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Full Length Research Paper

Soil classification and micromorphology: A case study of Cholistan Desert

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Cholistan Desert is an extension of the Great Indian Desert and covering an area of 26,330 km^2. The desert can be divided into two main geomorphic regions: Northern region, known as Lesser Cholistan, constitutes the desert margin and consists of a series of saline alluvial flats alternating with low sand ridges/dunes; and Southern region, known as Greater Cholistan, a wind resorted sandy desert comprising of a number of old Hakra River terraces with various forms of sand ridges and inter-ridge valleys. Cholistan Desert presents quite a complex pattern of alluvial and aeolian depositions. The westerly drifting of the river combined with the lowering of the base level of erosion caused the formation of a number of terraces, which represent different depositional stages. Soil morphology is the field observable attributes of the soil within the various soil horizons and the description of the kind and arrangement of the horizons.

Key words: Cholistan, Hakra River, sand ridges, sediments, soil horizon, soil morphology

INTRODUCTION

Cholistan Desert lies within the Southeast quadrant of Punjab Province, placed between 27° 42' and 29° 45' North latitude and 69° 52' and 73° 05' East longitude (Ahmad, 2002; 2006; 2008; 2010). The word 'Cholistan' is possible derived from a Turkish word, 'Chol', which means a desert (Figure 1); while some historians believe the name has been distorted from Iraqi (Kurdish) word, 'Chilistan' meaning waterless waste land (Ahmad et al., 1992; FAO/ADB, 1993; Auj, 1995; Ahmad, 1999; 1999a, 2005; Ahmad et al., 2005). Cholistan is popularly known as *'Rohi'*. In a dialect still spoken in some parts of Tibet, '*roh'* means a hill, from which the name *Rohilla* has been attributed. In fact, *Rohi* has been derived from the Pushto word *'roh'*, meaning a sandy desert. The man from *Rohi* is called *Rohilla* (Auj, 1987; 1991). However, a reference has been made in Geography of Sindh, that the word Cholistan has been derived from the 'Seraiki' word *'Wacholo'* meaning 'in between'. Since this desert is situated between the Thar and Rajasthan deserts, it was called *'Wacholo'*, which later became *'Cholo'* and then Cholistan. This appears to be a more probable explanation for the origin of the word (Khan, 1992; Ahmad, 2002).

Around 4000 BC, Cholistan was a cradle of civilization commonly known as Hakra valley civilization, when Hakra River flowed through the region. The river supplied water until 1200 BC and about 600 BC it became irregular in flow and consequently vanished (Auj, 1987). Cholistan forms a part of the vast Indo-Gangetic Plain lying in a great tectonic trough, which lies between the foothills of the Himalayan Mountains and the central core of South-Asia. This trough was subsequently filled up with the thick mass of alluvium derived from the Himalayan and deposited by the Indo-Gangetic system. This was later transformed into a vast plain (FAO/ADB, 1993).

RESEARCH DESIGN AND METHODS

The work involves investigation on both constructional and depositional aspects of the archaeological record and the micro-environmental conditions. It is often possible to relate a soil type to a particular ecological niche in the landscape (Retallack, 1994; Buol et al., 2003). Soils and their properties is the product of different soil-forming factors (Jenny, 1941) and the parent material. As soil-forming factors also govern geomorphic processes, landscape evolution is intimately related to soil development (McFadden and Kneupfer, 1990; Kapur and Stoops, 2008; Kapur et al., 2011). Soil samples from surface to 150 cm depth were collected at different locations from Cholistan desert and were subsequently analyzed. The methods included both fieldwork and laboratory analysis. Field survey was conducted with the collaboration of soil survey of Pakistan for micro classification of soil. Soils occurring on

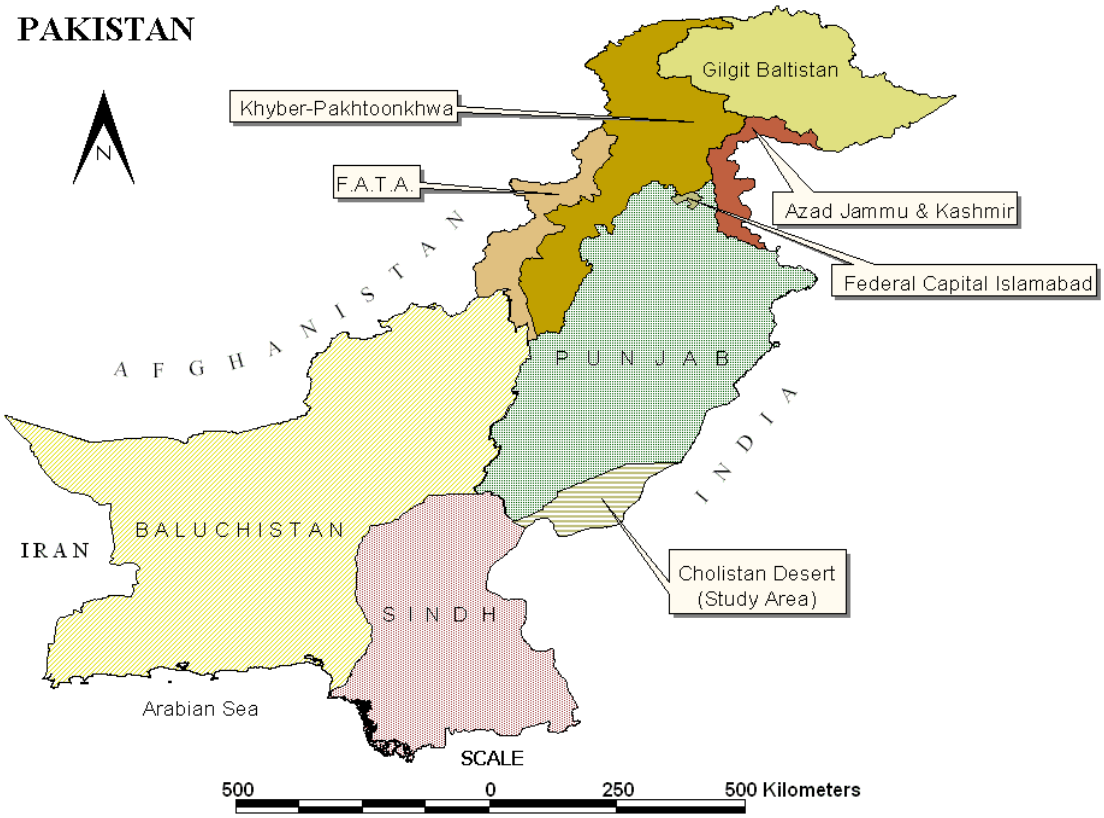

Figure 1. Location map of Cholistan Desert (Pakistan).

different topographic positions within each unit were studied and described according to the Soil Survey Manual (USDA, 1951) and the Guidelines for Soil Profile Descriptions (FAO, 1965).

GEOMORPHOLOGY

Geomorphologically the area presents quite a complex pattern of alluvial and aeolian depositions (Figures 2 and 3), which was followed by: (a) wind resorting and further deposition of the sediments into various forms and sand ridges; (b) resorting and further deposition in spill channels; (c) deposition of clayey sediments in flats; and (d) present day wind resorting and dune formation (Ahmad, 2002; 2008). The alluvium consists of mixed calcareous material, which was derived from the igneous and metamorphic rocks of the Himalayas and was deposited by the Sutlej and abandoned Hakra Rivers most probably during different stages in the sub-recent periods (FAO/ADB, 1993; Ahmad, 2008). The aeolian sands have been derived mainly from the Rann of Kutch and the sea coast and partly from the lower Indus Basin. Weathered debris of the Aravalli has also contributed. The material was carried from these sources by the strong South-western coastal winds (FAO/ADB, 1993; Ahmad, 2002; 2008). The westerly drifting of the river combined with the lowering of the base level of erosion caused the formation of a number of terraces, which represent different depositional stages.

Based on differences in topographic form, parent material and soils, Cholistan Desert can be divided into two main geomorphic regions: Northern region, known as Lesser Cholistan (12,370 km^2), constituting the desert margin and consisting of a series of saline alluvial flats alternating with low sand ridges/dunes; and Southern region, known as Greater Cholistan (13,960 km^2), a wind resorted sandy desert comprising of a number of old Hakra River terraces with various forms of sand ridges and inter-ridge valleys (FAO/ADB, 1993; Tahir et al., 1995; Ahmad, 2008).

The area consists of four main soil types, like dune land with topography ranging between undulating and steep slopes. The sand dunes lie parallel to each other and are connected by small streamers. They are very excessively drained, coarse textured, and their structure less derived from aeolian material deposited by strong winds. Sandy soils are nearly level to gently sloping, deep to very deep, excessively drained, calcareous, coarse textured. Loamy soils are level to nearly level with hummocks of fine sand on the surface, moderately deep, somewhat excessively drained to well drained, calcareous, moderately coarse textured to medium textured. Clayey soils are mostly level, moderately deep, poorly drained, calcareous, saline-sodic, fine moderate textured to fine textured (Baig et al., 1975).

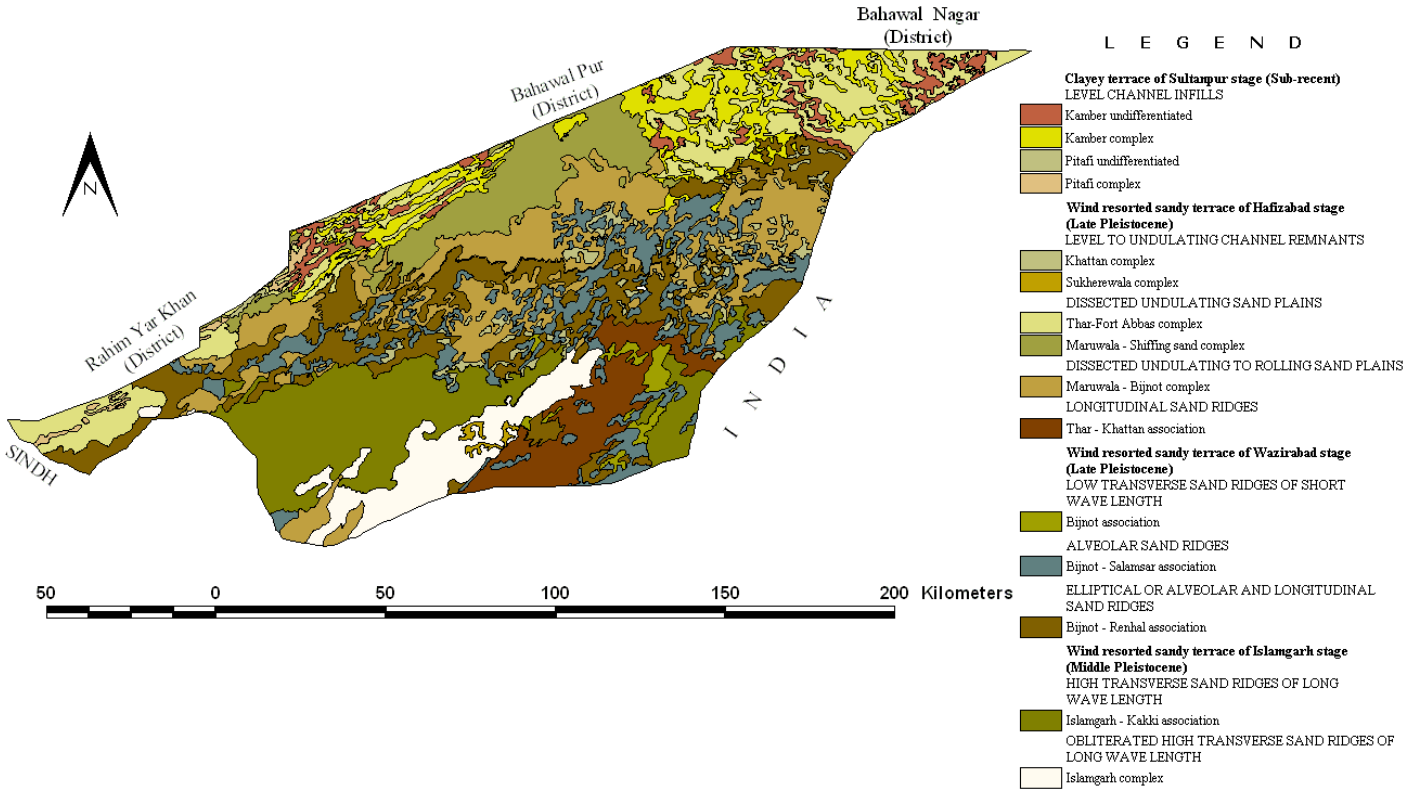

Figure 2. Cholistan: Soils and landforms. Source: After soil survey of Pakistan 1975, modified by the author.

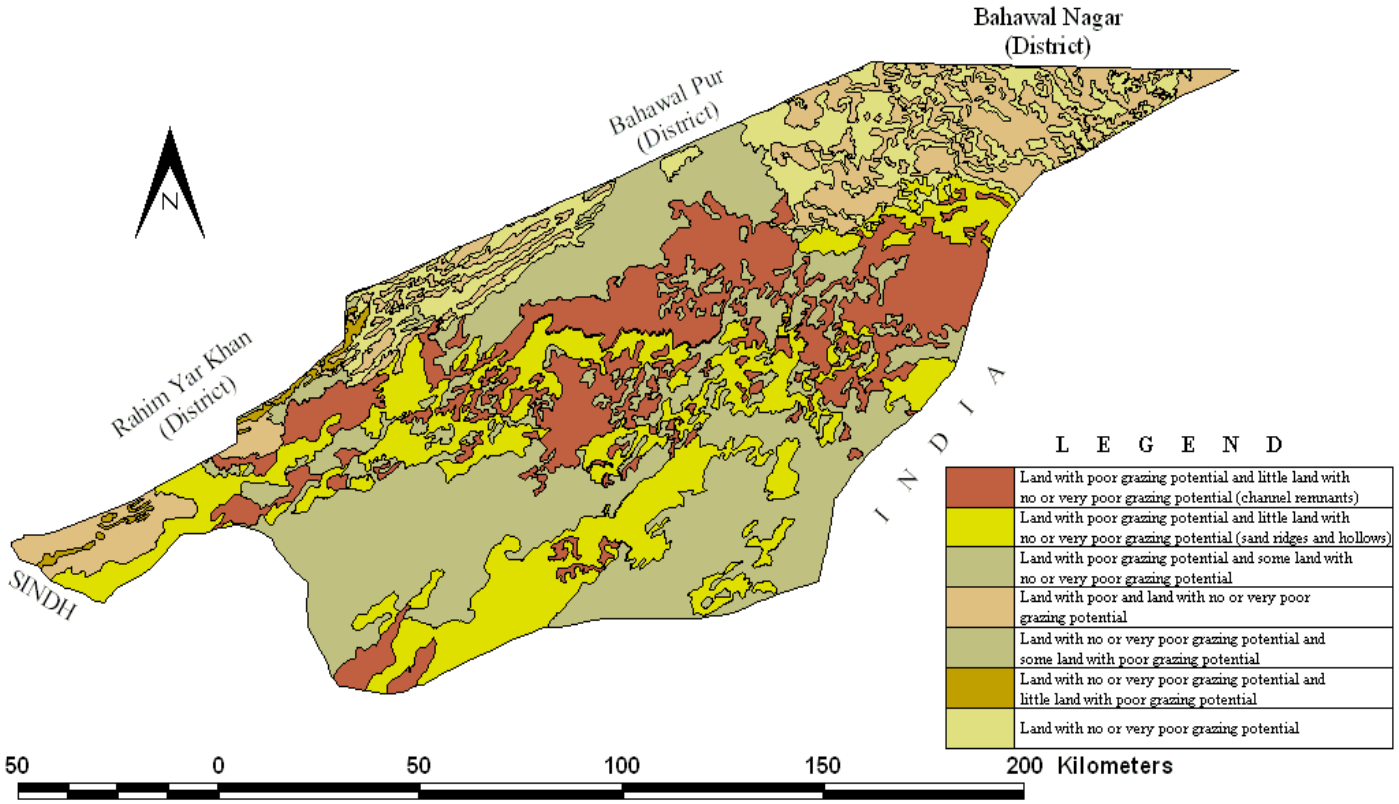

Figure 3. Cholistan: Land capability. Source: After soil survey of Pakistan 1975, modified by the author.

Desert margin (Lesser Cholistan)

This region lies 2 to 4 m below the wind resorted sandy desert (Greater Cholistan). It consists of a complex of two distinct terraces separated by a bluff ranging in height from about half a meter to three meters (FAO/ADB, 1993). The terraces are:

(a) Sub-recent clayey terrace (10,000-1,000 years ago).
(b) Dissected wind resorted sandy terrace of Hafizabad stage (17,000-10,000 years ago).

The sub-recent terrace is lower and comprises the saline alluvial flats causing the sub-recent channels of the drying Hakra River (Tahir et al., 1995). The sediments of this terrace are predominantly clayey and the soils are invariably saline or saline-sodic (Baig et al., 1980). The vegetation cover, which consists of xeromorphic halophytic plant species, is a true indicator of the saline soils of the region. The wind resorted sandy terrace is higher and older than the former and is represented by patches of undulating to rolling sand ridges/dunes occurring as remnants of Pleistocene terraces. The sediments of this terrace are sandy and bear a vegetative cover consisting true desert shrubs similar to those of the Greater Cholistan (FAO/ADB, 1993).

Wind resorted sandy desert (Greater Cholistan)

The three terraces have been distinguished in the wind resorted sandy desert formed during different stages of Pleistocene period. Each terrace is separated from the other by a bluff ranging in height from about one to six meters (FAO/ADB, 1993). The terraces are:

(a) Wind resorted sandy terrace of Hafizabad stage (Late Pleistocene, 17,000-10,000 years ago).
(b) Wind resorted sandy terrace of Wazirabad stage (Late Pleistocene, 50,000-20,000 years ago).
(c) Wind resorted sandy terrace of Islamgarh stage (Middle Pleistocene, 250,000-50,000 years ago).
Each terrace is associated with one or more type(s) of sand ridges and depressions. The form and orientation of these ridges and depressions control the soil moisture and eventually the vegetation and provide the basis for their development as rangelands (Baig et al., 1980). Four types of sand ridges and depressions have been recognized on these terraces. They are: (i) Longitudinal sand ridges, (ii) Alveolar sandy ridges, (iii) Low transverse sand ridges, and (iv) High transverse sand ridges (FAO/ADB, 1993).

The longitudinal sand ridges are found within the first and the lowest terrace of Hafizabad stage, the alveolar sand ridges and low transverse sand ridges are confined to the second intermediate terrace of Wazirabad stage whereas the high transverse sand ridges are connected with the third, the highest and the oldest terrace of Islamgarh stage (Baig et al., 1980).

In addition to the above mentioned physiographic units, courses of old abandoned river occur in patches as covered channel remnants throughout the wind resorted sandy desert. These channel remnants are 3 to 10 m below the general level of surrounding landscape and are 1.5 to 5 km wide (Baig et al., 1975; FAO/ADB, 1993). The soil of the wind resorted sandy desert are predominantly sandy ranging in texture from sand to sandy loam (Shirazi et al., 2004), although small proportion of loam soils are also found. In addition, some clayey soils occur as small scattered patches. The ridges are invariably made up of sands. The windward faces of the ridges contain stabilized sands, whereas the leeward faces and the crest carry shifting sands and semi-stabilized sands respectively. The inter ridge depressions contain soils ranging in texture from loamy sand through sandy loam parts of the depressions are occupied by loam and the intermediate parts by sandy loam. The soils are brown in colour, deeply homogenized with gradual gradation of colour and texture, which become lighter with depth. The soils are moderately to strongly calcareous containing very few fine to common, fine to medium scattered lime nodules in the profile but without a definite zone of lime accumulation (Mohammad and Mirza, 1985; Mohammad, 1989). The soils are non-saline and non-sodic with pH values ranging 8.2 to 8.4 (Baig et al., 1975).

MICROMORPHOLOGICAL CHARACTERISTICS AND SOIL PROFILE

The soil profile of Table 1, located in the Northwest of Ramewala *toba* in the vicinity of Dingarh Fort, shows profile texture to be clay loam to silty clay up to 34 cm depth, while the remaining depth of the profile up to 150 cm consists of loamy very fine and sand textures (PADMU, 1986; Malik, 1995). The soil horizon (cb) from depth 34 to 67 cm is buried and soils horizon (cg) from depth 90 to 110 cm is clayed (PADMU, 1986; Malik, 1995; Ahmad, 2002). The structure of the profile is between massive and sub-angular blocky characteristics. The pores in the top horizon (A) of the profile from soil surface to 6 cm depth are common fine vesicular types. These pores are not continuous; therefore, infiltration of water will not go deep. The pores in other horizons of the profile are absent. The pH of the profile is between 8.8 and 9 (PADMU, 1986; Malik, 1995). Due to high sodicity in the profile, the soil horizons are devoid of porosity. Mottles and roots are also absent in the profile. The soil profile up to 110 cm consists of $CaCO_3$ in the form of common very fine to fine lime nodules and a few lime *kankers* that also cause hardness (PADMU, 1986; Malik, 1995; Ahmad, 2002). The profile from soil surface to 34 cm depth is hard to very hard. The horizon from 90 to 110 cm is clayed indicating once it was under water; as a result there is no pore space. The characteristics of the profile indicate that the soils are non-porous and

Table 1. Profile characteristics as a catchment for rainwater harvesting located about 125 meters north-west of Ramewala *toba* in Dingarh vicinity.

Soil horizon	A	B	Cb	C1	Cg	C2
Soil depth (cm)	0 – 6	6 – 34	34 – 67	67 – 90	90 – 110	110 – 150
Texture	Clay loam	Silty clay	Loamy very fine sand	Loamy fine sand	Loamy fine sand	Loamy very fine sand
Structure	Massive	Sub angular blocky	Massive	Massive	Massive	Massive
Pores	Common fine vesicular	No	No	No	No	No
pH	8.8	9.0	9.0	8.8	8.8	8.8
Mottles	No	No	No	No	No	No
Roots	No	No	No	No	No	No
$CaCO_3$	Common very fine nodules	Common fine nodules	Common fine and a few lime *cankers*	Common very fine lime nodules	Common very fine lime nodules	Nil
Hardness	Hard	Very hard	Soft	Friable	Friable	Very friable

Source: PADMU - Pakistan Desertification Monitoring Unit 1986, modified by the author.

Table 2. Profile characteristics as a catchment for rainwater harvesting located about 2.37 km from Dingarh Fort on Barianwala *toba* track.

Soil horizon	A	B	Cb	C
Soil depth (cm)	0 – 8	8 – 35	35 – 90	90 – 150
Texture	Clay loam	Silty clay	Loamy very fine sand	Loamy fine to fine sand
Structure	Massive	Sub angular blocky	Massive	Massive
Type of pores	Vesicular	No	No	No
No. of pores	Common fine	Nil	Nil	Nil
pH	8.8	9.0	9.0	9.2
Mottles	No	Yes	Yes	Yes
No. of mottles	Nil	Common fine to Very fine	Many fine	Many fine
Roots	No	No	No	No
$CaCO_3$	Common fine lime nodules	Common fine lime nodules	Common fine to a few medium *kankers*	Common very fine lime *kankers*
Hardness	Hard	Very hard	Friable	Friable

Source: PADMU - Pakistan Desertification Monitoring Unit 1986, modified by the author.

non- drained to very poorly drain and indicate that this area is very suitable for rain runoff collection.

The profile of Table 2 is located at 2.37 km away from Dingarh Fort on Barianwala *toba* track towards west. The characteristics of this profile mostly resemble to profile under Table 1 except some features. The depth of buried horizon is more and profile does not contain clayed horizon. The profile is consisting of common very fine to fine mottles indicating that these soils once had been under water (PADMU, 1986; Malik, 1995; Ahmad, 2002). This profile also indicates that the area which is non to very poorly drained is therefore very appropriate for runoff harvesting and collection.

The profile of Table 3, located at 0.5 km North-west of Dingarh Fort, shows that the texture of the profile is between clay loam to silty clay up to 125 cm depth and the remaining profile which is up to 150 cm is buried, thereby having coarse textured fine sand (PADMU, 1986; Malik, 1995; Ahmad, 2002). The major part of the profile consists of B-horizon indicating developed soils. The.

Table 3. Profile characteristics as a catchment for rainwater harvesting located about 500 m north-west of Dingarh Fort.

Soil horizon	A	B21	B22	B23	Cb
Soil depth (cm)	0 – 9	9 – 75	75 – 108	108 – 125	125 – 150
Texture	Clay loam	Silty clay	Silty clay	Silty clay	Fine sand
Structure	Massive	Sub angular blocky	Sub angular blocky	Sub angular blocky	Sub angular blocky
Type of pores	Vesicular	Tubular	Tubular	No	No
No. of pores	Common fine	A few very fine	A few very fine	Nil	Nil
pH	9.0	9.0	9.0	9.0	9.2
Mottles	No	Yes	Yes	Yes	Yes
No. of mottles	Nil	Common fine	Common fine	Many fine	Common medium
Roots	No	Yes	No	No	No
No. of roots	Nil	A few fine	Nil	Nil	Nil
$CaCO_3$	Nil	Nil	Nil	Nil	Nil
Hardness	Hard	Very hard	Very hard	Very hard	Friable

Source: PADMU - Pakistan desertification monitoring Unit 1986, modified by the author.

Table 4. Profile characteristics as a catchment for rainwater harvesting located about 200 m south-west from Bachewala *toba*.

Soil horizon	A	B1	B2	Cb
Soil depth (cm)	0 – 8	8 – 50	50 – 70	70 – 150
Texture	Silty clay	Silty clay	Silty clay	Loamy sand
Structure	Massive	Sub angular blocky	Sub angular blocky	Sub angular blocky
Type of pores	Few fine vesicular	A few very fine tubular	A few very fine tubular	No
pH	9.0	9.2	9.0	9.2
Mottles	No	Yes	Yes	Yes
No. of mottles	Nil	Common fine	Common fine	Common fine
Roots	No	No	No	No
No of roots	Nil	Nil	Nil	Nil
$CaCO_3$	Nil	Nil	Nil	Common fine to common medium *Kankers*
Hardness	Hard	Very hard	Very hard	Friable

Source: PADMU - Pakistan desertification monitoring Unit 1986, modified by the author.

structure of the profile is massive to sub-angular blocky The profile up to 9 cm depth is consisting of common fine vesicular pores, while up to depth 108 cm are a few fine to very fine tubular pores. The pH of the profile is between 9.0 and 9.2 indicating very high sodicity (PADMU, 1986; Malik, 1995). The profile is consisting of common fine to many fine to medium mottles indicating that once this area was under water and it caused reduction of iron and manganese. Mottles also indicate that these soils are non-porous. The profile is devoid of roots except a few fine roots in the horizon B21 from depth 9 to 75 cm. The profile is hard to very hard up to depth 125 cm. The features of the profile indicate that the area is very poorly drained and suitable for rainwater harvesting and collection.

The profile of Table 4, located at 200 m South-west of Bachewala *toba*, is mostly similar to profile located about 500 m North-west of Dingarh Fort except for some minor features (PADMU, 1986; Malik, 1995). This profile indicates that the area is very poorly drained and very suitable for rainwater harvesting and collection. The profile of Table 5, located at about 4.15 km away from Dingarh Fort on Gappenwala *toba* track and about 500 m towards East, is almost similar to the profiles located at about 200 m South-west from Bachewala *toba* and the profile located at about 500 m North-west of Dingarh Fort, except minor difference. Therefore, this area is also a good catchment for rainwater harvesting and collection. The characteristics of mentioned profiles in Table 5 show that fine textured soil lies in Cholistan having level to nearly levelled topography is dense, impervious, non porous to very poorly porous, non/very poorly drained, saline-sodic, capable of generating maximum runoff after absorbing minimum water (PADMU, 1986; Malik, 1995). The features and characteristics of the soil indicate that Cholistan is the best catchment area for rainwater

Table 5. Profile characteristics as a catchment for rainwater harvesting located about 4.15 km from Dingarh Fort on Gappenwala *toba* track.

Soil horizon	A1	B1	B2	B3	Cb
Soil depth (cm)	0 – 12	12 – 45	45 – 75	75 – 125	125 – 150
Texture	Clay loam	Clay loam	Silty clay	Silty clay	Very fine sand
Structure	Massive	Sub angular blocky	Sub angular blocky	Sub angular blocky	Massive
Type of pores	Vesicular	Interstitial	Interstitial	No	No
No. of pores	Common very fine	A few fine	A few very fine	Nil	Nil
pH	9.0	9.0	9.2	9.2	9.2
Mottles	No	Yes	Yes	Yes	Yes
No. of mottles	Nil	A few fine	Common fine	Many fine	A few medium
Roots	No	Yes	Yes	No	No
No. of roots	Nil	A few fine & medium	A few very fine	Nil	Nil
$CaCO_3$	Common very fine nodules	Common fine nodules	Common fine nodules	Nil	Nil
Hardness	Hard	Hard	Very hard	Very hard	Very friable

Source: PADMU - Pakistan desertification monitoring unit 1986, modified by the author.

Table 6. Land system.

Mega	Macro	Percentage
Lesser Cholistan (12,370 km^2): Wind resorted dissected terrace remnants	1. Flats with sandy terrace remnants	31.7
	2. Sandy terrace remnants with some flats	15.8
Greater Cholistan (13,960 km^2): Wind resorted sandy terraces	3. Low sand dunes and hollows	15.3
	4. Longitudinal ridges and valleys	6.4
	5. Low transverse ridges and valleys	0.7
	6. Alveolar ridges and valleys	15.3
	7. High transverse ridges and valleys	13.0
	8. Partly covered channels	1.8

Source: Based on field survey, January 1998, January 1999 and June 2000.

harvesting and collection.

Conclusions

Mega land system (Lesser and Greater Cholistan) are split into macro land system (Table 6) which controls soils, moisture and eventually vegetation. Landforms map of Cholistan is compiled from the integration of information on geomorphology, soil, wind erosion, and vegetation. The units are biophysically homogeneous and versatile and such can be used confidently for land use planning of crops, range/livestock, irrigation and road alignment.

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