Study for the Evaluation of Rural Development Program (RDP) contribution to Water Use Management and Efficiency in Greece

EXTENDED ABSTRACT

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9th COMMON EVALUATION QUESTION (CEQ 9)

To what extent have RDP interventions supported the improvement of water management, including fertilizers and pesticides management (4B)?

The response to this common question is based on the net contribution of the measures related to the impact Indicator I.11 “Water quality”. The Indicator I.11 is complex and consist of the following two sub-indicators:

Indicator I.11 Water quality

1) Gross Nutrient Balance:

1.a) Gross Nitrogen Balance (GNB-N): Gross Nitrogen Surplus

1.b) Gross Phosphorus Balance (GNB-P): Gross Phosphorus Surplus

2) Nitrates in freshwater:

2.a) Quality of surface water: % of monitoring positions belonging to three quality classes (high, moderate, bad).

2.b) Quality of ground water: % of monitoring positions belonging to three quality classes (high, moderate, bad).

Both aforementioned sub-indicators relate to nutrient inputs management in farms and mainly to fertilizers management.

METHODOLOGICAL APPROACH – DATA RESOURCES - RESULTS

1) Gross Nutrient Balance

The estimation of gross nutrient balance was based on the relevant Eurostat calculation guide: Eurostat (2013) - Nutrient Budgets – Methodology and Handbook (Version 1.02. Eurostat and OECD, Luxembourg).

Taken into account both the instructions of the abovementioned guide and the available data, the main inputs and outputs as well as the corresponding utilized agricultural area for the years 2015 and 2018 were used to calculate gross nutrient balance and consequently gross nitrogen and phosphorus surplus. inorganic fertilizers, manure production and biological N fixation were used as inputs, while crop and fodder production were used as outputs

The gross nitrogen and phosphorus surplus in Kg/ha of utilized agricultural area, for the years 2015 and 2018, are presented in Figure 1. Results showed a clear decrease of the gross nitrogen surplus between 2015 and 2018, while the gross phosphorus surplus remained practically unchanged in this time period.

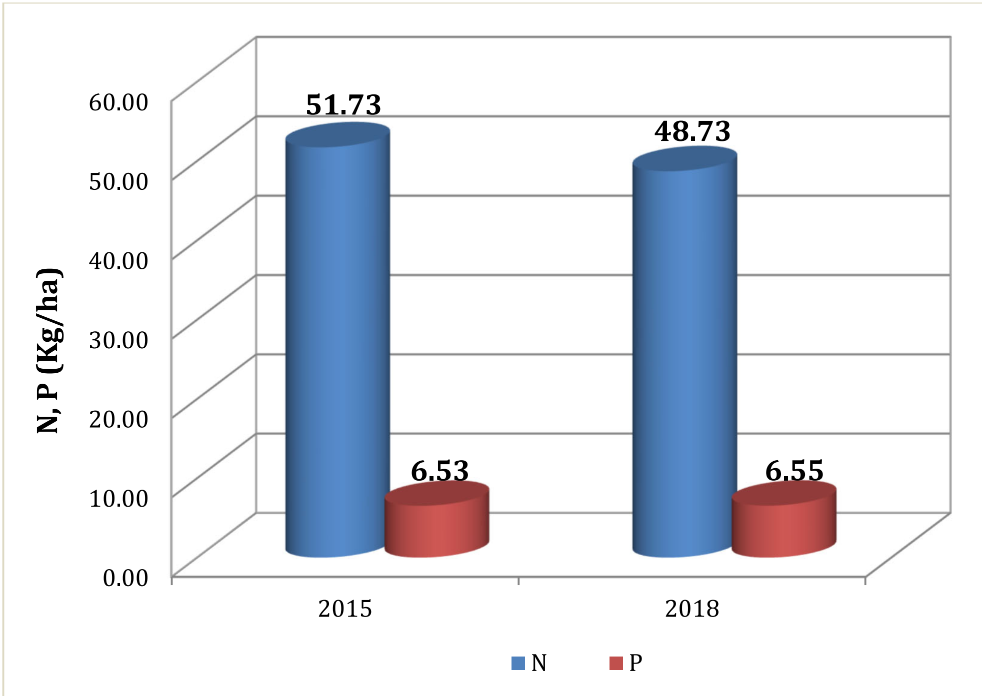


Figure 1. Gross nitrogen (N) and phosphorus (P) surplus for the years 2015 and 2018 in Kg/ha utilized agricultural area.

2) Nitrates in freshwater

The data of the National Water Monitoring Network of the Ministry of Environment and Energy were used to evaluate nitrate concentrations in surface and ground water for 2018. The year 2015 was used as reference year to estimate the contribution of the Rural Development Program on nitrate pollution since the national network had complete data for this year to draw qualitative and quantitative conclusions.

☞ **Surface water**

Comparative results of surface water nitrogen content for the years 2015 and 2018, in high, moderate and bad water quality, as well as the change in concentrations between 2015 and 2018 are presented in Table 1 and Figure 2.

Table 1. Comparative results of surface water nitrogen content for the years 2015 and 2018.

SURFACE WATER - QUALITY - NITROGEN (%)								
2015			**2018**			**Change 2015-2018**		
High	**Moderate**	**Bad**	**High**	**Moderate**	**Bad**	**High**	**Moderate**	**Bad**
84.05	12.58	3.37	84.58	13.55	1.87	**0.53**	**0.97**	**-1.50**

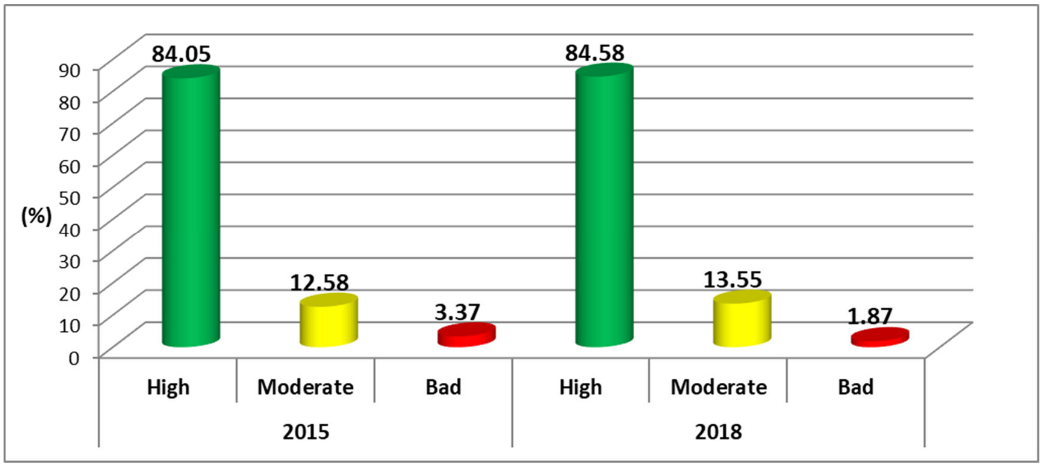


Figure 2. Distribution of surface water nitrogen concentrations percentages in high, moderate and bad water quality for the years 2015 and 2018.

☞ **Ground water**

Comparative results of ground water nitrates content for the years 2015 and 2018, in high, moderate and bad water quality, as well as the change in concentrations between 2015 and 2018 are presented in Table 2 and Figure 3.

Table 2. Comparative results of ground water nitrates content for the years 2015 and 2018.

GROUND WATER QUALITY NITRATES (%)								
2015			**2018**			**Change 2015-2018**		
High	**Moderate**	**Bad**	**High**	**Moderate**	**Bad**	**High**	**Moderate**	**Bad**
65.32	17.76	16.92	70.21	14.69	15.1	**4.89**	**-3.07**	**-1.82**

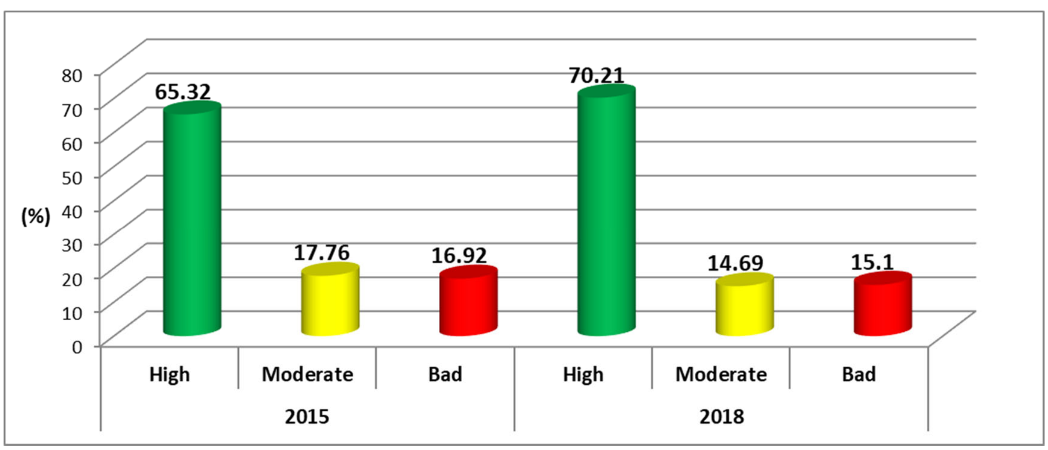


Figure 3. Distribution of ground water nitrate concentrations percentages in high, moderate and bad water quality for the years 2015 and 2018.

RESPONSE TO THE COMMON EVALUATION QUESTION 9

The study of Indicator 1.a showed that the gross Nitrogen surplus decreased between 2015 and 2018. This decrease can be attributed to the fact that inputs remained at the same levels between 2015 and 2018, while outputs increased for the same time period. The increase of outputs is mainly due to the increase of fodder crops and especially legumes for hay. This increase is a result of both the corresponding voluntary coupled support and the demands of the Action 10.1.4 “REDUCTION OF WATER POLLUTION FROM AGRICULTURAL ACTIVITY”

On the other hand, the study of Indicator 1.b showed that the gross Phosphorus surplus remained practically unchanged between 2015 and 2018.

The Indicator 2.a “Quality of surface water: % of monitoring positions belonging to three quality classes” showed no significant change in 2018 compared to 2015. There was a slight increase (0.53%) in the percentage of high and moderate quality positions and a decrease in the percentage of bad quality positions. With regard to the Indicator 2.b “Quality of ground water: % of monitoring positions belonging to three quality classes”, a moderate (4.89%) increase in high quality positions and a corresponding decrease in moderate and bad quality positions were observed.

In order to analyze the contribution of RDP interventions on the change of these indicators, measures/actions which may have a direct or indirect impact on water quality were investigated and the Action 10.1.4 “REDUCTION OF WATER POLLUTION FROM AGRICULTURAL ACTIVITY" was identified.

Subsequently, the parcels participating in the Action 10.1.4 in 2018 were identified and an analysis of the correlation between the indicators values and the percentages of cultivated areas participating in this Action in individual regions was made. These individual regions, in the case of surface water, consist of the sub-basins that make up the river basins of Greece (Ministry of Productive Reconstruction, Environment and Energy https://geodata.gov.gr/dataset/upolekanes-hydroscope-gr), and in the case of ground water, they consist the main aquifers of Greece (Ministry of Productive Reconstruction, Environment and Energy https://geodata.gov.gr/dataset/upogeia-udata).

To carry out the analysis, the polygons of the sub-basins and aquifers were spatially joined to both the sampling positions and the Integrated Administration and Control System (IACS) parcels. Further analysis of these data led to the estimation of: a) the average value of the surface and ground water quality for each sub-basin and aquifer, respectively; b) the values of the indicators 2.a and 2.b for each sub-basin and aquifer, respectively, as well as c) the parcels and their areas in each sub-basin and aquifer both totally and those participating in the Action 10.1.4 (Figures 4 and 5).

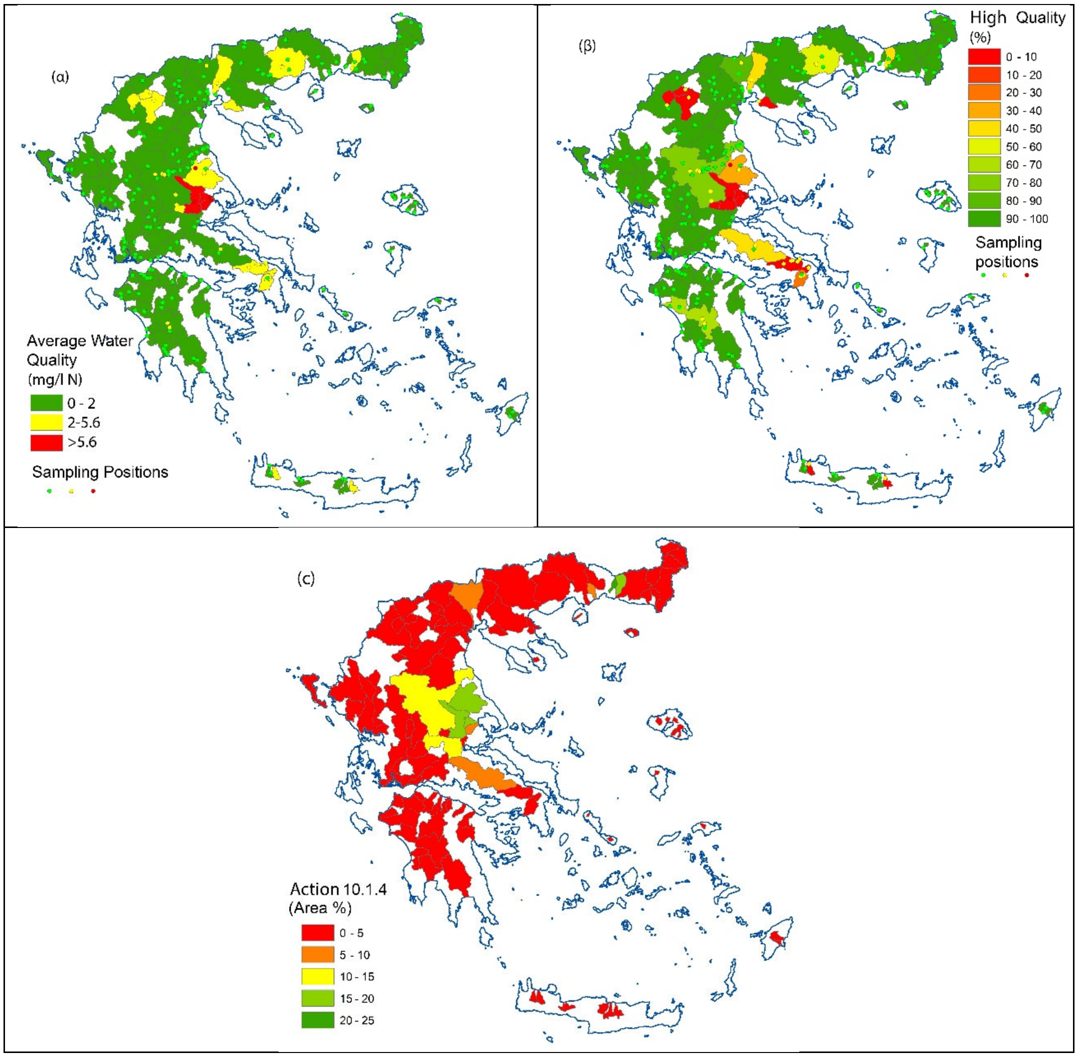


Figure 4. Average value of surface water quality (a), percentage of high quality sampling positions (b), and percentage of cultivated areas participating in the Action 10.1.4 (c) for each sub-basin.

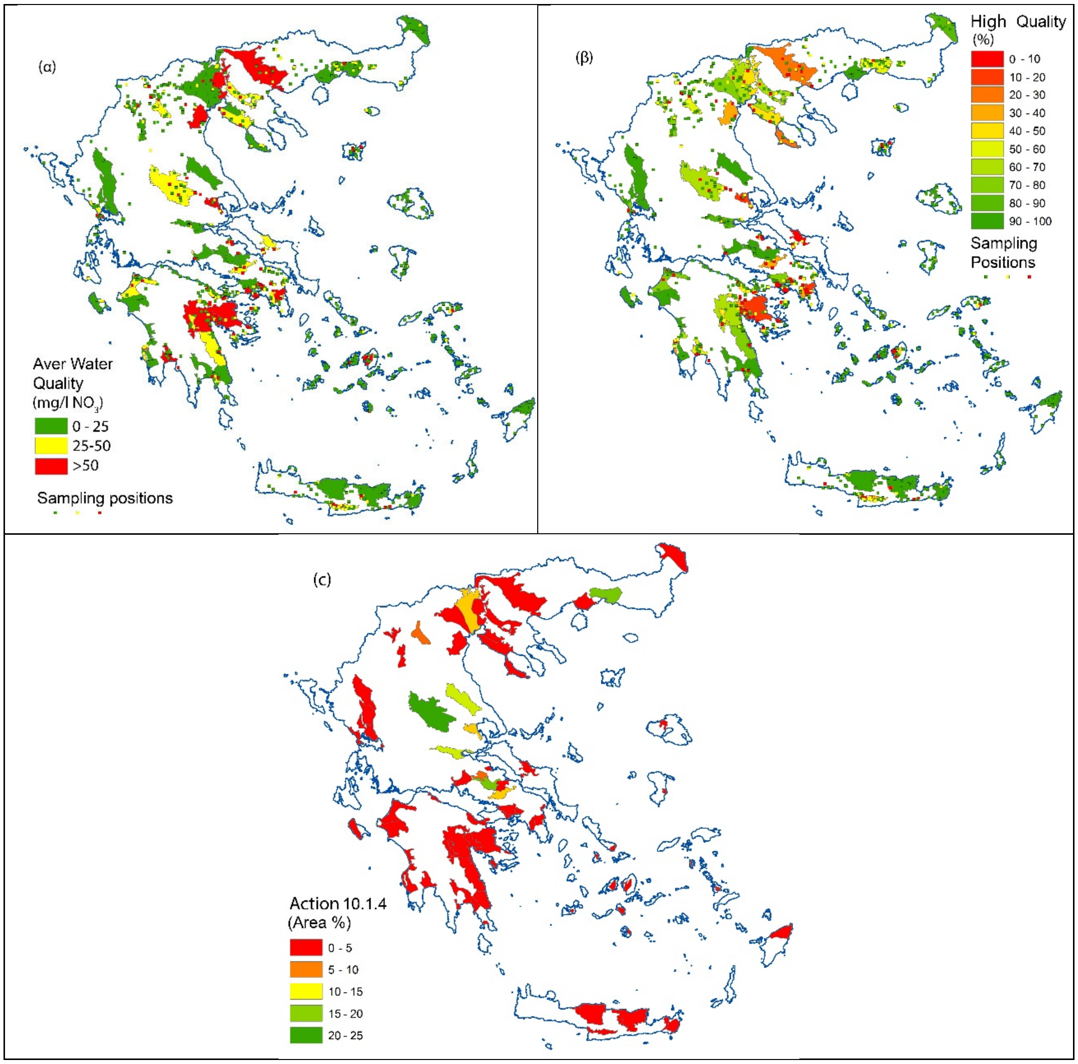
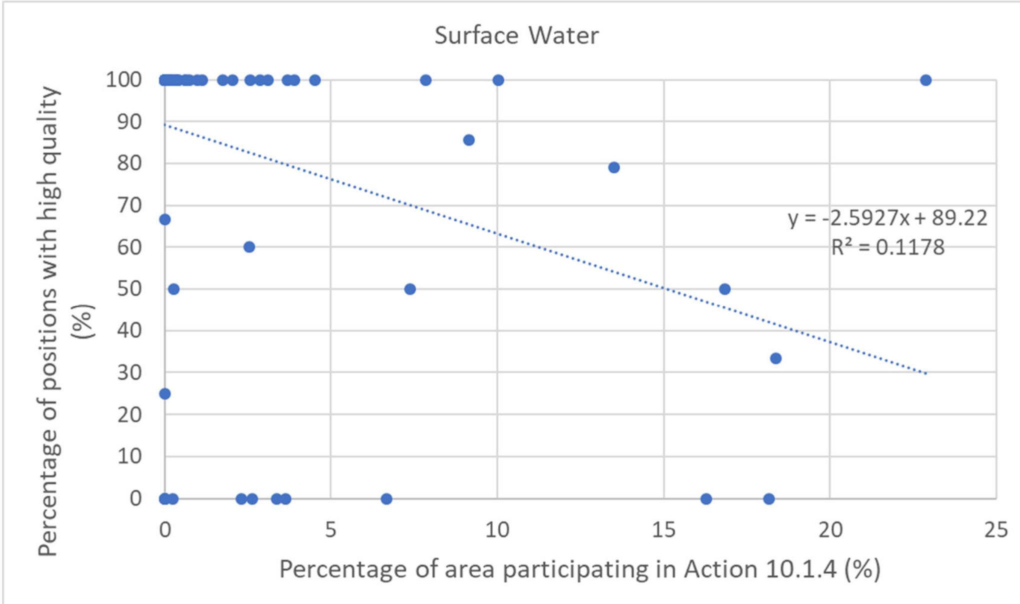


Figure 5. Average value of ground water quality (a), percentage of high quality sampling positions (b), and percentage of cultivated areas participating in the Action 10.1.4 (c) for each aquifer.

Based on these results for surface and ground water, possible correlations among the percentage of cultivated areas participating in the Action 10.1.4, the average water quality and the percentage of high quality sampling positions were investigated. The results were presented in Figures 6 and 7.



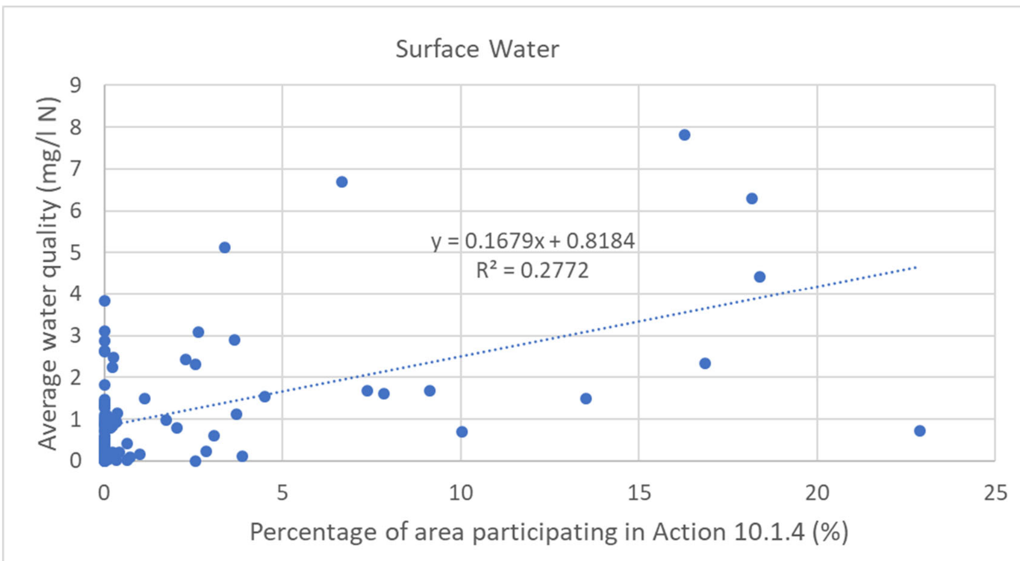
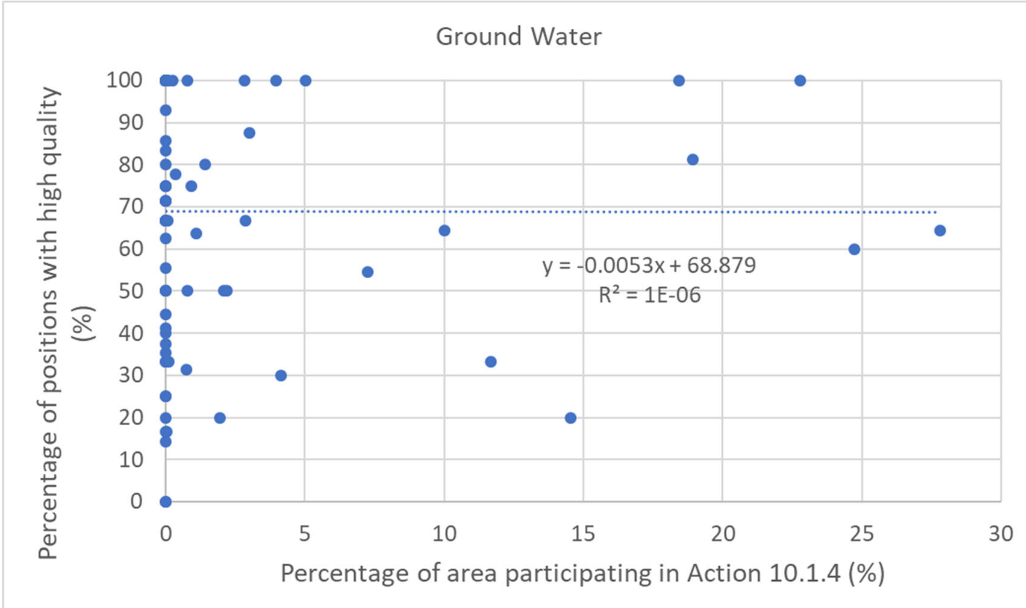


Figure 6. Correlations among the percentage of cultivated areas participating in the Action 10.1.4, the average value of water quality and the percentage of high quality sampling positions for surface water.



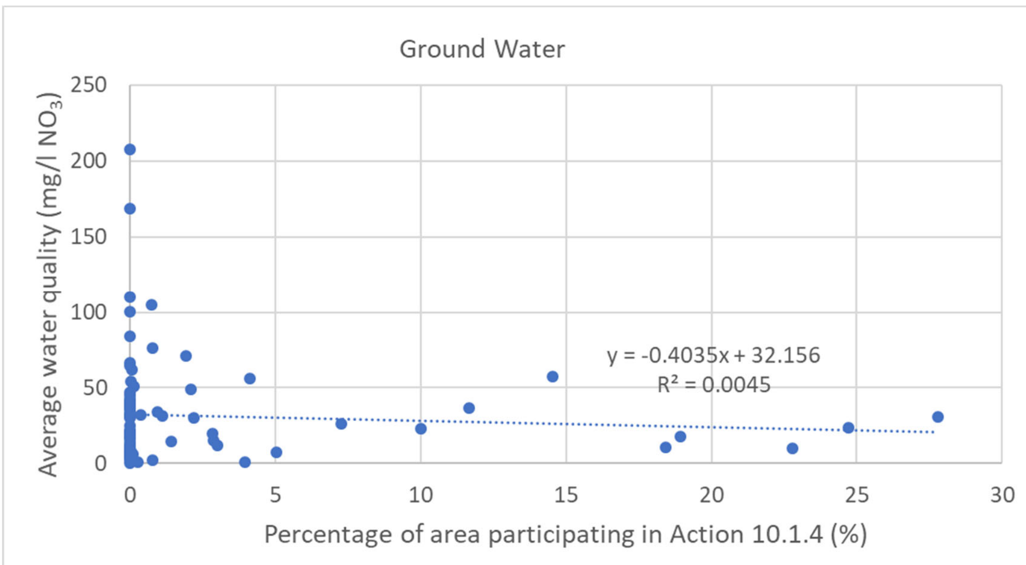


Figure 7. Correlations among the percentage of cultivated areas participating in the Action 10.1.4, the average value of water quality and the percentage of high quality sampling positions for ground water.

As shown in Figures 6 and 7, there is a very weak correlation between the average value of surface water quality and the percentage of cultivated areas participating in the Action 10.1.4. Even weaker correlation appears to be in the percentage of high quality sampling positions. These results may be due to the fact that where there is low quality there is a predominantly participation in the Action 10.1.4. As regards to ground water, there is no obvious correlation. This may be due to the long time needed by the system to respond to crop changes, but also due to sampling positions are likely to be in different layers (surface aquifers, deeper aquifers, etc.). In order to investigate in deep the contribution of the RDP interventions, a detailed and systematic analysis in targeted study areas is suggested.

Also, the analysis of crop distribution in the parcels participating in the Action 10.1.4 in 2018 but not participating in the corresponding Action in 2015, showed a decrease in the areas cultivated with cotton and an increase in the areas cultivated with legumes. The contribution of this fact to water quality could, under conditions, be positive.

This change in crop distribution had a positive effect on the Indicator 1.a) "gross nitrogen surplus" in agricultural land as has been already presented.

11th COMMON EVALUATION QUESTION (CEQ 11)

To what extent has the RDP contributed to the CAP objective of ensuring sustainable management of natural resources and climate action?

The impact indicator related to water is: I.10 – "Water abstraction in agriculture" and the response to the CEQ is based to the evaluation of the related RDP measures net contribution of in the improvement of the related impact indicator.

Indicator I.10 Water abstraction in agriculture)

The indicator I.10 refers to the volume of water which is applied to soils for irrigation purposes. Data concern water abstraction from total surface and ground water. According to the definition applied in Council Regulation (EC) No 1166/2008 and in Commission Regulation (EC) No 1200/2009 on farm structure surveys and the survey on agricultural production methods, the volume of water used for irrigation per year is defined as the volume of water in cubic metres that has been used for irrigation on the holding during the 12 months prior to the reference date of the survey, regardless of the source (VIII. Irrigation, Annex II of Commission Regulation (EC) No 1200/2009). The estimation may be produced by means of a model (art. 11 of Council Regulation (EC) No 1166/2008). According to the guidelines, the most appropriate data source so far is the Eurostat Survey on Agricultural Production Methods; however, these data are available only for 2010. Furthermore, the original data sources used in many countries are unclear given the lack of related monitoring infrastructure in local water distribution authorities or metering devices in individual farms. The quality of information collected is expected to improve in the future. Though, at this moment, the use of models estimating the volume of water used in agriculture on the basis of farm structure survey data, annual crop statistics and meteorological data, seems to be the most suitable methodology fulfilling the evaluation quality criteria, at least in countries facing data scarcity.

In this study, the solution developed for the case of Greece is being presented. Greece, as many other southern EU countries, is characterized by very small farms, very high spatial and temporal variability, and acute data scarcity, which present significant challenges for researchers studying water resources and agricultural policies. To address these challenges a specifically developed modelling approach, which is directly relevant with agricultural water policies evaluation and allows the reliable estimation of common impacts indicators, as well as the net effect of RDP on the indicators' change, was applied. The proposed methodology is using an entirely spatially distributed, continuous hydrological model to provide gridded output of the hydrological balance components, plants water deficit, and irrigation water needs in a daily time step for the entire country. The model operates as an extension of the ESRI ArcGIS to make use of the advanced capabilities of ArcGIS in managing geographical data. The base of this modeling approach is AgroHydroLogos model [1-5].

A significant problem is that even if the model can operate in very fine spatial resolutions, the resolution required for the accurate representation of the typically very small farms would be prohibiting in terms of computational requirements. To overcome this problem, a special algorithm was developed linking each farm's polygon in the spatial database of the Integrated Administration and Control System (IACS) with the nearest grid cell of the model with the same crop and the same conditions. In this way, the developed approach provides very precise information at farm level to facilitate further analysis and the estimation of water abstractions in agriculture considering all the information included in the IACS database (e.g. irrigation system, water source, applied agri-environmental measures). The model was applied for 34 years reference period (1971-2004) using a different setup for each modelled case. Specifically, it was applied using as input the IACS database for the base year (2015) and the evaluated year (2018) correspondingly. In the non-agricultural areas that are not covered by the IACS database, the CORINE land cover was used. In this way, the total water abstractions for each farm were estimated for the crop patterns and cultivation practices existing in 2015 and 2018 for the reference meteorological conditions (1971-2004) and included as information in the IACS database for each case (Fig. 8). The obtained results were then analyzed to estimate the values of the common impact indicators and answer to the common evaluation questions. Summary results of irrigation water requirements and the corresponding water abstraction in agriculture for the years 2015 and 2018 are presented in Greece (Table 3).

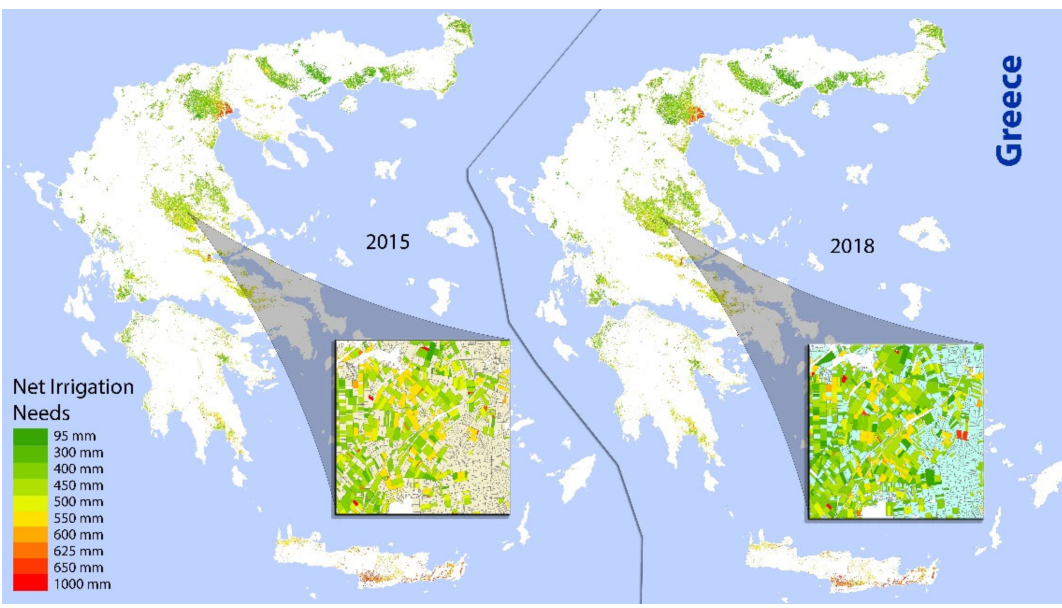


Figure 8. Average net irrigation needs for each farm in 2015 and 2018.

The model is calibrated and validated based on specific case studies (e.g. using data from local water distribution authorities for collective irrigation networks water abstractions and data from farms with metering devices) in order to improve the reliability of the results.

Table 3. Summary results of irrigation water requirements and the corresponding water abstraction in agriculture for the years 2015 and 2018 in Greece.

IACS 2015	Average year (34 years time series 1971-2004)					
	Number of fields	**Area (ha)**	**Net irrigation water needs (hm^3)**	**Needs with transmission losses (hm^3)**	**Total water abstractions (plus irrigation system losses) (hm^3)**	**Specific water abstractions (m^3/ha)**
Non irrigated	4,228,555	6,088,846.88	-	-	-	-
Irrigated	1,756,408	1,117,504.61	4,683.02	5,345.59	6,387.98	5,716.29
IACS 2018	Average year (34 years time series 1971-2004)					
	Number of fields	**Area (ha)**	**Net irrigation water needs (hm^3)**	**Needs with transmission losses (hm^3)**	**Total water abstractions (plus irrigation system losses) (hm^3)**	**Specific water abstractions (m^3/ha)**
Non irrigated	4,201,347	5,262,599.97	-	-	-	-
Irrigated	1,789,624	1,175,612.03	4,866.74	5,551.49	6,634.03	5,643.05
Differences (2018 - 2015)						
Difference	33,216	58,107.42	183.72	205.91	246.06	-73.24
Description	Increased in 2018	Increased in 2018	Increased in 2018	Increased in 2018	Increased in 2018	Decreased in 2018
Percentage	1.89%	5.20%	3.92%	3.85%	3.85%	-1.28%

As can be seen in Table 3, the total water abstractions for irrigation are higher in 2018 due to the increase in the irrigated area. In contrast, the water abstractions per cultivated area hectare are slightly lower in 2018.

Furthermore, these results reveal that the total water abstractions in agriculture are considerably lower than the corresponding estimations presented in Eurostat for the annual water abstractions by source and sector.

(http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en).

Specifically, for the years 2011 to 2015 the total water abstractions in agriculture reported in Eurostat are 8,282.54 hm^3, while with the current methodology were equal to 6,387.98 hm^3 for 2015 and 6,634.03 hm^3 for 2018.

Response to the common evaluation question 11

In order to investigate the quantification of the impact of RDP measures in the improvement of water use efficiency in agriculture, the following approach was followed. Initially, the measures that potentially have a clear direct or indirect impact in the water use efficiency in agriculture. The main measure identified was «10.1.4 Reduction of water pollution from agricultural activity». Following, the fields participating in the measure 10.1.4 in 2018 but were not participated in 2015 to analyze the changes in water use due to the participation in the measure 10.1.4. The results are presented in Table 4.

Table 4. Impact of the measure 10.1.4 in the water use efficiency in agriculture. Fields participating in the measure 10.1.4 in 2018 but were not participated in 2015.

2015							
	Number of fields	**Area (ha)**	**Average irrigation water needs (mm)**	**Net irrigation water needs (hm^3)**	**Needs with transmission losses (hm^3)**	**Total water abstractions (plus irrigation system losses) (hm^3)**	**Specific water abstractions (m^3/ha)**
Non irrigated	**16,500**	**26,126.2**	**-**	**-**	**-**	**-**	**-**
Irrigated	**76,568**	**135,294.7**	**423.0**	**572.679**	**641.864**	**767.027**	**5,669.31**
2018							
	Number of fields	**Area (ha)**	**Average irrigation water needs (mm)**	**Net irrigation water needs (hm^3)**	**Needs with transmission losses (hm^3)**	**Total water abstractions (plus irrigation system losses) (hm^3)**	**Specific water abstractions (m^3/ha)**
Non irrigated	**1,484**	**1,324.2**	**-**	**-**	**-**	**-**	**-**
Irrigated	**94,188**	**141,007.2**	**411.2**	**580.871**	**651.001**	**777.946**	**5,517.07**

As can be seen in the table, the fields participating in the measure 10.1.4 in 2018, but not participating in 2015, have slightly higher total water abstractions (≈10 hm^3) due to the larger irrigated area, though they have slightly lower average irrigation needs depths (≈12 mm) and lower total water abstractions per hectare (≈152 m^3/ha) or 2.7%.

As regards the comparison of the cultivation patterns, there is a reduction in the areas cultivated with cotton and an increase in the areas cultivated with beans. Accordingly, the observed reduction can be attributed to the effect of measure 10.1.4 in the cultivation patterns.

2β. Counterfactual statistical analysis for the evaluation year (2018)

Data and Methodology

The methodology aims to compare a sample of statistical units under the impact of Measure 10.1.4 (treatment group) with a corresponding sample of units which are not included to the Measure (control group) but it will be used as a counterfactual. Generally, the farm is considered as the statistical unit because at this level optimization decisions can be made (maximizing revenue, minimizing costs and maximizing profits).

However, the IACS 2018 available data provided information only at parcel level without any farm-level information (i.e. from which parcels a farm is consisted of). To overcome this limitation of data a canvas of 5x5 km (25 Km^2) was created covering the whole country. For each such square, the needs for crop irrigation water, as recorded in IACS, and the hydrological model, used for the estimation of irrigation needs, were calculated as described in the relevant chapter.

The area supported by actions 10.1.4, 11, 13 etc., the physical characteristics of each square (average height, mean slope, soil conditions, rainfall, evaporation, etc.) were also calculated. Finally, the elementary dependent variable, which is the cubic meter of water (based on irrigation needs) per hectare of irrigated area, was also estimated. The squares of this canvas were considered as the statistical units. Consequently, 6,418 squares were set, of which 4,897 contain irrigated land and were selected for this implementation. From these 4,897 squares, 1,044 contain parcels supported by action 10.1.4 and can be considered as the treatment group, while the rest 3,853 squares were considered as the control group.

Figure 9 shows the distribution of the sample squares. If we compare the treatment units with the control units then we induct partiality into the comparison because it isn't known whether the treatment and control units have the same characteristics. Attempting to compare the treatment units with the control units, as impartially as possible, the methodology of creating matching pairs of treatment-control units based on predefined characteristics was utilized, so as to be sure that the treatment square and the control square have the same characteristics. There are several algorithms for making such matched paired pairs, of which the most well-known are the propensity score and the nearest neighbour. The most important test is to make sure that after matching the pairings their differences in the selected pairing variables are statistically non-existent.

Calculation / results

Table 5 depicts the differences in irrigation water needs per hectare among the squares that are having parcels in Action 10.1.4 and for the squares that do not. The difference between the two averages is 618.71 m3 / ha less for the squares which are related to Action 10.1.4. However, this comparison may be incorrect because the squares are heterogeneous. For instance, squares that do not have parcels in Action 10.1.4 could be in plains, with more gentle slopes, fertile soils, water scarcity, etc., and therefore they appear to have higher irrigation water needs. For this reason, the pairs were selected to have the same characteristics and thus can be directly comparable. The propensity score matching (psm) algorithm was selected, as far as it concerns the variables describing geography (altitude, slope, soil), hydrology (rainfall, reference evapotranspiration), eligibility criteria (nitrate vulnerable areas, Natura 2000), and the action of other measures, such as M13 and M11.

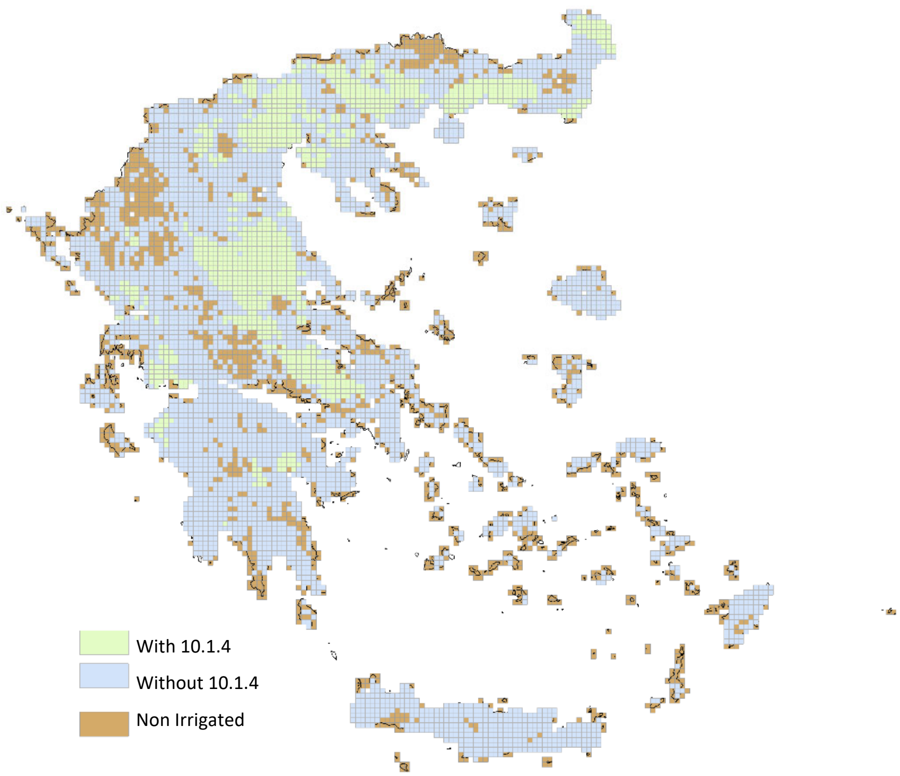


Figure 9. Distribution of Non-Irrigated and Irrigated sampling squares, supported (treatment) and unsupported (controls) by Action 10.1.4, 2018

Table 5. Average water demand (m^3/ha of irrigated areas) in squares with and without areas supported by Action 10.1.4.

Observations (squares)	m^3/ha irrigated land	Standard deviation	Minimum	Maximum	Number of Observations
With 10.1.4	4109.818	683.8586	2135.381	6486.974	1044
Without 10.1.4	4728.531	1127.514	1071.2	10723.1	3853

Conclusions

This study provided detailed data and detailed methodologies to estimate the indicators I.10 "Water abstraction in agriculture" and I.11 "Water quality" based on the available data and scientifically documented methodologies for both the base year (2015) as well as for the evaluation year (2018). The resulting indicator values appear to be much more realistic than those of the Eurostat indicators, especially for the total irrigation abstractions and surface water quality.

Nevertheless, considerable uncertainty still exists and therefore specific actions will be taken at a later stage to further improve the accuracy and reliability of the results as more data becomes available. Additional optional indicators (pesticides) will also be evaluated as soon as relevant data become available.

Regarding the results of the index values comparison, in general, all indicators' values appear to have a very small change between 2015 and 2018. One important reason for this is the short evaluation period (4 years), which is not sufficient to demonstrate the effect of RDP actions on indicator values, as far as many of these actions have been implemented gradually, while many related physical processes are very slow (eg nutrient movement) and it takes a long time for the system to respond to various changes.

Overall, regarding the efficiency of water use in agriculture, the thorough analysis showed that there was a significant improvement in the volume of water abstractions per hectare (-152 m3 / ha) comparing the reference and the evaluation year, 2015 and 2018 respectively, as a result of RDP actions. This significant change seems to related ith the change in crop structure due to RDP actions. Also, based on the statistical analysis using the counterfactual method for the evaluation year (2018) it was estimated that the net impact of the RDP is the water saving (852.46 m^3/ha). Hence, the overall the net water savings due to the Action 10.1.4, based on the 2018 model estimate of net irrigation needs, is 2.6%.

As far as it concerns the water quality, a small improvement of the indices was estimated in both surface and ground water. However, the analysis of the results has not been able to provide clear evidence of the contribution of the RDP actions to this improvement. Aiming to the investigation of RDP impact actions evaluation, a detailed and systematic analysis of targeted study areas is suggested, to accomplish more reliable conclusions.

Furthermore, the most recognizable effect of the RDP actions is the decrease in the areas cultivated with cotton and the increase in the areas cultivated with legumes. The potential contribution of this event to water quality is not unequivocal, and depends on other factors, but could be positive under certain conditions.

Finally, as it can be seen by the analytical results presented in the relevant chapter, the potential nitrogen surplus decreased between 2015 and 2018, mainly due to the increased outputs. The increase in outputs is mainly due to the increase in the production of fodder crops and primarily of legumes. The increase in the cultivation of the fodder crops is supported by Action 10.1.4.