for the classification of eutrophic brown soils and dystrophic brown soils. Taking into account all of the statistical analyses, there was created a field guide for the classification of brown earths (Fig. 4).

Table 1. Basic properties of the studied horizons between 25 and 75 cm

Soil type	HS [%]	BS [%]	Soil textural classes (PTG 2009)	pH H ₂ O	Hellige pH	CaCO ₃ [%]
BEt (n = 26)	11.1±9.0 (2.4–36.7)	88.9±9.0 (63.3–97.6)	SL, SCL, L, CL, SiCL, SiL, Si, SiC, C	6.7±0.7 (5.1–8.6)	7.5±0.7 (5.0–8.5)	3.2±3.8 (0.03–14.5)
BEw (n = 23)	14.9±10.0 (1.9–36.7)	85.1±10.0 (63.3–98.1)	L, CL, SiCL, SiL, Si, SC, C	6.9±0.6 (5.6–7.7)	7.3±0.6 (6.0–8.0)	0.0±0.0 (0.0–0.0)
BD (n = 28)	71.2±15.4 (41.1–97.4)	28.8±15.4 (2.6–58.9)	LS, SL, L, SiCL, SiL	4.8±0.6 (3.7–6.1)	5.0±0.8 (4.0–6.5)	0.0±0.0 (0.0–0.0)
Exception I	44.0	56.0	CL	6.1	6.0	0.48

BD – typical dystrophic brown soils, BEw – leached eutrophic brown soils, BEt – typical eutrophic brown soils, HS – hydrolytic saturation, BS – base saturation – mean, standard deviation values and minimum and maximum values in the brackets. Soil texture: LS – loamy sand, SL – sandy loam, SCL – sandy clay loam, L – loam, CL – clay loam, SiCL – silty clay loam, SiL – silt loam, Si – silt, SC – sandy clay, SiC – silty clay, C – clay.

DISCUSSION

A comparison between the 1989 and 2011 PSC showed differences in the BS limit values, which is one of the main factors used for dividing brown earths into two types – typical and acidic brown soils (PSC 1989) and eutrophic and dystrophic brown soils (PSC 2011); the Classification of Forest Soils in Poland (2000) was based on different BS limit values. This is important from the perspective of forestry (forests cover approximately 30% of Poland). It has been shown that a BS value of 60% (PSC 2011) is too high; according to Brożek (2012), dystrophic brown soils (according to the PSC 2011), characterised by a BS of 59% in the horizons at the depth of 25–75 cm, cannot be called “dystrophic brown soils”. The forest soils characterised by such high BS are rich eutrophic soils, or possibly oligotrophic or mesotrophic soils, which form rich forest units. Brożek (2012) also highlighted that the silty loam soil texture used in the PSC (2011) to define dystrophic brown soils contradicts the

term “dystrophic”. The name “dystrophic brown soils”, used in the PSC (2011) is inaccurate, indicating infertile soils and does not leave space for rusty soils, podzol soils and arenosols (Brożek 2012). Kabała (2014) proposed division of brown earths into three basic subtypes (proper brown soils, leached brown soils and acid brown soils). The received results and statistical analyses herein confirmed that these changes are needed. This requires a reversion to the divisions used in the PSC (1989) and, at the same time, maintains the brevity of the WRB classification (IUSS Working Group WRB 2015), where one unit – *cambisols* – is used. Based on the statistical analyses, a change in the BS limit from 60% to 50% is suggested. The proposed value (50%) is connected with accords with the BS used in the WRB (IUSS Working Group WRB 2015) and the Classification of Forest Soils in Poland (2000). This change would also help in classifying soils such as the one mentioned in this paper (Exception I) which had a BS of 50%–60% and had carbonates in the horizons at the depth of 25–75 cm; in this case, “Exception I” would be classified as a typical brown soil.

The CaCO_3 content is also an important factor in classifying brown earths. The presence of CaCO_3 in a profile to 100 cm depth classifies the soil as eutrophic (PSC 2011), whereas a lack of CaCO_3 in the profile to 100 cm depth classifies it as a BD or BEw. CaCO_3 content in the classification of brown earths is mandatory, but we suggest some changes to its limits. Typical brown soils should be characterised by the presence of CaCO_3 (primary or secondary) in the entry soil profile (at least to 50 cm depth). Leached brown soils should not have any CaCO_3 to the depth of the parent material or rock. In acidic brown soils, CaCO_3 should not occur throughout soil profile, including the parent material or parent rock. In addition, it is worth taking into consideration the fact that in Polish soil science, in leached brown soils, the pH value always increases with increasing depth of soil profile. A record of this fact in the Polish Soil Classification is suggested and should be discussed by the Commission Genesis, Classification and Cartography of Soils.

Another problem with the classification of brown earths is how to classify them in the field. In PSC (1989, 2011), brown earths are classified mainly based on the BS value. Determining this value in the field is impossible, thus making it impractical for soil classification during fieldwork. Based on our statistical analyses, we aimed to formulate a guide for classifying proper (typical) brown soils, leached brown soils and acid brown soils in the field. The research conducted by Kabała and Łabaz (2018) confirm that base saturation and soil pH are highly positively correlated, and pH can be used as a proxy for base saturation in the field. Thus, the field guide is based on the Hellige pH, as measured in the field, and the presence of CaCO_3 , which would enable the determination of the subtypes of brown earths (Fig. 4).

CONCLUSIONS

1. The research has shown usefulness of the Hellige pH to classify brown earths in the field. The pH measured in the field using a Hellige indicator (Hellige pH), corresponds closely to the BS values calculated in the laboratory.
2. This study has confirmed the necessity to change the hierarchy of brown earth types, with one type of brown earths being divided into three subtypes – proper brown soils, leached brown soils and acid brown soils, using a BS – 50% to distinguish the different subtypes.
3. Leached eutrophic brown soils/leached brown soils should be classified on the basis of the absence of CaCO₃ to the depth of the parent material or rock and the increase in pH with depth in the soil profile. The difference in pH between 25 cm and 75 cm (or the parent material) should be at least 1.5 units.

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