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RECLASSIFYING POLISH SOIL-AGRICULTURAL MAPS INTO USDA-COMPLIANT PTG2008 SOIL TEXTURAL CLASSIFICATION. CONSEQUENCE FOR MODELLING ENVIRONMENTAL PHENOMENA EXAMPLIFIED BY WIND EROSION

Abstract. This paper is a side effect of preparing international publications on our long term research on soils' susceptibility to wind erosion. For the paper to be internationally understandable we had to translate the texture classes from the Polish soil-agricultural maps (PTG1974), used as a basis to derive ten soil units investigated in the experiments, into the widely recognised USDA classification. We spotted that the PTG1974 classes of sandy soils, falling into USDA single SAND class, have large, reaching 1620% difference in deflation rates, 25% in the case of LOAMY SAND and SANDY LOAM class the difference was 300%. The differences of this magnitude within a single textural class imply that the USDA classes may be too general to be used in some domains of environmental modelling. This also implies that translating soil kinds (soil textural classes) in Polish soil-agricultural maps into the USDA textural classes is not rational and may lead to the loss of spatial variability of soil cover and the loss of credibility in modelling of environmental phenomena.

In Poland a soil-agricultural map remains the main source of information on soil cover. The map is a result of a country-wide surveying campaigns performed in the sixties of the 20th century, under the coordination of the Institute of Soil Science and Plant Cultivation in Pulawy (IUNG). The main reference map is in the scale of 1:5000. Several derivative maps with slightly different legends were developed in the scales of: 1:25000, 1:100000 and 1:500000. All of them have been digitised at

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the IUNG into spatial datasets and are widely used in spatial planning, research, environmental modelling, and especially environmental impact assessments. The description of a soil unit or polygon in the 1:5000 soil-agricultural map consists of:

Agricultural soil complex, describing the habitat in the form of its suitability for certain reference crops, e.g. maize, rye or white beet;

Soil type according to the PTG 1974 classification;

Soil kinds or textural classes in a soil profile, compatible with the PTG 1974 classification. Spatial character is added to each layer, providing the depth of its occurrence;

Tax category (bonitation class);

Polygon number and area;

Location and number of soil profile.

The original classification of soil texture derived from 6 main sorts of soils, consisting of several kinds (texture classes):

Gravels with 2 kinds (classes): sandy gravel and loamy gravel;

Sands with 4 kinds (classes): loose sand, weal-loamy sand, light loamy sand and strong loamy sand;

Loams with 3 kinds (classes): light loam, mean loam, heavy loam;

Clays with 2 kinds (classes): clay, silty clay;

Silts with 2 kinds (classes): ordinary silt, clayey silt;

Loess with 2 kinds (classes): ordinary loess and clayey loess;

Additionally there are three kinds of rendzinas and two kinds of mountain rocky soils plus 5 additional units for alluvial soils and bare rock. Altogether there are 25 soil texture units (soil kinds) to be found on a 1:5000 soil-agricultural map.

Throughout the years there were several updates of the PTG1974 soil taxonomy system. The most recent one was published in 2011 [1], while the soil textural classification was updated in 2008[2]. The soil textural classes introduced in 2008 are compatible with the USDA particle diameter and texture class definition. The translation of the Polish PTG'74 into the USDA was published by the Polish Society of Soil Science in Soil Science Annual (Roczniki Gleboznawcze tom LX Nr 2) on page 14. In general the transformation scheme presented in this article results in the aggregation of the PTG1974 texture classes, which obviously means deterioration of detail and may cause the loss of information on the diversity of soil cover in a spatial dimension. Potentially this aggregation may lead to an increase in uncertainty in modelling phenomena, in the case of which soil properties remain an important input by increasing the bias of results originated in poor spatial representation of soil texture. A good example of such modelling is watershed modelling, in the case of which spatial diversity of input data plays a key role in shaping the watershed properties: discharge, lag time, superficial outflow, erosion rates.

An exercise was established to assess in a quantitative way the consequences of direct transformation of soil texture classes between the PTG1974 and the USDA for a chosen physical phenomenon that may be modelled in two-dimensional space. We used a series of 181 measurements from the existing data collected during the long-term research on soil deflation.

METHODS

Polish [4,5] and international data [6–13] points at erosion as a main soil degradation factor. In Poland, the qualitative erosion risk maps[2] estimate wind erosion to affect 28% of unforested land surface, while the area of land totally degraded with soil erosion and unsuitable for agriculture is estimated to cover 700 thousand hectares.

Although the processes of erosion are considerably well recognised, their quantitative valuation, which remains strongly variable between local conditions, still needs continuing and widening of research in all spatial scales, starting from a plot throughout catchment up to national and regional extents [8, 14]. Although investigations at a plot scale, being actually point data, are considered unsuitable for country-wide erosion risk/intensity assessments [8, 13], they are very valuable in testing and validating modelling concepts [15–17] and providing good quality inputs for the models. For instance, the theoretical equations within the PESERA model were calibrated using plot measurements [8].

There are two main ways of field research regarding soil erosion: the first one, conducted in a passive way in natural conditions, without intervention in the course of erosion processes [8, 18, 19]. The main advantage of such an approach is the reflection of real state whereas the main disadvantage remains the long time period required for collecting sufficient amount of data for estimations of suitable quantitative indicators. The second method [8, 20, 21] a simulated research may be done in a shorter time period, which accelerates the estimation of interdependencies between factors and effects of erosion processes and allows for better control of the value ranges.

Model research on soils' susceptibility to wind erosion

In result of cartographical studies, performed on 1:5000 digital soil maps, precise locations of soil contours representing ten kinds of soil kinds were selected; three species from each group differing with susceptibility to deflation [21] (Table 1): loose sands(pl), weak clayey sands (ps) light clayey sands (pgl), strong clayey sands (pgm), light loam (gl), medium loam (gs), ordinary silt (płz), loess (ls), medium rendzina (Rs) and medium aluvial soil (Fs).

TABLE 1. TEXTURAL PARAMETERS OF CHOSEN TEN STUDIED SOILS

No.	Soil type (WRB 2006)	Texture PTG'74 (BN-78/9180–11)	Symbol	Texture (USDA[2])	Particle group content % (BN-78/9180–11)		
					sand 1–0,1 mm	silt 0,1–0,02 mm	clay <0,02 mm
1	Brunic Arenosol	loose sand	pl	Sand	90	5	5
2	Brunic Arenosol	weakly-loamy sand	ps	Sand	76	17	7
3	Haplic Cambisol	light loamy sand	pgl	Loamy sand	68	18	14
4	Cambic Albeluvisol	strong loamy sand	pgm	Loamy sand	60	20	20
5	Haplic Chernozem	light loam	gl	Sandy loam	52	22	26
10	Mollic Fluvisol	strong loamy silty sand	pgmp	Sandy loam	45	36	19
6	Haplic Hernozem	medium loam	gs	Sandy clay loam	28	24	48
9	Rendzic Phaeozem	heavy loam	gc	Clay loam	29	6	65
7	Haplic Cambisol	regular silt	pLz	Silt	13	67	20
8	Haplic Cambisol (Eutric)	loamy silt (loess)	pLg (ls)	Silt loam	9	60	31

The soil material was transported to experimental area and placed to dedicated chests – micro-plots [20, 21] 1m wide and 2 m long each. The plots were kept in permanent harrowed black fallow at the slope of 10%, with the wind direction down-slope.

Simulated deflation was carried out in a period from early March to early October in favourable weather conditions (positive temperature with absence of natural precipitation for at least 5 days).

Each simulation was accompanied by measurements of initial soil humidity, wind speed, and amount of soil blown off and caught by the cyclones. Simulations were ran in 9-hour-long sessions.

The mechanism of deflation measurement in each micro-plot was the following [22, 23]: soil material from a micro-plot was being deflated by the simulated wind which was generated with a regulated radial blower and directed through a 0,5 m wide, 0,4 m high, 2 m long wind tunnel placed tightly over a surface of a micro-plot. The tunnel was tightly adjusted to the surface of a micro-plot to ensure all the wind energy and soil mass stay within the tunnel.

At the time of the beginning of the simulation, the soil humidity at 4 levels: 5, 15, 25 and 35 cm was measured to assess not only the influence of soil

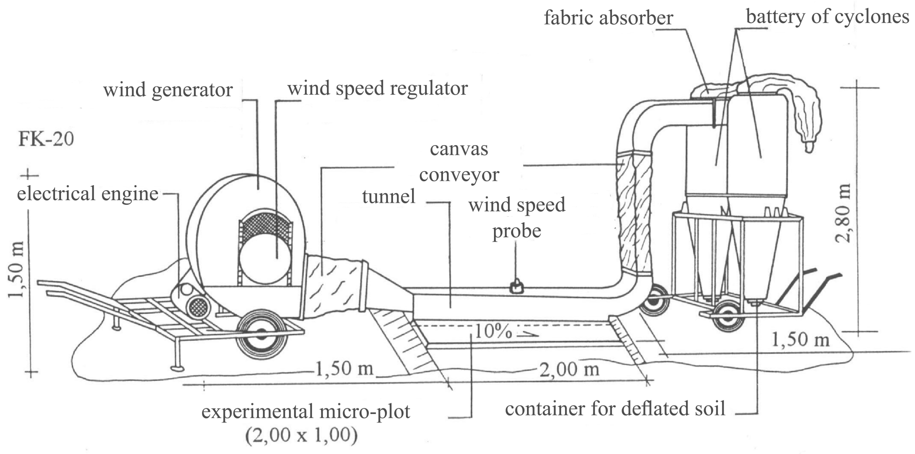

Fig. 1. The scheme of the model experiment of soilsabsence of natural precipitation for at least 5 days). ys). c [23].

humidity on the deflation rates but also to collect measurements on the drying effect of wind in the upper soil profile. The soil particles deflated and transported by the simulated wind outside the micro-plot were directed into two cyclones of the flow meter and deposited into containers. After 9 hours of simulation the containers were removed and the mass of eroded soil was measured.

There are numerous indications of the wind speed threshold value, over which wind erosion starts to occur. Stetler and Saxton [24] point at 6.35 $m \cdot s^{-1}$, while Johnson [25] points at 8 $m \cdot s^{-1}$. In this research the latter value was adopted.

RESULTS

The simulated research on the deflation rates for different soils was carried out in the years 1996–2015. For the sake of this exercise we chose a series of 181 measurements collected in 2001 and 2002.

The amount of deflated material differed largely between the investigated soil kinds (Table 2). The highest deflation rate was observed on Arenosol soil with the texture of loose sand amounting to 86.26 g m^{-2}, then – on Arenosol on weak loamy sand 61.48 g m^{-2}. The smallest deflation was observed on alluvial strong loamy silt sand Fluvisol amounting to 5.92 g m^{-2}.

TABLE 2. AVERAGE VALUES OF OBSERVED DEFLATION FOR POLISH PTG'79 TEXTURE CLASSES

Plot No	Soil type (WRB 2006)	Texture PTG'74 (BN-78/9180–11)		USDA texture class	Deflation [g m^{-2}]
1	Brunic Arenosol	loose sand	pl	Sand	1032,4
2	Brunic Arenosol	weakly-loamy sand	ps	Sand	59,9
3	Haplic Cambisol	light loamy sand	pgl	Loamy sand	26,1
4	Cambic Albeluvisol	strong loamy sand	pgm	Loamy sand	15,9
5	Haplic Chernozem	light loam	gl	Sandy loam	15,4
10	Mollic Fluvisol	strong loamy silty sand	pgmp	Sandy loam	4,8
6	Haplic Hernozem	medium loam	gs	Sandy clay loam	28,0
9	Rendzic Phaeozem	heavy loam	gc	Clay loam	8,5
7	Haplic Cambisol	regular silt	plz	Silt	29,1
8	Haplic Cambisol (Eutric)	loamy silt (loess)	ls	Silt loam	17,9

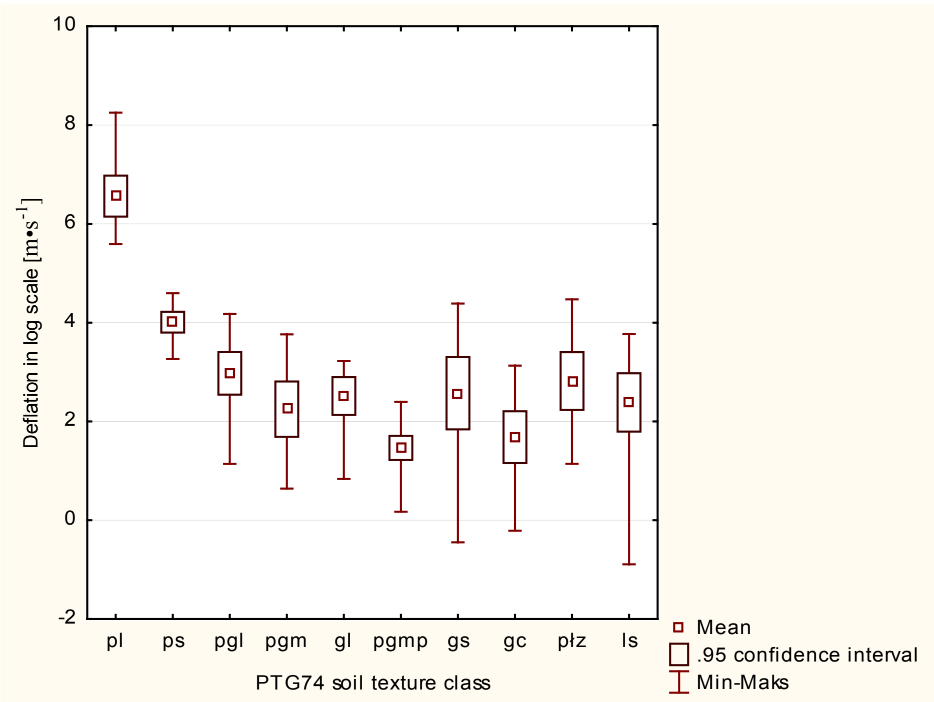

Figure 2. Deflation (log10) registered for 10 different PTG74 soil texture classes

DISCUSSION

Most of the country-wide soil maps available in Poland are based on the PTG'74 soil classification (the industrial norm BN-78/9180–11). They distinguish 25 kinds of 9 texture classes within the group of mineral soils. Due to the evolution of the soil taxonomy in Poland as well as the growing need to make the soil cartography interoperable and more widely available to the public, the Polish Society of Soil Science elaborated a transformation scheme between soil kinds from the older Polish classifications to 10 USDA textural classes [2].

Comparing the average deflation rates between six soil texture classes from the PTG'74 classification and their generalised texture classes according to the USDA classification (Table 2), a significant loss of information is evident for the SAND USDA class, in the case of which the difference between loose sand and weak loamy sand is more than fifteen-fold. For the LOAMY SAND class, the difference reaches barely 24% of the average rate. Although there is a large (three-fold) difference in SANDY LOAM texture class, the absolute deflation values are far lower than those for sands.

The observed variability of the deflation experiment results within the USDA texture classes generalised from the Polish PTG'74 soil taxonomy, puts into question the point to use the USDA taxonomy in cartographic assessments in Poland based upon existing agricultural soil maps which offer both a much higher diversity of texture classes as well as they are supplemented with a wide database of geo-tagged reference soil profiles.

These findings also imply a question on the generalisation of results to be published in international journals. It has become visible, especially for the above mentioned case of deflation rates within the SAND textural class, that averaging may not be an option for that high range of diversity of a given phenomenon within a textural class.

The issue of the transformation between soil taxonomies is of special importance in the aspect of practical implementation of the INSPIRE Directive [27] and preparation of datasets compliant with the data specifications of the INSPIRE soil theme [28]. The transformation schemes between existing soil data models and classifications assure overall interoperability of data, however the influence of the transformations onto the response to the representation of physical phenomena is not yet well recognised and assessed in the INSPIRE guidelines.

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DOSTOSOWANIE POLSKICH MAP GLEBOWO-ROLNICZYCH W ZAKRESIE KLASYFIKACJI UZIARNIENIA GLEB WG PTG2008 DO SYSTEMU USDA

Niniejszy artykuł traktuje o niekorzystnych efektach generalizacji gatunków gleb obecnych na mapie glebowo-rolniczej na przykładzie badań nad erozją wietrzną gleb. Przypadkiem, w czasie przygotowywania danych do publikacji w międzynarodowym czasopiśmie, odkryliśmy, że generalizując gatunki gleb obecne w mapie glebowo-rolniczej na klasyfikację USDA według reguły opublikowanej przez PTG w 2008 roku, tracimy zróżnicowanie w podatności gleb na erozję wietrzną, występujące naturalnie między gatunkami PTG 1974 ujętymi w obrębie jednej klasy USDA. W klasie piasku USDA, która łączy w sobie pl i ps z klasyfikacji PTG 1974, zakres różnic w deflacji zaobserwowanej w wyniku bezpośrednich pomiarów doświadczalnych sięga 1620%, w klasie USDA piasku gliniastego: 25% zaś w klasie USDA gliny piaszczystej – 300%. Przy różnicach tej wielkości w obrębie jednej klasy USDA należałoby bardzo ostrożnie podchodzić do projektowania doświadczeń polowych jak również przygotowania danych do modelowania procesów, pozostając przy klasyfikacji PTG1974, na której oparte są mapy glebowo-rolnicze a nie bezpośrednio na klasyfikacji USDA. Również przy statystycznej obróbce wyników i dyskusji wskazanym byłoby podawać oryginalne nazwy gatunków gleb wg PTG 1974 obok odpowiadających im klas USDA.