Chemical, physical, mineralogical and micromorphological properties of soils along a toposequence in Chelgerd region, Chaharmahal-va-Bakhtiar, Iran

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ABSTRACT: The optimum use of soil is possible with correct and complete understanding of its properties. The purpose of the present study was to enhance understanding of Vertisols in an area located on 35 km of Chelgerd region in Chaharmahal-va-Bakhtiar province, Iran. Soil temperature and moisture regimes of this region are mesic and xeric, respectively. Eight pedons located on a transect along the northern slope were sampled and described. The results showed that the soils of the area are Inceptisols and Vertisols according to the Taxonomy system, while in WRB system, they are named Cambisols, Calcisols and Vertisols. They are constituted mainly by smectites associated with some amount of illite, chlorite, kaolinite, quartz and illite-smectite as mixed minerals. Study of the thin sections revealed the presence of clay coating in the Btss and Btkss horizons. Also, calcite coating, calcite infilling and calcite accumulation with various forms such as calcite needle and calcite nodule in the Bk, Bkss and Btkss were also observed. The cause is the accumulation of calcite needle in the top of the slope due to highlands area, presence of enough moisture in the soil, the low salinity of soil and presence of biodegradable organic matter.

Keywords: Clay mineralogy, Physico-chemical properties, Soil classification, Topography

INTRODUCTION

A major factor limiting agricultural development in Iran is the lack of information on soil and land characteristics. Soil is a natural body arranged in layers, consisting of mineral constituents (Ahmakhian & Achimugu. 2011). Soil forms a continuum over the earth's surface. The continuum of soil cover on the earth's surface can barely be comprehended in its entirety and, hence, a subdivision is required to recognize and remember the various components of this continuum and to understand relationships with the factors that influenced their formation (Dudal. 2003).

A toposequence is a sequence of related soils from the hill top to the valley floor. Five major soil positions on a typical toposequence are: summit, shoulder, backslope, footslope, and toeslope. As the landscape is undulating, soil characteristics at different topographic positions differ. Soils differ in their characteristics primarily because of topography (Ahmakhian & Achimuau. 2011). Soil topography plays a major role as one of the factors that influence
pedogenesis and in the process that dictates the distribution and use of soils on the landscape (Hoosebeek et al. 2000., Esu et al. 2008). Toposequence and catena concepts have emanated as slope-soil evolutionary processes. Landscape position influences rainfall, drainage and erosion. Water velocity on a slope affects deposition of materials in suspension. The largest size particles, like sand, are the first to drop out of suspension. Fine clay size particles can be carried further away from the base of the slope before they are deposited (Glassman et al. 1980). Hill slope orientation also affects the microclimate of a place; inclined surface facing into the sun tends to be warmer and drier than flatter surface facing away from the sun (Atofarati et al. 2012). The study of soil along a toposequence is useful to understand the change of physical, chemical, and mineralogical properties of soil with increasing elevation, and to assess their suitability for crop development.

Soil classification generally aims to establish a taxonomy based on breaking the soil continuum into discrete geographical segments of restricted ranges in soil properties, i.e., more or less homogeneous groups with respect to defined objectives (Cline, 1949., Gou et al. 2003). Thereby, it can highlight the essential differences in soil properties and functions between classes. Systematic soil classification is also a vehicle for communicating research results and extending the benefits of new knowledge and information to other locations (Shi et al. 2010). Classification systems are conceptual frameworks that enable the assimilation of information and delivery of information to a user (Blum & Laker, 2003). Soil classification systems have come a long way from their humble beginnings as a means of levying taxes based on production (Simonson. 1962), and have progressed through various stages, including the descriptive stage to rather sophisticated, quantitative systems. Most early soil classification systems were based on the recognition of soil forming processes, whereas modern systems classify soils based on quantitative characteristics defined as diagnostic horizons, properties, and materials. This allows pedologists with different experiences to classify soils in the same way. Furthermore, most modern soil classification systems are developed to complement and support soil survey activities (Ahrens et al. 2003). They provide a method for planning agricultural output, allowing the application of new management techniques and supporting the use of environmentally sound land-use practices (Shi et al. 2010). The two most widely used modern soil classification schemes are Soil Taxonomy, or ST, (Soil Survey Staff. 2014) and the World Reference Base for Soil Resources, or WRB (FAO/ISRIC/ISSS. 1998; IUSS Working Group WRB. 2014).

Although in the ST and WRB systems, genesis (and soil forming factors) is declared only as a reason for the formation of soil properties, i.e., the classification is based on substantive principles (Gerasimova. 2010), the correlation between the results of both systems with regard to their taxa is an issue. ST has a strong hierarchy with six categoric levels, i.e., order, suborder, great group, subgroup, family, and series (Soil Survey Staff. 2014), whereas the WRB has a flat hierarchy with only two categoric levels, i.e., reference soil groups and soil units (IUSS Working Group WRB. 2014). However, both employ a key that permits unambiguous identification by a process of elimination when passing through a fixed sequence of definitions. Rossiter. (2001) stated that the reference soil group level of WRB is an intermediate in the conceptual level between ST orders and suborders, while the second-level subdivisions, i.e., soil units, which are defined by combinations of qualifiers, are similar to the ST great groups (one qualifier) or subgroups (multiple qualifier). Roca and Pazos. (2002) also found a rather good correlation between soil names at the subgroup level of ST and soil units in WRB for the area of zonal and interazonal soils, but for azonal soils, the different weight given to soil-forming processes in both systems, particularly those leading to organic matter accumulation, resulted in a low degree of correlation between the two systems. In the central arid region of Iran, Toomanian et al. (2003) focused on gysiferous soils and argued that, despite the effort of the ST system to overcome the shortcomings at the family level, it cannot compete with WRB in classifying gysiferous soils, i.e., the WRB seems to be the most appropriate system for the classification of these soils. Mojiri et al. (2011) compared ST and WRB systems for Aridisols of the Segzi plain in central Iran, and declared that both systems can reasonably classify these soils.

The soils along toposequence have been classified by many researchers. Therefore, the following classifications have been obtained, Alfisols (Ogunkunle. 1993), and Typic Sulfaquent (Akpan-Idiok. 2003). Subardja and Buurman. (1980) studied a toposequence of soils derived from Andesitic volcanic materials of the Gede- Panagrango volcanoes in the humid Puncak-Bogor-Jakarta area, and the results showed that elevation influenced soil properties, degree of weathering, and soil development. With decreasing elevation, soil sequence was found changing from Andisols to Inceptisols, and became Oxisols in the low elevation. Down to lower elevation, the soils became more weathered and developed, and leaching of bases/nutrients was more intense. Similar results were also reported by Van Schuylenborgh. (1957) and Subagio et al. (1997) in a toposequence of soils at various elevations of volcanoes in west Java. Subagio and Buurman. (1980) studied a soil catena developed from andesitic volcanic materials under relatively dry climatic conditions on the western slope of Lawu
volcano. They found that the soil sequence starting from the highest elevation was Andisols-Inceptisols-Alfisols-
Vertisols.

This study aimed to evaluate the relationship between topography and soil morphological, physical, chemical,
mineralogical and micromorphological characteristics of soils in a toposequence in Chelgerd area, Chaharmahal-
Va- Bakhtiari province, Iran, and to classify these soils according to the USDA and FAO soil classification systems,
to reflect on the differences and to highlight parallels between them.

MATERIALS AND METHODS

Study Site

Iran is located in central Eurasia and southwest of Asia between 44° 02′ and 63° 20′ eastern longitudes and
25° 03′ and 39° 46′ northern latitudes. The studied area is located in Chelgerd region, Chaharmahal-va-Bakhtiari
province (Figure 1). Mean annual rainfall and soil temperature are 1389.6 mm and 9.5°C, respectively. Soil
temperature and moisture regimes of this region are mesic and xeric regimes, respectively.

Figure 1. Location map of the study area

Sampling sites

Physiographic units were distinguished and separated on aerial photograps. Eight pedons were excavated
along a toposequence and morphological characteristics such as soil color (Munsell soil color charts), structure,
consistence, pores, drainage and depth were studied according to the "Field Book for Describing and Sampling
Soils” (National Soil Survey Center. 2002). Then, soil samples from different genetic horizons of all pedons were taken, and were analyzed for determining particle size distribution (hydrometer and pipette method), calcium carbonate equivalent (HCl treatment or titrimetric method), cation exchange capacity (NH4OAc, pH 7.0), organic matter (Walkley-Black method), soil reaction (saturated paste), electrical conductivity (saturated extract at 25°C), and percentage of rock fragments (by volume). Clay mineral composition was determined using X-ray diffractometer (XRD), with standard saturation of Mg and K saturation plus heating to 550°C (Kittrik and Hope. 1963) and micromorphological soil study was determined by Stoops method (Stoops. 2003). Then, soils were classified according to the ST (Soil Survey Staff. 2014) and WRB (IUSS Working Group WRB. 2014) soil classification systems. Finally, the soil units of WRB were compared with those obtained by applying ST up to the family level.

RESULTS AND DISCUSSION

morphological properties

Table 1 shows a summary of the morphological properties of the representative pedons for the study area. Pedons were generally deep, with a depth ranging from 120 to 150 cm. The soils were well drained. This study was carried out in September of 2015 at the beginning of autumn. At that time, during the field works cracks with 2-3 cm wide and 20-60 cm deep and gilgai microreliefs were observed at the surface of all pedons with the exception of pedons no. 8, 9 and 12, which is one of the special characteristics of the vertisols.

physical properties

Table 2 shows the physical properties of soil formed along a toposequence. All soils of the study area had some amount of gravels in its layers. As the elevation decreased, gravel content decreased. The decreasing gravel content can be used as an indicator or for increasing degree of weathering to get less energy from the sun and evaporation. These findings are in agreement with the results reported by Dahlgern et al. (1997); Yuanjun and Mingan. (2008). Soil structure was granular in surface horizon and wedge shape and prismatic in the subsurface horizons of pedons. Granular structure was formed after several months from puddling due to accumulation of organic matter that is produced from plant residues and presence of high clay in these soils (Tarasawa. 1975; Hassannezhad et al. 2008).

Yimer et al. (2006), reported that, in mountainous areas, soil texture is variable with slope position. Atotfarati et al. (2012), in a study in Ile-Oluji, Ondo state, Nigeria concluded that clay content increased with depth and the highest concentration of O.C and O.M occurred at the down slope and decreased with depth. Similarly, in the studied area, downslope with decreasing elevation, as sand content decreased, clay content increased. Clay content was high in alluvial plain and lowland but clay film was not observed in all pedons in this situation, because of dry-wet alternation (Nettleton et al. 1969; Prakongkep et al. 2007). The increasing clay content feature can be used as an indicator or for increasing degree of weathering. Van wambeke. (1962) used silt and clay ratio to estimate the degree of weathering of soil pedon and postulated that the lower the ratio, the higher the degree of weathering. By increasing weathering, the silt fraction changed into clay fraction so that clay content increased, thus the silt and clay ratio was to be lower.

Chemical Properties

Selected chemical properties of soil solutions extracted from samples of a toposequence are shown in the Table 2. Soil reaction was neutral to slightly basic. pH ranged from 7.32-8.01. The large accumulation of soil organic carbon observed in soil surface of all pedons and decreased with depth. The lowest concentration of O.C and O.M occurred at the topsoil of upper slope and increased with decreasing elevation. These findings are in agreement with the results reported by Idoga and Azogaku. (2005); Atotfarati et al. (2012). Cation exchange capacity seemed to be related with elevation, and thus also related to degree of soil weathering. As discussed earlier, soil weathering tends to increase with decreasing elevation. As soil weathering increased in pedons of medium elevation, lot of exchangeable cations had been released, so that their total contents became medium to high. CEC was high in lowland because of high presence of organic matter in surface horizons and high clay content in subsurface horizons (Akef et al. 2003; Hikmatullah et al. 2003 and Seyedmohammadi Meresht. 2013). Electrical conductivity was high in soils of lowland. Draining water from uplands was accumulated on lowland soils and consequently caused high electrical conductivity.
Table 1. Summary of morphological properties of the representative pedons in the study areaa.

<table>
<thead>
<tr>
<th>Pedon no.</th>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Color</th>
<th>Consistency</th>
<th>Structure</th>
<th>Concentration</th>
<th>Effervescence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dry</td>
<td>Moist</td>
<td>Gr Sz Ty</td>
<td>% Sz Ty Cl. Ag.</td>
<td></td>
</tr>
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<td>0-45</td>
<td>7.5YR4.5/4</td>
<td>7.5YR4/4</td>
<td>VH</td>
<td>1 f Gr 1 m Wg</td>
<td>f 2 CAM</td>
</tr>
<tr>
<td></td>
<td>Bk</td>
<td>45-130</td>
<td>7.5YR5.5/4</td>
<td>-</td>
<td>EF</td>
<td>M 2 CAM  m 2 CAM</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>ABk</td>
<td>0-35</td>
<td>5YR4.5/4</td>
<td>5YR4/4</td>
<td>MH</td>
<td>2 f Gr 2 CAM</td>
<td>EF 1 m 2 CAN</td>
</tr>
<tr>
<td></td>
<td>Bk</td>
<td>35-130</td>
<td>5YR6/4</td>
<td>-</td>
<td>EM</td>
<td>m 2 CAM  m 2 CAN</td>
<td></td>
</tr>
<tr>
<td>10</td>
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<td>0-50</td>
<td>7.5YR4.5/4</td>
<td>7.5YR4/4</td>
<td>VH</td>
<td>2 f Gr 2 m Wg</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Btss</td>
<td>50-130</td>
<td>7.5YR5/4</td>
<td>-</td>
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<td>M 2 CAM  m 2 CAN</td>
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<td>10YR4/4</td>
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<td>2 f Gr 2 m Wg</td>
<td>-</td>
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<td>10YR6.5/4</td>
<td>-</td>
<td>EF</td>
<td>M 2 CAM  m 2 CAN</td>
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<td>10YR3.5/3</td>
<td>-</td>
<td>VFI</td>
<td>2 f Gr 2 CAM</td>
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<td>10YR3.5/3</td>
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<td>EF</td>
<td>1 m Pr 1 f CAM</td>
<td>EF 1 m 2 CAN</td>
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<tr>
<td></td>
<td>Bkss2</td>
<td>110-150</td>
<td>10YR6.5/4</td>
<td>-</td>
<td>EF</td>
<td>M 2 CAM  m 2 CAN</td>
<td></td>
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<td>13</td>
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<td>10YR5/4</td>
<td>10YR4/4</td>
<td>VH</td>
<td>2 f Gr 1 m Wg</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bwss</td>
<td>25-130</td>
<td>10YR5/4</td>
<td>-</td>
<td>EF</td>
<td>1 m Pr 1 m Wg</td>
<td>-</td>
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<td>Apss</td>
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<td>10YR5/4</td>
<td>10YR4.5/4</td>
<td>EH</td>
<td>2 f Gr 2 m Wg</td>
<td>-</td>
</tr>
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<td>40-120</td>
<td>7.5YR4.5/4</td>
<td>7.5YR4/4</td>
<td>FH-SH</td>
<td>2 f Gr 2 m Wg</td>
<td>-</td>
</tr>
<tr>
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<td>Ap</td>
<td>0-5</td>
<td>7.5YR3.5/4</td>
<td>7.5YR3/4</td>
<td>VH-SH</td>
<td>2 f Gr 2 m Wg</td>
<td>-</td>
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<tr>
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<td>5-60</td>
<td>7.5YR4/4</td>
<td>7.5YR4/4</td>
<td>EH</td>
<td>2 c Wg 2 m Wg</td>
<td>-</td>
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<td>60-105</td>
<td>7.5YR3/4</td>
<td>-</td>
<td>EF</td>
<td>1 m Wg 1 m Wg</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bkss2</td>
<td>105-140</td>
<td>10YR4/4</td>
<td>-</td>
<td>FI</td>
<td>1 m 2 CAM  c 2 CAN</td>
<td></td>
</tr>
</tbody>
</table>

a Symbols are used based on National Soil Survey Center, 2002 as follows:
Dry consistency- SH: Slightly Hard, MH: Moderately Hard, VH: Very Hard, EH: Extremely Hard
Moist consistency- FI: Firm, VFI: Very Firm, EF: Extremely Firm
Structure grade- 1: weak, 2: moderate, 3: strong
Structure size- f: fine, m: medium, c: coarse
Structure type- Gr: Granular, Pr: Prismatic, Wg: Wedge shape, M: Massive
Percentage of concentration- f:<2%, 2%<c>20%, m>20%
Concentration size- 2: medium
Concentration type- CAM: Carbonate Masses, CAN: Carbonate Nodules
Effervescence class- NE: Noneffervescent, VS: Very Slightly Effervescent, ST: Strongly Effervescent, VE: Violently Effervescent
Effervescence agent- H2: 1 normal hydrochloric acid (HCl)
Table 2. Summary of physical and chemical properties of the representative pedons in the study area.

<table>
<thead>
<tr>
<th>Pedon no.</th>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Coarse fragment</th>
<th>Sand</th>
<th>Silty</th>
<th>Clay</th>
<th>Cray</th>
<th>Soil texture</th>
<th>pH</th>
<th>ECE (ds.m(^{-1}))</th>
<th>CEC (meq/100 g soil)</th>
<th>CLE</th>
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<td>0.84</td>
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<td>Bwss</td>
<td>5-60</td>
<td>2</td>
<td>25.5</td>
<td>31.5</td>
<td>43</td>
<td>0.73</td>
<td>18</td>
<td>41.8</td>
<td>3.3</td>
<td>0.72</td>
<td>31.68</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Bwss</td>
<td>60-105</td>
<td>4</td>
<td>29</td>
<td>29</td>
<td>42</td>
<td>0.69</td>
<td>18.2</td>
<td>43.3</td>
<td>0.5</td>
<td>32.83</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Btkss</td>
<td>105-140</td>
<td>12</td>
<td>19</td>
<td>22</td>
<td>59</td>
<td>0.37</td>
<td>25</td>
<td>42.3</td>
<td>36.5</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Micromorphology Properties

The study of thin sections of the Bk horizon of pedon 8 located in the shoulder slope, reflects the effects of the soil forming similar to calcite infilling and calcite cover pedofeatures that confirms the secondary nature of lime and caused calcitie crystallitic b-fabric (Figure 2-a). In fact calcium carbonate wash of the surface to the depth of profile has caused calcitie crystallitic b-fabric and the xeric soil moisture regime, due to favorable moisture conditions, and can have various forms of calcareous. Some of these forms are calcite infilling, calcite cover, calcite needle, and calcite nodule. Calcite needle crystals was observed at the surface of minerals in this situation of the slope (Figure 2-b). According to the results of Khormali, et al. (2006), accumulation of this form of calcium carbonate can be attributed to highlands area, enough moisture in the soil, low salinity of soil and presence of biodegradable organic matter.
Figure 2. (a) Calcite crystalite b-fabric. (b) Calcite needle accumulation of Bk horizon of pedon 8 in the top of the slope.

In the thin sections of the Btss horizon of pedon 10 located in the back slope, clayey and calcium carbonate pedofeature was observed (Figure 3). Clay coatings in soil are evidence of translocation of clay from the upper horizon to the lower horizon as a result of water infiltration. Dry periods as a key factor for clay accumulation has been reported. This means that dry periods allowed clay to move to be kept (Kodesova et al. 2006). The formation of an aggregate clay crust or on the walls of the pores of the soil show that there is high rainfall and enough water available for transfer of clay from the upper horizons in the lower horizons in this region. It also seems in this area several processes happened including: 1- Decalcification, 2- Illuviation and 3- Calcification.

Figure 3. Clay coating of Btss horizon of pedon 10 in the backslope.

In the thin sections of the Btkss horizon of the pedon 15 located in the foot slope, clay coating and pressure face pedofeature (Figure 4-a) and some of Excrements (Figure 4-b) was observed. But clay crust in this horizon was less compared with profiles located on the higher slope that the researchers attribute this fact to the expansion and contraction of this soil due to higher value of smectite (Kemp and Zerate. 2000 and Verhey and Stoops. 1973).
In the all thin sections which were studied, various forms of calcium carbonate including calcite infilling (Figure 5-a), calcite cover (Figure 5-b), calcite nodule (Figure 5-c) and calcite bridge (Figure 5-d) were observed. The presence of these pedofeatures in the lower soil horizons indicates the presence of a large amount of calcium carbonate in the soil parent material and fluctuating in wet and dry periods in summer and winter. According to the xeric soil moisture regime of the area, calcium carbonate in the soil parent material dissolved in water in rainy seasons and in dryness of the soil, and in the above-mentioned pedofeatures sediment had accumulated.
Figure 5. (a) Calcite infilling of Bkss horizon of pedon 11 in the back slope. (b) Calcite coating of Bk horizon of pedon 8 in the top of the slope. (c) Calcite nodule of Bkss horizon of pedon 14 in the foot slope.

Mineralogy Properties

Illite, smectite, chlorite, quartz, kaolinite and illite-smectite mixed minerals were found in all the studied soils. Figure 6 (a, b, c) shows the clay mineralogy of the Bk horizon of pedon 9 (located in the top of the slope), Bkss2 horizon of pedon 12 (located in the back slope) and Btkss horizon of pedon 19 (located in the foot slope), respectively. The presence of kaolinite, illite, chlorite, smectite, quartz and illite-smectite mixed minerals in parent material of this area (C horizon) confirms that these minerals can be originated from parent rocks inherent (Figure 6-d).

Illite, chlorite, quartz, kaolinite and illite-smectite mixed minerals have a relatively similar abundance in different of geomorphic positions that is why inheritance from parent material is the only possible source of these minerals (Karimzadeh et al. 2004). On the other hand, an environment with higher temperature and more humidity and leaching is needed for pedogenic formation of kaolinite and chlorite (Barnhisel and Bretsch. 1989). But such environmental conditions were not present in the study area. But smectite content increased toward down the
slope. Smectite clay mineral due to its tiny size, less precipitated by mechanical processes and by the flow of long distance transmitted water. Besides, transformation of illite to smectite could be another source of smectite in this area.

Figure 6- (a) X-Ray diffractograms of Bk horizon of pedon 9. (b) X-Ray diffractograms of Bkss2 horizon of pedon 12. (c) X-Ray diffractograms of Btkss horizon of pedon 15. (d) X-Ray diffractograms of parent material horizon

Classification of Soils

Due to the presence of calcic horizon in pedons 8 and 9 within a depth of 100 cm of the soil surface, and due to the presence of cambic horizon in pedon 12 that is within 100 cm of the soil surface and has a lower boundary at a depth of 25 cm or more below the soil surface, these pedons are classified as Inceptisols, but in other pedons due to a layer with 25 cm or thicker within 100 cm of the soil surface, that has slickensides or wedge-shaped ped and a weighted average of 30 percent or more clay in the fine earth fraction either between the soil surface and a depth of 18 cm or in an Ap horizon, whichever is thicker, and 30 percent or more clay in the fine earth fraction of all horizons between a depth of 18 cm and a depth of 50 cm and cracks that open and close periodically, classified as Vertisols (according to ST system). (Soil Survey Staff. 2014).

A xeric moisture regime was inferred for all pedons observed based on rainfall data which suggests a soil moisture regime in which the soil moisture control section, in normal years, is dry in all parts for 45 or more consecutive days in the 4 months following the summer solstice and moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice, therefore the soil is classified into suborder Xererts and Xerepts (according to ST system) (Soil Survey Staff. 2014).
The existence of xeric moisture regime and the presence of calcic horizon in pedon 8 have been accounted for both the soil classification systems (table 3). Similar conditions can also be seen for the classification of pedon 9. Table 4 shows a summary of the most important properties of the representative pedons by both classification systems.

Due to the presence of calcic horizon within 100 cm from the soil surface in pedons 8 and 9 and no presence of argic horizon above the calcic horizon (Table 1), these pedons classified as Calciisol reference soil group. Although the presence of calcic and cambic horizons in pedon 12 is considered adequately by both classification systems, another noticeable point is the depth of the calcic horizon (table 1) which is denoted by Cambisols reference soil group (Table 3) (IUSS Working Group WRB. 2014).

The Chromic suffix in the WRB name of pedon 9 (table 3) shows the presence of a subsurface layer within 30 cm or thicker within 150 cm of the soil surface that has a munsell colour hue redder than 7.5YR, moist (IUSS Working Group WRB. 2014). This feature is well described by the horizon designation in the ST system (table 1).

The Loamic and Epiloamic suffix in the WRB name of pedons 8, 9 and 12 and Ochric suffix in pedon 12 (table 3) shows large amounts of loam materials and presence of a surface horizon with at least 10 cm thick with 0.2 to 0.6 organic carbon, respectively, which are not referred by ST at all. Furthermore, Calcaric, Eutric and Hypereutric in the WRB name of pedons (table 3) show carbonates in overlying soil and base saturation more than or equal to 50% in all parts of the pedons, respectively, which are not referred by ST at all (IUSS Working Group WRB. 2014). The existence of expandable clays as well as vertic properties is one of the major characteristics of pedons 10, 11, 13, 14 and 15. Based on both classification systems (IUSS Working Group WRB. 2014 and Soil Survey Staff. 2014), vertisols must have at least of 25 cm thick with 30% clay throughout and have either slickensides or wedge-shaped structural aggregates and have shrink-swell crack. But in the older version of WRB, the presence of slickensides and wedge-shaped structural aggregates, is essential for this reason. In a study that Esfandiarpoor et al (2013), had done, as pedons do not have wedge-shaped ped, they do not meet all diagnostic criteria for a vertic horizon and classified as Cambisols and Calciisol. So, they suggested that, adjusted conditions for vertic horizons and replacing the word “or” instead of conjuctions “and” in association with wedge-shaped structural aggregates and slickensides, be included in the next version. That fortunately, this problem is solved in recent version of WRB system.

Pedons 14 and 15 have special morphological features (table 1). In these pedons Gilgaic suffix in the WRB name (table 3) and Humic suffix in the WRB name of pedons 13 and 14 shows the presence of microhighs and microlows with a difference in level at least of 10 cm thickness and presence of more than or equal to 1% organic carbon within 50 cm from the soil surface, respectively, which are not referred to by ST at all. So, WRB could better express the features of this soil, whereas ST could not account for enough of these properties (IUSS Working Group WRB. 2014).

More attention has been paid to the argic horizon in the WRB system. WRB system could better express the features of this horizon. Based on ST, argillic horizon, in addition to having the thickness and increasing clay over the eluvial horizon condition, must have evidence of accumulation of illuvial clay, but in WRB must have either increasing clay over the eluvial horizon or have evidence of accumulation of illuvial clay (IUSS Working Group WRB. 2014). It is suggested that, in the ST system, adjusted conditions for argillic horizon and replacing the word “or” instead of conjuctions “and” in association with accumulation of illuvial clay and increasing clay over the eluvial horizon, must be considered in the next version. According to the definitions in both systems, the second horizon in pedon 10 and fourth horizon in pedon 15, are argillic horizons. So, add suffix “Luvic” and “Lixic” to Vertisols reference soil group in WRB system and add “Argixererts” greatgroup in ST system due to lack of consideration of argillic horizon, recommended. The Luvic prefix in the WRB name of pedon 8 and 9 (Table 3), a feature which was not mentioned in ST, shows the presence of an argic horizon within 100 cm of soil surface that have a CEC and base saturation more than or equal to 24 cmol.kg-1 clay and 50% in all parts, respectively.
### Table 3. Classification of the representative pedons based on ST and WRB systems.

<table>
<thead>
<tr>
<th>Pedon no.</th>
<th>Classification system</th>
<th>ST</th>
<th>WRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Fine, carbonatic, mesic Typic Calcixererts</td>
<td>Luvic Calcisols (Loamic)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Fine, carbonatic, mesic Typic Calcixererts</td>
<td>Luvic Calcisols (Chromic, Amphiclayic, Epiloamic)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Fine, smectitic, mesic Chromic Haploxererts</td>
<td>Haplic Vertisols (Aric, Hypereutric)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Fine, carbonatic, mesic Chromic Calcixererts</td>
<td>Calcic Vertisols (Aric, Calcric)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Fine, smectitic, mesic Calcic Haploxererts</td>
<td>Eutric Cambisols (Aric, Amphiclayic, Epiloamic, Ochric)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Fine, smectitic, mesic Chromic Haploxererts</td>
<td>Haplic Vertisols (Aric, Humic, Hypereutric)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Fine, smectitic, mesic Chromic Haploxererts</td>
<td>Haplic Vertisols (Aric, Gilgaic, Humic, Hypereutric)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Fine, smectitic, mesic Chromic Haploxererts</td>
<td>Haplic Vertisols (Aric, Gilgaic, Hypereutric)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Comparison of the most important properties of the representative pedons based on ST and WRB systems.

<table>
<thead>
<tr>
<th>Pedon no.</th>
<th>Classification system</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>- The presence of calcic (Bk) horizon with in 100 cm of the soil surface is considered. -The existence of free carbonates in all parts above the calcic horizon has considered. -Considering more than 40% (by weight) carbonates at family level (by Carbonatic mineralogy class).</td>
</tr>
<tr>
<td>9</td>
<td>- The presence of calcic (Bk) horizon with in 100 cm of the soil surface is considered. -The existence of free carbonates in all parts above the calcic horizon has considered. -Considering more than 40% (by weight) carbonates at family level (by Carbonatic mineralogy class).</td>
</tr>
<tr>
<td>10</td>
<td>- The presence of argillic (Btss) horizon and slickenside with in 150 cm of the soil surface is considered. -Considering the vertic properties at order level, i.e., vertisols, and also the existence of expandable clays at family level (by Smectitic mineralogy class). -Considering the color property of soil (by the Chromic subgroup).</td>
</tr>
<tr>
<td>11</td>
<td>- The presence of argillic (Btss) horizon and slickenside is considered. -Considering the vertic properties at order level, i.e., vertisols, -Considering more than 40% (by weight) carbonates at family level (by Carbonatic mineralogy class). -Considering the color property of soil (by the Chromic subgroup).</td>
</tr>
<tr>
<td>12</td>
<td>- The presence of calcic horizon (Bkss) and slickenside is considered. -Considering the vertic properties at order level, i.e., vertisols, -Considering more than 40% (by weight) carbonates at family level (by Carbonatic mineralogy class). -Considering the color property of soil (by the Chromic subgroup).</td>
</tr>
</tbody>
</table>

59
cm of the soil surface is considered.
- Considering the existence of expandable clays at family level (by Smectitic mineralogy class)
- The presence of surface horizon with 40 cm thick with 0.46% organic carbon (by Ochric qualifier).
- Considering the base saturation ≥ 50% in the major part between 20 and 100 cm from the soil surface (by Eutric qualifier).

**13**
- The presence of cambic horizon (Bss) and slickenside is considered.
- Considering the vertic properties at order level, i.e., vertisols, and also the existence of expandable clays at family level (by Smectitic mineralogy class).
- Considering the color property of soil (by the Chromic subgroup).
- The presence of protovertic (Ap) and vertic (Ap) and cambic (Bss) horizons with in 100 cm from soil surface are considered.
- Considering the presence of ploughed to a depth of ≥ 20 cm from the soil surface (by Aric qualifier).
- Considering the base saturation ≥ 50% in the major part between 20 and 100 cm from the soil surface (by Hypereutric qualifier).
- Showing the presence of organic carbon ≥ 1% to a depth of 50 cm from the soil surface (by Humic qualifier).

**14**
- The presence of cambic horizon (Bkss) with accumulation of visible pedogenic calcium carbonate and slickenside is considered.
- Considering the vertic properties at order level, i.e., vertisols, and also the existence of expandable clays at family level (by Smectitic mineralogy class).
- Considering the color property of soil (by the Chromic subgroup).
- The presence of protovertic (Ap) and vertic (Bkss) horizons with in 100 cm from soil surface are considered.
- Considering the presence of ploughed to a depth of ≥ 20 cm from the soil surface (by Aric qualifier).
- Considering the base saturation ≥ 50% in the major part between 20 and 100 cm from the soil surface (by Hypereutric qualifier).
- The presence of microhighs and microlows with a difference in level of ≥ 10 cm, i.e. gilgai microrelief (by Gilgaic qualifier).
- Showing the presence of organic carbon ≥ 1% to a depth of 50 cm from the soil surface (by Humic qualifier).

**15**
- The presence of cambic (Bss1, Bss2), calcic (Btkss) and argillic (Btkss) horizons with slickenside are considered.
- Considering the vertic properties at order level, i.e., vertisols, and also the existence of expandable clays at family level (by Smectitic mineralogy class).
- Considering the color property of soil (by the Chromic subgroup).
- The presence of protovertic (Bss1, Bss2), veric (Bss1, Bss2), cambic (Bss1, Bss2), calcic (Btkss) and argic (Btkss) are considered.
- Considering the presence of ploughed to a depth of ≥ 20 cm from the soil surface (by Aric qualifier).
- Considering the base saturation ≥ 50% in the major part between 20 and 100 cm from the soil surface (by Hypereutric qualifier).
- The presence of microhighs and microlows with a difference in level of ≥ 10 cm, i.e. gilgai microrelief (by Gilgaic qualifier).

**CONCLUSION**

According to the results obtained in this study, WRB can be used as a more economical laboratory analysis for soil mapping than ST, due to the greater number of physical and chemical analysis and consequently the costs required for determining the family and series in ST. Additionally, the developers of WRB do not recommend the use of this system for soil surveys larger than 1:250000 scale. They suggest using national or regional classification systems instead of WRB to acquire more accurate and more detailed information about soil variations (IUSS Working Group WRB, 2014). However, the absence of a national soil classification system for developing countries like Iran and the more accurate descriptions of the soils of arid and semi-arid regions make the WRB system preferential to ST for soil survey purposes.
REFERENCES


Roca PN. Pazos MS. 2002. The WRB applied to Argentinian soils: two case studies. European soil bureau, research report no. 7. European Soil Survey Center, Lincoln, NE.


