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Project title: Improving Soil FERtility in Arid and semi-arid regions using Local organic DAte palm residues

D3-3 Site characterisation

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Summary

This report details the initial properties of the soils and the irrigation water of the study sites. Properties have been measured for 3 sites in Algeria, 2 sites in Tunisia and 2 sites in Spain. The sites in Algeria and Tunisia are notably used for field experiments. The sites in Spain are exclusively used for laboratory experiments. All the soils of the 7 sites have all been sampled. The initial parameters of the topsoil (0-20 cm) of all the study sites of the ISFERALDA project have been measured.

Five of the seven studied soil are sandy to loamy sand. The 2 other soils are loamier (Biskra and Saladares del Guadalentin sites). All soils are alkaline with pH ranging from 7.9 to 8.5. The 3 sites located in palm groves (Kebili, Oued Righ and Ouargla) have organic matter content below 1%. The 2 sites located in the institutes (El Fje-IRA, Biskra-UMKB) have slightly higher organic matter content, with value just above 1%. The 2 sites in Spain have the highest organic matter content, 2.28% and 2.17% for the sites of Saladares del Guadalentin and Cañada De Gallego respectively. The nitrogen content is higher in the Spanish sites, with value of 0.12 and 0.19 %. They are lower in Algerian and Tunisian soils with values ranging from 0.02 to 0.09 %.

Based on the electrical conductivity and ESP values of the surface horizons, the soils studied cannot be considered as saline or sodic soils. However, soils of Kebili and Oued Righ sites are gypseous especially at depth. Moreover, the electrical conductivity of the sampled surface horizons is always greater than or close to 1 mS/cm and can be as high as 4.14 mS/cm. This means that the soils studied have a fairly high salinity which may have an influence on the crops studied in the ISFERALDA project.

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1 Presentation

Five study sites were chosen for the field trials: 3 in Algeria and 2 in Tunisia (Figure 1). In Spain, two soils were also sampled for laboratory experiments (Figure 2). Samples were taken from these 7 sites to determine their initial properties. Irrigation water was also analyzed to assess notably the risk of salinization.

Figure 1: Location of study sites for field trials

Figure 2: Location of study sites in Spain

2 Methodology

To determine the initials properties of the soils, many parameters have been measured. The methods used are standardised and mostly performed in accredited laboratories. References of the methods are presented in the Table 1.

Table 1: References of the methods

Analysis	***Method reference***
Coarse sand (0.2 to 2 mm)	NF X31-107
pH water	*NF X-31-103*
Bulk Density	Ring method
Organic matter	OC x 1.72
Organic carbon (OC)	*NF ISO 14235*
Total Nitrogen	NF ISO 11261
phosphorus content (Olsen)	NF ISO 11263
Exchangeable potassium	*NF X31-108*
Exchangeable magnesium	NF X31-108
Exchangeable calcium	*NF X31-108*
Exchangeable sodium	NF X31-108
Cation Exchange capacity (CEC)	*NF X31-130*
Electrical conductivity	*PTA-FQ-012, based on UNE 77308*
Total limestone	NF ISO 10693
active limestone	*NF X31-106 (B)*
Extractable iron	Oxalic
Zinc (EDTA extraction)	NF X31-120
Copper (EDTA extraction)	*NF X31-120*
Manganese (EDTA extraction)	NF X31-120
Iron (EDTA extraction)	*NF X31-120*

Amount of exchangeable sodium expressed as a percentage of total exchangeable cations has been calculated as follow:

$$\text{ESP} = \frac{\text{Exchangeable sodium (meq/100g)}}{\text{Cation exchange capacity (meq/100g soil)}} \text{ X } 100$$

The Sodium adsorption ratio (SAR) is an irrigation water quality parameter used in the management of salted soils. It is an indicator of the suitability of water for irrigation. It is calcultated using the formula:

$$\text{SAR} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$ where Na, Ca and Mg contents are expressed in meq/L.

To know the quality of the irrigation water, pH and electrical conductivity were measured using electrode. Total dissolved Solid is estimated by summing contents of cations and anions.

3 Tunisian sites

3.1 El Fje - Medenine site

3.1.1 General description

The study area in which the experiments took place is located in El Fje on the site of the Institut des Régions Arides in the governorate of Médenine in south-eastern Tunisia (Figure 3). Located in the upper arid zone, the El Fjè area is characterised by a hot thermal regime with an average monthly temperature of 20.1°C. The summer is hot and dry with an average temperature of over 27°C, while the winter is mild with an average temperature of around 13°C. Rainfall is around 220 mm.

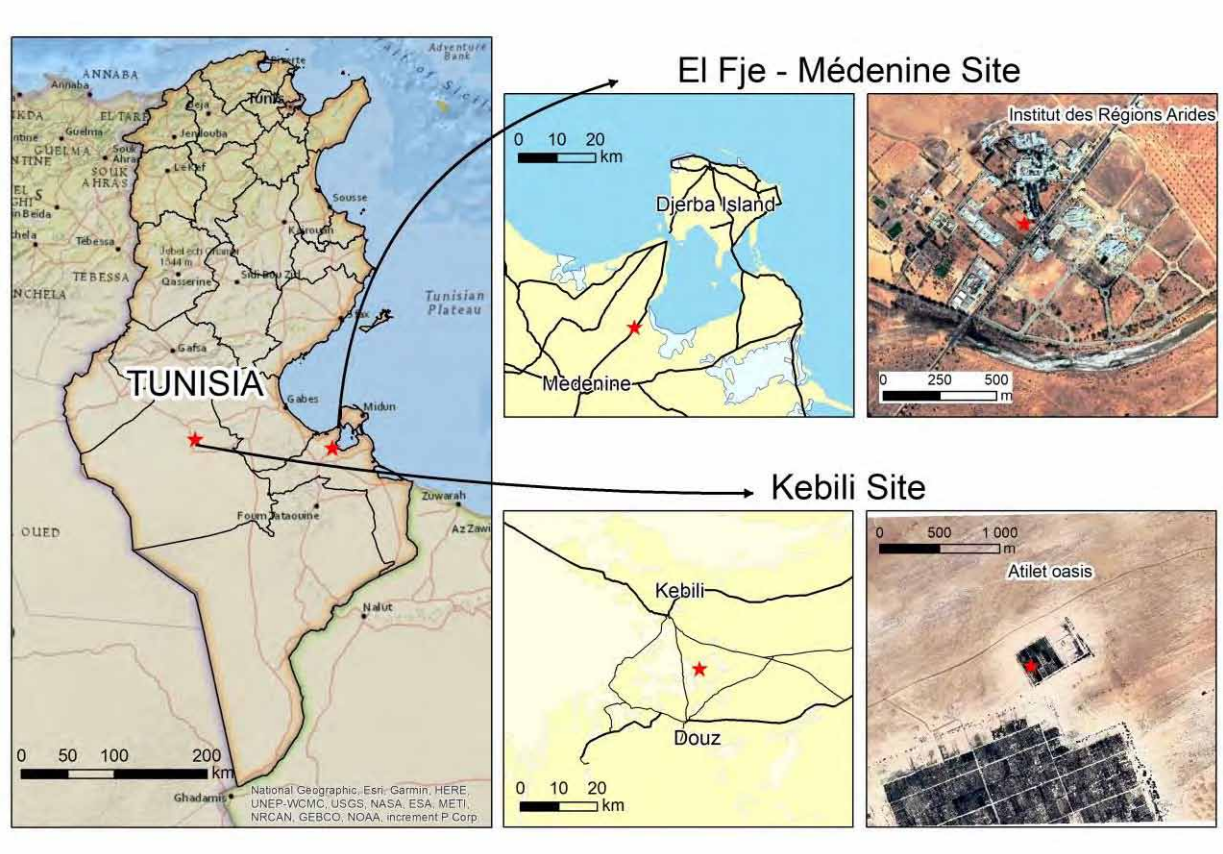


Figure 3: Location of Tunisian study sites

3.1.2 Initial soil characteristics

One sample was collected from the soil profile at a depth of 0-20 cm to determine initial topsoil properties. The sampling was performed in September 2021. The texture of the soil is loamy sand based on USDA classification with a slight percentage of silt in the surface layer (Table 2). The soil has a slightly basic pH and is characterized by high electrical conductivity. It is a soil with low organic carbon and nitrogen contents.

Table 2: Topsoil parameters for the El Fje site

Analysis	***Unit***	***Results***
Clay (< 2 µm)	%	9.5
Silt (2 to 50 µm)	*%*	*2.9*
Sand (50 to 2000 µm)	*%*	*87.6*
pH water		*7.89*
Bulk Density		1.41
Organic matter	%	0.75
Organic carbon (OC)	*% (C)*	*0.44*
Total Nitrogen	% (N)	0.045
C/N ratio		*9.7*
Cation Exchange capacity (CEC)	*meq/100g*	*10.3*
Electrical conductivity	*mS/cm*	*2.5*
Gypsum content	*%*	*2.9*

3.1.1 Characterization of the irrigation water of the El Fje site

The irrigation water of this site is tap water. It has a pH of 7.9. The electrical conductivity is 4.6 mS/cm. The total dissolved solid content is 1.3 g/L.

3.2 Kebili site

3.2.1 General description

The study site of Kebili is located in the oasis of Atilet (Figure 3). It is a continental oasis where the pilot experimental plot of the Institute of Arid Regions is located (Figure 4). This parcel, created in 1987, covers an area of 15 ha.

The Atilet oasis belongs to the Saharan climate characterized by low rainfall, very high temperature and evapotranspiration. This region is subject, throughout the year, to continental winds dry and cold during the winter, dry and hot during the summer. These winds are essentially responsible for the current morphology of sandy accumulations in pre-Saharan Tunisia. Pre-Saharan Tunisia is characterized by strong inter-day and inter-seasonal thermal

amplitudes. The average annual temperature is 21°C. This value is considered optimal for the development of the Deglett-Ennour date palm.

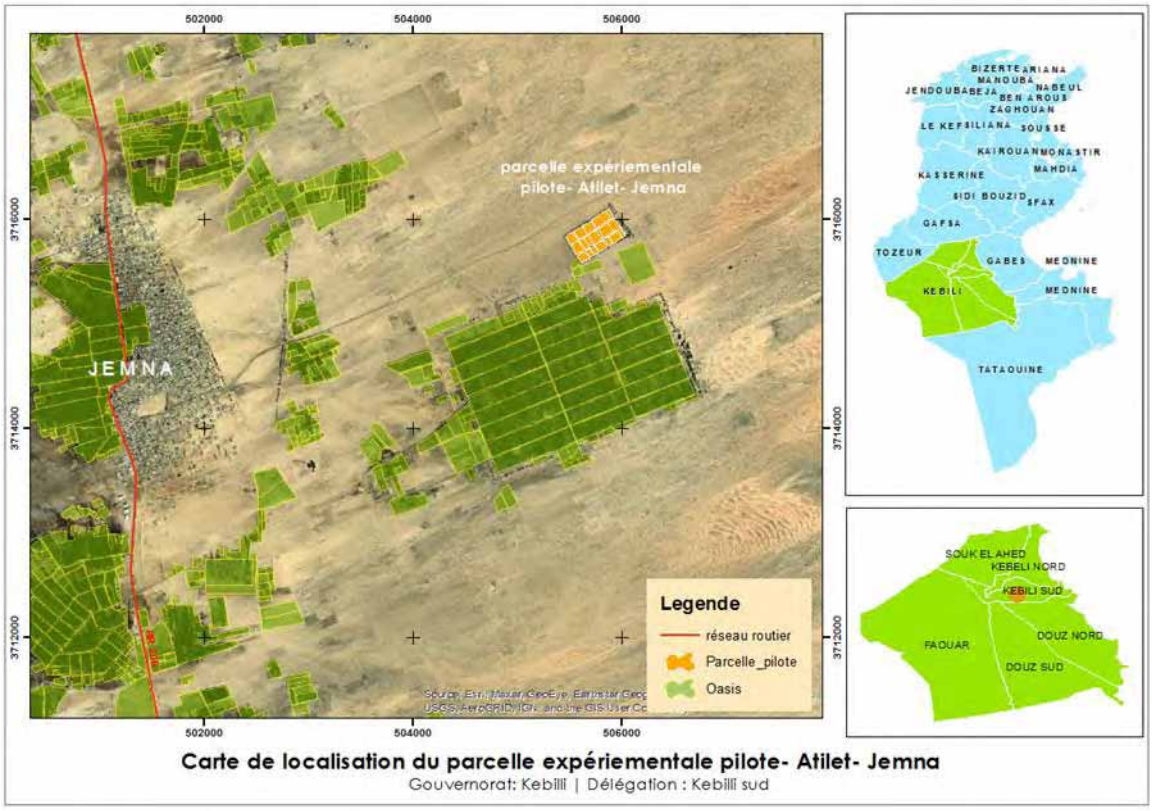


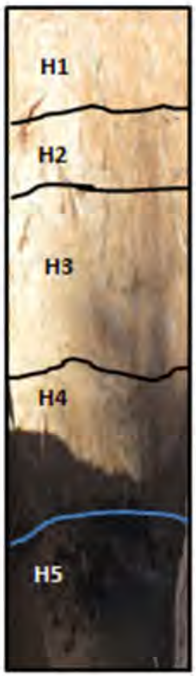
Figure 4: Location of Kebili site

3.2.2 Initial soil characteristics

The soil is deep and mostly sandy with gypsum concretions (Figure 5). In the deep horizons, there are compact crusts and gypsum crusts. This explains the high concentration of gypsum in all horizons of the profile, that can exceed 50%.

In the topsoil, the texture is sandy with a high proportion of medium and fine sand (

Table 3, Figure 6). The soil has a basic pH, with a value of 8.5. The organic matter content is 1.81% with the presence at different depths of gypsum crusts. Based on the classification of Choudhary and Kharche (2018, Table 4), as electrical conductivity in the topsoil is 2.5 mS/cm, the 0-20 cm horizon cannot be considered as a saline horizon. Moreover, as the ESP is smaller than 15, the topsoil cannot also be considered as sodic.



H1: 0-18 cm. Input horizon, dark gray in color (7/3 10YR) with the presence of traces of soil at the edge, with a sub-angular structure, not very compact, with a sandy texture. This horizon does not contain roots. At the base of the horizon, there are gypsum concretions. Biological activity is absent.
H2: 18-23 cm. It is a humic horizon, of different color (4/3 10YR and 5/3 10YR), with a fine sandy texture, subangular structure. At the top, there are few clays, at the base, we notice the presence of inert roots. There are often gypsum concretions. The biological activity is inert.
H3: 23-42 cm. It is a compacted horizon (8/6 10YR), subangular structure, sandy texture. characterized by the presence of small roots more or less important (mixture of annual roots and roots of date palms). Traces of machine passages can be seen.

H4: 42-80 cm. This is a transitional horizon (8/8 10YR), less compact, dark brown in color, marked by the presence of manure with an important concentration of date palm roots. The texture is sandy with little clay.

H5: 80-120 cm. Gley (2.5/5 5GY), uniformly greenish or bluish. It corresponds to the oscillation zone of groundwater, it is characterized by the presence of rusty spots.

Figure 5: Morphological description of the soil profile at the Kebili experimental site

Table 3: Topsoil parameters for the Kebili site

Analysis	***Unit***	***Results***
	Granulometry without decarbonation	
Clay (< 2 µm)	%	3.3
Fine silt (2 to 20 µm)	%	*5.3*
Coarse silt (20 to 50 µm)	%	2.9
Fine sand (50 to 200 µm)	%	*87.0*
Coarse sand (0.2 to 2 mm)	%	1.5
	Granulometry with decarbonation	
Clay (< 2 µm)	%	6.0
Fine silt (2 to 20 µm)	%	*6.6*
Coarse silt (20 to 50 µm)	%	3.6
Fine sand (50 to 200 µm)	%	*66.4*
Coarse sand (0.2 to 2 mm)	%	0.5
pH water		*8.5*
Bulk Density		1.41
Organic matter	%	1.81
Organic carbon (OC)	*% (C)*	*1.05*
Total Nitrogen	% (N)	0.09
C/N ratio		*11.7*

phosphorus content (Olsen)	mg/kg (P_2O_5)	<10
Exchangeable potassium	mg/kg (K_2O)	*178*
Exchangeable magnesium	mg/kg (MgO)	754
Exchangeable calcium	mg/kg (CaO)	*10 029*
Exchangeable sodium	mg/kg (Na_2O)	305
Cation Exchange capacity (CEC)	meq/100g	*5.6*
Exchangeable sodium percentage	%	*2.7*
Electrical conductivity	*mS/cm*	*2.5*
Gypsum content	*%*	*6.4*
Total limestone	% ($CaCO_3$)	12.8
active limestone	%	*2.4*
Extractable iron	mg/kg	24.6
Zinc (EDTA extraction)	mg/kg (Zn)	2.7
Copper (EDTA extraction)	*mg/kg (Cu)*	*<0.5*
Manganese (EDTA extraction)	mg/kg (Mn)	6.2
Iron (EDTA extraction)	*mg/kg (Fe)*	*24.6*

Table 4: Classification of salt-affected soils (table in Choudhary and Kharche, 2018)

Salt-affected Soil	*Soil pH*	*Electrical conductivity (mS/cm)*	*Sodium adsoprtion ratio (SAR)*	*Exchangeable sodium percentage (ESP)*
None	< 8.5	< 4	<13	< 15
Saline	< 8.5	>4	<13	< 15
Sodic	< 8.5	< 4	>13	>15
Saline-sodic	< 8.5	>4	>13	>15

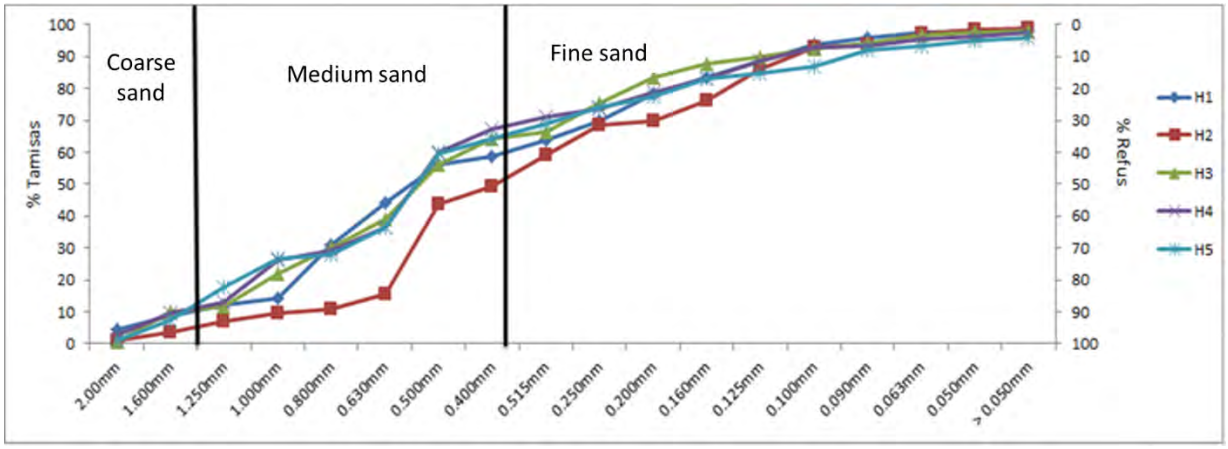


Figure 6: Granulometry of the sand in the soil profile of the Kebili site

3.2.3 Characterization of the irrigation water of the Atilet oasis

The pH of the irrigation water is neutral. These waters have high sodium (Na), calcium (Ca), potassium (K) and magnesium (Mg) contents (Table 5). Irrigation water has potassium and sodium facies. The water lead to a risk of soil salinisation but to a low risk of alkalinisation. The salinity, which is medium to high, remain acceptable for date palms, especially as the sandy texture of the studied soils allow salts leaching.

Table 5: Properties of the irrigation water of the Kebili study site

Parameter	Unit	
pH		7,76
Electric conductivity	(mS/cm) Réf 20°C	3,31
HCO_3^-	mg.L-1	122
F^-	mg.L-1	0
Cl^-	mg.L-1	709,5
NO_3^-	mg.L-1	0
SO_4^{2-}	mg.L-1	922,25
Na^+	mg.L-1	400,8
K^+	mg.L-1	48,75
Mg^{2+}	mg.L-1	74,25
Ca^{2+}	mg.L-1	265,75
Total Dissolved Solid	mg.L-1	2543,3
Sodium Adsorption Ration	$mmol^{1/2}\ L^{-1/2}$	30.74

4 Algerian Sites

4.1 Oued Righ Site

4.1.1 General description

The region of Oued Righ is located in the north of the Algerian Sahara. In this region, there is a vast set of palm groves surrounded by dunes. This region is bordered by the Ziban region to the north, to the east by the large dune alignments of the eastern erg, to the south by the oases of Ouargla and finally to the west by the Dzioua depression (Figure 7). The oases of this region are distributed from north to south over a length of about 150 km. The width of the area varies between 20 and 30 km.

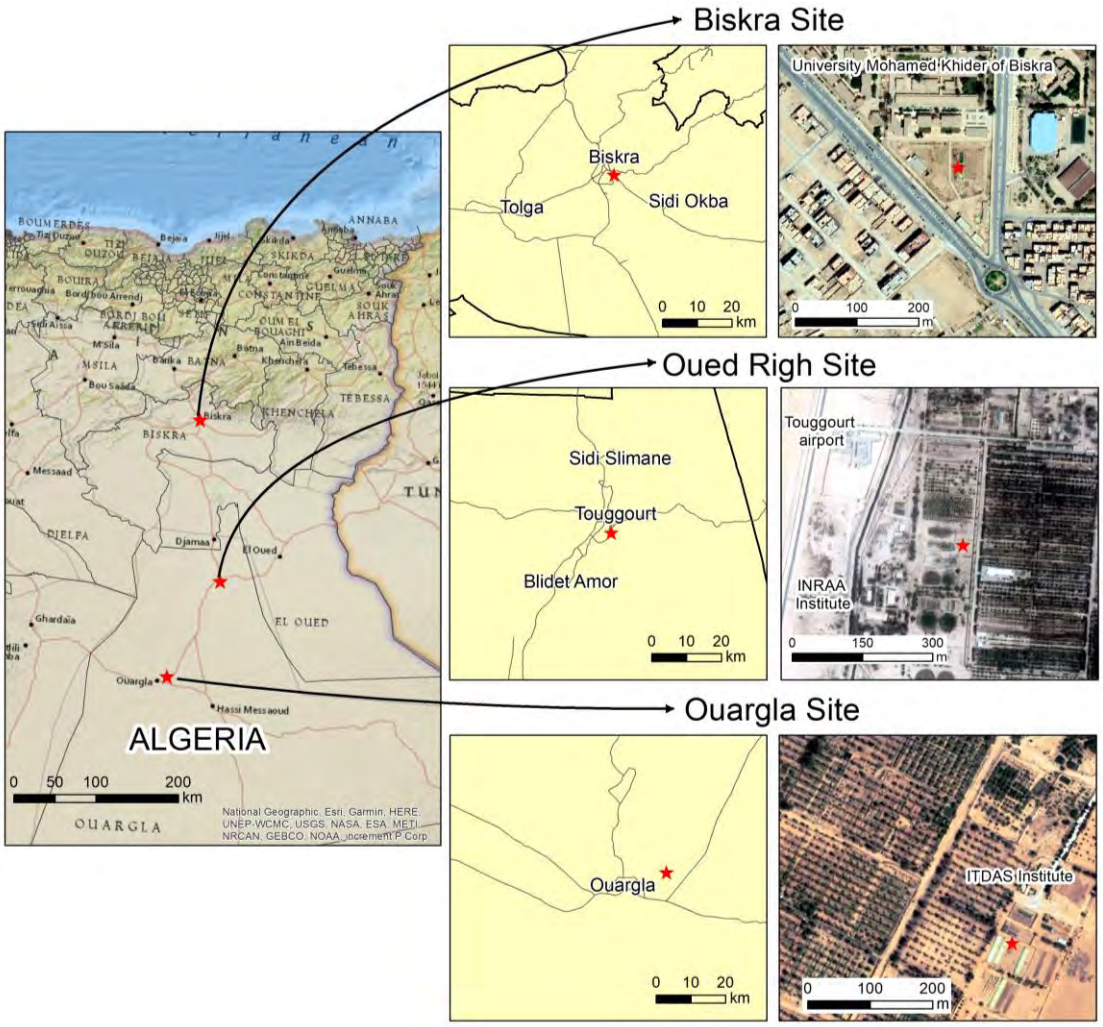


Figure 7: Study sites in Algeria

4.1.2 Initial soil characteristics

Table 6: Topsoil parameters for the Oued Righ site

Analysis	***Unit***	***horizon 0-20 cm***	***0-40 cm***
		Granulometry without decarbonation	
Clay (< 2 µm)	%	10.5	
Fine silt (2 to 20 µm)	%	*4.0*	
Coarse silt (20 to 50 µm)	%	4.5	
Fine sand (50 to 200 µm)	%	*58.6*	
Coarse sand (0.2 to 2 mm)	%	22.4	
		Granulometry with decarbonation	
Clay (< 2 µm)	%	2.5	
Fine silt (2 to 20 µm)	%	*5.4*	
Coarse silt (20 to 50 µm)	%	6.5	

Fine sand (50 to 200 µm)	%	*49.4*	
Coarse sand (0.2 to 2 mm)	%	23.4	
pH water		*8.3*	*8.3*
Bulk Density		1.25	
Organic matter	%	0.61	0.41
Organic carbon (OC)	*% (C)*	*0.35*	*0.24*
Total Nitrogen	% (N)	0.03	0.02
C/N ratio		*13.6*	*12.5*
phosphorus content (Olsen)	mg/kg (P_2O_5)	42	31
Exchangeable potassium	mg/kg (K_2O)	*171*	*178*
Exchangeable magnesium	mg/kg (MgO)	340	343
Exchangeable calcium	mg/kg (CaO)	*54 433*	*55 356*
Exchangeable sodium	mg/kg (Na_2O)	328	394
Cation Exchange capacity	meq/100g	*2.8*	*2.8*
Exchangeable sodium percentage	%	*0.6*	*0.7*
Electrical conductivity	*mS/cm*	*4.3*	
Total limestone	% ($CaCO_3$)	3.0	3.1
active limestone	%	*1.5*	*1.5*
Extractable iron	mg/kg	14.7	14.7

The pedogenesis of the soil of this site is dominated by the action of groundwater and the salts it contains. Under equal conditions, the degree of development of the morphological characteristics of the soils depends on the clay content (SOGETA-SOGHREA, 1969-1970).

The soils contain a very high proportion of gypsum crystals of all sizes (40% on average). The superficial and shallow horizons (less than 70 cm) are homogeneous. Their clay content varies around 10% and their texture is a loamy sand. The soil is salty, but there is no alkalinization of the absorbing complex. In fact, the type of salt is calcium sulfate, sodium chloride beyond. The ions present are chlorides and sulfates. The contents of bicarbonate are always low. The contents of carbonates are null. The cations are represented by sodium. Calcium is found in the form of gypsum and is therefore not very soluble. The potassium content is always low. The pH is slightly alkaline. The organic matter content is very low with a value of 0.61%.

In addition, the physical properties of the soils are characterized by a low apparent density of the soils in the regularly plowed surface horizons. It is about 1.25. The total porosity of the surface horizons has values between 40 and 60%. In the deeper horizons, the porosity is lower than that of the surface horizons, with values between 30 and 45%.

As Kebili site, Oued Righ site is an oasis ecosystem representative of many palm groves of the region.

4.1.3 Characterization of the irrigation water of the Oued Righ site

The water used for irrigation is groundwater coming from the terminal complex aquifer. It is generally shallow, 100 to 250 m. Its temperature is around 20 to 25 °C at the head of the borehole. The pH is 8.02. The Cl^- anions are the most abundant in this water. The distribution of cations is more balanced between sodium, magnesium and calcium ions (Table 7). The type of salt is sulphated – chlorinated. Sodium Adsorption Ration is lesser than 6 (4.84 $mmol^{1/2}L^{-1/2}$) and electrical conductivity is high with a value of 5.89 mS/cm. That means that this water is usable for irrigation, they may present a danger of alkalinisation of the soil, but no danger of soil salinization or reducing the infiltration rate.

Table 7: Properties of the irrigation water of the Oued Righ site

Parameter	Unit	
pH		8.02
Electrical conductivity	(mS/cm) Réf 25°C	5.89
HCO_3^-	mg.L-1	103.7
Cl^-	mg.L-1	1866.1
SO_4^{2-}	mg.L-1	997
Na^+	mg.L-1	384.6
K^+	mg.L-1	33.9
Mg^{2+}	mg.L-1	164.8
Ca^{2+}	mg.L-1	204.6
Total Dissolved Solid	mg.L-1	3754.7
Sodium Adsorption Ration	$mmol^{1/2}\ L^{-1/2}$	4.840

4.2 Ouargla site

4.2.1 General description

The Hassi Ben Abdallah farm in the Ouargla basin is one of the ITDAS demonstration and seed production farms. It is located in an oasis 30 km east of the city of Ouargla, in the south-eastern sector of the Hassi ben Abdallah palm grove. It covers an area of 21 ha. It was created from drillings in the albian groundwater.

Ouargla site is the southernmost of the ISFERALDA project study sites. The dominant climate is Saharan. During the year, there is practically no rainfall. The average temperature in Ouargla is 22.9°C. The average annual rainfall is 39mm. Warm Siroco winds and sandstorms cause a greenhouse effect throught the dust they raise. These contribute to the drying out of the climate, requiring the use of irrigation.

4.2.2 Initial soil characteristics

The texture of the soil of Ouargla site is loamy sand based on USDA texture triangle. It is an alkaline soil, with a pH of 8.5 in the topsoil (Table 8). The organic matter content is very low with a value of 0.33 %. With an electrical conductivity of 0.95 mS/cm, the soil has low salinity.

This soil is moderately calcareous and slightly gypseous according to the classification of Baize (2000).

Table 8 : Characteristic of the topsoil of the Ouargla plot

Analysis	***Unit***	***horizon 0-20 cm***	***20-40 cm***
		Granulometry without decarbonation	
Clay (< 2 µm)	%	5.8	
Fine silt (2 to 20 µm)	%	*2.0*	
Coarse silt (20 to 50 µm)	%	5.2	
Fine sand (50 to 200 µm)	%	*43.8*	
Coarse sand (0.2 to 2 mm)	%	43.2	
		Granulometry with decarbonation	
Clay (< 2 µm)	%	2.1	
Fine silt (2 to 20 µm)	%	*0.9*	
Coarse silt (20 to 50 µm)	%	4.2	
Fine sand (50 to 200 µm)	%	*37.1*	
Coarse sand (0.2 to 2 mm)	%	47.7	
pH water		*8.5*	*8.6*
Bulk Density			
Organic matter	%	0.33	
Organic carbon (OC)	*% (C)*	*0.02*	
Total Nitrogen	% (N)	0.024	
C/N ratio		*8.0*	
phosphorus content (Olsen)	mg/kg (P_2O_5)	41	
Exchangeable potassium	mg/kg (K_2O)		
Exchangeable magnesium	mg/kg (MgO)		
Exchangeable calcium	mg/kg (CaO)		
Exchangeable sodium	mg/kg (Na_2O)		
Cation Exchange capacity	meq/100g	*2.4*	
Exchangeable sodium percentage	%		
Electrical conductivity	*mS/cm*	*0.95*	*0.79*
Gypsum content	*%*	*1.66*	*1.66*
Total limestone	% ($CaCO_3$)	4.8	
active limestone	%	*1.0*	
Extractable iron	mg/kg	15.1	

4.3 Biskra site

4.3.1 General description

The wilaya of Biskra is located in the south-east of Algeria, in the southern piedmont of the Saharan Atlas. The Biskra site is located in the experimental plots of the University Mohamed Khider of Biskra. It is therefore not located in an oasis ecosystem.

The Biskra region is characterized by generally low and irregular rainfall. The annual average rainfall is around 146.2 mm. The average monthly atmospheric humidity between 2002 and 2011 in Biskra is characterized by low values, around 41.5%.

4.3.2 Initial soil characteristics

For field trials, experimental site of the agronomic sciences department of the University Mohamed Khider of Biskra (UMKB) has been chosen (Figure 7).

Characteristics of the soil sampled in the layers 0-20 and 20-40 cm are presented in the Table 9. The Biskra site has a different soil type compared to the other studied sites. The study of this soil type is important because it is representative of the region and has different agronomic qualities. The texture of this soil is a clay loam based on USDA texture triangle. The pH is alkaline with a value of 8.3. Organic matter content is 1.19%. Based on the value of Exchangeable Sodium Percentage, which is 10.5% in the topsoil and 14.6 just below, this soil is close to the limit of 15% and is therefore close to be considered as a sodic soil. The electrical conductivity in the layer 0-40m is equal to 2.43 mS/cm.

Table 9 : Characteristic of the topsoil of the Biskra site

Analysis	***Unit***	***horizon 0-20 cm***	***0-40 cm***
		Granulometry without decarbonation	
Clay (< 2 µm)	%	30.7	
Fine silt (2 to 20 µm)	%	*36.6*	
Coarse silt (20 to 50 µm)	%	11.0	
Fine sand (50 to 200 µm)	%	*16.1*	
Coarse sand (0.2 to 2 mm)	%	5.6	
		Granulometry with decarbonation	
Clay (< 2 µm)	%	3.3	
Fine silt (2 to 20 µm)	%	*24.8*	
Coarse silt (20 to 50 µm)	%	8.1	
Fine sand (50 to 200 µm)	%	*12.2*	
Coarse sand (0.2 to 2 mm)	%	5.8	
pH water		*8.3*	*8.3*
Bulk Density			

Organic matter	%	1.19	0.90
Organic carbon (OC)	*% (C)*	*0.69*	*0.52*
Total Nitrogen	% (N)	0.05	0.05
C/N ratio		*13.6*	*10.9*
phosphorus content (Olsen)	mg/kg (P_2O_5)	107	102
Exchangeable potassium	mg/kg (K_2O)	*327*	346
Exchangeable magnesium	mg/kg (MgO)	1299	1657
Exchangeable calcium	mg/kg (CaO)		
Exchangeable sodium	mg/kg (Na_2O)	2910	4126
Cation Exchange capacity	meq/100g	*12.1*	*12.3*
Exchangeable sodium percentage	%	*10.*	*14.6*
Electrical conductivity	*mS/cm*	*2.43*	
Total limestone	% ($CaCO_3$)	35.2	34.4
active limestone	%	*10.2*	*10.2*
Extractable iron	mg/kg	37.7	37.7

4.3.1 Characterization of the irrigation water of the Biskra site

The pH of the irrigation water of Biskra site is 8.02 (Table 10). The type of salt is sulphated – chlorinated. Sodium Adsorption Ration is lesser than 6 (5.09 $mmol^{1/2}\ L^{-1/2}$) and electrical conductivity has a value of 4.93 mS/cm. That means that this water is usable for irrigation, they may present a danger of alkalinisation of the soil, but no danger of soil salinization or reducing the infiltration rate.

Table 10: Properties of the irrigation water of the Biskra study site

Parameter	**Unit**	
pH		7,23
Electric conductivity	(mS/cm) Réf 20°C	4.93
HCO_3^-	mg.L-1	439.2
Cl^-	mg.L-1	941.5
SO_4^{2-}	mg.L-1	741.6
Na^+	mg.L-1	489
K^+	mg.L-1	8.2
Mg^{2+}	mg.L-1	240
Ca^{2+}	mg.L-1	300
Total Dissolved Solid	mg.L-1	3159.5
Sodium Adsorption Ration	$mmol^{1/2}\ L^{-1/2}$	5.09

5 Spanish Sites

In Spain, 2 soils with coarse texture, high salinity in semi-arid areas have been selected to perform laboratory experiments in France.

5.1 Saladares del Guadalentin site

The first sampled soil was located close to Alhama de Murcia in Murcia region (Figure 8) in the Guadalentin salt marshes. The

Table 11 shows the parameters of the soil of this site. The granulometry of this soil is silt loam based on USDA classification. It is an alkaline soil with a low value of bulk density. Based on the classification of Choudhary and Kharche (2018, Table 4), the soil cannot be considered as a saline or sodic soil. The value of electrical conductivity (3.26 mS/cm) is close to the limit for classifying a saline soil, the limit being 4 mS/cm. The ESP is too low to consider that soil as a sodic soil. Compared to the Algerian and Tunisian soils, it has a higher organic matter content (2.28 %).

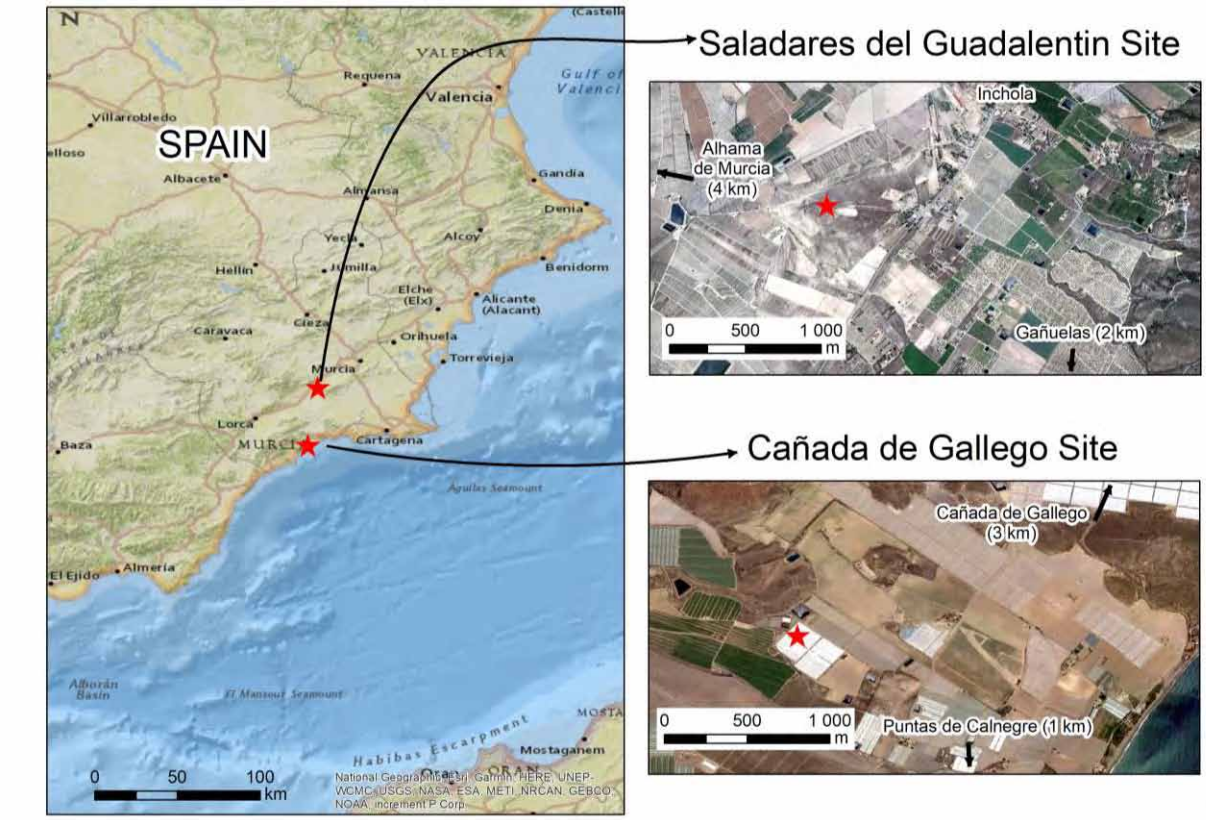


Figure 8: Spanish study sites

Table 11: Topsoil parameters for the Saladares del Guadalentin site

Analysis	***Unit***	***Results***
	Granulometry without decarbonation	
Clay (< 2 µm)	%	18.5
Fine silt (2 to 20 µm)	%	*35.7*
Coarse silt (20 to 50 µm)	%	27.4
Fine sand (50 to 200 µm)	%	*17.7*
Coarse sand (0.2 to 2 mm)	%	0.7
	Granulometry with decarbonation	
Clay (< 2 µm)	%	16.0
Fine silt (2 to 20 µm)	%	*26.2*
Coarse silt (20 to 50 µm)	%	30.5
Fine sand (50 to 200 µm)	%	*14.8*
Coarse sand (0.2 to 2 mm)	%	0.6
pH water		*8.14*
Bulk Density		1.01
Organic matter	%	2.28
Organic carbon (OC)	*% (C)*	*1.33*
Total Nitrogen	% (N)	0.12
C/N ratio		*10.9*
phosphorus content (Olsen)	mg/kg (P_2O_5)	24
Exchangeable potassium	mg/kg (K_2O)	*159*
Exchangeable magnesium	mg/kg (MgO)	1271
Exchangeable calcium	mg/kg (CaO)	*24 656*
Exchangeable sodium	mg/kg (Na_2O)	296
Cation Exchange capacity (CEC)	meq/100g	*8.7*
Exchangeable sodium percentage	%	*1.1*
Electrical conductivity	*mS/cm*	*3.26*
Total limestone	% ($CaCO_3$)	8.4
active limestone	%	*4.3*
Extractable iron	mg/kg	22.1
Zinc (EDTA extraction)	mg/kg (Zn)	1.2
Copper (EDTA extraction)	*mg/kg (Cu)*	*1.4*
Manganese (EDTA extraction)	mg/kg (Mn)	6.6
Iron (EDTA extraction)	*mg/kg (Fe)*	*1.1*

5.2 Cañada de Gallego site

The second sampled soil in Spain was located 3 km south east of the village of Cañada de Gallego in Murcia region (Figure 8) in arable land. The Table 12 shows the parameters of this soil.

The texture of this soil is sandy loam based on the USDA texture triangle. It is an alkaline soil with a value of bulk density of 1.26. Based on the classification of Choudhary and Kharche (2018, Table 4), the soil cannot be considered as a saline or sodic soil. The value of electrical conductivity (3.17 mS/cm) is below the limit for classifying a saline soil, which is 4 mS/cm. The ESP is too low to consider that soil as a sodic soil. Compared to the Algerian and Tunisian soils, it has a higher organic matter content (2.17%).

Table 12: Topsoil parameters for the Cañada de Gallego site

Analysis	***Unit***	***Results***
	Granulometry without decarbonation	
Clay (< 2 µm)	%	*11.6*
Fine silt (2 to 20 µm)	%	*22.8*
Coarse silt (20 to 50 µm)	%	*12.1*
Fine sand (50 to 200 µm)	%	*30.3*
Coarse sand (0.2 to 2 mm)	%	*23.2*
	Granulometry with decarbonation	
Clay (< 2 µm)	%	10.0
Fine silt (2 to 20 µm)	%	*21.4*
Coarse silt (20 to 50 µm)	%	13.2
Fine sand (50 to 200 µm)	%	*23.8*
Coarse sand (0.2 to 2 mm)	%	15.7
pH water		*7.92*
Bulk Density		1.26
Organic matter	%	2.17
Organic carbon (OC)	*% (C)*	*1.26*
Total Nitrogen	% (N)	0.19
C/N ratio		*6.8*
phosphorus content (Olsen)	mg/kg (P_2O_5)	254
Exchangeable potassium	mg/kg (K_2O)	*998*
Exchangeable magnesium	mg/kg (MgO)	1604
Exchangeable calcium	mg/kg (CaO)	*11 704*
Exchangeable sodium	mg/kg (Na_2O)	1678
Cation Exchange capacity (CEC)	meq/100g	*6.1*
Exchangeable sodium percentage	%	*10.5*
Electrical conductivity	*mS/cm*	*3.17*

Total limestone	% ($CaCO_3$)	11.6
active limestone	%	*2.9*
Extractable iron	mg/kg	109.0
Zinc (EDTA extraction)	mg/kg (Zn)	19.8
Copper (EDTA extraction)	*mg/kg (Cu)*	*9.3)*
Manganese (EDTA extraction)	mg/kg (Mn)	22.4
Iron (EDTA extraction)	*mg/kg (Fe)*	*10.9*

6 Synthesis

Seven sites are studied in ISFERALDA project: 3 in Algeria, 2 in Tunisia and 2 in Spain. The sites in Algeria and Tunisia are notably used for field experiments. The sites in Spain are exclusively used for laboratory experiments. All the soils of the 7 sites have all been sampled and analyzed. The initial parameters of the topsoil (0-20 cm) of all the study sites of the ISFERALDA project are presented in the Table 13.

Five of the seven studied soil are sandy to loamy sand. The 2 other soils are loamier (Biskra and Saladares del Guadalentin sites). All soils are alkaline with pH ranging from 7.9 to 8.5. The 3 sites located in palm groves (Kebili, Oued Righ and Ouargla) have organic matter content below 1%. The 2 sites located in the institutes (El Fje-IRA, Biskra-UMKB) have slightly higher organic matter content, with value just above 1%. The 2 sites in Spain have the highest organic matter content, 2.28% and 2.17% for the sites of Saladares del Guadalentin and Cañada De Gallego respectively. The nitrogen content is higher in the Spanish sites, with value of 0.12 and 0.19 %. They are lower in Algerian and Tunisian soils with values ranging from 0.02 to 0.09 %.

Based on the electrical conductivity and ESP values of the surface horizons, the soils studied cannot be considered as saline or sodic soils. However, soils of Kebili and Oued Righ sites are gypseous especially at depth. Moreover, the electrical conductivity of the sampled surface horizons is always greater than or close to 1 mS/cm and can be as high as 4.14 mS/cm. This means that the soils studied have a fairly high salinity which may have an influence on the crops studied in the ISFERALDA project.

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Table 13: Initial soil parameters of the topsoil (0-20 cm) of the study sites of ISFERALDA project

Analysis	Unit	El Fje	Kebili	Oued Righ	Ouargla	Biskra	Saladares del Guad.	Cañada de Gallego
Granulometry without decarbonation								
Clay (< 2 µm)	%	9.5	3.3	10.5	5.8	30.7	18.5	11.6
Fine silt (2 to 20 µm)	%	2.9	5.3	4.0	2.0	36.6	35.7	22.8
Coarse silt (20 to 50 µm)	%		2.9	4.5	5.2	11.0	27.4	12.1
Fine sand (50 to 200 µm)	%	87.6	87.0	58.6	43.8	16.1	17.7	30.3
Coarse sand (0.2 to 2 mm)	%		1.5	22.4	43.2	5.6	0.7	23.2
Granulometry with decarbonation								
Clay (< 2 µm)	%		6.0	2.5	2.1	3.3	16.0	10.0
Fine silt (2 to 20 µm)	%		6.6	5.4	0.9	24.8	26.2	21.4
Coarse silt (20 to 50 µm)	%		3.6	6.5	4.2	8.1	30.5	13.2
Fine sand (50 to 200 µm)	%		66.4	49.4	37.1	12.2	14.8	23.8
Coarse sand (0.2 to 2 mm)	%		0.5	23.4	47.7	5.8	0.6	15.7
pH water		7.9	8.5	8.3	8.5	8.3	8.1	7.9
Bulk Density		1.41	1.41	1.25			1.01	1.26
Organic matter	%	0.75	1.81	0.61	0.33	1.19	2.28	2.17
Organic carbon (OC)	% (C)	0.44	1.05	0.35	0.02	0.69	1.33	1.26
Total Nitrogen	%(N)	0.045	0.09	0.03	0.024	0.05	0.12	0.19
C/N ratio		9.7	11.7	13.6	8.0	13.6	10.9	6.8
phosphorus content (Olsen)	mg/kg (P_2O_5)		<10	42	41	107	24	254
Exchangeable potassium	mg/kg (K_2O)		178	171		327	159	998
Exchangeable magnesium	mg/kg (MgO)		754	340		1299	1271	1604
Exchangeable calcium	mg/kg (CaO)		10 029	54 433			24 656	11 704
Exchangeable sodium	mg/kg (Na_2O)		305	328		2910	296	1678
Cation Exchange capacity (CEC)	meq/100g	10.3	5.6	2.8	2.4	12.1	8.7	6.1
Exchangeable sodium percentage	%		2.7	0.6		10.	1.1	10.5
Electrical conductivity	mS/cm	4.14	2.5	4.3	0.95	2.43	3.26	3.17
Gypsum content	%	2.9	6.4		1.66			
Total limestone	% ($CaCO_3$)		12.8	3.0	4.8	35.2	8.4	11.6
active limestone	%		2.4	1.5	1.0	10.2	4.3	2.9
Extractable iron	mg/kg		24	14.7	15.1	37.7	22.1	109.0
Zinc (EDTA extraction)	mg/kg (Zn)		2.7				1.2	19.8
Copper (EDTA extraction)	mg/kg (Cu)		<0.5				1.4	9.3)
Manganese (EDTA extraction)	mg/kg (Mn)		6.2				6.6	22.4
Iron (EDTA extraction)	mg/kg (Fe)		24.6				1.1	10.9