Soilscapes of the Drâa basin / Southern Morocco

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Summary

Motivated by the project Impetus the soils in the Drâa basin are studied with the transect method using the WRB-System. The river Drâa is situated in the dry zone of southern morocco spending life for six waste river oases. 11 study sites along the transect of altitude and aridity are choosen crossing most divergent ecosystems. A high diversity of determined soilscapes is found: Kastonozem-Luvisol-soilscape and different soilscapes dominated from Calcisols in the High Atlas, degraded Leptosol-Regosol-soilscape in the crystalline Anti Atlas, different Anthrosol-soilscapes of oases of the middle Drâa ending in the Solonchak-soilscape of the drying former lake in the outer Sahara.

Introduction

The Drâa is situated in the dry zone of the southern part of the High Atlas Mountain in southern Morocco. The most divergent ecosystems from periglacial high mountain and perennial Mediterranean, sub-humid steppe forest ecosystems to the fully desert ecosystems of the outer Sahara are all encompassed. The Drâa basin is research area of the project IMPETUS, - an integrated approach to the efficient management of scarce water resources in West Africa. A regional comparison of soilscapes shows their different properties in land use.

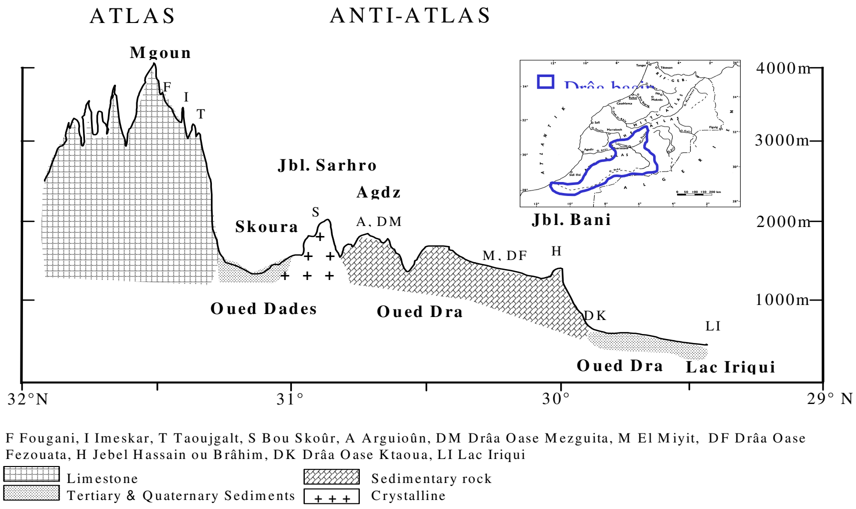
Methods and study site

A large N-S-transect (> 400 km) along an extreme gradient of altitude (3.200 - 445 m) and aridity (600 - 50 mm rainfall per year) at 6°30' W longitude is taken (Figure 1) in the framework of IMPETUS. 13 study sites are chosen along the transect (Figure 1). The soils are examined and described after the World Reference Base for Soil Resources (ISSS-ISRIC-FAO, 2002). So-called soilscapes are determined after the choric idea of soil geography (SCHLICHTING 1970) and the classification system for soilscapes after SCHMIDT & JAHN (2004).

Results

An overview of the developed soilscapes along the transect (Figure l) show a high diversity. A Kastanozem-Luvisol-soilscape is determined in the highest part of the High Atlas (F).
Different soilscapes dominated from Calcisols (F, I, T) follow up to the escarpment relief of the middle Drâa. A degraded Leptosol-Regosol-soilscapes is found in the hills of the crystalline Anti-

Climate Station[1]	M´Semir	Ifre	Ouarzazate	Agdz	Zagora	Tagounite
Altitude [m a.s.l.]	1992	1500	1050	1110	707	600
P [mm]	218	172	111	108	59	54,5
P/E-Index (UNEP, 1992)	0.3	0.2	0.1	0.1	0.06	0.01
Aridity Classification	semi-arid	semi-arid	arid	arid	arid	hyper-arid
Climate Classification (KÖPPEN 1923)	**H-BWk**	**H-BWk**	**BWh**	**BWh**	**BWh**	**BWh**



	geography	site	soilscapes (on slopes / alluvial deposits)
High Atlas	steep slope	F	Kastanozem-Luvisol
	steep slope	I	(Leptosol-) Calcisol
	erosion fan	T	Anthrosol-Calcisol-Leptosol-Luvisol
	erosion fan	L	Regosol-Calcisol-Luvisol
Anti Atlas	escarpment	S	Leptosol-Regosol
	river oasis		Anthrosol
	escarpment	A	Leptosol-Luvisol-Calcisol
	Drâa oasis	DM	Anthrosol-Arenosol-Fluvisol
	escarpment	M	Calcisol-Luvisol
	Drâa oasis	DF	Anthrosol
	escarpment	H	Leptosol-Luvisol
	Drâa oasis	DK	Anthrosol-Fluvisol
Sahara	lake	LI	Solonchak
	dahyet		Arenosol-Calcisol

Figure 1: Geographical Sketch from High Atlas to Sahara along 6°30'W and detected soilscapes

Atlas (S). The pastorally used mountains are generally degraded by water erosion. This can be observed by the splash structure of topsoils with their only very thin vegetation cover and the erosion phenomena on slopes where a thick stone cover is missing.

The Drâa oases are built up from different Anthrosol-soilscapes often suffering soil salinization (DM, DF, DK).

They end in the very strong saline Solonchak-soilscape of the final lake Iriqui (LI).

The studied soilscapes of the test sites Fougani (F) and the Drâa (DM, DF, DK and LI) are selected to present here exemplarily.

Fougani/ High Atlas

In the High Atlas at 3.200 meter altitude the test site Fougani (Figure 2) is located. The ESE facing, steep slope (35 %) of debris of limestone with thorn shrub vegetation is still extensively pastoral used. The high mountain climate with frequent frost leads to periglacial stripped soils. The diagnostic mollic, calcic horizons of these Kastanozems are the dark brownish topsoils with strongly humic properties (Table 1). They accumulate the organic matter up to 5,8 % (Table 2) in the topsoil on the upper slope – F 1: Silti-Calcic Kastanozem (Skeletic) Thapto Chromi-Skeletic Calcisol (Siltic) - due to the cold limit.

[1] In lack of a longtime climate station in the higher region the precipitation of the High Atlas is taken from literature.

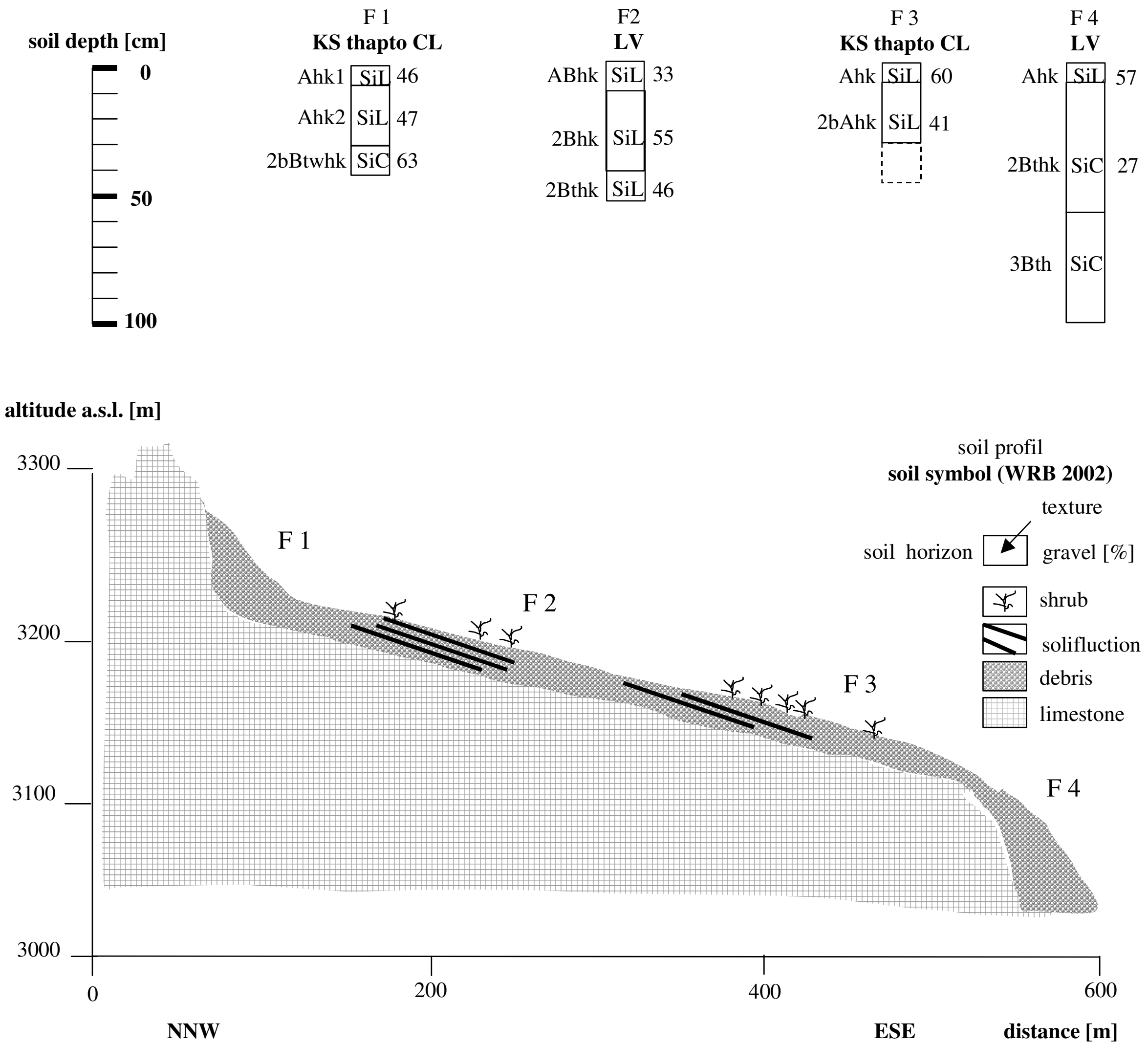


Figure 2: Kastanozem-Luvisol-soilscape of the catena Fougani/ High Atlas

Table 1: Diagnostic soil characteristic of the catena Fougani/ High Atlas

Profil	Depth	Diagnostic		
	[cm]	Horizon	Property	Material
F 1: Silti-Calcic Kastanozem (Skeletic) Thapto Chromi-Skeletic Calcisol (Siltic)				
Ahk1	0-7	Mollic, Calcic	Strongly humic properties	Siltic, Skeletic, Calcaric
Ahk2	7-30	Mollic, Calcic	Strongly humic properties	Siltic, Skeletic, Calcaric
2 Btwhk	30-45	Calcic, Argic, Chromic	Abrupt textural change, Strongly humic	Siltic, Skeletic, Chromic, Calcaric
F 2: Chromi-Calcaric Luvisol (Skeletic, Siltic)				
ABhk	0-12	Chromic		Siltic, Chromic, Calcaric
2 Bhk	12-40	Chromic		Siltic, Skeletic, Chromic, Calcaric
2 Bthk	40-55	Argic, Chromic	Abrupt textural change	Siltic, Skeletic, Chromic, Calcaric
F 3: Silti-Calcic Kastanozem (Skeletic) Thapto Chromi-Skeletic Calcisol (Siltic)				
Ahk	0-8	Mollic	Strongly humic properties	Siltic, Skeletic, Chromic, Calcaric
2 Ahk	8-30	Mollic	Strongly humic properties	Siltic, Skeletic, Chromic, Calcaric
	> 30			Siltic, Skeletic, Chromic, Calcaric
F 4: Chromi-Calcaric Luvisol (Skeletic, Siltic)				
Ahk	0-10	Chromic		Siltic, Skeletic, Chromic, Calcaric
2 Bthk	10-60	Argic,Chromic		Siltic, Skeletic, Chromic, Calcaric
3 Bth	60-100	Argic,Chromic		Siltic, Skeletic, Chromic

In the middle slope there are Luvisols (F2) with their diagnostic argic, chromic horizon (Table 1). The finally classified type of soilscape is as follows: Silti-Calcic Kastanozem/ Chromi-Calcaric Luvisol - Soilscape of Skeletic Silty Loam and Silty Clay of debris of limestone with periglacial structure phenomena.

High Silt contents (58 – 79 %, almost rough silt fraction), steep slope condition and slight vegetation cover (but stone cover) make them vulnerable for degradation by water erosion.

Table 2: General soil characteristics of the catena Fougani / High Atlas

Profil	Colour		Texture		Gravel	Sand	Silt	Clay	pH	C_{org}	C/N	CEC_{soil}	CEC_{clay}	EC_e	$CaCO_3$
	Dry	Wet	WRB	KA4	[%]	[%]	[%]	[%]		[%]		[cmolc/kg]		[dS/m]	[%]
F 1: Silti-Calcic Kastanozem (Skeletic) Thapto Chromi-Skeletic Calcisol (Siltic)															
Ahk1	7.5 YR 4/4	7.5 YR 3/2	SiL	Tu4	46	8	66	26	7,8	5,8	22	28	46	0,6	22
Ahk2	7.5 YR 4/3	7.5 YR 2/3	SiL	Ut4	47	10	67	23	8,0	4,5	23	28	66	0,4	25
2 Btwhk	7.5 YR 4/3	5 YR 4/3	SiC	Lu	63	12	60	28	8,3	1,9	47	18	53	0,3	37
F 2: Chromi-Calcaric Luvisol (Skeletic, Siltic)															
ABhk	7.5 YR 5/4	5 YR 3/4	SiL	Ut3	33	7	78	16	8,1	1,4	25	23	125	0,5	10
2 Bhk	7.5 YR 4/4	5 YR 3/4	SiL	Ut3	55	9	79	13	8,3	1,7	32	22	146	0,4	12
2 Bthk	7.5 YR 3/4	5 YR 3/2	SiL	Ut4	46	9	66	25	8,3	2,8	20	27	79	0,4	8
F 3: Silti-Calcic Kastanozem (Skeletic) Thapto Chromi-Skeletic Calcisol (Siltic)															
Ahk	7.5 YR 4/6	7.5 YR 3/2	SiL	Ut4	60	10	67	23	8,1	3,1	17	30	87	0,5	10
2 Ahk	7.5 YR 3/4	7.5 YR 3/2	SiL	Ut4	41	10	65	24	8,1	3,6	14	28	74	0,5	6
F 4: Chromi-Calcaric Luvisol (Skeletic, Siltic)															
Ahk	7.5 YR 5/4	5 YR 4/4	SiL	Lu	57	14	64	22	8,3	1,5	20	18	71	0,3	9
2 Bthk	7.5 YR 4/4	5 YR 3/3	SiC	Lu	27	8	65	28	8,3	1,4	12	19	60	0,5	3
3 Bth	7.5 YR 5/4	5 YR 3/4	SiC	Tu3	48	5	58	37	8,2	1,1	9	22	53	0,5	0

Drâa/ Anti Atlas

In the dry zone of the Anti-Atlas six old river oasis of the Drâa are irrigated since 1970 with artificial flushes of the dam in Ouarzazate (Figure 3). The less irrigation water quality continue to worsen to the south from high water salinity in Mezguita (1) to very high water salinity in Ktaoua (4). The Anthrosols of the oasis show increasing soil salinization to the south, too. The Anthrosols are in Mezguita (1) non-saline and in Fezouata slightly-saline. In Ktaoua (3) the Anthrosol is strongly-saline and out of use. The Drâa ends in the drying former lake Iriqui (4) with a strongly-saline Solonchak.

The Texture of topsoils in the oasis Mezguita (DM 3) and Fezouata (DF 2) (Table 4) is sandy loam. In the south in Ktaoua (DK 2) there is a more fine texture of silty loam. Salic and sodic properties increase to the south and campaigned in Ktaoua (DK 2) with gypsic properties.

In combination with the lack of water and less water quality even for irrigation this results in a dying of the drâa oasis Ktaoua. The hypersalic soil properties of the final lake Iriqui (LI 1) derives from the natural salt accumulation (primary salinization) of the ending Drâa river enriched with saline waste water of upper situated oasis (secondary salinization).

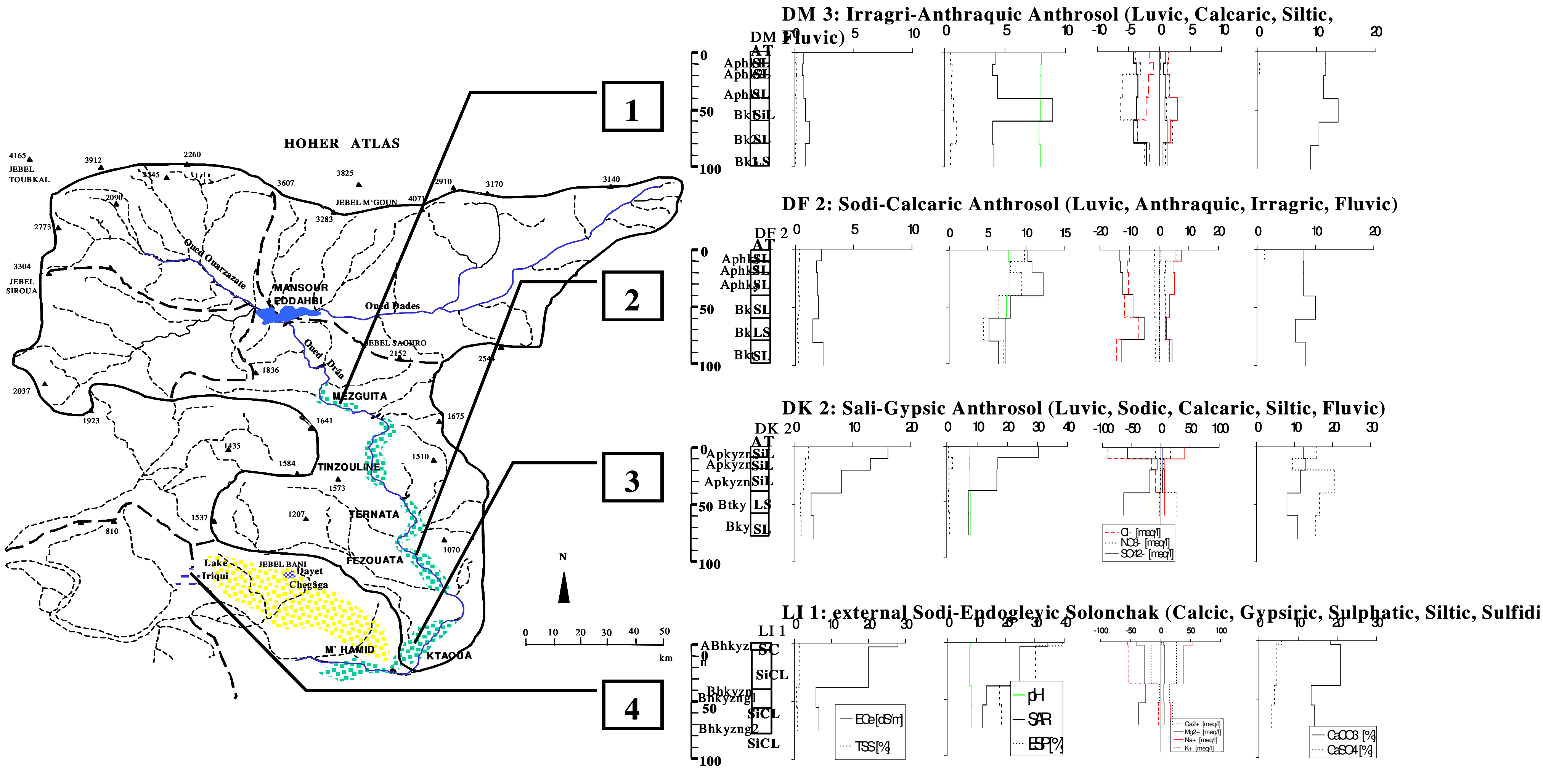


Figure 3: Anthrosols of the Drâa oasis and salinization

Table 3: Diagnostic soil characteristic of the middle Drâa oasis

Profil	Depth [cm]	Diagnostic Horizon	Property	Material
DM 3: Irragri-Anthraquic Anthrosol (Luvic,Calcaric,Siltic,Fluvic)				
Aphk1	0-10	Anthraquic, Irragric		Calcaric, Fluvic, Siltic
Aphk2	10-20	Anthraquic, Irragric		Calcaric, Fluvic, Siltic
Aphkt	20-40	Argic,Anthraquic,Irragric	Abrupt textural change	Calcaric, Fluvic, Siltic
Bk1	40-60			Calcaric, Fluvic, Siltic
Bk2	60-80			Calcaric, Fluvic
Bk3	80-100			Calcaric, Fluvic
DF 2: Sodi-Calcaric Anthrosol (Luvic,Anthraquic, Irragric,Fluvic)				
Aphky	0-10	Hyposodic,Anthraquic, Irragric		Calcaric, Fluvic
Aphk1	0-10	Hyposodic,Anthraquic, Irragric		Calcaric, Fluvic
Aphk2	20-40	Hyposodic,Anthraquic, Irragric		Calcaric, Fluvic
Bk	40-60	Hyposodic		Calcaric, Fluvic
Bk	60-80	Hyposodic		Calcaric, Fluvic
Bkt	80-100	Hyposodic,Argic	Abrupt textural change	Calcaric, Fluvic
DK 2: Sali-Gypsic Anthrosol (Luvic,Sodic, Calcaric, Siltic,Fluvic)				
Apkyzn	0-10	Gypsic,Salic,Anthraquic, Irragric		Calcaric,Gypsiric, Fluvic, Siltic
Apkyzn	10-20	(Hypo)Salic,Anthraquic, Irragric		Calcaric,Gypsiric, Fluvic, Siltic
Apkyzn	20 -40	Gypsic,Hyposalic, Anthraquic, Irragric		Calcaric,Gypsiric, Fluvic, Siltic
Btky1	40-60	Argic,Gypsic	Abrupt textural change, Secondary carbonates	Calcaric,Gypsiric, Fluvic
Btky2	60>80	Argic,Gypsic		Calcaric,Gypsiric, Fluvic, Siltic
LI 1: external Sodi-Endogleyic Solonchak (Calcic, Gypsiric, Sulphatic, Siltic, Sulfidic)				
ABhkyzn	0-3	Salic,Calcic,Sodic	Gleying (oximorph)	Gypsiric,Calcaric,Siltic,Sulfidic,Fluvic
Bhkyzn	3-38	Salic,Calcic,Sodic	Gleying (oximorph)	Gypsiric,Calcaric,Siltic,Sulfidic,Fluvic
Bhkyzng1	38-55	Salic, Sodic	Gleying (redoximorph)	Gypsiric,Calcaric,Siltic,Sulfidic,Fluvic
Bhkyzng2	55-75	Salic,Sodic	Gleying (redoximorph)	Gypsiric,Calcaric,Siltic,Sulfidic,Fluvic

Table 4: General soil characteristic of the middle Drâa oasis

Profil	Depth	Colour		Texture		Gravel	Sand	Silt	Clay	pH	C_{org}	C/N	CEC_{soil}	CEC_{clay}	ESP	EC_e	Salt	SAR	$CaCO_3$	Gipsum
	[cm]	Dry	Wet	WRB	KA4	[%]	[%]	[%]	[%]		[%]		[cmolc/kg]			[dS/m]	[%]	[%]	[%]	[Vol-%]
DM 3: Irragri-Anthraquic Anthrosol (Luvic,Calcaric,Siltic,Fluvic)																				
Aphk1	0-10	7.5YR 5/4	7.5YR 3/4	SL	Su4	0	50	45	5	8,0	0,6	59	4	80	0,6	0,7	0,2	4	12	
Aphk2	10-20	7.5YR 5/4	7.5YR 3/4	SL	Su4	0	52	43	5	8,0	0,9	45	4	62	0,6	0,6	0	4	12	0,5
Aphkt	20-40	7.5YR 5/4	7.5YR 3/4	SL	Su4	0	47	49	49	7,9	0,8	64	3	6	0,6	0,8	0	4	11	
Bk1	40-60	7.5YR 5/4	7.5YR 3/4	SiL	Us	0	41	55	4	7,9	0,4	73	4	96	0,7	0,9	0	9	14	
Bk2	60-80	7.5YR 5/4	7.5YR 3/4	SL	Su3	0	67	30	3	7,8	0,3	0	4	137	0,5	1,2	0	4	10	
Bk3	80-100	7.5YR 5/4	7.5YR 3/4	LS	Su2	0	77	21	2	7,9	0,4	0	4	138	0,4	0,9	0	4	9	
DF 2: Sodi-Calcaric Anthrosol (Luvic,Anthraquic, Irragric,Fluvic)																				
Aphky	0-10	5YR 5/4	5YR 4/4	SL	Sl3	0	65	26	10	7,7	1,1	39	5	48	0,3	2,3	0,1	10	7,9	3
Aphk1	0-10	5YR 5/4	5YR 4/4	SL	Su3	0	63	32	5	7,9	0,6	30	5	96	0,5	1,8	0,1	11	8	
Aphk2	20-40	5YR 5/4	5YR 4/4	SL	Su3	0	60	34	6	7,8	0,6	34	5	79	0,5	1,9	0,1	12	8	
Bk	40-60	5YR 5/4	5YR 4/4	SL	Su3	0	68	26	5	7,5	0,2	41	5	90	0,4	2	0,1	8	10	
Bk	60-80	5YR 5/4	5YR 4/4	LS	Su2	0	76	25	1	7,4	0,2	52	4	573	0,5	1,5	0	5	6,6	
Bkt	80-100	5YR 5/4	5YR 4/4	SL	Sl3	0	63	27	9	7,3	0,3	48	5	47	0,4	2,4	0,1	6	8,3	
DK 2: Sali-Gypsic Anthrosol (Luvic,Sodic,Calcaric,Siltic,Fluvic)																				
Apkyzn	0-10	7.5YR6/4	7.5YR 4/6	SiL	Uls	0	22	65	13	7,7	0,2	40	6	46	0,7	16,1	0	30	12	36
Apkyzn	10-20	7.5YR6/4	7.5YR 4/6	SiL	Uls	0	38	53	9	7,5	0,5	46	6	59	0,6	13	0	17	13	22
Apkyzn	20 -40	7.5YR6/4	7.5YR 4/6	SiL	Us	0	44	57	0	7,7	0,5	49	6	0	0,8	8,1	0	17	12	48
Btky1	40-60	7.5YR6/4	7.5YR 4/6	LS	Su2	0	72	25	4	7,8	0,4	80	3	92	0,5	2,7	0	7	8	38
Btky2	60>80	7.5YR6/4	7.5YR 4/6	SL	Su4	0	45	49	6	7,8	0,5	62	8	121	0,6	3,2	0	7	11	36
LI 1: external Sodi-Endogleyic Solonchak (Calcic,Gypsiric,Sulphatic,Siltic,Sulfidic)																				
ABhkyzn	0-3	7.5YR 6/6	7.5YR 4/6	SiCL	Tu3	0	6	58	36	7,9	0,8	35	12	30	0,4	28	0,4	414	18	13
Bhkyzn	3-38	7.5YR 6/6	7.5YR 4/6	SiCL	Tu4	0	2	69	29	7,8	0,8	36	13	40	0,5	28	0,3	247	21	10
Bhkyzng1	38-55	5YR 6/4	7.5YR 4/6	SiCL	Tu4	0	2	67	31	8,2	0,9	28	12	36	0,5	5,8	0,4	267	13	9
Bhkyzng2	55-75	5YR 6/4	7.5YR 4/6	SiCL	Tu3	0	4	60	36	8,2	0,8	29	12	31	0,4	6,6	0,4	278	14	7

Discussion

The waste rangeland in the Drâa basin of almost mountain country and is pastoral used. Its homogenized degraded vegetation cover through overgrazing pretend a homogene soil cover, too. But like relict sites (cemetery of marabout) showing better potential vegetation conditions, the soils are much more differentiated and equipped in each case with own different properties, too. For a sustainable land use a well-known understanding of the soil resource and further research is necessarily.

The oases as the most important arable land and their increasing soil salinization demand a better soil and irrigation management.

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