An algorithm for soil identification according to the World Reference Base for Soil Resources

https://doi.org/10.31713/MCIT.2023.051

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Abstract—**This paper addresses soil identification according to the World Reference Base for Soil Resources. A structure of the database of soil parameters of diagnostic horizons is proposed. Three variants of allocating soils to Reference Soil Groups based only on soil parameters, or on the combination of diagnostic horizons and soil parameters, or only on diagnostic horizons are considered.**

Keywords—diagnostic algorithm; database structure; soil identification; soil group; diagnostic parameters.

I. Introduction

The World Reference Base for Soil Resources (WRB) [1] was developed to identify soils and use the obtained data in different areas of everyday life: agriculture, forestry, animal husbandry, etc. Note that the WRB, developed by a group of soil scientists, is not meant to replace national classification systems. Besides this classification system, there are also different soil classifications designed by national soil science schools. The difference in the structures of these classifications necessitated the development of a diagnostic algorithm to correlate them with each other. A group of scientists headed by M. Babayev also developed a national soil classification system for Azerbaijan [5]. In order to compare these two systems, this study proposes a soil data structure, as well as an algorithm for soil identification according to the WRB classification on the basis of the proposed structure.

II. Problem Statement

The following objectives are set in this paper:

- Development of a data structure for soil types in the Reference Soil Groups (RSG) of the World Reference Base for Soil Resources (WRB);
- Development of a diagnostic algorithm according to the WRB soil parameters on the basis of the developed data structure.

An analysis of allocating soils to a particular WRB RSG was conducted in order to construct a diagnostic algorithm. Note that WRB is a two-tier system of soil classification, with the first level containing 32 major RSGs, and the second level assigning a set of principal and supplementary qualifiers to each RSG [2-3]. Soils are allocated to RSGs on the basis of principal soil parameters. In this paper, the first level of allocating soils to RSGs is considered. A structure of the database of principal soil parameters collected in the order of their comparison with RSGs is proposed. A diagnostic algorithm is developed for the principal soil parameters enabling the allocation of a soil to the appropriate reference base of soil resources.

III. Soil Data Structure

A detailed study of works of soil scientists revealed that soil parameters can be grouped into the following three classes:

- Measured directly in the field (numerical value);
- Determined by laboratory analysis (numerical value);
- Determined on the basis of expert opinion (listed variants).

A tabular structure of the soil data under consideration is proposed for conducting diagnostics. In accordance with the listed grouping, these tables can store data in interval form, in the form of specific values as well as enumerated values. The primary table contains the principal indicators identifying soil types accordingly to the RSGs. Each of the fields in the primary table of the database structure contains information about a specific soil indicator and has its own unique name and type of definition. It should also be noted that some soil parameters from the primary table are linked to auxiliary tables, which contain a full description of this parameter. For instance, a soil may contain soil materials of various types; therefore, the field in the primary table, which indicates the content of any material in the soil, is linked to the auxiliary table, which includes the names of all types of soil materials considered in the soil diagnostic algorithm.

IV. Developing the Soil Diagnostic Algorithm

When examining the soil group identifier key in the World Reference Base for Soil Resources, it was found that the description of RSGs is given in three different ways:

1) based only on certain soil parameters, e.g., the HISTOSOLS Reference Soil Group;

2) based on soil parameters and diagnostic horizons, e.g., the ANTHROSOLS Reference Soil Group;
3) based only on diagnostic horizons, e.g., the UMBRISOLS Reference Soil Group.

On the basis of these three variants, we propose respective soil diagnostic algorithms based on the structure of the first level soil parameter database.

In the following, we describe a functional algorithm for soil identification based directly on soil parameters. We will describe this algorithm on the example of the HISTOSOLS Reference Soil Group [4; p.95]. The structure of this soil group belongs to the first of the variants described above. To identify a soil as a member of the HISTOSOLS group, it is sufficient to consider the following soil parameters:

- soil thickness (MOSHNOST);
- type of material in the soil (MATERIALTYPE);
- soil depth (QLUBINA);
- residual moss in the soil (OSTATOKMXA).

The database structure is proposed in such a way that it is possible to store the values of these parameters. Namely, the soil thickness parameter takes the value specified in the MOSHNOST field from the primary SOIL_INDICATE table in the database structure. The MATERIALTYPE soil parameter determines the type of material in the soil. The value of this parameter is displayed in the primary table in the MATERIAL field, which takes its value from the MATERIALTYPE auxiliary table in the form of the following numbers: 1 – organic material; 2 – ice; 3 – technic hard material. The soil parameter indicating soil depth is determined by the QLUBINA field in the primary table of the database structure. In the HISTOSOLS Reference Soil Group, this parameter takes a value between 40 and 100 cm, or ≥ 60 cm but there must be residual moss in the soil. The parameter indicating the presence of residual moss takes the value determined by the OSTATOKMXA field in the primary table.

If all the above conditions are met, the soil can be allocated to the HISTOSOLS group with respect to the first level of the identifier key to the WRB Reference Soil Groups. The described algorithm can be given in the form of a functional module in an algorithmic language (Pascal):

```
Function Histosols;
  begin
    if ((MOSHNOST>=10) and ((MATERIALTYPE=1 or MATERIALTYPE=2 or MATERIALTYPE=3)) then
        begin
        if (QLUBINA>=40 or QLUBINA<=100) or ((QLUBINA>=60) and (OSTATOKMXA>=75)) then true;
        end
          else false;
  end;
```

This function returns true if the soil belongs to the Histosols group, false if the soil does not belong to the Histosols group. Thus, the described algorithm makes it possible to identify Reference Soil Groups based directly on soil parameters.

Consider the description of the functional algorithm for soil identification by soil parameters and diagnostic horizons. We will describe this variant of the algorithm on the example of the Anthrosols reference soil group [4; p.96]. For this purpose, all diagnostic horizons included in this group were analyzed: hortic, irragric, plaggic, terric, anthraquic, hydragric, pretic. To identify a soil as belonging to the Anthrosols group, we propose determining the parameters according to the above diagnostic horizons. The hortic horizon in the soil is examined for the following parameters:

- horizon position in the soil (UP_HORIZONT);
- type of material in the soil (MATERIALTYPE);
- Munsell color value, or lightness of soil color, (SVETLOTA);
- Munsell chroma, or saturation of soil color (NASISHENNOST);
- soil condition (SOSTOYANIYE);
- soil organic carbon (ORGUGLEROD);
- extractable P_2O_5 content (OBMENP2O5);
- soil mechanical composition (MEXSOSTAV);
- depth (QLUBINA);
- base saturation (BASESATUR);
- horizon thickness (MOSHNOST);
- signs of soil animal activity (PRIZNAKD_J).

The parameter indicating the horizon position in the soil take the value specified in the UP_HORIZONT field of the Soil_Indicate primary table in the database structure. The MATERIALTYPE soil parameter takes a value similar to the first variant of the algorithm. Parameters determining the Munsell color value and chroma, and soil condition take their values from the SVETLOTA, NASISHENOST, and SOSTOYAN_POC fields of the Soil_Indicate primary table, respectively. In the hortic horizon the SVETLOTA and NASISHENOST parameters should be ≤3, provided that the SOSTOYAN_POC parameter takes the value 1, moist. The soil organic carbon parameter takes the value from the ORGUGLEROD field and should be >1% in the hortic horizon. The content of extractable P_2O_5 corresponds to the OBMENP2O5 field of the Soil_Indicate primary table and should take a value of ≥ 100 mg·kg-1 with the depth, "QLUBINA", taking the value equal to 25 cm and the mechanical composition of the soil, "MEXSOSTAV", taking the value corresponding to fine earth. The base saturation parameter in this horizon takes its value from the BASESATUR field of the Soil_Indicate primary table and should be ≥ 50%. Along with these soil parameters, the algorithm also checks the thickness, MOSHNOST, of the horizon and the traces of soil animal activity, PRIZNAKD_J. Both of these parameters take their values from the MOSHNOST and PRIZNAKD_J fields of the Soil_Indicate primary table, respectively. The thickness should be ≥ 20 cm, and the signs of soil animal activity by volume should be ≥ 25%. The described algorithm of the hortic diagnostic horizon can be given in the form of a functional module in an algorithmic language (Pascal):

```
Function hortic
  begin
    If (HORIZONTS=4) and (MATERIALTYPE=5) and (SVETLOTA<=3) and (NASISHENOST<=3) and (SOSTOYAN_POC=1) and (ORGUGLEROD>=1) and (OBMENP2O5>=100) and (MEXSOSTAV=2) and (QLUBINA<=25) and (BASESATUR>=50) and (MOSHNOST>=20) and (PRIZNAKD_J>=25)
    then true;
    else false;
  end;
```

The parameters of the other aforementioned horizons of this soil group are described in a similar manner. As a result, a diagnostic algorithm is developed for each horizon of this soil group in the form of a functional module in an algorithmic language (Pascal). To obtain the final result of allocating a soil to a particular RSG, the described algorithm is given in the form of a functional module in an algorithmic language (Pascal) (Pascal).

The algorithm is as follows.

```
Function antrosols;
  begin
    ((Hortic or iraglik or plagic or terric) and (moshnost >50)) or ((anthraquic or hydragric) and (moshnost >50)) or ((pretic and (moshnost >50) and (qlubina ≤ 100))
  end;
```

Thus, we have described the second variant of the soil identification algorithm based on the combination of soil parameters and diagnostic horizons.

We proceed to the construction of the third variant of the algorithm, namely allocating a soil to a group based only on diagnostic horizons, on the example of the UMBRISOLS soil group [4; p.114]. In this case, parameters of the following diagnostic horizons are considered:

- umbric;
- mollic;
- hortic.

As can be seen, most of the above parameters of these horizons are determined similarly to the previous algorithm but take different values. Diagnostic algorithms were developed for each of these horizons. We will examine and describe the algorithm of soil parameters of one of the above-mentioned horizons, the umbric horizon:

- horizon position in the soil (UP_HORIZONT);
- type of material in the soil (MATERIALTYPE);
- horizon color (CVET);
- presence of artefacts (ARTEFAKTS);
- Munsell color value (SVETLOTA);
- Munsell chroma (NASIWENOST);
- soil condition (SOSTOYANIYE);
- soil organic carbon content (ORGUGLEROD);
- particle-size distribution (QLANUMSOST);
- base saturation (BASESATUR);
- horizon structure (STRUKTUR);
- extractable P_2O_5 content (OBMENP2O5);
- horizon thickness (MOSHNOST).

As can be seen, most of the above parameters of this horizon are determined similarly to the previous algorithm, while taking different values. For instance, the soil organic carbon parameter should take a value ≥ 0.6 %. Color in this horizon is one of the main parameters identifying a soil as belonging to this group and takes the text value "brown". The values of the SVETLOTA and NASIWENOST parameters in this horizon depend on the parameter indicating soil condition, SOSTOYANIYE. If the SOSTOYANIYE parameter takes a value equal to 1, moist, then the SVETLOTA parameter will take a value of ≤ 3, otherwise it take a value of ≤ 5. The NASIWENOST parameter will take a value ≤ 3 with the value of the SOSTOYANIYE parameter equal to 1, moist. The ORGUGLEROD parameter will take a similar value as in the plaggic horizon. Base saturation of the soil, BASESATUR, takes a value of <50% for this horizon. The most part of the umbric horizon has acidic reaction, which results in the acidity parameter, OBMENP2O5, taking a value of < 5.5. Horizon thickness is determined by the MOSHNOST field and takes a value of ≥ 20 cm. The following is the diagnostic algorithm of the umbric diagnostic horizon in the form of a functional module in an algorithmic language (Pascal):

```
Function umbric
begin
        If
((UP_HORIZONT=1) and (MATERIALTYPE=5) and (CVET=1) and (ORGUGLEROD≥0.6) and (ARTEFAKTS=1) and (SVETLOTA≤3) and (NASIWENOST≤3) and (SOSTOYANIYE=1) or ((SVETLOTA≤5) and (SOSTOYANIYE=0))) or ((QLANUMSOST=3) and (SVETLOTA≤5) and (NASIWENOST≤3) and (ORGUGLEROD≥2.5)) and (BASESATUR ≤50) and (OBMENP2O5 ≤5.5) and (MOSHNOST≥10) or (MOSHNOST≥20)
        then true
        else false
end;
```

Parameters of the next horizon of this group, the mollic horizon, take values similar to those of the umbric horizon. The algorithm of identifying a soil for this horizon is built similarly to the previous one. The only difference is the value of the BASESATUR parameter, which in this horizon takes a value of ≥ 50 %. The final result of this variant is that when allocating soils to this group, the parameters should satisfy the values of one of these horizons. The algorithm for determining whether the soil belongs to the hortic horizon was described earlier in the second variant. The described algorithm makes it possible to identify Reference Soil Groups directly on the basis of three diagnostic horizons.

Thus, we have developed an algorithm for soil identification according to the first level of soil allocation to WRB Reference Soil Groups. Three different variants of allocating soils to WRB Reference Soil Groups have been considered.

V. Conclusion

Soil identification according to the World Reference Base for Soil Resources (WRB) is investigated. A structure of the database of soil parameters of diagnostic horizons is proposed. A soil diagnostic algorithm is developed, which will allow identifying any soil type with the corresponding WRB Reference Soil Group. Three variants of allocating soils to WRB Reference Soil Groups based only on soil parameters, or on the combination of diagnostic horizons and soil parameters, or only on diagnostic horizons are considered.

References

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