TESTING WRB ON POLISH SOILS





Przemysław Charzyński

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Contents

1. INTRODUCTION 13
2. AIM OF THE PUBLICATION AND METHODS EMPLOYED 17
   2.1. AIM 17
   2.2. METHODS 18
3. CRITERIA FOR DELIMITATION OF SOIL UNITS IN THE *SYSTEMATICS OF POLISH SOILS* AND IN THE WRB SOIL CLASSIFICATION 20
   3.1. CRITERIA FOR DELIMITING SOIL UNITS IN THE *SYSTEMATICS OF POLISH SOILS* 20
   3.2. CRITERIA FOR DELIMITING SOIL UNITS IN THE WRB CLASSIFICATION 20
4. DIAGNOSTICS 22
   4.1. COMPARISON OF DEFINITIONS OF SURFACE DIAGNOSTIC HORIZONS (EPIPEDONS) DIFFERENTIATED IN THE *SYSTEMATICS OF POLISH SOILS* (SPS) AND THEIR EQUIVALENTS IN THE WRB SOIL CLASSIFICATION 22
      4.1.1. Comparison of the definition of the *mollic* horizon according to both the SPS and the WRB 23
      4.1.2. Comparison of the definition of the *anthropic* horizon according to the SPS with the *terric*, *hortic* and *anthraquic* horizons according to the WRB 24
      4.1.3. Comparison of the definition of the *plaggen* horizon according to the SPS and the *plaggic* horizon according to the WRB 25
      4.1.4. Comparison of the definitions of the *umbric* horizon according to both the SPS and WRB classifications 25
      4.1.5. The *melanic* horizon 26
      4.1.6. Comparison of the definition of the *histic* horizon according to both the SPS and the WRB 26
      4.1.7. Comparison of the definition of the *ochric* horizon according to both SPS and the WRB classification 27
   4.2. COMPARISON OF THE DEFINITIONS OF THE SUBSURFACE HORIZONS (ENDOPEDONS) DIFFERENTIATED IN *SYSTEMATICS OF POLISH SOILS* AND THEIR EQUIVALENTS IN THE WRB SOIL CLASSIFICATION 27
      4.2.1. Comparison of the definition of the *cambic* horizon according to both the SPS and the WRB classification 30
      4.2.2. Comparison of the definitions of the *argillic* horizon according to the SPS and *argic* horizon according to the WRB classification 30
      4.2.3 Comparison of the definition of the *natric* horizon according to both the SPS and the WRB classification 31
      4.2.4. Comparison of the definitions of the *spodic* horizon according to both the SPS and the WRB classification 31
      4.2.5. Comparison of the definitions of the *albic* horizon according both to the SPS and the WRB classification 32
      4.2.6. Comparison of the definition of the *fragilic* horizon according to the SPS and the *fragic* horizon according to the WRB 32
      4.2.7. Comparison of the definitions of the *salic* horizon according to both the SPS and the WRB classification 33

4.2.8. Comparison of the definitions of the *calcic* horizon according both to the SPS and the WRB classification ... 33
4.2.9. The *sideric* horizon according to the SPS ... 33
4.2.10. The *luvic* horizon according to the SPS ... 34
4.2.11. The *glejospodic* horizon according to the SPS ... 34
4.2.12. *Gleyic mottling* according to the SPS ... 34
4.2.13. The *agric* horizon according to the SPS ... 34
4.2.14. The *placic* horizon according to SPS ... 34
4.3. DIAGNOSTIC PROPERTIES AND DIAGNOSTIC MATERIALS DEFINED IN THE WRB SOIL CLASSIFICATION ... 35
4.3.1. Diagnostic properties ... 35
4.3.2. Diagnostic materials ... 35
5. COMPARISON OF THE DEFINITIONS OF THE LITHOGENIC SOILS TYPES IN *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 36
5.1. NONCARBONATE SOILS, INITIAL AND WEAKLY DEVELOPED ... 36
5.1.1. Initial loose soils (regosols) ... 37
5.1.2. Noncalcareous soils weakly developed from solid rocks (rankers) ... 37
5.1.3. Soils weakly developed from loose materials (arenosols) ... 38
5.1.4. Correlation of the soil types of the noncarbonate soils, initial and weakly developed with the units of the WRB soil classification ... 38
5.2. LITHOGENIC CALCAREOUS SOILS WITH DIFFERENT DEVELOPMENT DEGREE ... 39
5.2.1. Rendzinas ... 40
5.2.2. Pararendzinas ... 42
6. COMPARISON OF THE DEFINITIONS OF AUTOGENIC SOILS TYPES IN *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 44
6.1. CHERNOZEMIC SOILS ... 44
6.1.1. Chernozems ... 44
6.2. BROWN FOREST SOILS ... 46
6.2.1. Proper brown soils and acid brown soils ... 46
6.2.2. Soils Lessivès ... 49
6.3. PODZOL SOILS ... 52
6.3.1. Rusty soils ... 52
6.3.2. Podzol soils and podzols ... 54
7. COMPARISON OF THE DEFINITIONS OF SEMI-HYDROGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 57
7.1. GLEY-PODZOL SOILS ... 57
7.1.1. Gley-podzol soils and gley-podzols ... 57
7.2. BLACK EARTHS ... 59
7.2.1. Black earths ... 59
7.3. BOGGED SOILS ... 62
7.3.1. Pseudogley soils ... 62
7.3.2. Gley soils ... 64
8. COMPARISON OF THE DEFINITIONS OF HYDROGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 66

8.1. BOGGED SOILS ... 66
8.1.1. Mud soils ... 66
8.1.2. Peat soils ... 67
8.2. POST-BOG SOILS ... 69
8.2.1. Muck soils ... 69
8.2.2. Mucky soils ... 70
9. COMPARISON OF THE DEFINITIONS OF ALLUVIAL AND DELUVIAL SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 73
9.1. ALLUVIAL SOILS ... 73
9.1.1. River alluvial soils and marsh alluvial soils ... 73
9.2. DELUVIAL SOILS ... 76
9.2.1. Deluvial soils ... 76
10. COMPARISON OF THE DEFINITIONS OF SALINE SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 79
10.1. SALINE-SODIC SOILS ... 79
11. COMPARISON OF THE DEFINITIONS OF ANTHROPOGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION ... 80
11.1. CULTURE EARTH SOILS ... 80
11.1.1. Hortisols ... 80
11.1.2. Rigosols ... 81
11.2. INDUSTRIAL EARTHS AND URBAN SOILS ... 81
12. COMPARISON OF THE DESCRIPTION OF SMOLNICAS FROM THE APPENDIX TO *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENT IN THE WRB CLASSIFICATION ... 83
13. CONCLUSIONS ... 84
13.1. PROPOSITIONS FOR THE NEW EDITION OF THE *SYSTEMATICS OF POLISH SOILS* ... 84
13.1.1. General changes ... 84
13.1.2. Suggestions for changes in the definitions of the epipedons ... 85
13.1.3. Suggestions for changes in the definitions of the endopedons ... 86
13.1.4. Suggestions for changes in soil units ... 87
13.2. PROPOSITIONS FOR THE NEW EDITION OF WRB SOIL CLASSIFICATION ... 89
13.2.1. Suggestions for changes in the definitions of soil horizons and soil units ... 89
13.2.2. Suggestions for changes in the definitions of qualifiers ... 90
13.3. SUMMARY ... 91
REFERENCES ... 94
APPENDIX 1
DEFINITION OF *SIDERIC* HORIZON AND RZAVOSOLS SOIL REFERENCE GROUP – PROPOSAL ... 105
APPENDIX 2
ENGLISH TRANSLATIONS OF POLISH NAMES OF SOIL UNITS ... 106
APPENDIX 3
ACRONYMS AND ABBREVIATIONS USED IN THE TEXT ... 110

‘Classification is a basic requirement of all science and needs to
be revised periodically as knowledge increases’
(R. F. Isbell 1996)

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1. INTRODUCTION

Even the earliest ancient agricultural civilizations used quasi soil classifications based on fertility and productivity of soils, which have not survived until modern times. One of the earliest documented land evaluation systems that incorporated a soil classification was established in China during the Vao dynasty (2357–2261 BC). Soils were graded into nine classes, based on their productivity. It has been suggested that property taxes were based on the size of the individual land holding and soil productivity (Lee 1921, after: Ahrens, Rice, Eswaran 2003). About 2.5 thousand years ago a soil classification was published in Yugong. It was based on the following criteria: fertility, colour, texture, moisture conditions and salinity (Gong Zhang, Chen 2003). Theophrastus from Eresium on the isle of Lesbos (371–286 BC) can be called 'the Father of Soil Science', although he did not create one homogenous system of soil classification. Nevertheless, he precisely characterised a large variety of soil cover based on numerous distinguishing features, which he used inconsequently. Cato (Marcus Porcius Cato, 234–149 BC), widely regarded as the oldest of the main soil scientists of Rome, worked out a classification based on agricultural usefulness of soil types. His system included 9 types and 21 subtypes (Strzemski 1971, 1975).

Soil science as a branch of science appeared only at the end of the 19th century. The date of 14 April 1879 is regarded as the birth of modern soil science. It was then that Vasil Dokuchaiev gave a lecture on soil classification at the meeting of the Geology and Mineralogy Branch of the Petersburg Association of Nature Researchers (Strzemski 1971). This event supports the idea that the issue of classification is crucial for every branch of science. The Dokuchaiev system, modified and widened, was published in 1886 in the first volume of 'Materials for Land Valuation in Nizegorodskij District' (Dokuchaiev 1886). In the earlier part of the 20th century the school of the genetic approach to soil classification gained much popularity. It was used for regional soil classifications both in Europe and the USA (for instance the papers by Jenny, Aarnio and Stremme, Marbut).

The next milestone in soil classification was giving up the genetic (qualitative) approach in favour of a quantitative approach, which was initiated by the American Soil Survey Staff in 1960.

Sławomir Miklaszewski is widely regarded as the person who created the Polish soil science. Although working out the soil systematics he followed the genetic approach, he did not reject the importance of the achievements of both physicochemical and geological-pethrographic approaches.

Sławomir Miklaszewski's original classification, published in 1906 (Miklaszewski 1906), was based directly on soil properties. As the highest rank units Miklaszewski differentiated siliceous, calcareous and humus soils. The following editions, the second one of 1912 (Miklaszewski 1912) and the third one of 1930 (Miklaszewski 1930), differentiated also alluvial soils.

The post-war soil systematics in Poland is tightly connected with Arkadiusz Musierowicz and the Polish Society of Soil Science (PTG). The first detailed soil classification of the PTG and A. Musierowicz was published in 1956 (PTG). Next edition was published in the 1959, while the 3rd, modified one – in 1974. The contemporary edition of the *Systematics of Polish Soils* (4th edition) was published in 1989 (PTG).

In spite of the fact that over a hundred years have passed since the beginning of modern soil science, neither in the world nor in Poland the issue of scientific soil classification has been dealt with satisfactorily (Prusinkiewicz 1985, Dudal 1990).

The reasons for such a situation are numerous. The most important ones included highly diversified soil genesis as well as their physical, chemical and mineralogical variability. Additionally, it is extremely difficult to define spatial limits of a particular soil. A specific feature of soil classification is the fact that soil forms a continuum the properties of which change constantly. This does not ease delimitation of given soil individuals (Prusinkiewicz 1985, Deckers et al. 2002). Moreover, the definition of every taxon (type or soil group) is mostly an intellectual act and it results from the scientist's thinking the issue over. Delimitation of units in the form of soil groups, kinds or types is, in most cases, a difficult matter, which cannot be decided upon fully satisfactorily. The reason for this situation is the fact that taxonomy of soil types is complicated by the existence of numerous transition stages as well as deviations from standards (Strzemski 1971). Due to that the borders between individual systematic units are settled (as they have to be) arbitrarily (Dudal 2003).

Because of a specific character of a soil there has not been created a fully acceptable soil classification so far, not mentioning the soil systematic. Research-based progress in studies on soil genesis and classification led to both improvement of the existing systems (e.g. the *Soil Taxonomy* – Soil Survey Staff 1999), and creation of new, more universal systems of soil classification (WRB – FAO-ISSS-ISRIC 1998). Quite possibly an ideal classification will never be created. However, with time and the development of soil science new, better classifications will appear. In 1959 Manil stated: 'I hope soil scientists will create a universal classification pretty soon […] It could simply be a universally accepted reference system, not necessarily universally adapted'.

In 1998 an international soil classification was published. It is the *World Reference Base for Soil Resources* widely known as the WRB classification. This publication was preceded by publishing and discussing the classification draft four years earlier. The International Union of Soil Science (IUSS) suggests using the WRB classification as a comparative tool. This publication contains the following statement: 'The WRB is designed as an easy means of communication amongst scientists to identify, characterize and name major types of soils. It is not meant to replace national soil classification systems, but be a tool for better correlation between national systems. It aims to act as a common denominator through which national systems can be compared' (FAO-ISSS-ISRIC 1998). The *World Soil Resources Report No. 84*, which includes the WRB soil classification, is supplemented by two publications: *The World Reference Base for Soil Resources. Introduction* (ISSS Working Group

RB 1998a), and *The World Reference Base for Soil Resources. Atlas* (ISSS Working Group RB 1998b).

Contemporarily, the American soil classification – *The Soil Taxonomy* (Soil Survey Staff 1975, 1999) is the most popular world system of that type. It is used in over 40 countries [The Cooperative Research Group of Chinese Soil Taxonomy (CRG-CST) 2001]. However, the WRB soil classification, much younger than the American system, is of growing importance. This classification has already been brought into force in three countries: Italy, Vietnam (Prof. Otto Spaargaren, oral info), as well as Norway which until recently had been using the Canadian classification (NIJOS 2005). Moreover, the WRB soil classification has also been accepted by the European Commission as the official system within the European Union.

Both the *Soil Taxonomy* and the WRB, which is the continuator of the *Legend to the FAO Soil Map of the World in the scale 1:5000000 (FAO-UNESCO 1974, 1988)*, belong to the classifications based on quantitative criteria. They stand out from other classifications with diagnostic horizons and diagnostic materials. Such an approach has dominated the world research on soil classification in the recent decades [for instance the Cooperative Research Group of Chinese Soil Taxonomy (CRG-CST) 2001].

Most of the national systematics which have been published in the last 20 years are based on the two leading world classifications: the *Soil Taxonomy* and, to a lesser degree, the *Legend to the FAO Soil Map of the World in the scale 1:5000000* (FAO-UNESCO 1974, 1988) together with the WRB – its successor. The basic structure and criteria used in these systems are modified in accordance with the local conditions, and implemented with the use of experience of national soil science schools. The definitions of diagnostics (horizons, properties and materials) as well as nomenclature in individual countries are, to a certain degree, adjusted to local conditions [for instance the following classifications: Polish (PTG 1989), South African[1] (Soil Classification Working Group 1991), Brazilian (EMBRAPA 1999), Romanian (Florea, Munteanu 2000), Slovakian (Sobocká 2000), or the Czech one (Nemeček et al. 2001)].

The French system, *Référentiel Pédologique* (AFES 1995), based on the French soil science school, has also much to do with the WRB. Both classifications were created at the same time, and some of the soil units are defined in almost the same way (e.g. Andosols[2]). The way of creating the lower level units by the so called qualifiers is identical in both systems.

Russia has remained the bastion of the traditional soil classification. The Russian soil science school is developing simultaneously to the 'Atlantic' soil science. Both American and West-European have limited influence on classification research carried out in Russia. The most recent Russian classification (Shishov et al. 1997, 2001, 2004) presents a mixed profile-and-genetic approach. The quantitative parameters, however, mostly do not have strictly defined ranges. Thus, the attitude of Russian researchers towards classification differs significantly (the attachment to a tradi-

1. The work on the new version of South African Soil Classification began in 2001 (Laker 2003).
2. It stems from the fact that the above definition has been created by the same author.

tional genetic approach). The first step towards using soil properties for diagnosis, which are much easier for a quantitative depiction than soil forming processes, has already been taken. Yet, it has not been significant.

There is no, however, contradiction between a genetic and a quantitative approach. The differences are found in the accepted diagnostic methods, but not in the understanding of soil archetypes (Krasilnikov 2002). The numerical character of the criteria used in quantitative classification, which describe the properties of horizons or soil material, does reflect the course of the soil formation processes, while the very processes stay 'hidden'. Nevertheless, they form the basis of these classifications, even if they are not exposed.

The idea that the lack of a widely accepted soil classification constrains the development of soil science (Strzemski 1971, 1975) seems to be exaggerated. It remains a fact, however, that no standardized, universally adopted analytical procedures for defining soil properties limits the amount of data available for researchers.

2. AIM OF THE PUBLICATION AND METHODS EMPLOYED

2.1. AIM

Most correlations between the WRB and national classifications are approximate. They are based on a cursory treatment of similar units as identical. As a result the correlations worked out show only basic interrelationships.

In most cases a careful analysis of the consequences stemming from the differences in the boundary values of the individual criteria are non-existent. As far as most national correlations with either the *Soil Taxonomy* (Soil Survey Staff 1999) or the WRB classification are concerned, the studies are approximated and generalised. The evaluated correlation between the Brazilian classification and the WRB one has been presented by Palmieri et al. (2003). The approximated correlation between the WRB system and the Romanian classification has been included in the paper by Munteanu and Florea (2002). The Czech system (Nemeček et al. 2001) includes a subchapter on its correlation with the WRB classification as well as on the correlation with the *Soil Taxonomy* (Soil Survey Staff 1999), *Référentiel pédologique* (AFES 1995) and *Systematik der Böden und bodenbildenden Substrate Deutschlands* (Arbaitskreis für Bodensystematik der BDG 1998). Correlations between the WRB classification and a number of national classifications contemporarily (2005) in force[3] (Dutch, French, British, Polish, Hungarian, Bulgarian, Chinese, Japanese, Israeli, Brazilian, Cuban, Australian and New Zealand) are presented in the monographs by Krasilnikov (1999, 2002). A penetrating correlation between the Latvian classification and the WRB was presented in the paper by Karklins (2002). The author limited his work to the comparison of the diagnostics definitions without reclassification of the soil profiles from Latvia. However, he is constantly developing his correlation based on the new data he is receiving.

The aim of this study is to suggest a modification of the official *Systematics of Polish Soils* (PTG 1989) as well as of the *World Reference Base for Soil Resources* (FAO-ISSS-ISRIC, 1998). As a result, both systems will become more precise in describing the variety of soils of Poland (the first system) and of the entire world (the second system). The above aim will be supported by the following research tasks:

1. comparing the definitions of diagnostics used in the *Systematics of Polish Soils* with the ones used in the WRB classification;
2. comparing the soil units differentiated in the *Systematics of Polish Soils* with the ones used in the WRB classification;
3. working out the correlation between the Polish system and the WRB;
4. studying the usefulness of the WRB classification for the soil conditions of Poland.

3. As far as a few classifications are concerned (Romanian, South African, Canadian, German) their new versions were published after the Krasilnikov study had been finished.

2.2. METHODS

Studying a proper amount of soil pits which would represent all the units included in the *Systematics of Polish Soils*, together with the necessary analysis is more than one researcher might do. Due to that the author decided to use the professional literature data. Some dissertations of similar content have already been written at the University of Gent (Langhor 2002).

The first stage of the research was the study of the soil science literature published in the years 1989–2005. The aim was to gather possibly the largest number of data from the soil profiles representing all the typological units included in the *Systematics of Polish Soils*. Generally the papers published earlier than 1989, i.e. before the current *Systematics of Polish Soils* was published, were not studied. In case of lack of proper data for some soil units, the research papers published before 1989 were used, as well as the unpublished material collected in the Department of Soil Science of the Nicolaus Copernicus University in Toruń.

A large problem stemmed from the number of information on soil profiles found in professional literature. Most papers included the results of the analysis so as to fit the soil diagnostics solely according to the *Systematics of Polish Soils*. Moreover, the majority of the scientific publications presents only the selected soil properties to support this very publication. Additionally, the analysis undertaken for various papers were conditioned by the availability of the specific measurement equipment available to a given research institution. Sometimes, these were just traditional sets of analysis without really detailed consideration of the purpose of such measurements. Quite often all the above reasons do not allow soil scientist to reclassify soil types according to the WRB criteria. The author was often forced do draw conclusions on the base of incomplete data. The issue of limited usefulness of information on soil profiles found in the professional literature for classification purposes was also mentioned by Lopulis (1986), Vacca (1988), Ngongo (1990) and Vo-Tong Anh (1992) (after Langohr 2002).

The next stage of the research included the reclassification of soil profiles from the territory of Poland according to the WRB classification. Some of the analytical procedures which are used in Poland differ from those suggested by the WRB (Van Reeuvijk 2002). Only a few of the papers used for this dissertation do include the data on the C_{org} content, the pH, and the base saturation which would be in accordance with the recommendations of the international standards. Due to that fact, the data collected with the methods commonly used in Polish soil science was the basis for soil reclassification. The rH parameter is not measured in Poland, thus it could not be used for verifying the properties of soils with *gleyic* properties.

Any errors caused by the differences in the results, which might have appeared in the classification, stem from the dissimilarities in the analytical procedures, and are of insignificant importance. In most cases the analysed results were very diverse from the boundary values. Due to that, the fact they were obtained with the use of different procedures that those suggested by the WRB classification can be accepted.

In order to compare the values of some indicators, found in both analysed soil classifications in different units, it was necessary to unify them by recalculating:

- In the case of the cation exchange capacity, which is given in the Polish literature in $cmol_c$ kg^{-1} soil or in meq/100 g of soil, the results were recalculated into the unit which is in force in the WRB classification, i.e. $cmol_c$ kg^{-1} clay, corrected for contribution of organic matter in CEC soil according to the following formulas (Van Reeuwijk 2002):

$$CEC_{clay} (cmol_c\ kg^{-1}\ clay) = CEC_{soil} \cdot \frac{100}{\%clay}$$

$$CEC_{soil\ (mineral\ part)} = CEC_{soil} - CEC_{soil\ (organic\ part)}$$

$$CEC_{soil\ (organic\ part)} = 3.5 \cdot \%C_{org}$$

$$CEC_{clay(corr.)} (cmol_c\ kg^{-1}\ clay) = PWK_{soil\ (mineral\ part)} \cdot \frac{100}{\%clay}$$

- The paper by Miechówka (2001) included information on the carbonate CO_2 contents. It was recalculated into $CaCO_3$ according to the following formula (Arinushkina 1970):

$$CaCO_3 = 2.2743 \cdot CO_2$$

- In order to compare the phosphorus contents of the *anthropic* horizon according to the *Systematics of Polish Soils* with the *hortic* horizon according to the WRB soil classification the contents of P was recalculated into the contents of P_2O_5 with the use of the following formula (Arinushkina 1970):

$$P_2O_5 = P \cdot 2.291$$

- The chemical formula of ammonium acetate used by the WRB soil classification as NH_4OAc was transformed into CH_3COONH_4

The next aspect which is significantly different in the *Systematics of Polish Soils* and in the WRB classification is the division into particle size classes and soil texture classes (see Drzymała 2000; Drzymała, Mocek 2004). If texture is of diagnostic importance (e.g. in a definition of the *cambic* horizon or the Arenic qualifier) the content of the individual fractions was studied closely. Although sometimes this could not be done precisely, the research did enable the degree of compliance with the criterion to be estimated. In the case of the estimation whether the texture of the soil material is loamy sand or finer, an analysis indispensable for studying the texture criterion for the *cambic* horizon according to the WRB classification, the content of the fraction <0.05 mm was considered, as it is the closest to the upper limit of the coarse silt fraction according to the WRB soil classification in force.

In this paper soil colour has been estimated according to Munsell (Munsell Soil Colour Charts 2000).

The third stage of the research was in defining the correlation between the *Systematics of Polish Soils* and the WRB classification. It was based on a comparison of the definitions of the diagnostics used in both systems, as well as on the results of the reclassification, according to the WRB criteria, of over 500 soil profiles from the territory of Poland taken from 79 scientific papers[4].

The last stage of the research was undertaken to suggest the changes both in the *Systematics of Polish Soils* and the WRB classification.

4. From over 600 research papers only the ones which included the analytical data enabling soil reclassification in accordance with the WRB soil classification were used.

3. CRITERIA FOR DELIMITATION OF SOIL UNITS IN THE *SYSTEMATICS OF POLISH SOILS* AND IN THE WRB SOIL CLASSIFICATION

3.1. CRITERIA FOR DELIMITING SOIL UNITS IN THE *SYSTEMATICS OF POLISH SOILS*

The process of soil formation results in soil diversification into certain genetic horizons. The type, layout and properties of these genetic horizons are the effects of both previous and contemporary soil forming processes. A set of certain genetic horizons creates a specific soil. Morphology and properties of the genetic horizons belong to the basic criteria of soil classification.

The *Systematics of Polish Soils* (PTG 1989) includes six hierarchic units:

- a division – it is a superior unit of taxonomy. It includes the soils which were mainly influenced by one soil forming factor or by all the factors without the leading one. Taxonomy includes 7 divisions;
- an order – it includes the soils with a similar direction of development. Individual orders include soil which are similar ecologically but can be differentiated morphologically;
- a type – it is the basic unit in the Polish soil taxonomy. It includes the soils of similar origin, identical layout of the main genetic horizons and chemical and physical properties;
- a subtype – it is used when the features of the main soil forming factors overlap the features of a different process;
- a genus – it is defined on the basis of the origin and properties of the parent material rock on which the soil developed;
- a textural group – it is defined on the basis of texture of the soil material which build the profile.

3.2. CRITERIA FOR DELIMITING SOIL UNITS IN THE WRB CLASSIFICATION

The WRB soil classification is based on the soil properties defined in terms of diagnostic horizons and characteristics, which to the greatest extent possible, should be observable and measurable in the field. Delimitation of diagnostic horizons and characteristics considers their relation to soil forming processes. The processes themselves, however, should not be used as differentiating criteria. Soil classification does not apply climatic parameters.

The WRB system comprises two tiers of categorical detail:

- the *Reference base* which is limited only to the first level (30 reference soil groups);
- the *WRB Classification System* consisting of combinations of a set of prefixes as unique qualifiers added to the reference soil groups. They allow scientists to characterise and classify precisely individual soil profiles. Each reference

soil group of WRB is provided with a listing of possible qualifiers in priority sequence. This listing can be used for constructing various lower-level units.

The broad principles which govern the WRB class differentiation are:

- at the higher categoric level classes are differentiated mainly according to the pedogenetic process that has produced the characteristic soil features, except the situation when the 'special' parent materials are of overriding importance;
- at the lower categoric level classes are differentiated according to any predominant secondary soil forming process that has significantly affected the primary soil features. In certain cases, other soil characteristics may be taken into account, if they have a significant effect on soil use.

4. DIAGNOSTICS

4.1. COMPARISON OF DEFINITIONS OF SURFACE DIAGNOSTIC HORIZONS (EPIPEDONS) DIFFERENTIATED IN THE *SYSTEMATICS OF POLISH SOILS* (SPS) AND THEIR EQUIVALENTS IN THE WRB SOIL CLASSIFICATION

The *Systematics of Polish Soils* (PTG 1989) includes the following epipedons: *mollic*, *anthropic*, *umbric*, *melanic*, *plaggen*, *histic* and *ochric*. Two of them – *anthropic* and *plaggen* – originate due to the anthropogenic factors, while the others originate naturally. In the WRB soil classification (1998) have been separated and defined the epipedons analogue to those defined in *Systematics of Polish Soils*, except for the *melanic* horizon. The WRB definitions consider the same diagnostic features as the definitions included in *Systematics of Polish Soils*. Moreover, the WRB soil classification differentiates and defines as many as 6 anthropogenic (*anthropedogenic*) horizons: *terric*, *irragric*, *plaggic*, *hortic*, *anthraquic*, *hydragric*.

The definitions of the diagnostic horizons include 8 various diagnostic features: thickness, structure, colour, base saturation, the content of organic carbon /organic matter, phosphorus content, texture and water relations.

Table 1. Diagnostic indicators used for defining epipedons

	Mollic	Umbric	Ochric	Plaggen/ Plaggic	Histic	Melanic	Anthropic	Terric	Hortic
C_{org} content	SPS WRB	SPS WRB	WRB	WRB	SPS WRB	SPS	SPS		WRB
colour	SPS WRB	SPS WRB	SPS WRB			SPS	SPS		WRB
thickness	SPS WRB	SPS WRB	WRB	SPS	SPS WRB	SPS			
structure	SPS WRB	SPS WRB	SPS WRB			SPS	SPS		
V	SPS WRB	SPS WRB		WRB				WRB	WRB
phosphorus content	SPS	SPS		WRB			SPS		WRB
texture				WRB		SPS	SPS		
soil-water relationships					SPS WRB	SPS			

Table 1 shows the diagnostic features used for defining the surface diagnostic horizons which are found both in *Systematics of Polish Soils* and the WRB classification, as well as the ones found solely in *Systematics of Polish Soils*. In a few cases the horizons of similar character are found in the discussed classifications under different names: *plaggen/plaggic*, *anthropic* which refers to three horizons defined in the WRB classification, i.e. the *hortic*, *anthraquic* and *terric* horizons. The table does not include the horizons defined only in the WRB classification. The features were listed hierarchically, starting with the ones which are use in the largest number of definitions.

The features most often used in the definitions of epipedons include:

- organic carbon content: 5 times in the SPS and 6 times in the WRB classification;
- thickness: 5 times in the SPS and 4 times in the WRB classification;
- colour: 5 times in the SPS and 4 times in the WRB classification;
- structure: 5 times in the SPS and 3 times in the WRB classification;
- base saturation: twice in the SPS and 5 times in the WRB classification;
- phosphorus content: 3 times in the SPS and twice in the WRB classification;
- texture: twice in the SPS and once in the WRB classification;
- soil-water relationships: twice in the SPS and once in the WRB classification.

4.1.1. Comparison of the definition of the *mollic* horizon according to both the SPS and the WRB

The best defined horizon in the *Systematics of Polish Soils* (SPS) is the *mollic* horizon. In the definitions of the following horizons: *anthropic*, *umbric*, *melanic* and *ochric* the most important features, i.e. colour, structure, organic matter content, thickness and phosphorus content, were referred to the definition of the *mollic* horizon.

In both classifications the following features of the *mollic* diagnostic horizon are defined identically:

a. base saturation;
b. content of organic carbon.

The difference appears when the following features are mentioned:

a. thickness – the criterion used in *Systematics of Polish Soils* is based on texture and the depth of some of the other diagnostic horizons; depending on texture of the soil material, the thickness of the *mollic* horizon ranges from ≥10 cm to ≥25 cm. On the contrary, the thickness criteria of the WRB *mollic* horizon are based on the solum thickness, and also range from ≥10 cm to ≥25 cm;
b. structure – the granular is found in both classifications, while the other types of structure vary (crumb and coprolithic ones in the *Systematics of Polish Soils*, subangular blocky in the WRB classification);
c. colour – when comparing the colour of the *mollic* horizon with the C horizon in the *Systematics of Polish Soils* the chroma is used, while the WRB classification does not use this parameter; according to the WRB, however, it is necessary to refer to the value of the *mollic* horizon if there is more than 40% finely divided lime;

Additionally, the *Systematics of Polish Soils* includes the criterion of the phosphorus content (lower than 109 mg P kg^{-1} soil, soluble in 1% citric acid), and the maximum value of the organic carbon content (12%).

4.1.2. Comparison of the definition of the *anthropic* horizon according to the SPS with the *terric*, *hortic* and *anthraquic* horizons according to the WRB

Anthropic and *plaggen* epipedons according to *Systematics of Polish Soils*, and *terric*, *irragric*, *plaggic*, *hortic*, *anthraquic* and *hydragric* epipedons according to the WRB classification are characteristic for the soils which have been cultivated for a long time. The soil management practices used and their intensity influence the properties of these horizons. In the case of the horizons which have originated due to the human activity the phosphorus content is an important diagnostic feature. It is not however expressed for the *mollic*, *ochric* and *umbric* horizons. Two of the *anthropedogenic* horizons – *irragric* and *hydragric* are not found in the area of Poland due to the fact that the management practices which enable their origin are not in use. The *plaggic* horizon is compared to the *plaggen* horizon in a next part of this chapter (4.1.3.).

The comparison of the definition of the *anthropic* diagnostic horizon according to the SPS with the definition of the *terric*, *hortic* and *anthraquic* diagnostic horizons according to the WRB enables following conclusions to be drawn:

The *terric* horizon is defined very generally. The only quantitative criterion which differentiates this horizon is the base saturation (in 1 *M* CH_3COONH_4) >50%.

The *anthraquic* horizon includes the *puddled layer* (supersaturated with water, muddy) and the *plough pan*. A characteristic feature of this horizon is high compactness and the platy structure, which prevents water from infiltrating and results in its stagnation within the *puddled layer*. The *anthraquic* horizon is fund in the soils which have been ploughed for a long time.

When comparing the definitions of the *anthropic* horizon according to the SPS with the *hortic* horizon according to the WRB it may be realised that, however large the similarities are, these horizons are not identical:

- the colour of the *anthropic* horizon is lighter, the colour value and chroma of moist soil is <3.5; for the *hortic* horizon both parameters of the moist soil are ≤3;
- organic carbon content in the *hortic* horizon is ≥1%, while in the *anthropic* horizon it has to be ≥0.6%, except the situation when the colour criteria is omitted. Additionally, the maximum content of C_{org} (12%) is given for the *hortic* horizon;
- the required minimum of the P_2O_5 content for the *hortic* horizon is two and a half times lower than in the *anthropic* horizon (100 mg kg^{-1} and 250 mg kg^{-1} respectively).

It must be stressed that the definitions of the *anthropedogenic* horizons included in the WRB classification lacks consequence. The criteria of the *plaggic* horizon give the requirement for the extracted P_2O_5 in the 1% citric acid, while the criteria for the *hortic* horizon for the P_2O_5 extracted in 0.5 *M* $NaHCO_3$. For the classification needs, however, the criteria should be uniform and the analytical methods strictly defined. The criteria for the *plaggic* horizon include the P_2O_5 content in per cent, while the criteria for the *hortic* horizon give the P_2O_5 content in milligrams per 1 kilogram of soil. The way of putting down the data should be unified (SI system).

Besides the above mentioned features, the definition of the *anthropic* horizon includes the requirements which refer to the structure (identical with the *mollic* horizon), while the definition of the *hortic* horizon considers the criterion of the base saturation (≥50% in the *hortic* horizon and >50% in the *terric* horizon).

Moreover, in the case of the *anthropedogenic* horizons, contrary to the accepted convention, diagnostic criteria are not enumerated in subsections, as they are in the case of all the other diagnostic horizons. They are defined in a descriptive way, which makes it difficult to distinguish the most important features.

4.1.3. Comparison of the definition of the *plaggen* horizon according to the SPS and the *plaggic* horizon according to the WRB

The *plaggen* horizon in *Systematics of Polish Soils* and the *plaggic* horizon in the WRB classification represent the horizons which have originated due to the human activity. In spite of the fact that they both come from the same word *plag*, which means sod, their names vary. *Plaggen* horizon originates from sod applications.

The definition of the *plaggen* horizon in the *Systematics of Polish Soils* includes only one clear numerical criterion which enables this horizon to be differentiated. It has a significant thickness of over 50 cm. The WRB classification does not mention this horizon's thickness. It mentions, however, four other criteria:

- C_{org} content (weighted average) >0.6%;
- P_2O_5 content (extractable in the 1% citric acid) ≥0.25% within 20 cm of the soil surface;
- base saturation (in 1 *M* CH_3COONH_4) <50%;
- uniform texture, usually sand or loamy sand.

The analysis enables the author to draw the conclusion that the studied classifications lack common criteria of differentiating the *plaggen* and *plaggic* horizons.

4.1.4. Comparison of the definitions of the *umbric* horizon according to both the SPS and WRB classifications

The comparison of the definitions of the *umbric* diagnostic horizon in accordance with both the SPS and the WRB classifications shows that only one feature of this diagnostic horizon is defined identically. It is the base saturation (<50%).

The differences refer to the following features:

- organic carbon content ≥0.6% throughout the thickness of mixed horizon according to both the *Systematics of Polish Soils* and the WRB classification. The difference, however, is noted when the colour criterion is waived. In such cases *Systematics of Polish Soils* suggests the C_{org} content must equal or exceed 2.5% within the 18 cm surface layer, while the WRB suggests the C_{org} content should exceed the content in the C horizon by at least 0.6%.
- thickness – the criteria of *Systematics of Polish Soils* are based on differences in texture and the depth at which certain diagnostic horizons are found, while the

criteria of the WRB classification are based on the thickness of solum (similarly to the case of the *mollic* horizon, see section 3.1.1.);
- structure – granular is common for both classifications; the other structure types vary (similarly to the case of the *mollic* horizon, see section 3.1.1.);
- colour – in order to compare the colour of the *umbric* horizon with the C horizon *Systematics of Polish Soils* uses the hue, while the WRB classification does not use this parameter.

Moreover, the definition of the *umbric* horizon in *Systematics of Polish Soils* includes the requirement of the phosphorus content (below 109 mg kg^{-1} of soil, extractable in 1% citric acid).

4.1.5. The *melanic* horizon

Both the *Systematics of Polish Soils*, the WRB classification and the *Soil Taxonomy* (Soil Survey Staff 1975, 1999) includes the horizons called *melanic*. However, besides the name coming from the dark colour, these horizons do not have much in common. The origin of these horizons is totally diverse. According to the WRB classification and the *Soil Taxonomy* the *melanic* horizon is, similarly to the *andic* horizon, the diagnostic horizon associated with pyroclastic deposits. On the contrary, *Systematics of Polish Soils* treats the *melanic* horizon as the diagnostic one for the mucky soils. The WRB classification lacks the horizon with the character close to the *melanic* horizon, to be found in the *Systematics of Polish Soils*.

Due to the above reasons, as well as in order to avoid ambiguity in terminology, the new edition of the *Systematics of Polish Soils* should replace the name *melanic* with a new term which would not be connected with the horizon specific for the volcanic soils.

4.1.6. Comparison of the definition of the *histic* horizon according to both the SPS and the WRB

The comparison of the definition of the *histic* diagnostic horizon after the SPS and the WRB brings the conclusion that both classifications base the definition of this horizon on the same diagnostic features. The differences refer to the quantitative criteria which enable to distinguish this horizon:
- thickness – according to the SPS from 5 to 30 cm in mineral soils and over 30 cm in organic soils, while according to the WRB ≥10 cm;
- C_{org} content – a difference is noted when the *histic* horizon includes from 50 to 60% of clay, e.g. when the horizon contains 50% of clay it has to contain 30% of organic matter to be called *histic* by the SPS; it may include two per cent of organic matter less to be still called the *histic* horizon in accordance with the WRB;
- soil-water relationships – the WRB classification takes into accounts the possibility of dry years, when the horizon is not saturated with water throughout a month and also artificial draining (which is not allowed in *histic* horizon according to SPS).

4.1.7. Comparison of the definition of the *ochric* horizon according to both SPS and the WRB classification

The definition of the *ochric* horizon in the *Systematics of Polish Soils* is very general. It only states that this horizon needs to have the soil structure, and the Munsell value of ≥5.5 when dry and of ≥3.5 when moist.

The features of the *ochric* horizon in the WRB classification are defined precisely. This horizon lacks fine stratification, and it satisfies the following criteria:

- thickness is <10 cm if resting directly on hard rock, or the *petrocalcic*, *petroduric*, *petrogypsic* or *cryic* horizon; it is <20 cm or less than 1/3 of the thickness of the solum where the solum is less than 75 cm; it is ≤25 cm where the solum is more than 75 cm thick; or
- Munsell chroma of ≥3.5 when moist; the Munsell value is ≥3.5 when moist and ≥5.5 when dry; if the horizon contains ≥40% of finely divided lime, the colour value must be >5 when moist; or
- <0.6% of C_{org} throughout the thickness of mixed horizon; the C_{org} must be <2.5% if there is more than 40% finely divided lime; or
- it has massive structure and is (very) hard when dry.

It must be also mentioned that the definition of the *ochric* horizon in accordance with the WRB classification contains an error connected with the colour: 'Munsell chroma and value at least 3.5 when moist' (FAO-ISSS-ISRIC 1998); it should be: 'chroma or value'.

4.2. COMPARISON OF THE DEFINITIONS OF THE SUBSURFACE HORIZONS (ENDOPEDONS) DIFFERENTIATED IN *SYSTEMATICS OF POLISH SOILS* AND THEIR EQUIVALENTS IN THE WRB SOIL CLASSIFICATION

The *Systematics of Polish Soils* recognizes the following endopedons: *cambic*, *sideric*, *argillic*, *natric*, *spodic*, *agric*, *albic*, *luvic*, *glejospodic*, *placic*, *fragilic*, *salic*, *calcic* and *gleyic mottling*. All these horizons, except the *agric* one, develop naturally. The WRB classification recognizes a much larger number of the differentiated and defined subsurface horizons due to the fact that it covers all the world soils. It lacks, however, the analogues of the following subsurface horizons: *agric*[5], *sideric*, *luvic*, *glejospodic* and *placic*. In the WRB classification the horizons analogue to the *argillic* and *fragilic* ones have different names: *argic* and *fragic* respectively, while *gley mottling* have not been defined as a diagnostic horizon but as one of the criteria of the *gleyic* and *stagnic* properties (*gleyic* or *stagnic* colour).

The definitions of the diagnostic horizons include 26 various diagnostic features. Table 2 shows a list of the diagnostic features used for defining the individual endopedons in both *Systematics of Polish Soils* and the WRB classification. The features were organized hierarchically, beginning with the ones which are used in a largest number of definitions.

5. The *agric* and *placic* horizons are defined in the *Soil Taxonomy*.

Table 2. Diagnostics used in the definitions of endopedons

	albic	**argillic/argic**	**calcic**	**cambic**	**fragilic/fragic**	**natric**	**salic**	**spodic**	**agric**	**glejospodic**	**luvic**	**placic**	**gleyic mottling**	**sideric**
thickness	SPS WRB	SPS WRB	SPS WRB	WRB	WRB	SPS WRB	SPS WRB	WRB				SPS		SPS
colour	SPS WRB			SPS WRB	SPS			SPS WRB	SPS	SPS	SPS	SPS	SPS	SPS
texture	SPS	SPS WRB		SPS WRB	SPS	SPS WRB			SPS		SPS			SPS
structure		WRB		SPS WRB	SPS	SPS WRB		SPS		SPS				
carbonates content			SPS WRB	SPS WRB				SPS			SPS			
pH								SPS WRB	SPS					SPS
cementation degree				SPS	SPS WRB			WRB				SPS		
depth of occurrence				SPS	SPS							SPS		
micromorphological features		SPS				SPS		WRB						
mineral composition	SPS			SPS WRB										
C_{org} content				SPS	WRB			WRB						
V								SPS						SPS
bulk density					SPS WRB									

Table 2 cont'd

	albic	argillic/argic	calcic	cambic	fragilic/fragic	natric	salic	spodic	agric	glejospodic	luvic	placic	gleyic mottling	sideric
salt content							SPS							
product of thickness (in cm) times salt percentage							SPS WRB							
SAR						SPS WRB								
EC							WRB							
ESP						WRB								
illuviation index								SPS						
Mokma index								SPS						
C : N									SPS					
CEC				WRB										
ECEC				WRB										
$Al_{OX} + Fe_{OX}$								WRB						
ODOE								WRB						
penetration resistance					WRB									

The table 2 contains the list of the 26 diagnostic features used for defining the surface horizons which are recognized in the *Systematics of Polish Soils* and the WRB classification (in some cases named differently), as well as the ones which are only defined in the SPS classification. The table does not however, contain the horizons defined solely in the WRB classification.

The features listed below are the ones which were mentioned most times in the definitions:

- thickness: 7 times in the *Systematics of Polish Soils* and 7 times in the WRB classification;
- colour: 10 times in the *Systematics of Polish Soils* and 3 times in the WRB classification;
- texture: 8 times in the *Systematics of Polish Soils* and 3 times in the WRB classification;
- structure: 5 times in the *Systematics of Polish Soils* and 3 times in the WRB classification;

Fourteen diagnostic features were used only once in the definitions.

4.2.1. Comparison of the definition of the *cambic* horizon according to both the SPS and the WRB classification

In both classifications the following diagnostic features of the *cambic* horizon are defined identically: structure, depth and carbonates contents. Insignificant differences are found in the description of the following features:

- texture;
- colour;
- content of weatherable minerals;
- cementation degree.

For defining the *cambic* horizons the WRB classification uses three diagnostic features which are not included in the *Systematics of Polish Soils*: thickness >15 cm; CEC >16 $cmol_c$ kg^{-1} of clay; ECEC ≥12 $cmol_c$ kg^{-1} of clay.

4.2.2. Comparison of the definitions of the *argillic* horizon according to the SPS and *argic* horizon according to the WRB classification

The *argillic* diagnostic horizon in accordance with the *Systematics of Polish Soils* and the *argic* horizon in accordance with the WRB classification bear slightly different names, but similar, because both are derived from the Latin word *argilla* which means white clay. The definitions of these horizons are similar.

The required content of the clay fraction in the *argillic*/*argic* horizon is defined identically by both classifications. The main difference is found in the origin of the horizon. The textural differentiation in the *argillic* horizon may have been caused by the illuviation process and, in some cases, this difference may be caused by the lithological discontinuity. The textural differentiation in the *argic* horizon may have resulted from various processes: predominant pedogenetic formation of clay in the subsoil, the destruction of clay in the surface horizon, selective surface erosion of clay, biological activity or combination of these processes. A difference is also found in the requirement of the increase of the clay fraction content. In both systems it is accepted that if the *argillic/argic* horizon originated due to the illuvial process, the increase of the clay fraction content must appear within the vertical distance of 30 cm. The WRB classification, however, requires that the increase of the clay fraction content in all other cases between the overlying horizon and the *argic* horizon must take place within the vertical distance of 15 cm. The WRB classification also considers the criterion of the horizon structure (the *argic* horizon must lack the autochthonous rock structure in at least half of the horizon volume).

4.2.3 Comparison of the definition of the *natric* horizon according to both the SPS and the WRB classification

In the both analysed systems the *natric* horizon is treated as a specific kind of the *argillic* horizon (the SPS) or the *argic* horizon (the WRB).

The differentiating criteria of the *natric* horizon in the WRB classification and in the *Systematics of Polish Soils* are quite similar. Some differences are found in the structure descriptions (it is treated more widely in the *Systematics of Polish Soils*) and in the character of the sorption complex. In the *Systematics of Polish Soils* one of the criteria is the SAR index, while in the WRB classification the ESP index with the SAR index as an option[6].

4.2.4. Comparison of the definitions of the *spodic* horizon according to both the SPS and the WRB classification

In both classifications the origin of the *spodic* diagnostic horizon was defined identically – it is a horizon of illuvial accumulation of the amorphous substances composed of organic matter and aluminium, with or without iron.

The difference appears in features such as:

- requirements referring to the C_{org} content are described only in the WRB classification (≥ 0.6%);
- pH is defined precisely only in the WRB classification [pH (H_2O; 1:1) ≤ 5.9];
- minimum thickness of the *spodic* horizon is given only in the WRB classification (at least 2.5 cm);
- depth of occurrence of the *spodic* horizon is only given in the WRB classification (the upper limit of the *spodic* horizon must be found below 10 cm of the mineral soil surface);
- colour is defined much more precisely in the WRB classification [Munsell hue of 7.5YR or redder with value ≤5 and chroma ≤4 (moist and crushed), or hue of 10YR with value ≤3 and chroma ≤2 (moist and crushed)];
- texture of the *spodic* horizon is described only in the *Systematics of Polish Soils*; it is not, however, a strict requirement but a piece of information helpful in identification;
- the Mokma index[7] (Mokma 1983) is used only in the *Systematics of Polish Soils*;

6. Both indexes have similar meanings in practice (Richards 1954). $ESP\ (\%) = \frac{1.475 \cdot SAR - 1.26}{0.01475 \cdot SAR + 0.9874}$

7. $C_p/(Al_p+Fe_p)$ atomic ratio; p – sodium pyrophosphate extract.

- base saturation has only been defined in *Systematics of Polish Soils* (in most cases it does not exceed 20%);
- minimum content of the amorphous Fe and Al is mentioned only in the WRB classification (at least 0.5% of Al_o+½Fe_o[8], which should at least be twice as much as the amount of Al_o+½Fe_o in the overlying *umbric*, *ochric*, *albic* horizons or *anthropedogenic* horizon);
- requirement referring to an optical density of the oxalate extract (ODOE) (≥0.25 and also two times or more the value of the overlying horizons) is used only in the WRB classification.

4.2.5. Comparison of the definitions of the *albic* horizon according to both the SPS and the WRB classification

The *albic* horizon in the WRB classification has a broader definition than their namesake from *Systematics of Polish Soils* which defines two eluvial horizons. One of them is the *albic* diagnostic horizon for podzols and podzolic soils and the other one, the *luvic* horizon, for soils lessivès (luvisols). Both aluminium and iron have been removed from *albic* horizon into the underlying *spodic* horizon. According to the WRB classification, however, besides aluminium and iron, also clay have been removed. Thus, it is not only the *spodic* horizon which *albic* may overlie, as in *Systematics of Polish Soils*, but the *natric* and *argic* horizons as well.

Contrary to the WRB definition, the definition of the *albic* horizon in *Systematics of Polish Soils* lacks precise, clear numerical criteria. The WRB definition precisely describes the requirements in terms of the colour of the *albic* horizon. Colour of the *albic* horizon in the *Systematics of Polish Soils* is described simply as whitish or greyish. According to the WRB, the *albic* horizon must be at least 1 cm thick, while the *Systematics of Polish Soils* defines that the thickness: 'may vary from a few to a few dozen centimetres'. The *Systematics of Polish Soils* gives a description of the texture of the *albic* horizon (only sand, content of <0.02 mm fraction is <10%), as well as its mineral composition (domination of quartz).

4.2.6. Comparison of the definition of the *fragilic* horizon according to the SPS and the *fragic* horizon according to the WRB

The *fragilic* horizon in the *Systematics of Polish Soils* and the *fragic*[9] horizon defined in WRB classification represent the horizons with pedality and porosity patterns such that roots and percolating water penetrate the soil only along interped faces and streaks, but the sets of diagnostic criteria of these horizons varies greatly: In both systems the following feature of *fragic/fragillic* horizons is described nearly identically: slaking or fracturing of an air-dry clod when placed in water (but the WRB classification specifies a precise time (10 minutes) within which it should happen). The other diagnostic criteria are different for both systems. The *Systematics of Polish Soils* gives descriptions of texture (silty sand); in the Polish system a *fragic* horizon can be cemented. In the *Systematics of Polish Soils* the bulk density is speci-

8. Al_o and Fe_o – aluminium and iron extracted in acid oxalate (pH 3) solution.
9. These names, however, are similar as they both come from a Latin word *fragilis*, *frangere* 'to break'.

fied as large, while in the WRB it should be higher relative to the horizons above the *fragillic* horizon. The WRB classification requires three quantitative diagnostic criteria not present in the *Systematics of Polish Soils*: organic carbon content (less than 0.5%), thickness (at least 25 cm) and penetration resistance at field capacity (more than 50 kN m^{-1}).

4.2.7. Comparison of the definitions of the *salic* horizon according to both the SPS and the WRB classification

In both systems the following criteria are identical: thickness (15 cm or more); product of thickness times salt percentage (60 cm % or more). The salinity level is described by different indices: the Polish systematics uses salt percentage, while WRB uses electrical conductivity of the saturation extract (EC_e). There are in WRB two critical values for EC_e: more than 15 dS m^{-1} at some time of the year or more than 8 dS m^{-1} for alkaline carbonate and acid sulphate soils. It is important to mention that percent of salt was a diagnostic criteria in an earlier WRB draft. It has been deleted from the point of view of doubling criteria. An EC_e of 15 dS m^{-1} is approximately equal about 1% salt (Richards 1953). In the *Systematics of Polish Soils* the criterion of salt percentage, for the *salic* horizon is 2%. With regard to the specific properties of Polish salt-affected soils *Systematics of Polish Soils* differentiates additionally the following horizons or layers: saline, saline-sodic and sodic. These horizons, however, are not used for delimitating subtypes of salt-affected soils, which arouses doubts whether it is purposeful to define them.

4.2.8. Comparison of the definitions of the *calcic* horizon according to both the SPS and the WRB classification

The comparison of the definitions of the *calcic* diagnostic horizon in accordance with the SPS and the WRB classifications has led to the conclusion that both definitions are very similar. The definitions of the *calcic* horizon in both systems are based on the same diagnostic features. The boundary values of thickness and carbonates content are identical (15 cm and 15% respectively). The *Systematics of Polish Soils*, however, accepts the situation when the thickness of the *calcic* horizon is lower than 15 cm (but larger than 5 cm). It is the case when the *calcic* horizon contains 5% more of $CaCO_3$ than the C horizon.

4.2.9. The *sideric* horizon according to the SPS

The *sideric* horizon (from Greek *sideros,* iron) is counterpart of the *cambic* horizon in the sandy material. It is defined solely in the *Systematics of Polish Soils*. The Munsell hue of this horizon is 7.5YR to 10YR, value is ≥4 and chroma is ≥3. As a result of *in situ* weathering sesquioxides are released, similarly to the *cambic* horizon. The relation of the organic carbon to the sum of the aluminium and iron[10] (Mokma index) in *sideric* horizon does not exceed 25. The base saturation is lower than 30% (in forest soils).

10. $C_p/(Al_p+Fe_p)$ atomic ratio; p – sodium pyrophosphate extract.

4.2.10. The *luvic* horizon according to the SPS

The *luvic* horizon (from Latin *eluo*, to wash out) is an eluvial horizon from which clay and primary carbonates and other easily soluble salts have been removed. This substance was leached into the *argillic* (or *natric*) horizon, which directly underlies the *luvic* horizon. The WRB classification lacks a horizon bearing that name. However, the definition of the *albic* horizon in the WRB classification is defined much widely than in *Systematics of Polish Soils*, and it contains the features of both the *albic* and *luvic* horizon of Polish system.

4.2.11. The *glejospodic* horizon according to the SPS

The *glejospodic* horizon is similar to the *spodic* horizon but contains more free iron oxides, has platy structure and is influenced by the ground water. The degree of cementation of sand grains by sesquioxides and organic matter is often very high (presence of ortstein). The colour is dark orange brown. The upper part is black or brownish black due to the illuvial accumulation of organic matter. *Spodic* horizon with *gleyic* properties of the WRB is analogous to *glejospodic*.

4.2.12. *Gleyic mottling* according to the SPS

The 'mottled' horizon is a layer within the soil profile having mottles with contrasting colours in which some parts have chroma of 2 or less when moist and value darker than 4. The description of these features is included in definitions of *stagnic* and *gleyic* properties in the *Revised Legend to the Soil Map of the World in the scale 1:5000000* (FAO/Unesco 1988), but in the Polish system it is placed in a higher category of taxa.

4.2.13. The *agric* horizon according to the SPS

The *agric* (from Latin *ager*, field) is an illuvial horizon, which results from long-continued cultivation, and lies directly under a plough layer. It contains illuvial organic matter, clay and silt leached from the plough layer. The name and the definition of this horizon were taken from the *Soil Taxonomy* (Soil Survey Staff 1975).

4.2.14. The *placic* horizon according to SPS

The *placic* horizon (from Greek *plax*, flat stone, thin cemented layer) is a black to dark red layer cemented by iron oxides or iron and manganese oxides and by complexes of iron and organic matter as well. The thickness of this layer ranges in most cases from 2 to 10 mm. The *placic* horizon occurs in the upper 50 cm of soil and is a barrier to percolating water and plant roots. The name and the definition of this horizon were also taken from the *Soil Taxonomy* (Soil Survey Staff 1975).

4.3. DIAGNOSTIC PROPERTIES AND DIAGNOSTIC MATERIALS DEFINED IN THE WRB SOIL CLASSIFICATION

4.3.1. Diagnostic properties

The WRB soil classification defines a number of diagnostic properties. They, however, reflect specific soil conditions rather than horizons. Out of twelve diagnostic properties defined in the WRB six may be used for describing the soils found in Poland. They are the following properties: *gleyic*, *stagnic*, *abrupt textural change*, *continuous hard rock*, *secondary carbonates* and *albeluvic tonguing*.

4.3.2. Diagnostic materials

For the soil classification it appeared appropriate to define the diagnostic materials. These diagnostic soil materials are intended to reflect the original parent materials, in which the pedogenesis processes have not yet been so active that they have left significant mark. The WRB soil classification defines seven diagnostic materials: *anthropogeomorphic*, *calcaric*, *fluvic*, *gypsiric*, *organic*, *sulfidic* and *tephric*. All the mentioned diagnostic materials, excluding the *tephric* one, may be found in Polish soils.

5. COMPARISON OF THE DEFINITIONS OF THE LITHOGENIC SOILS TYPES IN *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

Both the structure and properties of the lithogenic soils predominantly depend on the properties of the parent material. The course of the pedogenesis is dominated by texture, mineral composition as well as chemical composition of the parent material. *Systematics of Polish Soils* subdivides lithogenic soils into two orders: noncarbonate soils, weakly developed (IA) and lithogenic calcareous soils with different development degree (IB). The name of the first order is not precise as besides weakly developed soils it also includes initial ones (regosols).

5.1. NONCARBONATE SOILS, INITIAL AND WEAKLY DEVELOPED

The order of the noncarbonate soils, initial and weakly developed includes the following five types:

- initial rocky soils (lithosols) (IA1) – soils developed *in situ* from various noncarbonate hard rocks of the AC-R soil profile;
- initial loose soils (regosols) (IA2) – soils developed from various not cemented clastic rocks with the (A)/C-C profile;
- initial clay soils (pelosols) (IA3) – soils of poorly diversified profile, noncarbonate, with the AC-C profile, developed on clayey or silty parent material;
- noncalcareous soils weakly developed from solid rocks (rankers) (IA4) – soils poorly diversified morphologically, with the AC-C profile, developed on the noncarbonate hard rocks;
- soils weakly developed from loose materials (arenosols) (IA5) – soils developed from various clastic materials, loose, noncarbonate, with the A-C profile.

The soil science literature from the years 1989–2004 includes six publications containing sets of analytical data of noncalcareous soils weakly developed from solid rocks (rankers), which partly allows for correlation with the WRB classification (14 profiles all together); two papers which include data on regosols (4 profiles) as well as one paper which presents the data of one arenosol profile. Due to insufficient material on arenosols and regosols, the author used unpublished data from the research carried out in the Department of Soil Science of the Nicolaus Copernicus University (13 profiles). However, no material was found on the analytical data referring to the other soil types of the noncarbonate soils, initial and weakly developed order, i.e. Lithosols and Pelosols.

5.1.1. Initial loose soils (regosols)

Table 3 contains the regosol profiles found in the published papers, as well as their reclassification according to the soil classification criteria of the WRB.

Table 3. Verification/reclassification of the regosols profiles

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification /verification
Skiba, Winnicki (1995)	1	lithosol	–	Humic Leptosol
	3	regosol	–	Parahumic Regosol
Jankowski, Bednarek (2000)	not specified	eolic regosol	Protic Arenosol	Protic Arenosol
	not specified	eolic regosol	Protic Arenosol	Protic Arenosol
Jankowski (2003)	R3	eolic regosol	–	Protic Arenosol

Polish regosols correspond to three reference soil groups: Leptosols, Regosols and Arenosols.

5.1.2. Noncalcareous soils weakly developed from solid rocks (rankers)

The definitions of rankers in the *Systematics of Polish Soils* says hard rock is found at the depth of 50 cm maximum, while in the definition of Leptosols in accordance with the WRB soil classification continuous hard rock must be found within 25 cm from the soil surface. Thus, rankers with the hard rock deeper than 25 cm cannot be included in the Leptosols.

Table 4. Verification/reclassification of the ranker profiles

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification /verification
Skiba et al. (1993)	1	raw humous ranker	–	Leptic Umbrisol
	2	brown ranker	–	Leptic Umbrisol
	16	brown ranker	–	Cambisol
	30	raw humous ranker	–	Leptic Umbrisol
Skiba, Winnicki (1995)	4	raw humous ranker	–	Parahumi-Epileptic Regosol
	5	brown ranker	–	Parahumi-Epileptic Regosol
Drewnik (1996)	15, 16	brown rankers	–	Dystric Regosols
Brogowski et al. (1997)	IV	proper ranker	–	Leptosol
	V	proper ranker	–	Leptic Umbrisol
	IX	brown ranker	–	Cambisol
Kabała (1998)	2, 3	proper rankers	–	Leptic Umbrisols
	4	proper ranker	–	Leptosol

The description of the humus horizon in the definition of rankers in accordance with the *Systematics of Polish Soils* suggests it is the *umbric* horizon. These soils, though, may be included either into Leptic Umbrisols or, in case they include 40% to 90% of gravel or other coarse fragments, to Skeleti-Leptic Umbrisols. Some brown rankers, which include the *cambic* horizon satisfying the criteria of the WRB, belong to Skeleti-Leptic Cambisols. Other rankers should be classified as Regosols.

Table 4 presents the ranker profiles found in the published papers as well as their reclassification in accordance with the WRB soil classification.

5.1.3. Soils weakly developed from loose materials (arenosols)

Table 5 includes the arenosol profiles which have been found in the literature as well as their reclassification in accordance with the WRB soil classification.

Table 5. Verification/reclassification of the arenosol profiles

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification /verification
Jankowski, Bednarek (2000)	not specified	arenosol	–	Haplic Arenosol
Radzanowski (1998)	3, 4, 5, 6, 7, 9, 10, 16	arenosols	–	Haplic Arenosols
Muś (1998)	3	arenosol	–	Haplic Arenosol
Jankowski (2003)	R2, R3, K3	arenosols	–	Haplic Arenosols

Arenosols correspond with WRB reference soil group of the same name.

5.1.4. Correlation of the soil types of the noncarbonate soils, initial and weakly developed with the units of the WRB soil classification

The analysis of the definitions in the subchapters 5.1.1.–5.1.3.:

- of the types and subtypes of *Systematics of Polish Soils* which belong to the order of noncarbonate soils, initial and weakly developed;
- of the following reference soil groups according to the WRB classification: Leptosols, Arenosols, Umbrisols and Regosols;
- of the qualifiers of the lower level units of these soil groups in the WRB classification,

as well as verification of the systematics of the profiles found in the literature in accordance with the WRB classification enables the author to work out the following correlation between the Polish system of soil classification and the international WRB system (Table 6).

Table 6. Correlation of types of order of noncarbonate soils, initial and weakly developed with the WRB classification units

Soil type according to Systematics of Polish Soils	WRB reference soils group	Possible qualifiers
initial rocky soils (lithosols)	Leptosols	Hyperskeletic, Lithic
initial loose soils (regosols)	Leptosols	Haplic Humic
	Arenosols	Protic
	Regosols	Parahumic
initial clay soils (pelosols)	Regosols	–
noncalcareous soils weakly developed from solid rocks (rankers)	Leptosols	Haplic
	Cambisols	Skeletic, Leptic
	Umbrisols	Skeletic, Leptic
	Regosols	Leptic
soils weakly developed from loose materials (arenosols)	Arenosols	Haplic

The initial rocky soils (lithosols) correspond with Hyperskeleti-Lithic Leptosols unit; the initial loose soils (regosols) correspond with Leptosols or Protic Arenosols; noncalcareous soils weakly developed from solid rocks (rankers), in which hard rock is found at the depth of 25 cm, correspond with Leptosols.

Rankers in which the hard rock is found deeper than 25 cm from the soil surface correspond with a few WRB units: Leptic Umbrisols, Skeleti-Leptic Umbrisols, Skeleti-Leptic Cambisols and Regosols. Correlation of the subtypes of noncarbonate soils, initial and weakly developed of *Systematics of Polish Soils* with the WRB classification is impossible. The exceptions include some brown rankers with the *cambic* horizon which satisfies the criteria of the WRB and the soils weakly developed from loose materials (arenosols). Such soils would correspond with Skeleti-Leptic Cambisols and Protic Arenosols respectively.

Initial clay soils (pelosols) belong to Regosols. There is no, however, a qualifier which would stress their specific character. Soils weakly developed from loose materials (arenosols) correspond with the WRB unit of the same name – Arenosols. Due to their typical expression of features it is necessary to add a qualifier Haplic which describes classically developed soils.

5.2. LITHOGENIC CALCAREOUS SOILS WITH DIFFERENT DEVELOPMENT DEGREE

The order of lithogenic calcareous soils with different development degree includes two soil types:

- rendzinas (IB1) – soils developed on calcareous or sulphureous materials with the ACca-Cca-R, profile, which contain a certain amount of coarse fragments of hard bedrock in its ACca horizon;
- pararendzinas (IB2) – soils developed from clastic rocks rich in carbonates.

5.2.1. Rendzinas

The study of the soil science literature from the years 1989–2004 resulted in founding ten papers containing analytical data on rendzinas. This enabled the author to correlate this soil type with the WRB classification. In total 65 profiles were analysed (Table 7).

The analysis of the definitions of:

- rendzinas according to the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Histosols, Leptosols, Cambisols and Regosols;
- qualifiers of the lower level units for the above soil groups in the WRB classification

as well as verification of the systematic position of soils presented in the papers in accordance with the WRB classification resulted in establishing the following correlation between the Polish system and the international WRB system (Table 8).

Table 7. Verification/reclassification of the rendzina profiles

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification/ verification
Zasoński (1993)	Czarnorzeki 2, Węglówka 3	proper rendzinas	–	Calcari-Paramollihumic Regosols (Endoskeletic)
	Czarnorzeki 1	brown rendzina	–	Calcari-Paramollihumic Regosol
Licznar et al. (1997)	1	brown rendzina	–	Calcari-Endoleptic Regosol
	2	relict redearth rendzina	–	Calcari-Epileptic Regosol
Zagórski (1999)	J-11	brown rendzina	–	Calcaric Cambisol
Ciarkowska (2000)	1	initial rendzina (sulphureous)	–	Paragypsiri-Lithic Leptosol
	2	brown rendzina (sulphureous)	–	Paragypsiri-Humic Regosol
	3	brown rendzina (sulphureous)	–	Molli-Leptic Cambisol (Calcaric, Gypsiric)
	4	brown rendzina (sulphureous)	–	Molli-Leptic Cambisol (Paragypsiric)
Miechówka (2000)	1, 2	initial rendzinas	Calcaric Regosols	Calcaric Regosols
	3, 4	mountain raw humous rendzinas	dystric-folic Histosols	Dystri-Folic Histosols
Zwydak (2001)	1, 2	mountain humous rendzinas	Mollic Leptosols	Rendzic Leptosols *or* Calcari-Mollihumic Regosols (Skeletic)
	3	chernozemic rendzina	Mollic Leptosol	Calcari-Mollic Cambisol

Table 7. cont'd

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification/ verification
Miechówka (2001)	1, 2	mountain raw humous rendzinas	–	Folic Histosols
	3	mountain humous rendzina	–	Calcaric Leptosol *or* Calcaric Regosol
	4	mountain humous rendzina	–	Calcari-Humic Leptosol *or* Calcari-Humic Regosol
	5, 6, 9	mountain humous rendzinas	–	Calcari-Humic Leptosols *or* Calcari-Humic Regosols
	7	mountain humous rendzina	–	Calcaric Leptosol *or* Calcaric Regosol
	8	mountain humous rendzina	–	Calcaric Leptosol *or* Calcari-Humic Regosol
	10	brown rendzina	–	Humic Leptosol *or* Humic Regosol
	11, 12	brown rendzinas	–	Calcaric Leptosols *or* Calcaric Regosols
Ciarkowska, Niemyska--Łukaszuk (2002)	group I	sulphureous rendzinas	Lithic rendzic Leptosols	–
	group II	sulphureous rendzinas	Mollic rendzic Leptosols	–
	group III	sulphureous rendzinas	Cambic rendzic Leptosols	–
	group VI	sulphureous rendzinas	Mollic rendzic Leptosols	–
Mocek, Spychalski, Kaczmarek (2003)	1	rendzina	–	Calcaric Leptosol
	8, 9	sulphureous rendzinas	–	Calcaric Regosol
	2, 3, 4, 5, 6, 7, 10, 11	rendzinas	–	Calcaric Regosol
Ciarkowska, Niemyska--Łukaszuk (2004)	1, 2	chernozemic rendzinas	Rendzic Leptic Phaeozems	Calcari-Mollihumic Regosols (Eutric)

The rendzina type from the *Systematics of Polish Soils* may be correlated with three reference soil groups of the WRB classification – Leptosols, Regosols and Histosols. Due to its small thickness and considerable content of parent rock fragments, the subtype of the initial rendzinas corresponds with the Hyperskeleti-Lithic Leptosols, a lower level unit of the WRB classification. The mountain raw humus rendzinas correspond with the Folic Histosols unit. Most of proper, chernozemic, mountain humus and brown rendzinas correspond with the lower level units of Calcari-Leptic Regosols (Skeletic and Mollihumic) and Calcari-Leptic Regosols (Mollihumic) (in the case of soils of the thickness less than 50 cm it is necessary to use the qualifier Paramollihumic rather than the Mollihumic). Only some of these subtypes of rendzinas correspond with the unit of Rendzic Leptosols, which formally should contain the Rendzinas of the *Revised Legend to the Soil Map of the World in the scale 1:5000000* (FAO/Unesco 1988). The reasons for this inconsistency are the definitions of the Leptosols and the Rendzic qualifier. The section of the Leptosols definition referring to Rendzinas is as follows: '…they are overlying material with a calcium carbonate equivalent of more than 40% within 25 cm from the soil surface' (FAO-ISRIC-ISSS 1998), while the definition of the Rendzic qualifier states it 'having a *mollic* horizon which contains or immediately overlies calcareous materials containing over 40% calcium carbonate equivalent' (FAO-ISRIC-ISSS 1998). Thus, the Leptosols unit excludes the Rendzinas which in the *mollic* horizon contain less than 40% of calcareous material. The definition of the qualifier allows the soils the *mollic* horizon of which does not contain 40% of carbonates if it overlies the material satisfying this condition to be qualified into the Rendzic Leptosols subunit. The definition of the superior unit (Leptosols), however, excludes the case described above (the *mollic* horizon also has to contain 40% of carbonates). Karczewska, Bogda and Gałka (2004) suggest that type of rendzinas should be correlated with the WRB Calcisols soil group. It is unacceptable as the *calcic* horizon, the diagnostic one for Calcisols, contains accumulations of secondary carbonates, and this process is not characteristic for rendzinas.

Table 8. Correlation of the rendzinas soil type according to the *Systematics of Polish Soils* with the classification units of the WRB

SPS type	SPS subtype	WRB reference soils group	Possible qualifiers
rendzinas	initial rendzinas	Leptosols	Lithic , Hyperskeletic, Parahumic, Paragypsiric[11], Calcaric
	mountain raw humous rendzinas	Histosols	Folic, Dystric, Eutric
	proper rendzinas chernozemic rendzinas mountain humous rendzinas	Leptosols	Rendzic
		Regosols	Leptic, Mollihumic, Calcaric, Skeletic, Gypsiric, Paragypsiric,
	brown rendzinas	Regosols	Humic, Gypsiric, Paragypsiric
		Cambisols	Leptic, Skeletic, Calcaric, Gypsiric, Paragypsiric

A simplified correlation of subtypes of proper, humous and brown rendzinas with the lower level units of the WRB classification is presented in the paper by Kalicka, Chodorowski and Dębicki (2004).

11. Sulphureous rendzinas (containing gypsum).

5.2.2. Pararendzinas

The analytical data of the pararendzinas which enables the author to reclassify the profiles and to correlate the *Systematics of Polish Soils* with the WRB classification were found only in two papers (Table 9).

Table 9. Verification/reclassification of the pararendzinas profiles

Author and year	Profile number	Classification according to the quoted author after SPS	after WRB	Reclassification /verification
Zasoński (1992)	1, 2	proper pararendzinas	–	Episkeleti-Calcaric Regosols
	3	brown pararendzina	–	Calcaric Regosol
	4	brown pararendzina	–	Episkeleti-Calcaric Cambisol
	5	proper pararendzina	–	Episkeleti-Calcaric Regosol
Brożek, Zwydak (2003)	21 – Kliniska 7	proper pararendzina	Calcaric Regosol	Endoskeletic Regosol
	22 – Osie 5	proper pararendzina	Calcaric Regosol	Regosol
	23 – Ustroń 2	brown pararendzina	Skeleti-Calcaric Cambisol	Endoskeleti-Calcaric Cambisol

The analysis of the definitions of:

- pararendzinas type in *Systematics of Polish Soils*;
- the following reference soil groups of WRB classification: Regosols and Cambisols;
- qualifiers of the lower level units for the above soil groups in the WRB classification

as well as verification of the systematic position of the soil profiles, which were found in the papers according to the WRB classification enables to establish correlation of *Systematics of Polish Soils* with the international WRB system (Table 10).

Table 10. Correlation of the pararendzinas type of *Systematics of Polish Soils* with the WRB classification units

SPS type	SPS subtype	WRB reference soils group	Possible qualifiers
pararendzinas	initial pararendzinas	Leptosols	Calcaric, Skeletic
	proper pararendzinas	Regosols	Leptic, Skeletic, Calcaric
	brown pararendzinas	Cambisols	Leptic, Skeletic, Calcaric
		Regosols	Skeletic, Leptic, Calcaric

The pararendzinas type in *Systematics of Polish Soils* may be correlated with three WRB reference soil groups – Leptosols, Regosols and Cambisols. The subtype of initial pararendzinas contains at least 10% of carbonates throughout. It corresponds with the Calcaric Leptosols unit of the WRB classification. If it contains a significant amount of coarse fragments the Skeletic qualifier can be used.

6. COMPARISON OF THE DEFINITIONS OF AUTOGENIC SOILS TYPES IN *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of autogenic soils (II) in the *Systematics of Polish Soils* includes three orders: chernozemic soils (IIA), brown forest soils (IIB) and podzol soils (IIC).

6.1. CHERNOZEMIC SOILS

The soils forming process in chernozems (IIA1) is dominated by biological processes and accumulation of organic matter rather than by weathering of mineral phase. Chernozems are developed from loesses. They have at least 40 cm thick A horizon. The order of chernozemic soils contains only one type: chernozems.

6.1.1. Chernozems

The chernozem type in the *Systematics of Polish Soils* corresponds to two soil groups in the WRB classification: Chernozems and Phaeozems.

The soils which are classified as chernozems according to the SPS can be verified as Chernozems in accordance with the WRB thanks to 3 visible numerical differences:

1. moist chroma of the *mollic* horizon in the WRB Chernozems is ≤2 if its texture is finer than sandy loam. In the case of sandy loam or coarser texture the chroma is less than 3.5. Generally, Munsell value and chroma of the humus horizon of the SPS chernozems should be <3.5 (the colour criteria of the *mollic* horizon in accordance to the SPS). As far as the leached chernozems are concerned, however, a lighter colour is accepted [‘symptoms of the *ochric* horizon’ (PTG 1989)];
2. according to the WRB classification Chernozems have to contain concentrations of *secondary carbonates* starting within 50 cm of the lower limit of the Ah horizon;
3. base saturation of the SPS strongly leached chernozems A horizon can be less than 50%, while A horizon of the WRB Chernozems must be *mollic* (base saturation ≥50%).

Soils classified as chernozems by the *Systematics of Polish Soils* can be verified as Phaeozems in accordance with the WRB classification due to 3 visible numerical differences:

1. both Munsell value and chroma of the humus horizon of Phaeozems must be <3.5 when moist; in the case of the SPS chernozems value and chroma should generally be <3.5 (colour criterion of the *mollic* horizon according to the SPS). However, in the case of the leached chernozems a lighter colour is acceptable – ‘symptoms of the *ochric* horizon’ (PTG 1989);
2. Phaeozems do not contain $CaCO_3$ down to the depth of at least 100 cm from the soil surface or to a contrasting layer;

3. base saturation (in 1 *M* CH_3COONH_4) of the A horizon of the SPS strongly leached chernozems can be less than 50%, while in Phaeozems it should by ≥50% down to a depth of 100 cm from the soil surface or to a contrasting layer.

The Polish soil science literature from the years 1989–2004 includes only three papers containing analytical data of chernozems which enable to verify their systematic position according to the WRB classification. Thus, three other papers were used although they were published earlier than 1989, i.e. before the current *Systematics of Polish Soils* was published. The available data were the base for classification of 19 Chernozem profiles in accordance with the WRB system.

Table 11. Verification/reclassification of the chernozem soil profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification /Verification
Skłodowski, Sapek (1977)	2, 3	degraded chernozems	–	Chernozems
	8, 10, 12	degraded chernozems	–	Phaeozems
	14, 16	degraded chernozems	–	Chernozems
Turski (1985)	1, 3, 22	chernozems	–	Chernozems
	7	chernozem	–	Phaeozem
Kowaliński et al. (1987)	1	nondegraded chernozem	–	Chernozem
	2, 3	degraded chernozems	–	Orthieutric Cambisols
	4	degraded chernozem	–	Chernozem
	5	degraded chernozem	–	Luvisol
Turski, Słowińska--Jurkiewicz (1994)	Oszczów	chernozem	–	Orthieutric Cambisol
Paluszek (1995)	1	degraded chernozem	–	Phaeozem
Brożek, Zwydak (2003)	24 – Mircze 1	nondegraded chernozem	Luvic Chernozem	Luvic Chernozem

The analysis of definitions of:
- the chernozems type in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Chernozems, Phaeozems, Cambisols, Umbrisols and Luvisols;
- qualifiers which form the lower level units for these soil groups in the WRB classification

as well as verification of the systematic position of the profiles quoted in the papers in accordance with the WRB classification (Table 11) enables the author to find the following correlation between the Polish soil classification system and the international WRB classification (Table 12).

The nondegraded chernozem subtype in *Systematics of Polish Soils* corresponds to two WRB soil groups: Chernozems and Phaeozems. The Chernozems group includes the soils which contain secondary carbonates within the 50 cm below the A horizon, while Phaeozems are the soils without carbonates. The degraded chernozems subtype may also sometimes correspond to Chernozems and Phaeozems. In the majority of the cases, however, these will be either Umbrisols (strongly leached chernozems with the base saturation of the A horizon lower than 50%) or Luvisols (when the process of clay fraction displacement has led to creating the *argic* horizon in the form of the WRB definition) or Cambisols. For Cambisols it is possible to use Eutric/Dystric and Calcaric qualifiers.

Table 12. Correlation of the chernozems type in the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	SPS subtype	WRB reference soils group	Possible qualifiers
chernozems	nondegraded chernozems	Chernozems	Haplic, Luvic
		Phaeozems	Haplic
	degraded chernozems	Chernozems	Haplic, Luvic
		Phaeozems	Haplic
		Umbrisols	Haplic
		Luvisol	Haplic
		Cambisols	Calcaric, Eutric, Dystric

6.2. BROWN FOREST SOILS

The pedogenesis in brown forest soils (IIB) shows intensive physical and chemical weathering. These soils have a classically developed *cambic* horizon (in brown soils) or *argillic* (in soils lessivès). Acid brown soils (IIB2) differ from the proper brown soils (IIB1) mainly with strongly acid soil reaction in the entire profile. The profile of soils lessivès (IIB3) has two parts. From the upper subsurface horizon clay have been removed (*luvic* horizon) and translocated down into the profile, where it gets accumulated and thus creates the clay-increase horizon (*argillic*). The characteristic colour of the eluvial horizon is fawn (lessivès) which has given its name to the entire soil type[12].

6.2.1. Proper brown soils and acid brown soils

The types of proper brown and acid brown soils in the *Systematics of Polish Soils* corresponds to the Cambisols soil group in the WRB classification.

Soils classified as brown soils according to the *Systematics of Polish Soils* can be verified as Cambisols in accordance with the WRB classification due to 3 visible numerical differences, which result from dissimilar definitions of the *cambic* horizon in the *Systematics of Polish Soils* and in the WRB classification (compare the chapter 4.2.1.):

- according to the WRB, the *cambic* horizon should have the texture in the fine earth fraction of sandy loam or finer;
- according to the WRB, the *cambic* horizon should have the thickness of at least 15 cm;

12. Fawn, *płowy* in Polish, soils lessivès – gleby płowe.

- according to the WRB, the CEC of the *cambic* horizon is >16 $cmol_c$ kg^{-1} clay.

From the soil science literature which refers to brown soils there were 7 papers selected (55 profiles) from the years 1989–2004. They present the analytical data which enable the author to verify their taxonomy position according to the WRB.

It must be mentioned that numerous soil profiles which were classified by the authors of other articles as brown soils *de facto* satisfy the criteria of soils lessivès in the *Systematics of Polish Soils*. Such profiles will be referred to in the subchapter 6.2.2., which deals with the systematic position of soils lessivès and their correspondence with the Luvisols unit of the WRB.

Table 13. Verification/reclassification of the brown soils profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Skiba, Winnicki (1995)	6	acid brown soil	–	Hyperdystri-Endoleptic Cambisol
	7	proper brown soil, leached and gleyed	–	Eutri-Gleyic Cambisol
Melke (1997)	4, 6, 7	brown soils	–	Eutric Cambisols
	9	brown soil	–	Dystric Cambisol
Brożek, Bąkowski, Filiński (2000)	KROS7, TMA5	proper brown soils	hapli-eutric cambisols	Haplic Cambisols
	SNI24, BIE5	grey-brown soils	humi-eutric cambisols	Eutric Cambisols
	NAR9, LUB6, JAN4, GRY7, BPN1, PIN4	leached brown soils	endoeutric cambisols	Endoeutric Cambisols
	WGA9, PIN6, KROS1, BdPN2, GRY4, OSIE3, OST5, OST4, KOZ2, ZWO15	leached brown soils	endoeutric cambisols	Epidystric Cambisols
	KROS2	leached brown soil	endoeutric cambisol	Orthidystric Cambisol
	OST2, KOZ4, STA1	leached brown soils	endoeutric cambisols	Endoeutric Cambisols
	DOBRO1	acid brown soil	dystric cambisol	Endoeutric Cambisol
	BdPN5, BIE6, WEJ9, SNI3, KROS4, KLI3	acid brown soils	dystric cambisols	Hyperdystric Cambisols
	TUCHO4,	acid brown soil	dystric cambisol	Cambisol
	TUR5, GDA7,	acid brown soils	dystric cambisols	Orthidystric Cambisols
	NIE1, JAN18,	acid brown soils	dystric cambisols	Epidystric Cambisols
	GRY5, DTA6	acid brown soils	dystric cambisols	Hyperdystric Cambisols
	SNI4, WEJ8	podzolized acid brown soils	protoalbic cambisols	Hyperdystric Cambisols

Table 13. cont'd

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Chodak (2000)	1	proper brown soil	–	Orthieutric Arenosol
	4	proper brown soil	–	Endoeutric Cambisol
Zwydak (2001)	9	grey-brown soil	Mollic Cambisol	Endoskeletic Phaeozem
	11	leached brown soil	Dystric Cambisol	Epidystric Cambisol
	13	typical acid brown soil	Dystric Cambisol	Epidystric Cambisol *or* Humi-Arenic Umbrisol (Skeletic)
Kowalczyk, Miechówka (2001)	1	acid brown soil	–	Hyperdystri-Endoskeletic Cambisol
Brogowski et al. (2003)	1, 22	leached brown soils	–	Hyperdystric Arenosols
	24	leached brown soil	–	Epidystric Arenosol

The analysis of definitions of:

- brown soils and acid brown soils types in the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Cambisols, Umbrisols and Arenosols;
- qualifiers which form the lower level units for the above soil groups in the WRB classification

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 13) enables the author to correlate the Polish system of soil classification with the international WRB system (Table 14).

The analysed data enables the author to conclude that the proper brown soil type in the *Systematics of Polish Soils* corresponds to 3 reference soil group of the WRB classification: Cambisols, Arenosols and Phaeozems. The proper brown soils subtype can be correlated with a lower level unit of Haplic Cambisols, while the grey-brown ones with Eutric Cambisols or Phaeozems. Depending on base saturation, gleyed brown and leached brown soils correspond to Eutric/Dystric Cambisols or Arenosols. Presence of gleying features can be marked with the Gleyic qualifier.

Acid brown soils in the *Systematics of Polish Soils* correspond to three soil groups of the WRB classification – Cambisols (in the majority of cases), Umbrisols and Arenosols. Depending on texture, base saturation, gleying features, C_{org} content and the presence of the early stage of eluvial horizon (removal of sesquioxides), the following qualifiers can be used: Skeletic, Arenic (only in Umbrisols), Dystric, Gleyic, Humic (only in Umbrisols) and Protoalbic (only in Arenosols).

Table 14. Correlation of the brown forest soils order in the *Systematics of Polish Soils* with the WRB units

SPS type	WRB reference soil group	SPS subtype	Possible qualifiers
brown soils	Cambisols	typical brown soils	Haplic
		grey-brown soils	Eutric
		gleyed brown soils	Eutric, Dystric, Gleyic
		leached brown soils	Eutric, Dystric
	Arenosols	leached brown soils	Dystric
	Phaeozems	grey-brown soils	Endoskeletic
acid brown soils	Cambisols	typical acid brown soils	Dystric, Skeletic
		podzolized acid brown soils	Dystric, Skeletic
		gleyed acid brown soils	Gleyic, Dystric, Skeletic
	Arenosols	typical acid brown soils	Dystric
		podzolized acid brown soils	Dystric, Protoalbic
		gleyed acid brown soils	Gleyic, Dystric
	Umbrisols	typical acid brown soils	Skeletic, Humic, Arenic

6.2.2. Soils Lessivès

The type of soils lessivès in *Systematics of Polish Soils* corresponds with two reference soil groups of the WRB classification: Luvisols and Albeluvisols.

Only one visible numerical difference enables the author to verify the systematic position of Polish soils lessivès with the WRB soil unit of Luvisols:

- CEC of the *argic* horizon in the WRB must be equal to or more than 24 $cmol_c\ kg^{-1}$ clay throughout; the *Systematics of Polish Soils* does not contain the requirement referring to CEC.

The boundary between the eluvial horizon (the *luvic* horizon in the *Systematics of Polish Soils*, the *albic* in the WRB) and the illuvial horizon (the *argillic* horizon in the *Systematics of Polish Soils*, the *argic* one in the WRB) both in the reference soil group of Albeluvisols in the WRB and in the subtypes of the podzolized soils lessivès and glossic soils lessivès in the *Systematics of Polish Soils* is of glossic character. This enables the author to conclude that both the above units to a certain degree correspond to each other.

Fourteen papers (40 profiles) on soils lessivès were selected from the professional soil science literature from years 1989–2004. The analytical data they contain enabled the author to verify the systematic position of the profiles in accordance with the WRB classification.

Table 15. Verification/reclassification of soils lessivès profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Brogowski, Mazurek (1990)	Gąbin	soil lessivè	–	Epidystric Luvisol
Bogda et al. (1990)	1, 2, 3	soils lessivès	–	Haplic Luvisols
Jaworska, Długosz (1996)	2, 4	soils lessivès	–	Dystric Luvisols
	5, 6, 13	soils lessivès	–	Haplic Luvisols
	14	soil lessivè	–	Dystri-Arenic Luvisol
	19	soil lessivè	–	Epidystric Luvisol
Melke (1997)	5	soil lessivè	–	Haplic Luvisol
	8	soil lessivè	–	Epidystric Luvisol
Marcinek et al. (1997)	1, 3	pseudogley soils lessivès	–	Stagnic Luvisols
	2	glossic pseudogley soil lessivè	–	Hypereutri-Stagnic Albeluvisol
Szrejder (1998)	1	pseudogley soil lessivè	–	Stagnic Luvisol
	2	pseudogley soil lessivè	–	Albi-Endostagnic Luvisol
Chodak (2000)	2	soil lessivè	–	Hypereutric Luvisol
	3	soil lessivè	–	Orthieutric Luvisol
Komisarek (2000)	P1, P2	glossic pseudogley soils lessivès	Eutri-Gleyic Albeluvisols	Eutri-Stagnic Albeluvisols
	P3	glossic gleyed soil lessivè	Molli-Gleyic Luvisol	Gleyic Luvisol
Kabała, Chodak (2000)	P1	pseudogley soil lessivè	Eutri-Stagnic Luvisol	Stagnic Luvisol
Długosz (2002)	Skąpe	soil lessivè	–	Albic Luvisol
	Siemczyno	soil lessivè	–	Hyperdystri-Albic Luvisol
	Ogorzeliny	soil lessivè	–	Albi-Gleyic Luvisol
	Obkaz	soil lessivè	–	Albi-Gleyic Luvisol (Dystric)
	Wieleń Zaobrzański	soil lessivè	–	Dystri-Albic Luvisol
	Bukowiec Górny, Jędrzy-chowice	soils lessivès	–	Albic Luvisols
	Łękanów	soil lessivè	–	Epidystri-Albic Luvisol
Brogowski et al. (2003)	21	typical soil lessivè	–	Albi-Arenic Luvisol (Epidystric)
	27	typical soil lessivè	–	Epidystri-Albic Luvisol
	29	pseudogley soil lessivè	–	Endoeutri-Stagnic Albeluvisol

Table 15. cont'd

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Marcinek, Komisarek (2004)	Prz1	glossic pseudogley soil lessivè	Endo-Gleyic Albeluvisols	Epistagnic Albeluvisols
	Ord3	glossic pseudogley soil lessivè	Cutani-Stagnic Albeluvisols	Cutanic Luvisol
	Bt1	glossic gleyed soil lessivè	Cutani-Gleyic Albeluvisols	Endogleyic Albeluvisol
Orzechowski, Smólczyński, Sowiński (2004)	1 (katena Studnica)	soil lessivè	–	Gleyic Luvisol
Sowiński (2004)	1	soil lessivè	–	Haplic Luvisol

The analysis of the definitions of:

- soils lessivès in the *Systematics of Polish Soils*;
- the following reference soil groups in the WRB classification: Luvisols and Albeluvisols;
- qualifiers which form the lower level units for these soil groups in the WRB classification

as well as verification of the systematic position of the profiles quoted in the scientific papers in accordance with the WRB classification (Table 15) enables the author to correlate the Polish soil classification system with the international WRB system (Table 16).

Table 16. Correlation of soils lessivés of the *Systematics of Polish Soils* with the units of the WRB classification

SPS type	WRB reference soil group	SPS subtype	Possible qualifiers
soils lessivès	Luvisols	typical soils lessivès	Albic, Dystric, Arenic
		browned soils lessivès	Haplic, Dystric, Arenic, Profondic
		pseudogley soils lessivès	Stagnic, Albic, Profondic[13]
		gleyed soils lessivès	Gleyic, Albic, Arenic
		soils lessivès with *agric* horizon	Albic
		glossic soils lessivès	Stagnic
		podzolized soils lessivès	Arenic
	Albeluvisols	glossic soils lessivès	Eutric, Stagnic
		podzolized soils lessivès	Arenic

13. The usefulness of the Profondic qualifier for the classification of Polish soils lessivès in accordance with the WRB was established by Świtoniak (2006).

The type of soils lessivès in the *Systematics of Polish Soils* correspond with two reference soil groups of the WRB classification – Luvisols and Albeluvisols. Subtypes of glossic and podzolized soils lessivès can be generally correlated with the soil group of Albeluvisols. If the texture is loamy fine sand or coarser in the upper 50 cm soil layer the Arenic qualifier should be used. In the presence of the eluvial horizon which satisfies the criteria of the *albic* horizon according to the WRB the Albic qualifier should be used. Gleyic or the Stagnic qualifiers could also be used. Proper analysis, however, should be undertaken in order to verify the criteria of both *gleyic* and *stagnic* properties in accordance with the WRB classification.

6.3. PODZOL SOILS

Podzol soils (IIC) on the Polish Lowland are connected with poor glacial deposits of last glaciation. In the mountainous areas parent material of such soils includes granites, gneisses, sandstones and noncarbonate conglomerates. The order of podzol soils is divided into three types: rusty soils (IIC1), podzol soils (IIC2), and podzols (IIC3).

The origin of rusty soils is connected with the process of 'rusting'. This process leads to formation of organic matter, iron and aluminium complexes coatings on sand grains. The name of this soil type comes from fact that coatings have rusty colour.

The origin of both podzol soils and podzols is connected with the process of illuviation of iron-alumino-organic complexes from the upper part of the profile (from the *albic* horizon).

6.3.1. Rusty soils

The *sideric* horizon, which has a characteristic rusty colour, is the diagnostic horizon for rusty soils. This horizon does not have a corresponding horizon in the WRB classification. It can be treated as analogous with the *cambic* diagnostic horizon of brown soils/Cambisols (Bednarek et al. 2004). The rusty soils type in the *Systematics of Polish Soils* have to be treated as correspondent to the Arenosols soil group in the WRB classification, but unfortunately there is no qualifier defined to emphasize their specific character.

Ten papers (57 profiles) were selected from the soil science literature from the years 1989–2004. They include analytical data which enable the author to verify systematic position of rusty soils in accordance with the WRB.

The analysis of the definitions of:

- rusty soils in the *Systematics of Polish Soils*;
- of the following reference soil groups in the WRB classification: Arenosols and Umbrisols;
- qualifiers which form the lower level units for the above soil groups in the WRB classification

as well as verification of the systematic position of the profiles found in scientific papers in accordance with the WRB classification (Table 17) enable to establish the following correlation between the Polish system of soil classification and the international WRB system (Table 18).

Table 17. Verification/reclassification of the rusty soils profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Bednarek (1991)	1, 2, 3, 4, 9, 10, 11, 12	rusty soils	–	Dystric Arenosols
Okołowicz (1996)	Jelonki 1	brownish rusty soil	–	Hyperdystric Arenosol *or* Arenic Umbrisol
Bednarek, Michalska (1998)	1, 2	proper rusty soils	–	Hyperdystric Arenosols
	3	proper rusty soil	–	Arenic Umbrisol
Prusinkiewicz et al. (1998)	A	rusty soil	–	Arenosol
Szafranek (1998)	5, 6, 10, 12, 19	rusty soils	–	Hyperdystric Arenosols
Janowska (2001)	2, 3, 4, 5, 6, 7, 12, 13, 14, 15, 16	proper rusty soils	–	Hyperdystric Arenosols
	8, 9, 10, 11	podzolized rusty soils	–	Hyperdystric Arenosols
Smal, Ligęza (2001)	Zalesie las, Wandzin las, Żurowe Bagno las, Żurowe Bagno pole, Gozdów las, Gozdów pole	rusty soils	–	Hyperdystric Arenosols
	Zalesie pole	rusty soil	–	Dystric Arenosol
	Wandzin pole	rusty soil	–	Eutric Arenosol
Brogowski et al. (2003)	17, 23, 26, 41	proper rusty soils	–	Hyperdystric Arenosols
	45	proper rusty soil	–	Dystric Arenosol
Marcinek, Komisarek (2004)	Zł2	proper rusty soil	Eutric Arenosol	Eutric Arenosol
Czubaszek, Banaszuk (2004)	Ławki Małe, Murawiniec, Maliniak, Łupnik, Szelągówka, Grzędy	proper rusty soils	–	Hyperdystric Arenosols
	Leszczynowe, Dębowe, Dąbrowa	proper rusty soils	–	Epidystric Arenosols
	Orli Grąd	proper rusty soil	–	Orthidystric Arenosol

The type of rusty soils in the *Systematics of Polish Soils* corresponds to the Arenosols soil group in the WRB classification. The majority of rusty soils fall into the WRB lower level unit of Hyperdystric Arenosols. Some of them may belong to the following lower level units: Epidystric, Orthidystric or Eutric Arenosols. Probably some brownish rusty soils can be correlated with the unit of Arenic Umbrisols.

Alas, the WRB soil classification does not define the qualifier which could be used to distinguish clearly rusty soils from other Arenosols.

Table 18. Correlation between the rusty soils types in the *Systematics of Polish Soils* with the WRB units

SPS type	WRB unit	SPS subtype	Possible qualifiers
rusty soils	Arenosols	proper rusty soils	Dystric
		brownish rusty soils	Eutric
		podzolized rusty soils	Rubic[14]
	Umbrisols	brownish rusty soils	Arenic

A suggestion to modify the WRB soil classification so as to distinguish rusty soils from other Arenosols is presented in chapter 13.

6.3.2. Podzol soils and podzols

According to the *Systematics of Polish Soils* the diagnostic horizons of both podzol soils and podzols are the *albic* and *spodic* horizons.

The podzol soils and podzols in the *Systematics of Polish Soils* correspond to the Podzols reference soil group in the WRB classification.

It is possible to verify the classification of the soil profiles of Polish podzol soils and podzols as the Podzols unit in the WRB on the basis of 6 numerically visible differences which result from diverse definitions of the *spodic* horizon in accordance to the WRB and the SPS:

1. the colour of the *spodic* horizon is defined precisely in the WRB classification (Munsell hue 7.5YR or redder with value ≤5 and chroma ≤4 when moist and crushed or hue of 10YR with value ≤3 and chroma ≤2 when moist and crushed); the colour criterion does not have to be met if the *spodic* horizon have a subhorizon which is at least 2.5 cm thick and which is continuously cemented by a combination of organic matter and aluminium as well as iron, or when *spodic* have distinct organic pellets between sand grains;
2. the criterion of the C_{org} content is only found in the WRB classification (≥0.6%);
3. the criterion of minimum content of amorphous Fe and Al is only present in the WRB classification (at least 0.5% Al_{ox}+½Fe_{ox}[15], which should be also at least twice as much as the amount of Al_{ox}+½Fe_{ox} in the overlying *umbric*, *ochric*, *albic* horizons or in the *anthropedogenic* horizons);
4. the criterion of the ODOE value (≥0.25 which also is two times or more the value of the overlying horizons) is only present in the WRB classification;
5. in accordance with WRB classification, the thickness of the *spodic* horizon should amount to at least 2.5 cm;
6. in accordance with WRB classification, the upper limit of the *spodic* horizon should be found deeper than 10 cm from the mineral soil surface.

From the soil science literature published in Poland in the years 1989–2004, which refers to podzol soils and podzols, the author selected 5 papers (11 profiles). They include analytical data which enable the author to verify their systematic position

14. The usefulness of the Rubic qualifier for the classification of rusty soils in accordance with the WRB was established by Świtoniak (2006).

15. Al_{ox} and Fe_{ox}: acid oxalate (pH 3) extractable aluminium and iron, respectively.

in accordance with the WRB. Due to a relatively small number of papers on these soil types the author used the unpublished data collected in the Department of Soil Science of the NCU (12 profiles). Out of the above profiles three are represent podzols while 20 are podzol soils.

Table 19. Verification/reclassification of the podzol soils and podzols profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Marcinek et al. (1997)	4	podzol	–	Hyperdystri-Albic Arenosol
Kabała (1998)	5	podzol	–	Haplic Podzol
Kabała, Chodak (2000)	profil 3 'Świeradów Zdrój'	podzol soil	Haplic Podzol	Haplic Podzol
	profil 4 'Czerniawa'	podzol soil	Haplic Podzol	Orthidystric Arenosol
Kowalczyk, Miechówka (2001)	3	podzol	Haplic Podzol	Skeletic Podzol
	4	podzol soil	Haplic Podzol	Skeletic Podzol
Degórski (2002)	15 'Płaska'	podzol soil	–	Haplic Podzol
	16 'Browsk', 17 'Józe-fów', 26 'Namyślin'	podzol soils	–	Hyperdystri-Albic Arenosols
	24 'Uzłogi'	podzol soil	–	Haplic Podzol
Charun (2003)	3 i 4	proper podzol soils	–	Arenosol
Domańska (2003)	1, 2, 3	podzol soils	–	Arenosols
Jankowski (2003)	Chorągiewka 2, 3, 4, 5, 6	proper podzol soils	Haplic Podzols	Arenosols
	Katarzynka 1, Sąsieczno 1	proper podzol soils	Haplic Podzols	Albic Arenosols

The analysis of the definitions of:

- podzol soils and podzols in the *Systematics of Polish Soils*;
- of the following reference soil groups in the WRB classification: Podzols and Arenosols;
- qualifiers which form the lower level units for the above soil groups in the WRB classification

as well as verification of the systematic position of the soil profiles found in scientific papers in accordance with the WRB classification (Table 19) enable to establish the following correlation between the Polish system of soil classification and the international WRB system (Table 20).

Table 20. Correlation between the podzol soils and podzols types in the *Systematics of Polish Soils* and the classification units of the WRB

SPS type	WRB reference soil group	Possible qualifiers
podzol soils	Podzols	Haplic, Skeletic
	Arenosols	Dystric , Albic
podzols	Podzols	Haplic, Skeletic, Placic, Densic
	Arenosols	Dystric, Albic

The podzol soils and podzols in the *Systematics of Polish Soils* corresponds to two soil groups of the WRB classification:

- Podzols (in the case when a given soil profile contains the *spodic* horizon which satisfies the criteria of the WRB). If the *albic* horizon satisfying the criteria of the WRB is present, a lower level unit can be diagnosed – Haplic Podzol. In case of Podzols it is also possible to use the following qualifiers: Skeletic, Densic and Placic;
- Arenosols (in the case when a given soil profile lacks the *spodic* horizon which satisfies the criteria of the WRB). If the *albic* horizon satisfying the criteria of the WRB is present, a lower level unit can be diagnosed – Albic Arenosol. It is also advisable to use the Dystric qualifier (together with the prefixes) in order to stress low base saturation.

7. COMPARISON OF THE DEFINITIONS OF SEMI-HYDROGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of semi-hydrogenic soils (III) in the *Systematics of Polish Soils* includes three orders: gley-podzol soils (IIIA), black earths (IIIB) and bogged soils (IIIC).

7.1. GLEY-PODZOL SOILS

Gley-podzol soils (IIIA) originate thanks to two soil-forming processes: podzolization in the upper section of the profile and reducing conditions in the bottom part of the profile, which leads to development of gleyic features. The order of gley-podzol soils is divided into two types: gley-podzol soils (IIIA1) and gley-podzols (IIIA2).

7.1.1. Gley-podzol soils and gley-podzols

Gley-podzol soils and gley-podzols in the *Systematics of Polish Soils* correspond to the lower level unit of Gleyic Podzols in the WRB classification:

Similarly to podzol soils, it is possible to verify the systematic position of the Polish gley-podzol soils and gley-podzols as the Podzols unit of the WRB thanks to 6 visible numerical differences which result from differences in the definitions of the *spodic* horizon in accordance with the WRB and *glejospodic* horizon in accordance with the *Systematics of Polish Soils*:

1. the colour of the *spodic* horizon is defined precisely in the WRB classification (Munsell hue 7.5YR or redder with value ≤5 and chroma ≤4 when moist and crushed or hue of 10YR with value ≤3 and chroma ≤2 when moist and crushed); the colour criterion does not have to be met if the *spodic* horizon have a subhorizon which is at least 2.5 cm thick and which is continuously cemented by a combination of organic matter and aluminium as well as iron, or when *spodic* have distinct organic pellets between sand grains;
2. the criterion of the C_{org} content is only found in the WRB classification (≥0.6%);
3. the criterion of minimum content of amorphous Fe and Al is only present in the WRB classification (at least 0.5% Al_{ox}+½Fe_{ox}[16]), which should be also at least twice as much as the amount of Al_{ox}+½Fe_{ox} in the overlying *umbric*, *ochric*, *albic* horizons or in the *anthropedogenic* horizons);
4. the criterion of the ODOE value (≥0.25 which also have to be two times or more the value of the overlying horizons) is only present in the WRB classification;
5. in accordance with WRB classification, the thickness of the *spodic* horizon should amount to at least 2.5 cm;
6. the upper limit of the *spodic* horizon according to WRB should be found deeper than 10 cm from the mineral soil surface.

16. Al_{ox} and Fe_{ox}: acid oxalate (pH 3) extractable aluminium and iron, respectively.

The soil science literature on gley-podzol soils and gley-podzols published in Poland in the years 1989–2004 contained only two papers (6 profiles) with analytical data, which enable to verify their systematic position according to the WRB classification. Due to a relatively small number of papers on gley-podzol soils and gley-podzols the author used the unpublished material collected in the Department of Soil Science of the NCU (5 profiles).

Table 21. Verification/reclassification of the gley-podzol soils and gley-podzols profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Kabała, Chodak (2000)	profil 2 'Rozdroże Izerskie'	proper gley-podzol	Stagnic Podzol	Hyperdystri-Albic Arenosol
Łachacz (2001)	5	proper gley-podzol soil	–	Albi-Gleyic Arenosol (Epidystric)
	9	proper gley-podzol soil	–	Densi-Gleyic Podzol
	10	mucky gley-podzol soil	–	Albi-Gleyic Arenosol (Endoeutric)
	11	mucky gley-podzol soil	–	Albi-Gleyic Arenosol (Eutric)
	12	peaty gley-podzol soil	–	Areni-Histic Gleysol
Nicewicz (2003)	2	peaty gley-podzol soil	–	Areni-Histic Gleysol
	3	proper gley-podzol	–	Densic Podzol
Jankowski (2003)	Katarzynka 9	proper gley-podzol soil	–	Areni-Endogleyic Umbrisol (Humic)
	Lasek Bielański 3	mucky gley-podzol soil	Humi-Gleyic Podzol	Haplic Podzol
	Wrzosy 1	mucky gley-podzol soil	Humi-Gleyic Podzol	Haplic Arenosol

The analysis of definitions of:

- the gley-podzol soils and gley-podzols types in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Podzols, Gleysols, Arenosols and Umbrisols;
- the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 21) enables the author to find the following correlation between the Polish soil classification system and the international WRB classification (Table 22).

Table 22. Correlation of gley-podzol soils and gley-podzols types in the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
gley-podzol soils	Podzols	Gleyic, Haplic, Densic
	Arenosols	Dystric, Albic, Gleyic
	Gleysols	Arenic, Histic
	Umbrisols	Arenic, Gleyic, Humic
gley-podzols	Podzols	Gleyic, Placic, Densic
	Arenosols	Dystric, Albic, Gleyic

Gley-podzol soils and gley-podzols in the *Systematics of Polish Soils* correspond to four soil groups in the WRB classification:

- Gleysols (in the case when *gleyic* properties are present within 50 cm from the soil surface);
- Podzols (in the case when the WRB *spodic* horizon is found);
- Umbrisols (in the case when the WRB *umbric* horizon is found);
- Arenosols (in all the other cases).

The Arenic and Histic qualifiers can be used for Gleysols, while the Gleyic, Densic, Placic and Haplic ones for Podzols. Furthermore, the Dystric, Albic and Gleyic qualifiers can be used for Arenosols, whereas the Arenic, Gleyic and Humic ones for Umbrisols.

7.2. BLACK EARTHS

Black earths (IIIB) originate due to the process of accumulation of organic matter in clay fraction and calcium carbonate rich deposits when groundwater level is high and there are conditions to develop gleyic features. The order of black earths contains only one soil type – black earths.

7.2.1. Black earths

The type of black earths in the *Systematics of Polish Soils* corresponds to the lower level unit of the WRB classification, namely Mollic Gleysols.

The verification of the systematic position of soils classified as black earths according to SPS as a lower level unit of Mollic Gleysols in accordance with the WRB is based on the fact that *gleyic* properties in Mollic Gleysols have to be found within 50 cm from the soil surface. The measurable rH parameter, which exists in the definition of *gleyic* properties in the WRB and which could be used for verification, is not a standard measure in Poland.

Table 23. Verification/reclassification of the black earths soil profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Chojnicki (1994)	9	proper black earth	–	Chernozem
	11	proper black earth	–	Endogleyic Chernozem
	10, 12	degraded black earths	–	Endogleyic Chernozems
	13	degraded black earth	–	Areni-Endostagnic Phaeozem
Konecka-Betley, Czępińska-Kamińska, Janowska (1996)	Sieraków 3, Ławy 10, Nart 5	degraded black earths	–	Areni-Gleyic Umbrisols
	Granica 4	degraded black earth	–	Umbric Gleysol
	Rogacz 8, Famułki Brochowskie 14	degraded black earths	–	Arenic Umbrisols
	Niepust 1	mucky black earth	–	Greyi-Gleyic Phaeozem
	Buda 9	mucky black earth	–	Greyic Phaeozem
Szrejder (1998)	5	gleyed black earth	–	Mollic Gleysol
Komisarek (2000)	P4	browned black earth	Molli-Gleyic Calcisols	Calci-Endogleyic Chernozem
	P5	browned black earth	Molli-Gleyic Calcisols	Calci-Mollic Gleysol
	P6	mucky black earth	Cumuli-Mollic Gleysols	Endogleyic Chernozem
Brogowski et al. (2003)	8	degraded black earth	–	Endostagnic Phaeozem
	19	degraded black earth	–	Arenic Umbrisol
Brożek, Zwydak (2003)	27 – Lubaczów 7	mucky black earth	Saprihistic Gleysol	Mollic Gleysol
	28 – Zwoleń 13	leached black earth	Mollic Gleysols	Mollic Gleysol
	29 – Babimost 2	proper black earth	Mollic Gleysol	Mollihumi-Endogleyic Regosols
	30 – Staszów 9	leached black earth	Molli-Luvic Gleysols	Epistagni-Endogleyic Umbrisol (Humic)
	31 – Janów Lubelski 17	leached black earth	Molli-Luvic Gleysols	Humi-Endogleyic Umbrisol
Marcinek, Komisarek (2004)	Pz4	browned black earth	Mollic Gleysols	Endogleyic Chernozem
	Pz6	mucky black earth	Cumuli-Mollic Gleysols	Endogleyic Chernozem
	Mo2	browned black earth	Areni-Mollic Gleysols	Endogleyic Chernozem

Seven papers (24 profiles) were selected from the soil science literature on black earths published in the years 1989–2004. They contain the analytical data enabling the author to verify systematic position of black earths with respect to the WRB.

The analysis of definitions of:

- the black earths type in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Gleysols, Chernozems, Phaeozems and Umbrisols;
- the qualifiers forming the lower level units for these soil groups in the WRB classification

as well as verification of the systematic position of the soil profiles presented in the papers in accordance with the WRB classification (Table 23) enables the author to establish the following correlation between the Polish soil classification system and the international WRB classification (Table 24).

Table 24. Correlation of the black earths type of the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
black earths	Gleysols	Mollic, Calcic, Hyposalic[17]
	Chernozems	Endogleyic, Calcic
	Phaeozems	Endogleyic, Stagnic, Arenic, Greyic
	Umbrisols	Arenic, Endogleyic, Stagnic, Humic
	Regosols	Endogleyic, Humic

The black earths in the *Systematics of Polish Soils* correspond to five soil groups in the WRB classification:

- Gleysols (in the case when *gleyic* properties are present within 50 cm from the soil surface);
- Chernozems (in the case when the profile contains secondary carbonates);
- Phaeozems (in the case when the profile does not contain carbonates within 100 cm from the soil surface);
- Umbrisols (in the case when A horizon is an *umbric* horizon according to WRB);
- Regosols (in all the other cases).

In case of Polish black earths it is possible to use the Mollic and Calcic qualifiers for the soil group of Gleysols; the Endogleyic and Calcic ones for Chernozems; the Endogleyic, Stagnic, Arenic and Greyic ones for Phaeozems; the Arenic, Endogleyic, Stagnic and Humic ones for Umbrisols; and the Endogleyic and Humic ones for Regosols.

17. The usefulness of the Hyposalic qualifier for the classification of black earths in accordance with the WRB was established by Hulisz (2005).

7.3. BOGGED SOILS

Bogged soils (IIIC) develop where drainage is poor and the water table is high or if the soil material is saturated with surface water. A reducing environment exists in the saturated layers. In bogged soils relatively thick A horizon is formed.

7.3.1. Pseudogley soils

Basically, the pseudogley soils type (IIIC1) has stagnic features and either the A-Gg sequence of horizons or the A-Gg-Bg-Cg-C one.

The WRB classification differentiates a separate group for soils with strong stagnic features caused by surface water stagnation due to *abrupt textural change* within 100 cm from the soil surface. It is the Planosols soil group. The soils with the *stagnic* properties caused by other factors are differentiated with the use of the Stagnic qualifier at the lower level units of numerous main reference soil groups.

Three papers were found in the soil science literature on pseudogley soils, published in Poland in the years 1989–2004. They contain the analytical data enabling the author to verify systematic position of pseudogley soils according to the WRB (18 profiles in total).

Table 25. Verification/reclassification of the profiles of pseudogley soils

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Gworek et al. (2000)	1, 7	stagno-gley soils	–	Dystric Planosols
	8	stagno-gley soil	–	Umbrihumic Planosol
Brogowski et al. (2003)	2	proper pseudogley soil	–	Umbric Planosol
	4	proper pseudogley soil	–	Stagnic Umbrisol
	6	proper pseudogley soil	–	Epidystri-Arenic Planosol
	12, 30	proper pseudogley soils	–	Areni-Stagnic Umbrisols
	18	proper pseudogley soil	–	Hyperdystric Planosol
Brożek, Zwydak (2003)	132 (Gryfino 8)	proper pseudogley soil	Stagni-Haplic Gleysol	Epistagnic Umbrisol
	133 (Narol 14)	proper pseudogley soil	Stagni-Haplic Gleysol (Glossic)	Epidystri-Epistagnic Regosol
	134 (Turawa 7)	proper pseudogley soil	Stagni-Haplic Gleysol	Hyperdystri-Epistagnic Regosol
	135 (Ostrowiec Świętokrzyski 10)	proper pseudogley soil	Stagni-Haplic Gleysol (Spodic)	Epidystric Arenosol
	136 (Babimost 8)	stagno-gley soil	Stagni-Fibrihistic Gleysol	Stagni-Arenic Umbrisol
	137 (Niepołomice 9)	stagno-gley soil	Stagni-Fibrihistic Gleysol	Stagni-Arenic Regosol (Hyperdystric)

Table 25. cont'd

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Brożek, Zwydak (2003) cont'd	138 (Dąbrowa Tarnowska 7)	stagno-gley soil	Stagni-Fibrihistic Gleysol	Hyperdystri-Epistagnic Regosol
	139 (Dobrocin 8)	stagno-gley soil	Stagnic Gleysols	Epistagni-Endogleyic Regosol (Eutric)
	140 (Janów Lubelski 8)	stagno-gley soil	Stagnic Gleysols	Hyperdystri-Endogleyic Regosol

The analysis of definitions of:

- the pseudogley soil type in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Planosols, Umbrisols, Arenosols and Regosols;
- the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as verification of the systematic position of the soil profiles presented in the papers in accordance with the WRB classification (Table 25) enables the author to establish the following correlation between the *Systematics of Polish Soils* and the international WRB classification (Table 26).

Table 26. Correlation of the pseudogley soils type in the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
pseudogley soils	Planosols	Umbric, Humic, Gleyic, Arenic, Dystric
	Umbrisols	Stagnic, Arenic, Humic
	Regosols	Stagnic, Gleyic, Arenic, Dystric
	Arenosols	Dystric

Pseudogley soils of the *Systematics of Polish Soils* correspond to four reference soil groups in the WRB classification:

- Planosols (in the case when the cause of the surface water stagnation is *abrupt textural change* within 100 cm from the soil surface);
- Umbrisols (in the case when A horizon is an *umbric* horizon according to WRB);
- Arenosols (in the case when soil have a texture which is loamy sand or coarser to a depth of at least 100 cm from the soil surface);
- Regosols (in all the other cases).

In the case of analysed Polish soils it is possible to use the Umbric, Humic, Gleyic, Arenic and Dystric qualifiers for Planosols; the Stagnic, Arenic and Humic ones for Umbrisols; the Dystric one for Arenosols; and Epistagnic, Endogleyic, Arenic and Dystric ones for Regosols.

7.3.2. Gley soils

Gley soils (IIIC2) have either the A-G sequence of horizons or the O-A-G one. They develop where drainage is poor and the water table is high. In saturated part of the profile sesquioxides of iron, are reduced to ferrous oxides by the removal of oxygen. This process gives a greenish-blue-grey colour to the soil.

The type of gley soils in the *Systematics of Polish Soils* corresponds to the WRB reference soil group of Gleysols

The verification of the systematic position of soils classified as gley soils according to SPS as Gleysols in accordance with the WRB is based on the fact that *gleyic* properties in Gleysols must be present within 50 cm from the soil surface.

The measurable rH parameter, which is found in the WRB definition of *gleyic* properties and which could help in verification, is not a standard procedure in Poland. Thus, the classification of gley soils in accordance with the WRB criteria must be based unfortunately only on morphologically developed gleyic features.

Only two papers (14 profiles in total) published on gley soils in Poland in the years 1989–2004 included analytical data useful for verifying the systematic position of these soils with respect to the WRB.

Table 27. Verification/reclassification of the profiles of gley soils

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Łachacz (2001)	2	peaty gley soil	–	Areni-Saprihistic Gleysol
	3	peaty gley soil	–	Areni-Histic Gleysol
	4	peat-like gley soil	–	Arenic Gleysol
	8	proper gley soil	–	Areni-Umbric Gleysol
Brożek, Zwydak (2003)	122 (Narol 7), 123 (Niepołomice 6), 124 (Staszów 8)	proper gley soils	Haplic Gleysols	Haplic Gleysols
	125 (Turawa 8)	proper gley soil	Mollic Gleysol (Abruptic)	Umbric Gleysol
	126 (Dąbrowa Tarnowska 1)	proper gley soil	Ferri-Umbric Gleysol	Endoeutri-Umbric Gleysol
	127 (Ostrowiec Świętokrzyski 8)	peaty gley soil	Fibrihistic Gleysol	Hyperdystri-Fibrihistic Gleysol
	128 (Kliniska 4)	peaty gley soil	Saprihistic Gleysol	Areni-Umbric Gleysol
	129 (Osie 1)	peaty gley soil	Saprihistic Gleysol	Areni-Saprihistic Gleysol (Epidystric)
	130 (Tuszyma 3)	peaty gley soil	Saprihistic Gleysol	Umbric Gleysol
	131 (Węgierska Górka 10)	mud-gley soil	Mollic Gleysol	Mollihumic Gleysol

The definition analysis of:

- the gley soils type in accordance with the *Systematics of Polish Soils*;
- the Gleysols reference soil group according to the WRB classification;
- the qualifiers forming the lower level units for this soil group in the WRB classification,

as well as verification of the systematic position of the soil profiles presented in the papers in accordance with the WRB classification (Table 27) enables the author to find the following correlation between the *Systematics of Polish Soils* and the international WRB classification (Table 28).

Table 28. Correlation of the gley soils type of the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
gley soils	Gleysols	Haplic, Umbric, Mollic, Humic, Arenic, Saprihistic, Fibrihistic, Dystric, Eutric

The gley soils type of the *Systematics of Polish Soils* corresponds to one reference soil group of the WRB classification – Gleysols. In case of Polish soils it is possible to use the following qualifiers: Haplic, Umbric, Mollic, Humic, Arenic, Saprihistic, Fibrihistic, Dystric and Eutric.

8. COMPARISON OF THE DEFINITIONS OF HYDROGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of hydrogenic soils (IV) in the *Systematics of Polish Soils* is divided into two orders: bogged soils (IVA) and post-bog soils (IVB).

8.1. BOGGED SOILS

The thickness of the A horizon in bogged soils exceeds 30 cm. Accumulation of organic matter is the result of the boggy processes: mud-forming (in anaerobic-aerobic conditions) or peat-forming (prevailing anaerobic conditions). The order of bogged soils is divided into two types:

- mud soils (IVA1);
- peat soils (IVA2).

8.1.1. Mud soils

Mud soils are found in the areas which get flooded, either permanently or periodically. Their origin is conditioned by periodical aeration which promotes the biochemical decomposition of plant debris. In these soils biological processes are very intensive.

The criteria for distinguishing mud soils from peat soils and the character of mud deposits have not been specified so far. There is not much data on the features which would enable to distinguish the above soils (Tobolski 2000).

Alas, the Polish soil science literature from the years 1989–2004 does not contain any papers with the analytical data of mud soils. The only paper on that soil type contains only the profile description (Roj-Rojewski, Banaszuk 2004). Due to that, the verification of the systematic position of the mud soil profiles with respect to the WRB was not possible.

The correlation presented in Table 29, though, was based on the analysis of the mud soils definition of the *Systematics of Polish Soils* and their comparison with definitions of Histosols, Gleysols and Fluvisols reference soil groups of WRB. It has not been verified by reclassification of the mud soils profiles in accordance with the WRB classification.

Table 29. Correlation of mud soils type of the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
mud soils	Histosols	Fibric, Sapric, Rheic, Dystric, Eutric
	Fluvisols	Histic, Gleyic, Mollic, Umbric, Humic, Calcaric, Dystric, Eutric
	Gleysols	Histic, Mollic, Umbric, Humic, Calcaric, Dystric, Eutric

Mud soils of the *Systematics of Polish Soils* correspond to three soil groups in the WRB classification:

- Histosols – in the case when the thickness of the organic horizon exceeds 40 cm and meets the criterion of the C_{org} content of the *histic* horizon according to the WRB classification;
- Fluvisols – in the case when the thickness of the organic horizon is from 30 to 40 cm or the criterion of the C_{org} content for the *histic* horizon according to the WRB is not satisfied and the profile contains the *fluvic* soil material (which shows stratification in at least 25% of the soil volume over a specified depth), which starts within 25 cm from the soil surface and continuing to a depth of at least 50 cm from the soil surface;
- Gleysols – in all the other cases.

If mud soils correspond to the Histosols unit it is possible to use the following qualifiers: Fibric or Sapric, depending on the level of the plant tissue decomposition; Rheic to show that water regime is conditioned by surface waters; Eutric if base saturation is ≥50%.

In the case when mud soils can be classified as Fluvisols or Gleysols, it is possible to use the following qualifiers: Histic, if the WRB *histic* horizon less than 40 cm thick is present; Mollic or Umbric, if the WRB *mollic* or *umbric* horizons are found; Humic, if the C_{org} content amounts to over 1% to a depth of 50 cm from the soil surface; Calcaric, if the $CaCO_3$ content exceeds 2% at least between 20 to 50 cm from the soil surface; Dystric, Eutric, depending on the value of base saturation. In the case of Fluvisols it is also possible to use the Gleyic qualifier.

8.1.2. Peat soils

Peat soils develop in conditions where biochemical decomposition of plant debris is retarded by persistent waterlogging and peat is accumulating. Peat soils can be divided into three subtypes: low peat soils, transitory peat soils and high peat soils.

The type of peat soils in the *Systematics of Polish Soils* corresponds to the WRB soil group of Histosols.

It is possible to verify the systematic position of the soils classified as peat soils of the SPS as Histosols in accordance with the WRB due to the fact that the *histic* (or *folic*) horizon in Histosols must be at least 40 cm thick (or ≥10 cm from the soil surface to a lithic or paralithic contact), while in the *Systematics of Polish Soils* the thickness of the organic horizon must exceed 30 cm.

The soil science literature on peat soils published in Poland in the years 1989–2004 includes three papers with the sets of analytical data (11 profiles in total). It enabled the author to verify these soils' systematic position according to the WRB (Table 30).

Table 30. Verification/reclassification of the peat soils profiles

Author and year	Profile number	Classification in accordance with the quoted author		Reclassification/ Verification
		after SPS	after WRB	
Skiba, Winnicki (1995)	2	peat soil	–	Ombric Histosol
Brożek, Zwydak (2003)	141 – Bieszczadzki Park Narod. 7	low peat soil	Eutri-Fibric Histosol (Ombric)	Rhei-Sapric Histosol (Epidystric, Endoeutric)
	142 – Tuchola 7	low peat soil	Eutri-Fibric Histosol (Ombric)	Rhei-Sapric Histosol (Eutric)
	143 – Staszów 3	low peat soil	Eutri-Fibric Histosol (Ombric)	Rhei-Fibric Histosol Eutric)
	144 – Śnieżka 1, 145 – Tuszyma 2	transitory peat soils	Dystri-Fibric Histosols	Hyperdystri-Fibric Histosols
	146 – Bieszczadzki Park Narod. 8	high peat soil	Dystri-Fibric Histosol (Rheic)	Ombri-Fibric Histosol (Hyperdystric)
	147 – Gdańsk 6, 148 – Tuchola 2, 149 – Szklarska Poręba 3	high peat soils	Dystri-Fibric Histosols (Rheic)	Ombri-Fibric Histosols (Hyperdystric)
Marcinek, Komisarek (2004)	Ob7	peat soil	Eutri-Fibric Histosols	Eutri-Fibric Histosol

The analysis of definitions of:

- the peat soils type in accordance with the *Systematics of Polish Soils*;
- the Histosols reference soil group according to the WRB classification;
- the qualifiers forming the lower level units for this soil group in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 30) enables the author to find the following correlation between the *Systematics of Polish Soils* and the international WRB classification (Table 31).

Table 31. Correlation of peat soils type of the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	SPS subtype	Possible qualifiers
peat soils	Histosols	low peat soils	Fibric, Sapric, Rheic, Hyposalic[18], Eutric, Dystric
		transitory peat soils	Fibric, Sapric, Dystric, Eutric
		high peat soils	Fibric, Sapric, Ombric, Dystric (Hyperdystric), Eutric

18. The usefulness of the Hyposalic qualifier for the classification of low peat soils in accordance with the WRB was established by Hulisz (2005).

The peat soils type of the *Systematics of Polish Soils* corresponds to one reference soil group of the WRB, namely Histosols. In order to define the lower level units the following qualifiers can be used: Fibric, Sapric, Ombric (for the subtype of high peat soils), Rheic (for the subtype of low peat soils), Dystric or Eutric.

8.2. POST-BOG SOILS

The order of post-bog soils (IVB) includes the soils which originate from bogged soils after their draining. This stops the process of the accumulation of organic material. Draining results in developing specific chemical, physical and biological properties, which all make up the soil mucky process. The post-bog soil order includes two soil types which differ from each other with the C_{org} content:

- muck soils (IVB1);
- mucky soils (IVB2).

8.2.1. Muck soils

Muck soils develop from the peat soils. Their characteristic feature is the existence of at least a 30 cm thick horizon which includes more than 20% of organic matter. Muck soils undergo a process which leads to changing the structure of the organic soil mass into the crumb or fine-granular ones, specific for muck.

Table 32. Verification/reclassification of the profiles of muck soil

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Okołowicz, Sowa (1997)	4 – Dąb Kobendzy, 5 – Dębowskie Góry	peat-muck soils	–	Orthieutri-Sapric Histosols
Okołowicz (1999)	Pożary 2	peat-muck soil	–	Orthieutri-Sapric Histosol
Brożek, Zwydak (2003)	150 – Babimost 7	peat-muck soil	Sapri-Eutric Histosol	Eutri-Sapric Histosol
	151 – Niepołomice 3	peat-muck soil	Sapri-Eutric Histosol	Dystri-Sapric Histosol
	152 – Kliniska 6	peat-muck soil	Sapri-Eutric Histosol	Epidystri-Sapric Histosol (Endoeutric)
	153 – Tuszyma 4	peat-muck soil	Sapri-Dystric Histosol	Hyperdystri-Histic Gleysol
	155 – Pińczów 8	overmuck soil[19]	Areni-Eutric Histosol	Eutri-Sapric Histosol
Marcinek, Komisarek (2004)	Wi4	peat-muck soil	Eutri-Sapric Histosols	Eutri-Sapric Histosol
	Wi6	mud-muck soil	Eutri-Sapric Histosols	Eutri-Sapric Histosol
Orzechowski, Smólczyński, Sowiński (2004)	4, Studnica catena	overmuck soil	–	Orthieutri-Sapric Histosol
	5, Studnica catena	peat-muck soil	–	Orthieutri-Sapric Histosol
	3, 4, Baranowo catena	overmuck soil	–	Orthieutri-Fibric Histosols

19. In WRB soil classification mineral horizons less than 30 thick, which lies on *histic* horizon are of no diagnostic significance, while in the *Systematics of Polish Soils* they are.

The type of muck soils in the *Systematics of Polish Soils* is correspondent to the WRB reference soil group of Histosols.

It is possible to verify the systematic position of the soils classified as muck soils as Histosols in accordance with the WRB due to the fact that the *histic* (or *folic*) horizon in Histosols must be at least 40 cm thick (or ≥10 cm from the soil surface to a *lithic* or *paralithic* contact), while according to the *Systematics of Polish Soils* muck soils must have a 30 cm or more thick horizon which contains over 20% of organic matter (12% C_{org}).

The Polish soil science literature on muck soils from the years 1989–2004 included 5 papers (15 profiles in total) with analytical data of muck soils. This was the base for verifying their systematic position with respect to the WRB classification.

The analysis of definitions of:

- the muck soil type in accordance with the *Systematics of Polish Soils*;
- the Histosols and Gleysols reference soil groups according to the WRB classification;
- the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 32) enables the author to find the following correlation between the *Systematics of Polish Soils* and the international WRB classification (Table 33).

Table 33. Correlation of muck soils type in the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
muck soils	Histosols	Fibric ,Sapric, Dystric, Eutric
	Gleysols	Saprihistic, Sodic[20], Dystric, Eutric

Muck soils in the *Systematics of Polish Soils* correspond to two reference soil groups in the WRB classification:

- Gleysols (in the case when organic horizon is less than 40 cm thick);
- Histosols (in all the other cases).

8.2.2. Mucky soils

Mucky soils (IVB2) are mineral-organic soils which contain less than 20% of organic matter (12% C_{org}), or which have a horizon with over 20% of organic matter (12% C_{org}) but less than 30 cm thick. The mucky process in these soils turns peat, mud or peaty deposit into muck of mucky deposit. The mucky soil type includes three subtypes:

- mineral-mucky soils;
- proper mucky soils;
- muckous soils.

20. The usefulness of Sodic qualifier for the classification of muck soils according to the WRB was established by Hulisz (2005).

Mucky soils of the *Systematics of Polish Soils* correspond to a WRB lower level unit of the Arenic Gleysols.

It is possible to verify the systematic position of the soils classified as mucky soils as the lower level unit of Arenic Gleysols in accordance with the WRB thanks to the fact that *gleyic* properties in Gleysols must be found within 50 cm from the soil surface. To satisfy the criteria of the Arenic qualifier, the soil material in the profile must have a texture of loamy fine sand or coarser throughout the upper 50 cm.

The Polish soil science literature on mucky soils from the years 1989–2004 contains only two publications with the analytical data of 6 profiles enabling the author to verify their systematic position in accordance to the WRB classification. Due to a relatively small number of papers on mucky soils the unpublished material collected in the Department of Soil Science of the NCU (5 profiles) was used.

Table 34. Verification/reclassification of the profiles of mucky soils

Author and year	**Profile number**	**Classification in accordance with the quoted author**		**Reclassification/ Verification**
		after SPS	**after WRB**	
Lejza (1998)	1, 2	muckous soils	–	Arenic Gleysols
	3	muckous soil	–	Arenic Umbrisol *or* Phaeozem *or* Arenosol
Wesołowska (2003)	2	muckous soil	–	Areni-Endogleyic Umbrisol *or* Endogleyic Arenosol
	3	muckous soil	–	Areni-Mollic Gleysol *or* Areni-Umbric Gleysol
Brożek, Zwydak (2003)	156 – Narol 6	mineral-mucky soil	Areni-Humic Gleysol	Areni-Humic Gleysol (Hyperdystric)
	157 – Osie 2	proper mucky soil	Areni-Humic Gleysol	Areni-Endogleyic Umbrisol (Humic)
	158 – Niepołomice 10	muckous soil	Humic Gleysol	Endoeutric Gleysol
	159 – Dąbrowa Tarnowska 3	muckous soil	Areni-Humic Gleysol	Areni-Umbric Gleysol
Łachacz, Piaścik (2004)	Olszyny	muckous soil	–	Greyi-Endogleyic Phaeozem
	Gawrychy	muckous soil	–	Areni-Mollic Gleysol

The analysis of definitions of:

- the mucky soil type in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Gleysols, Phaeozems, Arenosols and Umbrisols;
- the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 34) enables the author to find the following correlation between the *Systematics of Polish Soils* and the international WRB classification (Table 35).

Table 35. Correlation of mucky soils type in the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	Possible qualifiers
mucky soils	Gleysols	Umbric, Mollic, Arenic, Humic, Hyposodic[21], Hyposalic, Sodic, Eutric, Dystric
	Umbrisols	Gleyic, Arenic, Humic
	Arenosols	Gleyic
	Phaeozems	Gleyic, Greyic

The type of mucky soils of the *Systematics of Polish Soils* corresponds to four reference soil groups of the WRB classification:

- Gleysols (in the case when *gleyic* properties are present within 50 cm from the soil surface);
- Umbrisols (in the case when the *umbric* horizon is present);
- Phaeozems (in the case when the *mollic* horizon is found and there is lack of carbonates to a depth of 100 cm from the soil surface);
- Arenosols (in all the other cases).

21. The usefulness of the Sodic, Hyposodic and Hyposalic qualifiers for the classification of mucky soils in accordance with the WRB was established by Hulisz (2005).

9. COMPARISON OF THE DEFINITIONS OF ALLUVIAL AND DELUVIAL SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of alluvial and deluvial soils in the *Systematics of Polish Soils* is divided into two orders: alluvial soils (VA) and deluvial soils (VB).

9.1. ALLUVIAL SOILS

The order of alluvial soils contains two soil types: river alluvial soils (VA1) and marsh alluvial soils (VA2).

9.1.1. River alluvial soils and marsh alluvial soils

River alluvial soils are found on floodplains. Their profiles contain stratified alluvia. There are three subtypes of river alluvial soils differentiated: a) proper ones (they develop in the places which are often flooded); b) humous ones (they develop in the places in which the breaks between floods last longer; c) brown ones (they develop in the places which are periodically flooded).

Marsh alluvial soils form in the marine environment and their main chemical characteristics are the high amounts of sodium and calcium at the sorption complex. They cover a very small area in Poland (150 hectares in the vicinity of the village of Sobieszewo on the Vistula Spit; Witek 1965) and this may be the reason for lack of contemporary research on marsh alluvial soils. No subtypes of marsh alluvial soils are differentiated.

The types of river and marsh alluvial soils in the *Systematics of Polish Soils* correspond to the WRB soil group of Fluvisols.

It is possible to verify the systematic position of the soils classified as river alluvial soils in the *Systematics of Polish Soils* as a soil group of Fluvisols in accordance with the WRB thanks to a highly precise definition of Fluvisols as well as of the *fluvic* soil material, which is really what the definition is based on. The stratified material in Fluvisols must start within 25 cm from the soil surface and continuing to a depth of at least 50 cm.

The Polish soil science literature on river alluvial soils from the years 1989–2004 contains 11 papers with the analytical data of river alluvial soils (48 profiles in total). They enable the author to verify their systematic position in regard to the WRB classification. However, no papers on marsh alluvial soils have been published in the above period.

Table 36. Verification/reclassification of river alluvial soil profiles

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Dąbkowska-Naskręt (1990)	Łęgnowo 1, Grabowo 1, Grabowo 2	proper river alluvial soils	–	Fluvisols
	Starogród 1	proper river alluvial soil	–	Humic Fluvisol
	Łęgnowo 2, Staro-gród 2, Stare Pole	brown river alluvial soils	–	Fluvisols
	Fiszewo	brown river alluvial soil	–	Humic Fluvisol
Kopański, Kawecki (1994)	1	brown river alluvial soil	–	Mollic Fluvisols
	2	brown river alluvial soil	–	Mollihumic Fluvisols
Czarnowska et al. (1995)	Gołąb 23, Wólka Tyszyńska 6, Zawady 11, Kazuń Nowy 1, Gorzewnica 2	proper river alluvial soils	–	Mollic Fluvisols
	Gołąb 24	proper river alluvial soil	–	Eutric Fluvisol
	Przewóz 5, Przesławice 3, Nowy Troszyn 9, Drągacz 12 Nebrowo Wlk. 13	brown river alluvial soils	–	Mollic Fluvisols
	Borek 7, Borzumin 4, Łady Szosy 10	brown river alluvial soils	–	Eutric Fluvisols
	Płock Radziwie 8, Lipianki 14	brown river alluvial soils	–	Molli-Endogleyic Fluvisols
Czarnowska, Bontruk (1995)	Lisewo Malborskie 16, Kamionka 19	brown river alluvial soils	–	Molli-Endogleyic Fluvisols
	Lichnowy 17, Cedry Wielkie 21	humous river alluvial soils	–	Molli-Endogleyic Fluvisols
	Stara Wisła 15	humous river alluvial soil	–	Mollihumic-Epigleyic Fluvisol
	Mątrąg 18, Rybina 20, Steblewo 22	(gleyed) river alluvial soils	–	Molli-Epigleyic Fluvisols
Bednarek, Sowiński (2000)	1, 3, 5, 6	brown river alluvial soils	–	Fluvisols
	2, 4	humous river alluvial soils	–	Epigleyic Fluvisols
Miatkowski (2001)	Walichnowy	humous river alluvial soil	–	Molli-Endogleyic Fluvisol *or* Umbri-Endogleyic Fluvisol

Table 36. cont'd

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Brożek, Zwydak (2003)	161 – Staszów 5	proper river alluvial soil	Eutric Fluvisol	Eutri-Endogleyic Fluvisol
	162 – Gryfino 3	humous river alluvial soil	Mollic Fluvisol	Eutri-Arenic Fluvisol
	163 – Wejherowo 5	humous river alluvial soil	Mollic Fluvisol	Molli-Endogleyic Fluvisol
	164 – Tuchola 6	humous river alluvial soil	Mollic Fluvisol	Molli-Epigleyic Fluvisol
	165 – Ustroń 3	brown river alluvial soil	Fluvic Cambisol	Eutri-Fluvic Cambisol
	166 – BPN 1	brown river alluvial soil	Skeleti-Fluvic Cambisol	Skeleti-Fluvic Cambisol (Eutric)
	167 – Szklarska Poręba 1	brown river alluvial soil	Skeleti-Fluvic Cambisol	Hyperdystri-Skeletic Arenosol

The analysis of definitions of:

- the river and marsh alluvial soils types in accordance with the *Systematics of Polish Soils*;
- the following reference soil groups according to the WRB classification: Fluvisols, Cambisols and Arenosols;
- the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 36) enables the author to find the following correlation between the *Systematics of Polish Soils* and the WRB soil classification system (Table 37).

The type of river alluvial soils of the *Systematics of Polish Soils* corresponds to three reference soil groups of the WRB classification:

- both proper and humous river alluvial soils, as well as some of the brown ones, correspond to the Fluvisols reference soil group. To define the lower level unit the following qualifiers are useful: Gleyic, Mollic, Umbric, Arenic, Humic, Eutric and Dystric;
- some other brown river alluvial soils correspond to the Fluvic Cambisols lower level unit. The following qualifiers can be used: Skeletic, Eutric and Dystric;
- additionally, there are brown river alluvial soils which correspond to the unit of Arenosols. In such a case the following qualifiers can be useful: Skeletic and Dystric.

Table 37. Correlation of the marsh and river alluvial soils types of the *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	WRB reference soil group	SPS subtype	Possible qualifiers
river alluvial soils	Fluvisols	proper, humous and brown river alluvial soils	Gleyic, Mollic, Umbric, Arenic, Humic, Eutric, Dystric
	Cambisols	brown river alluvial soils	Fluvic, Skeletic, Eutric, Dystric
	Arenosols	brown river alluvial soils	Skeletic, Dystric
marsh alluvial soils	Fluvisols	–	Salic, Arenic

Lack of researches and published materials on marsh alluvial soils does not allow for a precise correlation with the WRB classification. It is considered, though, that marsh alluvial soils correspond to the WRB lower level unit of Areni-Salic Fluvisols. Lack of data does not allow for conclusion on the possibility to use other qualifiers

9.2. DELUVIAL SOILS

The order of deluvial soils (VB) includes one type of deluvial soils (VB1).

9.2.1. Deluvial soils

Deluvial soils are found at the foot and in lower parts of slopes influenced with strong erosion. They appear in hummocky terrain and in small valleys as well as at the edges of larger valleys. Upper sections of slopes and tops of hills are covered with eroded soils where the humus horizon has been thinned due to erosion and mixed with material building underlying mineral horizons. Such soils can be found especially in cultivated areas exposed to rain-water erosion. According to the *Systematics of Polish Soils* in deluvial soils accumulated sediment has to be 30 cm or more thick.

The WRB classification does not contain a higher level unit which would correspond to deluvial soils in the *Systematics of Polish Soils*.

The Polish soil science literature on deluvial soils from the years 1989–2004 contains three papers with the analytical data of deluvial soils (15 profiles in total). They enable the verification of the systematic position of the profiles of the deluvial soils with respect to the WRB.

The definition analysis:

- of deluvial soils in accordance with the *Systematics of Polish Soils*;
- of the following soil types according to the WRB classification: Chernozems, Phaeozems, Luvisols, Umbrisols, Cambisols and Arenosols;
- of the qualifiers forming the lower level units for these soil groups in the WRB classification,

as well as systematic verification of the profiles quoted in the papers in accordance with the WRB classification (Table 38) enables the author to find out that when covered with deluvial deposits the soils keep their taxonomic position (e.g. as Luvisols or Cambisols). However, in the case when the humus horizon developed on deluvial deposits satisfies the criteria of the *mollic* or *umbric* horizon, the soils may change their taxonomic position and become Umbrisols or Phaeozems.

Table 38. Verification/reclassification of the profiles of the deluvial soils

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Bieniek (1997)	Gisiel 6, Czarnowiec 4, Czarnowiec 5	proper deluvial soils	–	Haplic Phaeozems *or* Haplic Chernozems
	Wanguty 4	proper deluvial soil	–	Endogleyic Phaeozem *or* Endogleyic Chernozem
	Baranowo 4, Wanguty 5	humous deluvial soils	–	Haplic Phaeozems *or* Haplic Chernozems
	Gisiel 5	brown deluvial soil	–	Haplic Phaeozem *or* Haplic Chernozem
	Baranowo 3	brown deluvial soil	–	Endogleyic Phaeozem *or* Endogleyic Chernozem
Szrejder (1998)	3, 4	proper deluvial soils	–	Endogleyic Luvisol
Brożek, Zwydak (2003)	168 – Radymno 9	humous deluvial soil	Molli-Gleyic Fluvisol	Endogleyic Umbrisol
	169 – Gdańsk 3	humous deluvial soil	Mollic Fluvisol	Areni-Endogleyic Umbrisol
	170 – Gdańsk 4	brown deluvial soil	Calcari-Fluvic Cambisol	Calcaric Cambisol
	171 – Pińczów 11	brown deluvial soil	Calcari-Fluvic Cambisol	Calcaric Arenosol
	172 – Babimost 3	brown deluvial soil	Fluvi-Gleyic Cambisol	Endogleyic Cambisol

The WRB classification does not treat the process of deluvial accumulation as the superior one over the other soil-forming processes. As a result, the WRB classification lacks the higher level unit which would correspond, at least to a certain degree, to the type of deluvial soils in the *Systematics of Polish Soils*. Consequently, deluvial soils of the *Systematics of Polish Soils* are scattered over numerous units of the WRB classification, such as:

- Umbrisols;
- Phaeozems;
- Cambisols;
- Arenosols;
- Luvisols

and, possibly, over other units.

What is more, there is no specific qualifier which would enable to show the deluvial character of the humus horizon at the lower level units of the WRB. There exists the Cumuli prefix, which might be added to the main elements of the soil names to stress the repeated accumulation of soil material up to or over the thickness of 50 cm. However, it cannot be used for accumulative A horizons due to the fact that the Mollic and Umbric qualifiers cannot be used for Chernozems and Phaeozems as well as Umbrisols, as this repeats the information which is already found in the name of the soil group. As a result the mentioned prefix is of no use. It is concluded, thus, that the prefix Cumulic should be turned into a qualifier.

10. COMPARISON OF THE DEFINITIONS OF SALINE SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of saline soils (VI) in the *Systematics of Polish Soils* includes one order of saline-sodic soils (VIA).

The feature which differentiates saline soils is the presence of horizons containing an excess of salts easily soluble in cold water than gypsum within 100 cm from the surface. The thickness of theses horizons must be over 15 cm, and the contents of soluble salts must exceed 0.2%.

10.1. SALINE-SODIC SOILS

The order of saline-sodic soils includes three types:

- solonchaks (VIA1);
- solonchak-like soils (VIA2);
- solonetz (VIA3).

The criteria for both saline and sodic soils in the *Systematics of Polish Soils* were taken from the *Soil Taxonomy* (Soil Survey Staff 1975). They are not, alas, compatible with the conditions occur in Poland, and their definitions and descriptions include inaccuracies. Due to that, it is difficult to find soils which would satisfy the criteria found in the Polish system. It can be stated, though, that this is totally impossible (Czerwiński 1996; Pokojska, Bednarek and Hulisz 1998; Kwasowski 1999; Hulisz 2005). Some authors try to qualify the saline soils as solonchak-like soils or solonetz in accordance with the *Systematics of Polish Soils* (Pracz 2001, Kaszubkiewicz et al. 2003). This is done, however, by bending the criteria included in the Polish system. As a result, the Polish soil science literature on salt-affected soils from the years 1989–2005 lacks the papers which would include profiles classified as solonchaks, solonchak-like soils or solonetz in accordance with the contemporary system. The attempt to classify soils with the use of the criteria of the saline ones, undertaken by Hulisz (2005), proved it was impossible to do it properly for most of the soils. Because of a faulty system of saline soils in the contemporary Polish System correlation of saline soil in the *Systematics of Polish Soils* with the WRB classification is pointless.

What is needed is a deep modification of the saline soil division as well as of the criteria of their diversification. This should be based on as large amount of data as possible in order to best reflect the conditions found in Poland. One of the suggestions for new edition of *Systematics of Polish Soils* (Hulisz 2005) will be presented in chapter 13.

11. COMPARISON OF THE DEFINITIONS OF ANTHROPOGENIC SOILS TYPES IN THE *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENTS IN THE WRB CLASSIFICATION

The division of anthropogenic soils (VII) in the *Systematics of Polish Soils* includes two orders: culture earth soils (VIIA) and industrial earths and urban soils (VIIB).

11.1. CULTURE EARTH SOILS

The order of culture earth soils is subdivided into two types: hortisols (VIIA1) and rigosols (VIIA2).

11.1.1. Hortisols

Hortisols, or garden soils, have a thick accumulative A horizon which resulted from long-continued cultivation. They contain a large amount of organic matter. Hortisols of the *Systematics of Polish Soils* correspond to two lower level units of the WRB classification, namely Hortic Anthrosols and Terric Anthrosols.

The comparison of the definitions of the *anthropic* horizon in accordance with the SPS and the *hortic* horizon in accordance with the WRB shows major similarities. However, these horizons are not alike. The colour of the *anthropic* horizon can be lighter – the Munsell value and chroma of moist soil is <3.5; both parameters for the *hortic* horizon, however, amount to ≤3. Minimum content of C_{org} in the *hortic* horizon have to be ≥1%, while in the *anthropic* horizon it must be >0.6%. The definition of the *hortic* horizon includes the criterion of base saturation (≥50%). The mentioned differences demonstrate that the *anthropic* horizon has a wider definition than the *hortic* one. Hortisols, the accumulative horizon of which does satisfy the criteria of the *hortic* horizon according to the WRB may be classified as Hortic Anthrosols. Nevertheless, there exists soils classified as hortisols, the humus horizon of which does not satisfy the criteria of the *hortic* horizon according to the WRB. In such cases the Hortic qualifier cannot be used. Such horizons would satisfy the criteria of the *terric* horizon, and the soils with such horizon will be classified according to the WRB as Terric Anthrosols.

The Polish soil science literature from the years 1989–2004 does not contain any papers which would present a set of analytical data of hortisols. The only paper about this soil type (Gąsiorek, Niemyska-Łukaszuk 2004) does not include the indispensable information even for approximate classification in accordance with the WRB criteria.

The above correlation is based on the analysis and comparison of the definitions of hortisols type and the *anthropic* horizon in the *Systematics of Polish Soils*, and the definition of the Anthrosols unit and the *hortic* and *terric* horizons in accordance with the WRB. It has not been verified by reclassification of the hortisols profiles in accordance with the WRB classification.

11.1.2. Rigosols

Rigosols are the soils totally transformed by deep ploughing or by introducing extraneous material into the soil profile.

Alas, the soil science literature from the years 1989–2004 does not contain any papers which include analytical data on rigosols.

Basing oneself on the analysis and comparison of the definition of the rigosols type, the definition of the *anthropic* and *plaggen* horizons in the *Systematics of Polish Soils*, and the definition of the Anthrosols reference soil group and the *plaggen* and *terric* horizons in accordance with the WRB it can be concluded that the Rigosols which originated by introducing extraneous material may correspond to the unit of Terric Anthrosols. It seems that Rigosols which originated by deep ploughing may only correspond to a lower level unit of WRB of Aric Regosols due to the homogeneity of the material and destruction of the diagnostic horizons sequence.

Alas, due to lack of data the above statement cannot be verified.

11.2. INDUSTRIAL EARTHS AND URBAN SOILS

The order of industrial earths and urban soils includes four soil types:

- anthropogenic soils with unformed profile (VIIB1);
- anthropogenic humous soils (VIIB2);
- anthropogenic pararendzinas (VIIB3);
- anthropogenic saline soils (VIIB4).

Soil types in the order of industrial earths and urban soils (except anthropogenic saline soils), contrary to all other soil types, are not differentiated on the basis of the horizon sequence and chemical/physical properties, but on the basis of the type of material transformed by human activity. A similar concept is found in the WRB classification.

The Polish soil science literature from the years 1989–2004 contains 2 papers on industrial soils (7 profiles).

Table 39. Verification/reclassification of the profiles of the industrial earths

Author and year	Profile number	Classification in accordance with the quoted author after SPS	after WRB	Reclassification/ Verification
Sołek-Podwika et al. (2004)	1, 2, 3	industrial earths	Antropic Gleyic Regosols	Stagni-Anthropic Regosols
Kowalik (2004)	1, 2, 3, 4	anthropogenic pararendzinas	–	Spoli-Anthropic Regosols (Calcaric)

The analysis of definitions of:

- industrial earths and urban soils of *Systematics of Polish Soils*;
- Regosols reference soil group according to the WRB classification;
- the qualifiers forming the lower level units for this soil group in the WRB classification,

as well as verification of the systematic position of the soil profiles in the professional literature in accordance with the WRB classification (Table 39) enables the author to find the correlation between the *Systematics of Polish Soils* and the international WRB classification[22] (Table 40).

Table 40. Correlation of industrial earths and urban soils of *Systematics of Polish Soils* with the units of the WRB soil classification

SPS type	**WRB unit**
anthropogenic soils with unformed profile	Urbi-Anthropic Regosols Spoli-Anthropic Regosols Garbi-Anthropic Regosols
anthropogenic humous soils	Anthropic Regosols Humi-Anthropic Regosols
anthropogenic pararendzinas	Spoli-Anthropic Regosols (Calcaric)
anthropogenic saline soils	Hyposalic Regosols

All soil types of the order of industrial earths and urban soils of the *Systematics of Polish Soils* correspond to one WRB reference soil group of Regosols. Anthropogenic soils with unformed profile corresponds to three lower level units of WRB: Urbi-Anthropic Regosols, Spoli-Anthropic Regosols or Garbi-Anthropic Regosols. Anthropogenic humous soils correspond to lower level units of WRB Anthropic Regosols or Humi-Anthropic Regosols. Anthropogenic pararendzinas correspond to lower level unit of WRB Spoli-Anthropic Regosols (Calcaric) and anthropogenic saline soils correspond to Hyposalic Regosols.

22. An attempt to correlate soil types of the order of industrial earths and urban soils was undertaken already by the author in the earlier paper (Charzyński 2002).

12. COMPARISON OF THE DESCRIPTION OF SMOLNICAS FROM THE APPENDIX TO *SYSTEMATICS OF POLISH SOILS* WITH THEIR EQUIVALENT IN THE WRB CLASSIFICATION

A separate soil type, which has not been included in any edition of *Systematics of Polish Soils*, are the so called 'smolnicas'. Their general description is found in the appendix VIII to *Systematics of Polish Soils* (1989).

The Polish word smolnica comes from Serbian language (*smonica*), although similar names are found in other Balkan languages. The humus horizon of smolnicas is considerably thick and contains a significant amount of clay minerals that expand upon wetting and shrink upon drying. What makes smolnicas a separate type is the process of shrinking and swelling, which leads to forming of slickensides. The origin of smolnicas, their detailed characteristics and a suggestion of systematic position has been recently presented by Prusinkiewicz (2001).

Smolnicas correspond to the WRB reference soil group of Vertisols. The diagnostic horizon of Vertisols is the *vertic* horizon. To be classified as Vertisol, the soil must have the *vertic* horizon within 100 cm from the soil surface, it must contain 30% or more clay to a depth of 100 cm from the soil surface as well as have cracks which open and close periodically.

A typical smolnica soil profile from Gniew, which is included in the paper by Prusinkiewicz (2001), satisfies the criteria of Vertisols: it contains 51–85% of clay within 100 cm from the soil surface, it has slickensides and cracks, and the thickness of the *vertic* horizon exceeds 25 cm (it amounts to 60 cm). The only information the profile description does not mention is the shape of soil aggregates. The author of the article classifies the profile as the WRB lower level unit – Grumi-Pellic Vertisol (Mazic). The Grumic and Mazic qualifiers are contradictory to each other. The proper qualifier for this profile is the Grumic one, which means that the surface layer 3 cm or more thick have structure finer than very coarse granular.

The above example shows clearly that the smolnicas of Gniew (and probably smolnicas from other regions of Poland – the vicinity of Pyrzyce, Kętrzyn and Reszel) should be correlated with the WRB reference soil group of Vertisols. They should also be included in the coming fifth issue of *Systematics of Polish Soils* as a new taxonomy unit, which has been postulated by Prusinkiewicz for many years.

The idea of taxonomical position of smolnicas in *Systematics of Polish Soils*, suggested by Prusinkiewicz (2001), will be presented in chapter 13.

13. CONCLUSIONS

Chapter 13 aims to summarise the outcomes of entire dissertation. Chapter 4 compares definitions of diagnostic horizons used for delimitation of soil units in the *Systematics of Polish Soils* with their equivalents in the WRB classification. Chapters 5 to 12 discuss individual soil types differentiated in the *Systematics of Polish Soils*. The analysis of the criteria used for their delimitation, as well as reclassification of over 500 profiles of almost all soil types found in the *Systematics of Polish Soils* in accordance with the WRB requirements were used to correlate the Polish system with the *World Reference Base for Soil Resources* (FAO-ISSS-ISRIC 1998).

13.1. PROPOSITIONS FOR THE NEW EDITION OF THE *SYSTEMATICS OF POLISH SOILS*

The authors of the *Systematics of Polish Soils*, which was published in 1989, predominantly used the *Soil Taxonomy* (1975) and the FAO classification (1974) for working out the definitions of the diagnostic horizons and the soil units. They did not, however, reject the achievements of the Polish soil science.

Sixteen years have passed since the *Systematics of Polish Soils* was published. At that time the FAO developed its classification into the *World Reference Base for Soil Resources* (FAO-ISSS-ISRIC 1998; Polish translation FAO-ISSS-ISRIC-PTG 2003) and a new edition of *Soil Taxonomy* was published (1999).

Numerous publications evaluating the *Systematics of Polish Soils* (1989), and suggesting correcting it, have been published since the beginning of the 1990s (including Bednarek 1992; Pracz, Kwasowski 2001a, b, c; Charzyński 2002; Janowska et al. 2002; Klimowicz et al. 2004; Hulisz 2005). The suggestions the author sees as interesting will be quoted further on.

13.1.1. General changes

A new edition of the *Systematics of Polish Soils* requires certain methodological and systematic changes which would enable the Polish soil science achievements to be transferred abroad. As it has been pointed out by Bednarek (1992), the structure of the *Systematics of Polish Soils* is illogical at places as well as inconsequent and non-exhaustive. These faults should be eliminated.

The following general changes are suggested by the author:

- employing a unified methods of studying properties of soils; accepting internationally recognized standards (van Reeuvijk 2002);
- including in the *Systematics of Polish Soils* an appendix on the methodology of laboratory analysis, or publishing it as a separate book, as it has been done with Procedures for Soil Analysis (van Reeuvijk 2002);
- accepting particle size classes and soil texture classes concordant with international standards; either in accordance with the USDA or with the Polish Norms PN-R-04033 (Drzymała 2000; Drzymała, Mocek 2004);

- accepting a system of qualifiers used in the WRB for delimiting the lower level units for soil subtypes in the *Systematics of Polish Soils*;
- translating the full version of the new *Systematics of Polish Soils* into English in order to propagate internationally the Polish soil science though.

13.1.2. Suggestions for changes in the definitions of the epipedons

As far as surface diagnostic horizons (epipedons) are concerned, the author suggests modifications, a little changed in regard to the earlier propositions (Charzyński 2002), of the definitions of the following horizons in the *Systematics of Polish Soils*:

- *mollic*:
  a) introducing the thickness criteria referencing to the thickness of the solum instead of the texture, as it is used in 1989 edition of SPS;
  b) accepting few modifications in regard to colour as used in the WRB classification;
  c) excluding the requirement of the phosphorus content amounting to <109 mg P kg^{-1} of soil;
- *anthropic*:
  a) changing its name into the *hortic* one:
  b) increasing the required minimum content of organic carbon up to 1%;
  c) modifying the requirements with regard to colour;
  d) introducing the requirements of base saturation on the model of the WRB: ≥50%;
  e) modifying the requirements of the phosphorus content; i.e. introducing the criterion of >100 mg kg^{-1} fine earth 0.5 *M* $NaHCO_3$ extractable P_2O_5;
  f) removing the requirements in regard to the structure;
- *umbric*:
  a) introducing the thickness criteria referencing to the thickness of the solum instead of the texture, as it is used in 1989 edition of SPS;
  b) modifying the requirements in regard to colour on the model of the WRB classification;
  d) excluding the requirement of the phosphorus content amounting to <109 mg P kg^{-1} of soil;
- muck horizon:
  naming this diagnostic horizon *mursic* or *murshic*. Soils which are classified as muck soils by the *Systematics of Polish Soils* are not differentiated by the world classifications. The German system (Arbaitskreis für Bodensystematik der BDG 1998) is the only one, apart of SPS, which differentiates muck horizons (Hm, Hv, Ha) (Ilnicki, Zeitz 2002; Zeitz, Velty 2002). This achievement of Polish soil science (Okruszko 1960, 1993) should be propagated at an international forum;
- *melanic*:
  naming this diagnostic horizon *mursitic* or *murshitic* in order to avoid ambiguities connected with the fact that the world classifications are recognizing

a *melanic* horizon of a totally different origin and properties. The issue of an ambiguous name of the mucky horizon in the *Systematics of Polish Soils* was discussed in the Department of Soil Science of the NCU (Lejza 1998, Bednarek et al. 2004). Controversies connected with that name were also mentioned by Łachacz (2001);

- *plaggen*:
  deleting the *plaggen* horizon from the *Systematics of Polish Soils* due to the fact that plaggosols are not found in the territory of Poland;
- *histic*:
  a) changing the thickness criterion into ≥10 cm;
  b) modifying the diagnostic criterion of C_{org} content, i.e. changing the limit of the clay fraction, which influences the content of organic carbon, from 50% into 60%;
  c) enhancing the horizon's definition by adding the words: 'in most years' to the sentence ending with: '… during at least 30 consecutive days';
- *ochric*:
  changing the definition into the one on the model of the WRB classification;
- introducing the following new diagnostic horizons: *folic*, *terric* and *anthraquic* as defined in the WRB classification.

13.1.3. Suggestions for changes in the definitions of the endopedons

As far as subsurface horizons are concerned (endopedons) the modification of the following horizons of the *Systematics of Polish Soils* are suggested by the author:

- *cambic*:
  introducing two diagnostic criteria which have not been present in the *Systematics of Polish Soils* so far, namely the cation exchange capacity (CEC) (in 1 *M* CH_3COONH_4) >16 $cmol_c$ kg^{-1} clay; thickness >15 cm; modifying the criteria referring to texture on the model of the WRB;
- *argillic*:
  changing the name into *argic* in order to unify European classifications; modifying the criteria referring to texture on the model of the WRB;
- *spodic*:
  introducing the diagnostic criteria for differentiating the *spodic* horizon in accordance with the WRB together with the following modifications:
  a) the requirement of the Al_o+½Fe_o content should be lowered from 0.5% to 0.25%; similarly, the ODOE value should be lowered by half, i.e. down to 0.125 (Charzyński 2000; Charzyński, Hulisz, Bednarek 2005);
  b) the requirement of the C_{org} content should include the reservation of 'at least in some part of the horizon';
- *albic*:
  maintaining the differentiation criterion, currently used in the *Systematics of Polish Soils*, i.e. texture (in order to diversify the *albic* horizon from the *luvic* horizon) as well as adapting the WRB criteria of differentiating this horizon, i.e. the thickness and colour;

- *fragic*:
  changing the name into *fragilic* in order to unify the names internationally; the differentiation criteria should be based on the model of the WRB;
- *salic*:
  introducing the following criteria (Hulisz 2005):
  a) thickness ≥15 cm; and
  b) electric conductivity of the saturated extract (EC_e) >2 dS m^{-1} at 25°C at least a few times a year; and
  c) pH_e <8,5 or for acid sulphate soils <3,5; and
  d) SAR_e<13 or ESP <15%;
- *sideric*:
  using the texture as criteria of differentiating (in order to distinguish clearly the *cambic* horizon from the *sideric* one) as well as the indicators used for the *spodic* horizon, i.e.:
  a) pH (H_2O) ≤5,9 and
  b) Munsell hue of 7,5YR to 10YR when moist and crushed, value ≥4 and chroma ≥3; and
  c) Al_o + ½Fe_o content cannot be larger than the double value of the content in the overlying horizon[23] ; and
  d) thickness ≥2,5 cm; and
  e) texture coarser than loamy sand.
  Janowska et al. (2002) also suggest using the indicators used for defining the *spodic* horizon in accordance to the WRB for defining the *sideric* horizon. This proposition, however, of not including the criterion which compares the content of Al_o + ½Fe_o in the B horizon with the overlying horizon cannot be accepted. It is due to the fact that the transfer of aluminium and iron compounds testifies podzolization takes place, while the lack of it – the rusting process;
- *gleyic mottling*
  the 'mottled' horizon should be substituted with *gleyic* and *stagnic* properties defined on the model of definitions of *gleyic* and *stagnic* properties of the WRB classification;
- introducing the *vertic* horizon into the *Systematics of Polish Soils* with the definition based on the WRB; smolnicas, recognized in Northern Poland, correspond to the WRB soil reference group of Vertisols (Prusinkiewicz 2001).

13.1.4. Suggestions for changes in soil units

As far as the soil units of the *Systematics of Polish Soils* are concerned, the following modifications of their definitions are suggested:

- combining the following soil types into one type: podzol soils, podzols, gley-podzol soils and gley-podzols; differentiating of the above soil types on subtypes level in the new edition of the *Systematics of Polish Soils*;

23. This criterion is used to distinguish the *sideric* horizon from the *spodic* one.

- differentiating of salinity features at the subtype level (Hulisz 2005):
  soil salinity should be indicated at the level of subtypes with the use of the *salic* and *sali-sodic* properties[24] defined as follows:
  salic: within 100 cm there is the horizon (or layer) at least 15 cm thick which fulfils the following criteria:
  a) EC_e >2 dS m^{-1} at 25°C during a certain period of the year;
  b) pH_e <8.5 or for acid sulphate soils <3,5;
  c) SAR_e<13 or ESP <15%;
  sali-sodic: within 100 cm there is the horizon (or layer) at least 15 cm thick which satisfies the following criteria:
  a) EC_e >2 dS m^{-1} at 25°C during a certain period of the year;
  b) pH_e <8.5 or for acid sulphate soils <3,5;
  c) SAR_e>13 or ESP >15%.
  The above properties could be used for any soil types in case there it is needed. If soil meets the criteria of the *salic* properties, the main soil unit (type) would be described by adding the adjective 'saline'; if it is the *sali-sodic* – the adjective 'saline-sodic' would be added, e.g. saline peat soil or saline-sodic muck soil;
- distinguishing clearly the border between brown and rusty soils on the basis of the texture (in the definitions of the *cambic* and *sideric* horizons);
- introducing the smolnica soil type (Vertisols) (Prusinkiewicz 2001);
- introducing the 'umbriziemy' soil type with the definition based on Umbrisols of the WRB classification; Umbrisols constitute a unit located 'across' most of the soil types in the *Systematics of Polish Soils* (rankers, acid brown soils, rusty soils, black earths and others); thus introducing of 'umbriziemy' would significantly ease correlation between the Polish system and the WRB classification;
- introducing the subtype of chernozems which would correspond to Phaeozems in the WRB classification;
- eliminating of the order and type of deluvial soils. Accumulation of deluvial deposits should be indicated on the subtype level;
- changing the order of industrial earths and urban soils into the order of 'technoziemy', the definition and subdivision of which should be based on the definition of Technosols in the 2006 edition of the WRB in preparation and on the suggestions of Stroganova and Prokofieva (2000), Burghardt (2000) and Rossiter (2005);
- the new edition of the *Systematics of Polish Soils* should include the soils enriched with iron, which were discussed after the latest edition of the *Systematics of Polish Soils* was published (PTG 1989) (Czerwiński, Kaczorek 1996; Czerwiński 2001; Pracz, Pastuszko 2001, Jankowski 2001), as well as the soils which contain a significant amount of sulphides and sulphates (Pracz, Kwasowski 2001a, b, c). The amount of the collected information, however, does not enable the in-depth analysis of the position of these soils in the *Systematics of Polish Soils* by author of this dissertation.

24. Author of this dissertation is proposing change in nomenclature, salic and sali-sodic qualifiers proposed by Hulisz (2005) could be called *salic* and *sali-sodic* properties.

13.2. PROPOSITIONS FOR THE NEW EDITION OF WRB SOIL CLASSIFICATION

The translation of the WRB into Polish (FAO-ISSS-ISRIC-PTG 2003), undertaken in 2002, led to the discovery of about 50 inaccuracies in the original WRB version. A list of these inaccuracies was passed on to the editors of the WRB. Over 90% of them were accepted and will be considered while preparing the next edition of the WRB (Bednarek, Charzyński, Pokojska 2003).

Very careful reading of *World Reference Base for Soil Resources* (FAO-ISSS-ISRIC 1998), indispensable in case of comparative and correlation studies, as well as an attempt to use the WRB classification to reclassification of over 500 soil profiles from the territory of Poland have also contributed to finding inaccuracies and gaps in the WRB system. As a result, a suggestion for modifications of the WRB definitions has been put forward.

Since the WRB classification was published in 1998, numerous papers have been published in order to test and evaluate the system's usefulness for individual countries or geographical regions (Krogh and Greve 1999; Charzyński 2000; Greve et al. 2000; Rogel et al. 2001; Schad et al. 2002; Yli-Halla, Mokma 2002; Herrero 2004; Mokma et al. 2004; Blume and Giani 2005; Charzyński, Hulisz, Bednarek 2005; Garcìa Calderòn et al. 2005). Suggestions for improving the WRB have also been put forward.

13.2.1. Suggestions for changes in the definitions of soil horizons and soil units

As far as the soil horizons and soil units of the WRB are concerned, the following modifications are suggested:

- the *spodic* horizon:
  an attempt of using the WRB system for the classification of podzol soils and podzols proved the criteria for the *spodic* horizon in this system are too restrictive (Charzyński 2000, Degórski 2002). Illuvial horizons of morphologically well developed podzol soils in North Poland rarely satisfy the criterion of the Al_o + ½Fe_o contents for the WRB *spodic* horizon. It is due to the fact that their parent material does not contain much of iron and aluminium compounds. Moreover, the requirement of the C_{org} content, which is >0.6%, seems to be too high. Though the following solution is suggested:
  a) lowering the requirement of the Al_o + ½Fe_o content from 0.5% to 0.25%;
  b) lowering the requirement of the ODOE value from 0.25 to 0.125;
  c) lowering the requirement of the C_{org} content from 0.6% to 0.5% and limiting it to a section of the horizon by adding the following words to the definition: 'at least in part of the horizon';
- the *ochric* horizon:
  correcting the colour criterion: 'a Munsell chroma of 3.5 or more when moist, a value of 3.5 or more when moist' (FAO-ISSS-ISRIC 1998), should be changed into: 'the chroma or value';
- differentiating a new diagnostic horizon in the WRB classification, namely the *sideric* one, and a new soil group, namely Rzavosols, the definitions of which

would be based on the definition of rusty soils of the *Systematics of Polish Soils*; a suggestion for a definition of the *sideric* horizon and the soil unit of Rzavosols for the WRB classification is presented in the appendix 2. Horizon with the same set of properties like *sideric* was introduced in new Russian classification of soils (iron-metamorphic horizon) (Shishov et al. 2004);

- a soil unit of Phaeozems:
  accepting the presence of primary carbonates {this modification was introduced in the WRB classification published in *Lecture notes on the major soils of the world* [Driessen et al. (ed.) 2001], which has not been officially accepted by the IUSS};
- soil units of Arenosols and Regosols:
  completing the list of the accepted horizons in these soil groups with the *histic* horizon. A need for such a modification is proved by the profile 137 (Niepołomice 9) in the Atlas of Brożek and Zwydak (2003).

13.2.2. Suggestions for changes in the definitions of qualifiers

As far as the WRB qualifiers are concerned, the following changes are suggested:

- explaining the origin of the qualifiers' names, similarly to those of soil units and soil horizons;
- forming the lower level units by adding the qualifiers only before the name of the main soil group. The place after the name would be used for the qualifiers defined in individual countries. Thus, the third-order units would be formed;
- eliminating the gap in the qualifiers Episkeletic, Humic, Epidystric, Eutric and Gypsiric for the soils of the thickness of 50 cm or less by adding the following: 'at least at the depth from 20 to 50 cm from the soil surface or to continuous rock at the depth from 25 to 50 cm from the soil surface';
- including the *folic* horizon into the list of those horizons which may be found in Podzols;
- it is pointless to define the Leptic qualifier when the Epileptic and Endoleptic qualifiers are defined;
- accepting the Rendzic qualifier used for the soil unit of Phaeozems in order to best classification of deep humous rendzinas;
- accepting the Histic qualifier used for the soil units of Arenosols and Regosols. The need for such a modification is proved by the profile 137 (Niepołomice 9) in the Atlas of Brożek and Zwydak (2003);
- accepting the Rhodic qualifier used for the soil unit of Regosols (the need for such a modification is proved by the profile 1 described in the papers by Licznar, Drozd and Licznar (1997);
- the definitions of the Orthieutric and Eutric qualifiers are alike; thus, the Orthieutric qualifier should be either excluded or redefined;
- accepting the use of the Sodic and Hyposodic qualifiers for Histosols (Hulisz, Charzyński 2003). The need for such a modification is proved by the site of Zgłowiączka (Hulisz 2005), as well as the soils of the coastal areas both in Poland and elsewhere (Giani L., Giani D. 1990; Rogel et al. 2001; Chernousenko, Oreshnikova, Ukrainceva 2001);

- defining the Deluvic qualifier in order to indicate the deluvial origin of humus horizon (instead of the prefix Cumuli). A need for modification of the WRB classification in order to better classification of deluvial soils was expressed by Komisarek (2000), Szrejder (2000) and Bauziene (2002). The unit of Cumulic Anthrosols, which was differentiated in the *Legend to the FAO Soil Map of the World in the scale 1:5000000* (FAO-UNESCO 1974, 1988), group together the soils with a deluvial origin of a humus horizon;
- defining a new qualifier Murshic to mark out soils with permanently dry organic horizons.

13.3. SUMMARY

Preparations to publish the next edition of the *Systematics of Polish Soils* have so far taken many years. It is assumed that the authors of the new edition will consider the latest achievements in world soil classification as it was in the case of the contemporary one.

The above suggestions for amendments in the Polish system may inspire the discussion over the character as well as the range of application of the WRB criteria in the new edition of the *Systematics of Polish Soils*.

As the table 41 demonstrates, within the area of Poland soils of 16 WRB soil groups are found. An individual soil unit of the *Systematics of Polish Soils* often corresponds to a number of the WRB soil units and *vice versa*. This is the effect of the differences found in the definitions and the criteria used in both systems. If the suggested changes were taken into consideration in the *Systematics of Polish Soils* and in the WRB classification both systems would be correlated better.

Table 41. Correlation between the soil units of the WRB classification and the types and subtypes of the *Systematics of Polish Soils*

WRB reference soil group	*Systematics of Polish Soils* type (subtype)
Histosols	peat soils muck soils mud soils rendzinas (mountain raw humous)
Anthrosols	hortisols rigosols
Leptosols	initial rocky soils – lithosols initial loose soils – regosols noncalcareous soils weakly developed from solid rocks – rankers rendzinas (initial, proper, chernozemic, mountain raw humous) pararendzinas (initial)
Vertisols	smolnicas
Fluvisols	river alluvial soils (proper, humous, brown) mud soils marsh alluvial soils
Gleysols	gley soils gley-podzol soils black earths mud soils muck soils mucky soils (muckous)
Podzols	podzol soils podzols gley-podzol soils gley-podzols
Planosols	pseudogley soils
Chernozems	chernozems (nondegraded, degraded) black earths
Phaeozems	chernozems (nondegraded, degraded) brown soils (grey-brown) black earths mucky soils deluvial soils
Albeluvisols	soils lessivés (glossic, podzolized)
Luvisols	soils lessivés (typical, browned, pseudogley, gleyed, with the *agric* horizon, glossic, podzolized) chernozems (degraded) deluvial soils

Table 41. cont'd

WRB reference soil group	***Systematics of Polish Soils* type (subtype)**
Umbrisols	noncalcareous soils weakly developed from solid rocks – rankers chernozems (degraded) acid brown soils (typical) rusty soils (brownish) gley-podzol soils black earths pseudogley soils mucky soils deluvial soils
Cambisols	brown soils (typical, grey-brown, gleyed, leached) acid brown soils (typical, podzolized, gleyed) noncalcareous soils weakly developed from solid rocks – rankers rendzinas (brown) pararendzinas (brown) chernozems (degraded) river alluvial soils (brown) deluvial soils
Arenosols	initial loose soils – regosols soils weakly developed from loose materials – arenosols brown soils (leached) acid brown soils (typical, podzolized, gleyed) rusty soils (brownish, proper, podzolized) podzol soils podzols gley-podzol soils gley-podzols pseudogley soils mucky soils (muckous) river alluvial soils (brown) deluvial soils
Regosols	initial clay soils – pelosols noncalcareous soils weakly developed from solid rocks – rankers rendzinas (proper, chernozemic, mountain raw humous, brown) pararendzinas (proper, brown) black earths pseudogley soils rigosols anthropogenic soils with unformed profile anthropogenic humous soils anthropogenic pararendzinas anthropogenic saline soils

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APPENDIX 1

DEFINITION OF *SIDERIC* HORIZON AND RZAVOSOLS SOIL REFERENCE GROUP – PROPOSAL

Rzavosols (RS)

Other soils having
1. *a sideric* horizon,
2. lacking an *albic* horizon.

Sideric horizon

General description

The *sideric* horizon (from Latin *sideros*, iron) is a dark coloured subsurface horizon, which contains amorphous substances composed of organic matter and aluminium and iron. The sesquioxides are released in consequence of 'in situ' weathering.

Diagnostic criteria

A *sideric* horizon must have:
1. pH (1:1 in water) of 5.9 or less (unless limed) **and**
2. colours, moist (crushed and smoothed sample), as follows:
   i. Munsell hue of 7.5YR to 10YR with value of 4 or more and chroma of 3 or more **and**
   ii. 10 percent or more cracked coatings of amorphous organic material on sand grains; **or**
3. either less than two times more of Al_{ox} + ½Fe_{ox} than an overlying *anthraquic*, *hortic*, *ochric*, *plaggic*, *terric* or *umbric* horizon; **or**
   an optical density of the oxalate extract (ODOE) value identical or smaller than the overlying horizons; **and**
4. thickness of at least 2.5 cm; **and**
5. texture in fine earth fraction coarser than loamy sand.

Field identification

A *sideric* horizon meets the brownish black to reddish brown colours. *Sideric* horizons can also be characterized by the presence of organic pellets as well as cracked coatings of amorphous organic matter around the sand grains in the B horizon.

Relationships with some other diagnostic horizons

Sideric horizon is logical counterpart of *cambic* horizon in sandy material (the sesquioxides released in consequence of 'in situ' weathering). *Sideric* horizon is distinguished from *spodic* horizons, which have at least twice as much the Al_{ox} + ½Fe_{ox} percentages than an overlying horizons, such as an *albic*, *anthraquic*, *hortic*, *ochric*, *plaggic*, *terric* or *umbric* horizon. This criterion normally does not apply to *sideric* horizons which have usually identical amount of Al_{ox} + ½Fe_{ox} than overlying horizons.

APPENDIX 2
ENGLISH TRANSLATIONS OF POLISH NAMES OF SOIL UNITS

Division and order dział i rząd	Type Typ	Subtype Podtyp
I. Lithogenic soils Gleby litogeniczne IA. Noncarbonate soils, initial and weakly developed Gleby mineralne bezwęglanowe inicjalne i słabo wykształcone	IA1. initial rocky soils (lithosols) gleby inicjalne skaliste (litosole)	• eroded – erozyjne • polygonal (structural) – poligonalne (strukturowe)
	IA2. initial loose soils (regosols) gleby inicjalne luźne (regosole)	• eroded – erozyjne
	IA3. initial clay soils (pelosols) gleby inicjalne ilaste (pelosole)	• eroded – erozyjne
	IA4. noncalcareous soils weakly developed from solid rocks (rankers) gleby bezwęglanowe słabo wykształcone ze skał masywnych (rankery)	• proper – właściwe • brown – brunatne • podzolized – bielicowane
	IA5. soils weakly developed from loose materials (arenosols) gleby słabo wykształcone ze skał luźnych (arenosole)	• proper – właściwe
IB. Lithogenic calcareous soils with different development degree Gleby wapniowcowe o różnym stopniu rozwoju	IB1. rendzinas rędziny	• initial – inicjalne • proper – właściwe • chernozemic – czarnoziemne • brown – brunatne • mountain humous – próchniczne górskie • mountain raw humous – butwinowe górskie
	IB2. pararendzinas pararędziny	• initial – inicjalne • proper – właściwe • brown – brunatne

Division and order dział i rząd	Type Typ	Subtype Podtyp
II. Autogenic soils Gleby autogeniczne		
IIA. Chernozemic soils Gleby czarnoziemne	IIA1. chernozems czarnoziemy	• nondegraded – niezdegradowane • degraded – zdegradowane
IIB. Brown forest soils Gleby brunatnoziemne	IIB1. brown soils gleby brunatne właściwe	• typical – typowe • grey-brown – szarobrunatne • gleyed brown – brunatne oglejone • leached brown – brunatne wyługowane
	IIB2. acid brown soils gleby brunatne kwaśne	• typical – typowe • podzolized – bielicowane • gleyed brown – brunatne oglejone
	IIB3. soils lessivés gleby płowe	• typical – typowe • browned – zbrunatniałe • podzolized – bielicowane • pseudogley – opadowo-glejowe • gleyed – gruntowo-glejowe • with the *agric* horizon – z poziomem *agric* • glossic – zaciekowe
IIC. Podzol soils Gleby bielicoziemne	IIC1. rusty soils gleby rdzawe	• proper – właściwe • brownish – brunatno-rdzawe • podzolized – bielicowo-rdzawe
	IIC2. podzol soils gleby bielicowe	• proper – właściwe
	IIC3. podzols bielice	

Division and order dział i rząd	Type Typ	Subtype Podtyp
III. Semi-hydrogenic soils Gleby semihydrogeniczne		
IIIA. Gley-podzol soils Gleby glejo-bielicoziemne	IIIA1. gley-podzol soils gleby glejobielicowe	• proper – właściwe • mucky – murszaste • peaty – torfiaste
	IIIA1. gley-podzols glejobielice	• proper – właściwe
IIIB. Black earths Czarne ziemie	IIIB1. black earths czarne ziemie	• gleyed – glejowe • proper – właściwe • browned – zbrunatniałe • leached – wyługowane • degraded (grey) – zdegradowane (szare) • mucky – murszaste
IIIC. Bogged soils Gleby zabagniane	IIIC1. pseudogley soils gleby opadowo-glejowe	• proper – właściwe • stagno-gley – stagno-glejowe
	IIIC2. gley soils gleby gruntowo-glejowe	• proper – właściwe • peat-like – torfiasto-glejowe • peaty – torfowo-glejowe • mud-gley – mułowo-glejowe
IV. Hydrogenic soils Gleby hydrogeniczne		
IVA. Bogged soils Gleby bagienne	IVA1. mud soils gleby mułowe	• proper – właściwe • peat-mud – torfowo-mułowe • gyttja – gytiowe
	IVA2. peat soils gleby torfowe	• low peat – torfowisk niskich • transitory peat – torfowisk przejściowych • high peat – torfowisk wysokich
IVB. Post-bog soils Gleby pobagienne	IVB1. muck soils gleby murszowe	• peat-muck – torfowo-murszowe • mud-muck – mułowo-murszowe • gyttja-muck – gytiowo-murszowe • overmucky – namurszowe
	IVB2. mucky soils gleby murszowate	• mineral-muck – mineralno-murszowe • proper – właściwe • muckous – murszaste

Division and order dział i rząd	Type Typ	Subtype Podtyp
V. Alluvial and Deluvial soils Gleby napływowe VA. Alluvial soils Gleby aluwialne	VA1. river alluvial soils mady rzeczne	• proper – właściwe • humous – próchniczne • brown – brunatne
	VA2. marsh alluvial soils mady morskie	–
VB. Deluvial soils Gleby deluwialne	VB1. deluvial soils gleby deluwialne	• proper – właściwe • humous – próchniczne • brown – brunatne
VI. Saline soils Gleby słone VIA. Saline-sodic soils Gleby słono-sodowe	VIA1. solonchaks sołonczaki	• crusty – powierzchniowe • internal – wewnętrzne
	VIA2. solonchak-like soils gleby sołonczakowate	–
	VIA3. solonetz sołońce	• typical – typowe • solonchak-solonetz – sołonczakowate
VII. Anthropogenic soils Gleby antropogeniczne VIIA. Culture earth soils Gleby kulturoziemne	VIIA1. hortisols hortisole VIIA2. rigosols rigosole	
VIIB. Industrial earth and urban soils Gleby industrio- i urbanoziemne	VIIB1. anthropogenic soils with unformed profile gleby antropogeniczne o nie wykształconym profilu VIIB2. anthropogenic humous soils gleby antropogeniczne próchniczne VIIB3. anthropogenic pararendzinas pararędziny antropogeniczne VIIB4. anthropogenic saline soils gleby słone antropogeniczne	

APPENDIX 3
ACRONYMS AND ABBREVIATIONS USED IN THE TEXT

Al_o	acid oxalate (pH 3) extractable aluminium
CEC	cation exchange capacity
EC_e	electrical conductivity of the saturation extract
ECEC	effective cation exchange capacity
ESP	exchangeable sodium percentage
NCU	Nicolaus Copernicus University
Fe_o	acid oxalate (pH 3) extractable iron
ODOE	optical density of the oxalate extract
PTG	Polish Society of Soil Science (Polskie Towarzystwo Gleboznawcze)
SAR	sodium adsorption ratio
SPS	Systematics of Polish Soils (1989)
BS	base saturation
WRB	World Reference Base for Soil Resources