Chapter2

WP 3.4.1, 3.4.2, 3.4.3 Monitoring of water, soil, crop quality

3.4.1, 3.4.2, 3.4.3 MONITORING DATA (before pilot plant start up)

PILOT SITE –ARBOREA (SARDINIA, ITALY)

During MEDISS first year current data on water supply, water quality, soil composition and crops are collected in each area, were analyzed and organized. Also, a socio-economical analysis and legislation and policies analysis is carried out in each area to provide baseline data on water-related issues. These baselines surveys provide technical directions for pilot initiatives set-up (WP4), and represent reference values to monitor and evaluate their impact. In the final year, while MEDISS pilots will be operative, specific analyses of water, soils and crops will carry out with regularity and resulting data compared with reference and target values to check effectiveness.

The Arborea plain is the most important agricultural area in Sardinia, mainly devoted to the dairy industry (Fig.1) This area is the result of the reclamation of a previous wetland, which occurred between 1919-1935. The landscape is characterized by regular and uniform fields with rectangular plots of equal size. The area is well facilitated with a system of canals and dikes with dewatering pumps that regulated the levels of waters. The management of waters distribution system is operated by “Consorzio di Bonifica of Oristanese”. Moreover the irrigation system was changed recently ensuring a reduction of water quantity use.

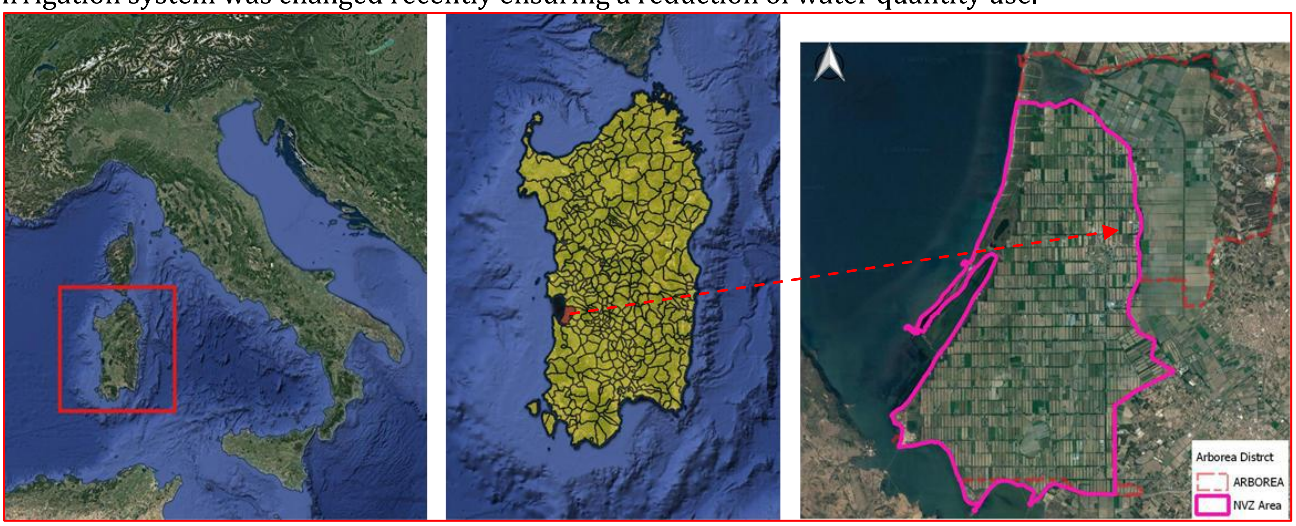


Fig.1 – Location area

In Arborea area two WWTP were built, one is dedicated mainly to the dairy industry (3A -Dairy Industry) and the other one for the rest of wastewater (EX-SIPAS). The Ex-SIPAS sludges will be used by the pilot area for ammonia stripping in the pilot WWTP . The plant is also equipped (not working at the moment) with a system for energy recovery through biogas cogeneration, which allows producing large amounts of electricity and heat that contribute to the support of the plant itself. The pilot plant will be built in the north-east of the Arborea area where the high-efficiency biogas-powered cogenerator is present, produced by anaerobic fermentation of biomass and sludge stored in special structures. The pilot plant will be itself equipped with a photovoltaic plant to reduce the cost of energy in the system.

<u>Legislation and inspection bodies</u>

In European countries, Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures.

The Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (the Nitrates Directive) was adopted on 12 December 1991. It aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices.

This Directive is transposed in Italy with the D.Lgs 152/99 and apply by Autonomous Region of Sardinia Del. n. 4/13 31/01/2006 with the adoption of an Action Program (AP) for the Nitrate Vulnerable Zone (NVZs) in Arborea, involving all the stakeholders for the issue solution. The Oristano Province and ARPAS (Sardinian Regional Agency for the Environment Protection) are the inspections authorities that verify the efficiency of AP through the Monitoring and Control Plan. The water quality monitoring on surficial water bodies, groundwaters, soils and dumps are an ARPAS entrust.

The monitoring activity started in 2007 applying the regulated AP, with the collaboration of the Regional Agency of Idrographic District (ARDIS). Biyearly ARPAS transmit the Report of Activities done and the program activity for the next two years to ARDIS. The last reports considered here is dated 12 November 2018 concerning the 2017 activities that also summarize the previous monitoring results.

In the next paragraphs the ongoing monitoring plan of ARPAS, concerning groundwater and soils into Arborea plain is described. Furthermore is supply a monitoring plan proposal by ENAS, written in collaboration with the agencies described above and other stakeholders operative in this area, with the aims to safely test the Ammonium Sulphate produced by the pilot plant in the crops of the fields, this activity involves Arborea's cooperative of farmers (Cooperativa Produttori Arborea) final beneficiaries of the project.

<u>Groundwater monitoring net - ARPAS (Regional Agency on Environmental Control)</u>

Groundwater is monitored quarterly in 43 stations, 33 of these in the first (I) aquifer (22 piezometers and 11 private wells) and 10 in the second (II) aquifer (5 piezometers and 5 private wells). All of the monitoring stations in NVZ of Arborea insist in the Plio-Quaternary Detritic-Alluvial aquifer n. 1713. In tab n. 1 are listed the monitoring stations in the area, reporting Infos on place, metrics coordinates (Gauss Boaga), elevation, type (well or piezometer), involved aquifer (I or II).

Tab. 1- List of groundwater monitoring stations in Arborea NVZs

Name	ID Regional net	Place	X (m)GB	Y (m) GB	Elevation (m slm)	Type	Aquifer
P1	697	Strada 22 ovest	1461822	4404068	0,61	Piezometer	I
P2	698	Strada 22 ovest	1462676	4404175	2,55	Piezometer	I
P3	699	Strada 22 ovest	1463784	4404120	5,47	Piezometer	I
P4	700	Strada 18 ovest	1461827	4402326	2,51	Piezometer	I
P5	701	Strada 15 ovest	1461089	4401294	1,65	Piezometer	I
P6	702	Strada 15 ovest	1462041	4401295	2,39	Piezometer	I
P7	703	Strada 15 ovest	1462681	4401298	3,06	Piezometer	I
P8	704	Strada 15 ovest	1463638	4401312	5,64	Piezometer	I
P9	705	Strada 14 est	1464559	4400944	4,99	Piezometer	I
P10	706	Strada 11 ovest	1461298	4399696	2,65	Piezometer	I
P11	707	Strada 9 ovest	1463194	4398697	3,87	Piezometer	I
P12	708	Strada 6 ovest	1462232	4397659	5,64	Piezometer	I
P13	709	Strada 15 ovest	1462153	4401301	2,58	Piezometer	I
P14	710	Strada 14 ovest	1463004	4400714	5,24	Piezometer	I
P15	711	Strada 16 ovest	1464058	4401674	6,98	Piezometer	I
P16	712	Strada 16 est	1464305	4401715	6,90	Piezometer	I
P17	713	Strada 9 ovest	1462679	4398862	4,30	Piezometer	I
P20	714	Strada 27 ovest	1463630	4406291	3,92	Piezometer	I
P21	715	Strada 9 ovest	1459818	4398880	1,95	Piezometer	I
P22	716	Strada 11 ovest	1461480	4399497	8	Piezometer	I
P23	717	Strada 5 ovest	1458979	4397398	1,29	Piezometer	I
P24	718	Strada 3 ovest	1461322	4396575	3,72	Piezometer	I
P26	719	Strada 26 est	1464478	4406084	3,71	Piezometer	II
P27	720	Strada 27 ovest	1464053	4406267	6	Piezometer	II
P28	721	Strada 15 ovest	1463428	4401316	4	Piezometer	II
P29	722	Strada 13 ovest	1462680	4400524	3	Piezometer	II
P30	723	Strada 7 ovest	1460133	4398219	3	Piezometer	II
P31	724	Strada 28 ovest	1462527	4406750	0,03	Private well	I

P32	725	Strada 28 ovest	1462867	4406754	1,59	Private well	I II
P33	726	Strada 27 ovest	1463157	4405806	3,33	Private well	I
P34	727	Strada 12 ovest	1461601	4400012	2,67	Private well	I
P35	728	Strada 18 ovest	1462910	4402481	4	Private well	I II
P36	729	Strada 14 ovest	1460371	4400952	0,67	Private well	I
P37	730	Strada 14 ovest	1460447	4400813	1	Private well	I II
P38	731	Strada 2 ovest	1460720	4396137	1,47	Private well	I
P39	732	Strada 22 est	1465064	4404271	3,02	Private well	I
P40	733	Strada 18 est	1464834	4402669	4,14	Private well	I
P41	734	Strada 10 est	1464852	4399395	5,19	Private well	I
P42	735	Strada 4 ovest	1461481	4396963	2,46	Private well	I
P43	736	Strada 4 ovest	1459541	4396958	1,54	Private well	I
P45	737	Strada 2 ovest	1461870	4396181	2	Private well	I II
P46	738	Strada 6 ovest	1463964	4397928	7	Private well	I II
P47	739	Strada 6 ovest	1461138	4397782	4	Private well	I

Out of Arborea NVZ, there are other 2 stations for the monitoring of another aquifer, called Bonifica Sassu aquifer (n. 1712 - Plio-Quaternary Detritic-Alluvial aquifer (Tab. 2).

Tab. 2 - List of groundwater monitoring station out of NVZ

Name	X (m)GB	Y(m) GB	Elevation (m	Type	Aquifer name
P18	1465693	4402788	2	Piezometro	Sassu
P19	1466683	4402784	2	Piezometro	Sassu

The 27 piezometers were made in 2007 for the Monitoring and Control Plan in the NVZ by Regional Authority, the other 16 monitoring stations are private wells for domestic, irrigation and livestock use. In the private wells, where the I and II aquifer are involved, the waters are blended, but taking into account that the II aquifer is more productive than the I these stations must be considered representative of the deep aquifer.

The monitoring stations were identify following homogeneous criteria, take into account the main direction of groundwater flow to be representative of their quality (Fig. 2).

ARPAS monitoring is quarterly based and started in 2007, till 2019 51 monitoring cycles were done. Recorded data till 2015 concern parameters were useful to characterize the aquifers since 2016 both hydrogeochemical and pollutants parameters were recorded (Tab. 3).

Fig. 2 - Groundwater monitoring net stations in the Arborea plain.

Parameters were recorded on field trough multiprobe and portable spectrophotometer test (Tab. 3).

Tab. 3 – ARPAS monitored parameter till 2015 and since 2016 till today

Parameters till 2015	**Parameters since 2016**
pH; Conductivity; Temperature; Redox; Piezometer level;	pH; Conductivity; Oxigen; Temperature; Redox; Piezometer level; Nitrates; Nitrites; Ammonia

Laboratory analysis, with a major number of parameters, are run half-yearly on 10 stations, 8 in the I aquifer and 2 in the II one, these stations are listed in Tab. 4.

Tab. 4 - List of half-yearly groundwater monitoring stations.

Name	**ID Regional net**
P1	697
P3	699
P4	700
P8	704
P11	707
P20	714
P22	716
P23	717
P27	720
P29	722

Analysis done in laboratory:

- ionic balance (chlorides, bicarbonates, sulphates, potassium, sodium, calcium, magnesium, fixed residue at 180 ° C);
- nitrogen compounds (ammonium ion, nitrates, nitrites, total nitrogen);
- metals (iron, manganese, arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc);
- phosphates;
- pesticides (total pesticides);
- TOC (Total Organic Carbon);
- microbiological pollutants (TBL-Total Bacterial Load, Escherichia Coli).

Water samples are collected after the bleed run through a low-flow air pump (bladder pump), where water flow is more than 0.2 l/s submerged pumps is used. A sampling-tab are filled on-field reporting recorded data and hydrogeological and geological features of sampling station.
Types of flasks used to preserve samples:

- 500ml polyethene flask for base parameters;;
- 50 ml polyethene flask, previously acidify with Nitric-Acid, for metals;
- 1000 ml dark glass bottle with teflon sealing gasket for pesticides.

The samples are preserved in portable fridge-box at 4°C till the delivery at ARPAS's Labs.

Historical analysis of Arborea NVZ (ARPAS Activity 2018)
Historical analysis of NVZ site of Arborea is based on 48 monitoring cycles (March 2006-February 2019) focalizing on nitrate compound content dynamic in the first (I) aquifer, the reason that considers this area a Nitrate Vulnerable Area (NVZ) under EU Directive 91/676/EEC.
Nitrate compounds data were analysed yearly and quarterly (Figg. 3, 4), considering 33 sampling stations. These charts track the groundwater nitrate contamination in Arborea NVZ, the upper limit permitted by EU legislation is equal to 50 mg/L NO^{3-}.

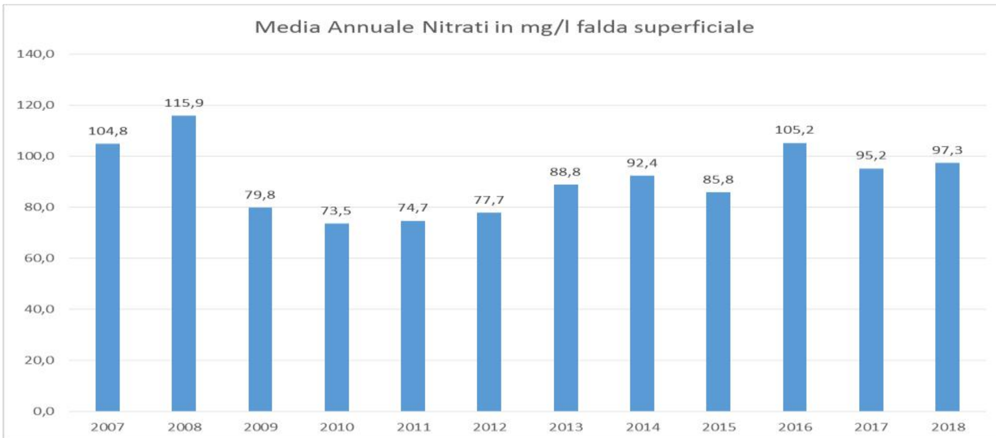


Fig. 3 - Medium annual content of nitrate in the I aquifer (ARPAS- Activity 2018)

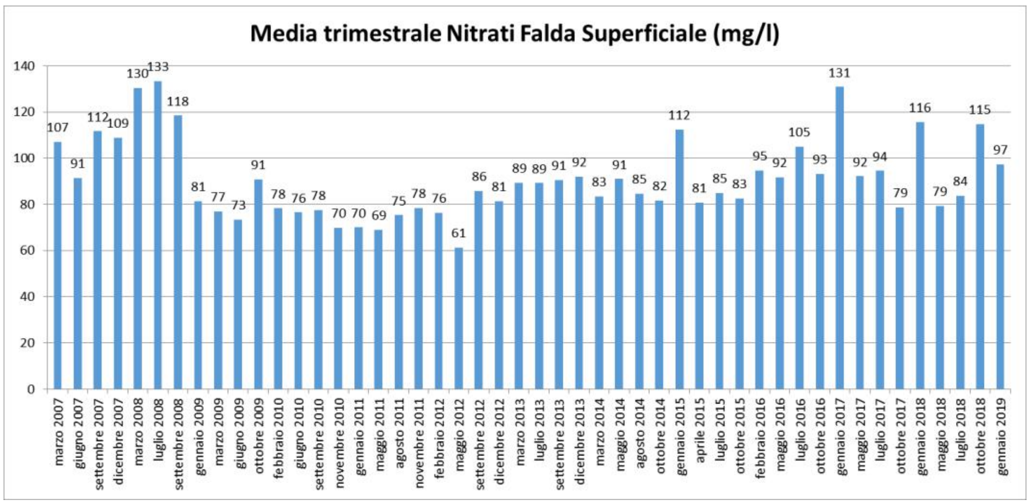


Fig. 4 – Medium quarterly content of nitrate in the I aquifer (ARPAS- Activity 2018)

These data show a decreasing since 2009 till 2012, where a lower value was recorded, following by an increase that settle-down for all 2015, except for the tip of 112 mg/l in the same year (Figure 3). In 2016 another increase, where the highest values were recorded and quite similar to 2008. In 2017 these values were ranged between 79-94 mg/l in May, July and October 2017 follows by a tip of 116 mg/l in January 2018.
In 2018 the values were still high, October 115 mg/l, follows by lesser values in January and July, the annual average is high than in 2017 and 2016 as well as 2007 and 2008.
Analyzing quarterly data from 2007 till 2017 a seasonality trend can't be detected (Fig. 5).

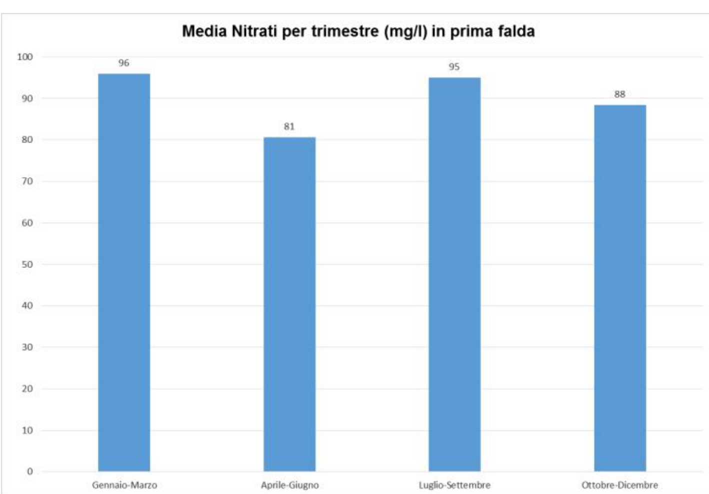


Fig. 5 - Quarterly medium nitrate contents in the I aquifer 2007-2018 (ARPAS Activity 2018)

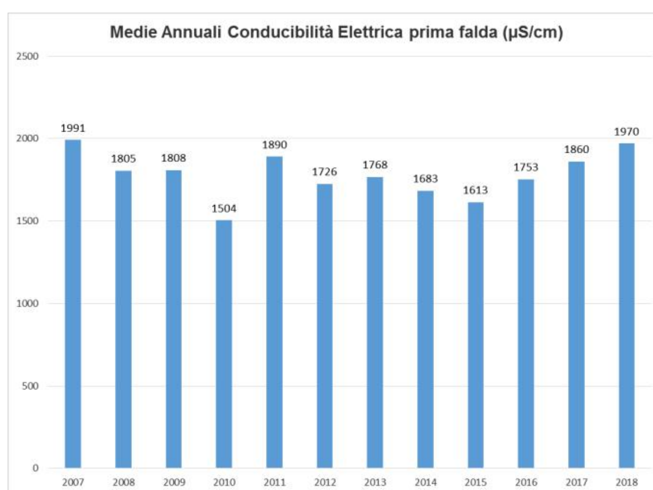


Fig. 6 - Conductivity annual average in I aquifer (ARPAS Activity 2018)

In piezometers P18 and P19 referred to Sassu aquifer, the nitrate content is low, the two stations are placed out of NVZ and without containment pollution measures.

Conductivity data (EC) are useful to detect a saline intrusion, till 2015 a stability of values was recorded in both aquifers (1500-2000 µS/cm in the I and 2000-3000 µS/cm in the II). Since 2016 a less increasing was recorded in both aquifers. Higher values were recorded in P18 e P19, in some station of I aquifer (P15, P17, P24, P31) and also in the II one (P30, P37).

The higher chloride values were recorded in Sassu aquifer were frequently over 10.000 mg/L in P19 and P18. Furthermore, often chloride is over 1000 mg/L in the P17 and P31 in the I aquifer and P30 and P37 in II one. The same trend was observed for sulphates, over 250 mg/L, in P17, P19 and P30. About metals, only nickel and lead sometimes were over limits. Ammonium is constantly present in P18 and P19, P09 and P30 (Fig.6).

Soils monitoring - ARPAS

Action Program for soils takes into account a monitoring net in fields interested by manure spreading on the NVZ. Since 2007 till first semesters of 2013 were recorded pollution indicators trough chemical parameters, as well as data, need to evaluate the quality of soils for agricultural use. Monitoring data shows the stability of recorded parameters of total nitrogen and metals values under the limits of laws, while phosphorus often is over it. The little variability of results lead to a decision of half-yearly monitoring of soils every 4 years, the last monitoring cycles were in 2017 and 2018. The monitoring run in the whole NVZ divided into squares of 1 km side into 55 sampling stations, half-year monitored.

Samples are collected through an Edelman hand-drill for sandy soils to 40 cm deep, into agricultural layer frequently ploughed and scrambled. The sampling stations reported in Fig.7.

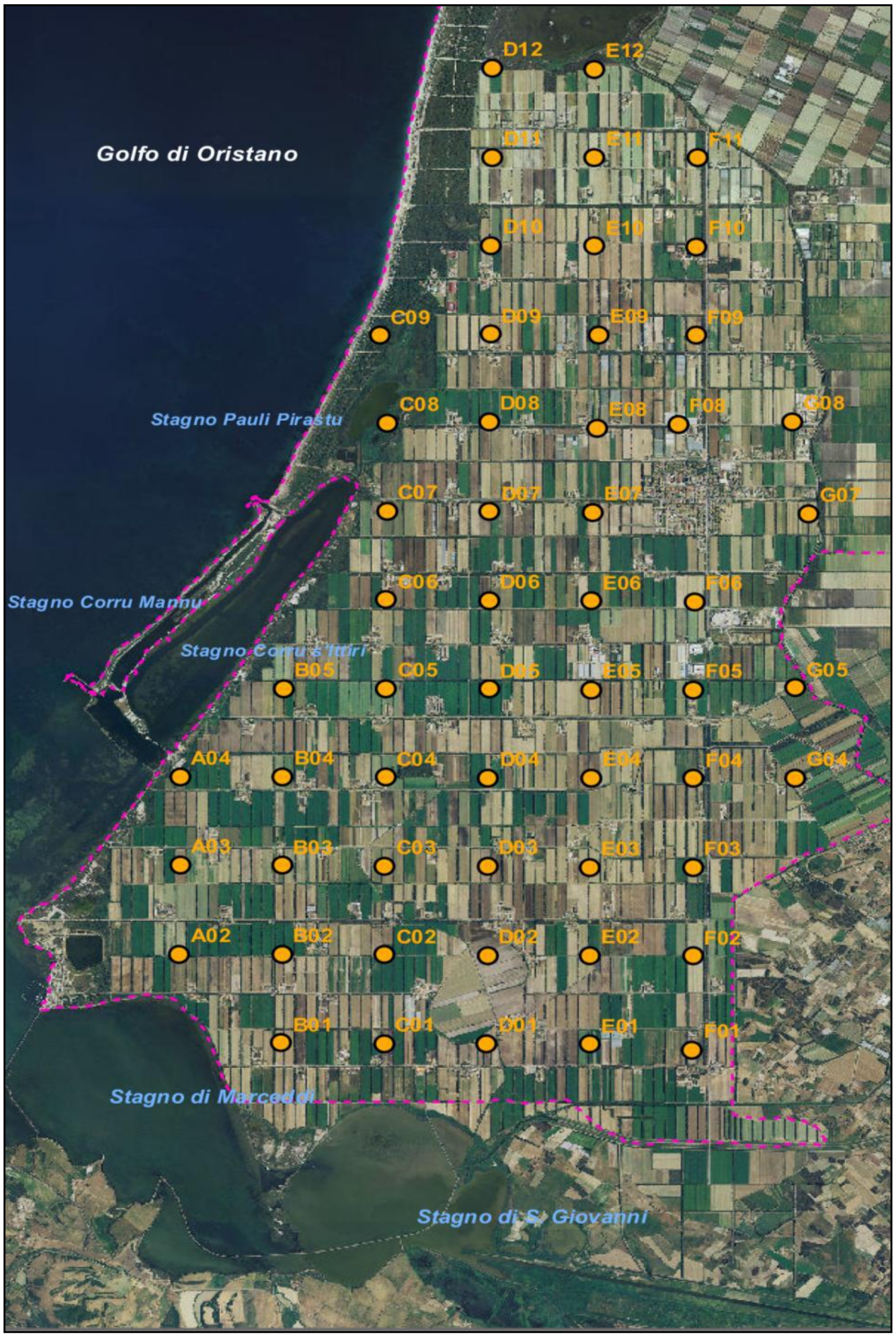


Fig. 7 - Soils monitoring net in NVZ (Waste-water treatment plant annex)

In soils, samples are recorded pH, humidity, copper, total zinc and other metals, reactive phosphorus, sodium and the others techniques reported in DM 13 September 1999 of the MPAF.
The collected samples were stored in polyethene flasks and delivered to ARPAS Lab for the analysis. In Tab. 5 are listed the parameters requested by law and methods of detections.

Tab. 5- List of parameters recorded for soils and methods applied (ARPAS – Activity 2018)

	Paramers	methodical
Chemical agronomic parameters	pH	*Method III.1 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Organic Carbon	*Method VII.2 -VII.1 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Electric conductivity	*Method IV.1 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Cation exchange capacity	*Method XIII.2 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Base Exchange	*Method XIII.5 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Total acidity	*Method XIII.3 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Nitrogen	*Method XIV.3 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
	Assimilable phosphorus	*Method XV.3 - "Official methods of soil analysis" (Ministerial Decree 13 September '99)*
Heavy metals soils	Heavy metals soils	*Method XI.1 - "Official methods of soil analysis" (Ministerial Decree 13 September '99).EPA Methodical 6010C/2000*

Historical analysis (Arborea NVZ – ARPAS 2018)
2017-2018 soils samples shows pH values ranged between 4.4 e 8.3, the maxim values was 8.3 in a sample rich in clay, the medium value was 6.3.

LAORE monitoring activity – 2019
In 2019 the Regional Agency for the Agricultural Development (LAORE) ran a sampling campaign to characterize soils with specialized cultures (Corn-Fodder) in the NVZ.
Data are soon available and useful for our project, forming a strong basis for the current nature of soils in this area.
For our monitoring we addressed for soil n.201 (close to station 2 Piezo), 491 (close to pilot plant) and 1047 (close to station 1 Piezo) but all the soil are presents in the GIS of project.

1	Periodo_Ca	Campione	Coltura	Scheletro	S_	L_	A_	Tessitura	Reazione_p	Cond_elet	Calcare_to	:alcare_a	Sostanza_o	Azoto_tota	Fosforo_As	Azoto_nitr	Calcio_Sca	Magnesio_S
2	maggio_giugno	201	MAFO	AS	91	5	4	S	7,1	0,207	TRA		1,9	0,105	63	17	800	104
3	settembre_ottobre	1047	ERLO	TRA	23	35	42	A	7,6	0,489	5,8	2,1	4,17	0,236	48	2	6300	1140
4	settembre_ottobre	491	ERLO	TRA	87	8	5	SF	6	0,153	AS		0,89	0,06	41	6	460	90

1	Potassio_S	Sodio_Scam	C_S_C_meq	Calcio_meq	Magnesio_m	Potassio_m	Sodio_meq_	Idrogeno_m	Saturazion	Carbonio_O	Rapporto_2	Anidride_F
2	38	90	5,36	4	0,87	0,1	0,39	0	100	1,102088167	10,49607778	144,27
3	960	320	44,85	31,5	9,5	2,46	1,39	0	100	2,418793503	10,24912501	109,92
4	74	98	6,16	2,3	0,75	0,19	0,43	2,49	59,6	0,516241299	8,604021655	93,89

Land use and crop cultivation
The study area is in the western coastal area and is included in a sensitive area for a organic nitrate-vulnerable zone (NVZs). The Arborea plain is the most important agricultural area in Sardinia, mainly devoted to the dairy industry. This area is the result of the reclamation of a large wetland, which occurred between 1919-1935. The landscape is characterized by regular and uniform fields with rectangular plots of equal size. The area is well facilitated with a system of canals and dikes with dewatering pumps that regulated the levels of waters. The management of waters distribution system is operated by "Consorzio di Bonifica (Consortium of reclamation) of Oristanese". Moreover the irrigation system was changed recently ensuring a reduction of water quantity use.

Companies and land use
In the delimited territory there are 183 farms gathered in 163 livestock farms with about 30,000 heads, dedicated to the production of cow's milk and associated with the Arborea Associated Assignee Cooperative - 3 A and in the Arborea Producers Cooperative; about 25% of these integrate the company income with horticultural products (potato, strawberry, watermelon and melon). There are also 3 sheep and goat farms, 25 specialized horticultural farms, 3 citrus farms and a social stable, with about 3,500 places, aimed at fattening the calves given by the members of the Arborea Producers Cooperative (site where the MEDISS pilot plant is installed).

The main crops grown in the area are the following:

Corn	Ha 3000
Autumn-winter grasses of grasses and mixtures	Ha 2200
Triticale	Ha 350
Alfalfa	Ha 600
Potato	Ha 250
Carrot	Ha 140
Melon	Ha 30
Watermelon	Ha 50
Strawberry	Ha 15
Lettuces	Ha 10
Salads	Ha 15
Eggplant	Ha 20
Zucchini	Ha 20
Table tomato	Ha 25

Forage farming

As in all dairy cattle farms, the main forage crop is corn.

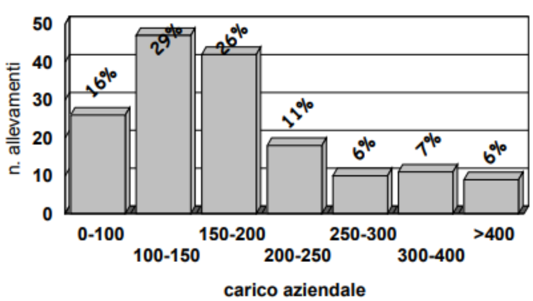
In the area in question, double cultivation is practiced and, for most of the cases, corn is followed by an autumn-winter herbage of grasses (ryegrass, triticale, oat, mixtures) in repeated cultivation, also destined for the production of grass silage and / or haymaking. The high nitrogen requirement of grass species in double cultivation allows for an appropriate agronomic use of livestock effluents; the use of chemical fertilization is practiced as a supplement to organic fertilization. The types of fertilizers used and the methods of distribution vary according to the season and the soil situation: nitric and nitroammonia fertilizers, often slow-release, are used in the winter while ammonia fertilizers in the spring-summer period.

Furthermore, in sandy soils, nitrogen fertilizations are divided into several interventions and the contributions of potassium are greater, while in clayey soils the nitrogen fractionation is lower and the contribution of phosphate fertilizers greater. **The aim of our MEDISS project is to reduce the use of eccess of nitrates.**

Animal husbandry

The animal husbandry of Arborea, the flagship of Sardinian agriculture, represents a particularly advanced farm management system that has nothing to envy to the production system of the more specialized regions in the production of cow's milk. In the designated area, in the main periods useful for spreading, i.e. before the sowing of corn in the spring and before the sowing of the autumn-winter weeds in the autumn, the handling of the slurry requires a considerable use of company labor, partially

replaced in the years of support from external contracts.



Fonte: Dati Ersat Sardegna - U.O.T. Centro Zonale di Arborea

Cattle size

Recent demonstration activities conducted by ERSAT Sardinia in the area in the study area revealed the possibility of an optimal use of large quantities of livestock manure. The activity involved field tests on chopped maize weeds where 80% of the nitrogen crop needs were provided by manure and separated liquid and solid fractions of sewage, administering quantities well above those prescribed for vulnerable areas by the Nitrates Directive. On the other hand, it is important to underline that the specific pedoclimatic situation of the area, the constant vegetal cover of the soils and the widespread adoption of rotations with particularly demanding crops in terms of nitrogen nutrition, create all the conditions for quantities exceeding 170 kg / ha. / year of nitrogen from livestock manure can be used without prejudice to the objective of improving the state of the aquifer.

Prohibitions and methods of agronomic use of nitrogen fertilizers (currently used)

In order to contain the dispersion of nutrients in surface and deep waters, the techniques for distributing livestock manure, nitrogen fertilizers and organic amendments and waste water must ensure their correct application to the soil, in accordance with the provisions of this action program and of the CBPA to ensure in particular: a) uniformity of fertilizer application; b) the high utilization of nutritional elements obtainable through the application of good practices which ensure, among other things, the administration of nitrogen fertilizers as close as possible to the moment of their use, the fractionation of the dose with the use of several repeated applications in the year and the use of spreading means to minimize nitrogen emissions into the atmosphere; c) the spreading of the sewage with pressure dispensing systems that do not cause the jet to become pulverized; d) the adoption of crop rotation systems in land use management in accordance with the provisions of the CBPA; e) compliance of irrigation practices with the provisions of the CBPA (Agronomic plan of Consortium).

Methods of agronomic use of zootechnical effluents

On the land used for spreading, zootechnical effluents must be used as fertilizers, the application quantities of which must take into account, for the purpose of respecting the nitrogen balance, the real needs of the crops, the net mineralization of the soils and the contributions nitrogen-fixing organisms. The quantity of manure used for spreading must not in any case determine in each individual farm or farm a nitrogen supply exceeding 170 kg per hectare and per year, understood as the average farm quantity, calculated on the basis of the values in Table 2 of annex 1 of the Nitrate Directive, or alternatively, on the basis of other values determined according to the indications given in the annex itself, including the manure deposited by the animals when they are grazed and any organic fertilizers deriving from livestock manure referred to in law 19 October 1984, n. 748 and wastewater.

Prohibitions on the use of manure (not treated with stripping plant)

The agronomic use of manure and related materials is prohibited: a) within 5 m of distance from the banks of the artificial canals; b) within 10 m of distance from the banks of the Rio Mogoro; c) within 25 m of distance from the beginning of the beach for marine-coastal and transitional waters; d) in the autumn-winter season, from November 15th to February 15th; from 1 November to the end of February for poultry droppings dried with a rapid process at dry matter contents above 65%; e) on surfaces not affected by agricultural activity, with the exception of public and private green areas and areas subject to environmental recovery and restoration; f) in the woods, with the exception of manure released by animals in wild breeding; g) on frozen, snow-covered land, with outcropping aquifer, with landslides in progress and soils saturated with water, with the exception of land used for crops that require submersion; h) in all situations in which the competent authority issues specific prohibition or prescription measures in order to prevent infectious, infestive and spreading diseases for animals, humans and for the defense of water bodies.

Guidelines and rules - The Agronomic Utilization Plan (PUA) and the Fertilization Plan (PdF) in the Arborea ZVN (Nitrates Vulnerability Zone)

In order to minimize nitrogen losses in the environment, the use of nitrogen fertilizers must be carried out in compliance with the balance between the foreseeable nitrogen needs of the crops and the nitrogen supply to the crops. The nitrogen supply to the crops referred corresponds to: - the amount of nitrogen present in the soil when the crop begins to absorb it significantly; - the nitrogen supply through the net mineralization of organic nitrogen reserves in the soil; - nitrogen from atmospheric deposition; - the addition of nitrogen compounds from livestock manure and waste water; - the addition of nitrogen compounds deriving from the irrigation reuse of purified waste water as per decree no. 185 of the Minister of the Environment and the protection of the territory, from fertilizers referred to in law no. 748 of 1984 and from sewage sludge as per legislative decree no. 99 of 1992. 3. For a rational management of nitrogen fertilization practices, the PUA or PdF must be drawn up, aimed at defining and justifying, for a period of no more than five years, the fertilization practices adopted, respecting the limit of 170 Kg / ha per year of nitrogen referred. The obligation regarding the preparation of the PUA and the PdF is differentiated according to the quantities of nitrogen in the field from livestock manure or total nitrogen used by the company, as follows: a) The companies that use a quantity of nitrogen to the manure field over 3000 kg / year must draw up the PUA; b) Farms that use a quantity of nitrogen from livestock manure equal to or less than 3000 kg / year and a quantity of total nitrogen greater than 3000 kg / year must draw up the PdF; c) Companies that use a quantity of total nitrogen equal to or less than 3000 kg / year are exempted from drawing up the PUA and PdF.

Water consumption per sector (industry, tourism related activities, primary, etc)/ total consumption

The area served by the Reclamation Consortium in the Terralba - Arborea area is about 120 km2 and the study area in question is about 55 km2, just under half of the entire area. Being the area almost totally cultivated it can be reasonably assumed that 50% of the water supplied in the area by the Reclamation Consortium is destined to the irrigation needs.

Arborea	J	F	M	A	M	J	J	A	S	O	N	D	Tot
Average rain water (in mm)	79,8	70,0	60,8	55,3	35,1	14,1	2,7	6,7	44,2	87,5	101,0	102,3	659,5
Average irrigued (in mm)	0,0	1,8	14,6	40,0	54,6	81,8	116,4	96,4	34,5	12,7	3,6	0,0	456,4
R + Irr average (in mm)	79,8	71,8	75,4	95,3	89,7	95,9	119,1	103,1	78,7	100,2	104,6	102,3	1115,9

ARBOREA - Proposal for MEDISS monitoring

Historical and current data analysis in this area providing guidance for this first phase of the investigations. The analysis will be performed for both environmental components: groundwater and soil.

Monitoring of groundwater

Enas proposal suggests the implementation of the existing groundwater monitoring network through two new 10 m deep piezometers, able to intercept the first aquifer and to evaluate the effects of the fertilizer produced with the new ammonia stripping plant use.

The location of the two piezometers was agreed with all the bodies involved and operating on the territory (stakeholders) and on the basis of the available data. In particular, the existing network of piezometers and the results of past monitoring activity leading on the identification of sites with a low and stable nitrate content in water over time, useful during the fertilizer testing from the pilot plant.

The positions of the two piezometers are expressed according to different reference coordinate systems summarized in Tab. 6.

Tab. 6 - Summary table of the location of the two newly built piezometers according to different coordinate systems.

System of geographical coordinates	PIEZOMETERS	Longitude (°)	Latitude (°)	Site
WGS 84	STATION 1	8.558547°	39.78328°	Str.21 Ovest
	STATION 2	8.533195°	39.742490°	Str. 10 Ovest
System of di projected coordinates		**X (m)**	**Y (m)**	
Gauss-Boaga Roma 40 fuso Ovest	STATION 1	1462228,797	4403803,146	Str.21 Ovest
	STATION 2	1460034,318	4399286,934	Str. 10 Ovest
UTM WGS 84 fuso 32 N	STATION 1	462198.779	4403797.054	Str.21 Ovest
	STATION 2	460004.310	4399280.932	Str. 10 Ovest

Fig. 8 - Location of the two newly built piezometers within the ZVN area of Arborea and pilote site for crops and greenhouse

Processing of results

The data and results obtained from this monitoring plan proposed complement the geodatabase prepared by Enas on a QGIS platform in which the basic thematic cartographies related to the project have already been upload (geology, soil, land use).

All the data within the QGIS project have been processed through spatial analysis to assess the criticality and identify the susceptibility of the area to the use of fertilizer produced by the new plant.

PILOT SITE – JERICHO (PALESTINE)

By Timesis

Jericho is a Palestinian city in the West Bank. It is located in the Jordan Valley, with the Jordan River to the east and Jerusalem to the west.
Jericho is located 258 metres (846 ft) below sea level in an oasis in Wadi Qelt in the Jordan Valley, which makes it the lowest city in the world (Fig.9).

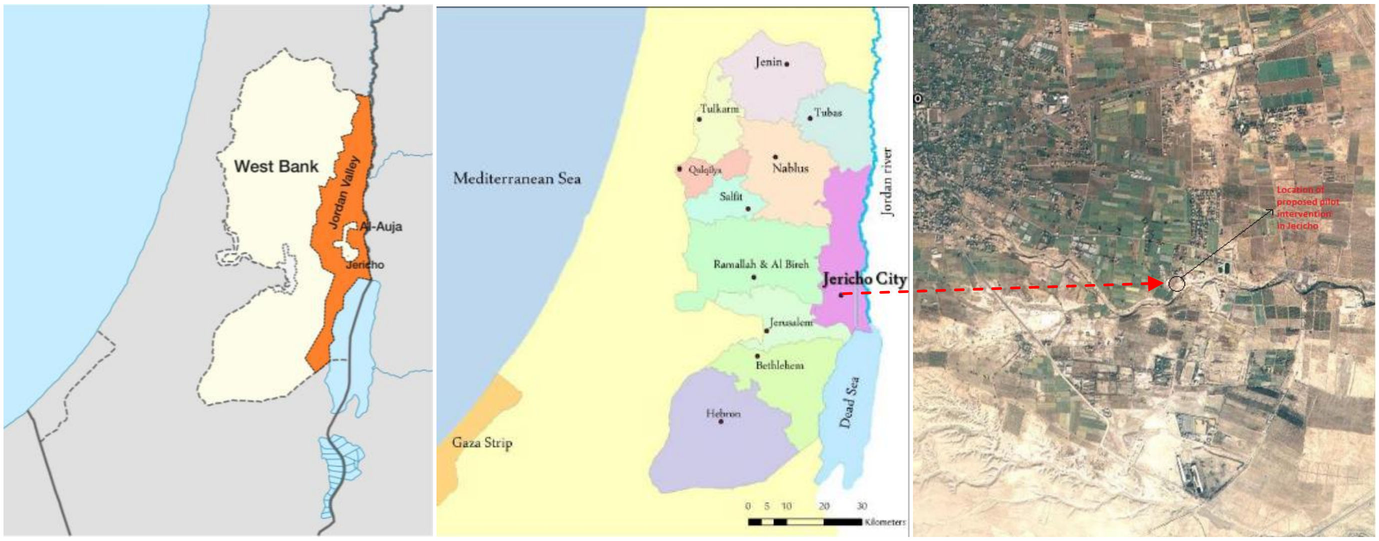


Fig. 9 - Location area

Legislation and inspection bodies

- **Palestinian water authority**: achieve integrated and sustainable asset management of water resources, protection and preservation within organizational tools help them to gain access to a healthy environment by ensuring a balance between quantity and quality of water available and the needs of the Palestinian people to achieve sustainable development through water resources.
- **Ministry of Agriculture**: Directing and managing the agricultural sector.
- **Jericho Municipality**: Jericho Municipality seeks to promote the city by standing on the most critical needs, projects and try to perform a large portion of these projects in cooperation with friendly cities and donor institutions in the city for the latest and finest as befits their level historical and cultural.
- **Governorate of Jericho & Al Aghwar (GoJ)**: implement the public policy of the State of Palestine and to supervise production and service facilities within the governorate boundaries
- **Environment Quality Authority:** The Environment Quality Authority is the central authoritative body for all environmental issues in the Palestinian territories. It is the umbrella under which all environmental regulations, projects and strategies are created and implemented.
- **Palm Farmers Cooperative Association (PFCA):** support the Palestinian agriculture development and supports date palm farmers, small producers in particular, with a view to improve economic, social, cultural, environmental conditions.

Groundwater monitoring

PWEG has been testing the quality of fresh (Wadi water) and farmers, the results are disseminated to all farmers in the Jordan Valley to help them use the optimal ratio of blended water to be used in irrigation.
Several tests have been made such as Nitrite, Nitrate, Chloride, HCO3, EC, Total dissolved solids (TDS), pH, temperature and Chemical oxygen demand (COD), the following table shows the results of these testes.

Wells

Water Test sample form
Sampling date: 15/12/2020 Region: Jericho / Palestine
Test date: 15/12/2020 Weather: Sunny

Sample name ➢ Test ⮛		Daeeq (Dahia) Farm	Daeeq (Mashro) Farm	Abu Raed Farm A1	Abu Raed Farm A2	Abu Yazan Farm	Abu Al-Ezz Farm	Musab Farm
Temperature	c	25	25	25	25	25	25	25
BOD	mg/L							
COD	mg/L	50	100	100	200	200	400	600
TDS	PPT	1.35	2.83	1.65	2.09	1.4	0.85	2.86
EC	mS/cm	3.6	6.18	3.33	3.82	2.81	1.7	5.38
PH	PH	7.3	7.4	7.5	7.5	7.7	7.3	7.6
Nitrate	mg/L	0.01	0.02	0.04	0.05	0.01	<<	0.03
Nitrite	mg/L							
Chloride	mg/L	18	29.5	16.5	19	14	10	26
CaCO3	mg/L							
Sulfate	mg/L							
Mn	mg/L							
MgCO3	mg/L							
HCO3	mg/L	100	230	90	145	145	130	105

Sampling date: 11/11/2021 Region: Jericho / Palestine
Test date: 11/11/2021 Weather: Sunny

Sample name ➢ Test ⮛		Daeeq (Dahia) Farm	Daeeq (Mashro) Farm	Abu Raed Farm A1	Abu Yazan Farm	Abu Al-Ezz Farm	Musab Farm
Temperature	c	25	25	25	25	25	25
BOD	mg/L						
COD	mg/L	50	100	100	150	140	170
TDS	PPT	1.5	2.95	1.75	1.5	5.3	2.9
EC	mS/cm	4.1	6.8	4.3	3.05	11.8	6.1
PH	PH	7.3	7.5	7.9	7.8	7.2	7.6
Nitrate	mg/L	0.01	0.01	0.03	0.01	0.04	0.03
Nitrite	mg/L						
Chloride	mg/L	21	34.1	19.1	15.7	58.4	31
NaCl	mg/L	34.5	57.1	30.1	24.8	95.7	49.6
Sulfate	mg/L						
Mn	mg/L						
MgCO3	mg/L						
HCO3	mg/L	90	110	85	120	130	105

WADI

Water Test sample form

Sampling date: 26/1/2022

Test date: 26/1/2022

Region: Jericho / Palestine

Weather: cloudy

Sample name ➢ Test ⮛		Wadi water
Temperature	c	16
BOD	mg/L	
COD	mg/L	
TDS	PPT	0.2
EC	mS/cm	0.7
PH	PH	8.5
Nitrate	mg/L	0.1
Nitrite	mg/L	
Chloride	mg/L	3.4
NaCl	mg/L	5.4
CaCO3	mg/L	
Sulfate	mg/L	
Mn	mg/L	
MgCO3	mg/L	
HCO3	mg/L	

Sampling date: 22/1/2021

Test date: 22/1/2021

Region: Jericho / Palestine

Weather: Sunny

Sample name ➢ Test ⮛		Wadi water
Temperature	c	17
BOD	mg/L	
COD	mg/L	
TDS	PPT	0.3
EC	mS/cm	0.4
PH	PH	8.6
Nitrate	mg/L	
Nitrite	mg/L	
Chloride	mg/L	2
NaCl	mg/L	3.3
CaCO3	mg/L	
Sulfate	mg/L	
Mn	mg/L	
MgCO3	mg/L	
HCO3	mg/L	235

Annex - Water sampling

<u>*The soil baseline survey*</u>

The sils of the Jericho area were the subject of an in-depth study that Timesis carried out in the years 1996-2000 (Arab Studies Society, Land Research Center, 2000). The knowledge acquired during that work has been updated with the new analyses carried out during this survey.

The soil forming factors and the pedogenetic processes

Climate

According to Köppen-Geiger climate classification system, which divides climates into five main groups based on seasonal precipitation and temperature patterns, West Bank's climate belongs to group Csa, Temperate climates with hot-dry summer, characterised by average temperature above 0°C but below 18°C in their coolest months, less than 30 mm of precipitation in dry months (April-September) and average temperature in the warmest month above 22°C.

There are two distinctive climatic seasons in the West Bank, typical of Mediterranean climate: a wet colder season and a dry summer; in Jericho, the low elevation (258 m below sea level) causes particularly high temperatures, making its climate a "hot desert climate" (BWh), according to the Köppen classification.

In Jericho, temperatures range from 6-17°C in the winter season and reach 32°C during the hottest season. The coldest month is January and August the warmest. The average maximum temperatures during January and August are around 15°C and 32°C respectively. The average minimum temperatures for the same months are around 6°C and 21°C respectively.

The maximum precipitation is registered in January but in general the months from November to March are the rainiest one, while the critical months are from June to September when 0 mm of precipitation are registered (Tab.7). Total annual precipitation is about 204 mm on average (Fig. 10-13).

Tab.7 Monthly climatology of Max-temperature, Mean-temperature, Min-temperature (°C) and precipitation (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	19.0	20.6	24.4	29.5	34.4	37.0	38.6	37.9	35.8	32.7	28.1	21.4	30.0
Daily mean °C	10.7	12.6	16.3	22.4	26.6	30.4	30.9	30.4	28.6	25.8	22.8	16.9	22.9
Average low °C	4.4	5.9	9.6	13.6	18.2	20.2	21.9	21.1	20.5	17.6	16.6	11.6	15.1
Average precipitation mm	59	44	20	4	1	0	0	1	2	3	5	65	204
Source: Arab Meteorology Book													

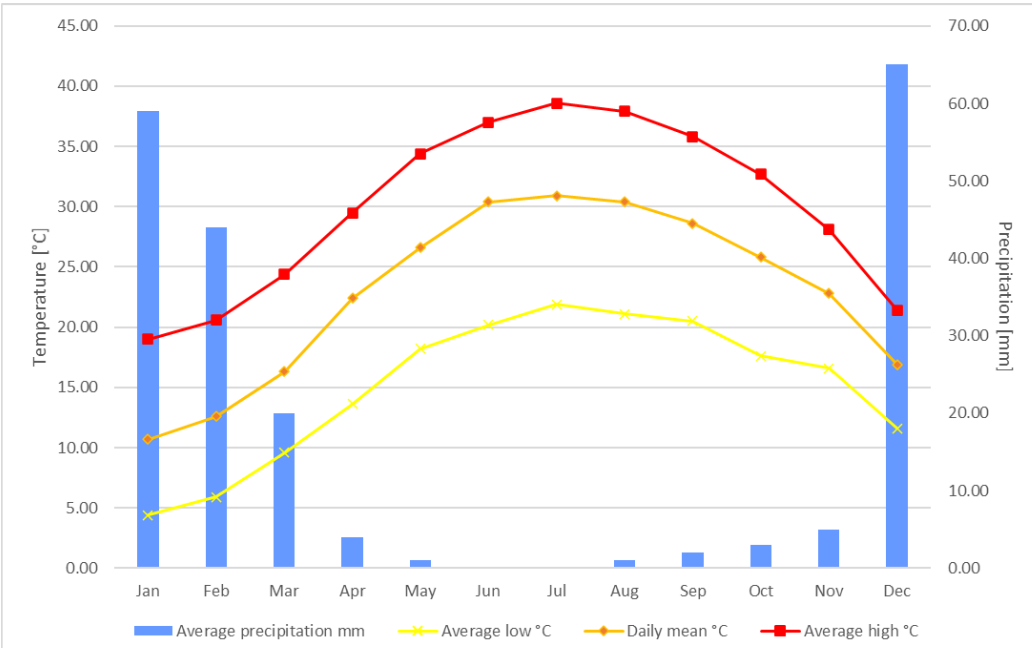


Fig. 10 Monthly Climatology of Min-Temperature, Mean-Temperature, Max-Temperature and precipitation in Jericho (source: Arab Meteorology Book).

The following figures show annual average temperature and precipitation of the last century.

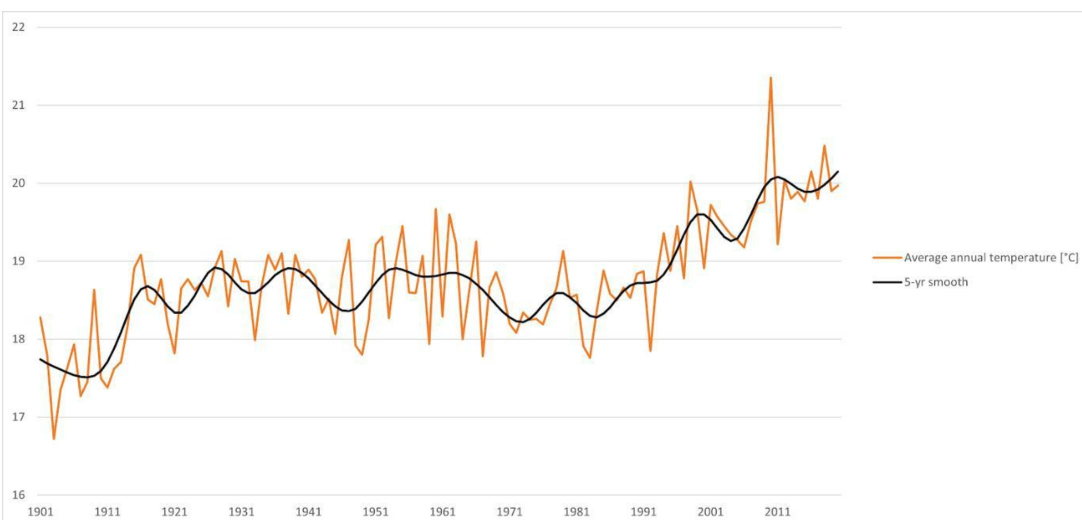


Fig. 11 Observed Annual Mean-temperature of Jericho for 1901-2020 (source: West Bank Gr., Climate Change Knowledge Portal)

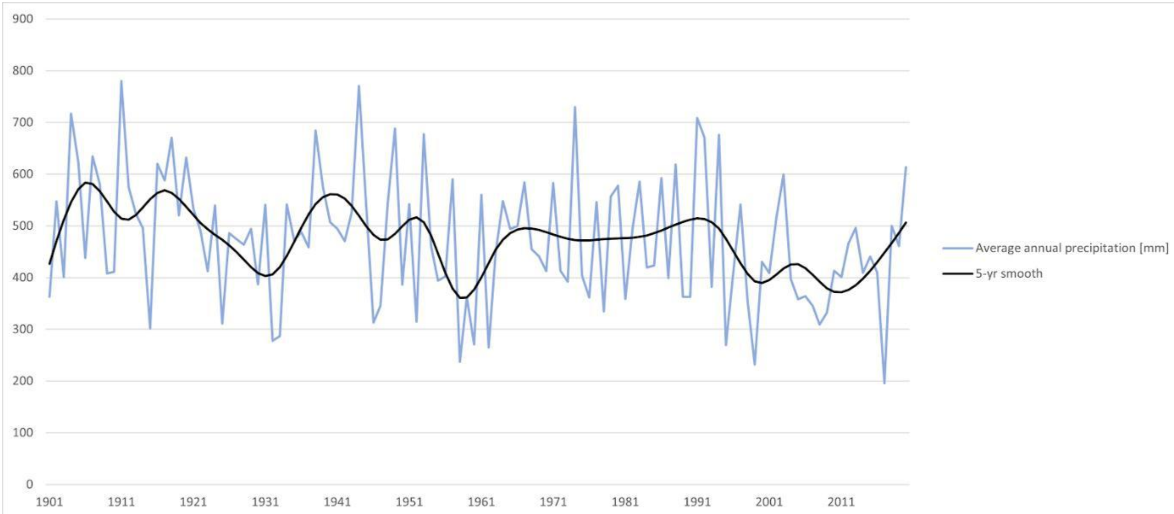


Fig.12 Observed Average Annual Precipitation of Jericho for 1901-2020 (source: West Bank Group, Climate Change Knowledge Portal)

In general, an increase in average temperature is observed. Precipitation trend presents greater variability, but a decrease can be seen. In particular, the average temperature of the last thirty years has risen by 1.1°C compared to the previous thirty years (1961-1990), and average annual precipitation decreased by 37.2 mm.

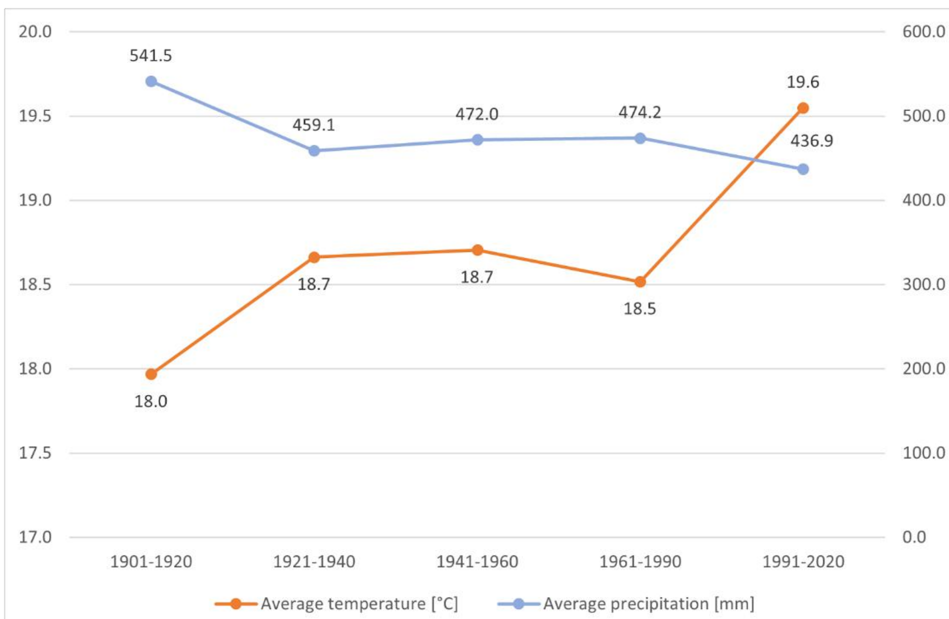


Fig.13 Mean-temperature and Mean-Precipitation trend of the last century for past and current climatology periods (30 years).

Geology and geomorphology

The geology of the Jordan Valley is characterized by the formation of the Jordan rift, which is part of the continental rift that extends from east Africa along the Red Sea northwards to the east of the Mediterranean. The length of the Jordan Rift is 600 Km and the width is 10 - 20 Km.

According to several studies, the rift formation had begun during the Miocene and the oldest post-rift formation called Usdum formation. This one is mainly salts that originate from the then connected Mediterranean Sea. A younger formation of Al-Samara of Pleistocene age overlaid the Usdum formation with fresh lake sediments, the evaporites of Lisan Formation (mainly aragonite and gypsum), which is the result of sedimentation of salty lake of Pleistocene age. This one was then overlaid by the recent alluvial fans transported to the valley bottom by mostly periodic wadis.

There are two theories that explain the formation of the Jordan Rift:

Graben Tectonics Theory, which explains the formation of the rift by the effects of parallel dip - slip faults on north - south direction, each fault caused a minor subsidence of the area (step faulting). The main fault of the Graben is a big one that goes parallel to the eastern side of Jordan River.

Horizontal Tectonics Theory, that justifies the rift formation by the horizontal northward movement of the Arabian Plate (Arab Peninsula, Jordan and Iraq) along a central fault that separates it from the stationary Sinai Plate, which caused depressions. This theory does not deny the presence of vertical movement, but states that it is of less extent.

Related to the geomorphology of the study area, it has two main plain levels that are separated a 3 m height by north - south oriented escarpment. The main level, which represents the deep part of Wadi Al Qelt alluvial fan, is limited to the north by Jericho, on the south and southwest by Wadi Al Marar, and bordered by another escarpment to the east. A dendritic south - east oriented drain system is present. Erosive drain lines are separated from the plain by moderately steep to steep escarpments. The relative relief is about 3 to 7m.

The lower alluvial fan of Wadi Al Qelt is located south east of Jericho, limited on the north, east and south by borders of mapped area and separated on the west from the upper fan by a scarp. The area is a level or gently inclined plain, a dendritic south oriented drain system (rills and gullies) is present in the lower part of the area. The relative relief is very low (drain lines maximum depth is 2 m). Close to the by-pass road and the scarp there are small rises of lacustrine deposits that are either gently connected ore limited by scarps.

Many local steps that reflect different levels of Lisan Lake could be seen, the relative relief between the main level of the plain and the rising steps is less than 5m. Horizontal layers of non-weathered powder of lacustrine material and petrocalcic/petrogypsic horizons coan be seen on scarps.

Land use and vegetation

The western part of the mapped area, closest to Jericho (upper alluvial fan of Wadi Al Qelt) has been irrigated and cultivated for the longest time. In the southern and eastern part (lower alluvial fan of Wadi Al Qelt) agriculture has been more recently introduced, particularly in the last 2 decades. Previously, these areas were being used for extensive grazing or not managed.

This evolution in land use is clearly visible by comparing historical satellite images. The following figure compares the images of the year 2004 and the most recent one (2021) (Fig.14).

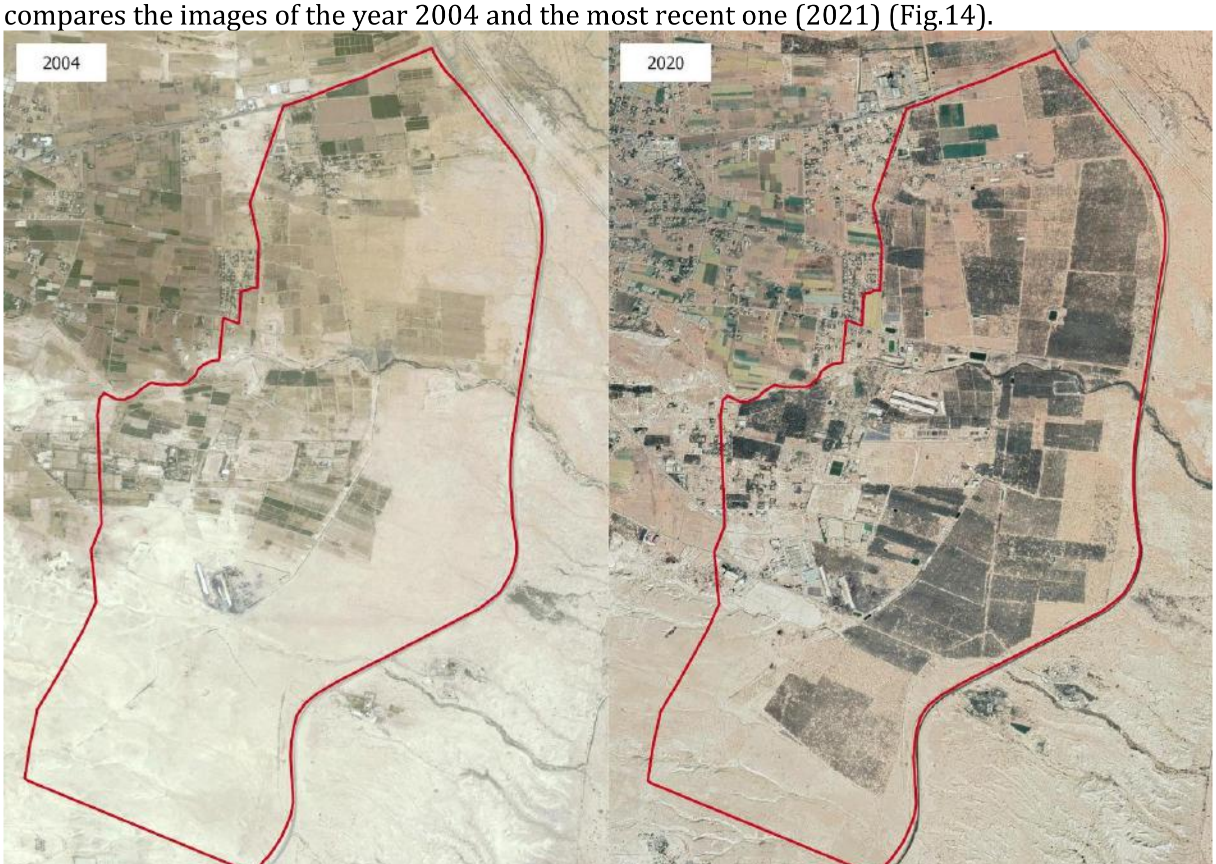


Fig. 14 Land use changes from 2003 to 2021 in The Jericho area (from Google Earth)

The pedogenetic processes

The variability of soils in the mapped area is the result of the action of some soil formation processes.

The very well-marked aridic and hot characteristic of the climate of the area is one of the main aspects influencing genesis and characteristics of soils. Due to high temperatures and low precipitation, water inside the soil body tends to have a prevalent ascending direction, moving upwards to the surface horizons. Thus, soluble salts, such as carbonates and more soluble salts, tend to accumulate in the top layers, changing chemical soil characteristics and influencing soil fertility.

At the same time, high temperature and intensive insolation contribute to the rapid oxidation of the organic matter of the surface horizon.

The second main aspect influencing the soil formation processes of the area is the parent material. As described above, the mapped area is characterised by the presence of two different parent materials, the alluvial and the lacustrine deposits. These two materials differ from each other both for their origin, and for their characteristics.

The alluvial deposit consists of sediments originated from the weathering of limestones and dolostones and from terra rossa residues common in the more humid and colder highlands, and it is transported by the wadis coming from the reliefs placed upstream, to the west of the area. The lacustrine parent material is originated from the deposits of frequent fluctuations of the inland lake. Lacustrine deposits consist of marls with high content of carbonates, gypsum and more soluble salts, which lead to the formation of saline and alkaline soils.

The area is a level to gently inclined alluvial fan where erosion is particularly active in proximity of the drainage lines escarpments. In the eastern part of the mapped area wind erosion and deposition are also active.

Among factors that have been influencing the formation of soils in the mapped area are the human activities. In fact, the presence of many springs made agricultural activities possible on the terraces of Wadi Al Qelt since the first settlements of the man around Jericho, which is reputed to be the oldest city in the world.

From the last half of the last century, these agricultural activities became more intensive and extended to areas not cultivated in the past. As a consequence of that, water needs for irrigation increased, leading to the lowering of the water table and obliging the farmers to use water that is less suitable for irrigation. Intensive irrigation with bad quality waters and fertilisation may cause the accumulation of soluble salt and loss of fertility of the cultivated horizons.

The main pedogenetic processes identified in the area are the following:

Carbonates and sulphates redistribution. The parent material has a relatively high carbonate content, since soils of the area have a total carbonate content between 30 to 60 % in weight. Calcium carbonate is present in both alluvial parent material and lacustrine deposits (more abundant in alluvial deposits and in some layers of the lacustrine ones), while the calcium sulphate (gypsum) is mainly available in the lacustrine parent material and in the alluvial deposits of the lower alluvial fan as secondary deposition. Redistribution and accumulation of carbonates is a process commonly observed in most arid regions. When having limited amount of rainfall, and reduced circulation of water inside the soil body, carbonates accumulate in the water solution and deposit in secondary forms (pseudomycelya, concretions, nodules and crystals).

Formation of petrocalcic/petrogypsic horizon. In the mapped area, the process leading to the formation of a cemented calcic horizon affects soils which are localised in the southern part of the main level of the plain and on small rising terraces in the lower alluvial fan of Wadi Al Qelt. Cemented calcic horizons were found only in portions of soils from lacustrine parent material and are originated from the accumulation and hardening of carbonates to the extent that plant roots can not penetrate it. The occurrence of cemented calcic layer at shallow to moderate depth reduces the depth of available soil for the plants (reducing the rooting depth) and sensibly affects the drainage. The low permeability results in accumulation of salts in the surface horizon. The petrocalcic/petrogypsic horizon at shallow to moderate depth is very common in the southern part of the mapped area.

Salinisation and alkalinisation. Accumulation of soluble salts is a risk, which concerns, to different extents, all the mapped area. Salinisation and alkalinisation of soils are processes commonly observed in most arid regions where rainfall is not sufficient to ensure water leaching to clean out salts from the surface horizons. In aridic conditions, ascending capillarity is the main water movement inside the soil body, which results in accumulation of salts in the surface horizons. Salt crusts are widespread, affecting the top 5-10 cm of the surface soil layer; they are particularly rich in salts, whitish, in the eastern, lower part of the alluvial fan.

Erosion (by water and wind). Despite the moderate energy of the landform, soil erosion is a process affecting almost all the mapped area. Water soil erosion is active at different degrees in most of the area. Erosion, mainly sheet erosion, is particularly active close to escarpments, resulting in regressive erosion, which reduces the size

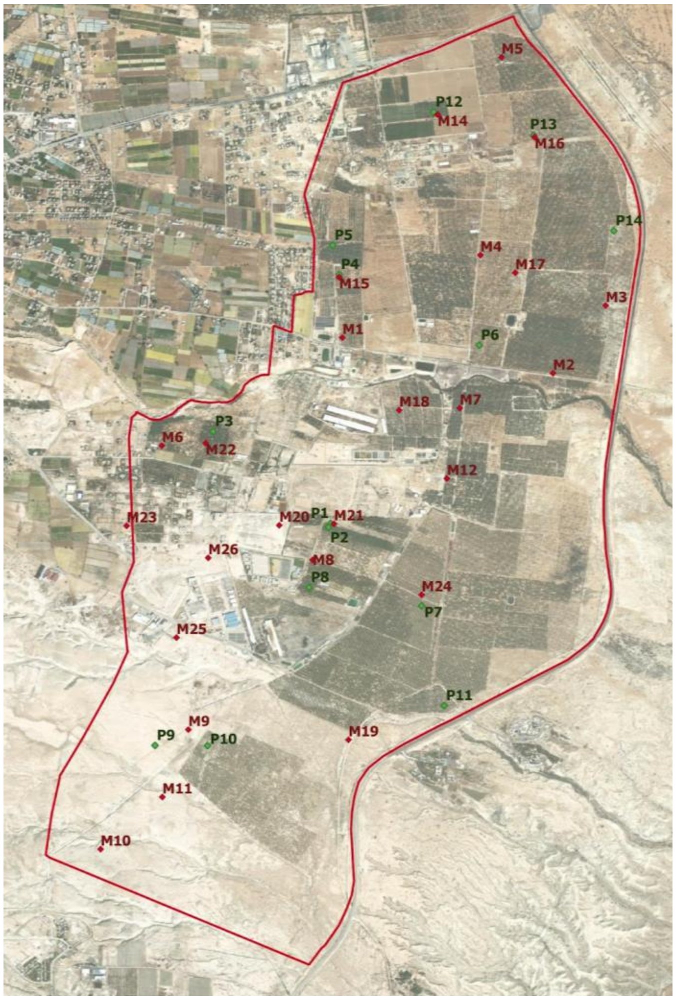


Fig. 15 location of the soil observations in the study area (P: profiles; M: minipits).

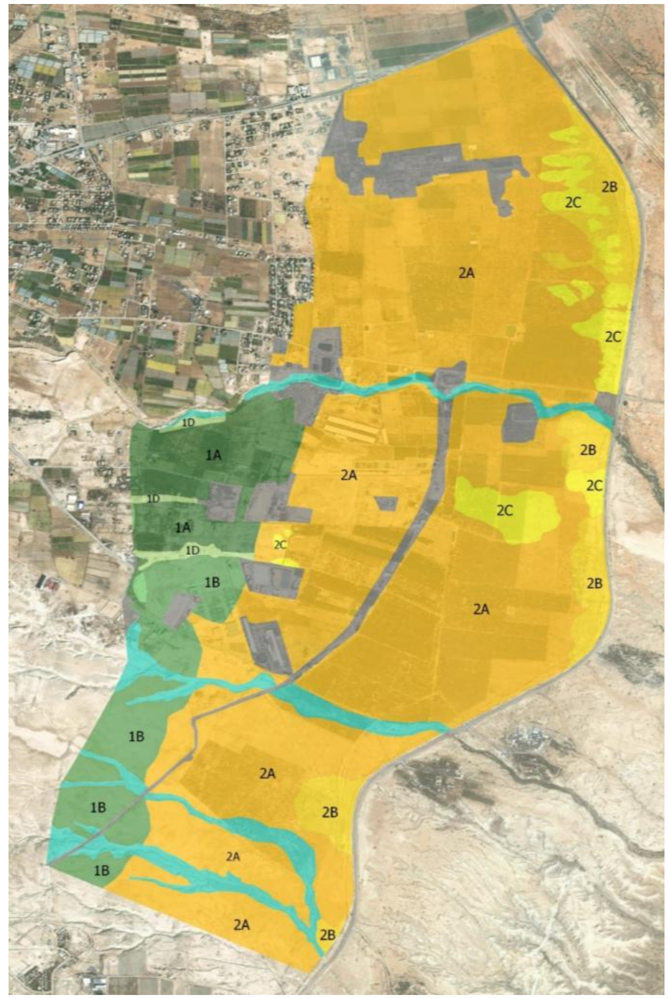


Fig. 16 The Land Units map of Jericho area

- 1 - Upper Alluvial Fan
- 1A - Main level of the plain cultivated
- 1B - Main level of the plain, unclutivated or recently cultivated
- 1C - Erosion areas
- 1D - Drain lines of the main level of the plain and upper terraces of the main wadis
- 2 - Lower Alluvial Fan
- 2A- Main level of the plain
- 2B - Depressions of the main level of the plain with frequent drain lines and gullies
- 2C - Drain lines of the main level of the plain and upper terraces of the main wadis
- Urban areas
- Wadi's winter beds

of the cultivated plots and lowers the fertile surface horizons. On the main level of the plain, sheet erosion is moderate, while escarpments and small terraces of the drainage system show severe to extreme water erosion, in form of sheet and rills, sometimes tunnels.

Field survey campaign and laboratory tests

Following the preparation of the Land Unit Maps of the areas of interest, the baseline soil survey was aimed at carrying out a set of laboratory analyses, addressed to start the monitoring inside the pilot areas, by detecting the chemical-physical parameters of the soils before the start of the project experimental activities.

A group of farmers has been selected in the study area. In each farm a plot has been identified where to collect soil samples by carrying out mini pits. This selection was also made taking into account the land unit map, in order to analyse the main soils present in the area. All the farms presented a cultivation crop in progress of Palm trees. For each site 5 mini pits have been excavated in order to obtain a mixed sample from the topsoil and a mixed sample from the subsoil. The collected samples were analysed in laboratory.

In the figure (Fig.15) below the position of the selected sites is shown.

The Land units map

The Land Units map of the study area and its legend are shown in the following figure and table (Fig.16).

A description of the land subunits is given in the following table.

Land Unit	Land subunit Code	Definition	Description
1 - Upper Alluvial Fan	1A	Main level of the plain, cultivated	The surface is level (inclination less than 3 %). The parent materials are mainly lacustrine deposits, which may appear on the soil surface. Sometimes they are covered with shallow to moderately deep alluvial deposits. Soil erosion is generally slight. It is moderate on the edges of the terraces close to scarps and drain lines. The area has been under cultivation for the longest time.
	1B	Main level of the plain, uncultivated or recently cultivated	The surface is level (inclination between 1 to 2 %). The surface stoniness is few to common; water sheet erosion is moderate to severe. The parent material is mainly lacustrine deposits, which may appear on the soil surface or be covered with shallow alluvial deposits. The area is not cultivated or recently planted with date palms.
	1C	Erosion areas	Small rises (0.5 - 1 m) over the main level of the plain in which the lacustrine material emerges. The surface is level (inclination < 3 %). The surface stoniness is many to abundant. The area is in an erosive phase, sheet erosion is moderate. Cultivated with annual irrigated crops or not cultivated.
	1D	Drain lines of the main level of the plain and upper terraces of the main wadis	The surface is level to gentle inclined (inclination between 3 and 4 %). The erosion is severe; very rare flooding may occur. The parent material is mainly lacustrine deposits. They are cultivated with annual irrigated crops or not cultivated.
2 - Lower Alluvial Fan	2A	Main level of the plain	The surface is level (inclination 1-3 %). The Parent materials consist of alluvial deposits (clay and silt) over lacustrine deposits. Erosion is mainly slight, sometimes moderate. Wind erosion/deposition is slight to moderate. Area recently cultivated (date palms). Natural vegetation of the area consists of scared shrubs, which are grazed.
	2B	Depressions of the main level of the plain with frequent drain lines and gullies	The surface is gentle inclined (inclination 3 - 8 %), and undulated by the presence of rills and gullies and petrocalcic outcrops. Water erosion is severe. Occasional flooding may occur. In part recently cultivated with date palms, in part covered by natural vegetation (scared shrubs).
	2C	Remnant surfaces of lacustrine material rising from the main level of the plain	Rises of lacustrine material (less than 5 m high) from the main level of the plain. Rises could be either gentle connected with the main level of the plain either limited by scarps. On scarps horizontal layers of lacustrine material and petrocalcic horizons are exposed. Petrocalcic outcrops are locally visible on the top of the terraces. The surface is level to gentle inclined (inclination < 8 %), sometimes covered by abundant stoniness. Water sheet erosion is moderate to severe. Mainly recently cultivated with date palms, in part still covered by natural vegetation (scared shrubs).
W	Wadi's winter beds		Small terraces, scarps and winter beds of Wadi Al Qelt, Wadi El Marar, and other minor wadis. On terraces, surface is almost flat. Surface parent material is both alluvial and lacustrine deposit. On scarps inclination is > 18 %, and parent material is mainly lacustrine deposits. On winter bed, surface is level to gentle inclined (inclination < 4 %). These areas are frequently flooded during the winter. Not cultivated.
U	Urban areas		Built up areas, dumping sites, channels, roads.

The soils of the study area

In this section soil types and phases (Tab.9) identified in the mapped area are described. In the table below seven soil types, with fifteen phases, are listed. A soil phase is a further subdivision of the soil type, operated for practical purposes, established on the basis of a single parameter that is important for its management. Each soil is classified according to World Reference Base for Soil Resources" (IUSS Working Group WRB, 2015).

Tab.9 Soil Types and Phases in Jericho area

Soil type	WRB Classification	Soil phase	
1	Gypsic Salic Solonetz	1a	with lacustrine substrate placed at a deep or very deep depth (> 100 cm)
		1b	with lacustrine substrate placed at a moderate depth (50-100 cm)
2	Calcic Gypsisols (Endosalic, Vertic)		
3	Gypsic Sodic Solonchaks	3a	with lacustrine substrate placed at a deep or very deep depth (> 100 cm)
		3b	with lacustrine substrate placed at a moderate depth (50-100 cm)
4	Haplic Calcisols		
5	Gypsic Sodic Solonchaks (Hypersalic)	5a	with few or common stoniness
		5b	with abundant stoniness
		5c	on drain lines, with severe erosion risk
		5d	moderately deep (50-100 cm), for the presence of a petrocalcic horizon
6	Petrocalcic Gypsic Solonchaks	6a	shallow deep (< 50 cm), for the presence of a petrocalcic horizon
		6b	phase with severe soil erosion risk
		6c	moderately deep (50-100 cm), for the presence of a petrocalcic horizon
7	Sodic Solonchaks (Ochric)	7a	with lacustrine substrate placed at a shallow depth (30-50 cm)
		7b	with lacustrine substrate placed at a very shallow depth (< 30 cm), due to soil erosion

Soil type 1

The Soil Type 1 is located in areas of the main level of the lower alluvial fan and in its depressions, which are either not cultivated or recently cultivated (see Fig.17 below).

Fig.17 a/b - Uncultivated areas (left) and recently planted areas (right)

Fig.17 c - Soil type 1, and P7, with its salty crust

These soils originated by thick alluvial deposits that cover the lacustrine deposits, which can be found at depths greater than 50 cm, and both extremely saline and extremely sodic, with presence of gypsum crystals. The texture is sandy clay loam, somewhere clay loam in the subsoil.

In uncultivated soils, soil drainage is moderate due to platy structure of the first 10 cm of the profile and the presence of a thick crust on the surface. With irrigation and ploughing drainage can be improved since the soil is very porous. Soil is extremely sodic, extremely saline and moderately alkaline. Cation exchange capacity is medium. Coarse fragments are very few and the soil workability is good.

The phase 1 has contact with the lacustrine substrate at depths greater than 100 cm. In the phase 2, the lacustrine deposit is 50 - 100 cm deep, and gypsum crystals may not be present.

Soil type 2

The Soil Type 2 is located in the main level of the lower alluvial fan, in stable cultivated areas. As the soil type 1, is originated by thick alluvial deposits. The lacustrine deposits are more than 1m deep (see Fig.18). Erosion is generally absent or slight.

These soils are fine textured (clay in the first horizons, clay loam or sandy clay loam in the deeper horizons), moderately sodic and very slightly to moderately saline. Few calcium carbonate concretions may be present and gypsum crystals are present from the lower boundary of the topsoil to the limit with lacustrine material.

Due to the high content in clay, fine cracks may be present on the surface. Medium crust is sometimes evident. The drainage is in general good.

Soil type 3

This Soil Type is located in the main level of the lower alluvial fan. The parent material consists of deep or very deep alluvial fine (silt and sand) deposits over lacustrine material (see Fig.19). Erosion is generally moderate and the soil is well drained.

Fig.18 An example of Soil Type 2: the two parent materials are very evident: the alluvial deposit in the upper part, the lacustrine in the lower part

Fig. 19 Soil Type 3: in this profile the alluvial deposit is very thick, and the lacustrine material was not reached (P12, 2022).

Fig. 20- Soil Type 4: the greyish-whitish lacustrine material at about 100-120 90 cm deep (P4, 2022

The texture ranges from sandy clay loam to loam, sometimes clay in the subsoil. These soils are moderately sodic in the surface horizons, sometimes extremely sodic in the subsoil. Surface horizon is generally moderately saline. Few calcium carbonate concretions may be present and gypsum crystals are present from the lower boundary of the topsoil.
The phase 1 has contact with the lacustrine substrate at depths greater than 100 cm. In the phase 2, the lacustrine deposit is 50 - 100 cm deep.

Soil type 4

The soil type is typical of the upper part of Wadi Al Qelt alluvial fan, and it is diffused in areas that are cultivated with annual irrigated crops. The parent material consists of lacustrine deposits and moderately deep (50-100 cm) alluvial fine deposits (see Fig.20).

These soils have horizons enriched with secondary calcium carbonate (calcic horizon). In these horizons the content of carbonates riches 40-50%. The texture is clay and the drainage is generally good but locally it may be moderate since the soil is sometimes compacted.
They are moderately sodic and, in surface layers, very slightly to slightly saline.

Soil type 5

In this Soil Type (Fig.21), substratum and parent material consist of non or slightly weathered lacustrine deposits. These soils are present both in the upper and lower part of the alluvial fan. On the upper part of the alluvial fan they have been cultivated for longer, while in the lower part are not or very recently cultivated.

Fig. 21 Soil Type 5: see the fine horizontal stratification of lacustrine deposits (P9, 2022), the gypsum crystal layers and the salt crust on the surface

The texture ranges from sandy loam to loam, and the soil is moderately well drained, moderately to strong sodic, and strong saline. Common to abundant horizontal layers of powder gypsum and/or carbonates are present beneath the ploughed horizon.

The phase 1 has few or common stoniness. In the phase 2, the stoniness is abundant. lacustrine deposit is 50 - 100 cm deep. The phase 3 is located on drain lines, where the soil erosion risk is severe. Phase 4 is moderately deep (50-100 cm), for the presence of a petrocalcic horizon.

Soil type 6

This soil type (Fig.22) is characterised by the presence of a petrocalcic/petrogypsic horizon at shallow depth (< 50 cm). This horizon is permanently cemented, and constitutes an obstacle to the deepening of plant roots and for a free soil drainage; its presence at shallow to moderate depth is very common in the southern part of the mapped area.

Fig. 22 Soil Type 6: A broken the petrocalcic/petrogypsic horizon starts from 40-60 cm deep; petrogypsic horizon fragment and surface salt crust (P14 2022)

The parent material of Soil Type 6 consists of shallow - very shallow alluvial fine deposits over lacustrine material. Surface stoniness is generally few and consists of pebbles. Stoniness may be abundant to dominant, consisting of broken petrogypsic/petrocalcic layers with flat shape. The topsoil is in general clay textured and saline. The drainage is moderate, water erosion may range from moderate to strong.

The phase 1 is shallow deep (< 50 cm), for the presence of the petrogypsic/petrocalcic horizon. In the phase 2, surface is gentle inclined and undulated and the soil erosion risk is severe. The phase 3 is moderately deep, for the presence of the petrogypsic/petrocalcic 50-100 cm deep.

Soil type 7

This soil type (Fig.23) originates from shallow alluvial deposit on the lacustrine parent material. As per Soil Type 5, these soils are present both in the upper and lower part of the alluvial fan. The soil is deep and in general well drained.

The texture ranges from clay (alluvial parent material) to loam (lacustrine parent material). The surface horizons are saline or moderately saline and sodic. Lacustrine parent material is strongly saline.

The phase 1 has contact with the lacustrine substrate at shallow depths (30-50 cm). The phase 2 is located in in depressions of the main level of the plain, where the soil erosion is higher. In this phase, the lacustrine deposit is at very shallow depth (< 30 cm).

Fig. 23 Soil Type 7: representative profile, with 30 cm deep alluvial DEPOSITS (P3 2022)

The Soil map of the study area

The soil map of the study area was obtained indicating the prevalent soil types in each of the identified land units. The soil map and its legend are shown in the figure (Fig.24) and table below.

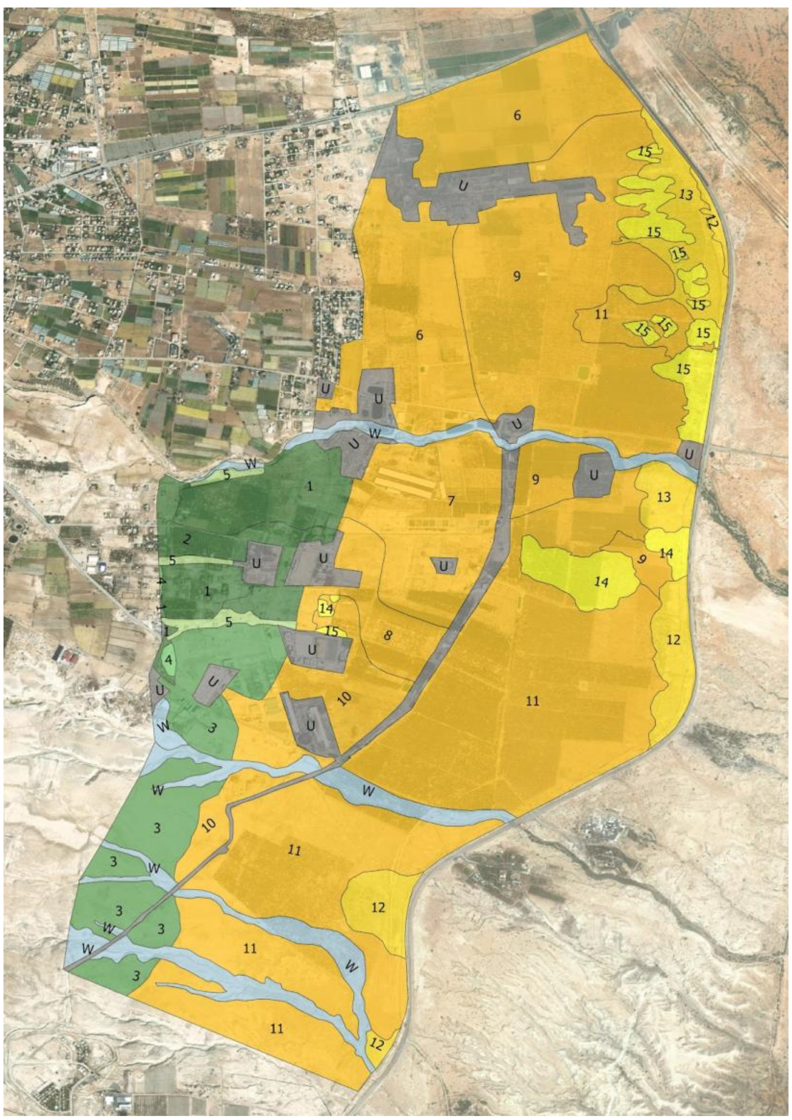


Fig. 24 The Soil map of Jericho area

In the following table 10 are indicated the dominant soil types for each soil map unit.

Tab. 10 dominant soil types in the map units

Land Unit	Land subunit	Soil map unit	Soil Types and phases
1 - Upper Alluvial Fan	1A - Main level of the plain, cultivated	1	7a
			4
		2	5a
	1B - Main level of the plain, unclutivated or recently cultivated	3	7b
			5a
	1C - Erosion areas	4	5b
	1D - Drain lines of the main level of the plain and upper terraces of the main wadis	5	5c
			7b
2 - Lower Alluvial Fan	2A- Main level of the plain	6	2
			3a
		7	6a
			6c
		8	7a
		9	3a
			3b
		10	5a
			7a
		11	1b
			6c
			6a
	2B - Depressions of the main level of the plain with frequent drain lines and gullies	12	6b
		13	1a
			5c
	2C - Remnant surfaces of lacustrine material rising from the main level of the plain	14	6a
		15	5d
Wadi's winter beds		W	
Urban areas		U	

The land suitability for irrigation

In the area the irrigation system currently most used is drip irrigation. In the two following tables (Tab.11,12) some significant characteristics and properties are indicated for each of the soil types identified in the study area.

Tab.11 Characteristics of the soil types (part 1).

Soil Type	Drainage	Soil depth to permanently cemented horizon (cm)	Stoniness (%)	Topsoil textural class	Topsoil clay (%)	Topsoil sand (%)	Subsoil textural class	Topsoil coarse fragments (%)
1a	good	>100	8-10	Sandy clay loam	23-27	50-60	Sandy clay loam	1
1b	good	>100	8-10	Sandy clay loam	23-27	50-60	Sandy clay loam	1
2	good	>100	1-3	Clay	60-70	10-20	Clay loam	1
3a	good	>100	3-8	Loam to Sandy clay loam	25-30	50	Sandy clay loam to Clay	1
3b	good	>100	3-8	Loam to Sandy clay loam	25-30	50	Sandy clay loam to Clay	1
4	good	>100	3-8	Clay	40-45	30	Clay	3
5a	moderate	>100	2-3	Clay loam	30	25	Loam	1
5b	moderate	>100	30-50	Clay loam	30	25	Loam	10
5c	moderate	>100	3-10	Clay loam	30	25	Loam	5
5d	moderate	50-100	2-3	Clay loam	30	25	Loam	1
6a	moderate	20-40	2-3	Clay	50	35	Clay loam	8
6b	moderate	20-40	2-3	Clay	50	35	Clay loam	8
6c	moderate	50-100	2-3	Clay	50	35	Clay loam	8
7a	good	>100	10-12	Clay	40	30	Loam	1
7b	good	>100	12-20	Clay	40	30	Loam	1

Tab.12 Characteristics of the soil types (part 2), EC = Electrical Conductivity, ESP = Exchangeable Sodium Percentage, OM = Organic Matter.

Soil Type	Structure (topsoil)	Hydraulic conductivity	EC (dS/m)	ESP %	pH topsoil		pH subsoil		Gypsum (%)	OM topsoil (%)
1a	moderate	slow	50/4	32	7.9	alkaline	8.0	alkaline	0-9	2.8
1b	moderate	slow	50/4	32	7.9	alkaline	8.0	alkaline	0-9	2.8
2	moderate	slow	8-15	16/6	7.1	slightly alkaline	7.6	slightly alkaline	1/3	1.6
3a	weak	slow	7-8	10/30	8.3	alkaline	7-7.8	slightly alkaline	1-23/0	1.0
3b	weak	slow	7-8	10/30	8.3	alkaline	7-7.8	slightly alkaline	1-23/0	1.0
4	weak	slow	2	10	7.8	slightly alkaline	8.1	alkaline	traces	1.2
5a	weak	moderate	20-25	7/18	7.8	slightly alkaline	7.6	slightly alkaline	17/0	1.8
5b	weak	moderate	20-25	7/18	7.8	slightly alkaline	7.6	slightly alkaline	17/0	1.8
5c	weak	moderate	20-25	7/18	7.8	slightly alkaline	7.6	slightly alkaline	17/0	1.8
5d	weak	moderate	20-25	7/18	7.8	slightly alkaline	7.6	slightly alkaline	17/0	1.8
6a	weak	very slow	20/6	5/8	7.0	neutral	7.0	neutral	12/22	1.3
6b	weak	very slow	20/6	5/8	7.0	neutral	7.0	neutral	12/22	1.3
6c	weak	very slow	20/6	5/8	7.0	neutral	7.0	neutral	12/22	1.3
7a	moderate	slow	12-15	10-17	7.0	neutral	8.0	alkaline	0-1	1.9
7b	moderate	slow	12-15	10-17	7.0	neutral	8.0	alkaline	0-1	1.9

An important property of the soil to be considered for irrigation purposes is the Available Water Capacity (AWC). The AWC is the amount of water that a soil can store that is available for use by plants, and it is calculated by making the difference between the soil water content at the field capacity and the water content at the wilting point. For this purpose, the Saxton pedotransfer function (Saxton-Rawls, 2006) was used. Two matrix potential points were considered: pF 2.5, which is considered as the condition of the field capacity, and pF 4.2, which corresponds to the soil moisture at the point of permanent drying (i.e. the water content in the soil is too low for the plant's roots to extract water).
In the following table (Tab.13) the AWC values obtained for the soil types of the area are reported.

Tab. 13 The AWC for the soil types.

Soil Type	AWC	
	mm/m	
1	44	very low
2	25	very low
3	107	moderate
4	81	low
5	63	low
6	27	very low
7	91	low

AWC values are largely low or very low. This result is certainly linked to the soil salt content, which renders less water available to plants because of the osmotic pressure in the soil solution.

The assessment of land suitability for drip irrigation was conducted according to the parametric evaluation system (Sys et al., 1991), in order to achieve a first thematic map of the study area from this point of view. The land suitability for irrigation classes are summarised in the table below.

Tab.15 Land suitability classes (Sys et al., 1991)

Land suitability classes

S1 Very Suitable: Land Units with no or only slight limitations.

S2 Moderately Suitable: Land Units with moderate limitations.

S3 Marginally Suitable: Land Units with severe limitations.

N1 Actually Unsuitable and Potentially Suitable: Land Units with very severe limitations which can be corrected.

N2 Unsuitable: Land Units with very severe limitations which can not be corrected.

The land evaluation was determined based upon topography (slope) and soil characteristics and properties such as soil texture, depth, salinity, drainage and calcium carbonate content.

In the following table (Tab.14), the land suitability for drip irrigation for the soil types and phases is shown.

Tab.14 Land Suitability for drip irrigation of the Soil Types and Phases

Soil Type	Suitability class for drip irrigation	Main limiting factors
1a	N2	Slope (5-8%), very strong salinity
1b	N2	Very strong salinity
2	S3	Moderate salinity, clay texture
3a	S2	Weak salinity, high calcium carbonate
3b	S2	Weak salinity, high calcium carbonate
4	S2	High calcium carbonate, clay texture
5a	N2	Strong salinity
5b	N2	Strong salinity
5c	N2	Strong salinity
5d	N2	Slope (5-8%), strong salinitySalinity in the topsoil, sodicity
6a	N1	Slope (5-8%), shallow depth, clay texture
6b	N1	Slope (5-8%), shallow depth, clay texture, high calcium carbonate
6c	S3	Very high calcium carbonate, clay texture
7a	S2	Very high calcium carbonate
7b	S3	Very high calcium carbonate, high coarse fragments

In the following figure (Fig.25) is showed the result of the application of the above-mentioned scheme to the soil map.

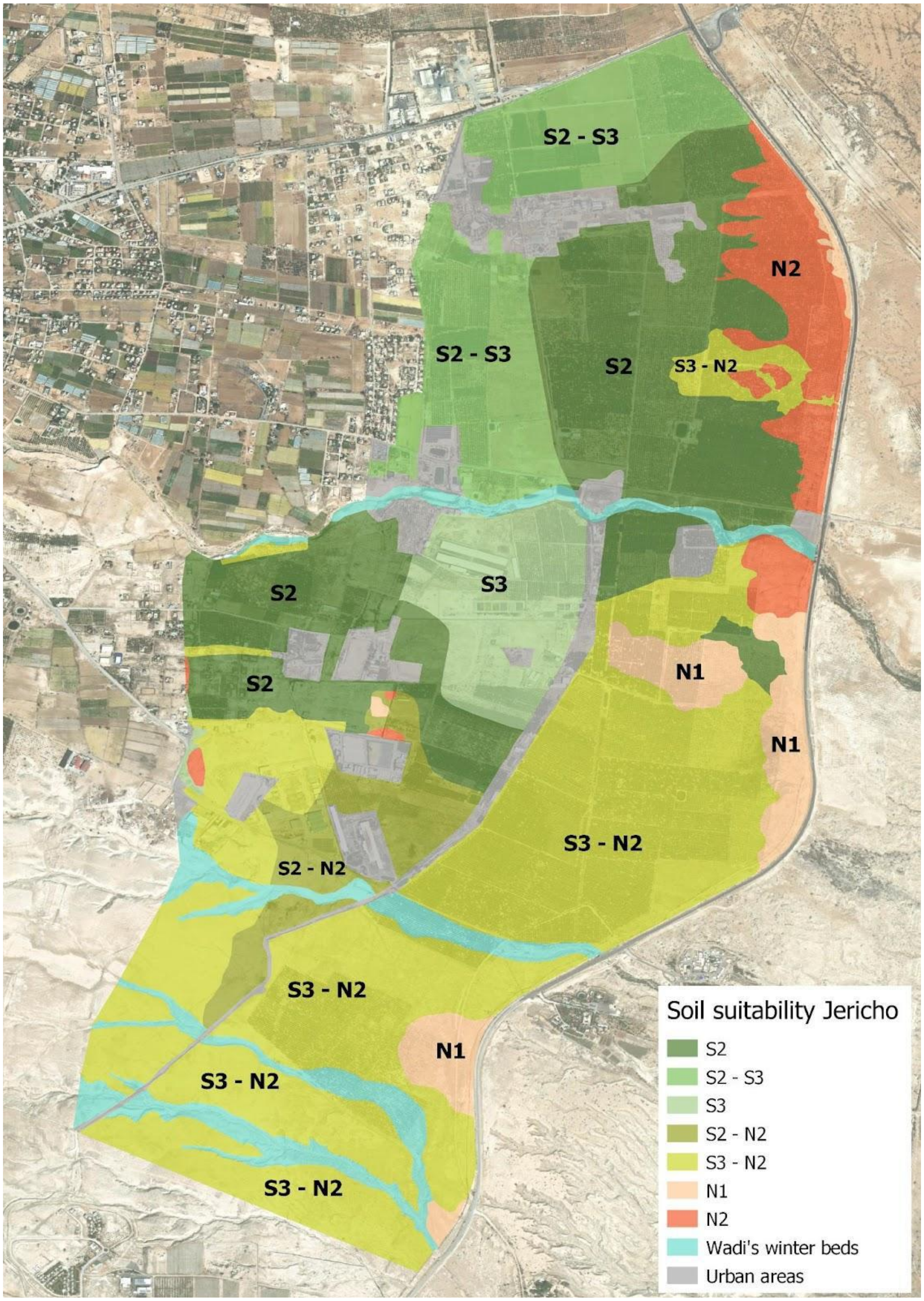


Fig.25 Land Suitability map of the study area, based on the properties of the land units and the dominant soil types.

In the table below the detail of the irrigation suitability assessment for the land units of the soil map is summarised, with the description of the main limiting factors involved and the area covered by the land units.

Tab.15 Land Suitability classes in the land units of the Jericho area.

Land subunit	Soil map unit	Soil Types	Land suitability for drip irrigation	
			Class	Main limitations
1A	1	7a	S2	Very high calcium carbonate
		4	S2	High calcium carbonate, clay texture
	2	5a	S2	Very high calcium carbonate
1B	3	7b	S3	Very high calcium carbonate, high coarse fragments
		5a	N2	Strong salinity
1C	4	5b	N2	Strong salinity
1D	5	5c	N2	Strong salinity
		7b	S3	Very high calcium carbonate, high coarse fragments
2A	6	2	S3	Moderate salinity, clay texture
		3a	S2	Weak salinity, high calcium carbonate
	7	6a	S3	Shallow depth, clay texture, high calcium carbonate
		6c	S3	Moderate depth, clay texture, high calcium carbonate
	8	7a	S2	Very high calcium carbonate
	9	3a	S2	Weak salinity, high calcium carbonate
		3b	S2	Weak salinity, high calcium carbonate
	10	5a	N2	Strong salinity
		7a	S2	Very high calcium carbonate
	11	1b	N2	Very strong salinity
		6c	S3	Very high calcium carbonate, clay texture
		6a	N1	Slope (5-8%), shallow depth, clay texture
2B	12	6b	N1	Slope (5-8%), shallow depth, clay texture, high calcium carbonate
	13	1a	N2	Slope (5-8%), very strong salinity
		5c	N2	Slope (5-8%), strong salinity
2C	14	6a	N1	Slope (5-8%), shallow depth, clay texture
	15	5d	N2	Slope (5-8%), strong salinity
W				
U				

The first indication is that there are not areas with a "highly suitable" (S1) class in the study area. The reasons are mainly due to the soil characteristics, as salinity, calcium carbonate content, texture, in some cases shallow soil depth.

With regard to the N1 an N2 classes, in this area the nature of the limitations (salinity in large prevalence) is such that in reality it could be partially overcome with important investments and using tolerant crops.

The practice of soil leaching to remove salts is widespread in the area. In the period of greater water availability and less evapotranspiration, the available water is distributed through the drip irrigation system in order to favor the removal of salts from the topsoil. For this practice to be successful, a very useful intervention is to improve the deep drainage of the soils to facilitate the removal of the drained saline solution; in fact, if this is not removed, the dissolved salts inevitably rise towards the surface in periods of strong evapotranspiration.

To minimize the evapotranspiration in the driest periods, and to reduce the rising of the salts to the surface, a soil covering with mulch may be useful, also in order to limit the formation of the surface crust. Reducing or eliminating the surface crust is important both to stop the capillary rising of the salts and to increase the infiltration of rainwater by limiting the runoff as much as possible.

The agricultural baseline survey

The survey aimed at assessing the agriculture practices and its load on water resources. It also focussed on the characteristics of the value chains existing in the target area and its main actors.

The relevant information was collected by interviewing the General Director and the Agricultural extensionists of the general directorate of agriculture in Jericho. The local consultant also met the Director of the Palestinian Farmers Union and the manager of the waste water treatment plant. In addition, the central vegetable market was visited to understand the marketing process of vegetables, through interviewing farmers, buyers and wholesalers. Finally, eight farmers of palm dates were met to get specific information on technical requirements of dates cultivation and marketing channels. Relevant documents, like the Palestinian statistics reports, were reviewed and data used in this report are referred to the statistics report of agriculture season 2017-2018.

The following picture (Fig.26) shows a typical date palm orchard in the Jericho area.

Fig. 26 A date palm orchard in Jericho area

Palestinian agriculture sector and the Jordan Valley

The Jordan Valley is the most important agricultural area for production of vegetables and dates in the Palestinian territories. Despite of a peace accord between Palestinian and Israel the persistent expansion of Israeli settlements and other restrictions, imposed by the Israeli authorities, have made the life extremely challenging for Palestinian communities and business activities.

The Jordan Valley comprises over one third of the territory of the West Bank (in the area of three Governorates: Jericho, Nablus and Tubas) and contains vital land and water resources for the natural expansion of the Palestinian towns. It has abundant water resources – estimated as one-third of the underground water reserves in the West Bank – and has vast potential for agricultural, industrial and tourism industries. The economic development of the Jordan Valley is considered essential for Palestinian growth and recovery and is therefore crucial for the sustainability and viability of an independent Palestinian State. At the same time the Jordan Valley is one of the most restricted areas on earth. Since 1967 Israel has devised and implemented systematic measures aimed at ensuring absolute control over the region and isolating it from the rest of the West Bank.

In 2018, the value of agriculture production in the Palestinian territories was estimated as 2,465,050 thousand USD. In particular, in the Jordan valley the animal production value and the plant production value were estimated as 88,255 thousand USD and 52,051 thousand USD, respectively.

Animal husbandry

The livestock sector in Palestine contributes up to 46% of the total agricultural value. The backbone of this sector is represented by sheep and goats (small ruminants), dairy cattle and poultry. Agriculture is the main livelihood of 25.3% of livestock breeders. In the Palestinian territories, in 2018 there were 972,000 heads of sheep and goats, and 39,000 heads of cattle. The livestock sector’s total added value was 581 million USD. In various locations of the country, livestock is raised as a secondary activity to provide supplementary income to rural households. The small ruminants’ sector is therefore an important source of income for many Palestinian families, as it provides important products to local consumers and creates employment. It is also a sector where women contribute greatly. In the Jordan valley there are about 1,500 heads of cattle, 50,000 of goats and sheep and around 5,000 beehives. The production value of poultry meat and eggs in 2017-2018 season counts 264 million USD and 90,820 million USD, respectively.

In recent years, the livestock sector in Palestine has been facing severe difficulties in securing necessary production inputs (as most are procured from Israel), and timely technical support. It is worth mentioning that limited access and climate change weigh heavily on the availability of grazing land which play an important source of livestock feed a few months of the year. Moreover, aggressive competition from Israeli products (mainly poultry and eggs – a product for which Palestine reached self-sufficiency) often leads to major price fluctuations and subsequent financial losses. Furthermore, the breeders' households have been adversely affected by the construction of the military closed areas and the confiscation of land to establish settlements and natural reserves. In addition to these access restrictions, the high cost of imported commercial fodder, as an alternative in view of recurrent drought and the outbreak of animal diseases, has constrained the development of the livestock sector.

The cropping pattern in the Jordan Valley

The Jericho and Jordan Valley makes up 55% of the total area of irrigated lands in the West Bank. It accounts for 60% of vegetables produced in the West Bank and all dates harvested in Palestine. Most residents of the Jordan Valley's rural areas are engaged in agriculture, among plant and livestock production. Farmers own small holdings that do not exceed 5 dunums1 per family in certain cases, but there are also big landlords and tenants. They mostly produce seasonal vegetables, notably tomato, cucumber, pepper, eggplant, cauliflower, zucchini, cabbage, yellow corn, melon and watermelon. Since these crops are generally not valued on the local market, many farmers try to plant other crops which they deem more profitable, such as dates. Presently, date palms in the Jordan Valley take about 22,000 dunums, 16,000 dunums of which are mature and fully productive trees. Total production of dates from the Jordan Valley in 2019 reached 11,000 tons, of which 65% was exported. Product quality complies with the highest international standards and it is marketed extensively worldwide. The Medjool date is unique in the world and sold at high prices (Fig.27). Given the promising potential of the Palestinian dates' sector, plantation areas are increasing in direct response to market demand.

Fig.27 Medjool dates

The vast majority of agriculture land in the Jordan Valley is irrigated. The local climate is characterized by warm wet winter and hot dry summer. The annual precipitation in the area is 160 mm, thus not effective for agriculture. The daily irrigation requirements range between 1 mm in winter and 8 mm in summer for perennials. There are two main growing seasons for vegetables and field crops cultivation. The first one goes from August/September to January; the second one goes from January to June. There is also a third season which takes place in between the 2 main seasons, but it is very short.

Tab. 18 shows specific data of irrigated and rainfed crops in the Jericho and Jordan Valley. Noteworthy, there are just around 2,000 dunums of rainfed crops, located in the northern part of the Valley and adjacent to the western slopes, where herders sow barley or other field crops in winter. Most of these field crops do not reach maturity and are used for grazing purposes.

Out of the total area planted with vegetables (Fig.28), about 12,000 dunums are under greenhouses and 14,000 dunums are open field cultivations. Most of the land cultivated with vegetables is irrigated with fresh or low salinity water, either springs or well boreholes. Under greenhouses, farmers grow mainly cluster tomatoes, cucumber, pepper, beans and Mulukhiyah (Corchorus olitorius).

Productivity of vegetables is considered acceptable but not high. The average production of vegetables produced in open field, using drip irrigation, is about 3.4 tons/dunum, while it reaches up to an average of 13 tons/dunums under greenhouse. The average total production cost for open field crops is estimated as 2,700 NIS/dunum, while under greenhouse the cost raises up to 8,000 NIS/dunum.

Cultivated area in Palestine by Governorate

Table 1: Cultivated Area of Fruit Trees, Vegetables and Field Crops in Palestine by Governorate, 2017/2018 in Donums													
Governorate	Generl Total	Field Crops			Vegetables				Fruit Trees				
										Unbearing		Bearing	
		Total	Irrigated	Rainfed	Total	Protected Irrigated	Open Irrigated	Rainfed	Total	Irrigated	Rainfed	Irrigated	Rainfed
Palestine	**1,579,801**	**356,317**	**37,551**	**318,766**	**205,662**	**57,427**	**128,514**	**19,721**	**1,017,822**	**34,027**	**160,339**	**101,109**	**722,347**
West Bank	**1,389,508**	**312,060**	**20,179**	**291,881**	**147,230**	**45,989**	**81,520**	**19,721**	**930,218**	**12,937**	**160,339**	**34,595**	**722,347**
Jenin	**301,824**	**98,304**	7,578	90,726	**37,010**	6,861	23,836	6,313	**166,510**	302	21,120	1,269	143,819
Tubas	**90,809**	**39,365**	6,115	33,250	**27,193**	10,123	15,100	1,970	**24,251**	355	3,630	1,776	18,490
Tulkarm	**107,617**	**3,538**	1,360	2,178	**10,678**	6,009	4,370	299	**93,401**	488	9,074	3,188	80,651
Nablus	**186,391**	**29,987**	3,827	26,160	**10,591**	3,227	7,006	358	**145,813**	1,604	17,505	1,924	124,780
Qalqiliya	**67,154**	**3,398**	1,080	2,318	**2,893**	1,561	961	371	**60,863**	2,039	7,016	7,755	44,053
Salfit	**67,070**	**2,456**	54	2,402	**2,006**	24	774	1,208	**62,608**	-	8,182	105	54,321
Ramallah and Al-Bireh	**148,157**	**17,816**	-	17,816	**4,019**	121	1,253	2,645	**126,322**	96	32,600	467	93,159
Jericho and Al-Aghwar	**52,242**	**2,194**	30	2,164	**26,070**	12,291	13,779	-	**23,978**	7,359	-	16,619	-
Jerusalem	**29,931**	**5,213**	2	5,211	**1,042**	32	300	710	**23,676**	2	5,777	-	17,897
Bethlehem	**61,953**	**5,600**	-	5,600	**5,206**	432	4,278	496	**51,147**	-	13,191	302	37,654
Hebron	**276,360**	**104,189**	133	104,056	**20,522**	5,308	9,863	5,351	**151,649**	692	42,244	1,190	107,523

Fig. 28 Season vegetables grown in the Jericho area

Marketing of the vegetable crops

The Palestinian agricultural sector suffers from weak marketing capacity, due to poor organisation and coordination between the various stakeholders. These shortcomings have a negative effect on farmers' incomes and prevent the achievement of a better level of import substitution. Most of vegetables and field crops are sold through the central markets for vegetables (Fig.29).

There are about 12 central markets of vegetables in the West Bank, covering all governorates, except Jerusalem and Salfit. All of them are managed by local governorate units, either directly or by a third party. These markets were established in order to provide appropriate services to farmers, traders and intermediaries when handling agricultural produce, in addition to supplying a steady income to local entrepreneurs.

Services provided by central markets include guarding, cleaning and trade monitoring and they guarantee the collection of transactions and pay farmers. Some markets offer refrigeration services to store accumulated products. The market in Jericho is a small market and the municipality charges 0.6 NIS on each unit / box sold in the market. There is no refrigeration or long storing facility which forces the producers to sell directly to traders and or to the retailers. In general, between 30-35% of the selling price goes to the farmer, after deducting input costs. Margin (commission) of the wholesalers and retailers is set to 7% in Jericho, but it can vary from one governorate to another. Since the product may pass through more than one market and more than one intermediate, the average mark-up for wholesalers can typically reach up to 15% of the price paid by the final consumer. Costs for wholesalers include procurement, municipal/market charges, financing, storage and product losses. The margin of retailers varies according to source (market, via distributor, etc.), location and product variability. Overall, retail rates are about 40% of consumer prices. Costs are calculated based on a purchase price, rent, wages of workers in addition to damaged goods, which vary during summer and winter at a rate of around 7%.

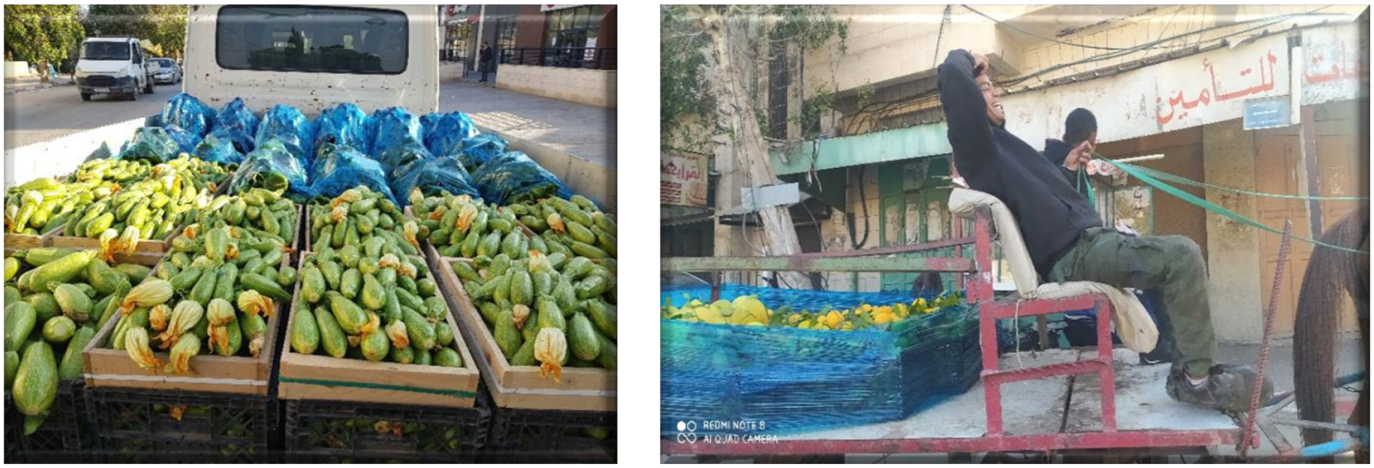


Fig. 29 Fresh products are transported to the general market of Jericho

Pricing policies

Farmers in general have little influence on vegetables prices. The majority of farmers who sends the produce to the wholesale markets base their pricing on supply and demand on the local market. Only a few of them depend on prices previously agreed with traders. It is worth noting that prices vary among governorates depending on the availability of produce in the market. When preparing this report, it was noted that prices were falling sharply, due to the local availability of produce coming from other governorates, as consequence of the negative weather conditions occurring in the Jordan Valley. The current prices for major crops, like tomatoes, per box reach 15 NIS; squash about 15 NIS; eggplant about 8 NIS. The weight of one generic box of produce ranges between 18 to 22 kg.

Obstacles to vegetable crops production in the Jordan Valley

Marketing is the main issue faced by small farmers, as reported by almost all interviewed producers. The following are the main challenges encountered by the farmers (Fig.30,31):

*High cost of inputs, which limits competition and profit margins;

*Inadequate technical and marketing services to farmers, with poor information on market opportunities and their requirements;

*High cost of agricultural loans coupled with the high risk of natural (climatic) disasters and lack of an efficient insurance system to reduce the risk of investment;

*High transaction costs. Such costs keep high the cost of export, so they represent a major constraint to the ability of Palestinians to compete when compared to similar costs of the neighbouring countries.

Fig. 30 e 31 Fresh products displayed at the general market of Jericho

PILOT SITE – AL-RISHA (JORDAN)

By Timesis

The pilot area is located in Ar-Rishah site, located in Wadi Araba valley, ca. 75 km north of Aqaba (see Fig.32 below).

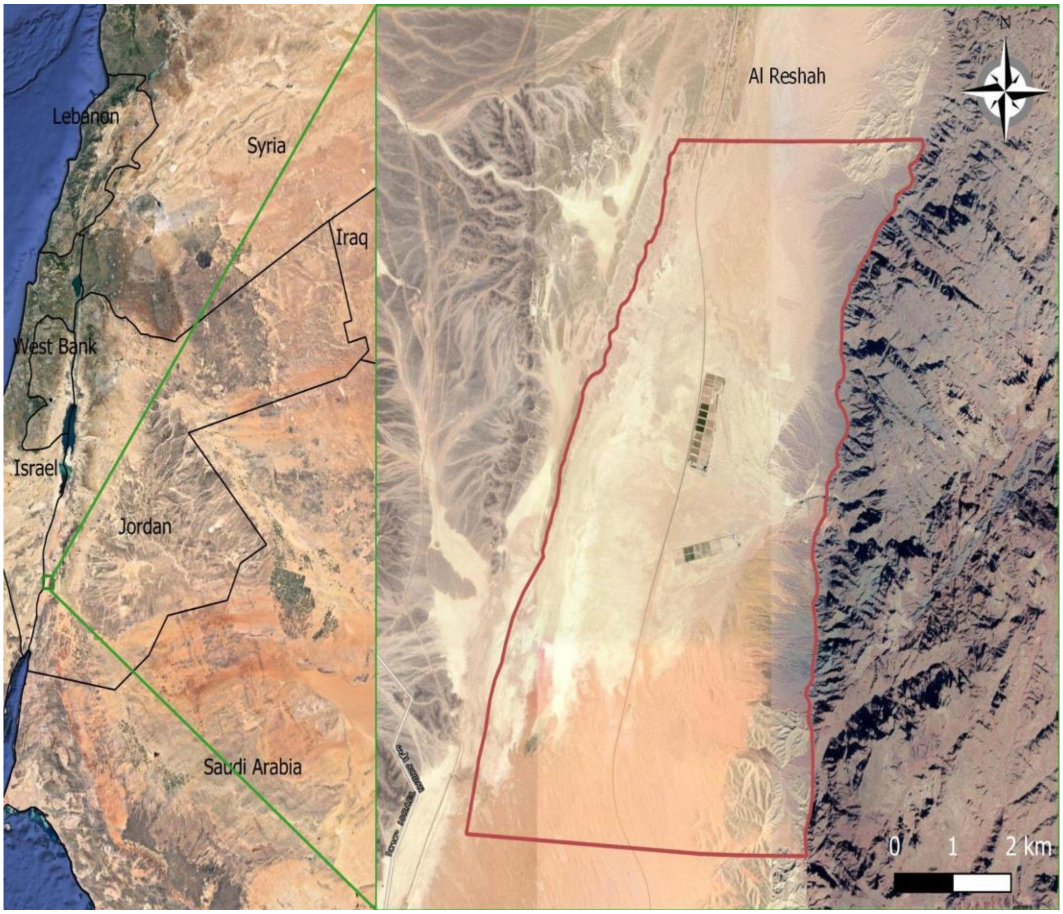


Fig. 32 The MEDISS project area in Jordan

The soil baseline survey

The soil forming factors and the pedogenetic processes

Climate

The Ar-Rishah site is located in the valley floor of Wadi Araba valley, at an altitude between 180 and 250 m asl.
According to *Köppen-Geiger climate classification system*, which divides climates into five main groups based on seasonal precipitation and temperature patterns, Jordan's climate belongs to group B, *Dry (desert and semi-arid) climates.* In particular Aqaba region is classified as **BWh**, hot desert climate, with average annual temperature above 18 °C and annual precipitation amount less than 50% of the potential evapotranspiration value.
Jordan's climate is influenced by the Dry Sirocco (Khamsin) winds, which can lead to large temperature anomalies, with increases of up to 15°C. The Shammal Winds are also an influencing factor, blowing from the north and northeast and causing high daytime temperatures.
In Aqaba region temperatures range from 4-18°C in the winter season and reach 36°C during the hottest season. The coldest month is January and August the warmest. The average maximum temperatures during January and August are around 16 °C and 36 °C respectively. The average minimum temperatures for the same months are around 4.9°C and 21.43°C respectively.
The maximum precipitation is registered in February but in general the months from December to March are the rainiest one. Total annual precipitation is about 46.8 mm on average but there is high variation with a maximum of 80.2 mm and minimum of 28.3 mm in the last 30 years (Tab.16, Fig.33).

Tab. 16 Monthly climatology of Max-temperature, Mean-temperature, Min-temperature (°C) and precipitation (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max-Temperature °C	16.25	18.22	22.07	26.70	31.20	34.60	36.06	36.29	33.87	29.84	23.28	18.12
Mean-temperature °C	10.57	12.11	15.59	19.72	23.97	26.84	28.67	28.83	26.67	22.87	16.96	12.26
Min-temperature °C	4.94	6.03	9.15	12.79	16.80	19.12	21.35	21.43	19.53	15.97	10.70	6.45
Precipitation mm	6.77	8.51	5.71	3.79	4.06	1.80	3.00	0.46	0.77	3.46	2.75	5.31

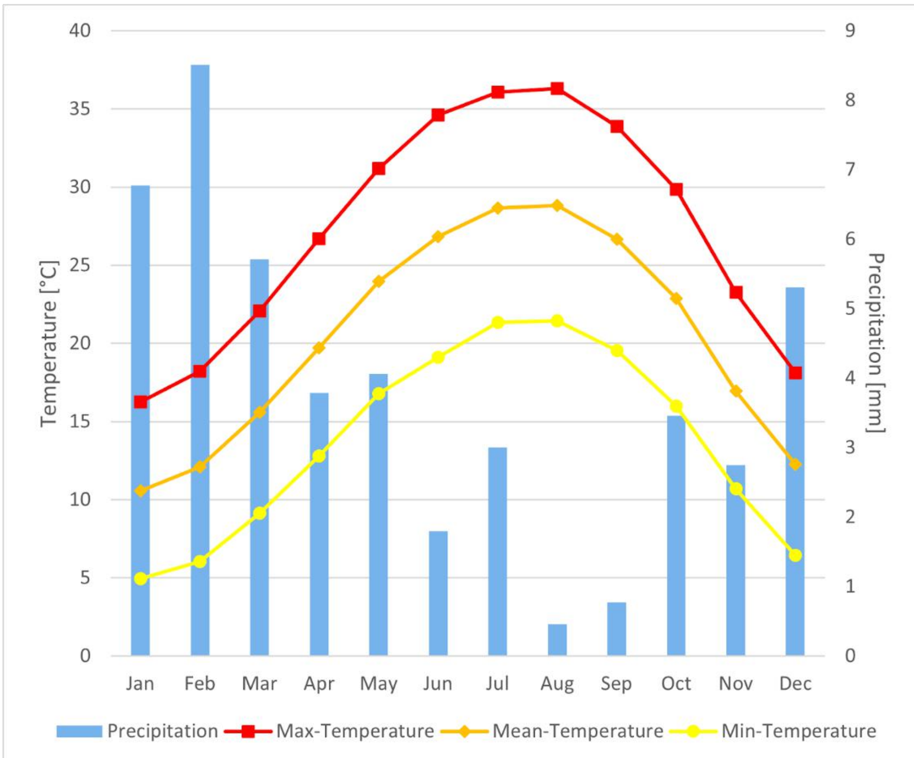


Fig. 33 Monthly Climatology of Min-Temperature, Mean-Temperature, Max-Temperature and precipitation 1991-2020, Aqaba (Jordan) (source: West Bank Group, Climate Change Knowledge Portal)

The following figures (Fig. 34-36) show annual average temperature and precipitation of the last century.

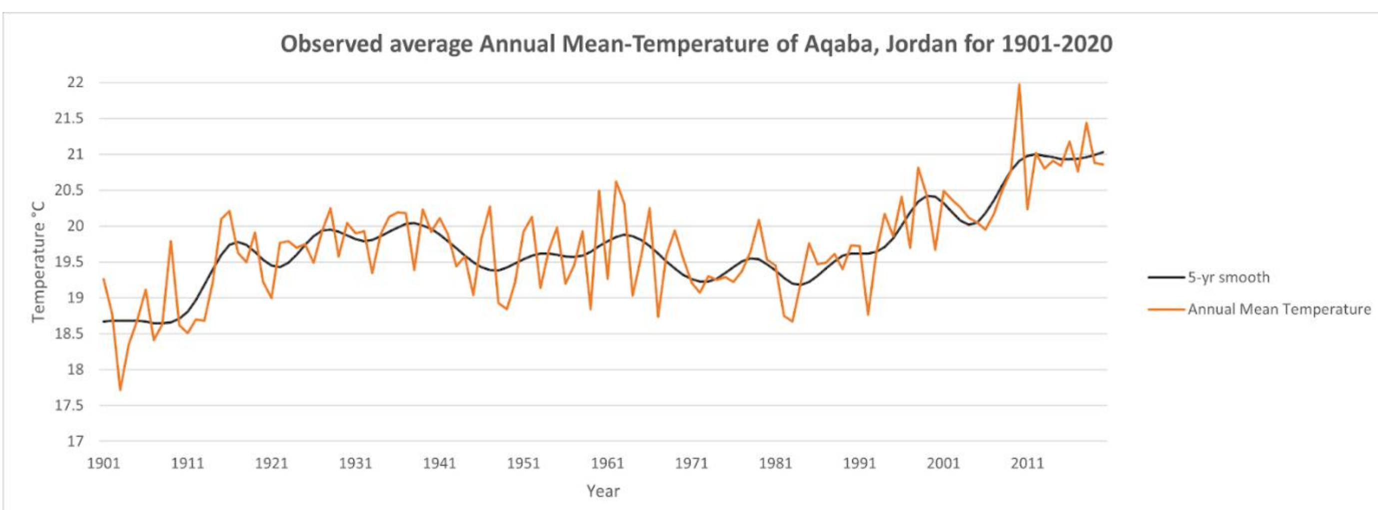


Fig.34 Observed Annual Mean-temperature of Aqaba, Jordan for 1901-2020 (source: West Bank Group, Climate Change Knowledge Portal)

In general, an increase in average temperature is observed. Precipitation trend presents greater variability, but a decrease can be seen. In particular, the average temperature of the last thirty years has risen by 0.9°C compared to the previous thirty years (1961-1990), and average precipitation decreased by 9.6 mm/year.

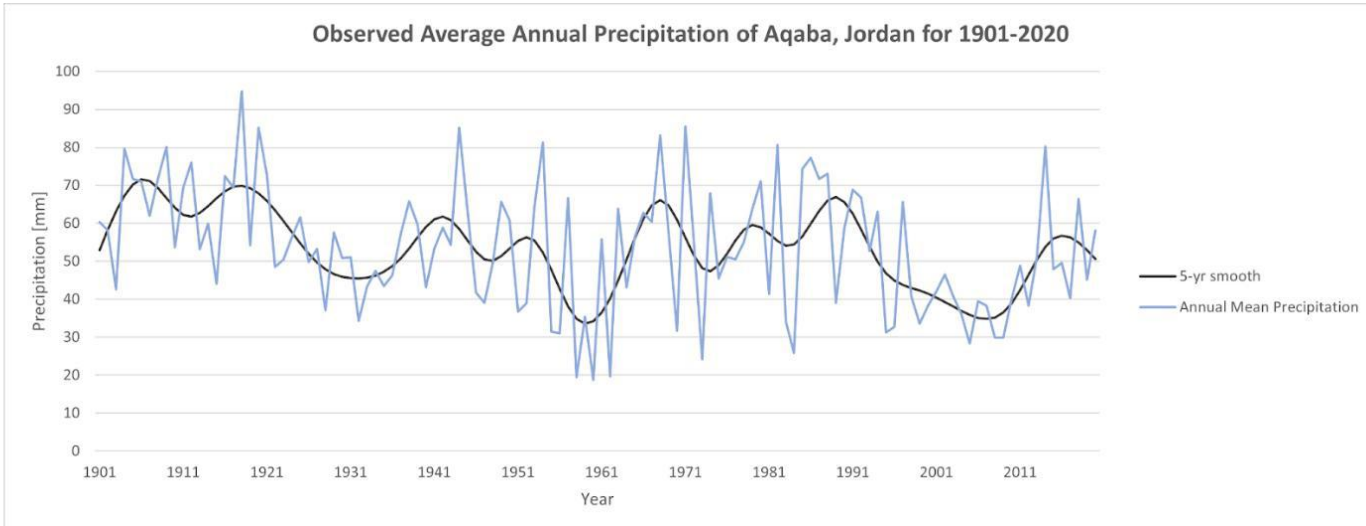


Fig. 35 Observed Average Annual Precipitation of Aqaba, Jordan for 1901-2020 (source: West Bank Group, Climate Change Knowledge Portal)

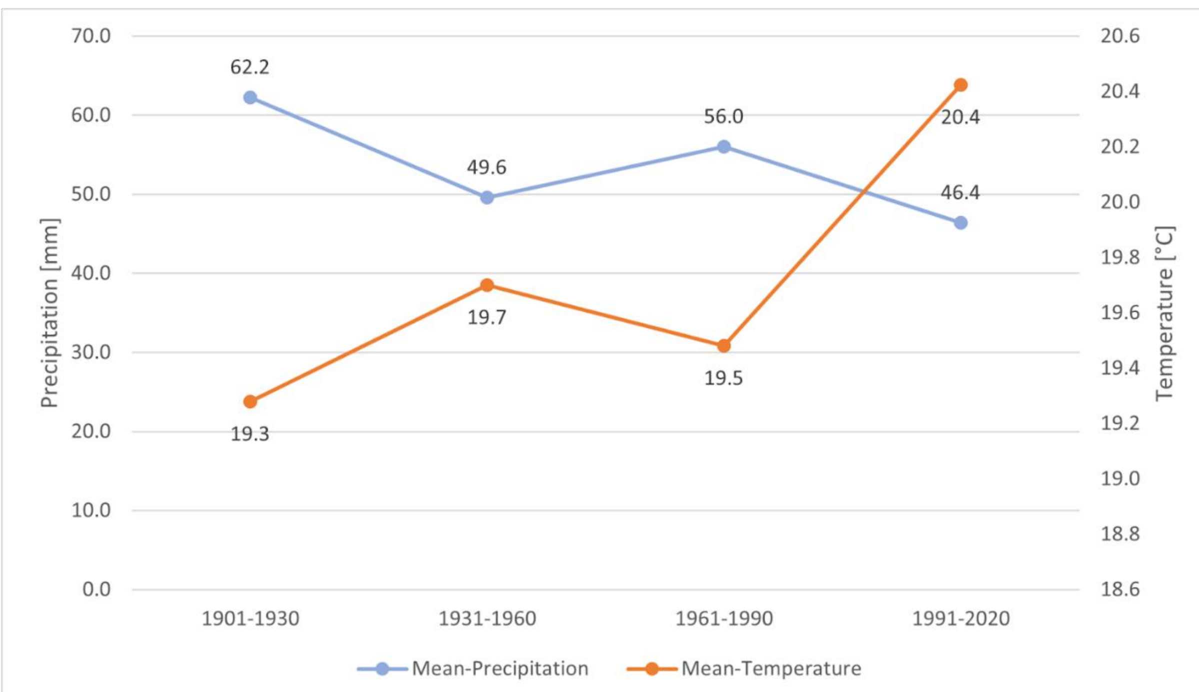


Fig. 36 Mean-temperature and Mean-Precipitation trend of the last century for past and current climatology periods (30 years).

Geology and geomorphology

The valley is part of the Rift Valley, surrounded by mountains composed of many different lithologies. Large alluvial fans and glacis occupy the eastern part of the valley, close to the mountain bases; the clasts composing them can be considered representative of the parent material lithologies for the studied soils. In particular, granitoid rocks are the large majority, but some carbonatic and mafic/ultramafic clasts are also present; some clasts are derived from the many dikes intersecting the mountain slopes, composed of dark volcanic rocks (presumably basalt).

Land use and vegetation

The vegetation cover is very sparse, and strong water erosion characterize the slopes during the few winter rainfall events; this means that the alluvial fans and colluvial glacis are highly active and the soils are usually quite young.

Large areas are covered by orange aeolian sands, while deflation areas are hard, whitish, silt-rich flats, also interested by low-energy floods during the winter rainfall events.

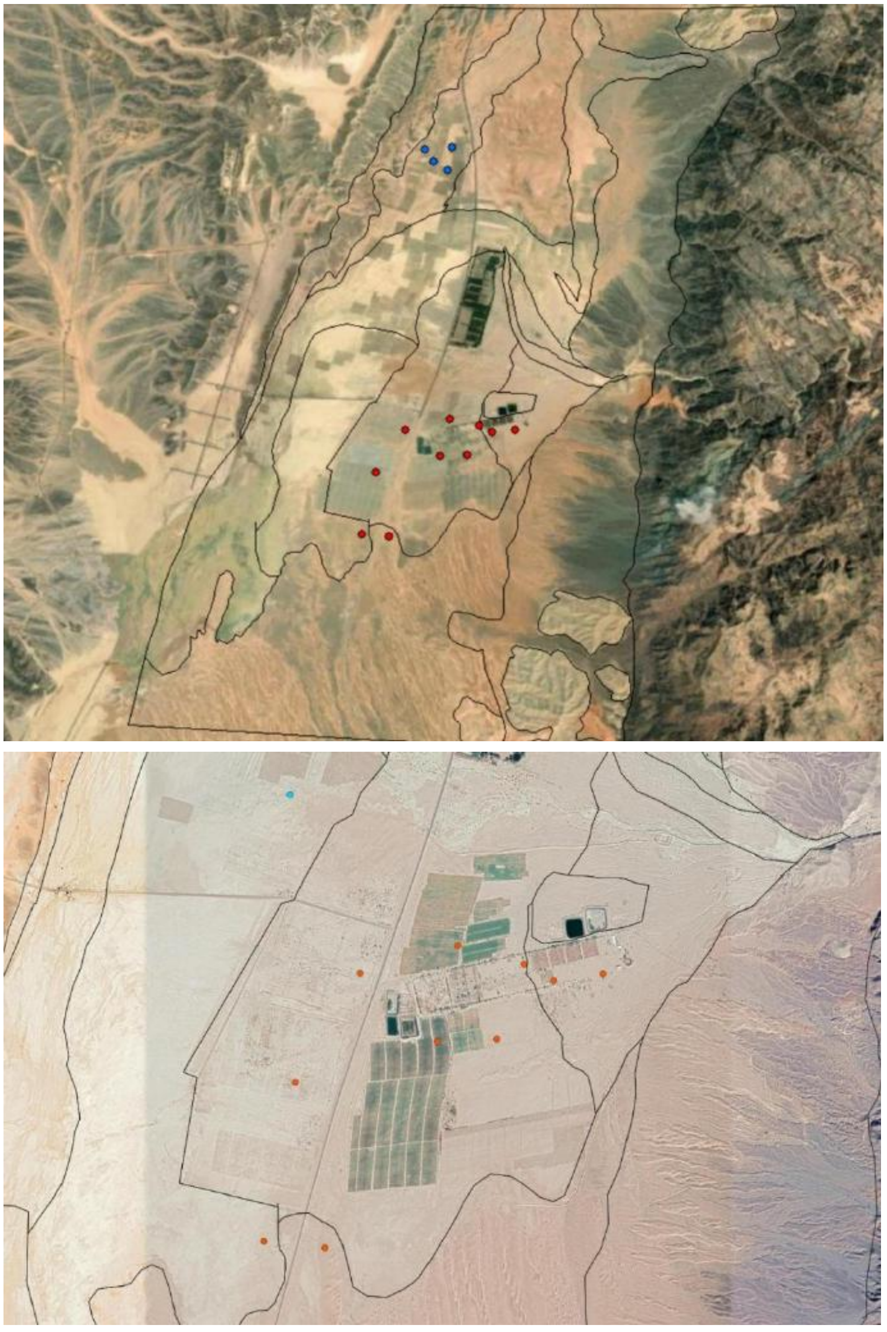


Fig.37 a, b: location of the soil observations in the study area; soil profiles are evidenced in red, auger holes in blue. The land units are shown but they will be explained in the next images.

The pedogenetic processes

In the southern part of Wadi Araba, soils are all weakly developed, and the main pedogenic processes can be summarised by accumulation of alluvial material, followed by wind erosion and deposition and weak salt, gypsum and calcium carbonate redistribution.

Extensive areas are covered by aeolian sands, while others (deflation areas) are more silty; stone rich soils are more common approaching the base of the mountain slopes. Soil salinity is not particularly high, thanks to the proximity to the water divide between the Red Sea basin and the Dead Sea one, but salts are nevertheless concentrated in surface horizons thanks to the high ariditiy of the area, giving rise to ascending water movements in the soils thanks to capillarity. Gypsum is not abundant, but a few gypsum crystals can be seen under a microscope in most soil types. Calcium carbonate enriched horizons (or partly cemented ones) are common as well, at a few tens of cm from the soil surface.

Field survey campaign and laboratory tests

The first phase of the soil investigation included the preliminary delineation of Land Units, based on the available GIS materials (satellite images available on Google and Bing platforms), defined mainly on the land use, interpreted from aerial photographs at the 1:10.000.

The field work was carried out in August 4th and 5th, during which 10 soil profiles were dug and described in the precise sites chosen by local stakeholders, as shown in the map; the soil pits were dug with the help of a local excavator (Fig. 37 a,b,38). The sites were both in non-irrigated soils, where the future implementation of the irrigation system should take place, and in soils previously irrigated but abandoned at present. All main environmental units (aeolian deposition and ablation areas, coarse and fine alluvial fans, valley floor) were characterized. After the realization of the field activities and the soil profiles, a modification of the Soil Unit map was performed.

Seven additional samples were taken from topsoil and subsoil layers in four minipits in the northern part of the study area (T1, T2, T3, T4).


Fig. 38 excavator digging profile P2, in a previously irrigated field but abandoned at present

Soil pits and the environmental properties of the sites were described according to standard methods (FAO, 2006), and the data were collected on a field sheet. In particular, the depth and thickness of the horizons were observed, their colour characterized using Munsell tables, the structure, consistence, plasticity were characterized as well, the stones and roots were quantified, and possible cementations and coatings were described. The main environmental properties were characterized as well. The soils were than classified according to the WRB international system (IUSS Working Group, 2015).

In particular, in each soil pits, the following soil and land features have been observed and assessed:

- land features: landform, slope, land use, rock outcrops, surface coarse fragments, surface sealing, surface cracks, microrelief;
- soil depth, depth of top and bottom of layer;
- nature of the soil horizons;
- colour of soil in each horizon using the Munsell soli colour system, mottles included;
- soil texture of each horizon as determined by hand texturing method;
- soil structure;
- rock fragments content, shape and weathering degree;
- voids and pores;
- consistence
- soft concentrations, nodules and concretions
- roots
- photographs of the soil profile, soil structural aggregates from different horizons and landscape

Approximately 1 kg of soil material was collected from all genetic horizons in every soil profile (n=28), to perform the standard chemical and physical laboratory analysis. The results are required for the evaluation of soil fertility, salinity and suitability for irrigation.

All the chemical and physical analysis were performed by the selected laboratory (in the Jordan University Farms in As Salt, Northern Jordan, by Dr Zohuire A. Albalawna). In particular, the following standard lab analysis have been performed on the 28 disturbed samples:

- Texture (pipette method; 3 fractions: sand (50-2000 μm), silt (2-50 μm), clay (<2 μm);
- pH in water (1:2.5 soil-water ratio), on both field wet samples and after drying;
- Electrical Conductivity (ECe, 1:2.5 soil-water ratio);
- Total carbonate content (The carbonate content was calculated by volumetric analysis of the carbon dioxide liberated by a 6 M HCl solution in a calcimeter);
- Cation Exchange Capacity (CEC, ammonium acetate method);
- Exchangeable bases (Ca, Mg, K, Na), measured by Flame Absorption technique (FAAS) on the CEC extract;
- Total carbon and total nitrogen were measured with a CN analyzer, later organic carbon was calculated as difference between total C and carbonate-C;
- Total Nitrogen (Kjeldahl method);
- Available Phosphorous (Olsen methods, as soil pH was above 7).

Given the loose consistence and lack of structure of most soil horizons, we could not collect undisturbed samples for the evaluation of the available water capacity (AWC) and permeability (Ks); these important parameters were thus calculated using pedotransfer functions (Saxton et al., 1986) based on soil texture (eq. 1). We decided to use only such simple functions, without considering structure or organic matter, as the latter was extremely scarce, and structure was extremely weak in most horizons.

Eq 1: □□ = 2.778 × □□□(□)

Where:

□ = 12.012 − 7.55 × 10^{-2}(□□) + {−3.895 + 3.671 × 10^{-2}(□□) − 0.1103(□□) + 8.7546 × $10^{-4}$$(□□)^2$}/□□

□□, porosity = 0.332 − 7.251 × (□□) + 0.1276 □□□10(□□)

Sa: sand (%)

Cl: clay (%)

The Land units map

The Land Units map was carried out and checked during the soil field survey. In particular, during the field work soil types were correlated with geomorphic units (Land Units), and the results showed that pedogenesis/soil properties in the area were quite well correlated with them.

The Land Units map and its legend are shown in the table (Tab. 17) and figure (Fig. 39) below.

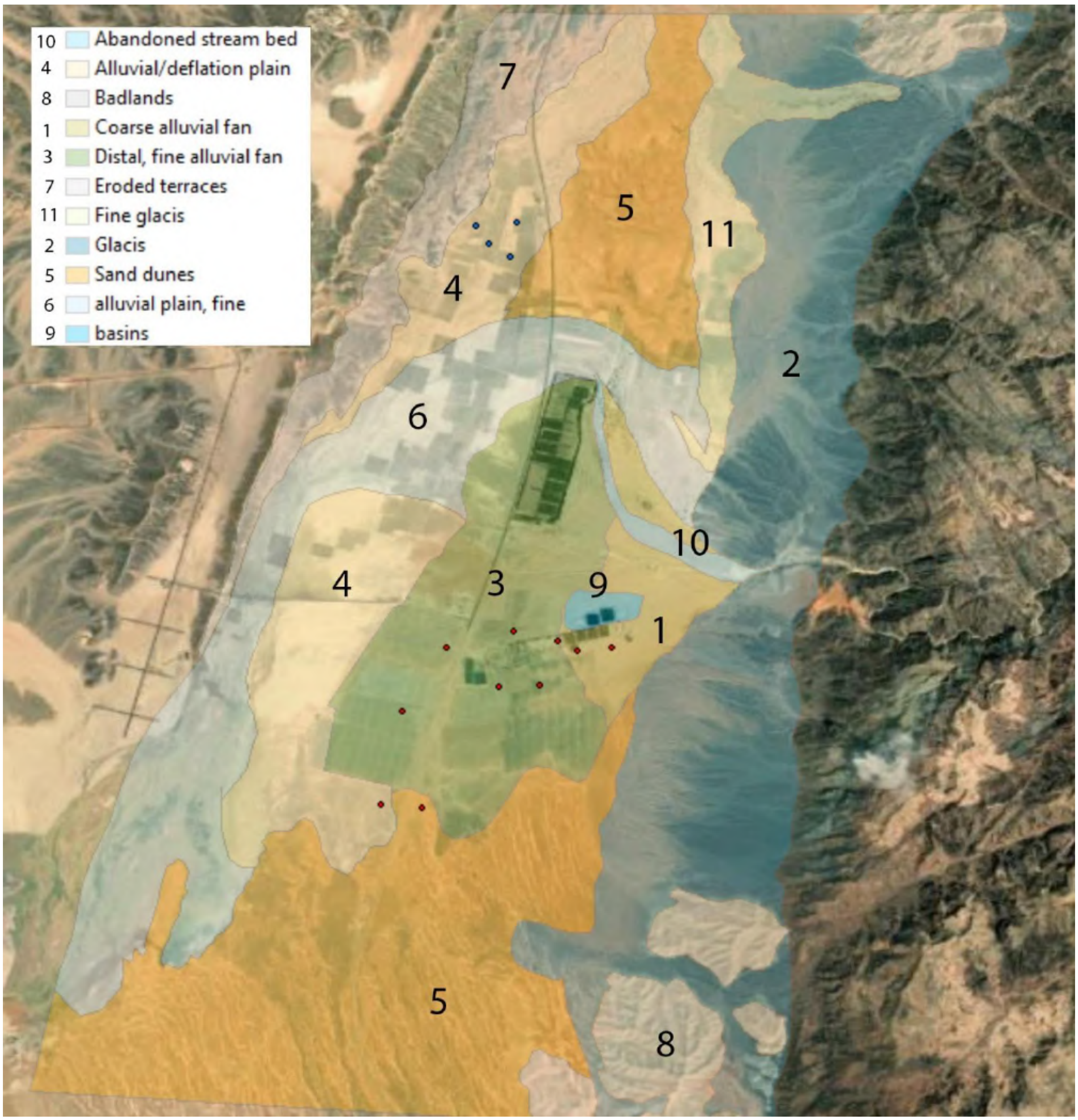


Fig. 39 The Land Units map of Ar-Rishah area

Tab.17 The Legend of the Land Units map

LU code	Description	Field soil features and limitations	Main soil type
1	Alluvial fan, coarse materials	Very stony soils, very well drained but sometimes cemented horizons (cemented by $CaCO_3$) can limit percolation	1
2	Colluvial glacis and small alluvial fans; not planned to be cultivated soon because of steepness.	Very stony soils, very well drained but sometimes cemented horizons (cemented by $CaCO_3$) can limit percolation	1
3	Distal alluvial fan, mostly sandy-loamy or loamy, seldom flooded during winter rainfall events	The soils are finer, with few stones and a generally sandy-loamy or loamy texture.	2
4	Alluvial – deflation flatlands, seldom flooded during winter events	Quite hard soils, with a thick silty crust on the surface and buried crusts at depth; fine texture (silty or clayey)	3
5	Sand dunes	Loose sands, sometimes burying hard deflation surfaces with finer materials and harder consistence	4
6	Alluvial areas, often flooded during winter rainstorms, not planned to be cultivated.	Quite hard soils, with a thick silty crust on the surface and buried crusts at depth; fine texture (silty or clayey)	3
7	Remnants of older terraces, quite steep and strongly eroded; not cultivated		
8	Badlands		
9	Basins created to collect floodwater during winter rainfall events; not precisely mappable	Very stony soils	1
10	Streambeds, flooded during winter rainfall events		
11	Distal colluvial glacis and small alluvial fans	The soils are finer, with few stones and a generally sandy-loamy or loamy texture.	2

The soils of the study area

Four main types of soils have been recognized in the study area, mostly based on textural variations, well associated with the geomorphic Land Units; approaching the limits of the Land Units, soils tend to acquire intermediate properties, such as buried layers belonging to different soil types. Quite often, loamy or sandy-loamy alluvial materials cover aeolian sands preserving the original cross bedding, typical of dune deposition (P2, P9, P10). Both morphological and chemical properties are analogous to the ones observed in nearby areas by Jenny et al. (1990) and Smettan et al. (1993).
The soils are classified according to the "World Reference Base for Soil Resources" (IUSS Working Group WRB, 2015, Tab.18).

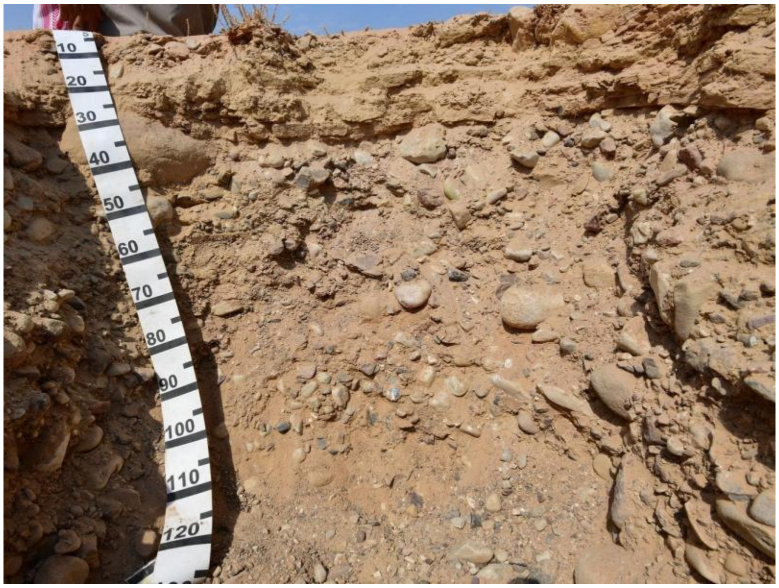
Tab. 18 Soil Types in Ar-Rishah area

Soil type	WRB classification	Profiles
1	Hyperskeletic Petric Calcisols (Hypercalcic, Ochric, Aridic) / Calcaric Skeletic Fluvisols (Arenic, Protocalcic, Ochric, Aridic)	P6, P7, P8
2	Calcaric Fluvic Arenosols (Ochric, Aridic) / Calcaric Fluvic Arenosols (Aeolic, Aridic)	P1, P2, P5, P9, P10
3	Calcaric Pantofluvic Fluvisols (Siltic, Densic, Ochric, Takyric)	P3, T1, T2, T3, T4
4	Calcaric Chromic Arenosols (Geoabruptic, Aeolic, Ochric, Aridic)	P4

Soil type 1

The first soil type (Fig.40) consists of stony soils located in the coarsest parts of the alluvial fans. An extremely high stone content characterizes the subsurface horizons, while the surface Ap (sometimes cultivated in winter) is enriched in finer aeolian sand and silt.

As usually observed in the study area, with few exceptions, the surface Ap horizon is loose and extremely poor in organic matter and biological activity; below, the subsurface horizons are sometimes cemented by $CaCO_3$, even if the carbonate content does not show a clear trend with depth. Drainage is of course extremely fast in these coarse materials, even if the cemented layers can locally slow it down.



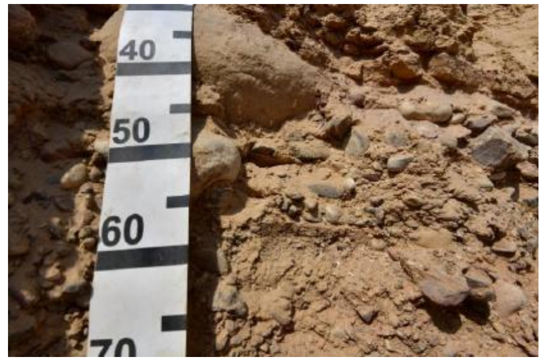


Fig. 40 Profile n. 6, typical example of soil type 1, in the coarse part of the alluvial fans; the deeper horizons are sometimes cemented by pedogenic $CaCO_3$ (Ckm horizon, on the right).

Soil type 2

The second soil type, located in the lower parts of the alluvial fan and the glacis, are sandy, with very few stone fragments (Fig. 10); at least the upper horizons are developed from fine alluvial materials, still preserving its sedimentary layers, while the deeper horizons are sometimes aeolian sands, still preserving the original cross bedding, characteristic of sand dunes (fig. 40, lower right). Some fluvial horizons are quite hard, probably thanks to a higher $CaCO_3$ content. However, drainage is always fast and the consistence is mostly loose.

The soils belonging to this unit are the most widely cultivated, and some of the observed soils have been recently irrigated with drip systems, now mostly disrupted. However, some of the deepest horizons are humid (P2, P5, P9, P10). Irrigation slightly modified the chemistry if topsoil horizons, as visible in Fig 41: pH values, electrical conductivity (EC), Na and K are significantly higher in irrigated soils, likely because of the salt-enriched water and the capillary rise and solute concentration near the soil surface. In subsoils the difference is not observed, even if there was still humidity.

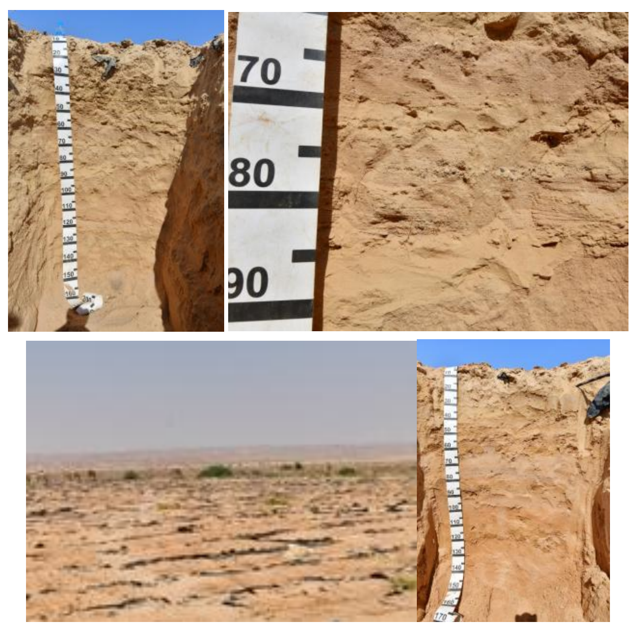


Fig. 41 P1, an example of soil type 2, showing the typical alluvial layerings, and P2 and its location, showing an abandoned irrigation system associated to the humidity of the orange sandy deepest horizon (dune sands, below 65 cm of dept).

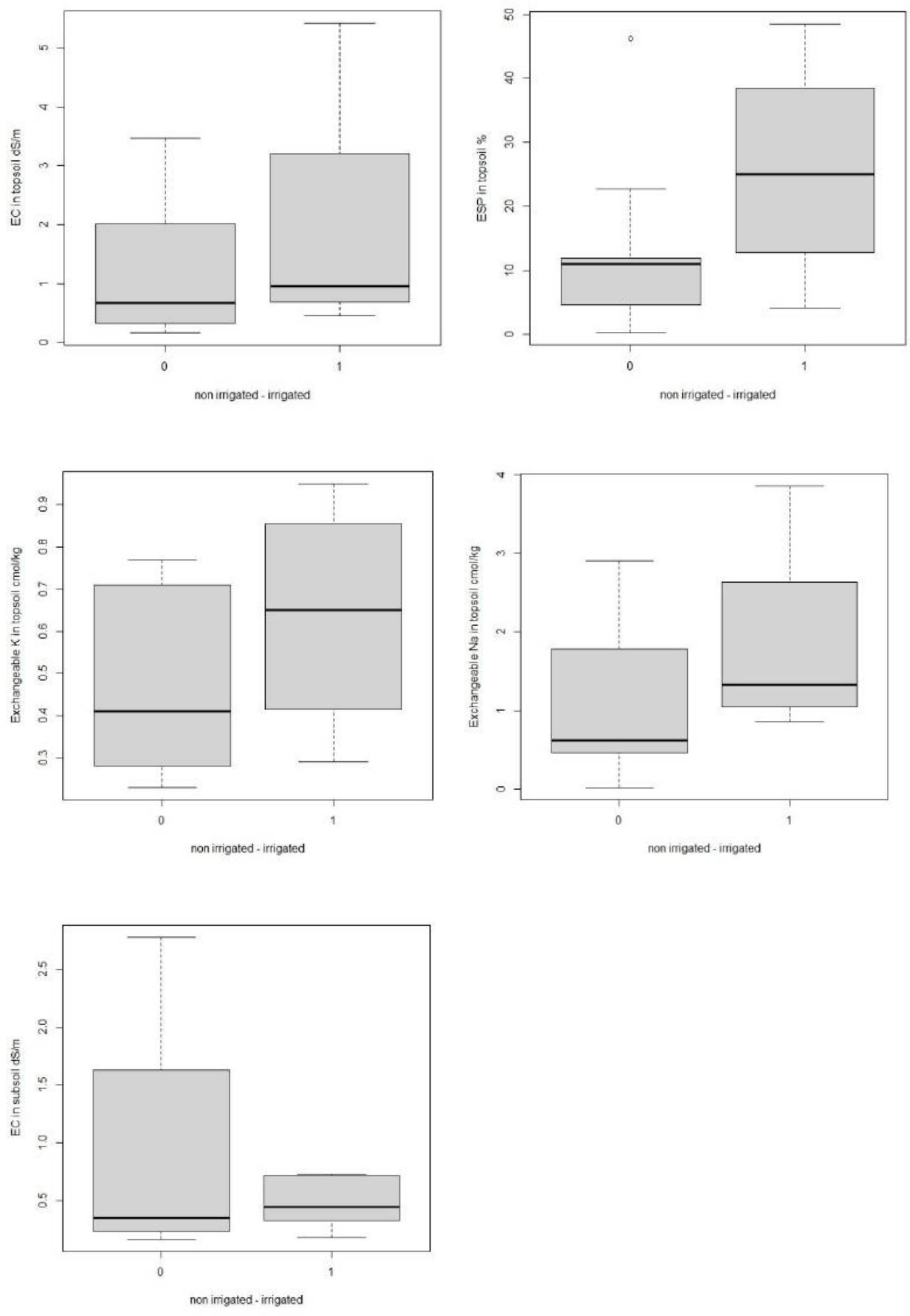


Fig. 42 Electrical conductivity - EC, ESP, K and Na in topsoil samples, higher in irrigated than in non-irrigated soils; in subsoil the difference is not observed (lowest boxplot).

Soil type 3

The third soil type (Fig.43) is located in deflation flatlands, covered by a thick, whitish silty crust visibly eroded by wind. The soil is not cultivated at present; it is hard, and composed of an alternation of buried surface crusts, sometimes partly cemented by $CaCO_3$, and aeolian sandy layers. This soil type has the finest texture of the observed ones in the study area, with a clay content reaching 30% in the hard crusts. The crusts are thinly laminated, and quite hard, and these properties likely reduce drainage and might increase the possibility of salinization in case of irrigation with salty waters; the presence of the hard crusts is evidenced by the Takyric qualifier.

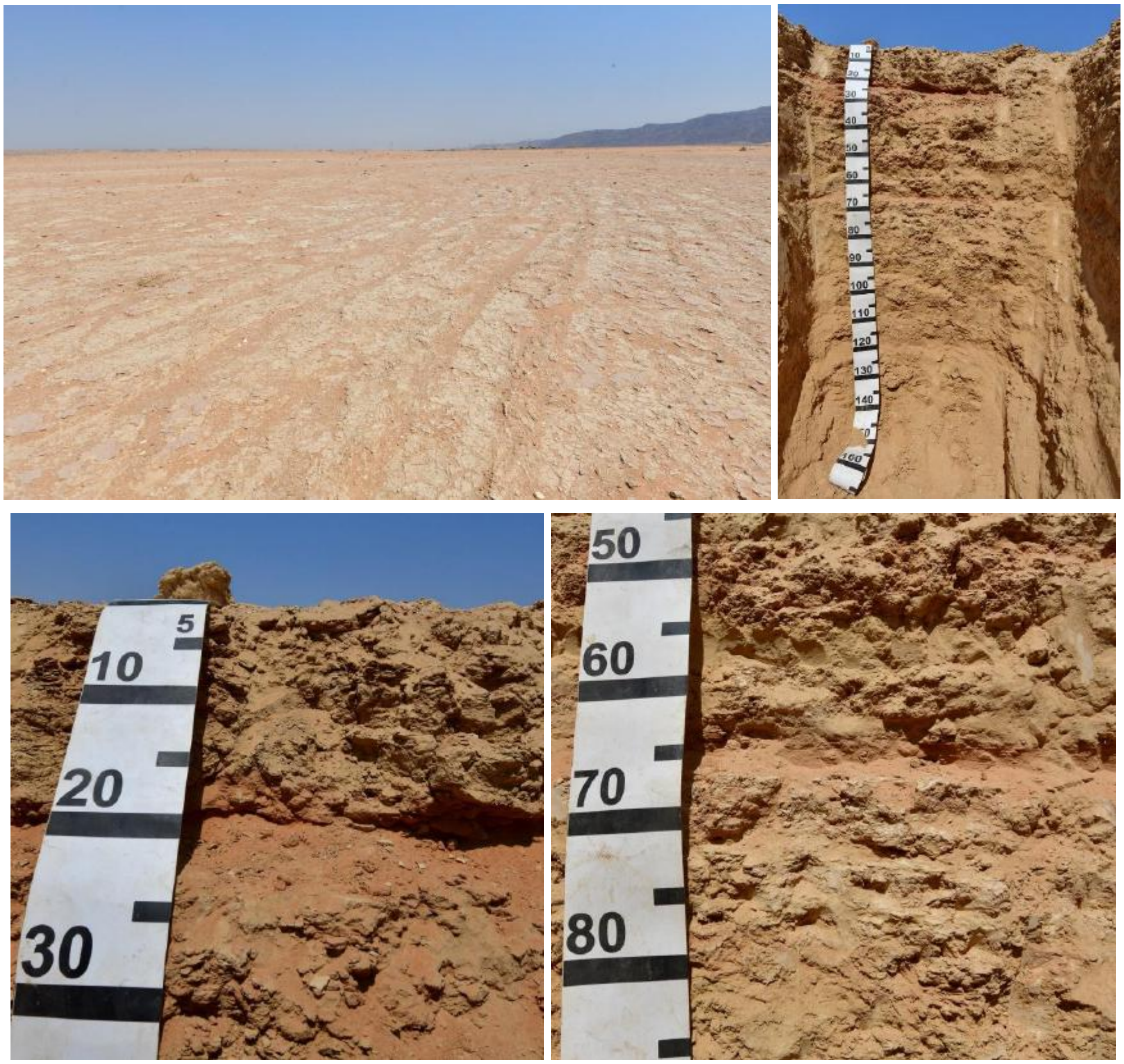


Fig. 43 P3, an example of soil type 3, developed in deflation areas, characterized by a thick whitish silty crust; inside the profile, many of these crusts are visible, buried below thin sandy layers and likely finer alluvial materials

Soil type 4

Soil type 4 (Fig.44) is developed in sand dune areas, and is composed of loose, orange sands overlying a buried, harder soil at depth with similar properties as soil type 3. Extremely fast drainage and surface instability are the main properties of this soil type. From the chemical point of view, high potassium sometimes characterizes the aeolian sands.

Soil properties variability

The 4 main soil types showed quite similar chemical properties but some differences as well, both in the surface and subsurface horizons.

Texture differs strongly in the different soil types, particularly clay and sand (shown below), while silt maintains a similarly low content in all soil types (Fig. 45). The soils in the alluvial/deflation zone are the richest in clay. It is important to remember that subsoils in sand dunes are of the same type as soil type 3, quite rich in fines, clay included. Sand in subsoils is very different in the soil types, decreasing from ST 1 to ST 4.

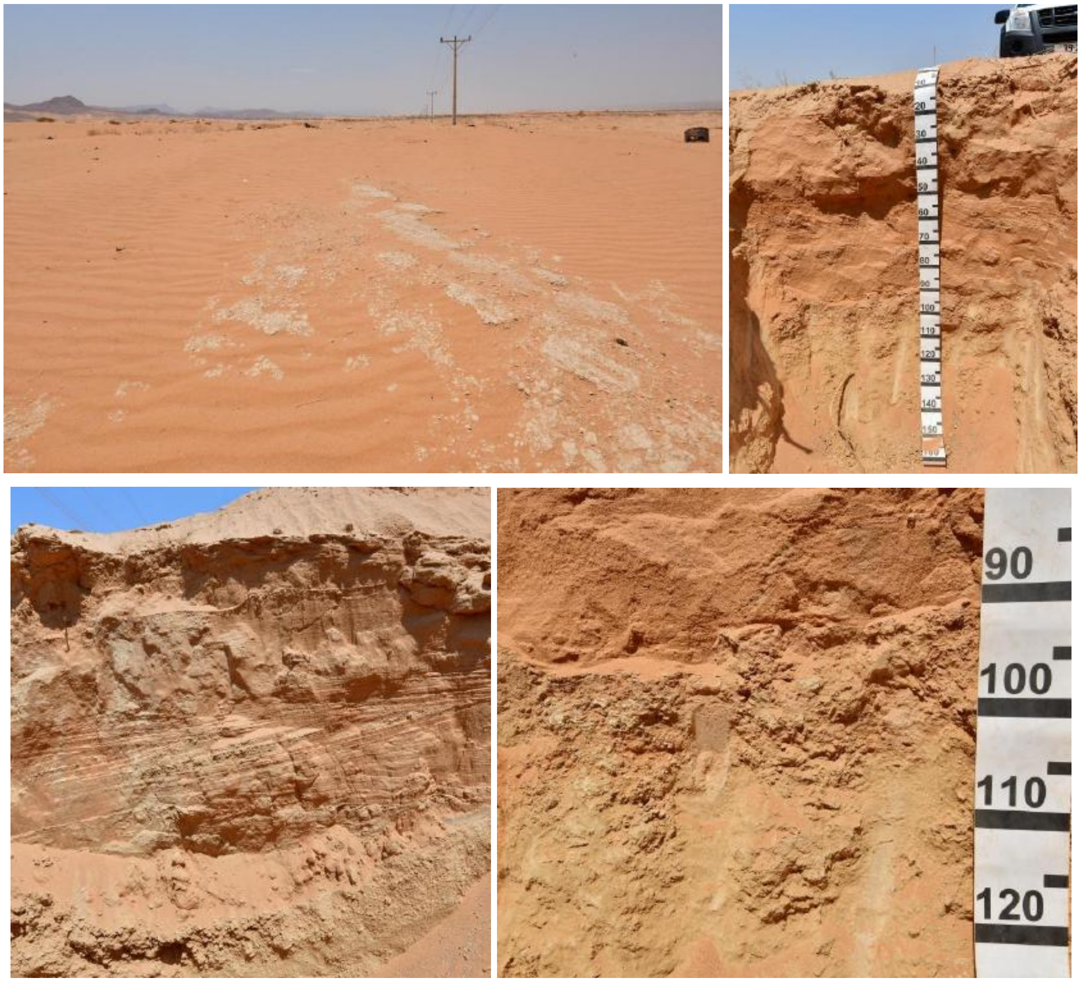


Fig. 44 Soil type 4 (P4), developed in sand dune areas, composed of loose sands showing the typical cross beddings of sand dunes; at around 95 cm of depth, a sharp discontinuity is visible, separating the loose sands from the deeper harder fine materials with characters similar to soil type 3.

No serious salinity issues have been observed, with the exception of a single topsoil horizon (P5 Ap), as shown by the EC values always below 4; according to FAO (1988), most of the soils can be considered non- or slightly saline, with EC values between 0.15 and ca. 4. Horizon P5 Ap is moderately saline, and this can limit agricultural possibilities. ESP (exchangeable sodium ratio) indicates that Na excess is observed in many soils, with slightly higher values in topsoil samples compared to subsoils, likely caused by the intense evaporation characterizing desert soils; the highest values are observed in ST 1 and 2 (Fig. 46).
pH values are quite similar in all soil types, thanks to the high $CaCO_3$ contents and the quite low salinity (Fig. 47).
Exchangeable Ca and Mg have optimal values, compatibly with the carbonate-rich materials (not shown).
Organic carbon is very low (Fig.48) in all soils, with slightly higher values in fine textured ST 3, as expected in desert areas; available P is quite high in topsoils, particularly in the coarsest textured ST1 and ST4. Total nitrogen is well correlated with organic C, and it is thus quite scarce (not shown). The C/N ratio is between 8 and 20, without significant trends in the different soil types.
An important property of the soil to be considered for irrigation purposes is the Available Water Capacity (AWC). The AWC is the amount of water that a soil can store that is available for use by plants, and it is calculated by making the difference between the soil water content at the field capacity and the water content at the wilting point. For this purpose, the Saxton pedotransfer function (Saxton-Rawls, 2006) was used. Two matrix potential points were considered: pF 2.5, which is considered as the condition of the field capacity, and pF 4.2, which corresponds to the soil moisture at the point of permanent drying (i.e. the water content in the soil is too low for the plant's roots to extract water). In addition, during the field survey some undisturbed soil samples were collected in order to carry out a verification of the results obtained by applying the pedotransfer function.
In the following table(Tab.19) the AWC values obtained for the soil types of the area are reported.
Soil permeability, calculated based on texture according to Saxton et al. (1986), is different in the 4 soil types (Fig.49), as expected.

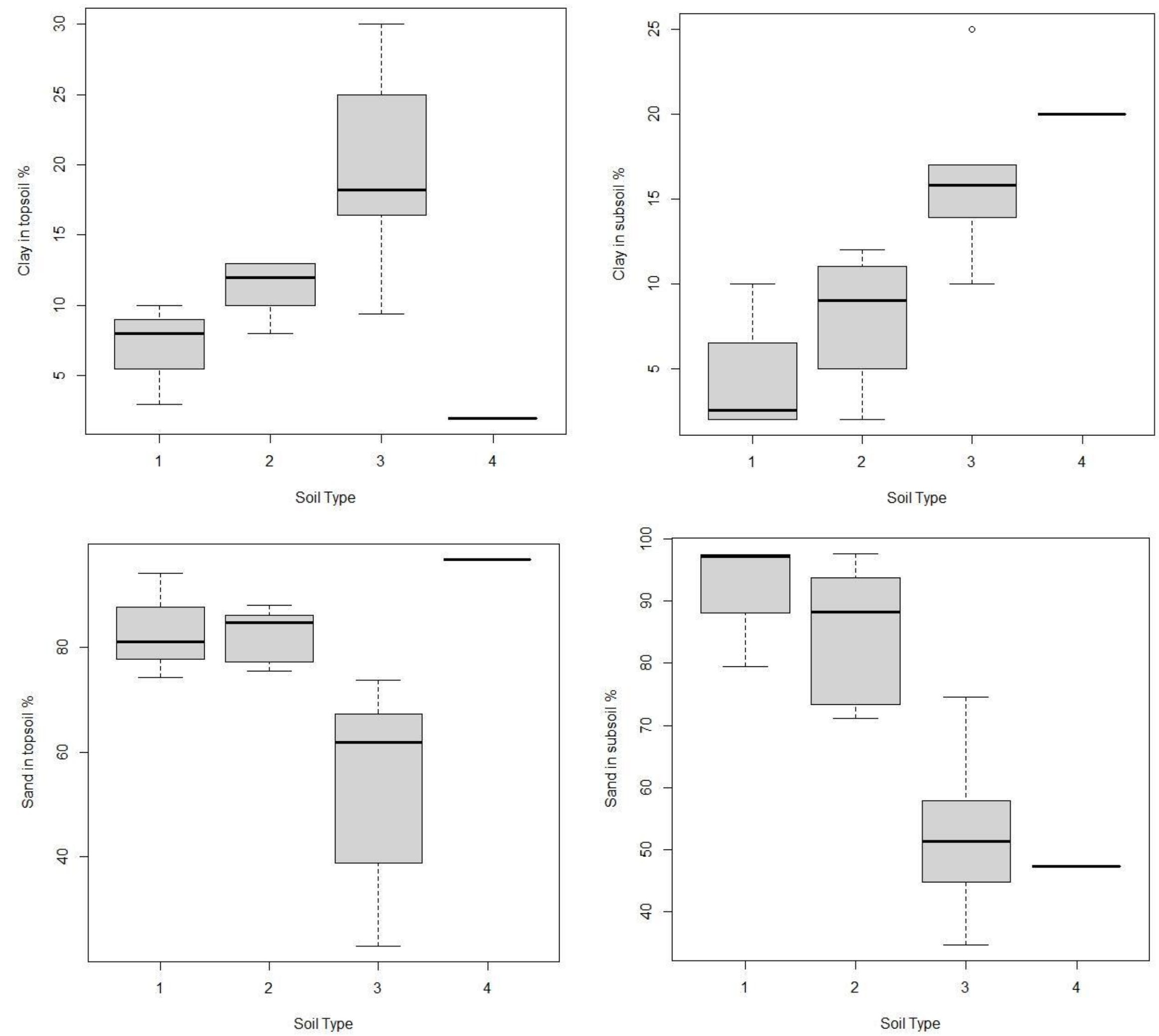


Fig. 45 Clay and sand content in A horizons and in C ones in the 4 main soil types.

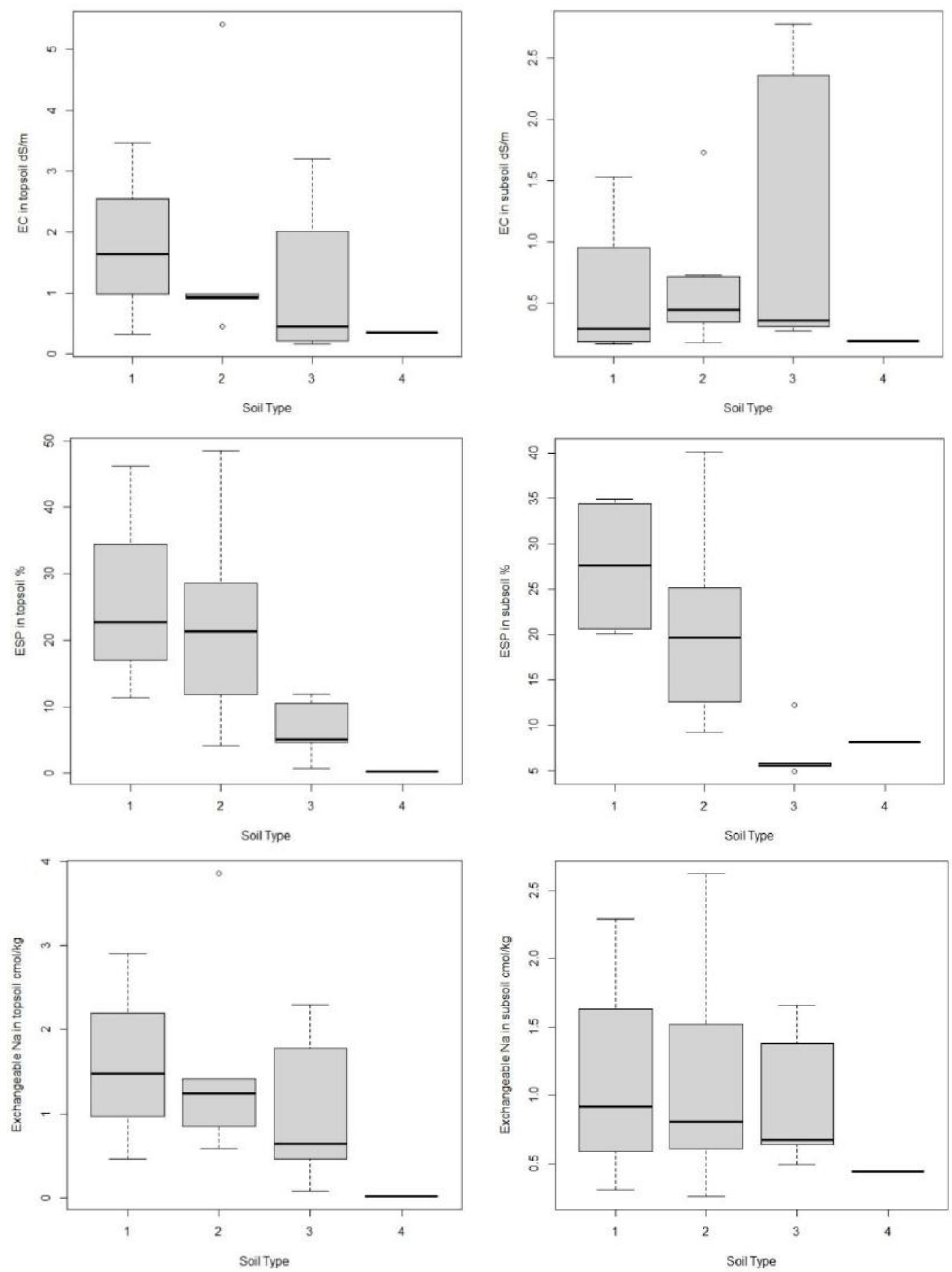


Fig. 46 Salinity properties in topsoil and subsoil samples: electrical conductivity (EC), exchangeable sodium ratio (ESP), exchangeable Na in the 4 soil types.

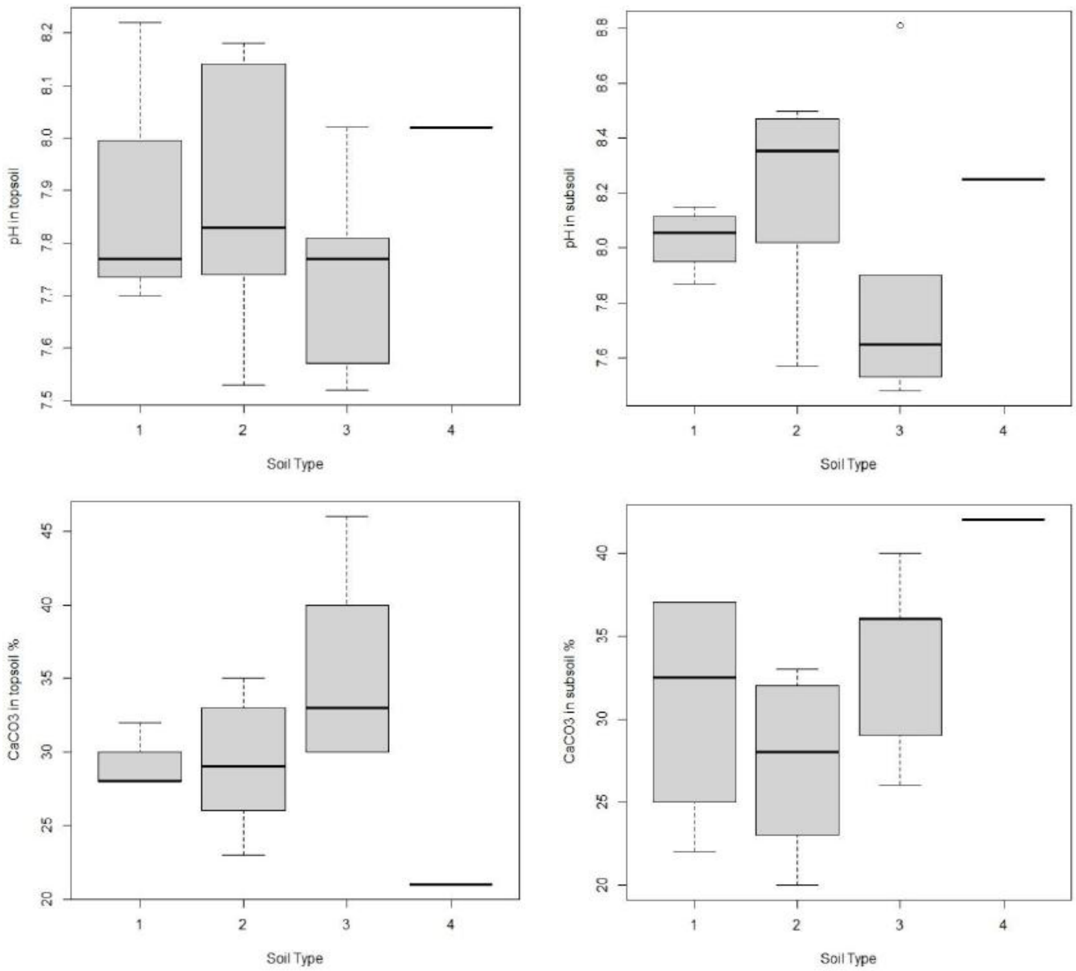


Fig. 47 pH and CaCo3 in topsoil and subsoil samples for the 4 soil types

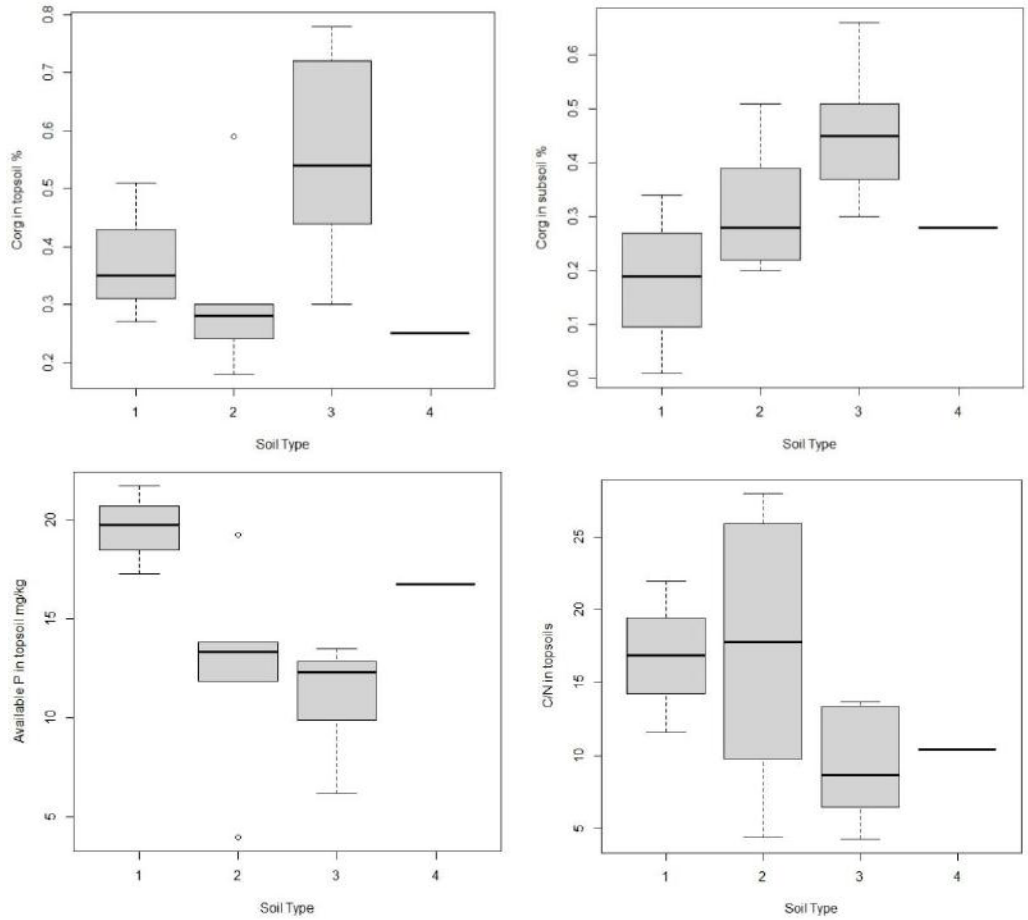


Fig. 48 Total organic carbon (Corg), and available P and the C/N ratio in topsoil samples in the 4 soil types (Corg also in subsoil ones).

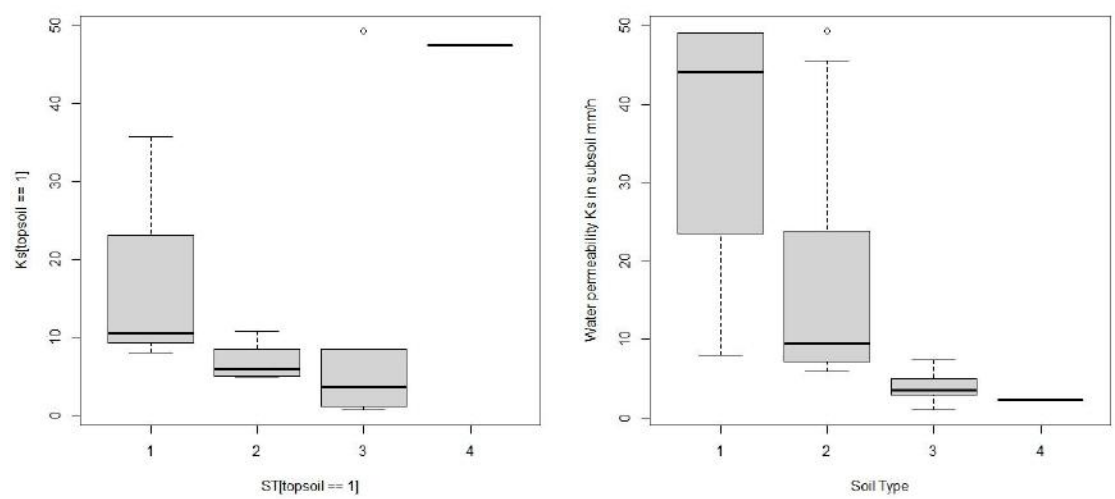


Fig. 49 Water permeability Ks in topsoil and subsoil samples of the 4 soil types.

Tab.19 The AWC for the soil types.

Soil Type	AWC	
	mm/m	
1	48	very low
2	93	low
3	153	moderate
4	97	low

The low AWC values of the majority of soil types are mainly due to the sandy texture and high stoniness.

The Soil map of the study area

The soil survey carried out in August 2021 has led to the reconnaissance of the main types of soil present in the study area (see paragraph above). During the soil survey it was carried out also an assessment of the distribution of the different soil types within the land units. The soil map of the study area was obtained indicating the prevalent soil type in each of the identified land units. The soil map and its legend are shown in the figure below (Fig.50).

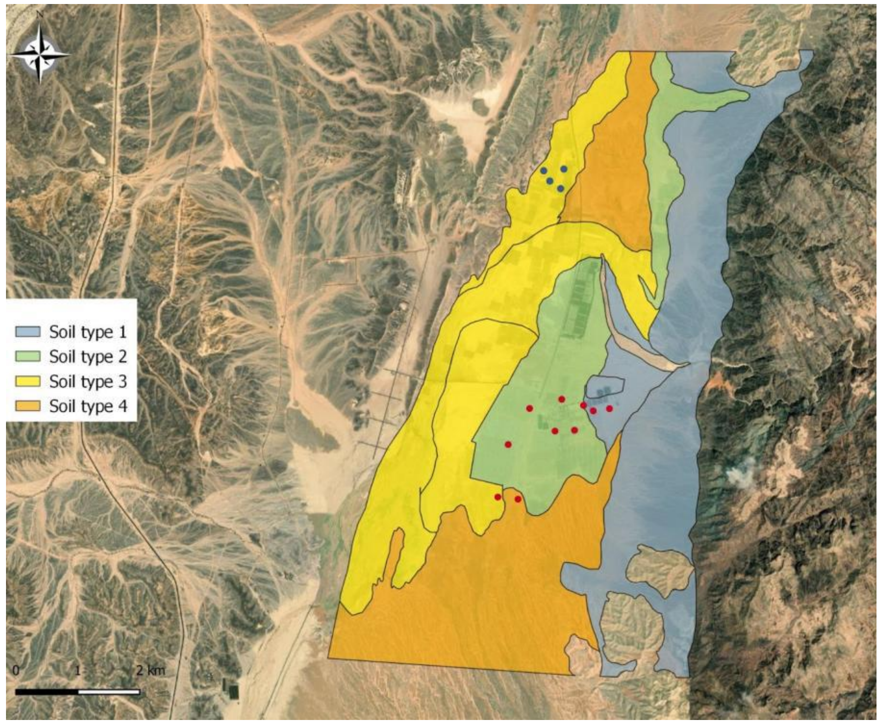


Fig. 50 The soil map of the study area

The Land suitability for irrigation

In the two following tables some important characteristics of the main soil types are indicated (Tab.20).
The soils in the study area are generally not limited by bedrock, but depth limitations associated with pedogenesis are sometimes observed, particularly in soil type 1 (cemented horizons) or compaction (soil type 3). Stoniness is absent in 3 soil types on the 4 observed.

Tab. 20 Characteristics of the soil types (part 1).

Soil Type	Drainage	Water table depth (cm)	Rock outcrops (%)	Stoni-ness (%)	Soil depth (cm)	Rooting depth (cm)	Topsoil textural class	Topsoil clay (%)	Topsoil sand (%)	Subsoil textural class	Topsoil coarse fragments (%)
1	Very fast		0	20	40-100	40-100	Sand	2	90	Sand	20
2	Very fast		0	1	> 100	> 100	Sand	5	80	Sand	1
3	Slow		0	0	> 100	20-100	Silty-loam	30	30	Sand	0
4	Very fast		0	0	> 100	80->100	Sand	2	95	Silty-loam	0

The hydraulic conductivity, related to the soil texture and the presence of cemented or dense horizons, varies from very low (soil type 3 and subsoil in soil type 4) to very high (soil types 1, 2, and topsoil in soil type 4). In particular, dense fine textured layers are characteristic of soil type 3 (and subsoil in 4), while cemented layers at shallow depths can be present in soil type 1, though porosity is seemingly maintained thanks to the very high stone content.

From a chemical point of view, the soils of the study area are slightly saline and quite rich in sodium, with an alkaline reaction, associated with quit high carbonate contents. Nutrients are sufficient in all landscape positions, despite the extremely low plant cover typical of desert soils (Tab.21).

Tab. 21 Characteristics of the soil types (part 2), EC = Electrical Conductivity, ESP = Exchangeable Sodium Percentage, OM = Organic Matter.

Soil Type	Structure (topsoil)	Hydraulic conductivity	EC (dS/m)	ESP %	pH topsoil		pH subsoil		OM topsoil (%)
1	Loose	High	1.8	26.7	8.0	Alkaline	8.0	alkaline	0.65
2	Loose	High	1.7	22.9	8.3	Alkaline	8.2	alkaline	0.55
3	Laminar	Very low	1.2	6.5	7.9	Alkaline	7.9	alkaline	0.95
4	Loose	Very high	0.35	0.3	8.3	Alkaline	8.3	alkaline	0.25

The assessment of land suitability for irrigation was conducted following the land suitability for irrigation classes used according to the FAO Land Suitability Classes (FAO 1981), and the model (Baldaccini P., Vacca A., 2009) described above, in paragraph 1.1.6).

In the following table (Tab.22), the land suitability for drip irrigation for the study area is shown:

Tab. 22 The land suitability for drip irrigation according to land units and soil types

Land unit	Soil type	Suitability for drip irrigation	Main limiting factors
1	1	S3	Sand texture, high calcium carbonate
2	1	N1	Slope, sand texture, high calcium carbonate
3	2	S3	Sand texture, high calcium carbonate
4	3	S1	
5	4	S3	Sand texture, high calcium carbonate
6	3	S1	
7		N2	Slope
8		N2	Badlands
9	1	S3	Sand texture, high calcium carbonate
10		N1	High stoniness
11	2	S3	Sand texture, high calcium carbonate

In the following figure (Fig.51) is showed the result of the application of the above-mentioned scheme to the soil map.

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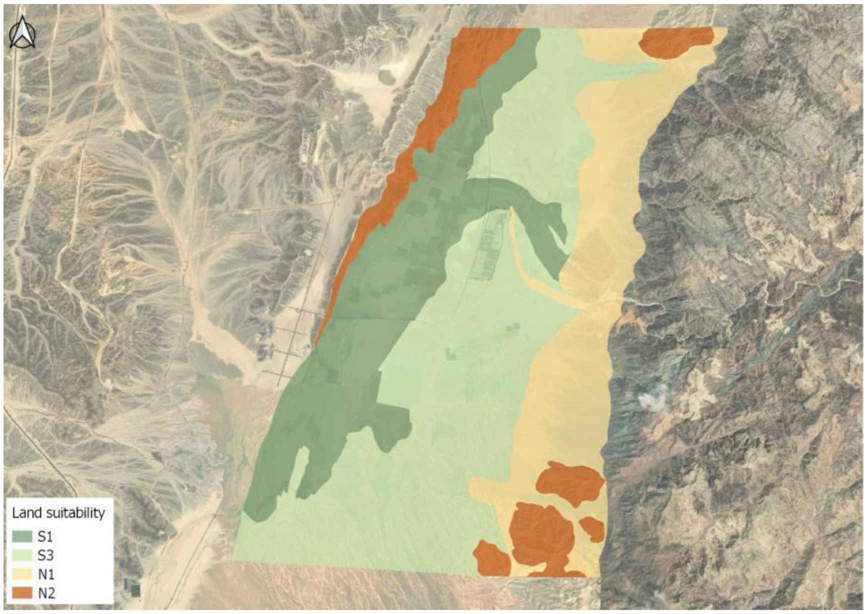

Fig. 51 Land Suitability map of the study area, based on the properties of the land units and the dominant soil types

In the area the main factors limiting the irrigation practices are sand texture and high calcium carbonate content.

The agricultural baseline survey

Pilot field tests of innovative watering techniques are planned in a specific agricultural area that is close to the village of Ar-Rishah, in the Wadi Araba Valley (Jordan). In these forthcoming activities the project partner Aqaba Water Company (AWC) will be involved. The agricultural engineer Laith Saeed Abdel latif Al Mayta, of Aqaba, has carried out the field data collection because the international consultant could not travel in the project site due to the pandemic restrictions.

The following picture (Fig.52) shows one water reservoir (fed by wells), managed by the Qaa Al Saeedin Association of Farmers.

Fig. 52 One of the two water reservoirs which are fed by deep wells at the Qaa Al Saeedin Association of Farmers. This Association will host the foreseen MEDISS agricultural trial

The farming system

Wadi Araba is a semi-desert area, where summer temperature reaches about 45 °C. Annual average rainfall rarely exceeds 50 mm while the rate of evaporation is about 3,500 mm. As a consequence, all agricultural and livestock rearing activities depend on irrigation, which is carried out principally through the use of groundwater the quality of which however is not always good. Due to these not optimal environmental conditions, agriculture is not so diffuse in the project area.

Crops and cropping techniques

Two cropping cycles take place in a year. In summer, water melon and sweet melon are grown while in winter main crops is tomato, but more recently onion and potato have been also introduced in the cropping system. In addition, perennials are grown in the area, such as table grape, date palm and citrus. These crops are all irrigated through drip irrigation.

Soil preparation consists of ploughing and harrowing, done right after the harvest of previous crop. Tillage is carried out by tractor. Potatoes and onions are harvested by machinery. All other crops are collected by hand.

Farmers use to apply both organic and mineral fertilisers. Animal manure (collected from goats and sheep which are locally bred) is often ripened in holes during 2 months, then applied to the field.

Mineral fertilisers are applied after the organic one. They are: NPK (20:20:20 or 12:12:36) + Mg. Urea, super-phosphate and potassium sulphate are also common. Soluble fertilisers are also supplied to crops through the drip irrigation network, both to annual and perennial crops (Fig. 53,54).

Agro-chemicals are intensively used by the farmers to control pests and diseases.

Fig. 53 Drip irrigation on table grape

Fig. 54 Growing potatoes

Fig. 55 Mulching on sweet melon

Fig. 56 Camels feeding on crop residues

Plastic mulching is diffusely used on the vegetable crops, to prevent the loss of moisture from soil, to control weeds and avoiding direct contact with soil of the fruits (Fig. 55).

Livestock husbandry

Traditionally, sheep, goats and camels have been reared in the area since ancient times. Animals use to feed on crop residues and natural vegetation, which is however scarce because of the drought conditions of the land. Due to that, the majority of the herds is under nourished and very low productive (Fig.56). The richest breeders provide also grains to the animals (barley and bran). Nevertheless, rearing animals is a not profitable business.

The ownership structure of the farms

Most of the original land owners in the target area cannot afford the whole amount of farming inputs nor the continuous investments required for sustaining the production and the post-harvest operations. Therefore, they lease their farms to private investors, who pays the annual lease around 1,500 USD/ha.

The survey identified a number of farming entities/projects in the target area.

A. Public land (owned by the Jordan Government). It is a limited portion of rainfed land where farmers (principally breeders) grow wheat and barley in winter time. Given the very low rainfall, grains yield is often poor.

B. Qaa Al Saeedin Association. It is an agricultural association, which owns 80 hectares. 30 hectares are leased to an agricultural investor and the 50 remaining hectares are managed by the Association. There are two deep wells for irrigating the whole area. Principal crops are tomato, water melon and potato.

C. Qaa Al Saeedin irrigation project. This project was implemented by the Wadi Araba Development Company, which in the past provided to 78 households 2 hectares each, mostly for self-subsistence (total: 156 hectares). The same company also arranged agricultural units, supplied with water at cheap cost from 5 wells, owned by the company. Out of this land, 62 hectares were leased to two agricultural investors: this area is grown with water melon, potato, onion and tomato.

Fig. 57 Deep-well

D. Al Haq farm Qaa Al Saeedin. Cropland extends on 50 hectares, which are cultivated with citrus, table grape and date palm trees, irrigated through 3 deep wells.

E. Ar-Rishah agricultural lands. It extends on around 13 hectares. It is cultivated by 2 households with tomato and water melon. It is irrigated by water coming from the Ar-Rishah desalination plant.

All farms use drip irrigation systems and depend on use of groundwater for irrigation, except the project "Ar-Rishah agricultural lands" which uses the water coming from desalination plant (Fig.57).

Tab. 23 describes the characteristics of the deep wells used by the above entities, and the salinity of the water. It is highlighted that the groundwater has always moderate salinity (TDS between 1,000 and 1,500 mg/L, namely 1.5 - 3.0 dS/m).

Tab. 23 Characteristics of the wells used for irrigation in the project area and water quality

Farm ownership	Well ID	Q (m^3/h)	Depth (m)	TDS (mg/L)
Qaa Al Saeedin Association	1	55	204	1,470
	2	35	N/A	N/A
Qaa Al Saeedin irrigation project	1	58	257	1,365
	2	53	260	1,385
	3	38	260	1,365
	4	55	248	1,375
	5	55	251	1,130
Al Haq farm Qaa Al Saeedin	1	50	125	N/A
	2	55	300	N/A
	3	40	240	N/A
Ar-Rishah agricultural lands	Desalination plant			1,300

Main constraints to crop productivity

The main constraint to crop productivity is represented by the poor quality of groundwater, which is extracted by deep wells and characterised by overall "moderate salinity". The salt content in the water negatively affects productivity of the moderate sensitive crops, such as citrus, potato, sweet melon, and others. Date palm is the most salt tolerant among the crops grown in the project area.

It has to be however considered that the salinity of groundwater must be sum up to the salinity already accumulated in the soil, meaning that the resulting salinity of the circulating soil solution is probably higher than

the one of the groundwater alone, thus posing serious hindrance to crop productivity and undermining soil fertility as a whole.
As explained by the farmers, another problem is represented by shortage of water as the mentioned wells do not supply a constant discharge of water, which limits the possibility to irrigate all available agricultural land.
Another constraint to farm productivity is the cost of the farming inputs, which are usually available locally but at high price. It has to be also considered that the application of mineral fertilisers, if not done appropriately, risks to further increase soil salinity, which calls for an efficient service of technical assistance to the farmers.

Production cost and current market for the products

Data of cost of single components of the production process have been obtained from the interviews carried out to a group of local farmers. Reported costs in Tab. 24 are general and not crop-specific.

Tab. 24 Costs of some farming operations and inputs (not exhaustive)

Item	Cost (USD/ha)
Land preparation	90
Organic fertiliser	150
Chemical fertiliser	1,800
Pesticides	1,000
Irrigation hoses	500

Tab. 25 shows (i) the overall production cost of some of the mentioned crops, (ii) the range of crop yield (which is assumed under optimal conditions of water and soil fertility) and (iii) the crop price during the high and the low season of market demand, respectively. The information has been collected from the Ministry of Agriculture and the interviewed farmers. The overall production cost includes all steps of production, namely cropping practices, the inputs (irrigation networks, agro-chemicals, etc.), harvest and packing operations, and transport to Aqaba by truck.

Tab. 25 Production cost, attainable yield and crop price

Crop	Overall production cost (USD/ha)	Attainable yield (t/ha)	Price (USD/t)	
			Low price	High price
Date Palm	N/A	12	1,500	2,500
Citrus	N/A	30 - 40	350	700
Table Grape	N/A	25	350	700
Potato	N/A	60 - 70	350	700
Tomato	3,500	35 – 40	120	350
Water melon	5,000	60 – 65	150	400
Sweet melon	4,500	50	150	500
Onion	N/A	50 - 60	150	300

It should be noted that the actual crop yields hardly reach 50% of the attainable figures shown (Fig.58) in Tab.32 because of the low quality of the irrigation water and poor technical skills of the farmers.

The marketplaces of reference are:
- The Amman Central Market. When the demand is high and therefore prices are also high;
- The local market and the Aqaba city's market. When demand is limited and prices are low.
Farmers also get paid by breeders when allow livestock to feed on crop residues, after harvest.
No post-harvest structures are present in the area (i.e. efficient packing or (cool) storing facilities). Very basic sorting and packing is carried out on site by the local workers (both females and males).
Farmers are not organised in producer associations which highly reduces their power of bargaining with the big buyers (often middle-men).

Fig. 58 One farmer operating in the project area, with bags of mineral fertiliser

New potential crops to be grown/expanded in the target area

The survey confirmed the economic relevance in the current cropping systems of crops like sweet melon, water melon and tomato. These crops have been cultivated in the area for many years, and typically allow farmers to fetch good prices since they are available when demand is high, within the present market conditions. However, such crops require high quantity and quality inputs to obtain viable production, therefore high investment at the beginning of the season. Furthermore, the bad status of groundwater, as described above, often prevents the farmers to obtain an acceptable yield.
Crops recently introduced in the project are onion and potato. Potential yields are high, but again only if appropriate inputs are provided and the irrigation water is of good quality and quantity.

Fig. 59 Date palm and lemon orchards in the project area

Most of the farmers prefer vegetables because of the economic return in the short term, but there is a small group of farmers who also grow fruit trees, such as lemon, table grape and date palm (the latter showing good tolerance to the current degree of salinity of the groundwater).
Fruit tree crops in fact represent a good option for the area since the good market price they always fetch, and they should be expanded. However, this requires high technical skills and high capacity of capital investment by the farmers, which can be supported by dedicated low-interest loans by local banks (Fig.59).
Information about the recommended fruit tree crops is shown below:
- Date palm. It needs 7 years to yield satisfactory economic return. Expected production is 16 t/ha;
- Lemon. It needs 4 years to yield satisfactory economic return. The orchard can be harvested twice in a year, with annual production of around 30 - 40 t/ha;
- Table grape. It needs 4 years to yield satisfactory economic return. Expected production is 25 t/ha.

The locally available extension and advisory services for the farmers

Technical support is provided to farmers through the National Center for Agricultural Research. The Center has the task to arrange field tests of new crops and varieties, also suggesting innovative cropping techniques, to match the local and national market demands. However, it is highlighted that farmers are resistant to changing the original cropping system, as they need stronger raising of awareness, more technical assistance on innovative agricultural practices and on improvement of water use efficiency, especially when dealing with moderately saline water.

Foreseen activities

During the mission held from 7 to 10 November 2021, the consultant visited the Qaa Al Saeedin Association, which will host the agricultural trial. As explained above, the association owns 80 hectares. 30 hectares are leased to an agricultural investor and the 50 remaining hectares are managed by the Association. There are two deep wells for irrigating the whole area, with 2 reservoirs. Principal crops are tomato, water melon, sweet melon, potato and table grape.
The water of one of the reservoirs has been analysed by the AWC's technician, showing EC of 3.14 mS/cm.
The desalination plant under construction has been also visited. It should start working by end of January 2022. The action plan foresees to use part of the desalinised water to irrigate one pilot field (around 1,000 m2) and observe the effect on the growth of vegetable crops. The distance between the site of the desalination plant and the farm is around 3 km. Furthermore, the brine water (by-product from the desalination plant, with an expected EC of 6.15 mS/cm) will be mixed with the water from the 2 deep wells and verified its EC in order to use it for irrigation.

Annex - List of interviewed farmers in Ar-Risha

1. Eng. Iyad al Dweak/private investor - Qaa AlSaeedin irrigation project (interviewed in site), with cultivated area of 21 hectares, currently potato;
2. Mr Mohammad AlSaeedin/private investor - Qaa AlSaeedin irrigation project (interviewed in site), with cultivated area of 41 hectares;
3. Mr Khaled Alryatie /private investor - Qaa AlSaeedin association (interviewed on phone / not available in site), with cultivated area of 30 hectares, currently watermelon;
4. Salem AlSaeedin / Farmer - Alriysha agricultural lands (interviewed on phone / not available in site), with cultivated area of 3 hectares, currently watermelon;
5. Awwad AlSaeedin/Owner - Qaa AlSaeedin irrigation project (interviewed in site).

Water monitoring

Rishah village is located at the southern part of Jordan the nearest large town is Aqaba (80 KM).
Existing data and new campaign on water monitoring
The results in 2018, that is, before the start of the project, were as follows

Attention :-
Aqaba Water Company
P.O. Box 252 Aqaba 77110 Jordan
Tel: +962 3-201-4390
Fax: +962 3-201-5982

Analysis Test Report

2715

Laboratories and Quality Department / Water Authority
Khansa's Street, Bladar Wadi Esser (next to Civil Defer
Amman 11183 P.O. Box 2412 Jordan
Tel +962 6 5834351/2, Fax +962 6 5825275
E-mail: info-wajlava@yahoo.com

Sample No / Lab. Ref.160390 (W152334)

Field Trip No: WJ022445
Sampled by: Eng. Ziyad Ta'ani
Sample Receiv. On: 29/3/18 09:30
Sampling Date: 28/3/18 14:45
Issue Status: Complete 9/4/18 9:22

Sample Point: Reesheh Well NO.9
Treatment Stage: Raw water
Governerate: Aqaba Governerate
Area: Aqaba
Priority: ROUTINE

Component	Result	Unit	LRV	National Standards	Method Used
[A] Electrical Conductivity	1432	Us/cm	1.		Laboratory Method (Ref: CHI-EC)
[N] Carbonate	0.0	mg/L			Potentiometric titration
[N] Bicarbonate	257.3	mg/L	7.7		Potentiometric titration
[N] hydroxide	0.0	mg/L			Potentiometric titration
[A] Nitrate as NO3	6.9	mg/L	0.5	50.00	In- House On Chromatography (Chromeleon) (Ref:CHI_NO3_IC)
[A] Chloride	167.5	mg/l	0.8	500.00	In-house ion chromatography(Chromeleon)
[A] Sulfate	304.2	mg/l	0.5	500.00	In-house ion chromatography(Chromeleon)
[A] Sodium	133.3	mg/L	2.0	200.00	In-house ion chromatography(Chromeleon) (Ref: CHI-CAT)
[A] Potassium	5.9	mg/L	1.0		In-house ion chromatography(Chromeleon) (Ref: CHI-CAT)
[A] Magnesium	67.1	mg/L	0.5		In-house ion chromatography(Chromeleon)
[A] Calcium	78.7	mg/L	1.0		In-house ion chromatography(Chromeleon)
[N] Hardness as CaCO3	472	mg/L		500	In-house ion chromatography(Chromeleon)
[N] Chromium	0.008	mg/L	0.005	0.05	Inductively Coupled Plazma/Atomic Emission Spectro

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Analysis Test Report

Sample No / Lab. Ref. 160390 (W152334)

Component	Result	Unit	LRV	National Standards	Method Used
[N] Nickel	<0.01	mg/L	0.01	0.07	Inductivety Coupled Plazma/Atomic Emission Spectro
[A] Iron	0.23	mg/L	0.01	1.00	Inductivety Coupled Plazma/Atomic Emission Spectro (Ref:CHI_MTICP)
[A] Copper	<0.02	mg/L	0.02	2.0	Inductivety Coupled Plazma/Atomic Emission Spectro (Ref: CHI-MTICP)
[A] Zinc	<0.02	mg/L	0.02	4.00	Inductivety Coupled Plazma/Atomic Emission Spectro (Ref:CHI_MTICP)
[A] Manganese	<0.005	mg/L	0.005	0.400	Inductivety Coupled Plazma/Atomic Emission Spectro (Ref:CHI_MTICP)
[N] Cadmium	<0.003	mg/L	0.003	0.003	Inductivety Coupled Plazma/Atomic Emission Spectro
[N] Lead	<0.005	mg/L	0.005	0.01	Inductivety Coupled Plazma/Atomic Emission Spectro

[A] Test accredited by UKAS according to ISO 17025 [N] Test out of scope of accreditation [LRV] Lowest Reportable Value detected level by this method [V] Result version after approval

[$] Sample was deviating for this test therefore result may be invalid

National Standards: Jordanian Standards for Drinking Water No 286/2015

Test results represent the sample that is sent by Custumer where it was analysed upon Custumer request. Analysis Test Report is considered invalid if not duly signed.
All the items tested in this report were carried out in the permanent facilities of WAJ Labs located in Amman unless stated otherwise.
For more information regarding analysis data, records are available at the relevant analytical sections.

Authorised by
/ Eng. Ahmad A. AL-Uleimat
ASG / Laboratories and Quality Affairs

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Monthly average of results for water well Al-Rishi 9

Month	Total Alkalinity	Total Hardness	EC	Turb.	pH
	mg/l	mg/l	µs/cm	NTU	Unit
1/2022	220	440	1365	1.5	7.8
2/2022	230	440	1335	3.1	7.9
3/2022	235	445	1390	2.1	7.6
4/2022	230	440	1399	3.3	7.7
5/2022	220	440	1403	3.8	7.8

EC of the 2 wells used by Qa'a Al-Saadeen Association.

1- Qa'a Al-Saadeen Well No 6: EC = 2.41 mS/cm = 2410 µS/cm

2- Qa'a Al-Saadeen Well No 1: EC = 2.35 mS/cm = 2350 uS/cm

Water monitoring program

This program is approved for the first six months of operation

Analysis	*Unit*	*Frequency of examination*
Color	Unit	Once a week/4 times a month
Taste	----	Once a week/4 times a month
Odor	----	Once a week/4 times a month
Turbidity	NTU	Twice a week / 8 times a
Total Dissolved Solids	mg/l	Twice a week / 8 times a
PH	Unit	Twice a week / 8 times a
Electric Conductivity	µs/cm	Twice a week / 8 times a
Total Hardness	mg/l	Twice a week / 8 times a
Total Alkalinity	mg/l	Twice a week / 8 times a
Total Coliform	MPN/100ml	once a month

Water collection and agriculture monitoring program by the association

Twice a Month

- After the initial run-up, tests are carried out for the incoming water and the product, in addition to the wastewater.
- Begin conducting operational examinations according to the program prepared for this purpose.
- See the measures taken by the association and farmers to use the water presented.

Processing of results

The data and results obtained from this monitoring plan proposed will complement the geodatabase prepared by Enas on a QGIS platform in which the basic thematic cartographies related to the project have already been upload (geology, soil, land use).

All the data within the QGIS project will then be processed through spatial analysis to assess the criticality and identify the susceptibility of the area to the use of fertilizer produced by the new plant.

PILOT SITE – BECHIMA (TUNISIE)

In the Tunisia, treated municipal wastewater seems to be an alternative water resource for forage crops irrigation with a correct salts management. However, studies of different types of wastewater and soils are needed before these results can be generalized, because changes in microbial community are also considerably influenced by soil type and certain agricultural practices.

The study area, located in the region of Hammet Gabes (Bechima perimeter), extends over 03 plots which differ in the duration of the irrigation period ranging from one (01) year to 15 years (Fig.60)).

A plot not irrigated by treated wastewater (rainfall regime) was taken as a reference.

Studies on soil and water resources in the Bechima region have begun with the MEDISS project. The first sampling campaign for soil analysis began in 2020 for the summer season, and the second campaign for the winter season was conducted in 2021. The analyses of the treated wastewater and the monitoring of the operation of the wastewater treatment system started in 2021.

There are no previous studies on groundwater monitoring for Bechima region.

There are no previous studies on data crops monitoring.

Therefore, this work aimed to estimate the changes in soil fertility and the microbial biomass diversity in response to 1, 7, and 15 years of WWTP irrigation on arid soil in the Gabes agricultural area of "Chenchou Hammet Gabes", south of Tunisia. The effectiveness of WWTP irrigation practice was based on: 1) evaluation of soil physical and chemical properties (2) soil enteric bacteria (coliforms and streptococci) amount, 3) soil microbial biomass carbon and nitrogen, (4) bacterial number (mesophilic aerobic bacteria [MAB], staphylococcus, Salmonella), cultivated and not cultivated bacteria (DGGE). Pathogens in wastewater could arise problems when WWTP are disposed. But, the specific experimental site (Gabes region) and the diversity of information on the changes in the soil chemical, biochemical and biological parameters after WWTP irrigation could be useful for both farmers and scientists facing an increasing problem of water shortage.

Legislation and inspection bodies

Laws relating to the reuse of water resources in the region are

- Tunisian standard NT. 106.02 (1989) relating to the discharge of effluents in the water environment (Environmental protection).
- Tunisian standard NT 106.03 (1989): environmental protection - use of treated wastewater for agricultural purposes: physicochemical and biological specifications

Introduction

This research work is articulated around three axes: 1- Experimentally evaluate the impact of wastewater on the physico-chemical parameters and on the indigenous microbial communities of the soil. 2- Evaluate the impact of wastewater on the eco-physiological parameters of olive groves. 3- Evaluate the impact of this practice on the yield and quality parameters of the finished product (olive oil).

In order to meet these objectives, 02 soil sampling campaigns have been scheduled. The first was carried out during the month of July 2020. The second during the month of March 2021. On the other hand, in order to study the quality of the olive oil, two other sampling campaigns have been scheduled. The first during the month of November 2020. The second during the month of November 2021.

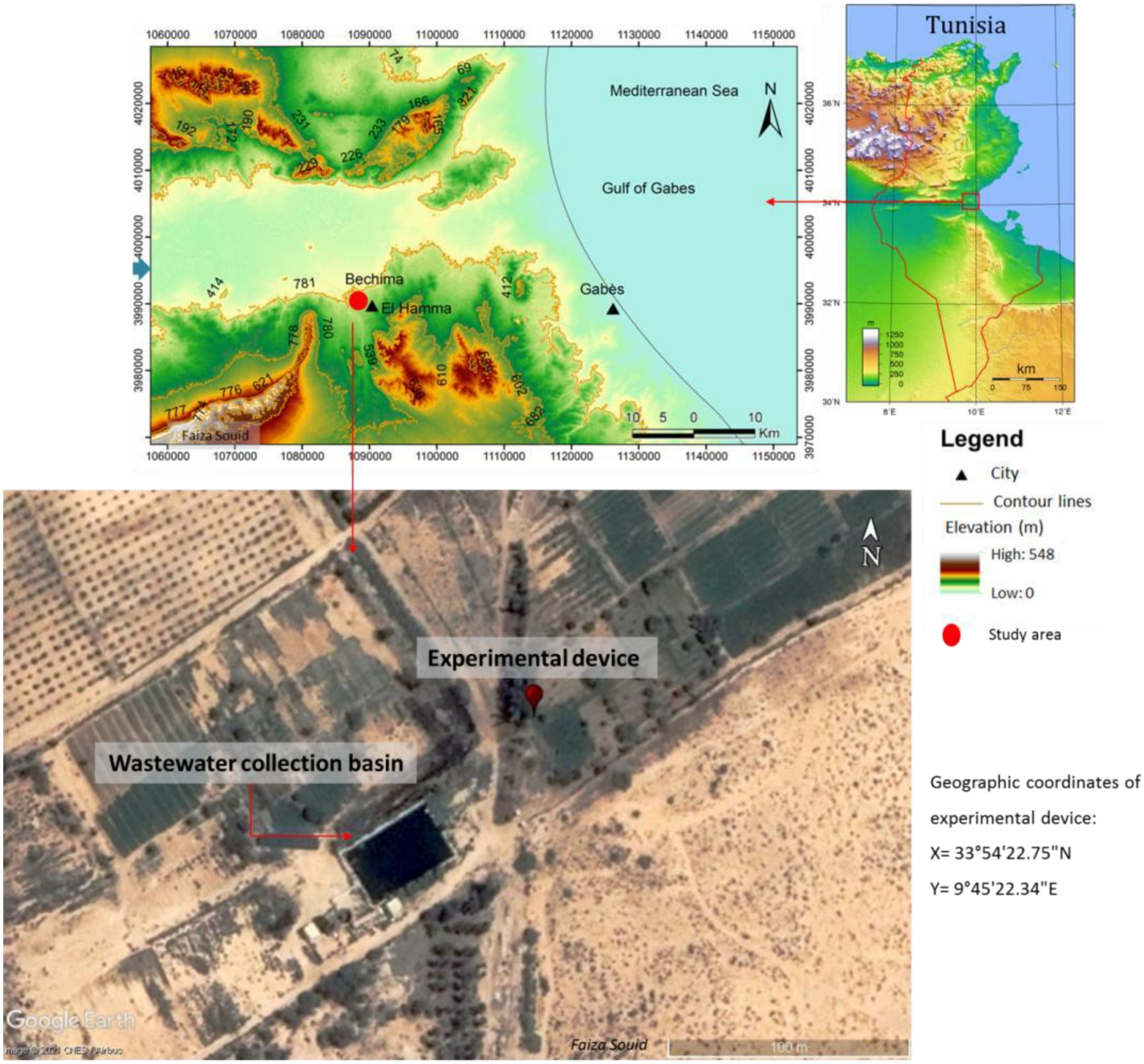
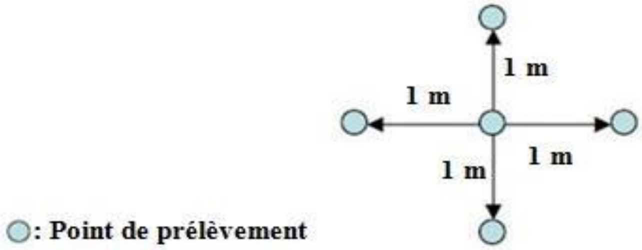
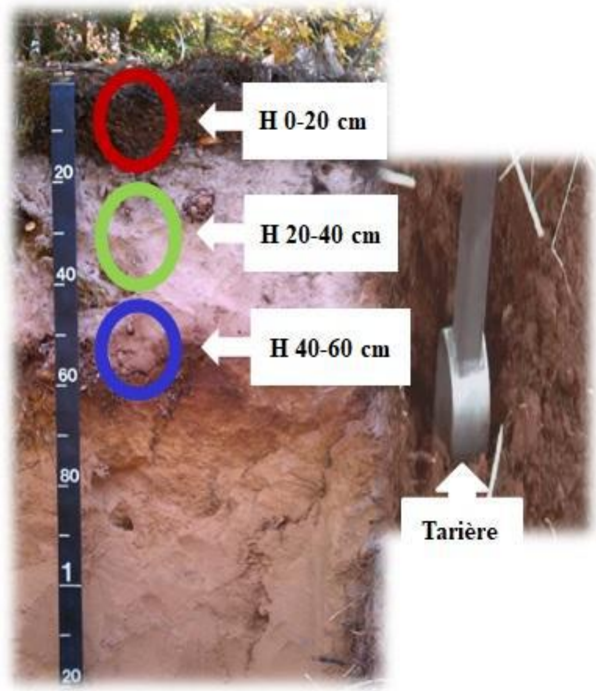


Fig.60 Location area

The study area, located in the region of Hammet Gabes (Bechima perimeter), extends over 03 plots which differ in the duration of the irrigation period ranging from one (01) year to 15 years (fig. 60). A plot not irrigated by treated wastewater (rainfall regime) was taken as a reference.Since its inception, no analysis of soils irrigated with treated wastewater has been published, so our job is to sample in different areas of this irrigated perimeter, during different seasons and at different depths in this soil to subsequently perform analyzes of the different physicochemical and microbiological parameters. four small plots were chosen (Fig.1):
P1: Plot not irrigated by wastewater;
P2: Plot irrigated by wastewater for one year;
P3: Plot irrigated by wastewater for 7 years;
P4: Plot irrigated by wastewater for 15 years.

Sampling strategy
The purpose of soil sampling is to provide a small volume of soil for analysis that is representative of the entire volume of soil in the area of interest. In order to achieve this goal, in our study, the samples were taken, in the center of each elementary plot, according to the cross pattern (fig. 61), with the taking of five soil sub-samples spread over 4 m2.





Particle size composition
Our results revealed that the analyzed soils have a sandy-silty texture (Fig. 61). It is a medium-light texture with a low water retention capacity.
For this type of soil, the water supply should be well controlled to avoid losses by leaching of the mineral elements provided. It is therefore advisable to split the doses as much as possible.

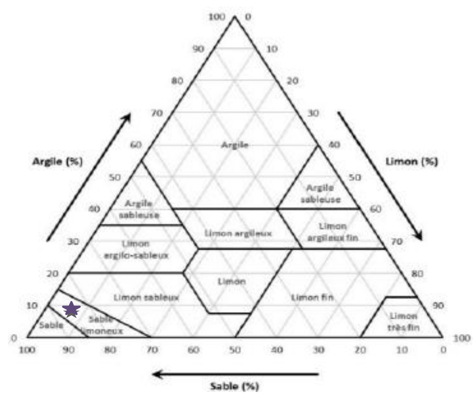
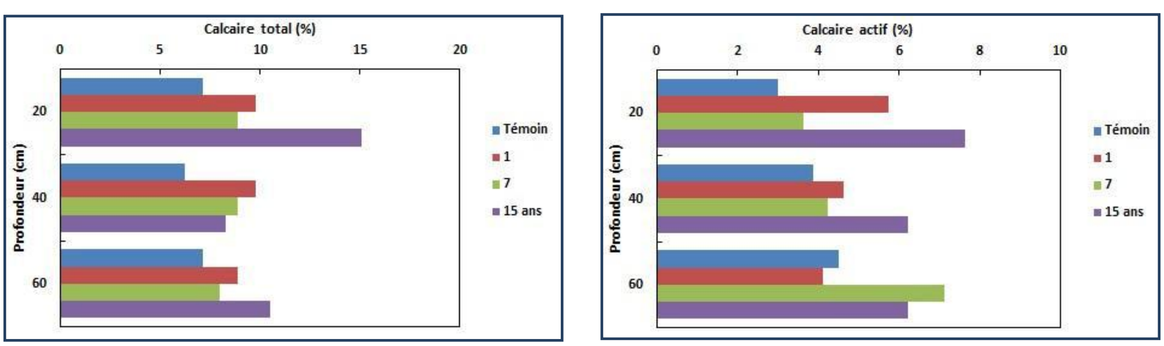


Fig 61. Texture triangle (Analyzed soils)

Determination of total and active limestone content (CaCO3) in the study area
The evaluation of the total and active limestone content showed that the soils of plots P1 (Control), P2 and P3 are moderately calcareous (Fig.62). However, plot P4 has high levels of active limestone, hence the risk of ferricchlorosis. These results are valid for the three horizons studied (0-20, 20-40 and 40-60 cm).



(A) (B)

Fig. 62. Evolution of total (A) and active (B) limestone content as a function of the duration of the irrigation period.

Determination of cation exchange capacity (CEC)

The determination of the CEC highlighted the results displayed in Figure 63. According to these results, the highest CECs were recorded in the plot irrigated the longest by the EUTs (P4: 15 years). The soils of this plot have CECs of around 5.5; 5.3 and 4 meq/100g of soil respectively for depths 0-20; 20-40; 40-60cm. The control plot shows the lowest CECs. They are respectively of the order of 3; 2.5 and 2.90 meq/100g of soil.

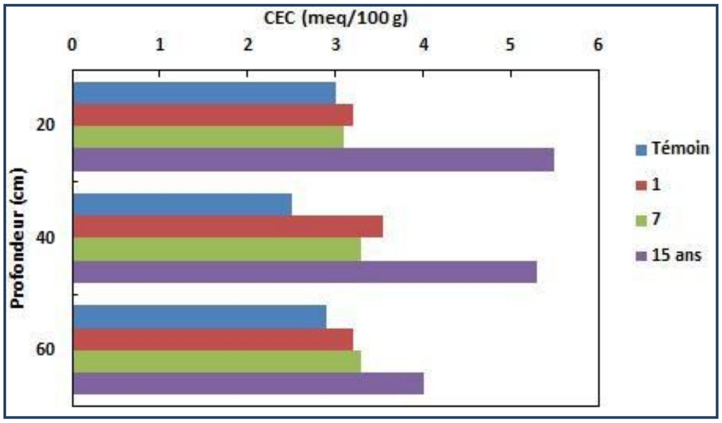


Fig. 63. Evolution of the CEC (meq/100 g) according to the duration of the irrigation period.

Based on these results, it can be concluded that for the analyzed soils, the CEC is very low. Thus the availability of mineral nutrients is inefficient for the plant. These soils have a low capacity to retain applied nutrients. This capacity was improved following irrigation by EUTs, particularly, for a long period (15 years).

Variation of the hydrogen potential (pH) according to the duration of the irrigation period

The results of our analyzes show a variable pH of 8.01 and 8.73 in plots P1 (Control), P2 and P3 (Fig. 64). These three plots have frankly basic soils.

The P4 plot irrigated for 15 years by treated wastewater presents, for the three depths studied, a variable pH between 7.81 and 7.94 respectively for the surface horizon (0-20 cm) and for the depth horizon. (40-60cm). This decrease in pH value seems to be dependent on the duration of the irrigation period with treated wastewater. In fact, EUTs, loaded with organic compounds (humic and fulvic acids) can contribute to the reduction of soil pH, resulting in a greater availability of mineral elements for the plant (soil solution).

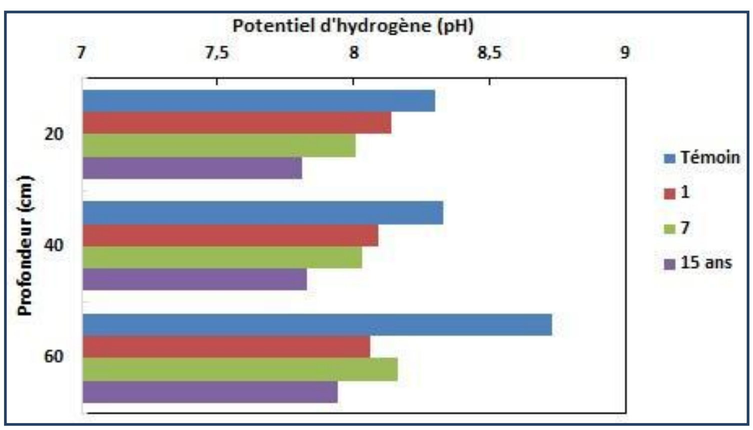


Fig 64. Evolution of soil pH as a function of the duration of the EUT irrigation period.

Electrical Conductivity (EC)

The evolution of the EC, of the soil solution, as a function of the duration of irrigation by the EUTs for the three horizons studied (0-20; 20-40; 40-60 cm) is displayed in figure 65. According to these results, the soils analyzed reveal a variable CE between excessive and severe. They are therefore classified as saline. In order to reduce the saline stress exerted on the plant cover, these soils must be irrigated excessively by water of low to medium salinity. This practice facilitates the accumulation of salts in the depth horizons.

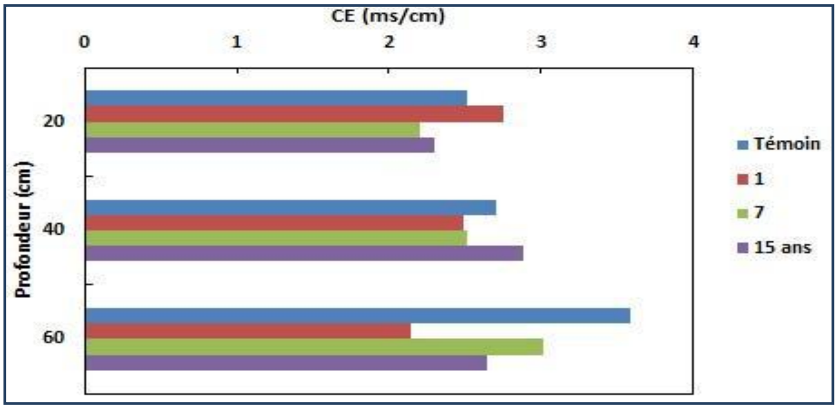


Fig. 65 Evolution of EC (ms/cm) as a function of the duration of the irrigation period with EUTs.

Organic matter (OM, %)

The variation of organic matter content as a function of the duration of the irrigation period and the depth of the soil is shown in Figure 66.

Our results reveal an excessively low organic load in all the soils analyzed. Only the plot irrigated the longest by EUTs has a moderately low organic load (1.17%). The results displayed in Figure 7 highlight an increase in the organic matter content, depending on the duration of the irrigation period by the EUTs. These results are valid for the three soil horizons studied. Hence the fertilizing effect of this practice.

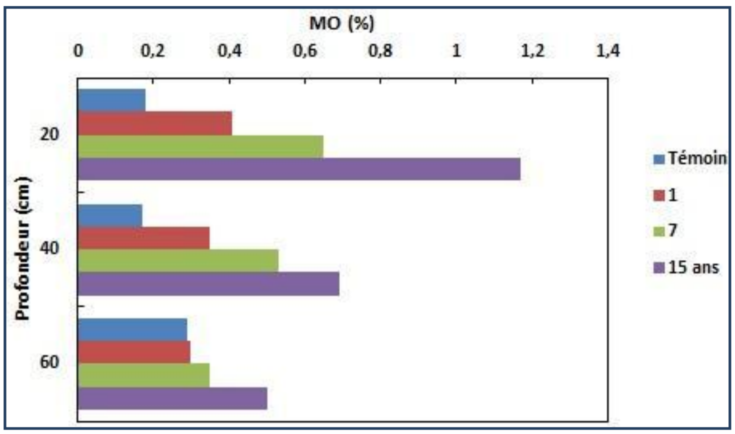


Fig. 66 Evolution of the organic load (OM, %) as a function of the duration of the irrigation period with EUTs.

Total Kjeldahl Nitrogen (NTK, ‰)

The results displayed in Figure 67 reveal an increase in total Kjeldahl nitrogen content dependent on the duration of the EUT irrigation period. This increase is visible mainly in the surface horizons (0-20 and 20-40 cm).

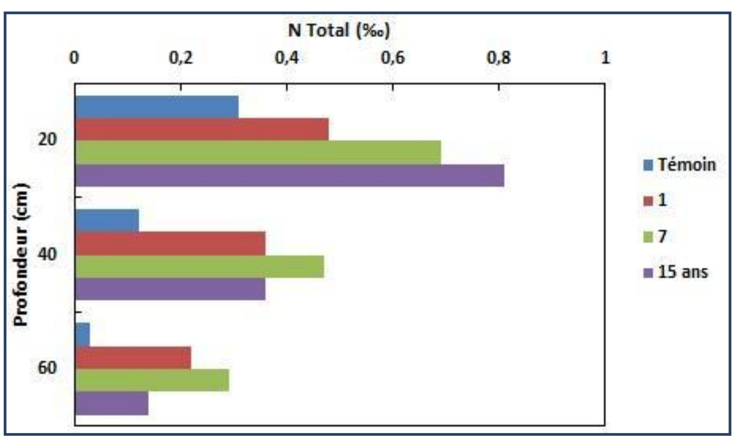


Fig. 67 Evolution of the total Kjeldahl nitrogen content (Total N, ‰) as a function of the duration of the irrigation period with EUTs.

The C/N ratio

The results shown in Figure 68 show the variation of the C/N ratio as a function of the duration of the irrigation period by the EUTs and as a function of the soil horizon studied. According to these results, the C/N ratio varies between 3.35 and 8.37 for the 0-20 cm horizon, between 4.45 and 11.11 for the 20-40 cm horizon and between 7 and 56.07 for the horizon 40-60 cm. According to the LCA classification (2008) the soils of the control plot show rapid mineralization for the two surface horizons (0-20 and 20-40 cm). At the level of the depth horizon (40-60 cm) the rate of mineralization becomes slow. These results seem to be caused by the lack of nitrogen and the excessive salinity in the deep horizons. These stressful conditions disrupt the multiplication of microorganisms and inhibit the biological activity of the soil. Plots irrigated by EUTs show adequate biological activity. Only the 40-60 cm horizon belonging to the oldest plot irrigated by EUTs (P4: 15 years) shows slow biological activity.

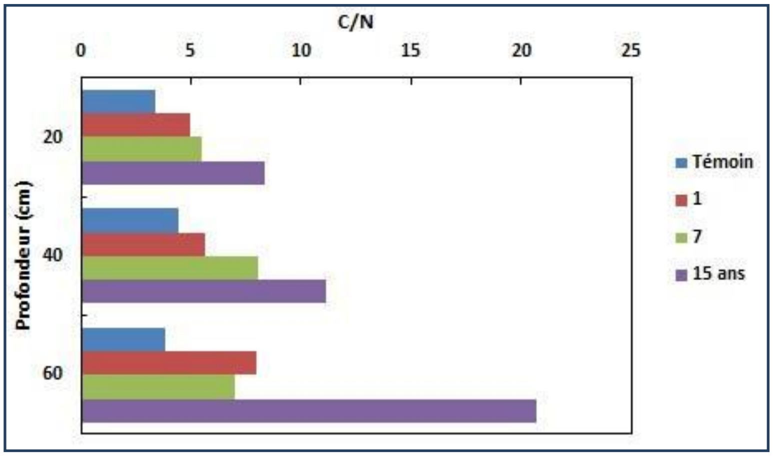
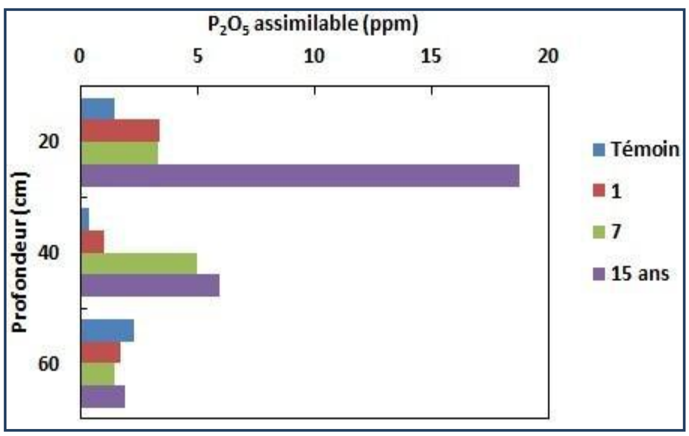
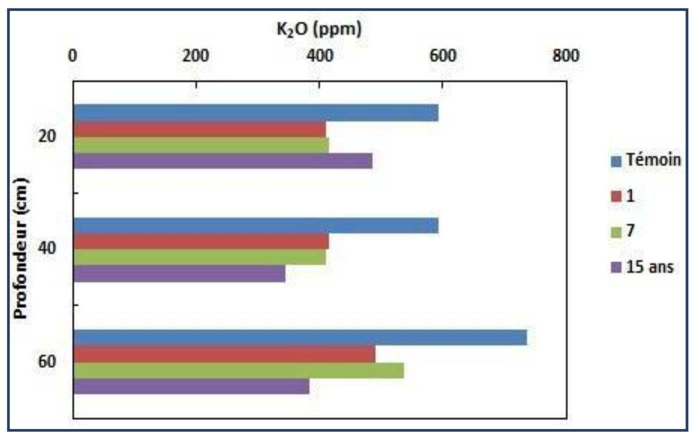


Fig 68 Variation of the C/N ratio as a function of the duration of the irrigation

Nutritional elements

The variations in P2O5 and K2O content as a function of EUT irrigation time are displayed in Figure 69.





(A) **(B)**

Fig. 69. Determination of phosphorus (A) and potassium (B) content according to the period of irrigation by EUTs.

According to these results, the soils of the control plot (horizon 0-20; 20-40 and 40-60 cm) have a low load of assimilable phosphorus. The load in this element increased in plots irrigated by EUT. It should be noted that plot P4 (15 years of EUT irrigation) has the highest content of assimilable phosphorus. This increase seems to depend on the duration of the irrigation period.

The evaluation of the exchangeable potassium content revealed low levels in all the soils analyzed.

Microbiological analyzes

Enumeration of microbial flora (bacterial and fungal flora)

The effect of EUT irrigation on the indigenous cultivable microbial biomass of the soil was studied using the solid agar count method (PCA medium: bacterial flora and PDA: fungal flora). It should be noted that the enumeration of the bacterial flora was carried out following inoculation in depth and at an incubation temperature of the order of 30°C (total mesophilic germs, GMT). Enumeration of fungal flora by surface seeding at a temperature of 28°C for 48 hours. The results of the analyzes are displayed in Tables 27 and 28, highlighting a significant increase in GMT and fungal flora in plots irrigated by EUTs. These results are particularly visible in medium and old irrigated plots seem to be dependent on the duration of the irrigation period. These results are valid for the 3 soil horizons studied (0-20; 20-40 and 40-60 cm). It is that the number of GMT decreased significantly in the depth horizons (20-40 and 40-60 cm).

Table 27. Enumeration of total mesophilic germs (GMT).

	P. témoin	**P_1 (1 année)**	**P_2 (7 ans)**	**P_3 (15 ans)**
		10^3 UFC/g s.s.		
0-20 cm	132 ± 3,3	216 ± 1,6	1520 ± 16,3	2980 ± 16,3
20-40 cm	11,9 ± 0,2	12,5 ± 0,4	32 ± 2	61,3 ± 3
40-60 cm	4,5 ± 0,1	5,5 ± 0,2	8,6 ± 0,2	25,5 ± 0,4

CFU/g s. s. : Colony-forming unit per gram of dry soil.

Our results agree with those highlighted by Ramirez-Fuentes et al. (2002) and Hidri et al. (2012).
According to these authors, soil irrigation with treated wastewater seems to induce a significant increase in the microbial load. This microbial growth can be explained by the accumulation of easily biodegradable organic matter.

Table 28. Enumeration of fungal flora.

	P. témoin	**P_1 (1 année)**	**P_2 (7 ans)**	**P_3 (15 ans)**
		UFC/g s. s.		
0-20 cm	1967 ± 9,4	2153 ± 18,8	2967 ± 9,4	17667 ± 94,3
20-40 cm	1393 ± 15,3	1260 ± 10	2310 ± 10	6267 ± 115,5
40-60 cm	450 ± 8,2	463 ± 4,7	563 ± 26,2	1113 ,7

Evaluation of the sanitary quality of the soil

Enumeration of faecal pollution indicators (NPP Method)

The results of the count of total coliforms, faecal coliforms and Escherichia coli are shown in Table 29. According to these results, the soils of the control plot have a very low number (< 0.3 MPN/g dry soil) of total coliforms , faeces and Escherichia coli. The plots irrigated by the EUTs present a bacteriological load much higher than that existing in the control plot. For example, the number of faecal coliforms increases to reach 11 x 103 MPN/g dry soil. It should be noted that the number of the three bacteria studied in this part (total coliforms, faecal coliforms and Escherichia coli) is proportional to the duration of the irrigation period by the EUTs. The pattern is different when migrating in depth. In fact, the lowest number of these bacteria was recorded for the depth 40-60 cm.

These results seem to be due, on the one hand, to the high bacteriological load conveyed by EUTs. On the other hand, these waters are rich in easily biodegradable organic matter (high BOD5).
The count of total streptococci in the control plots (tab. 30) revealed low numbers in the three soil horizons studied (0-20; 20-4 and 40-60 cm). This result turns out to originate from the organic stock which is deficient in these plots. The count of faecal streptococci, a subgroup of total streptococci, revealed significant values in the plots irrigated the longest by EUTs (7 and 15 years).
Overall, it can be concluded that the indicators of faecal pollution, counted during this research work, tend to increase according to the duration of the irrigation period by EUT. Our results also showed that these bacteria accumulate better at the surface than at depth. These outcomes seem to be related to the organic load brought to the soil by this agricultural practice (fertilizing effect of EUTs).

Table 29. Enumeration of total and faecal coliforms and Escherichia coli (MPN/g dry soil).

Période d'irrigation (EUT)	**Profondeur (cm)**	**Coliformes totaux**	**Coliformes fécaux**	***Escherichia coli***
Témoin	0 - 20	< 0,3	< 0,3	< 0,3
	20 - 40	< 0,3	< 0,3	< 0,3
	40 - 60	< 0,3	< 0,3	< 0,3
P_1 (1 année)	0 - 20	67 ± 6	53 ± 12	< 0,3
	20 - 40	63 ± 6	< 0,3	< 0,3
	40 - 60	< 0,3	< 0,3	< 0,3
P_2 (7 ans)	0 -20	2033 ± 58	207 ± 8	63 ± 6
	20 - 40	1000 ± 173	120 ± 17	33 ± 6
	40 - 60	467 ± 115	83 ± 12	< 0,3
P3 (15 ans)	0 - 20	11000 ± 0	2067 ± 58	103 ± 12
	20 - 40	767 ± 115	634 ± 58	53 ± 12
	40 - 60	103 ± 12	83 ± 12	< 0,3

Table 30. Enumeration of total and faecal Streptococci (MPN/g dry soil).

Période d'irrigation (EUT)	Profondeur (cm)	Streptocoques totaux	Streptocoques fécaux
Témoin	0 - 20	< 0,3	< 0,3
	20 - 40	< 0,3	< 0,3
	40 - 60	< 0,3	< 0,3
P_1 (1 année)	0 - 20	833 ± 115	< 0,3
	20 - 40	83 ± 11,6	< 0,3
	40 - 60	37 ± 6	< 0,3
P_2 (7 ans)	0 -20	967 ± 115	833 ± 115
	20 - 40	203 ± 6	103 ± 12
	40 - 60	137 ± 23	< 0,3
P3 (15 ans)	0 - 20	1033 ± 115	767 ± 115
	20 - 40	467 ± 115	667 ± 58
	40 - 60	247 ± 29	< 0,3

pathogens (Salmonella, Stapthylococcus and Pseudomonas aeruginosa)

The counting of the presence of Salmonella spp, Staphylococcus spp and Pseudomonas aeruginosa was carried out according to a culture-dependent approach (cultivable approach). The results of the analyzes carried out are illustrated in Table 31. These results revealed the presence of the pathogens studied, mainly in the plots irrigated the longest by the EUTs.

Table 31. Count of pathogenic bacteria (CFU/g dry soil).

Période d'irrigation (EUT)	Profondeur (cm)	*Salmonella*	*Staphylococcus*	*P. aeruginosa*
Témoin	0 - 20	Absence	470 ± 8,2	1513 ± 4,7
	20 - 40	Absence	373 ± 5,8	963 ± 5,7
	40 - 60	Absence	313 ± 4,7	343 ± 125
P_1 (1 année)	0 - 20	298 ± 1,6	1743 ± 12,5	29733 ± 124,8
	20 - 40	188 ± 2	1543 ± 20,8	12267 ± 251,6
	40 - 60	Absence	292,3 ± 0,5	413 ± 4,7
P_2 (7 ans)	0 -20	6000 ± 94,3	2240 ± 163,3	187333 ± 1247,2
	20 - 40	307 ± 5,8	2973 ± 11,5	49000 ± 2000
	40 - 60	Absence	327 ± 9,4	13833 ± 205,5
P3 (15 ans)	0 - 20	6133 ± 94,3	123667 ± 471,4	51333 ± 4714
	20 - 40	413,3 ± 5,8	15333 ± 115,4	224000 ± 3464,1
	40 - 60	323 ± 4,8	780 ± 8,22	17833 ± 286,7

These results seem to be due to the poor bacteriological quality of wastewater from the STEP El Hamma used for irrigation, this water transmits these three opportunistic pathogens to the ground, a place of manipulation and work of a large number of people and farmers, hence the risk of contamination of this population. It should be noted that animals are also vulnerable to this contamination.