DESERT 2021, 26(2): 219-235
DOI: 10.22059/jdesert.2021.318248.1006804

RESEARCH PAPER

Capability of Soil Taxonomy (2014) compared to updated WRB (2015) in describing Lut Desert soils

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Received: 31 January 2021, Revised: 02 February 2021, Accepted: 27 February 2021

Abstract
Soil classification is a useful tool for understanding and managing soils. The objective of the present research was to compare the capability of Soil Taxonomy (ST, 2014) and World Reference Base for soil resources (WRB, 2015) systems related to soil description and classification in Lut Desert. Marginal and central parts of Lut with typical aridic/thermic and extreme aridic/hyperthermic soil moisture/temperature regimes were selected. Twelve representative pedons on alluvial fan, plain, rock pediment, Gandom Beryan lava plateau, and playa were described and sampled. The obtained results showed further capability of the WRB system to reflect soil forming processes. However, it could be recommended to add anhydritic qualifier to Solonchaks, Solonetz, and Gypsisols, aquatic qualifier to Solonchaks and Solonetz, and abruptic, leptic, and paralithic qualifiers to Solonchaks. The ST system has not been successful in expressing soil forming processes due to considering only two great groups for saline soils and giving priority to Salids in comparison with the other suborders of Aridisols. That is why Petrosalids, Gypsisalids, Natrisalids, and Argisalids great groups and Anhydritic Natrisalids, Anhydritic Argisalids, Anhydritic gypsisalids, Anhydritic Petrosalids, Calcic Natrisalids, Calcic Argisalids, Calcic Gypsisalids, Natric Petrosalids, Natric Haplosalids, Natric Gypsisalids, Petrogypsic Petrosalids, and Epipetrosalic Aquisalids subgroups are suggested to be added to Soil Taxonomy system. Meanwhile, defining anhydritic horizon and considering textural differences in strongly contrasting particle size class of family level and aquic conditions in playa are among the merits of Soil Taxonomy. Nonetheless, it could be suggested to remove (or adopt) color (Hue) requirement of anhydritic horizon.

Keywords: Saline soils, Gypsiferous soils, Anhydritic horizon, Paralithic qualifiers, Aquic conditions

Introduction

Soil classification is one of the basic aspects of soil science, which aims to create an international systematic method for quickly achieving the pedogenic properties of the soil and identifying soil resources. Thus, mapping, soil use determination, and soil resource management have been well conducted. In this regard, different soil classification systems were created to cover the soil continuum and provide almost uniform classes whereby fundamental differences in soil properties could be identified (Cline, 1949). Soil Taxonomy (ST) and World Reference Base for soil resources (WRB) soil classification systems are among the most

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frequently employed classification systems in the world. Twelve keys to Soil Taxonomy (from 1975 up to now) and three versions of WRB (from 1988 to date) have been updated for better describing soil characteristics. Structural differences in the two systems, such as non-equal levels of classification (12 orders of Soil Taxonomy compared to 32 reference soil groups of WRB), non-equal levels of hierarchy (six levels in Soil Taxonomy compared to two levels in WRB), lack of climatic data requirement in WRB system, difference in the number of characteristic horizons, properties and materials between the two systems, and the non-similarity of the two systems to describe similar selected soil horizons (Cline, 1949) resulted in several pieces of research to be conducted to harmonize the two classification systems (Brevik *et al*., 2016; Sarmast *et al*., 2016; Esfandiarpour Boroujeni *et al*., 2018a).

Esfandiarpour Boroujeni *et al*. (2011) concluded that soil names in WRB system provide further information about surface and depth properties of saline soils compared to those in the ST system. On the other hand, Finstad *et al*. (2014) concluded that NaCl and $NaNO_3$ enriched horizons were not considered properly in Atacama Desert via the ST system. Additionally, nitratine (NaNO3) in hyper-arid climates was not investigated by WRB system. Using ST and WRB systems to classify gypsiferous soils of northwestern Isfahan, central Iran, Toomanian *et al.* (2003) stated that although the ST system tries to overcome the weaknesses of higher taxa at the family level, this system is not capable of competing with the WRB system in classifying gypsiferous soils. However, in the study of soils in Babaheidar area, western Iran, Sarshogh (2010) concluded that the ST system (Soil Survey Staff, 2010) could better describe the characteristics of shallow soils in semiarid regions compared to the WRB system (2015). Moreover, soil mineralogy class at the family level of the ST system is another strong point of this system for management purposes compared to the WRB.

The criteria used to classify Aridisols are mainly derived from the characteristics of deserts located on the western North America (Finstad *et al.*, 2014). This seems to be the reason why certain properties of other desert areas with different characteristics are neglected in this classification system. Aridity rate in soil could be investigated according to the input and output of humidity using precipitation (P) to potential evapotranspiration (PET) ratio. The ratio of P/PET in the majority of the soil in western North America is between 0.05-0.2 (Finstad *et al.*, 2014). However, several pieces of research over the last decade have proved that special soil characteristics in hyper-arid areas ($P/PET<0.05$) were different from the characteristics of North America Deserts (Ewing *et al.*, 2006; Quade *et al.*, 2007; Bockheim and McLeod, 2008). Minor amounts of sulfates and more soluble salts in the majority of North American deserts have been reported. In contrast, the prolonged lack of rainfall in hyper-arid deserts, such as Atacama and Negev, prohibited salt leaching and caused chlorides, sulfates, and nitrates to be accumulated in soil, which in some cases, formed cemented and hard layers composed of a combination of salts (Amit and Yaalon, 1996; Amundson *et al*., 2012; Finstad *et al*., 2016). Ewing *et al*. (2006) studied the soils formed in hyper-arid areas and concluded that weathering of silicates and biological processes had been stopped. On the other hand, atmospheric dusts deposited were among the dominant soil forming processes. The identification of pedogenic processes could be highly conducive to classification of these soil resources for better monitoring. It is also of particular importance in sustainable management and desertification combat projects in the area.

Deserts are divided into four groups, namely hot-arid, semiarid, coastal, and cold deserts. Hot-arid deserts are characterized by intense aridity, high different rate of day and night temperature, high evapotranspiration, low precipitation, and scarce vegetation. Lut Desert is also in the hot-arid group of deserts (Khosroshahi, 2016). About 55% of the total area in Iran is covered with desert areas (Khosroshahi, 2016); various landscapes have been formed with specific soils different from non-arid areas (due to complex interactions of environmental factors, including climate, geology, and hydrology). Based on the above literature, the objectives of the present research included: 1) comparing the capabilities of Soil Taxonomy (2014) and WRB (2015) classification systems to identify the key processes affecting genesis of soils in Lut Desert, central Iran and 2) highlighting the similarities and differences between the two systems and providing suggestions on the improvement and harmonization of the systems in desert areas of the present research.

Materials and Methods

Study area

Lut Desert (about 100,000 km^2 extent) is among the most arid parts of the Iranian Central Plateau (Ghobadian, 1990). It is located in the southeast of Iran, in the center of Lut Watershed (Fig. 1a). The lowest and driest depression in Iran with the elevation of about 205 m above the sea level (asl) has been reported in the Lut Desert. The mean annual precipitation at the elevations is about 100-150 mm and in the central parts, it reaches less than 50 mm; there may not be any rain even for several years (Krinsley, 1970). Central Lut has an extreme aridic/hyper thermic (Ae-Ht) soil moisture/temperature regime which changes to typic aridic/thermic (At-Th) regime in the alluvial fans at the margins of Lut Desert based on precipitation versus evapotranspiration curve provided by JNSM software (USDA-NRCS, 2012) and soil moisture/temperature map of Iran (Banaie, 1998).

Sediments of Pleistocene age have filled the central depressions as reported by Krinsley (1970). Playa, Kalut, sand dune, and Gandom Beryan lava plateau are among the landforms found in the central parts of the desert. Playa, as the lowest lying part of Lut Desert, and Kaluts, with the extent of 150 km length and 70 km width and with a northwest to southeast direction (Ghodsi, 2017), are other landforms in the central Lut Desert, which have been highly affected by aeolian processes and erosion. Gandom Beryan lava plateau is covered by basaltic rocks. Nayband Fault activity in the area has caused crust weakness and removal of lava along the breaks has caused a lava plateau to be formed (Walker *et al*., 2009).

Field and laboratory studies

Digital elevation model and Google Earth images, together with field studies, helped to determine the match line of the area and to separate the geomorphic surfaces in the area. Twelve representative pedons, which best showed the variations in soil, were selected. Pedons 1 to 4 were located on alluvial fans at the margins of Lut Desert with the aridic/thermic soil moisture/temperature regimes. Pedons 5 to 12 were described and sampled on playa (saline clay flat, saline puffy ground clay flat, and salt crust geomorphic surfaces), Gandom Beryan lava plateau, alluvial fan, and plain and rock pediment landforms with hyper aridic/hyperthermic soil moisture/temperature regimes at the central Lut Desert (Figs. 1b and c). Soil description and sampling were performed using the guideline proposed by Schoeneberger *et al.* (2012).

The collected samples were air dried, ground, and passed through a 2-mm sieve. Primarily, coarse fragments were determined. Routine physical and chemical analyses were then performed. Pipette method was used for particle size analysis (Gee and Bauder, 1986). The pH of saturated paste and the EC of saturated extract were determined via Jenway pH meter and BPTC-500 PrismaTech EC meter, respectively. Back titration method was utilized for equivalent calcium carbonate investigation (Nelson, 1982). Flame photometry, complexometry, and titration methods were respectively used for the determination of soluble Na^+ (Gammon, 1951), soluble Ca^{+2}, and Mg^{+2} (Ringbom *et al*., 1958), which were the basis for the calculation of sodium adsorption ratio (SAR) and soluble Cl^- (Richards, 1954). Cation exchange capacity (CEC) was investigated by substituting sodium acetate with ammonium acetate at pH=7 (Bower and Hatcher, 1966). The sum of gypsum and anhydrite was determined employing acetone method (Nelson, 1982). Subsequently, gypsum content was quantified through the thermal gravimetric analysis (TGA) method (Wilson *et al*., 2013). The samples in the TGA method were heated in the range of 20-200 °C at a rate of 2 °C/min. Weight loss in the range of 75-115 °C was used to quantify gypsum content. Anhydrite content was calculated by subtraction of TGA from acetone results. ST (Soil Survey Staff, 2014) and WRB (IUSS Working Group WRB, 2015) systems were used for soil classification.

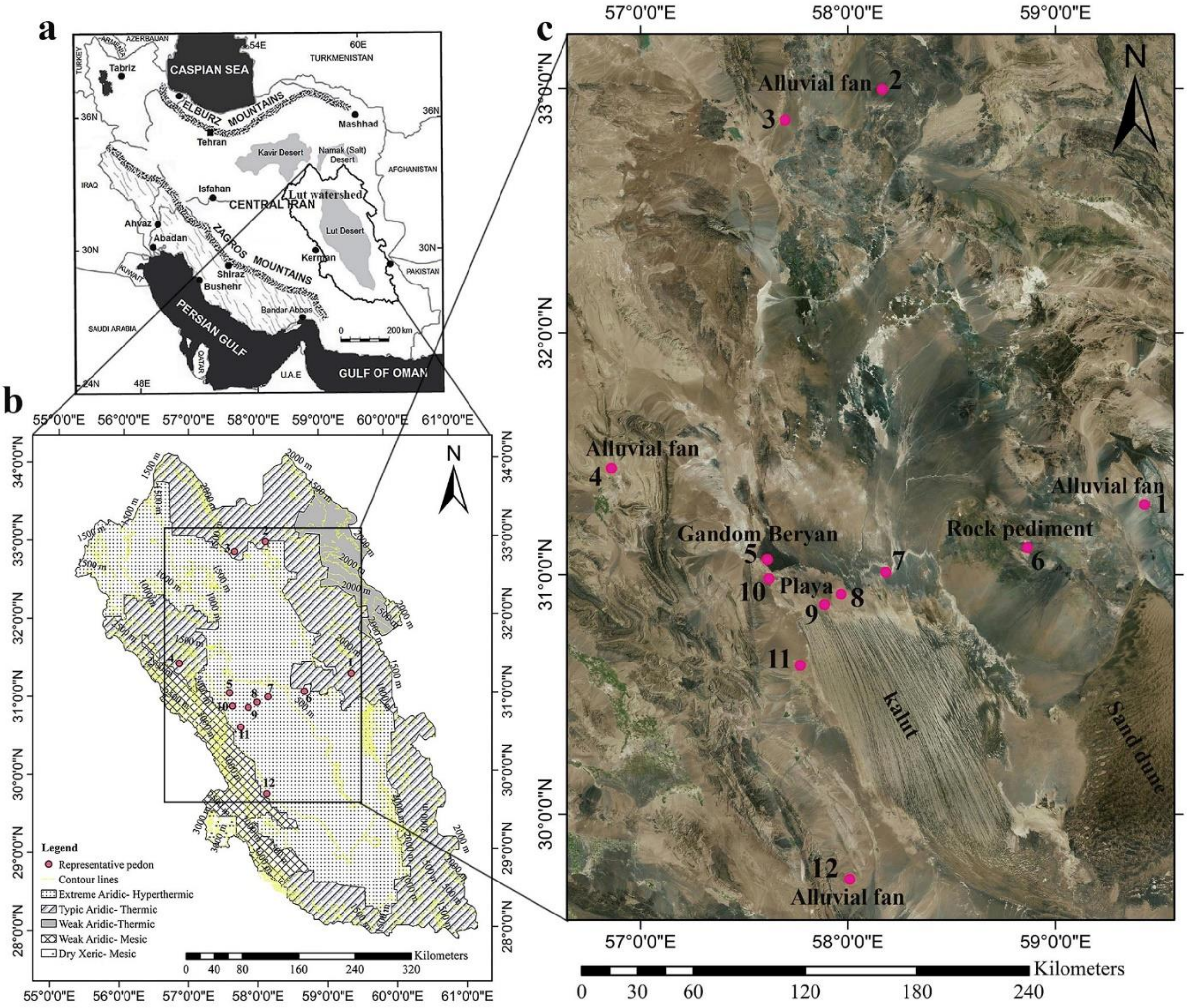

Figure 1. (a) Location of the study area; (b) Soil moisture/temperature regimes map (adopted from Banaie (1998)), elevation variations, and position of representative pedons, (c) Location of representative pedons on Google Earth image

Results and Discussion

Tables 1 and 2 respectively depict the selected morphological properties and physicochemical characteristics of representative pedons. Table 3 shows the classification of soils based on Soil Taxonomy (2014) and WRB (2015) systems. The diagnostic horizons or characteristics neglected by the two classification systems were presented schematically in Fig. 2 with red color.

Table 1. The selected morphological properties of the studied pedons

Horizon	Depth (Cm)	Color		Structure[a]	Consistency[b]		Concentrations[c]
		Dry	Moist		Dry	Moist	
Pedon 1							
Az	0-7	10YR 6/4	10YR 4/4	1, m, abk	S	L	FDS, TOT
Bzyy	7-25	10YR 8/2	10YR 6/4	2, m, abk	SH	VFR	m, 3, I, GYM, MAT- FDS, TOT
Bzy	25-60	7.5YR 6/4	7.5YR 4/4	2, m, abk	SH	VFR	m, 2, I, GYX, MAT- FDS, FDC, TOT
Btny	60-85	7.5YR 6/4	7.5YR 4/4	2, m, pr, cpr	MH	FR	c, 3, I, GYX, MAT- c, 2, I, CAM, MAT f, 3, I, CBM, MAT
Btnky	85-115	7.5YR 7/4	7.5YR 5/4	2, m, pr, cpr	VH	VFI	c, 3, I, GYX, MAT- m, 3, I, CAM, MAT f, 3, I, CBM, MAT
Bkz	115-150	7.5YR 7/4	7.5YR 5/4	2, m, pr, cpr	VH	VFI	m, 3, I, CAM, MAT
Ck	150-170	7.5YR 7/4	7.5YR 5/4	Sg	S	L	c, 2, I, CAM, MAT
Pedon 2							
A	0-5	10YR7/4	10YR 4/4	1, m, pl	S	L	FDC, TOT
By1	5-30	10YR 7/3	10YR 5/4	2, m, abk,	EH	SR	m, 4, I, GYX, MAT
By2	30-80	7.5YR 6/4	7.5YR 4/6	2, m, abk	SH	VFR	c, 2, I, GYX, MAT
By3	80-100	7.5YR 6/4	7.5YR 4/6	1, m, abk	SH	VFR	f, 1, I, GYX, MAT
2Btb1	100-115	7.5YR 6/4	7.5YR 4/6	1, m, abk	SH	VFR	f, 2, I, CBM, MAT
2Btb2	115-150	7.5YR 6/4	7.5YR 4/4	1, m, abk	SH	VFR	f, 2, I, CBM, MAT
Pedon 3							
Azyy	0-30	10YR 8/2	10YR 7/6	2, m, abk	SH	VFR	m, 3, I, GYM, MAT
By	30-50	7.5YR7/4	7.5YR 6/6	2, m, abk	MH	FR	c, 1, I, GYX, MAT
2Btyb1	50-70	10YR 8/4	10YR 7/6	3, co, abk	HA	FI	m, 1, I, GYX, MAT- f, 3, I, CBM, MAT
2Btyb2	70-100	7.5YR 8/4	7.5YR 6/6	3, co, abk	MH	FR	m, 1, I, GYX, MAT - f, 3, I, CBM, MAT
2Bkyb	100-128	7.5YR 7/4	7.5YR 6/6	3, m, abk	SH	VFR	f, 1, I, GYX, MAT- c, 2, I, CAM, MAT
2Bwb	128-150	7.5YR 7/4	7.5YR 6/6	3, m, abk	MH	FR	FDG, FDC, TOT
Pedon 4							
Az	0-7	5 YR 5/4	5 YR 4/6	1, m, abk	SH	VFR	FDS, FDC, TOT
Bkz	7-27	2.5YR5/4	2.5YR4/4	2, co, abk	MH	FR	c, 1, I, CAM, MAT- FDS, TOT
Bky1	27-50	5 YR 6/4	5 YR 5/4	1, m, abk	MH	FR	m, 2, PE, GYM, BRF- f, 1, I, CAM, MAT
Bky2	50-72	5 YR 5/4	5 YR 4/6	1, m, abk	MH	FR	c, 1, I, GYX, MAT- f, 1, I, CAM, MAT
Bky3	72-110	5 YR 5/4	5 YR 4/6	1, m, abk	SH	VFR	c, 1, I, GYX, MAT- f, 1, I, CAM, MAT
Bky4	110-150	5 YR 5/4	5 YR 4/6	Sg	S	L	c, 1, I, GYX, MAT- f, 1, I, CAM, MAT
Pedon 5							
Az	0-5	7.5YR 7/4	7.5YR 5/4	2, co, abk	SH	VFR	FDS, TOT
Bzyy	5-25	10YR 8/2	10YR 7/4	2, co, abk	S	L	m, 3, I, GYM, MAT- FDS, TOT
Bzym	25-45	7.5YR 7/4	7.5YR 5/4	m	R	R	FDS, FDG, TOT
R	+45	-	-	-	-	-	-
Pedon 6							
A	0-4	10YR 6/3	10YR 3/4	Sg	S	L	FDS, TOT
Bzyy	4-20	10YR 8/2	10 YR 6/6	2, m, abk	SH	FR	m, 3, I, GYM, ARF- FDS, TOT
Bzm	20-30	10YR 7/3	10YR 4/4	m	EH	SR	m, 4, I, SAX, TOT
Cr	30-135	10YR 7/4	10YR 4/3	Sg	S	L	FDS, TOT
Pedon 7							
Azy	0-35	10YR 8/2	10YR 6/4	2, m, abk	SH	VFR	m, 3, I, GYM, MAT- FDS, TOT
Bzm	35-60	10YR 7/3	10YR 5/4	m	R	R	FDS, FDG, TOT
Bz	60-110	10YR 7/4	10YR 5/4	2, m, abk	MH	FR	FDS, TOT
B´zm	110-115	10YR 7/3	10YR 6/4	m	R	R	FDS, FDG, TOT
B´z	115-140	10YR 6/4	10YR 4/4	2, m, abk	MH	FR	FDS, TOT
Pedon 8							
Azm	0-15	10YR 6/4	10YR 4/4	m	R	R	m, 4, P, SAX, TOT
Bz1	15-50	10YR 6/4	10YR 4/4	2, m, cpr	SH	VFR	FDS, FDC, TOT
Bz2	50-85	10YR 7/4	10YR 4/4	2, m, cpr	SH	VFR	FDS, FDC, TOT
Bz3	85-100	10YR 6/4	10YR 4/3	2, m, cpr	H	FI	FDS, FDC, TOT
Bz4	100-120	10YR 7/4	10YR 4/4	2, m, cpr	VH	VFI	FDS, FDC, TOT
Pedon 9							
Azm	0-10	10YR 8/2	10YR 6/3	m	VR	VR	m, 4, P, SAX, TOH
Bz1	10-50	7.5YR 6/4	7.5YR 4/6	2, m, cpr	H	FI	FDS, FDC, TOT
Bz2	50-75	10YR 6/4	10YR 4/4	Sg	S	L	FDS, FDC, TOT
Bz3	75-105	10YR 7/4	10YR 4/4	2, m, pr	MH	FR	FDS, FDC, TOT
Bz4	105-150	10YR 7/4	10YR 4/4	2, m, cpr	MH	FR	FDS, FDC, TOT
Bz5	150-200	10YR 7/4	10YR 4/4	m	MH	FR	FDS, FDC, TOT

Table 1 Continued. The selected morphological properties of the studied pedons

Horizon	Depth (Cm)	Color		Structure[a]	Consistency[b]		Concentrations[c]
		Dry	Moist		Dry	Moist	
Pedon 10							
Az	0-12	10YR 7/3	10YR 6/4	1, m, abk	S	L	FDS, FDC, TOT
Bzym	12-25	10YR 7/2	10YR 6/4	m	R	R	m, 4, P, SAX, TOT - FDG, TOT
Bzy1	25-40	10YR 8/2	10YR 7/4	1, m, abk	SH	VFR	m, 1, I, GYM, TOT- FDS, FDC, TOT
Bzy2	40-65	7.5YR 6/4	7.5YR 4/6	1, m, abk	SH	VFR	f, 1, I, GYX, TOT- FDS, FDC, TOT
Bz	+65	7.5YR 6/2	7.5YR 5/4	Sg	S	L	FDS, FDG, FDC, TOT
Pedon 11							
Az	0-15	7.5YR 6/4	7.5YR 4/6	2, m, pr, cpr	SH	VFR	FDS, FDC, TOT
Bzm	15-30	7.5YR 7/4	7.5YR 5/4	m	R	R	FDS, FDC, TOT
Bzy1	30-60	10YR 8/2	10YR 7/4	2, m, abk	SH	VFR	m, 3, I, GYM, MAT- FDS, FDC, TOT
Bzy2	60-85	5YR 6/4	5YR 4/4	2, m, pr, cpr	SH	VFR	f, 1, I, GYX, MAT- FDS, FDC, TOT
Btnz1	85-115	5YR 5/4	5YR 4/4	2, m, pr, cpr	MH	FR	f, 2, I, CBM, MAT- FDS, FDC, TOT
Btnz2	115-160	5YR 6/3	5YR 4/4	2, m, pr, cpr	MH	FR	f, 2, I, CBM, MAT- FDS, FDC, TOT
Bz	160-175	5YR 5/3	5YR 3/4	2, m, pr, cpr	SH	VFR	FDS, FDC, TOT
Pedon 12							
Azy	0-35	10YR 7/4	10YR 5/4	2, co, abk	SH	VFR	c, 1, I, GYM, TOT - FDS, FDC, TOT
Bzym	35-90	10YR 8/2	10YR 7/3	m	VR	VR	FDS, FDG, FDC, TOT
C1	90-130	10YR 6/4	10YR 5/4	Sg	L	L	FDS, FDG, FDC, TOT
C2	130-190	10YR 6/4	10YR 5/4	Sg	L	L	FDS, FDG, FDC, TOT

[a] Structure: grade (1 - weak, 2 - moderate, 3 - strong); size (m - medium, co - coarse); type (abk - angular blocky, pl - platy, pr - prismatic, cpr - columnar, sg - single grain, m - massive).

[b] Consistency: dry (L - loose, S - soft, SH - slightly hard, MH - moderately hard, HA - hard, VH- very hard, EH - extremely hard, R- rigid, VR - very rigid); moist (L - loose, VFR - very friable, FR - friable, FI - firm, VFI - very firm, SR - slightly rigid, R - rigid, VR - very rigid).

[c] Concentrations: quantity (f - few, c - common, m - many); size (1 - fine, 2 - medium, 3 - coarse, 4 - very coarse); shape (I - irregular, PE - pendular, P - platy); kind (FDC - finely disseminated carbonates, FDS - finely disseminated salts, FDG - finely disseminated gypsum, CAM- carbonate masses, CBM - clay bodies, GYM- gypsum masses, GYX - gypsum crystals, SAX: salt crystal); location (MAT - in the matrix (not associated with peds/pores), TOT - throughout, TOH - at top of horizon, ARF - around rock fragments, BRF - on bottom of rock fragments).

Various concentration types of calcium carbonate, gypsum, and more soluble salts affected by geomorphic surface and an increase in the aridity rate were observed. The maximum anhydrite content (65.9%) belonged to the rock pediment and the maximum soluble salts (695 dS/m) was observed in the salt crust geomorphic surfaces. The maximum secondary calcium carbonate (48.2%) and gypsum (34.6%) contents were also found in the alluvial fans at the margins of Lut Desert (Table 2). Petrosalic layer was formed in almost all the geomorphic surfaces of the central Lut Desert with a hyper aridic soil moisture regime, yet no evidence of such layer was found at the margins of the desert. Salic, gypsic, calcic, and natric horizons were observed in pedon 1 with aridic soil moisture regime.

Table 2. The selected physical and chemical properties of the studied pedons

Horizon	Depth (Cm)	ECe[a] (dS/m)	pH	OC (%)	Cl meq/L	CEC[b] (cmol_c /kg)	CCE[c]	Gy[d]	An[e]	SAR[f] $(\text{meq/L})^{0.5}$	Sand	Clay	CF[g]	Texture[h]
							Unit (%)				Unit (%)			
Pedon 1														
Az	0-7	332.0	7.1	0.2	3220	12	13.7	2	ng[i]	438.9	61	21	5	SL
Bzyy	7-25	77.2	7.5	0.2	850	11	10.0	0.49	52.5	150.5	32	21	5	L
Bzy	25-60	289.0	7.9	0.2	2150	9	8.0	29.3	ng	825.6	73	13	8	SL
Btny	60-85	287.2	7.9	0.2	2240	17	11.5	8.1	ng	795.3	69	19	4	SL
Btnky	85-115	86.7	8.1	0.2	890	28	16.0	8.6	ng	230.2	51	24	5	SCL
Bkz	115-150	166.0	7.7	0.3	1420	27	15.0	ng	ng	349.1	51	21	10	SCL
Ck	150-170	209.0	7.7	0.3	1700	20	15.0	ng	ng	446.1	60	19	15	SL
Pedon 2														
A	0-5	15.3	7.4	0.2	144	16	13.0	ng	ng	4.05	55	17	30	SL
By1	5-30	3.9	7.6	0.2	12.8	15	7.0	34.6	ng	5.5	83	10	20	LS
By2	30-80	21.7	7.8	0.2	200	19	9.0	15.5	ng	55.7	75	12	15	SL
By3	80-100	27.3	7.9	0.1	314	20	7.5	9.0	ng	91.9	71	14	50	SL
2Btb1	100-115	23.8	8.2	0.1	232	27	7.5	0.7	ng	88.7	78	18	35	SL
2Btb2	115-150	13.3	8.1	0.1	110	30	8.0	2.2	ng	60.3	72	19	45	SL

Table 2 Continued. The selected physical and chemical properties of the studied pedons

Horizon	Depth (Cm)	ECe[a] (dS/m)	pH	OC (%)	Cl meq/L	CEC[b] (cmol$_c$ /kg)	CCE[c]	Gy[d]	An[e]	SAR[f] (meq/L)$^{0.5}$	Sand	Clay	CF[g]	Texture[h]
							Unit (%)				Unit (%)			
Pedon 3														
Azyy	0-30	38.6	7.7	0.6	310	10	11.7	0.64	51.3	71.3	70	15	8	SL
By	30-50	36.6	7.7	0.3	290	14	14.0	14.5	ng	62.9	78	10	15	SL
2Btyb1	50-70	25.1	7.8	0.1	170	17	11.5	14.3	ng	42.3	56	18	15	SL
2Btyb2	70-100	4.9	7.9	0.1	25	29	11.5	14.0	ng	9.3	58	18	10	SL
2Bkyb	100-128	9.0	7.7	0.1	54	12	15.0	10.5	ng	20.5	80	9	15	LS
2Bwb	128-150	3.5	7.7	0.03	17	15	4.0	4.3	ng	7.5	78	11	5	SL
Pedon 4														
Az	0-7	90.1	7.4	0.3	920	9	37.5	ng	ng	152.6	65	22	5	SCL
Bkz	7-27	74.1	7.8	0.1	750	10	38.5	ng	ng	183.7	67	20	15	SCL
Bky1	27-50	27.2	7.9	0.1	310	10	32.2	1.27	21.6	140.2	68	12	47	SL
Bky2	50-72	19.6	7.8	0.1	230	6	47.7	22.2	ng	37.5	75	11	45	SL
Bky3	72-110	20.5	7.6	0.04	210	7	40.2	8.6	ng	44.3	75	12	45	SL
Bky4	110-150	10.07	7.6	0.04	90	7	48.2	5.0	ng	22.3	77	13	50	SL
Pedon 5														
Az	0-5	66.47	7.5	0.1	940	14	6.4	1.05	ng	149.4	60	29	ng	SCL
Bzyy	5-25	194	7.5	0.11	1930	10	5.5	0.66	55.8	450.8	67	15	ng	SL
Bzym	25-45	495	7.4	ng	6680	6	9.5	12	ng	1494.9	60	14	ng	SL
R	+45	-	-	-	-	-	-	-	-	-	-	-	-	-
Pedon 6														
A	0-4	18.2	7.7	0.2	180	4	8.2	ng	ng	33.7	86	8	30	LS
Bzyy	4-20	32.0	7.5	0.1	460	9	5.0	0.57	65.9	65.2	73	17	40	SL
Bzm	20-30	593.0	7.1	ng	5620	5	1.5	ng	ng	1189.4	66	13	-	SL
Cr	30-135	11.4	8.3	0.1	160	-	3.5	ng	ng	77.7	-	-	90	-
Pedon 7														
Azy	0-35	150.1	7.7	ng	640	6	10.5	1.76	46.1	626.9	63	20	5	SL
Bzm	35-60	601.0	7.5	ng	4920	4	6.5	2.6	ng	1188.5	77	11	-	SL
Bz	60-110	183.3	8.1	0.2	1380	8	7.2	ng	ng	490.3	77	9	30	SL
B´zm	110-115	410.0	7.6	0.2	3860	6	12.2	8.2	ng	949.6	66	10	-	SL
B´z	115-140	32.7	8.5	0.1	310	7	10.5	ng	ng	76.6	78	9	10	LS
Pedon 8														
Azm	0-15	577.5	7.2	ng	5100	3	10.5	1.5	ng	516.3	-	-	ng	-
Bz1	15-50	330.5	7.6	0.4	2620	5	16.5	2.4	ng	526.5	31	17	ng	SIL
Bz2	50-85	318.0	7.6	0.2	2500	6	17.5	4.2	ng	557.2	41	15	ng	L
Bz3	85-100	204.2	7.9	0.2	1920	6	19.5	2.5	ng	354.8	25	11	ng	SIL
Bz4	100-120	367.0	7.9	0.8	3800	14	19.2	1.7	ng	697.9	3	44	ng	SICL
Pedon 9														
Azm	0-10	695	7.1	ng	5680	-	6.0	ng	ng	1051.6	-	-	ng	-
Bz1	10-50	282	7.5	0.5	2900	8	19.7	2.5	ng	295.0	37	26	ng	L
Bz2	50-75	95.1	8.0	0.1	800	4	16.5	1.0	ng	157.3	90	3	ng	S
Bz3	75-105	275.5	7.9	0.5	2140	10	18.0	2.2	ng	267.7	19	27	ng	SIL
Bz4	105-150	301	7.9	0.3	1980	6	20.2	2.5	ng	200.7	33	11	ng	SIL
Bz5	150-200	491	7.6	0.7	3220	11	23.0	ng	ng	565.8	6	23	ng	SIL
Pedon 10														
Az	0-12	443	7.3	0.2	3100	4	18.5	7.0	ng	411.0	83	8	ng	LS
Bzym	12-25	590	7.1	ng	5680	4	5.7	10.1	ng	912.6	64	17	ng	SL
Bzy1	25-40	81.1	8.0	0.08	580	12	15.5	1.04	23.9	148.0	61	15	ng	SL
Bzy2	40-65	86.4	8.0	0.08	880	8	19.0	11.8	ng	228.6	77	15	ng	SL
Bz	+65	61.3	8.1	0.08	470	5	27.0	ng	ng	127.8	87	9	ng	LS
Pedon 11														
Az	0-15	142.2	7.5	0.10	1560	4	27.0	ng	ng	262.6	78	14	ng	SL
Bzm	15-30	551.0	7.4	0.00	5240	3	15.5	ng	ng	1485.0	61	19	ng	SL
Bzy1	30-60	47.0	8.2	0.00	580	8	15.0	0.01	31.9	108.6	70	9	ng	SL
Bzy2	60-85	42.3	7.9	0.20	510	6	21.7	5.0	ng	102.0	65	9	ng	SL
Btnz1	85-115	58.0	7.8	0.20	740	11	24.7	ng	ng	189.7	31	26	ng	L
Btnz2	115-160	45.3	7.9	0.20	560	10	24.7	ng	ng	147.7	42	24	ng	L
Bz	160-175	30.0	8.1	0.10	380	7	25.0	ng	ng	159.9	64	13	ng	SL

Table 2 Continued. The selected physical and chemical properties of the studied pedons

Horizon	Depth (Cm)	ECe[a] (dS/m)	pH	OC (%)	Cl meq/L	CEC[b] (cmol$_c$ /kg)	CCE[c]	Gy[d]	An[e]	SAR[f] (meq/L)$^{0.5}$	Sand	Clay	CF[g]	Texture[h]
							Unit (%)				Unit (%)			
Pedon 12														
Azy	0-35	249.0	7.5	0.21	1144	7	30.2	5.4	18.8	280.7	60	14	37	SL
Bzym	35-90	631.5	7.7	0.00	5540	2	15.5	12.2	ng	1227.4	74	11	40	SL
C1	90-130	232.2	8.2	0.17	1640	6	34.7	8.5	ng	442.0	76	9	60	SL
C2	130-190	152.2	8.1	0.19	1600	7	35.7	2.8	ng	368.9	74	10	69	SL

Notes: [a]ECe: electrical conductivity of soil saturated extract; [b]CEC: cation exchange capacity; [c]CCE: calcium carbonate equivalent; [d]Gy: gypsum; [e]An: anhydrite; [f]SAR: sodium adsorption ratio; [g]CF: coarse fragment; [i]ng: negligible;

[h] Texture: SL - sandy loam; L: loam; SCL: sandy clay loam; LS: loamy sand; S: sand; SIL: silt loam; SICL: silty clay.

Comparison of the ST and WRB systems in pedon 1 revealed that non of the two systems could properly show what is really observed in the field. This soil was classified as Haplosalids and Solonetz in the ST and WRB systems, respectively. The preference of Salids compared to Argids in the ST and Solonetz compared to Solonchak in WRB clearly showed the different significance of salic and natric horizons in the two systems, which has also been reflected in the classification of the same soil. The presence of a natric horizon in the depth of 100 cm from the soil surface was focused on in Solonetz reference group. However, the natric horizon has totally been neglected in Salids of the ST classification system. The capability of simultaneously considering salic, gypsic, calcic, and natric horizons is among the merits of WRB system. On the other hand, Haplosalids and Aquisalids, as the only two great groups introduced by the ST, are not capable enough of showing the properties of saline soils, which could be accounted as a weak point for this system compared to the WRB. The presence of gypsic, calcic, natric, argillic (argic), and anhydritic horizons in soils of arid regions has been demonstrated in several pieces of research (Esfandiarpour Boroujeni *et al*., 2011; Wilson *et al*., 2013; Voigt *et al*., 2020). Addition of Argisalids, Natrisalids, and Gypsisalids great groups, as well as Anhydritic Argisalids, Anhydritic Natrisalids, and Anhydritic gypsisalids subgroups, to the ST system seemingly improves the capability of this system to show the current soil forming processes occurring in these soils, which were suggested in the present research.

While gypsum is the only sulfate mineral known as gypsic horizon in WRB system, the white powder of anhydrite evaporite is not totally considered as a mineral in this system. Since the presence and amount of anhydrite in soils of arid regions are of great importance, the lack of anhydritic horizon in WRB seems to be a weak point for this system compared to Soil Taxonomy. Soil Taxonomy has introduced an anhydritic horizon and paid attention to the correlation between anhydritic and salic horizons. Anhydritic subgroups and mineralogy class at the family level have been also introduced by Soil Taxonomy (2014) system. The increased aridity and salinity gradient toward Lut Desert has increased the percentage of soil anhydrite, which has in turn rose hollowness of soils enriched by this mineral and increased erodibility potential in these soils, as also supported by Ekhtesasi *et al*. (2003) in Yazd Province, Central Iran.

It is noteworthy that the color requirements of the ST system for anhydritic horizon were not met in the soils of Lut Desert (Table 1). This could be attributed to the red detrital sedimentations of Tertiary followed by the orogenic activities of late Cretaceous to Miocene which divided Tethys Sea into several individual lakes (Krinsley, 1970; Aghanabati, 2004). There were considerable amounts of anhydrite in the soils of the research area. Due to the lack of color requrement (Hue) for anhydritic horizon, the use of anhydritic subgroups in soils and sediments located in this area is not possible. Therefore, it could be suggested that the Hue be adopted or the color be removed from the necessary requirements of this horizon in the areas with colored parent material so that anhydritic subgroups could be used in such soils enriched by anhydrite. Meanwhile, the location of anhydrite accumulated layer out of the mineralogy control section caused this mineral not to be covered at the family level. Since anhydrite concentrations in arid and hyper-arid environments are dominant on one hand, and mineralogy class identification helps describing soil behavior against management on the other hand, addition of the anhydritic class to all the control sections of mineralogy class could be suggested.

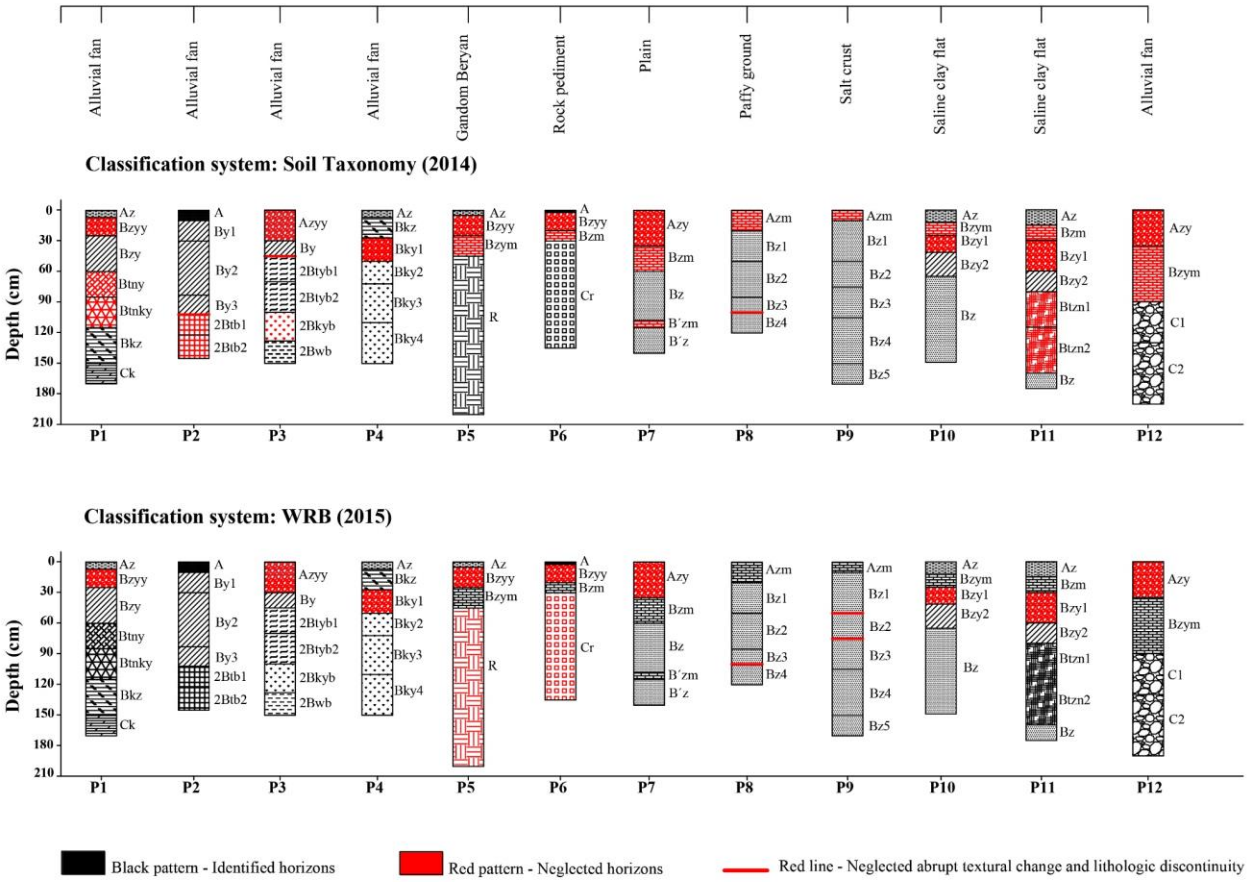

Figure 2. Schematic presentation of the diagnostic horizons in the representative pedons along the landforms under study

Additionally, anhydrite subgroup is suggested to be added to the ST system; the reason is that if anhydritic horizon is the only diagnostic horizon in the pedon, the present classification of soil would be Typic Haplocambids (as of pedon 6) and the presence of this horizon would not be considered at all. Moreover, "a" and/or "aa" suffixes for anhydritic horizon nomenclature and ANM symbol are recommended for anhydrite accumulation to be added to the guideline of NRCS (Schoeneberger *et al*., 2012). These were initially suggested by Sarmast *et al*. (2016), but were also emphasized by the findings of the present research in Lut Desert.

Pedon 2, on the alluvial fan at the margins of the central Lut Desert, is a developed soil buried by Quaternary sediments. For note, the maximum soil development for the classification of buried soils is the formation of a cambic horizon in the upper soil. Since gypsic horizon in the upper part of this pedon is formed, the pedon could be considered as a paleosol. Both classification systems try to reveal the past and present pedogenic processes in soils. Classification of both the upper modern soil and the buried soil is of great importance to describe and interpret the soil forming processes in polygenetic soils with argilluviation and salinization processes. Using the "over" between the buried and the upper soils, the WRB system has the capability of classifying the buried soils in detail. This could be taken into account as an advantage for the WRB compared to the ST system; the reason is that it increases the capability of the WRB system for soil survey and separating soils into homogeneous units.

It is to be noted that argillic horizon in pedon 2 is located in the depth of more than 100 cm; that is why the presence of this horizon was not included in the classification of this pedon.

Furthermore, surface characteristics of soils, including desert varnish (pedon 2), are specifically focused on by WRB system compared to ST. Formation of desert varnish, as a unique geochemical property in surface soils of arid areas, is shown by the "yermic" qualifier in WRB system, which could be considered as another strong point for this classification system compared to the ST.

Different definitions of salic diagnostic horizon in the two systems led to non-harmonization of the two systems in pedon 3. The thickness of > 15 cm and the EC > 30 dS/m, in addition to the EC multiplied by thickness of > 900, are required for salic horizon in ST system, which were not existed in pedon 3. That is why this soil was not classified as Salids. On the other hand, the minimum EC content of >15 dS/m and the EC multiplied by thickness of > 450 in WRB system allowed us to classify the soils of pedon 3 as a Solonchak. The difference in definition of some diagnostic horizons in the two classification systems was also demonstrated by Dekers *et al*. (2003) as a reason behind the low correlation observed between the systems. It is to be noted that the lack of anhydritic horizon in WRB seems to be a weak point for this system. The color requirements for anhydritic horizon in this pedon, similar to pedon 1, were not existed (Table 1). Meanwhile, since dissolution and re-precipitation of gypsum (affected by high salt concentration) are probable origins of anhydrite in arid regions (Voigt *et al*., 2020), addition of the Anhydritic subgroup to great groups of Gypsids may increase the capability of Soil Taxonomy in describing soil properties. Similar to pedon 1, the location of the major part of the anhydrite enriched layer out of the mineralogy control section of this pedon prohibited anhydrite to be investigated at the family level.

Moreover, pedon 3, similar to pedon 2, is a paleosol. Argillic horizon in pedon 3 is located at a depth less than 100 cm; that is why argillic horizon together with gypsic horizon was included in the classification with the ST system. However, using different qualifiers and further flexibility in reflecting soil characteristics, the WRB system seems to be more efficient to classify paleosoils compared to the ST system.

Pedogenic powdery pockets of carbonates were observed in the calcic horizon of pedon 4; however, calcic horizon formation in the Taxonomy nomenclature of this soil is neglected due to the lack of enough great groups in Salids. Using carbonatic mineralogy class, Soil Taxonomy has to an extent compensated this weak point in the upper categories. Nonetheless, calcic horizon with at least 15% calcium carbonate content could not yet be investigated in saline soils similar to that of pedon 1.

Since natric and gypsic horizons are dominant in arid regions, Natrisalids and Gypsisalids great groups are suggested to be added to Salids. Moreover, Calcic Natrisalids and Calcic Gypsisalids subgroups are also suggested for the same reason. However, not only is calcic horizon in WRB system reflected but also the addition of Panto specifier shows the presence of calcium carbonate throughout the pedon. In addition, the role of increased salt concentration in the determination of dominant sulfate mineral in pedon 4 was clearly observed. Sulfate mineral concentrations, as anhydrite powdery accumulations, were investigated in the upper soil horizons with increased salinity. However, the decrease in salinity in lower depths, contributed to the formation of gypsum crystals. This clearly shows the correlation between salic and anhydritic horizons mentioned in ST system. All these findings proved that the addition of anhydritic qualifier in the reference soil groups with high salt accumulations dominant in arid areas, including Solonchaks, Solonetz, Calcisols, and Gypsisols, may sharply increase the capability of WRB system.

Table 3. Classification of the studied pedons based on Soil Taxonomy (2014) and WRB (2015) systems

Climate Regimes	Pedons	Classification system	
		Soil Taxonomy (2014)	WRB (2015)
At-Th	1	Fine-silty, Mixed, Superactive, Thermic Gypsic Haplosalids	Endohypocalcic Epihypergypsic Pantohypersalic Solonetz (Endocutanic, Pantoloamic, Hypernatric, Ochric)
	2	Coarse-loamy, Gypsic, Thermic Leptic Haplogypsids	Endoskeletic Gypsisols (Epiarenic, Katohypogypsic, Katoloamic, Ochric, Katosodic, Yermic) over Skeletic Luvisols (Cutanic, Loamic, Raptic, Sodic)
	3	Fine-silty, Mixed, Superactive, Thermic Typic Argigypsids	Epihypergypsic Sodic Solonchaks (Calcaric, Epichloridric, Epiloamic, Ochric, Epihypersalic) over Luvic Calcic Gypsisols (Hypogypsic, Loamic, Raptic, Sodic)
	4	Loamy-skeletal, Carbonatic, Thermic Gypsic Haplosalids	Katocalcic Katohypogypsic Solonchaks (Epichloridic, Pantoloamic, Ochric, Epihypersalic, Katoskeletic)
Ae-Ht	5	Loamy, Mixed, Active, Hyperthermic, Shallow Typic Haplosalids	Epihypergypsic Sodic Epipetrosalic Solonchaks (Aridic, Calcaric, Chloridic, Epidensic, Loamic, Hypersalic)
	6	Loamy, Mixed, Semiactive, Hyperthermic, Shallow Typic Haplocambids	Epihypergypsic Sodic Epipetrosalic Solonchaks (Aridic, Chloridic, Densic, Epiloamic, Hypersalic)
	7	Coarse-loamy, Mixed, Active, Hyperthermic Typic Haplosalids	Epigypsic Pantosodic Amphipetrosalic Solonchaks (Aridic, Chloridic, Densic, Pantoloamic, Pantohypersalic)
	8	Coarse-silty, Mixed, Semiactive, Hyperthermic Typic Aquisalids	Pantosodic Epipetrosalic Solonchaks (Pantocalcaric, Chloridic, Katoloamic, Puffic, Pantohypersalic)
	9	Loamy over sandy aniso, Mixed, Semiactive, Hyperthermic Typic Aquisalids	Pantosodic Epipetrosalic Solonchaks (Pantocalcaric, Chloridic, Densic, Evapocrustic, Epiloamic, Pantohypersalic)
	10	Coarse-silty, Mixed, Superactive, Hyperthermic Gypsic Haplosalids	Amphigypsic, Pantosodic Epipetrosalic Solonchaks (Pantocalcaric, Chloridic, Amphiloamic, Pantohypersalic)
	11	Fine-silty, Mixed, Active, Hyperthermic Gypsic Haplosalids	Amphigypsic Pantohypersalic Solonetz (Cutanic, Pantoloamic, Hypernatric, Ochric)
	12	Loamy-skeletal, Mixed, Semiactive, Hyperthermic Typic Haplosalids	Epigypsic Pantosodic Amphipetrosalic Solonchaks (Calcaric, Chloridic, Densic, Pantoloamic, Ochric, Pantohypersalic, Katoskeletic)

Salic, petrosalic, petrogypsic, and natric soil horizons were found in pedons 5 to 12 in the central Lut Desert with extreme aridic/hyperthermic soil moisture/temperature regimes. The interaction of high temperature and continuous hyper-arid conditions in pedons 5 to 7 and 12 was found to have increased salt concentration and soluble ions accumulation (mainly Na and Cl), which in turn trigger the formation of petrosalic layer. Petrosalic, as a diagnostic horizon, is not defined in Soil Taxonomy system. To show the depth limitation originated from salt concentrations and to emphasize the pedogenic processes dominant in hyper-arid regions, the addition of petrosalic, as a diagnostic horizon (with a minimum thickness of 10 cm cemented by salts more soluble than gypsum and with lateral continuity that only permits roots to pass through the vertical fissures with at least 10 cm horizontal distance), to Soil Taxonomy could be suggested. This was also suggested by Finstad *et al*. (2014) in the Atacama Desert.

For note, petrosalic qualifier was added to the second edition of WRB. Furthermore, Epi, Endo, and Amphi specifiers were found to show the location of this cemented layer in the pedon. The scarce formation of petrosalic and its un-stability (dissolution of the layer after floating in water) was stated by Finstad *et al*. (2014) as the probable reasons why Soil Taxonomy system does not define petrosalic as a diagnostic horizon. However, petrosalic horizon was reported in several pieces of research, including the papers studying Atacama (Ewing *et al*., 2006), Negev (Amit and Yaalon, 1996), Libian (Aref *et al*., 2002), and Arabian (Goodall *et al*., 2000) deserts with hyper-arid conditions. Meanwhile, due to the change of requirements in the definition of petrogypsic horizon (at least 0.5 cm thick and 40% gypsum with or without other cementing agents) from the 11th edition of Soil Taxonomy, pedons 6 and 12 with 12% gypsum could not be considered to have petrogypsic horizon. The definition presented by WRB system (10 cm thick and 5% gypsum with or without other cementing agents) could however better show the reality of the field since both pedons 6 and 12 would have petrogypsic and petrosalic diagnostic horizons simultaneously. The definition of petrogypsic horizon in previous versions of Soil Taxonomy could be better harmonized with WRB and could also better show the reality of the field. At the same time, Petrosalids great group and Petrogypsic Petrosalids subgroup are suggested to be added to the present version of Soil Taxonomy for better harmonization with WRB and management purposes.

On the other hand, despite the significant amounts of anhydrite mineral in pedens 5 to 7 and 12, the anhydritic horizon was not specified at upper levels of the ST system due to the lack of the color requirements (Hue). The anhydrite mineral was not specified at the family level as well. The reason was that the ST system does not consider the petrosalic limiting layer at a depth of less than 36 cm in these pedons. This caused the horizons containing anhydrite accumulations to be outside the control section. Furthermore, the anhydritic horizon is neglected in WRB. This reveals that both systems seem non-efficient in the management of desert soils.

Continuous lithic (R) and paralithic (Cr) layers in pedons 5 and 6 were investigated as shallow soil depth class of family level in Soil Taxonomy system. However, no qualifier is defined for Solonchak reference group to emphasize shallow depth soils, which seems to be a weak point for WRB system to describe these soils. That is why the addition of Leptic and Paralithic qualifiers to Solonchak reference group seems necessary. It is also to be noted that paralithic materials are totally neglected in WRB system, which seems to be a weak point.

Nevertheless, aridic diagnostic property in WRB, which shows evidence of wind erosion, is a strong point for this classification system. Aridic qualifier was used for pedons 5 to 7 in the central Lut Desert. Soil evolution in these pedons was highly affected by wind processes. An extent area covered by Kaluts and sand dunes proved the importance of wind activity, which could also be focused on by the soil name in WRB system as a strong point. Saline soils of arid and hyper-arid areas suffer from scarce vegetation cover, which is why these soils are potentially under wind erosion. Considering the qualifiers showing wind erosion evidence is therefore invaluable to identify and classify these erodible soils. This in turn, is of high importance in performing projects dealing with desertification combat and soil conservation practices from the soil management point of view. Therefore, addition of topsoil characteristics class at the family level for soils of desert areas (with scarce vegetation, flat topography, lack of surface roughness, soil hollowness increased by anhydrite concentrations, aeolian and wind erosion processes) seems to be important and necessary from the sustainable soil management and environmental points of view.

Playa is among the landforms of desert areas. Pedons 8 to 11 were located on puffy ground saline clay flat (pedon 8), salt crust (pedon 9), and saline clay flat without puffy ground (pedons 10 and 11) geomorphic surfaces. A saline shallow depth water table was found in salt crust and saline puffy ground clay flat surfaces, which were located at the lowest hydrography position of the study area. This has in turn caused an aquic condition in one or more layer(s) of the soil for one or more month(s) during normal years. Aquisalids introduced by Soil Taxonomy system may accordingly show the internal properties of such soils. In addition to gleyic and stagnic qualifiers, WRB system also tries to show the reducing conditions in Solonchaks reference group, but color patterns related to these conditions are missed in the definition. That is why Aquatic qualifier is suggested for the reference groups found in playa, including Solonchaks and Solonetz.

The Puffic and Evapocrustic qualifiers in the WRB system are among the strong points of this system, which show the surface soil properties in playa. Formation of petrosalic layer in the surface of soils in pedons 8 and 9 is considerable, which was caused by a water table close to the surface evaporated in the hyper aridic soil moisture regime in the area. Salt crusts in desert areas play an important role in increasing the stability of soil against wind erosion and are helpful in desertification combat projects. Thus, the Epipetrosalic Aquisalids subgroup could be suggested to the Soil Taxonomy to facilitate the identification of soils for management and environmental conservation projects.

The presence of different particle size classes, such as layers of clay mixed with silt, calcareous material, and gypsum-sand material, is among the most dominant features observed in the central parts and low lying areas of Lut Desert as was also elucidated by Krinsley (1970). Pedon 9 on salt crust geomorphic surface clearly showed the above-mentioned feature. Description of soils with strongly contrasting textural classes is a great goal for soil scientists and geomorphologists (Philip, 2007). The reason is that it is conducive to a better understanding of soil development in different areas. Although elluviation and illuviation are dominant processes in formation of soils with strongly contrasting textures (Esfandiarpour Boroujeni *et al.*, 2018b), other processes, including erosion and sedimentation, biological mixing, and textural differences caused by different parent materials, have been also reported by several researchers (Philips, 2007, Bockheim, 2016). Study of soils in North Carolina, Phillips (2007), proved erosion and sedimentation processes controlling formation of soils with contrasting textures. Even though abruptic, alb, and pale prefixes in the selected great groups and subgroups of Soil Taxonomy already existed, the prefixes are only applicable if the changes are pedogenic and between elluvial and illuvial (argillic, glosic, kandic, and natric) horizons. On the other hand, other factors (as mentioned above) could also affect abrupt textural changes in the soil. Using strongly contrasting particle size class, Soil Taxonomy could efficiently show the previously mentioned other factors influencing abrupt textural changes in compensating the weak point.

Soil Taxonomy system explains that if two parts with strongly contrasting particle size classes or their substitutes are presented in the particle size control section and each part is at least 12.5 cm thick and the transition between the parts is less than 12.5 cm, the name of both classes should be used in the particle size class of the family level. If there are more than one pair of strongly contrasting classes, the aniso prefix is used (Soil Survey Staff, 2014). Accordingly, the textural difference at the salt crust geomorphic surface (pedon 9) was found as Loamy over sandy, aniso. Therefore, considering the layers with strongly contrasting textures in the central Lut Desert and the morphological evidence in the soils, Soil Taxonomy system was capable of showing the role of erosion and sedimentation processes in soil development in the area.

It is noteworthy that if the abrupt textural change is located outside the control section, the strongly contrasting textured layers would be neglected (as of pedon 8). On the other hand, the abrupt textural difference in the WRB system is shown by abruptic qualifier regardless of its pedogenic and/or non-pedogenic origin. At the same time, the lack of abruptic qualifier in Solonchak reference group has clearly decreased the capability of the classification system to describe the affecting factors experienced in the area. At the same time, addition of abruptic prefix in the Solonchak reference group of WRB is also suggested.

Petrosalic, salic, gypsic, and natric horizons were found in pedons 10 and 11 on the saline clay flat. Pedon 11 was classified as Haplosalids and Solonetz by Soil Taxonomy and WRB systems, respectively. Different viewpoints of the two systems in the order of the importance of salic and natric horizons in classifying soils could clearly be emphasized in pedon 11. Petrosalic and natric horizons are totally neglected in the classification by Soil Taxonomy system. That is why Natric Petrosalids is suggested to be categorized in Salids subgroups. Natric prefix is also suggested for Haplosalids and Aquisalids to make subgroups. Anhydrite evaporitic mineral formation was not focused on neither at the subgroup (due to the lack of color requirements) nor at the family levels of Soil Taxonomy system in the pedons 10 and 11 on saline clay flat geomorphic surface. At the first glance, not focusing on the anhydrite mineral in the mineralogy class of the family level may not seem considerable, but gypsiferous-salty limiting layer formation at shallow depths is a common property of soils in hyper-arid climates, which reduces the depth of the control section down to the limiting layer. Therefore, considering only the upper parts of the limiting layer at family level can not cover the weak points of the higher taxa of Soil Taxonomy system in desertous areas. Anhydrite concentrations at the upper and/or lower parts of petrosalic layer in Sabkha coasts (Wilson, 2013) and Atacama Desert (Finstad *et al*., 2016) were also reported. Hence, identifying the location of anhydrite concentrations could shed light on the interpretations of ecological processes in the area. This is the reason why anhydritic mineralogy class for all the control sections of mineralogy class could efficiently increase the capability of Soil Taxonomy system in desert areas. However, the lack of anhydritic horizon is believed to be a weak point for WRB system to classify pedons 10 and 11.

Conclusions

Soil Taxonomy and WRB, as the two most popular classification systems, try to cover as many soil characteristics as possible. The capability of the two systems in desert areas with warm and arid climate was studied in the present research. The highlighted conclusions are as following:

1. Soil Taxonomy has only two Aquisalids and Haplosalids great groups, which seems to be a weak point for this system to classify soils of desert areas and it may not properly show the soil forming processes involved in these areas. To increase the capability of Soil Taxonomy system in desert areas, the Gypsisalids, Argisalids, Natrisalids, and Petrosalids great groups and Anhydritic Natrisalids, Anhydritic Argisalids, Anhydritic Gypsisalids, Anhydritic Petrosalids, Calcic Natrisalids, Calcic Argisalids, Calcic Gypsisalids, Natric Petrosalids, Natric Haplosalids, Natric Gypsisalids, Petrogypsic Petrosalids, and Epipetrosalic Aquisalids subgroups could be suggested to be added to this classification system.

2. The presence of anhydritic diagnostic horizon in Soil Taxonomy helps this system to more efficiently classify soils with sulfate evaporitic minerals compared to WRB; meanwhile, it could be suggested that the color requirements be removed from the definition of anhydritic horizon or Hue requirements be adopted.
3. The lack of petrosalic, as a horizon with limiting layer characteristics, caused the anhydrite accumulations to be outside the control section in ST system. It also caused the anhydritic mineralogy class not to be determined in this system.
4. The anhydritic qualifiers suggested to be added to Solonchaks, Solonetz, and Gypsisols. The aquatic qualifier is recommended to be added to Solonchaks and Solonetz. The Abruptic, Leptic, and Paralithic qualifiers are also suggested to be added to the list of qualifiers for Solonchaks reference soil groups of the WRB system.
5. The presence of petrosalic qualifier and Epi, Endo, and Amphi prefixes may efficiently represent the location of petrosalic layer in the pedon, which highly increases the capability of WRB system to interpret soil properties in warm and arid areas. However, petrosalic diagnostic horizon is totally neglected in Soil Taxonomy system.
6. Soil survey and mapping natural bodies in classes with similar properties and behaviours to rapidly reach soil data are among the objectives of soil classification systems. Considering paleosols in the landscape also seems to be necessary. WRB system focuses on the buried soils and using "over", separates the modern and buried soils and efficiently classifies the buried soil.
7. The difference in the definition of salic and petrogypsic horizons in the two classification systems was among the reasons behind the mismatch of the two systems.
8. Definition of anhydritic mineralogy class helps interpretation of ecological processes in desert environments. Moreover, addition of topsoil characteristics class at the family level was suggested for sustainable management and the environmental points of view in desert areas.
9. Using Yermic, Aridic, Puffic, and Evapocrustic qualifiers, WRB system could clearly show the surface characteristics of soils in Lut Desert.
10. Strongly contrasting particle size classes of Soil Taxonomy system and the use of aniso prefix are the strong points of this system, which is capable of showing the erosion and sedimentation processes in development of soils in an area.
11. The hyper aridic moisture regime with the P/PET ratio of 0.05, which has been found in warm and arid deserts, could be suggested to be added to Soil Taxonomy system.
12. The results of the research clearly implied that both Soil Taxonomy and WRB systems have their own strong and weak points. However, using different qualifiers, WRB system could show the reality of the field more efficiently. On the other hand, the two systems are still not only complimentary, but also necessary.

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