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Morocco's Vertisol Characterization (Tirs)

R. Moussadek[1*], M. Laghrour[2*], R. Mrabet[1], E. Van Ranst[3], M. Badraoui[2], M. Mekkaoui[2]

1. National Institute of Agricultural Research (INRA), Scientific Division, Vectoire Ave,P.O Box. 415 RP-Rabat- Morocco.
2. Groupe Physicochemistry of Materials, Nanomaterials and Environment, Faculty of Sciences, Mohammed V University, Ibn Battuta Avenue, P.O. Box 1014, Rabat, Morocco.
3. Department of Geology and Soil Science (WE13), Ghent University, Krijgslaan 281 (S8), B-9000 Gent, Belgium.

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rachidmoussadek@yahoo.fr ;
laghrour.malika@gmail.com
+212668829271; +212 41510686

Abstract

In Morocco, the Vertisols, known by vernacular name Tirs, are often used for cereal and arboriculture. Because of their difficult physical properties due to their high content of swelling clay and the presence of cracks, Vertisols are generally underutilized at present. This paper presents a state of the art on Vertisols and their distribution in the world. Then, it focuses on the criteria for soil classification used in the Moroccan system and the American system (Soil Taxonomy). Additionally, a part of this paper will address the typology of Tirs and its degree of similarity with the Vertisols class; this paper concludes with the major constraints and potentiality of those soils in Morocco.

1. Introduction

Generally, Vertisols are fertile soils in many regions in the world [1-3]. However, these soils are often less productive and this finding is observed mainly in areas where the population is suffering from low nutrition and high poverty [4]. Indeed, Vertisols generally have a significant production potential but they are difficult to manage [5]. Their high content of swelling clay (smectite) [6] reduces their range of optimum moisture for tillage [1]. Although their high natural fertility and positive response to management make Vertisols attractive for agriculture, some of their other properties impose critical limitations on low-input agriculture. The inherent limitations of Vertisols are largely a function of the moisture status of the soils and the narrow range of moisture conditions within which mechanical operations can be conducted. Farmers using traditional methods of agriculture are aware of the high risks associated with the use of these soils [3,7].
In recent decades, there has been an international interest in improving the management of these soils to increase agricultural production [8, 9]. In Africa, where these soils occupy more than 120 million hectares [1], improved management will contribute to reversing the food deficit into a surplus of agricultural production [1]. Research on Vertisols was also intensified in several regions in the world, particularly in the processes of soil genesis and classification of these soils through the work of the International Commission for Vertisols (ICOMERT).
In Morocco, Vertisols known by vernacular name (Tirs), are important agricultural soils, those are highly productive [6,8] and they are reserved for industrial crops and cereal cultures [11].
The purpose of this research is to determine the distribution of these Vertisols in the world and in Morocco, and to highlight their classification and typology, and to show their major constraints and potentiality.

2. Distribution and Properties of Vertisol

2.1. Classification and characteristics of Vertisol

Vertisols have attracted the attention of researchers since 1898 when black soils were distinguished in the Indian peninsula by their high production potential [12]. Since then, studies concerning these soils have been conducted in the United States [13] and Sudan [14]. Farmers distinguish Vertisols based on color and texture [15]. In the U.S. classification [16], Vertisols are characterized by their property to swell and shrink depending on climate conditions, which causes the formation of cracks, varying from 50 cm to over a meter [17,18]. This property depends on the nature of the parent material that contains more than 30% clay, which is dominated by smectites [1].

2.2. Distribution in the World

In 1965, the surface of black clay soils (dark clay soil) in the tropics and sub-tropics was estimated to be about 257 million hectares. However, it was difficult to know if these soils correspond to the definition of Vertisols [14]. They were located in more than 76 countries, the majority of them were Australia (70 million ha), India (60 million ha) and Sudan (50 million ha). In its latest survey USDA-SCS, estimated the area occupied by Vertisols globally to be about 308 million hectares [18]. However, the exact area is not well-defined due to the lack of such information in several countries [2]. In addition, Vertisols often have a small area which does not allow their representation on compiled maps at the national scales [1].

Vertisols are found in many climatic zones and are most abundant in the tropics and sub-arid regions [1,15,19].

Because of its shrinking and swelling characteristics, a large number of local and vernacular names are attributed to Vertisols, sometimes in the same country such in India where they are known under 13 different names, (Table 1) [14-15,21]

Table 1: The names given to Vertisols or Vertic soils character [15]

Vernacular name	Area	Vernacular name	Area	Vernacular name	Area
Barros pretos	Portugal	Subtropical black clays	Africa	Tropical black soils	Africa, India
Black clays	South Africa and Australia	Tropical black soils	Africa	Gilgai soils	Australia
Shachiang soils	China	Terra nera	Italy	Regur	India
Black cracking soils	Ouganda	Terras negras tropical	Mozambic	Smolnitza	Bulgaria, Romania
Black earths	Africa, Australia	Terras negras del Andalucia	Spain	Smonitza	Austria
Black turfs	South Africa	Tropical black earth	Angola Ghana	Sols de palads	France
Dark clay soils	U.S.A	Margalite soils	Indonesia	Tirs	Morocco

2.3. Distribution in Africa

In Africa, Vertisol occupy about 120 million hectares, representing 35% of Vertisol in the world [1]. They are spread over several countries (Table 2) and climatic zones; about 50% are located in semi-arid and sub-humid bioclimatic zones with annual rainfall between 200 and 800 mm. The importance of Vertisols is usually felt in Sudan and Ethiopia, but also in Central African countries such as Zimbabwe, Somalia, Niger, Nigeria, Ghana, Ivory Coast, Togo and South Africa and in North Africa countries including Morocco [2].

Table 2: Distribution of Vertisol in Africa [1]

Country	Superficies (M ha)	Country	Superficies (M ha)	Country	Superficies (M ha)	Country	Superficies (M ha)
Angola	0.5	Ghana	0.2	Mozambique	1.1	Sudan	50
Benin	0.1	RD Congo	0.3	Namibia	0.7	Tanzania	7
Botswana	0.5	Ivory Coast	2.8	Niger	0.1	Togo	0.1
Burkina Fasso	0.4	Madagascar	0.8	Nigeria	4	Oganda	1.7
Cameroun	1.2	Malawi	1	Senegal	0.2	Zambia	5
Egypt	1	Mali	0.7	Somalia	0.8	South Africa	2.1
Ethiopia	13	Morocco	1*	Zimbabwe	1.8		

(*) Recent estimation

3. Morocco Vertisols: classification and typology

The progress of soil studies have enabled to realize that Vertisols can be assimilated into a large family of land described in various parts of the world. In the Mediterranean countries, they are called "Barros pretos" in Portugal, "Terra negra" in Italy, "Terras negras del Andalucia" in Spain, "Touers" in Algeria, "Black Earth" of Limagne in France and "Tirs" in Morocco.

Although these soils have different names, they are similar in their physical and morphological characteristics. However, the description of profiles and their laboratory studies differ from one author to another.

In Morocco, the first soil scientists classified the "Tirs" from the steppe soils [22], the hydropedic soils [23] and hydromorphic soils [24]. Since the adoption of the French classification system by Moroccan soil [27], the "Tirs" were classified as Vertisols [8].

Certainly, the assimilation of "Tirs" to Vertisols could solve the problem of soil classification, however, it could create confusion in terms of pedogenesis (soils formation) of "Tirs"[8].

Then, it appears interesting to compare the analytical data of "Tirs" profiles with other worldwide Vertisols profiles. These data will assess the typology of "Tirs" using not only the morphological characteristics, but also using physical, chemical and mineralogical properties. Comparison using the genesis properties could not be performed due to the oldness and scarcity of these studies [26-28].

3.1. Typology of Tirs

Following the presentation of Vertisols in soil taxonomy and the French classification, it would be judicious to focus on Tirs to compare their analytical characteristics with those of the typical Vertisols. The Tirs are usually dark-colored clay soils. The upper part of their profiles, uniformly colored, can reach over a meter. The dark color varies from light gray, frank black to dark brown. Another important feature of Tirs is their angular fragmentary structure. During wet conditions, the Tirs have a massive structure that melts dry crack, leading to the formation of different sized soil prisms. These are very rude, by massive columns to lumps of irregular shapes and rough face in gray Tirs. The structure becomes finer, to more clear forms and shiny faces in the "black" and "brown" soils [29-30].

In the latter, large prismatic lumps delimited by wide and deep slots fragment easily to finer elements, cubic or prismatic net clods with bright faces and well-pronounced angles. In deep horizons, massive block-structure gray Tirs warp following the intersection of the vertical and horizontal or oblique orientation cracks. These forms of tetrahedral shapes have shiny, striated sides (slickensides).

Bedrock appears more or less transformed in depth. It can be tender as silt, clay, marl or eruptive rock alteration products, especially basalts, or hard like encrusted limestone [8].

3.1.1. Analytical Characteristics of Tirs

To compare the Tirs and their analytical character with the typical Vertisols, we proceeded to collect data from studies on these soils in different regions of Morocco, particularly in the regions of Gharb, Doukkala and Zaer (Table 3).

Profiles depth

In the regions of Gharb and Doukkala (relatively wet areas), Tirs are generally deep soils formed on marl or on alluvial and colluvial material. Marl profile thickness can reach several meters before finding a calcareous crust or a sandy horizon. Thus, the profile may have a uniform particle size over a large depth. By contrast, shallow Tirs developed on lamellar crusts are frequently found in the semi-arid plains of Chaouia.

Texture

The clay content of Tirs varies between 30 and 55% and can reach about 80% in Gharb (Table 3) because the rocks are from marl and highly altered schists. The Tirs have an almost homogeneous texture from the bottom to the top of profile with a slight enrichment in clay on the surface. The textural class is clay to silty clay in the intake areas (such as the area of Gharb) or sandy clay in the Doukkala area [26]. Thus the texture homogeneity of Tirs profiles is not a particular character but rather specific criteria of these soils. The same finding is observed in Vertisols in Mediterranean countries, including Portugal and Spain, which also have a homogeneous composition depending on the depth (Tables 4 and 5).

Mineralogy

Work on clay mineralogy of Tirs [27,31-34] showed that its clays are often richer in smectite in the plains of Gharb, Sais, Chaouia than in the plateau of Doukkala.

Limestone

The limestone content of Tirs varies greatly; it can range from a soil uniformly "limestone" (Table 3) to a completely decalcified soil with an accumulation zone at depth. Thus, in the Gharb region, young Tirs (gray Tirs) developed in recent formations are limestone’s dice the surface. The rate of Calcium carbonates varies from around 10 to 20% without significant differentiation in the B-151 and B-333 profiles (Table 3). The Tirs that develop on the older formations are clearly without calcareous. (Profiles B 152 and Z-1, Table 3). A similar process is also observed in other regions of Morocco, especially in Doukkala where Tirs with an undifferentiated limestone profile occupy flat areas of the watershed (LR-54 profile Table 3). According to the work of Bryssine [26], the presence of swelling clay does not appear to hamper the normal development of the process of decalcification.

Table 3: Analytical data of some types of Tirs profiles in Morocco

Profile	Region	Depth (cm)	Clay %	Slit %	Fine sand %	Coarse sand %	pH water	$CaCO_3$ (%)	C (%)	N (%)	CEC	Ca	Mg	Na	K
											cmol (+)/kg soil				
B-151	Gray Tirs, Ouled Ameur, Gharb	0-10	65	32	2	1	7.9	15	1.14		38				
		20-70	68	30	1	1	8.1	14	0.94		38				
		70-100	74	25	1		7.9	17	0.59		34				
		100 +	72	27	1		8.0	17	0.42						
B-333	Tirs near of Moghrane, Gharb	0-10	61	38		1	8.0	11	0.98	0.15	28	72	19	7	2
		20-30	77	22	1		7.9	13	0.89	0.13	38	67	25	8	2
		30-40	78	20	2		8.4	13	0.98	0.14		66	22	6	1
		70-80	82	16	2		8.3	11	1.04	0.14	36	55	30	12	2
B-152	Black Tirs of Sidi Slimane, Gharb	2--15	62	18	13	7	8.0	0	0.42		48				
		20-30	60	23	13	4	8.0		0.45		46				
		55-80	66	18	15	1	7.9	3	0.34		39				
		80-110	63	20	16	1	8.0	6	0.25		39				
		110-160	64	20	15	1	8.0	11	0.18		35				
B-331	Black Tirs near of Moghrane, Gharb	0-10	64	21	13	2	7.8	2	1.54	0.15	53	74	22	2	11
		40-50	63	22	13	2	8.2	2	1.01	0.1	54	70	26	3	1
		70-80	62	22	13	3	8.6	1	0.78	0.08	52	60	30	9	1
		110-120	64	22	12	2	8.3	2	0.71	0.12	50	52	34	13	1
		130-140	64	27	6	3	8.2	18	0.56	0.06					
		150-160	56	24	19	1	8.2	45	0						
		170-180	43	38	15	4	8.3	34	0						
B-335	Brown Tirs = Brown soil of Sidi Slimane Gharb	0-10	62	18	17	3	7.8	2	0.94			81	16	2	2
		30-40	65	16	17	2	7.6	1	0.93			78	17	2	4
		50-60	67	13	13	7	7.8	1	0.47		42	74	21	3	2
		90-100	60	25	13	2	8.0	2	0.48		40	75	20	3	2
		120-130	58	24	17	1	8.1	11	0.46		30	72	22	4	2
		150-160	46	17	36	1	8.0	21	0.27						
Z-1	Gray Tirs Zaer	0-10	40	46	9	5	7.3	1	0.75	0.08	43	67	18	7	8
		10-40	45	43	7	5	7.1	0	0.63	0.06	44	65	25	6	4
		40-80	46	42	7	5	7.2	0	0.5	0.04	41	58	33	5	3
LR-24	Coarse Black Tirs , Doukkala	0-10	53	6	32	9	7.6	0	1.25	0.08	39				
		10-50	57	7	26	10	8.1	3	1.06	0.08		88	10	2	
		50-100	59	6	25	10	8.0	3	0.96	0.07	43	76	22	2	
		100-200	59	7	26	8	7.9	7	0.74	0.05	39	62	36	2	
LR-54	Gray BrownTirs, Doukkala	0-10	34	12	38	16	7.5	2	1.33	0.17	24	96	1	3	
		10-50	45	13	30	12	7.9	17	0.78	0.08	22	90	8	2	
		50-100	44	13	30	13	8.3	12	0.62	0.07	22	83	16	1	
		100-200	51	19	14	16	8.2	17	0.18	0.04	23	81	17	2	
LZ-18	Brown Soil tirsified, Doukkala	0-10	34	4		62	6.9	0	1.11	0.07					
		10-30	44	4	37	15	7.0	0	1.07	0.09	33	86	2	1	
		30-50	46	5	34	15	7.7	17	0.64	0.08	23	93	6	1	
		50-150	61	4	25	10	7.8	49	0.31	0.03	17	93	5	2	

The evolution of limestone appears to begin in young Tirs per its concentration in the form of granules, although hydrological conditions are unfavorable to its displacement, for two main reasons: the topographical situation and age of the soil.
If we compare these data with those of Vertisols in the Mediterranean region, we find that these soils have the same characteristics as the Tirs of Morocco. Indeed, two profiles "Barrus" of Portugal (Table 4) are completely decalcified.

Table 4: Physical and chemical characteristics of Vertisols in Portugal [8].

Profile	Soil description	depth (cm)	Clay %	Slit %	Sand %	pH eau	$CaCO_3$ (%)	C (%)	N (%)	CEC	Ca	Mg	Na	K
										cmol (+)/kg sol				
1-P	Black Profile very decarbonized "barrus"	0-40	43	19	38	7.8		0.95	0.12	21.6	61.1	20.8	4.6	1.4
		40-70	48	17	35	8		1.05	0.13	28.8	57.3	31.3	3.5	1
		70-90	41	16	42	8.3	3.1	0.64	0.07	30.7	55.7	34.2	4.1	
2-P	Black Profile reddish very decarbonized "barrus"	0-30	61	11	29	7.4	0,9			25.8	76.5	11.6	3.9	
		30-80	60	25	15	7	0,5			31.1	64.6	20.6	2.2	

By contrast, profiles of the "terra negra / Andalucia" are uniformly limestone from the surface (Table 5).

Table 5: Physical and chemical characteristics of a Vertisol in Spain [8].

Profile	Soil Description	depth (cm)	Clay %	Slit %	Sand %	pH water	$CaCO_3$ (%)	C (%)	N (%)	CEC	Ca	Mg	Na	K
										cmol (+) /kg sol				
1-E	Vertisol lithomorph	0-5	53	17	29	7.5	31	0.6	0.1	19	81.5	11.3	6.9	0
		5-35	46	24	29	7.6	31.4	0.5	0.1	19.3	84	10.4	5.5	
		35-70	43	24	32	-	34.2	0.3	0	-	-	-	4	3.2
		70-150	40	24	35	7.7	32.8	0.1	0	17.3	65	17.9	14.5	2.9

Furthermore, the profile of the black soil of Limagne (France) looks suspiciously like profile P 151 gray Tirs of Gharb (Table 6).

Table 6: Physical and chemical characteristics of a Vertisol in France [8].

Profile	Soil description	Depth (cm)	Clay %	Slit %	Sand %	pH water	$CaCO_3$ (%)	C (%)	N (%)	CEC Cmol (+)/kg soil
1-F	Black soil of Limagne	0-30	62	24	15	8	16.1	1.9	0.1	49.7
		30-40	54	31	15	8.3	17.4	1.6	0.1	53.2
		40-70	48	40	12		11.7	1.1		
		70-105	52	32	16	8.1	4.4	1.0	0.08	53.4
		105-140	55	25	20		1.6	1.2	0.06	
		140-150	54	22	25		2.1			

Vertisols Texas (USA) are completely decalcified (Table 7) and similar toTirs of Doukkala (LR-24, Table 3), but those soils have high content of silt like Tirs of Zaer (Z-1, Table 3).

Table 7: Physical and chemical characteristics of Vertisols in U.S.A. [12]

Profile	Region	Depth	Caly	Silt	Sand	pH (H_2O)	$CaCO_3$ (%)	CEC cmol(+) / kg soil	Ca	Mg	Na	K
		(cm)	%	%	%				ech	ech.	ech.	ech.
									cmol (+)/kg sol			
1-U	Typic chromoxerert , Riverside County, Texas	0-10	27	50	23	7.8	t*	25	17	6	1.9	0
		10--25	37	43	19	7.8	t	31	20	9	1.2	1
		25-36	40	40	20	8.9	t	32	29	8	0.8	2
		36-61	40	42	18	9.3	4	31	30	8	2.8	1
		61-84	41	40	19	9.3	5	31	31	8	4	1
		84-135	44	41	15	9	4	37	34	9	5.9	1
		135-150	47	45	8	8.7	2	48	42	13	8.1	1
		150-170	47	45	8	8.7	1	53	51	14	8.6	1
		170-185	35	44	21	8.7	t	59	47	15	8.8	1
2-U	Udic Pellustert, Collin County, Texas	0-15	36	41	23	6.4	t	27	23	4	0.3	1
		15-56	44	39	17	6.3	t	32	27	5	1.4	1
		56-84	45	39	16	6.6	t	33	28	5	2.6	1
		84-125	45	39	16	7.7	t	32	25	4	3.7	1
		125-165	48	38	14	7.6	1	32	26	4	4.2	1
		165-200	50	35	15	7.7	1	31	26	4	4.5	1
		200-245	50	33	17	7.8	4	28	25	4	4.5	1

* t= trace

Since these Vertisols are under a semi-arid to subhumid climate, they are enriched by Illuviation because they are often poorly drained. As a result, their pH is high, sometimes exceeding 8 with the presence of $CaCO_3$ dice the surface and accumulate in depth (profils 2-Su and 4-Ni, table 8). However, Acid Vertisols are also present with a pH below 6 (Profile 1-Et, Table 8) and high saturation of Mg [35]. The profile of Tirs in Gharb (B-331, Table 3) is similar to the profile of Vertisol of Sudan (2-Su, Table 8) while that of Nigeria (4-Ni, Table 8) is most similar to the profile Tirs of Gharb (B-152, Table 3).

Organic matter

Tirs organic matter content is generally less than 2% as in the majority of Moroccan soils [36].
Its distribution in Tirs profiles can lead to the following notes;

- In soils low in humus, organic matter rate remains fairly constant throughout the soil mass, while slightly decreasing with depth (B-152 profiles and Z-1, Table 3).
- In rich humus soils, there is a stratification of organic matter and its rate decreases rapidly and regularly from the top to the bottom profiles (profiles B-151, B-331 and LZ-18, Table 3).

The same phenomenon can be observed in the Vertisols of the Mediterranean basin. In the first group (isohumic) belong profiles 1-P in Portugal (Table 4) and 1-E in Spain (Table 5) and the second group corresponds to profile 1-F in France (Table 6).
The C/N ratio varies generally around 10 in Moroccan Tirs. It would be as low in the soils of the Iberian Peninsula and higher as in the soils of France (Table 6).

Coloration

In Vertisols, the black color intensity is not related to the organic content. The humic clay complex explains the intensity of this black color [15]. The oxidation of the organic matter by hydrogen peroxide gives the soil a darker shade. For Tirs, the color is yellowish (Table 9) as shown in the Munsell code and the "hue" varies from 5YR to 10 YR. For brown Tirs, the values of "hue" are found in the board of 7.5 YR.

Table 8: Physical and chemical characteristics of Vertisols in Africa [1].

Profil	Region	Depth (cm)	Clay %	silt %	sand %	pH (H_2O)	$CaCO_3$ (%)	CEC cmol(+) / kg soil	Ca	Mg	Na	K
									cmol (+)/kg sol			
1-Et	Typic Chromuster, Holetta, Ethiopia	0-15	31	41	28	5.7	-	55	17	17	-	2.2
		15-45	51	33	16	5.2	-	49	18	18	-	0.68
		45-75	67	21	12	6.6	-	49	26	11	-	1.2
		75-160	73	11	16	7.1	-	66	37	15	-	1.92
		160-190	71	17	12	7.6	-	66	44	15	-	0.92
2-Su	Dinder series typic Chromuster, Dinder, Kenana and Mazmurares, Sudan	0-3	75	20	4	7.2	1.1	84	-	-	0.9	1
		3-20	66	28	5	7.6	2.1	87	-	-	1.6	0.8
		20-45	73	21	5	8.4	1.8	84	-	-	3	0.8
		45-80	75	20	4	8.3	1.8	83	-	-	6	0.5
		80-120	77	19	3	8	1.2	83	-	-	7.5	0.8
		120-145	77	19	3	8.5	1.8	75	-	-	8.9	0.5
		145-185	77	18	4	7.9	3.1	84	-	-	8.7	0.5
3-Zi	Entic Pellustert, Chisumbanje, Zimbabwe	0-10	62	23	15	7.5	0.1	86	52	40	0.7	1.73
		12-27	67	13	20	7.6	0.1	92	50	42	1.37	1.32
		30-45	72	11	17	7.7	0.1	85	46	45	2.41	1.23
		60-75	75	11	15	7.8	0.1	95	46	48	4.26	1.23
		95-110	79	8	14	7.8	0.1	96	45	50	5.72	1.29
4-Ni	Typic Pellustert, Ngala, Nigeria	0-40	68	16	16	8.2	5.5	47	16	5	4.1	0.9
		40-103	76	10	14	8.6	6	52	18	5	7.8	1
		136-175	74	3	23	9.3	4.5	67	24	13	1.1	0.2

According to Bryssine, [8], we can see two parallel processes of evolution of the coloration of Tirs:

- An increasing degree of reddish contrast, which is gradually affecting the upper horizons of the Gharb Tirs;
- Tirsification by the presence of a yellowish color in the upper horizons in Tirs Doukkala.

It should be noted that the brilliance of the soil colors is also related to the existence of glossy surfaces in deep horizons with angular structure (prismatic, cubic, flat or tetrahedral) pronounced. Such a structure is clearly visible in dark Tirs. By contrast, brilliance does not exist in the upper horizons of these soils or in the deep horizons gray Tirs.

pH of Tirs

The pH of limestone Tirs is basic from the surface and increases with depth (B-154 and B-333, Table 3). In completely decalcified Tirs (Z-1 and LZ-18, Table 3) the pH is nearly neutral.

Unlike Tirs, Vertisols of other countries have a wide range of pH and a wider distribution of its values in the profiles. Thus, some Vertisols of the U.S.A. (Table 7) and Ethiopia (Table 8) are acidic. Note that the soils of the Iberian Peninsula that approach the Moroccan Tirs seem less acidic.

3.1.2. Soil structure

Tirs structure is an essential element in their soil classification. The soil is grainy on the surface horizon, prismatic and developed in the underlying horizon, and tetrahedral with sliding surfaces lustrous depth. These characteristics are found in dry soils. However, as in all soils of Morocco, the structural state (condition) of Tirs depends on water status and processes of internal pedogenesis can occur in the presence of water. Several authors have described the structural condition of wet Tirs, the change caused by desiccation and also their structural state when drying [8,29,30,37].

Table 9: Profiles coloring Vertisols [8]

Country	Profile	Depth	Munsell		
		Cm	Hue	U	V / C
Morocco's Tirs Plain of Gharb.	B – 153	0-15	10	YR	3/3
		65-73	10	YR	4/3
		> 90	10	YR	5/4
	B - 335	0-10	7.5	YR	3/2
	B - 155	0-12	5	YR	3/3
		60-90	5	YR	4/4
		>90	5	YR	5/4
Spain Vertisol	3 - E	0-5	5	Y	6/3
		35-70	5	Y	5/2
		70-150	2.5	Y	5/3
		> 150	10	YR	6/6
U.S.A. Vertisol	10 - USA	0-15	5	Y	3/1
		125-165	5	Y	4/3
		165-200	5	Y	4/1

Dynamics of structure

The dynamics of the structure of Tirs, as was described by Bryssine [29], is similar to that of other Vertisols presented by some authors [15]. Indeed, the structure of these soils relates to the water content of the horizons. To better appreciate the structure, it is necessary to assess it at different humectations. Figure 1 shows the variability of the structure in a standard profile, taking into account its pedogenetic properties [15].

Zone 1: the depth of this zone starts from surface to 25 cm. It is characterized by frequent alternations of wet and dry conditions which lead to have a prisms form in dry condition.

Zone 2: in this zone, the cracks penetrate vertically contributing to isolate the large prisms. These give rise to polyhedral medium clods.

Zone 3: the depth of this horizon is variable from 10 to 100 cm. The soil stays moist longer. This induces the formation of shaped aggregates in horizontal layout.

Zone 4: this profile is not moist enough to be plastic with fragment structure, is solved by a massive structure giving polyhedrons (slickensides) guarding a sloping trend [15]. The length of this zone can vary from 50 to 125 cm and this massive structure is observed when the mass of clay is from 35 to 40% leading to endohydromorphy status of the soil.

Zone 5: this clay zone is underlying zone 4 or sometimes directly to zone three. It has a massive structure with frequent presence of gypsum and carbonate.

In Vertisol, total macro porosity is high and decreases with depth profile of microporosity which dominates in the wet state. Indeed, dry lumps are hard and compact; they degrade to give the molten appearance [15,38].

The same characteristics are observed in the Tirs. Indeed, despite their high content of clay fractions, these soils are very porous, their total porosity ranges from 60% to 40-45%in volume in the upper and dipper horizons respectively. Dry lumps are extremely compact with a bulk density of clods oscillating around 1.6 $g.cm^{-3}$. It would be about 1.4 $g.cm^{-3}$ in moist soils [10,4].

4. Tirs in Morocco

Several soil [23, 29,39,40] have tried to draw the geographical distribution of Tirs in Morocco. They are often located in the plains and plateaus of the Atlantic slopes Doukkala, Chaouia, Zaer, Gharb, Loukkous, Tangier, Pre-Rif, Sais, Tadla and Haouz. According to a previous estimate [39], the area of tirsified land in Morocco was 0.2 million ha, but this estimate proved below reality. Indeed, consultation about 6.5 million ha of soil studies, conducted over the past decades on various scales (1 / 20,000, 1 / 50,000 and 1 / 100,000), allowed us to estimate the size 1 million hectares spread over several regions of Morocco (Fig. 2).

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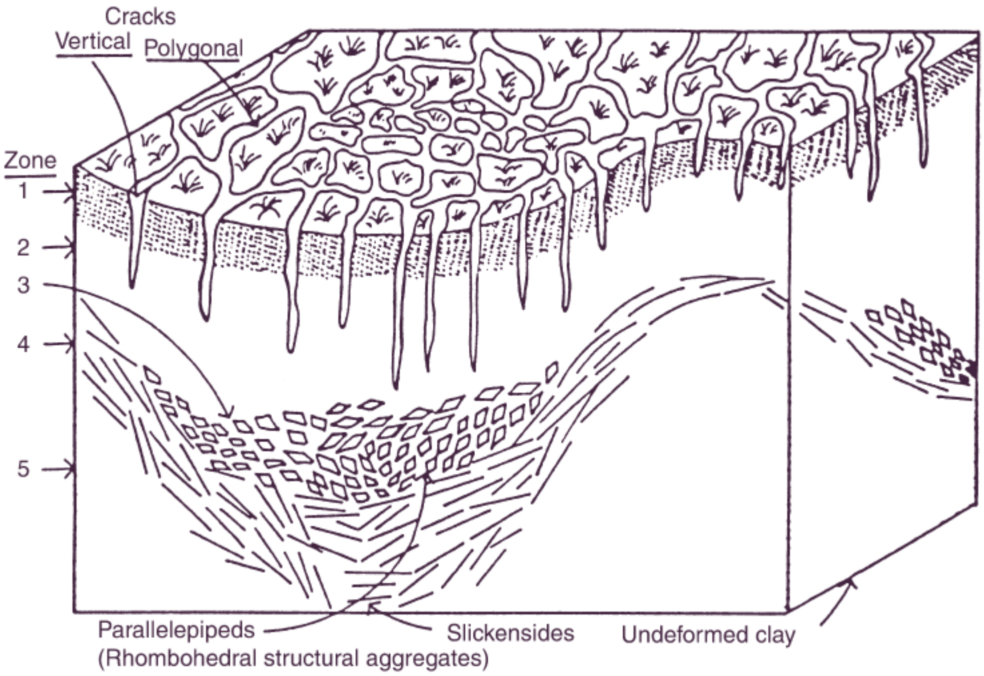

Figure1: Horizons of a Vertisol profile type [15]

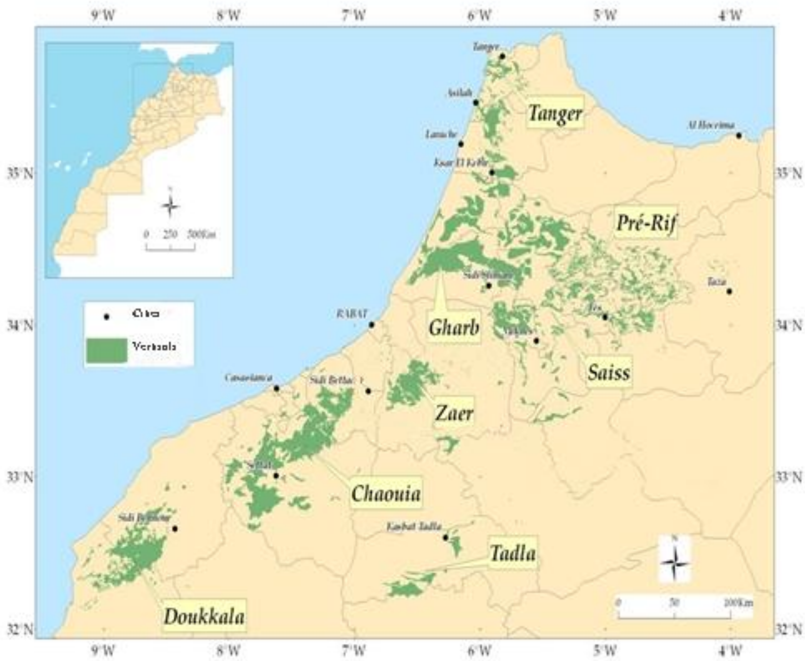

Figure2: Map of the distribution of Tirs in Central and North Morocco

Climate intervenes to explain the degree of profiles tirsification. Indeed, most of the Tirs is in the wide coastal strip of 70 km, with high humidity.

5. Tirs management

Though Tirs soils, like most Vertisols, have a high agricultural production potential , they remain difficult to manage for different reasons [4,15,39].

5.1. Physical constraints

Physical constraints are the major problem of Vertisols and are related to their water regime [2]. As those soils are rich in swelling clays, they retain a lot of water when there are dry generating double intervention of draining of exceeding water and watering to avoid hydric deficiency, [29,10]. This was confirmed by the work of Dudal, De Pauw et al. [41,42]. This result shows that these soils are vulnerable to climate variability if they are not properly managed.

In the dry state, the appearance of cracks is a serious problem for agricultural production in these soils [5]. The management of Vertisol in the semi-arid areas of Morocco through the identification of cropping systems which are able to conserve water in the soil profile as long as possible to reduce the creation of cracks and their vulnerability to erosion[8,10].

5.2. Fertility constraints

Vertisols are considered relatively rich in nutrients [43]. Certainly their potassium rates are often high, while the phosphorus content is generally low. Similarly, the nitrogen content is often low [5,39,44,45], but the input of nitrogen in these Vertisols must be careful in order to avoid losses due to volatilization and denitrification [3]. The same observations were raised in the case of Tirs. Indeed, authors Badraoui and Moujahid [32,34] showed that the mineralogy of these soils creates fertility constraints in terms of phosphorus and nitrogen availability for crops. Development of a cropping system able to improve soil's organic content is recommended to increase the rate of phosphor and nitrogen in those soils [46].

Conclusion

In conclusion, we can say that the Tirs of Morocco have many similarities with Vertisols under Mediterranean climate and occupy a large area in the country (about one million ha). However, these soils are often over-exploited and degraded. They require the adoption of crop management systems to improve their physical and chemical qualities and to make them sustainably productive. Conservation agriculture can be a promising alternative to the sustainable management of Morocco's Tirs but the adoption of such system requires the completion of research on the behavior of these soils under conservation farming techniques (eg no-tillage) taking into account local environmental conditions.

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