AQUIFER PROJECT: "Innovative instruments for an integrated management of groundwater in a context of an increasing scarcity of hydrological resources"

Deliverable 1.4.3

Available data and their interpretation.

An assessment of the regulations related to pollution shall also be provided.

1. INDEX

2. INTRODUCTION

Groundwater bodies are increasingly being used to obtain quality water, either for agricultural and livestock activities or to produce drinking water. With the increasing consumption of water from aquifers, it is important to have as much knowledge as possible about them.

The need for more information on aquifers, their monitoring networks and sustainable management led to the creation of the Aquifer project. The Aquifer project aims to "capitalize on, test, disseminate and transfer innovative practices for the preservation, monitoring and integrated management of aquifers, to assist them in making decisions regarding the management of groundwater resources, improve technology transfer to local actors, create new synergies and develop common tools in a context of scarce water resources and environmental threats."

What sets this project apart from others is the fact that it studies both the water quality and the water quantity existing in groundwater bodies, through the study of aquifer recharge management and the use of monitoring network and hydrological modeling. Another point to highlight is the creation of a website open to the public that helps decision making on good agricultural practices that prevent the degradation of aquifers and increase their water quality and quantity.

To make this project as complete as possible, several national and international entities joined forces: Centro Nacional do Instituto Geológico e Mineiro de Espanha (IGME), Instituto Superior de Agronomia da Universidade de Lisboa (ISA-UL), AR - ÁGUAS DO RIBATEJO, E.I.M., S.A., Comunitat d'Usuaris d'Aigües del Delta del Llobregat (CUADLL), Aqua-Valley, Serviço Nacional de Geologia, BRGM, Parceria Portuguesa para a Água (PPA), Catalan Water Partnership (CWP) and Comunidade de Regantes do Campo de Cartagena (CRCC)

In order for each entity to give its best contribution, different groups of activities were created, and later distributed among the different partners. The first group of activities aims to obtain a pilot aquifer monitoring network and a hydrogeological database. The second group is focused on hydrogeological modeling, aquifer recharge and on defining innovative solutions for water resources management. The third group is responsible for creating a decision support network for groundwater management and for exploring the limitations and difficulties of combined use. Finally, the last group defines innovative practices for aquifer management in situations of scarcity and to create a transnational website with all this information available.

This activity belongs to the first group of activities. The main objective is proving that crop production in agricultural field respects the legally binding measures, having into consideration the environmental impact of this activity.

3. LEGALLY BINDING MEASURES

The legally binding measures that the farmer is obligated to follow are the ones associated with irrigation management and inorganic fertilization.

3.1. Irrigation management

- Irrigation allocation: The volume of water used during irrigation should be stipulated considering the needs of the crop and soil characteristics, such as "water retention capacity, its degree of humidity at the time of irrigation and the thickness of layer to be moistened". (Ministério da Agricultura, Despacho nº. 1230/2018, 2018)
- Uniform application of irrigation water: irrigation water should be applied uniformly in order to avoid areas of excess water that may lead to surface runoff or "deep seepage movements". "Sprinkler irrigation, drip irrigation or coveting" should be used in sloping areas reducing surface runoff. (Ministério da Agricultura, Despacho nº. 1230/2018, 2018)
- Make irrigations before the plants reach water shortage, this way the plant will absorb more water and nutrients reducing residual nitrogen and phosphorus. (Ministério da Agricultura, Despacho nº. 1230/2018, 2018)
- Estimate crop irrigation needs: Estimating irrigation needs and considering weather forecasts and phenological state of the crop, leads to a reduction of water consumption and loss of water and nutrients, both by infiltration and runoff. (Ministério da Agricultura, Despacho nº 1230/2018, 2018)

Irrigation management adapted to each soil type.

- "Adopt the most appropriate irrigation method": the irrigation method should be chosen based on local characteristics: soil, land topography, land area, water quality and abundance, crop requirements and local climatic conditions. There are some measures adapted to different soil types:

- "On soils with high permeability and in all areas of high or moderate risk of losses of nitrates, phosphate ions and/or soluble organic phosphorus compounds", gravity irrigation methods should not be used as water losses by leaching are high. Sprinkler irrigation or localized irrigation is recommended.
- In medium-textured soils (loamy and silty-loamy), there is no limitation regarding the type of irrigation, if it is done in a timely manner, with the right amount of water and in a homogeneous way.
- When dealing with fine-textured soils, in low-risk areas, any irrigation system can be used if measures are taken to reduce soil compaction, as these soils are "endowed with poor permeability, low infiltration rates and high retention capacity for water" (Ministério da Agricultura, Despacho nº. 1230/2018, 2018)

3.2. Method of application of inorganic fertilizers

- "Apply nitrogen and phosphorus at the most appropriate times and in the most appropriate forms and in quantities according to the expected production": The amount of fertilizer to apply must be estimated based on the expected production of the crop, the availability of irrigation water and the specific needs of the crop, so that excesses of nitrogen and phosphorus are avoided and washed into water bodies. (Ministério da Agricultura, Despacho nº. 1230/2018, 2018)
- In forage crops, it is not allowed to apply "manure, sargasso, guano, sludge and composts, slurries and nitrogenous chemical fertilizers between 1 November and 1 February". (DGADR, 2018)
- No fertilizer application is allowed after the harvest of spring-summer crops (Ministério da Agricultura, 2012)
- The application to the soil of fertilizers, during the vegetative cycle, is not permitted when the soil is in a situation of excess water, the indicated thing being to wait for it to normalize the water content in the soil (Ministério da Agricultura, 2012)
- For the application of fertilizers in places near water bodies, it is necessary to respect the minimum safety distances from the river or stream bed, as referred to in the Decree-Law. (Ministério da Agricultura, 2012)

- For the application of fertilizers in locations near groundwater abstractions, it is necessary to respect the minimum safety distances from the abstraction, as referred to in the Decree-Law. (Ministério da Agricultura, 2012)
- A fertilization plan must be carried out based on soil and irrigation water analysis, leaf analysis and expected yield. (Ministério da Agricultura, 2012)
- Farms must perform soil and irrigation water analysis to determine: the concentration of nitrogen, phosphorus, potassium and magnesium in the soil, the soil pH and the nitrate content in irrigation water. These analyses must be done annually (Ministério da Agricultura, 2012).
- The amount of nitrogen to apply to the crop should be calculated in advance based on the analyses carried out and the needs of the crop. (Ministério da Agricultura, 2012)
- The mode of application of the fertilizer must allow maximum uptake of the nutrients in the fertilizer and the fertilizer must be applied as uniformly as possible. (Ministério da Agricultura, 2012)

4. MEASURES USED BY THE FARMERS

In Portugal, most of the farmers are worried about the environmental impact of the crops and try to keep updated about the new technology. The main goal is to keep the costs, the production yield, and the environmental impact balanced. The two main aspects that the farmers try to turn more efficient is the irrigation and the fertilization, which in turn means reducing costs without reducing the crop yield, therefore making them more attractive for the owner.

In the agricultural farm where the field experiments were set, the farmer used a circular pivot to irrigate all the maize field, using this method for both irrigation and fertilizing purposes (fertirrigation). The circular pivot is one of the best irrigation systems when it comes to guaranteeing a uniform application of the water along the agricultural field.

The amount of water used for irrigation wasn't always the same as farmer would take in consideration different factors. The main one being the weather and particularly the existence of rain and it's amount. To complement the weather information, the farmer installed a humidity probe on the maize field. This humidity probe would give the exact amount of water that existed in the soil at that exact time. This information guaranteed that the right amount of water is used for irrigation and was applied in a uniform way.

Fertilizing was done via the watering system (fertirrigation) and the owner chooses to do it according to the crop growing stage, with some days between each fertilization. This method is good because the plants always have nutrients available, but the amount of nutrients leached is smaller, as observed in the experiments. All the fertilizer was applied in the first stages of plant growth as it is when the nutrients are most needed. By supplying the nutrients on the right time, they are more likely to be absorbed by the crop and therefore avoiding the leaching of nutrients to the groundwater bodies.

All these measures reduce the amount of nutrients going to the groundwater and reduces the environmental footprint of this crop's production.

5. RESULTS FROM THE FIELD ACTIVITY

To prove that the methods chosen by the owner were a good choice and their effectiveness , we did two field activities. The first one was conducted between 15 June 2021 and 14 September 2021 and the second one between 6 of June of 2022 to 29 of august of 2022. During these field activities we installed nitrogen probes that collected data the entire time. To double check the values we collected soil samples regularly.

5.1. Soil samples

During the field activity a soil sample was collected at each site on each visit.

Samples collected in the first year

		Probe 1		Probe 2	
ID	Date	NO_3^-	NH_4^+	NO_3^-	NH_4^+
M1	15/6/21	56,3	17,8	67,1	28,3
M4	22/6/21	82,5	217	33,6	144
M7	29/6/21	122	88	127	95,4
M10	7/7/21	24,9	16,7	30,6	13,3
M13	13/7/21	48,7	76,2	49,8	44,6
M16	22/7/21	109	241	91,4	29,9
M19	27/7/21	50	27,6	24,2	19,8
M22	5/8/21	29,8	10	23,2	10
M25	12/8/21	131	26,9	80,5	39,1
M28	31/8/21	68,5	12,3	16,2	10
M31	17/9/21	12,1	10	121	10

TABLE 1: SOIL SAMPLES COLLECTED FROM JUNE OF 2021 TO SEPTEMBER OF 2021

Samples collected in the second year

Samples from sandy soil at 20cm depth (9007)							
		mg/kg N-NH_4		mg/kg N-NO_3		Average	
ID	Date	NH_4 Con. 1	NH_4 Con. 2	NO_3 Con. 1	NO_3 Con. 2	Average_NH_4	Average_NO_3
N_Ag_20_2	27/06/2022	10,35	10,3	45,75	44,55	10,325	45,15
N_Ag_20_3	18/07/2022	11,1	11,7	25,7	25,05	11,4	25,375
N_Ag_20_4	01/08/2022	11,8	11,75	41,35	41,75	11,775	41,55
N_Ag_20_5	15/08/2022	6,7	6,7	23,5	23,7	6,7	23,6
N_Ag_20_6	29/08/2022	8,1	8,3	44,3	45,3	8,2	44,8

TABLE 2: SANDY SOIL SAMPLES COLLECTED AT 20CM FROM JUNE OF 2022 TO AUGUST OF 2022

Samples from sandy soil at 60cm depth (9007)							
		mg/kg N- NH_4		mg/kg N- NO_3		Average	
ID	Date	NH_4 Con. 1	NH_4 Con. 2	NO_3 Con. 1	NO_3 Con. 2	Average_NH_4	Average_NO_3
N_Ag_60_2	27/06/2022	9,45	9,4	29,7	29,3	9,425	29,5
N_Ag_60_3	18/07/2022	11	10,85	25,7	25,2	10,925	25,45
N_Ag_60_4	01/08/2022	8,5	8,6	27,05	26,45	8,55	26,75
N_Ag_60_5	15/08/2022	8,8	8,9	6,4	7,1	8,85	6,75
N_Ag_60_6	29/08/2022	7,6	7,4	29,1	26,2	7,5	27,65

TABLE 3: SANDY SOIL SAMPLES COLLECTED AT 60CM FROM JUNE OF 2022 TO AUGUST OF 2022

Samples from clay soil at 20cm depth (9008)							
		mg/kg N- NH_4		mg/kg N- NO_3		Average	
ID	Date	NH_4 Con. 1	NH_4 Con. 2	NO_3 Con. 1	NO_3 Con. 2	Average_NH_4	Average_NO_3
N_Ar_20_2	27/06/2022	14,95	14,55	61,5	60,85	14,75	61,175
N_Ar_20_3	18/07/2022	15,6	15,85	96,55	98,65	15,725	97,6
N_Ar_20_4	01/08/2022	14,95	14,7	79	78,5	14,825	78,75
N_Ar_20_5	15/08/2022	13	12,5	130,5	125,4	12,75	127,95
N_Ar_20_6	29/08/2022	7,5	7,9	32,9	30,1	7,7	31,5

TABLE 4: CLAY SOIL SAMPLES COLLECTED AT 20CM FROM JUNE OF 2022 TO AUGUST OF 2022

Samples from clay soil at 60cm depth (9008)							
		mg/kg N- NH_4		mg/kg N- NO_3		Average	
ID	Date	NH_4 Con. 1	NH_4 Con. 2	NO_3 Con. 1	NO_3 Con. 2	Average_NH_4	Average_NO_3
N_Ar_60_2	27/06/2022	18,55	18,85	39,75	41,35	18,7	40,55
N_Ar_60_3	18/07/2022	9,95	10,05	36,65	37,9	10	37,275
N_Ar_60_4	01/08/2022	7,7	7,7	8,65	13,85	7,7	11,25
N_Ar_60_5	15/08/2022	7,8	7,6	9,8	10,3	7,7	10,05
N_Ar_60_6	29/08/2022	8	7,6	8,3	8,1	7,8	8,2

TABLE 5: SAMPLES FROM COLLECTED AT 60CM FROM JUNE OF 2022 TO AUGUST OF 2022

5.2. Nitrogen probes

The nitrate probe collected data continuously during the field activity periods.

Data from the first year

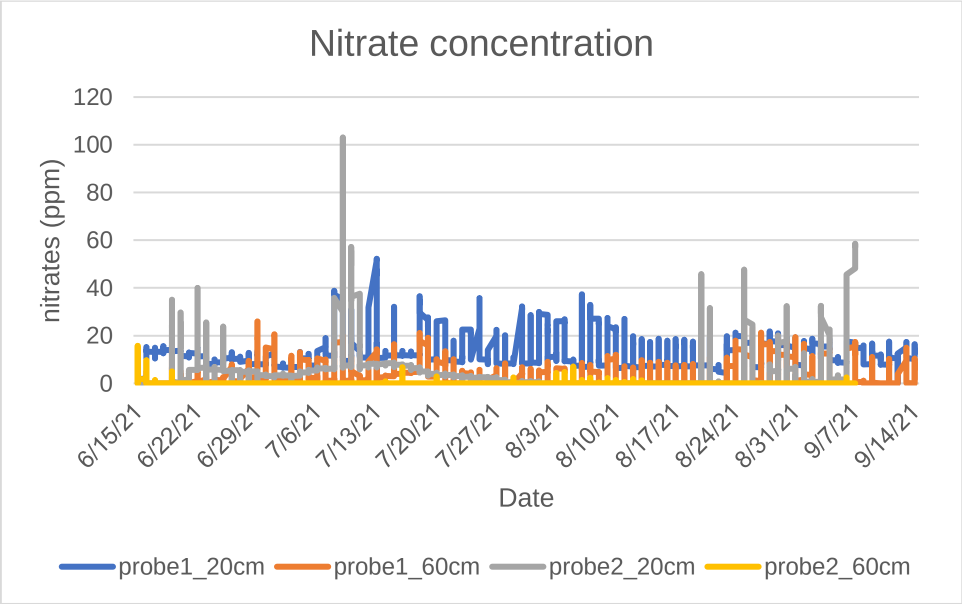

FIGURE 1: DATA OBTAINED BY THE NITROGEN PROBE IN 2021

When looking at figure 1, you can see that the amount of nitrogen in the 20 cm layer is a lot bigger than the amount in the 60 cm. Many reasons can cause this, but the more likely ones are the fact of the 20 cm are closed to the surface so it receives the nitrogen from fertirrigation first. The second cause is the fact that the 20 cm layer is the place for all the plants roots, so they absorb most of the nutrients, which reduces the amount of nutrients below.

Data from the second year

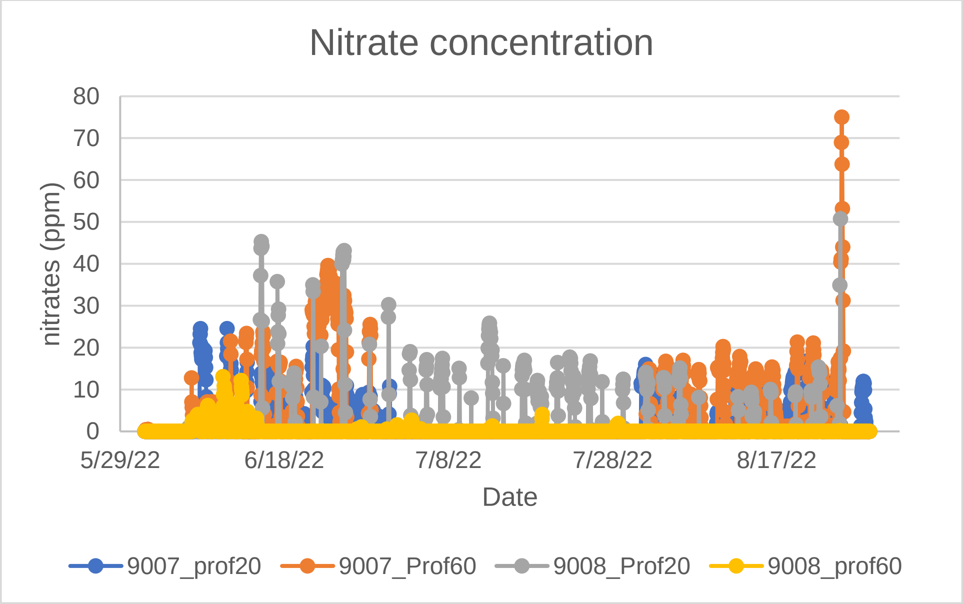

FIGURE 2: DATA OBTAINED BY THE NITROGEN PROBE IN 2022

In Figure 2, we noticed that the type of soil has a big influence on the variation of nitrates in the different soil layers. In a sandy soil (probe 9007), the amount of nitrogen at 60 cm is a lot bigger than the amount at 20 cm, which means that a big part of the nitrogen just went away with the water. In the opposite, with the clay soil (probe 9008), the biggest amount of nitrogen is at 20cm, so this nitrogen will be available for the plants for a longer period of time.

5.3. Relation between the nitrogen probes and the soil samples

From June of 2021 to September of 2021

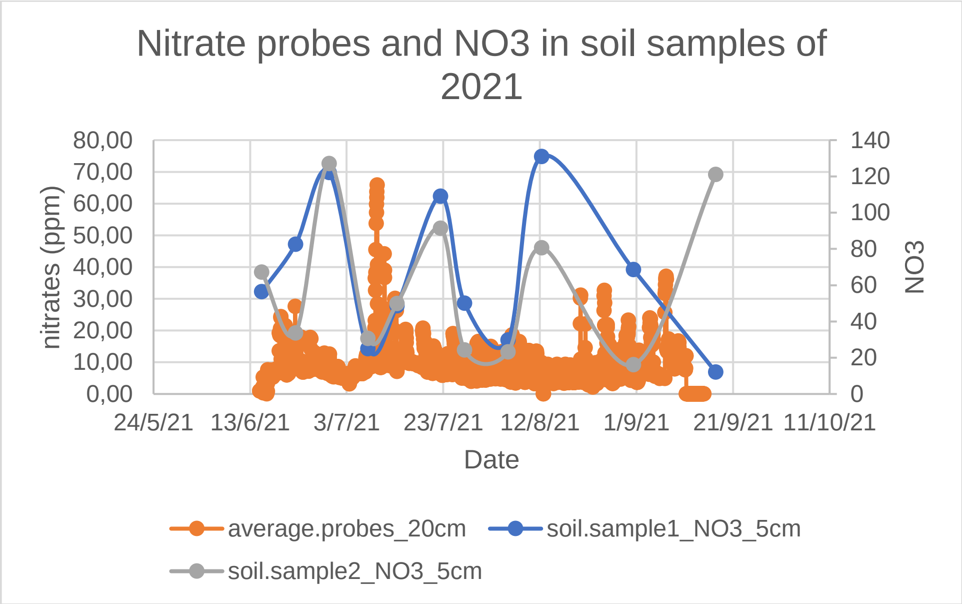

FIGURE 3: RELATION BETWEEN NITRATE PROBES AND NO_3^- IN SOIL SAMPLES IN 2021

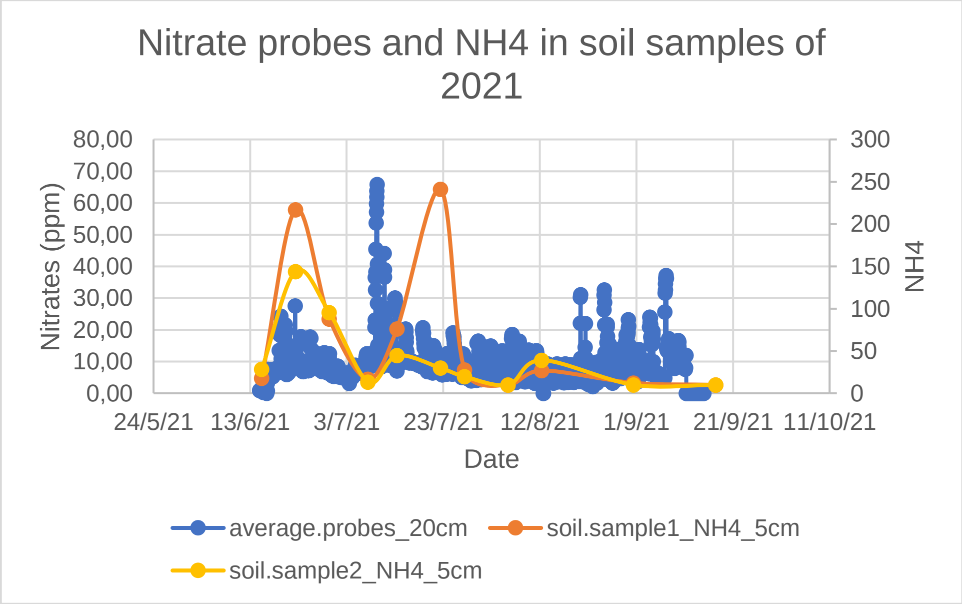

FIGURE 4: RELATION BETWEEN NITRATE PROBES AND NH_4^+ IN SOIL SAMPLES IN 2021

The soil samples from 2021, presented in figures 3 and 4, were collected at the surface and the probes were installed at 20 cm depth. This means that the data coming from the probes and the data from the soil samples have very different results. With that information is possible to have as idea how much nitrogen the plants absorb and how much nitrogen goes dipper into the soil.

From June of 2022 to august of 2022

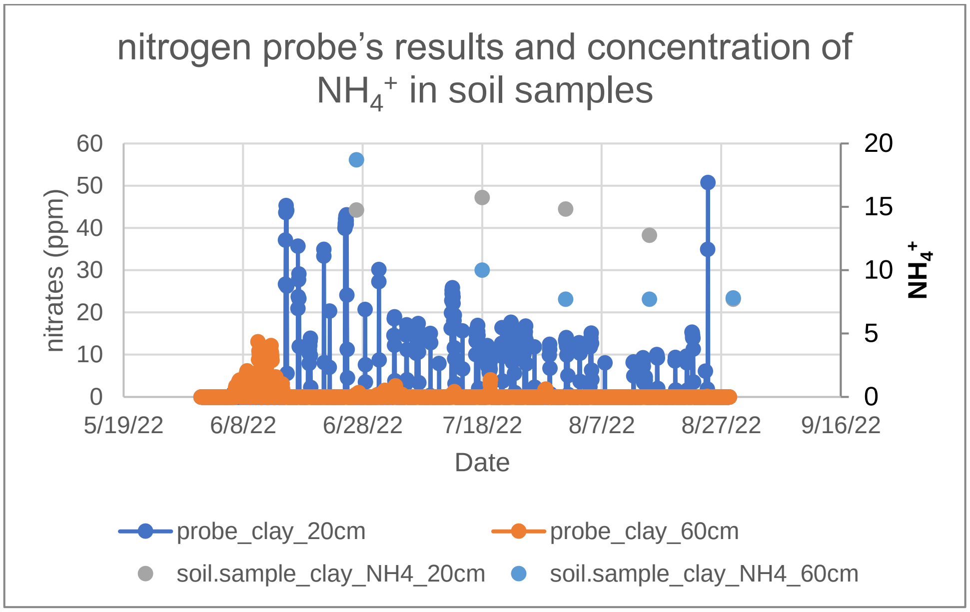

FIGURE 5: RELATION BETWEEN NITRATE PROBES AND NH_4^+ IN CLAY SOIL SAMPLES IN 2022

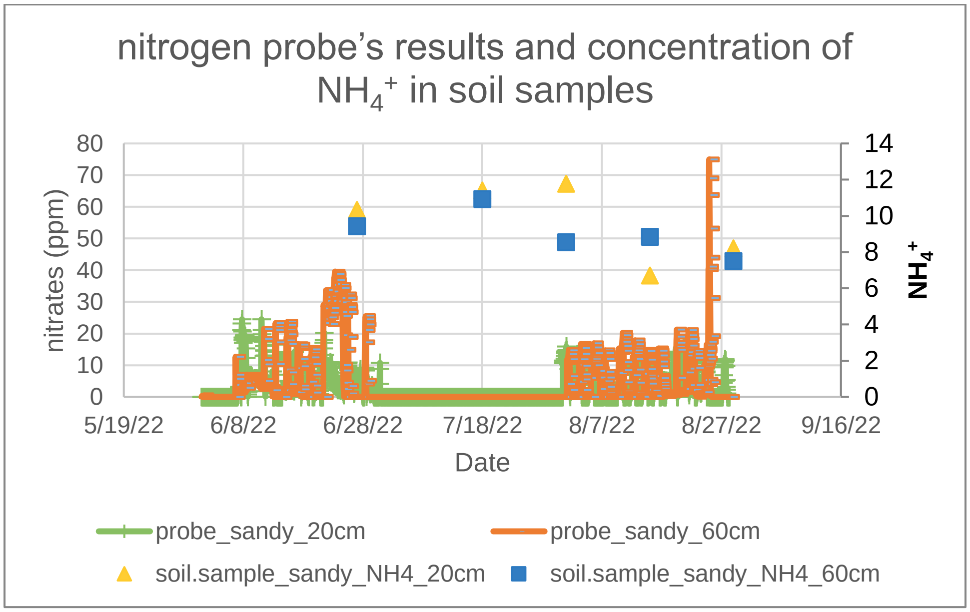

FIGURE 6: RELATION BETWEEN NITRATE PROBES AND NH_4^+ IN SANDY SOIL SAMPLES IN 2022

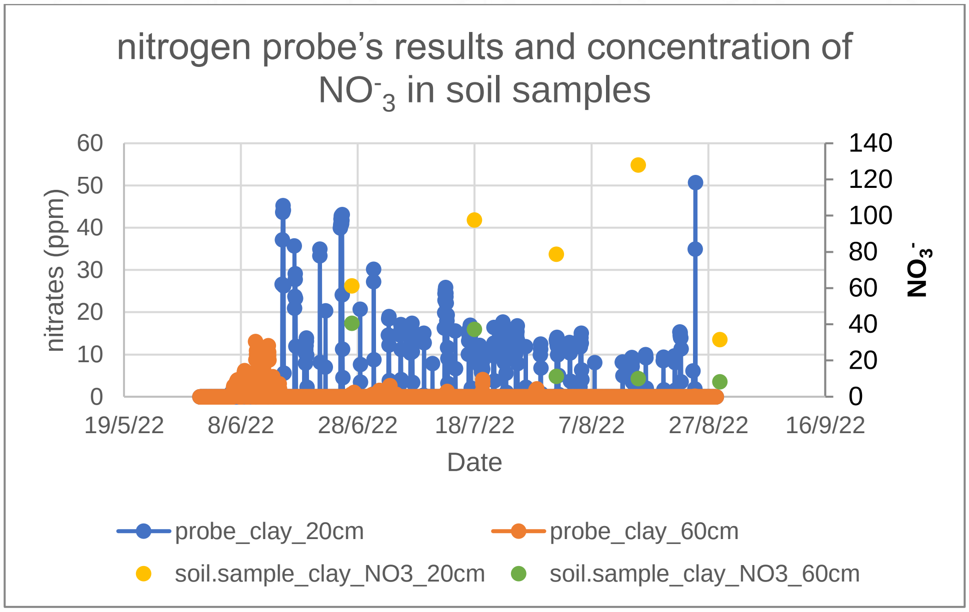

FIGURE 7: RELATION BETWEEN NITRATE PROBES AND NO_3^- IN CLAY SOIL SAMPLES IN 2022

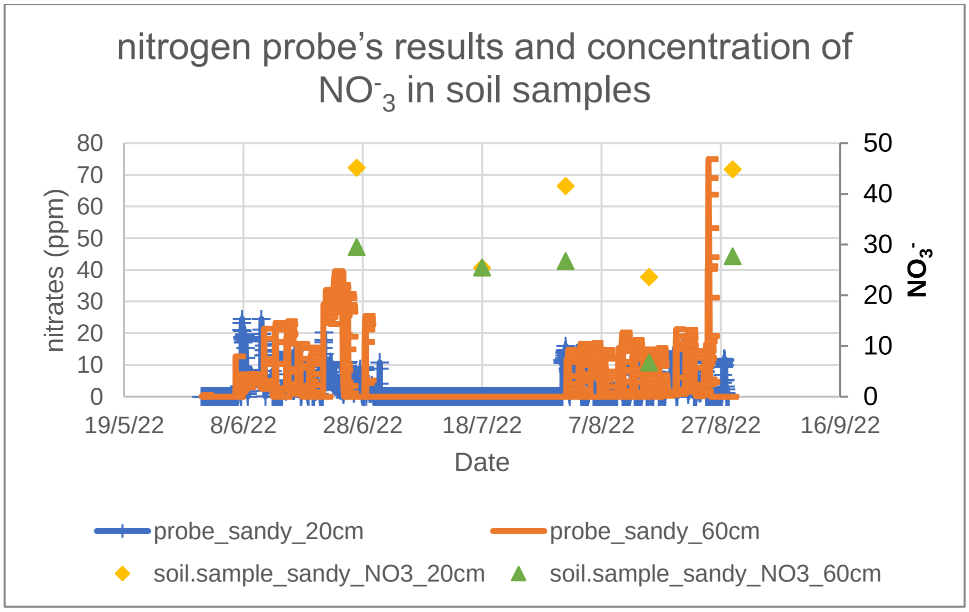

FIGURE 8: RELATION BETWEEN NITRATE PROBES AND NO_3^- IN SANDY SOIL SAMPLES IN 2022

The soil samples from 2022, presented in figures 5,6,7 and 8, were collected at the same depth that the nitrogen probes were installed. With this information we can confirm that the data provided by the probes is correct. Looking at the figures you can see that the pattern from the soil samples and a very similar pattern from the nitrogen probes.

6. CONCLUSION

On any producer's perspective the main goal is attaining profit out of his crop and that means balancing production yield and it's costs. In this type of agriculture the measures involving efficient irrigation and fertilization are more attractive to the farmer because they lead to a cut in costs while still maintaining the same production.

Effectively increasing the efficiency of the watering allows the farmer to improve his profits by reducing the costs while at the same time reducing the impacts on the groundwater bodies.

This farmer used a circular pivot for irrigation and fertilizing and improved upon it by using more measures that increase the efficiency of the system. This measures are based on the use of the necessary amount of water and fertilizer and in the right time.

We concluded from the results, that the amount of nitrogen leached was low, which means that the correct amount of fertilizer was used as the plants absorbed the most of it.

With all the information obtained from the farmer and collected from the field activity, we can prove that all the measures he adopted were effective and successful in terms of reducing the environmental impact.

However the fact that the environmental impact was reduced doesn't mean that the impact was null, so even though the amount of nitrates going to the ground water is low, they should be taken in to account and there is still room for improvement.