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Mapping and Analysis of Pressures on Water Resources from Agriculture to Target Water and Agriculture Policies

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There is a close connection between the water policy, for which the main reference is Water Framework Directive (WFD), and the Common Agricultural Policy (CAP), even more evident in the new regulation of the CAP 2014-2020. Indeed, the interdisciplinary nature of water resources problems requires the integration of technical, economic and environmental aspects into a coherent analytical framework.
The main goal of this study was to apply a geo spatial analysis method in order to assess if the measures foreseen in the River Basin Management Plans (RBMPs) and in the Rural Development Programmes (RDPs) 2014-2020 address agriculture pressure on water resources, in particular those linked to irrigation service. To provide an analytical framework, this assessment method was applied to all Italian River Basin Districts (RBDs), combining GIS data with publically available data to assess the impact and spatial distribution of agriculture pressures on water resources at provincial level. Twelve pressure indicators were identified, concerning qualitative and quantitative pressures on water resources and environmental constraints. Hierarchical cluster analysis of indicators was used to evaluate the existence of agricultural pressure or bundles of pressures. The results show that 16 different clusters were identified in the cluster analysis. There are two main clusters, characterized by average values of most indicators, which cover about 76% of the provinces. The others clusters show specific issue related to quantitative or qualitative problems, or environmental constraints and each includes a lower number of provinces.
Furthermore, there is a different spatial variability of clusters through national territory, with lower variability in Central and Southern Italy and higher variability in Northern Italy. The analysis method appears as a simple and effective way to identify the main issues at the province scale, highlighting that the agricultural sector could potentially activate policies as regional RDPs responding to the problems identified, contributing to the objectives of the RBMPs.
Keywords: Irrigation, Water Resources, Cluster analysis; WFD, Water Framework Directive; River Basin Management Plans (RBMPs); River Basin Districts (RBDs); Rural Development Programmes (RDPs).

1. Introduction

Integration of policies for water and agriculture is essential for rational and efficient use of water resources for agriculture. By 2050, over 40% of the world's population is expected to live in river basins under severe water stress and the global water demand will probably increase from around 3500 km3 in the year 2000 to nearly 5500 km3 in 2050 (OECD, 2012). The Water Framework Directive (WFD) was one of a major effort for a common integrated management of environmental resources in the European Union. The WFD states that Water is not a commercial product it is an heritage which must be protected. Irrigated agriculture is the largest consumer of water in European Mediterranean areas, and an important economic activity in the rest of the European landscape (Barbel and Gutiérrez Martín, 2004).
One of the most innovative elements of the Water-Framework Directive (WFD) is the important role that economic analysis is assigned in achieving its environmental objectives (Gómez-Limón and Martin-Ortega, 2013). There is a close connection between the water policy, for which the main reference is Water Framework Directive (WFD), and the Common Agricultural Policy (CAP), even more evident in the new

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regulation of the CAP 2014-2020 (Zucaro et al., 2014). The integration between the policies is one of the strategic objectives at EU level for a more efficient use of financial resources and for the pursuit of objectives of common interest. For agricultural use of water resources, integration is more difficult due to the different spatial reference level at which policies operate. According to the WFD the only reference should be the River basin district (RBD) and its planning instrument, the River basin management plan (RBMP), while Rural development policies follow a regional programming and, therefore, lose sight of a number of issues linked to the presence of inter-regional river basins. In Italy there are 7 River basin districts (RBDs): River Po, Eastern Alps, Northern Apennines, Central Apennines, Southern Apennines, Sicily and Sardinia.
Coherence between BMP measures and agricultural issue can be a key aspect to reach environmental WFD objectives. The objective of this paper is to to apply a geo spatial cluster analysis method in order to assess the coherence and integration of the measures foreseen in the RBMPs the Rural Development Programmes (RDPs) 2014-2020 measures, in order to address agriculture pressure on water resources, particularly those linked to irrigation service.

2. Methods

2.1 Study area

The study was applied to all Italian RBDs. Zucaro (2014) has reported that geomorphological characteristics of the hydrographic network in Italy are extremely varied with different typologies of water resources ranging from large water river basin in the North, water bodies of medium and variable size in the Centre to irregular stream-like water bodies in the South and in the Islands. The areas that may be potentially used in agriculture for production and irrigation purposes are concentrated along the coasts and in valleys of small and medium size with the exceptions of some extensive valleys, such as the Po River, the plain of Agro Pontino and the plains of Foggia, Catania, and Oristano.
The climate varies considerably from the north to the south of Italy. In the north of the country the climate is characterize by cold winters and hot and humid summers. In central Italy the climate is milder, with a smaller difference in temperature between summer and winter and a shorter and less intense cold season than in the north. In southern Italy and the islands winters are never particularly harsh, and spring and autumn temperatures are similar to those reached in the summer in other areas of Italy. In the north of Italy rainfall ranging between 1150 and 750 mm, in the center between 920 and 700 mm and in the south between 910 and 500 mm.
Total agricultural land is 16,678,032 hectares, of which 74.5% (12,425,733 ha) is represented by the utilized agricultural area (UAA). The livestock unit (LU) in Italy are 14,547,319 of which 49% are poultry and 29% cattle, which are located mainly in Lombardy (22% cattle and 21% poultry), followed by Piedmont and Veneto (12 % cattle and 18% poultry) and Emilia Romagna (10% cattle and 30% poultry).
The crops are arable crops, lawns and woody agricultural crops. The spatial distribution mainly differs depending on the climate and nature of the terrain and the presence of irrigated areas. In fact, in lowland and coastal areas are widespread arable crops, vegetables and woody crops in mountainous-hilly areas are more widespread meadows and woody crops.

2.2 Data collection

It was referred to data that was public and open available at the province level, quantifiable and comparable. Twelve pressure indicators were identified (Table 1), concerning qualitative and quantitative agricultural pressures on water resources (ISTAT 2010_a, ISTAT 2010_b, Munafò et al. 2015, and SIGRIAN webGIS - National Information System for Water Management in Agriculture) as the ratio between: UAA/TAA, UAA_{irri}/UAA, $UAA_{irri,}$ UL/UAA (United Livestock), Fertilizers (Kg of fertilizers sold per province), Pests (Kg of pesticides sold per province) GW (m^3) (Ground water withdrawals), SW(m^3)/UAA (Surface Water withdrawals). Were used other indicators of environmental constraints as Natura 2000 areas and Nitrate Vulnerable Zones (ISPRA), and risk indicators related to drought and floods as Land consumption and RDI (Reconnaissance Drought Index).

2.3 Analysis method

To enable comparison across the whole national territory, pressure indicators were calculated by provinces areas. For each indicator, values were further normalized, to facilitate comparisons among them. The cluster analysis was done by a Software open source, *QGIS 2.12- Lyon,* Geographical Information Systems to produce maps of the distribution of indicators across the study area. All data were subjected to correlation analysis to identify the existence of negative or positive significant relationships between two indicators (Zhou et al., 2004). Hierarchical clustering method was used to identify the magnitude of distinct types of indicators. It was selected the Ward's method to get dendrogram in order to minimize variance within each cluster. For choose the best number of clusters were used dendrogram's horizontal ties, that represent the degree similarity, indicating smaller number of clusters with maximum homogeneity (REScoop, 2006; Dulli, Furini e Peron, 2009). The ties were "cut" at reasonable distance to address spatial variability and characteristic of whole national territory. The clusters analysis was done with "Attribute based clustering" plugin (Duque e Botero, 2014) supported by the geodatabase open source QGIS 2.12- Lyon. In order to classify the indicators value within each cluster, each one was weighted by using Jenks optimization method (Jenks, and George, 1967). Final weighted class was assigned to each indicator identify as: Very High, High, Medium, Low and Very Low. Cluster classification and characterization was use to assess the coherence among RBMPs and RDPs (2014-2020) measures compared to pressure analysis (and relative indicators) to verify the real match between policies. For each RBD, it has been analysed RBMP's Program of Measures (PoM) containing basic measures (actions necessary to implement community legislation on water resources) and additional (supplementary measures of basic measures to achieve environmental objectives). For each RBD, for the new cycle for Rural Development 2014-2020, it has been analyzed the actions activated in regional RDPs in order to contribute, in a direct or indirect manner, to water protection.

3. Results and discussion

Following the dendrogramm, were chosen 16 cluster as best number of cluster (Figure1). The cluster numbering (from 1 to 16) does not match any risk classification. The characterization of each cluster was evaluated depending on the level of each indicators which gave values classified as high and very high in according to the Jenks optimization method (Table 1).

There is a different spatial variability of clusters through the study area, with lower variability in Central and Southern Italy and higher variability in Northern Italy as show in Figure 1. In fact, the greater variability of clusters is highlighted in the north west of the country, which coincides substantially with the River basin district of the Po River (6 other clusters), while the less diversity is found in the Central Italy (one other cluster). There is high frequency of two principle clusters, cluster 15 (18 provinces out of 110) and cluster 16 (45 provinces), characterized by average values of most indicators which cover about 76% of the provinces.

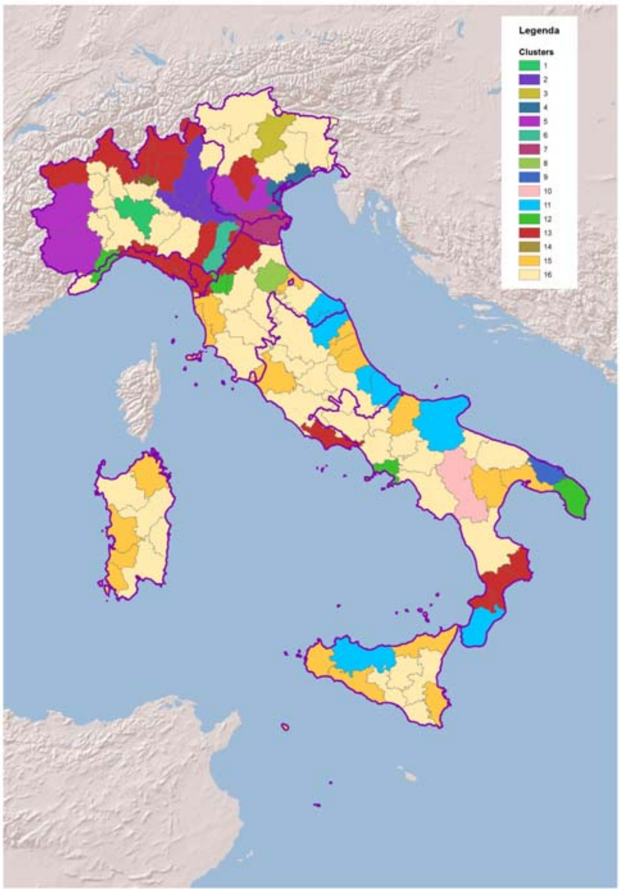

Figure 1: Map of the study area clusters

In Table 1 it should be noted that clusters 11, 12 ,15 and 16 show average or low values for the main indexes. Whereas, clusters 13 and 14 even though they have non-significant indexes values, it can be note a greater pressure in term of livestock pressure and environmental constraints. Water resource pressure indicators show greater sensitivity of the provinces belonging to clusters 1, 2, 4, 5 and 7 particularly due to widespread presence of irrigated agriculture. Some clusters highlighted specific issues related to both qualitative and quantitative indicators. For example, cluster 6 it is characterized by intensive agriculture and livestock burden, while cluster 8 show high level of livestock pressure. Cluster 3 show high presence of Natura2000 areas and low or medium-low values of all other indicators and total absence of NVZ.
Cluster 9 underline a sensitivity about drought and groundwater withdrawals. Clusters 4 and 5 show high level of risk indicators related to floods while cluster 10 highlights the sensitivity to drought-related issues.

Table 1: Cluster characterization by indicators

Cluster	***UAA/TAA***	***UAA_{irri}/UAA***	***UAA_{irri}***	***Fert.***	***Pest.***	***LU/UAA***	***GW***	***SW/UAA***	***Land consumption***	***RDI***	***NVZ***	***N2000***
1	Very high	Very high	Very high	Medium	Low	Low	Very low	High	Low	Very low	Low	Medium
2	High	Very high	Very high	Medium	Low	Very high	Very low	Low	High	Very low	Very high	Low
3	Very low	Very low	Very low	Very low	Very low	Low	Very low	Very low	Low	Very low	NC	Very high
4	High	High	High	Medium	Low	Low	Very low	Very low	Very high	Very low	High	High
5	Medium	High	Very high	Medium	Low	High	Low	Low	Very high	Low	High	Low
6	Very high	Very low	Very low	Very high	Very high	Very high	Very low	Low	Low	Low	Medium	Low
7	Very high	High	High	Medium	Low	Low	Very low	Low	High	Very low	Very high	Medium
8	Low	Very low	Very low	Low	Low	Very high	Low	Low	Very low	Very low	Low	Low
9	Very high	Low	Low	Very low	Low	Very low	Very high	Low	Very low	Very high	NC	Very low
10	Medium	Very low	Low	Very low	Very low	Very low	Very low	Low	Very low	Very high	Very low	High
11	High	Low	Low	Low	Very low	Low	Low	Low	Low	Medium	Low	Medium
12	Low	Medium	Very low	Low	Medium	Medium	High	Low	Very low	Very low	Medium	Low
13	Low	Low	Low	Low	Low	Medium	Low	Very low	Low	Low	Low	Medium
14	Very high	Medium	Very low	Very low	Very low	High	Very low	Very low	Very low	Medium	Very high	Very low
15	Medium	Low	Low	Very low	Very low	Low	Low	Low	Low	Very low	Low	Medium
16	Medium	Medium	Low	Low	Low	Medium	Low	Low	Low	Very low	Low	Medium

Table 2 that summarizes the relevance of the measures, implemented in all RDP which affect directly or indirectly the water resources with respect to the specific critical issue linked to each cluster. Overall it appears that the effort of the agricultural sector for the environmental objectives of the DQA is very high, thanks to the high number of measures implemented to achieve environmental objectives. Particularly, measures 1, 4, 10, 11 and 16 of RDPs seem to be more consistent than the issues that emerged by cluster analysis. Instead, measure 12 could be important for cluster 3 due to high presence of Natura 2000 areas.

Table 2: Relevance of RDP measures addressing the cluster criticalities. Table lines: RDP measures (number into brackets relates to the article of REGULATION (EU) 1305/2013).

RDP Measure, sub-measures / Cluster type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M01 (14) Knowledge transfer and information actions																
M01.1 Vocational training and skills acquisition actions	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
M01.2 Demonstration activities and information actions	x	x			x	x	x						x	x		x
M01.3 Long-term farm and forest management exchange as well as farm and forest visits									x	x	x	x	x		x	x
M02 (15) Advisory services, farm managm. & relief services																
M02.1 Support to help benefit from the use of advisory services	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
M04 (17) Investments in physical assets																
M04.1 Support to improve the overall performance and sustainability of an agricultural holding				x	x	x	x	x			x	x	x		x	x

Table 2: Relevance of RDP measures addressing the cluster criticalities. Table lines: RDP measures (number into brackets relates to the article of REGULATION (EU) 1305/2013).

RDP Measure, sub-measures / Cluster type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M01 (14) Knowledge transfer and information actions																
M01.1 Vocational training and skills acquisition actions	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
M01.2 Demonstration activities and information actions	x	x			x	x	x						x	x		x
M01.3 Long-term farm and forest management exchange as well as farm and forest visits									x	x	x	x	x		x	x
M02 (15) Advisory services, farm managm. & relief services																
M02.1 Support to help benefit from the use of advisory services	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
M04 (17) Investments in physical assets																
M04.1 Support to improve the overall performance and sustainability of an agricultural holding				x	x	x	x	x			x	x	x		x	x
M04.3 Support for infrastructure related to the development, adaptation or modernisation of agriculture and the supply and saving of energy and water (collective irrigation schemes)	x				x	x	x	x	x	x	x	x	x		x	x
M04.4 Support for non-productive investments linked to the provision of agri-environmental climate objectives	x	x		x	x	x	x		x		x	x	x	x	x	x
M10 (28) Agri-environment-climate																
M10.1 Agri-environment-climate commitments	x	x		x	x	x	x	x				x	x	x	x	x
M11 (29) Organic farming																
M11.1 Conversion of conventional farming to organic farming	x	x		x	x	x	x		x		x	x	x	x	x	x
M11.2 Maintenance of certified organic farming	x	x		x	x	x	x	x			x	x	x		x	x
M12 (30) Natura2000 & Water Framework Directive payments																
M12.1 Natura 2000 agricultural areas: compensation payments on agricultural land associated with Natura 2000			x	x					x	x			x			
M12.2 Natura 2000 forest areas: compensation payments on forest land associated with Natura 2000;					x						x		x		x	x
M13 (31) Payments to areas facing natural/other constraints: mountains areas			x	x			x							x		
M16 (35) Co-operation																
M16.1 EIP Operational Groups	x	x	x		x								x	x		x
M16.2 Pilot projects	x	x			x								x	x		x
M16.5 Environment and climate change	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x

4. Conclusions

Proposed analysis method appears as a simple and effective way to identify the main issues at the province scale to assess integration of policies for water and agriculture. The analysis of RBMP's and RDP's measures, highlights how structural measures (on-farm and off-farm investments) are widely used and effective to address quantitative criticalities in the water use, while measures to promote and encourage the use of sustainable farming practices (eg agri-climate-environmental measures, non-productive investments) are more effectively implemented to address quality-critical issues. That highlights how the agricultural sector could potentially activate policies responding to the problems identified, contributing to the objectives of the RBMPs.

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