



# Mediterranean Integrated System for Water Supply «MEDISS»

Agreement No: A\_B.4.1\_0249

## WP3 ACTIVITIES

### Piano di Monitoraggio

### Analisi storica e Proposta MEDISS

*PROJECT DURATION:*  
August 1, 2019 - July 31, 2022



مياه العقبة  
Aqaba Water





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## PREFACE

WP3 is a technical WP that embraces the whole project and it is aimed to:

- collecting relevant and consistent baseline data in the 4 MEDISS areas;
- analyzing and organizing data in a comprehensive database;
- provide target values and tools for monitoring;
- evaluate MEDISS impact on water, soils and crops during and after pilot tests;
- identify up-scaling opportunities and elaborate solid proposal for future funding.

During MEDISS first year current data on water supply, water quality, soil composition and crops are collected in each area, 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 provides 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 are operative, specific analyses of water, soils and crops are carried 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. 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.

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.

## ONGOING MONITORING PLANS IN NVZ AREA



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## Legislation and inspection bodies

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 Hydrographic 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.



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## Groundwater monitoring net - ARPAS

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



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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	III
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	III
P36	729	Strada 14 ovest	1460371	4400952	0,67	Private well	I
P37	730	Strada 14 ovest	1460447	4400813	1	Private well	III
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	III
P46	738	Strada 6 ovest	1463964	4397928	7	Private well	III
P47	739	Strada 6 ovest	1461138	4397782	4	Private well	I



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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 NVZs

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 NVZs 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. 1).





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Fig. 1 - Groundwater monitoring net stations in the Arborea plain.



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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).

Parameters were recorded on field through 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; Oxygen; 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 Lab:

- 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);





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- 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:

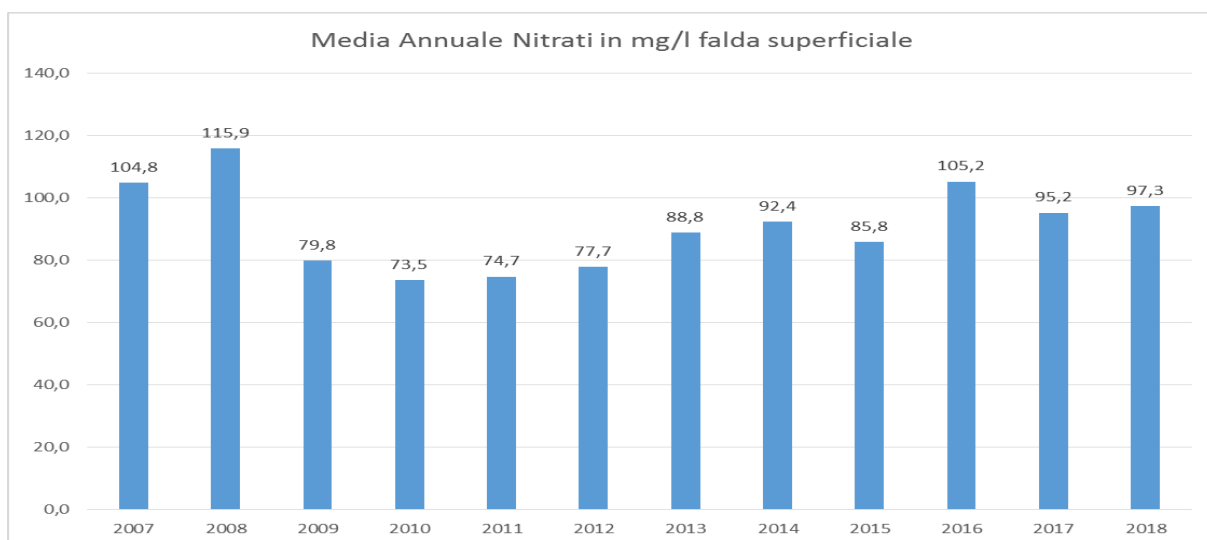
- 500ml polyethene flask for base parameters;;
- 50 ml polyethene flask, previously acidify with Nitric-Acid, for metals;
- 1000 ml dark glass bottle with teflon sealing gasket for pesticides.

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

### Historical analysis of Arborea NVZs (ARPAS Activity 2018)

Historical analysis of NVZs 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 (NVZs) under EU Directive 91/676/EEC.

Nitrate compounds data were analysed yearly and quarterly (Fig. 2, 3), 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<sup>3-</sup>.





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Fig. 2 - Medium annual content of nitrate in the I aquifer (ARPAS- Activity 2018)

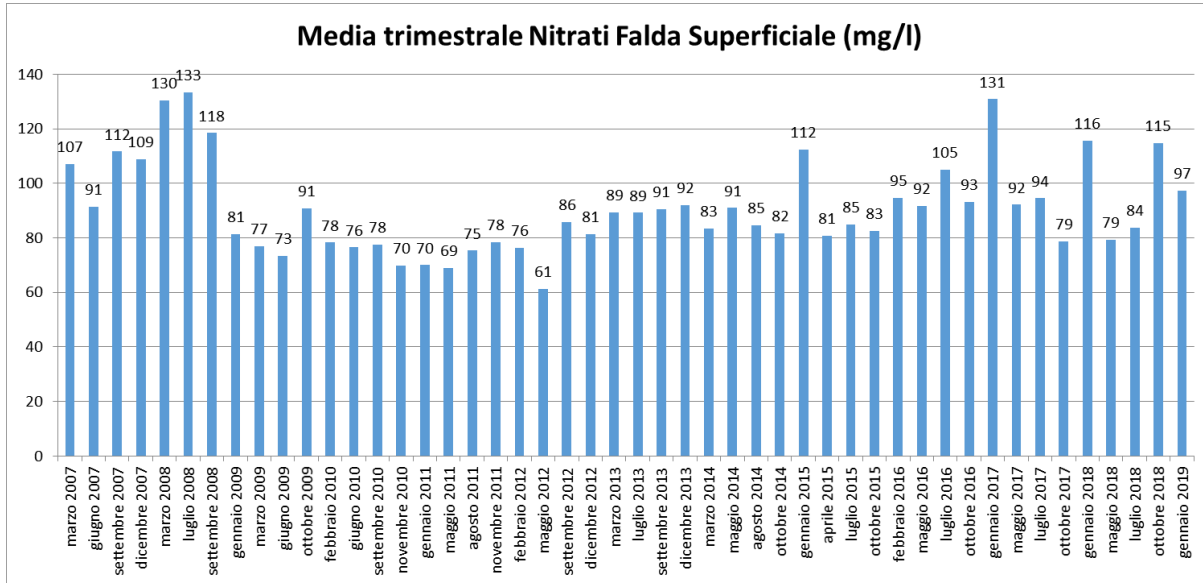


Fig. 3 – Medium quarterly content of nitrate in the I aquifer (ARPAS- Activity 2018)

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 (Fig. 3). In 2016 another increase, where the highest values were recorded and quite similar to 2008. In 2017 these values were ranged between 79 e 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. 4).



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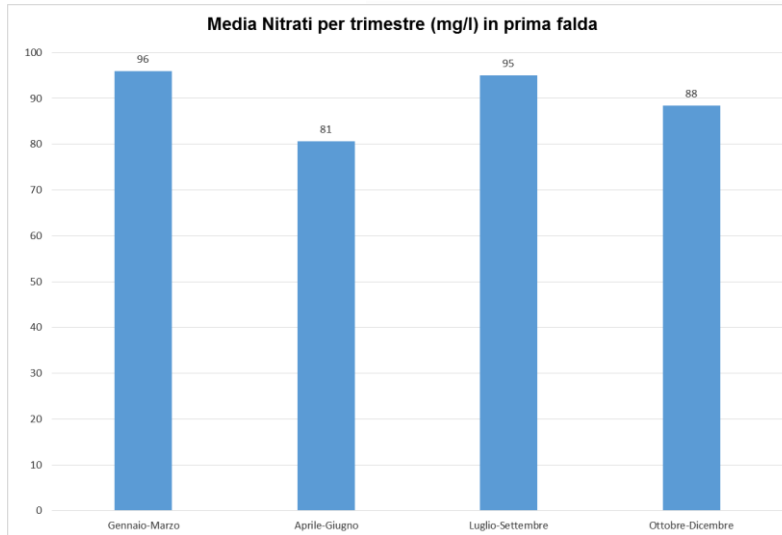


Fig. 4 - Quarterly medium nitrate contents in the I aquifer 2007-2018 (ARPAS - Activity 2018)

In piezometers P18 and P19 referred to Sassu aquifer, the nitrate content is low, the two stations are placed out of NVZs 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  $\mu\text{S}/\text{cm}$  in the I and 2000-3000  $\mu\text{S}/\text{cm}$  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 II one (P30, P37).



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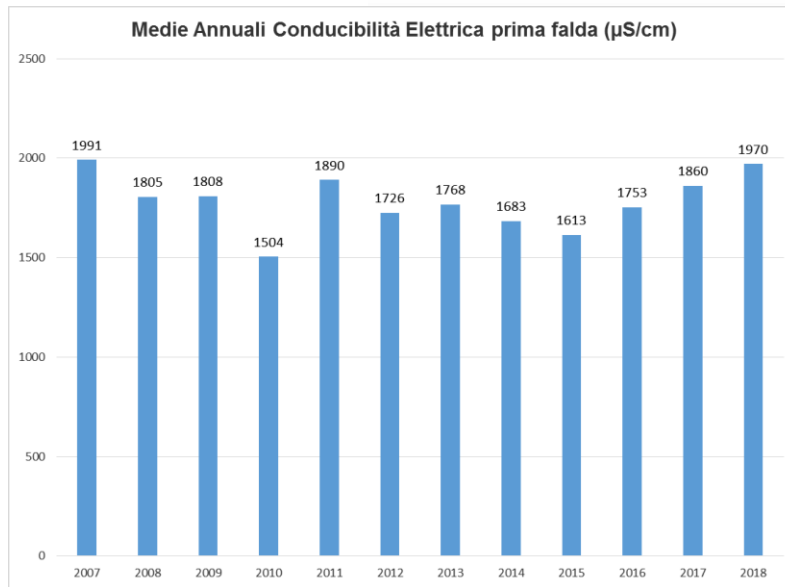


Fig. 5 - Conductivity annual average in I aquifer (ARPAS Activity 2018 )

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.

### 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 are listed in Tab. 5 with information on geographic coordinates (Gauss-Boaga), referring maps, places, also reported in Fig. 9.



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ID postazione	Tipo osserv.	Profondità m	Longitudine	Latitudine	CTR 1:10000	Località
F 01	Trivellata	0,4	1464112,5	4396330,0	538070	tra strada 2 e 3 W a N di Linnas
E 01	Trivellata	0,4	1463115,7	4396390,2	538070	a E dell'idrovora Luri
D 01	Trivellata	0,4	1462115,7	4396395,2	538070	presso idrovora Luri
C 01	Trivellata	0,4	1461115,7	4396400,2	538070	tra strada 2 e 3 a E della strada long. 40 W
B 01	Trivellata	0,4	1460115,7	4396405,2	538070	tra strada 2 e 3 presso la strada long. 40 W
A 02	Trivellata	0,4	1459119,7	4397410,2	538070	presso strada 5 W poco a E di Marceddi
B 02	Trivellata	0,4	1460119,7	4397405,2	538070	presso strada 5 poco a SW di Torrevecchia
C 02	Trivellata	0,4	1461119,7	4397400,2	538070	presso strada 5 a SE di Torrevecchia
D 02	Trivellata	0,4	1462120,7	4397395,2	538070	strada 5 a S di Luri
E 02	Trivellata	0,4	1463119,7	4397390,2	538070	strada 4W presso il canale Pauli Estius
F 02	Trivellata	0,4	1464120,5	4397385,0	538070	su strada 5 W presso la strada rettilineo sud
F 03	Trivellata	0,4	1464124,5	4398385,0	538070	presso strada 8 W vicino alla strada rettilineo sud
E 03	Trivellata	0,4	1463124,7	4398390,2	538070	tra strada 7 e 8 presso il canale Pauli Estius
D 03	Trivellata	0,4	1462124,7	4398395,2	538070	tra strada 7 e 8 a N di Luri
C 03	Trivellata	0,4	1461124,7	4398400,2	538070	presso strada 7 a E della strada long. 40 W
B 03	Trivellata	0,4	1460124,7	4398405,2	538070	presso strada 7 vicino alla strada long. 40 W
A 03	Trivellata	0,4	1459124,7	4398410,2	538070	presso strada 7 poco a NE di Marceddi
A 04	Trivellata	0,4	1459129,7	4399410,2	538070	presso strada 10 vicino alla peschiera di Coru S'Ittiri
B 04	Trivellata	0,4	1460129,7	4399405,2	538070	presso strada 10 vicino alla strada long. 40 W
C 04	Trivellata	0,4	1461129,7	4399400,2	538070	presso strada 10 W
D 04	Trivellata	0,4	1462129,7	4399395,2	538070	poco a N di strada 10 a SE di Pompongiadas
E 04	Trivellata	0,4	1463129,7	4399390,2	538070	presso strada 10 poco a SE di Pompongiadas
F 04	Trivellata	0,4	1464129,5	4399385,0	538070	presso strada 10 W vicino alla strada rettilineo sud
G 04	Trivellata	0,4	1465121,5	4399393,0	538080	presso strada 10 W a S della strada SP49
G 05	Trivellata	0,4	1465118,7	4400408,9	538040	tra la strada SP 49 e il canale adduttore Tirso Arborea
F 05	Trivellata	0,4	1464134,7	4400384,9	538030	presso strada 12 W vicino alla strada provinciale 22
E 05	Trivellata	0,4	1463134,8	4400390,1	538030	presso strada 12 W
D 05	Trivellata	0,4	1462134,8	4400395,1	538030	presso strada 13 poco a NW di Pompongiadas
C 05	Trivellata	0,4	1461134,8	4400400,1	538030	presso strada 12 W
B 05	Trivellata	0,4	1460134,8	4400405,1	538030	presso strada 13 vicino alla strada long. 40 W
C 06	Trivellata	0,4	1461139,8	4401400,1	538030	presso strada 15 W a E dello stagno Coru S'Ittiri
D 06	Trivellata	0,4	1462139,8	4401395,1	538030	presso strada 15 W a E della strada 25 E
E 06	Trivellata	0,4	1463139,8	4401390,1	538030	presso strada 15 W
F 06	Trivellata	0,4	1464139,7	4401384,9	538030	presso strada 15 W vicino alla strada provinciale 22
E 07	Trivellata	0,4	1463144,8	4402390,1	538030	presso strada 17 W a W di Arborea
D 07	Trivellata	0,4	1462144,8	4402395,1	538030	presso strada 19 W a E dell'estremità N dello stagno
C 07	Trivellata	0,4	1461144,8	4402400,1	538030	presso la curva della strada 18 W vicino all'estremità N dello stagno
C 08	Trivellata	0,4	1461149,8	4403400,1	538030	presso strada 20 W vicino a Pauli Pirastu
D 08	Trivellata	0,4	1462135,8	4403409,1	538030	presso strada 20 W a E dello stagno Pauli Pirastu
E 08	Trivellata	0,4	1463186,8	4403339,1	538030	presso strada 20 W a NW di Arborea
F 08	Trivellata	0,4	1463981,7	4403383,9	538030	presso strada 20 W vicino alla strada provinciale 22
G 07	Trivellata	0,4	1465252,7	4402371,9	538040	presso la strada 17 E a E di Arborea
G 08	Trivellata	0,4	1465095,7	4403412,9	538040	presso la strada 20 E vicino al canale delle acque medie
F 09	Trivellata	0,4	1464154,7	4404384,9	538030	presso strada 22 W vicino alla strada provinciale 22
E 09	Trivellata	0,4	1463209,8	4404392,1	538030	presso strada 22 W
D 09	Trivellata	0,4	1462154,8	4404395,1	538030	a N della strada 22 W presso l'incrocio con la strada 25 E
C 09	Trivellata	0,4	1461075,8	4404382,1	538030	presso la strada 22 a S del complesso Ala Birdi
F 10	Trivellata	0,4	1464159,7	4405385,9	538030	presso S'Ungroni vicino alla strada provinciale 22
E 10	Trivellata	0,4	1463159,8	4405390,1	538030	presso strada 24 W a W di S'Ungroni
D 10	Trivellata	0,4	1462159,8	4405395,1	538030	strada 25 W presso l'incrocio con la strada 25 E
D 11	Trivellata	0,4	1462164,8	4406395,1	528150	presso strada 27 a E della colonia marina
E 11	Trivellata	0,4	1463164,8	4406390,1	528150	presso strada 27 W
F 11	Trivellata	0,4	1464164,7	4406385,9	528150	presso strada 27 W vicino alla strada provinciale 22
E 12	Trivellata	0,4	1463169,8	4407389,1	528150	presso il limite N dell'area designata ZVN
D 12	Trivellata	0,4	1462169,8	4407395,1	528150	presso il limite N dell'area designata ZVN

Tab. 5 - List of soils sampling stations in Arborea NVZ (-ARPAS-2018)





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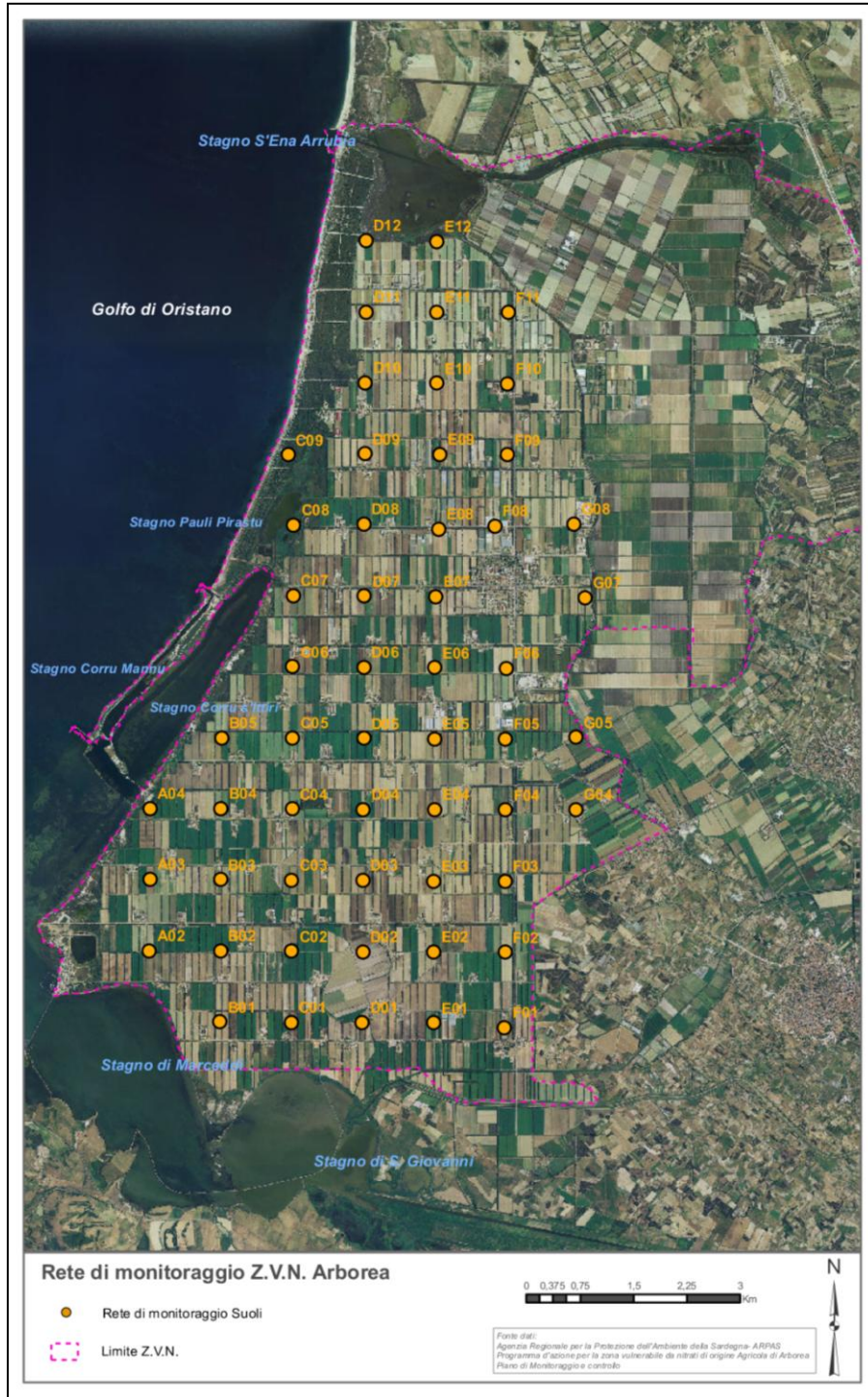


Fig. 6 - Soils monitoring net in NVZ ( Waste-water treatment plant annex)



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In soils, samples are recorded pH, humidity, copper, total zinc and other metals, reactive phosphorus, sodium and 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. 6 are listed the parameters requested by law and methods of detections.

Tab. 6- List of parameters recorded for soils and methods applied (ARPAS - Attività 2018)

	Parametri	Metodica
Parametri agro-chimici	pH	Metodo III.1 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Carbonio organico	Metodi VII.2 - VII.1 "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Conducibilità elettrica estratto	Metodo IV.1 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Capacità di scambio cationico	Metodo XIII.2 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Basi di scambio	Metodo XIII.5 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Acidità totale	Metodo XIII.3 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Azoto	Metodo XIV.3 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
	Fosforo assimilabile	Metodo XV.3 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99)
Metalli pesanti	Metalli pesanti	Metodo XI.1 - "Metodi ufficiali di analisi chimica del suolo" (D.M. 13 Settembre '99. Metodica EPA 6010C/2000

### Historical analysis (Arborea NVZ – ARPAS 2018)

2017-2018 soils samples shows pH values range 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.