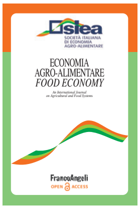
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 8, pp. 1-19 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12758



Modeling change in the ratio of water irrigation costs to farm incomes under various scenarios with integrated FADN and administrative data

Patrizia Borsotto[*,a], **Francesca Moino**[a], **Silvia Novelli**[b]

[a] CREA, Council for Agricultural Research and Economics, Italy
[b] University of Turin, Italy

Abstract

The Water Framework Directive 2000/60/CE (WFD) of 2000 was issued by the European Union (EU) to prevent water deterioration and promote its restoration. It introduced a water pricing policy in the agricultural sector that is based on a 'polluter-pays' principle. To date, some Member States have yet to comply with the pricing requirement for two main reasons: water cost estimates, as defined by the WFD, are particularly complex and difficult in the agricultural sector and farmers in marginal economic and environmental contexts may be unable to bear higher water costs. In Italy, water services are managed by regional administrations that also set irrigation water prices. This research estimated the effect of changes in irrigation water costs borne by farmers on farm incomes in a case study in the Aosta Valley Region where extensive farming is practice in a significantly naturally-disadvantage area. The analysis was modeled using four cost scenarios with economic data from the Farm Accountancy Data Network (FADN) integrated with irrigation water cost data provided by a regional administrative database. Estimated water costs averaged 2.65% and 1.06% of farm incomes, depending on the presence or absence of regional subsidies. Water costs represented higher income proportions on specialized grazing livestock farms, which is the predominant type of farming in Aosta Valley. These results raise concerns for WFD implementation, in particular, in mountain and agriculturally-disadvantaged areas with extensive and less-profitable farming.

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
15/09/2021
Available online:
12/01/2022

JEL codes:
Q12, Q15

Keywords:
Water Framework Directive
Irrigation
Farm income
Farm Accountancy Data Network

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

---

* *Corresponding author*: Patrizia Borsotto - Researcher - CREA, Council for Agricultural Research and Economics, Research Centre for Agricultural Policies and Bioeconomy - Strada delle Cacce, 73 - 10135 Torino, Italy. E-mail: patrizia.borsotto@crea.gov.it.

Introduction

In recent years, the European Union (EU) has utilized political actions to not only reduce the pressures on environmental resources, but also to encourage their restoration. For example, the Water Framework Directive 2000/60/EC (WFD) is directed at ensuring good quality water is available to meet the economic and social needs of Member States (MSs) (European Commission, 2019). The Directive was innovative as it introduced a uniform pan-EU water pricing policy for saving water and recovering service costs based on the 'polluter-pays' principle (WFD, Art. 9). It requires each Member State (MS) to set water charges by economic sector, such as agriculture, manufacturing, transportation, and so on. While the last report on WFD implementation (European Commission, 2019) indicated that some MSs have upgraded their water pricing policies, others have yet to meet the original requirements. Shortcomings are most often attributed to the complexity of estimating costs as defined by the Directive for the agricultural sector (Zucaro, 2014).

According to European guidelines (European Commission, 2000), the water pricing policies must include three cost types: i) 'financial costs' for water management and provisioning services, including operating, maintenance, and capital costs; ii) 'environmental costs' for environmental/ecosystem damage resulting from poor water use; iii) 'resource costs' or alternative water use opportunities lost to exploitation or depletion (European Commission, 2000; WFD, Art. 9). While financial costs are relatively easy to define, environmental and resource costs are less straightforward and lead to estimation problems (Zucaro, 2014). Nonetheless, Reg. (EU) 1303/2013 – laying down common provision on the European Structural and Investment Funds for the 2014-2020 programming period –, introduced the ex ante conditionality for accessing European funds. Water resource ex ante conditionality establishes: i) a water pricing policy which provides adequate incentives for users to use water resources efficiently, and ii) an adequate recovery of the costs of water services at a rate determined in the approved River Basin Management Plans.

In Italy, water services are managed regionally and administered by the Irrigation and Reclamation Consortia and the Consortia for Land Improvement. Water sector pricing estimates are set at the regional level. The criteria for estimating environmental and resource costs for the sectors was clarified when the Italian Ministry of Environment adopted the WFD through Ministerial Decree no. 39/2015. The Decree also explained Directive exemptions for "disproportionate costs" and other circumstances (WFD, Art. 4). According to the Decree, a disproportionate cost is one that exceeds its benefits or one that is beyond a party's ability and willingness to pay.

In many EU economic and environmental contexts, affordability limits implementation of the Directive, as farmers may not be able to bear higher water costs. The Aosta Valley Region represents one such region. Almost entirely mountainous and nearly completely constrained by natural and environmental factors, the EU considers most of its territory as being a "disadvantaged area" for agriculture. In this valley, irrigation water services are provided subject to peculiar social and cultural habits and practices that make it difficult to establish water price policy based on European guidelines. In this case, the consortia costs are largely borne by the Region, while only a small amount are paid by users through a special water payment called *ruolo*. The *ruolo* is defined by the Regional Law no. 3/2001, which provides that consortia may impose contributions to the users of irrigation services, whether they are farmers or non-agricultural users (e.g., residents with gardens). The law specifies that such payments are meant to contribute to compensate management, operating and ordinary maintenance costs borne by the consortia (Law no. 3/2001, art. 13). Environmental costs and resource costs are not included, therefore the EU claims that the *ruolo* does not meet the WFD guideline and that the current regional water policy is not suitable under the Directive. Moreover, these payments are often very low or go unpaid as the consortia members work voluntarily to maintain their territorial water network in lieu of payment through *corvées* (Francois and Garello 2004; Seroglia and Zucaro, 2009; Florio, 2013).

The non-conventional irrigation water pricing in the Aosta Valley Region raised questions as to how it might comply with WFD guidelines and how costs might be borne by farmers. For these reasons, the research was aimed at: i) estimating the proportion of farm incomes used to cover irrigation water costs, and ii) developing of various scenarios from which water costs can be estimated, to provide different calculation methods that policymakers might adopt to allocate costs.

Several authors have considered the economics of water policy pricing from various perspectives. Massarutto (2003) studied an economic approach like that sought by the WFD, analyzing the trade-off between economic efficiency and environmental sustainability in water pricing policy. Gòmez-Limòn and Riesgo (2004) proposed a mathematical programming model to evaluate the economic and social impacts of irrigation water pricing policy on heterogeneous farmers. Bazzani *et al.* (2004 and 2005) tested a farm-level model under different scenarios to identify suitable policy instruments for WFD application. More recently, Galioto *et al.* (2013) developed a methodology using Farm Accountancy Data Network (FADN) information to assess WFD guideline-based disproportionate costs to estimate agricultural income losses in the Emilia-Romagna Region. The FADN database has previously been used to analyze similar topics: identification of an efficient irrigation water management for rescue protection efforts under the Common Agricultural Policy (CAP) (Capitanio *et al.*, 2015); evaluation of CAP and WFD coordination on water use savings (Kampas *et al.*, 2012); evaluation of the impact of taxes on daily farm income volatility (Vrolijk *et al.*, 2020).

Two features distinguish this study from those above. First, the work concerns the territorial peculiarities of the Aosta Valley Region, which is characterized by significant natural disadvantages and extensive farming. Second, various cost scenarios were considered using integrated data sourced from the FADN (economic data) and from regional administrations (irrigation water cost data).

1. The study area

The Aosta Valley is an Italian Region located in northwestern Italy. It extends to the inner side of the Alpine chain, between the Graie and Pennine Alps. Its mainly-mountainous territory is typically divided into three areas: Upper, Middle, and Lower Aosta Valley. It includes the entire west to east alpine stretch of the Dora Baltea River that flows into the Po River, branching off along its route in a large number of tributaries. Almost all of the 700 natural and artificial lakes in the area lie in the Dora Baltea basin and cover a total of 9.5 km^2. The orography of the Region characterizes its climate. At higher altitudes, the summers are short while the winters are rigid and long. Downstream, poor ventilation makes the summers hot and humid and in winter the temperature drops below zero. The precipitation profile includes two maxima during the spring and autumn seasons and two minima during the summer and mostly snowy winter (RAVA, 2019). Generally, annual precipitation averages 1000 mm, although the topography can cause large territorial differences. For example, high mountains can hamper air mass circulation and cause an arid central area where rainfall averages about 550 mm per year. The low annual rainfall, especially in summer, makes irrigation essential for agricultural production. On average, the regional water consumption for the sector is about 770 million m^3/year. Water availability to meet irrigation needs during summer in the Region is highly influenced by snow and ice melt (RAVA, 2019; Seroglia and Zucaro, 2009).

The regional Utilized Agricultural Area (UAA) spans about 56,000 ha, 15,000 ha (26.8%) of which are irrigated (Istat, 2010). Nearly the entire UAA (about 54,000 ha, 27.7% irrigated) is devoted to extensive grazing due in part to the pedoclimatic conditions that are unfavorable to other types of cultivations. In addition, area farms have specialized in dairy cattle for Fontina, a PDO cheese, which requires a largely diffuse zootechnical sector.

The remaining area is cultivated with permanent crops, mainly vineyards, followed by orchards, mostly for apple production (Trione, 2020).

Irrigation water management for agricultural purposes is administrated through nonprofit private Land Improvement Consortia (LIC). Of the 176 LIC in the Aosta Valley Region (Regione Valle d'Aosta, 2021), most are responsible for managing irrigation networks. A smaller share function exclusively as land improvement bodies. The area under LIC administration includes about 177,000 ha, which accounts for more than half of the regional surface. In most cases, LIC were started by farmers who self-organized to manage irrigation activities, and their administrative and technical management activities continue to be performed voluntarily by members today. The high number of LIC allows them to address local needs, but it makes it difficult to develop a homogeneous management – and uniform water irrigation policy – throughout the territory (Seroglia and Zucaro, 2009).

2. Materials and methods

Data sources

As mentioned, this study attempts to enhance the information available on the ratio of water irrigation costs to farm incomes (water costs-to-income ratio). The data used in this study were collected from two sources: the Farm Accounting Data Network (FADN) economic data, compiled from a survey of farms, and the Spatial Data Infrastructure (SDI), that houses LIC regional cost data. The data sourced from the Aosta Valley FADN comes from its annual survey of about 250 farms. The sample includes the main types of commercial farms, chosen by Economic Size (ES) and measured by total Standard Output (SO)[1]. About 1,000 variables on physical and structural data (location, crop areas, livestock numbers, labor force, etc.) as well as economic data (revenue, redeployment, final stocks, purchases of technical equipment, and others) and financial and balance data (debts, credits, public aid, production rights, acquisition and disposal, etc.) are collected through a survey submitted to each farm (FADN, 2018). SDI is a logically-structured administrative database containing territorial, environmental, and socio-economic information on the Aosta Valley Region (Regione Valle d'Aosta, 2018). The SDI provides in single database spatial information concerning environment, economy, cartography, structures and transport.

---

[1] The Standard Output (SO) is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given region. It is calculated by MSs per hectare or per head of livestock, by using basic data for a reference period of 5 successive years.

Water costs-to-income ratio was obtained by creating a cross-database from the two sources, including total cost of LIC sourced from the SDI (used to calculate a water pricing proxy) and farmers' income sourced from FADN.

Analysis design

The methodology adopted to assess the water costs-to-income ratio integrates Italian FADN economic data and LIC cost data as a proxy for water price.

Four steps comprise the analysis undertaken (Figure 1):

1. Select a sub-sample of farms and variables in the Aosta Valley FADN database;
2. Select LIC data from SDI database and define a water pricing proxy;
3. Construct a common dataset using data from the SDI database;
4. Define evaluation scenarios.

Figure 1 - Diagram of methodological approach

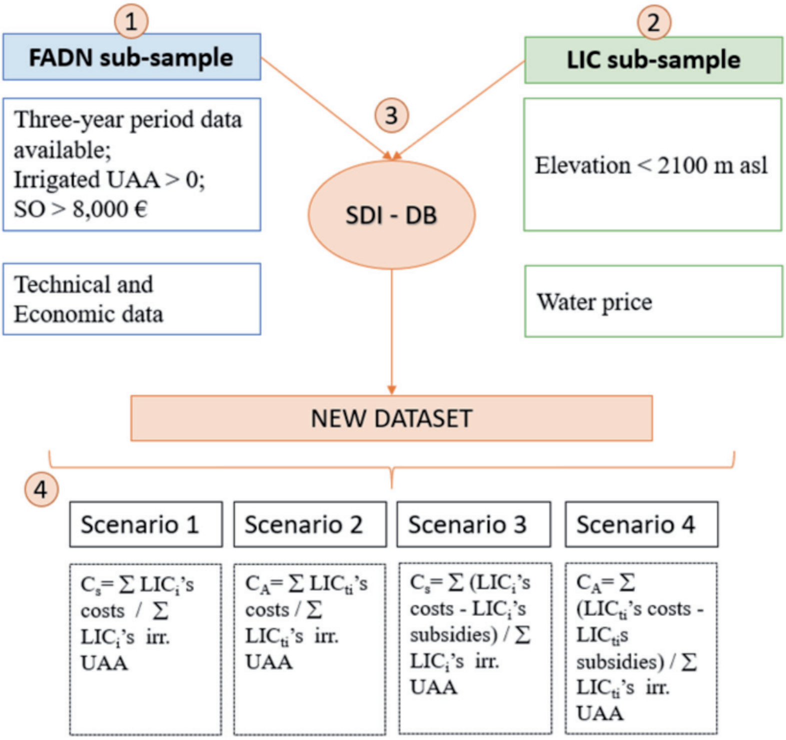


Table 1 - Description of structural and economic variables used for simulation

Variables	Description
Utilized Agricultural Area (UAA)	Total utilized agricultural area of holding expressed in hectares
Irrigated UAA	Hectares of irrigated UAA
Farm Net Income (FNI)	Remuneration to fixed factors of production of the farm (work, land and capital) and remuneration to the entrepreneurs' risks (loss/profit) in the accounting year
Water costs	Known costs of water input per hectare in one year

Source: FADN (2018)

In the first step, a sub-sample of farms were selected from 2016, 2017, and 2018 from the Aosta Valley FADN database. Selection criteria were as follows: (1) farm data must be available for each year of the three-year period; (2) farms must have irrigated UAA; (3) the SO of farms must be at least 8,000 € (minimum to be classified as commercial in Italy) (FADN, 2018). Based on these criteria, 191 farms were selected. Next, a set of structural and economic variables was selected from the FADN database for simulation (Table 1). Additional variables were assigned to aggregate the selected farms into different categories/classes for result interpretation (Table 2). In order to obtain significant results, categories/classes were included in the analysis if the relevant sample size exceeded five units. Table 3 shows the descriptive statistics of the structural and economic variables used for the simulation.

In the second step, eligible expenses and subsidies were selected from regional LIC farms located below 2,100 m asl in a potentially-irrigable area. This decision was made to include consideration of the largest area of fertigated pastures during the 2016-2018 three-year period. A total of 2,833 farms fit these characteristics and belonged to 127 different LIC. A conservative estimation was made, assuming the worst-case scenario where farmers have to bear all LIC costs (i.e., management, operational, and regular maintenance of land improvement work costs) Hence, for each LIC, total cost data were extracted and considered as a proxy for water price. Then, an average unit cost per farm-associated LIC was calculated.

During the third step, a dataset was built of both FADN and SDI variables that linked each FADN farm with its associated LIC. Next, this linkage allowed a newly-derived FADN-based variable (net income) to be calculated in which water cost data are LIC-based.

The final step in the method defined different scenarios to assess the effect of water cost on farm incomes. They were created by linking water

Table 2 - Description of the variables used to classify the selected farms into different categories/classes

Variables	Description	Categories/Classes
Economic Size (ES)	Defined as the total Standard Output (SO) of the holding expressed in euro	Small = 8,000 – 25,000 € Medium-Small = 25,000 – 50,000 € Medium = 50,000 – 100,000 € Medium-Large = 100,000 – 500,000 € Large = > 500,000 €
Type of Farming (TF)	Classify the farms by their typological affinities that each agricultural activity presents with other. The TF are defined in terms of the relative importance of the different enterprises on the farm. Relative importance is itself measured quantitatively as a proportion of each enterprise's SO to the farms' total SO	Specialist field crops Specialist horticulture Specialist permanent Crops Specialist grazing livestock Specialist granivore Mixed cropping Mixed livestock Mixed crops-livestock
Utilized Agricultural Area (UAA)	The holdings are distinguished by classes according to the number of UAA hectares	< 5 ha 5-15 ha 15-40 ha > 40 ha

Source: FADN (2018)

Table 3 - Descriptive statistics of the variables used for simulation

	Mean	Std. Deviation	Min	Max
UAA (ha)	73.26	103.05	0.55	487.14
Irrigated UAA (ha)	10.31	13.08	0.21	90.02
FNI (€)	52,493	71,296	–16,163	788,871
Added value (€)	75,998	101,637	3,750	893,113

Source: our elaboration on FADN data (2018)

costs calculated in step 2 with farm income variables extracted in step 1. Scenarios were differentiated based on the type of water costs assigned to each farm – average or specific costs. Average costs (C_A) were calculated as the ratio between the sum of management costs across all the LIC and the total irrigated UAA (from LIC data), while specific costs (C_S) were calculated as the ratio between the sum of management costs of the LIC to which the farm belonged and its associated irrigated UAA. In addition, water costs were estimated both with and without consideration of regional subsidies. In the first case, costs were calculated absent public support recognition (gross subsidies). In the second case, costs were calculated taking public support into account by discounting the relevant grant (net of subsidies). This resulted in the farm irrigation cost being the product between the irrigated UAA and the unit cost as described above. Four scenarios were identified:

Scenario 1: C_S is used as a proxy for water pricing. Water costs are allocated to each farm based on the irrigated UAA extracted from the Aosta Valley Region SDI. This scenario assumes a water cost borne by farms based on the specific costs to manage the corresponding LIC.

Scenario 2: C_A is used as a proxy for water pricing. An average unit value of 153.65 €/ha was employed, calculated as the ratio of total management costs of all LIC to total hectares of irrigated UAA. In this scenario, a fair cost distribution is estimated for the entire territory, regardless of the corresponding LIC.

Scenario 3: C_S, discounted for regional subsidies (net of subsidies), is used as a water pricing proxy. These subsidies are estimated to be 60% of LIC-incurred management costs.

Scenario 4: C_A, discounted for regional subsidies (net of subsidies), is used as a water pricing proxy. The average unit value equaled 61.46 €/ha, calculated as the ratio of total management costs of all LIC (net of subsidies) to total hectares of irrigated UAA.

Sample description

The 191 farms selected from the FADN database were categorized according to the classes of Economic Size (ES), Type of Farming (TF), and Utilized Agricultural Area (UAA). For ES, the farms were distributed relatively equally across the first four ES classes: Small (20%), Medium-Small (26%), Medium (29%), and Medium-Large (25%). Farms with a SO value of more than 500,000 € (Large) were excluded from the sample (Table 4). As expected, the Farm Net Income (FNI) grew as the ES increased (average value was approximately 53,000 €). The average physical farm size was about 73 ha, of which nine ha (13%) were irrigated. The share of irrigated area decreased as the ES increased (from 72% in Small farms to 9% in Medium-Large farms).

In the case of TF, the majority of farms were specialized grazing livestock farms (dairy farms); the remainder were specialized permanent crop farms (either vineyards or orchards) (Table 5). Livestock farms produced

Table 4 - Farm structural and economic average data by Economic Size (ES) class

ES	Sample size (n)	UAA (ha)	Irrigated UAA (ha)	Irrigated UAA/total UAA (%)	FNI (€)
Small	39	3.32	2.38	72	16,160
Medium-Small	49	19.56	4.81	25	38,822
Medium	55	65.49	9.89	15	51,172
Medium-Large	48	193.80	17.95	9	97,482
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

Table 5 - Farm structural and economic average data by Type of Farming (TF)

TF	Sample size (n)	UAA (ha)	Irrigated UAA (ha)	Irrigated UAA/total UAA (%)	FNI (€)
Specialist field crops	4	4.43	4.16	94	30,564
Specialist horticulture	2	0.81	0.64	80	37,724
Specialist permanent crops	51	3.94	2.98	75	65,379
Specialist grazing livestock	115	111.85	12.71	11	49,305
Specialist granivore	0	0	0	0	0
Mixed cropping	6	4.41	4.36	99	76,546
Mixed livestock	0	0.00	0.00	0	0
Mixed crops-livestock	13	67.91	5.49	8	28,060
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

milk that was processed into PDO fontina, which yielded a reduced net income compared with less-represented TFs. The farms in the sample that specialized in field crops and horticulture numbered fewer than the five-unit threshold, so these TFs were excluded from the analysis.

In Table 6 the farms are classified in four UAA classes. The largest group is that with an average physical size higher than 40 ha, in this case the ratio between irrigated UAA and total UAA is very low. The opposite goes to farms with less than 5 ha of UAA, where almost the whole area is irrigated. Large farms (> 40 ha) are generally specialized in livestock with extensive pasture areas, therefore not irrigated or with a small share of irrigated area.

Table 6 - Farm structural and economic average data by UAA classes

UAA class (ha)	**Sample size (n)**	**UAA (ha)**	**Irrigated UAA (ha)**	**Irrigated UAA/total UAA (%)**	**FNI (€)**
<5	55	2.36	1.96	83	34,288
5-15	38	9.50	7.23	76	67,243
15-40	25	26.03	12.80	49	45,332
>40	73	176.04	14.09	8	60,984
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

The 127 LIC analyzed in the study manage about 60,000 ha of UAA, of which about 17,000 were potentially irrigable. The maintenance and management expenses for irrigation canals totaled approximately 1.4 million € each year. Regional subsidies equaled about 886,000 € annually (Table 7). Values per surface unit were 153.65 €/ha and subsidies were 92.12 €/ha. Based on these unit costs, subsidies estimated in this simulation equated to 60% of the management costs carried by the LIC.

Table 7 - LIC description

Variable	**Data**
Number	127
Total UAA	59,756 ha
Potentially irrigable UAA	17,101 ha
Eligible expenditure	1,362,680 €
Total contribution	885,742 €

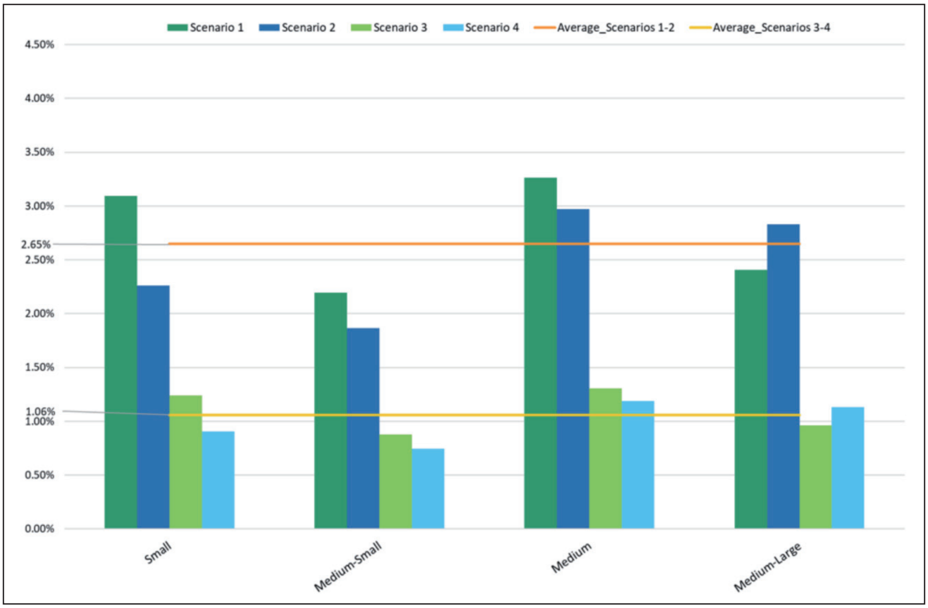
Source: SDI database

3. Results

The average change in the water costs-to-income ratio (both gross and net of subsidies) was estimated for the four scenarios. In Scenario 1 and 2, where the estimate excludes public support, the average ratio of water management costs on net farm income was 2.65%. In Scenario 3 and 4, where costs were discounted for regional subsidies (net of subsidies), the estimated mean ratio was 1.06%.

In order to assess the effects of water cost changes on farms of differing characteristics, the farms in the four scenarios were aggregated by ES, TF, and UAA class and then analyzed. For ES, the highest change in the water costs-to-income ratio was in Medium farms. Their Scenario 1/2 and Scenario 3/4 estimated values were greater than the overall average values (2.65% and 1.06%, respectively). The opposite was true for Medium-Small farms, for which the estimated values for all scenarios were lower than the overall average values (Graph 1). A comparison of the type of water costs assigned to the farms (C_A or C_S), the largest difference was found in Small farms. In the case of Small farms, the Scenario 1 and 3 ratios were above the average value, while Scenario 2 and 4 ratios stayed below.

Graph 1 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by ES class

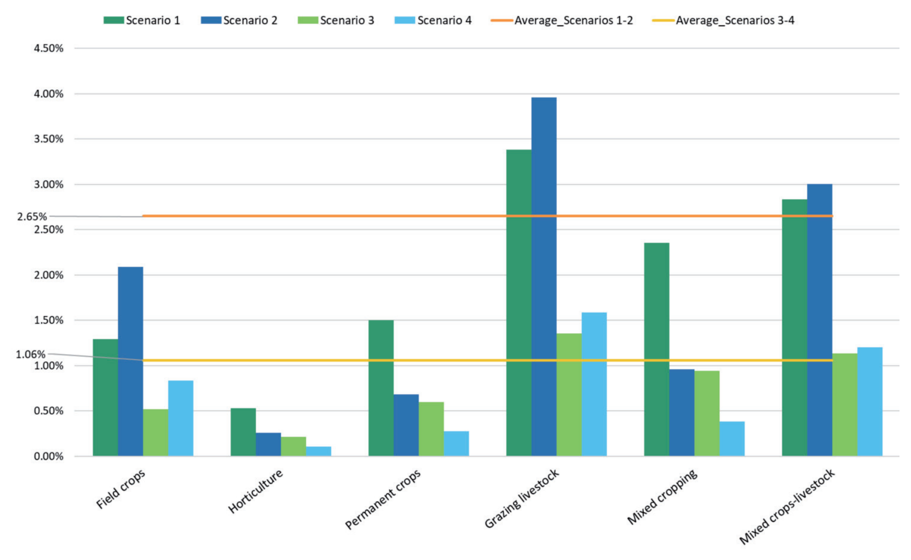


Source: our elaboration on FADN and SDI data.

Analysis of the results by TF were consistent in every scenario. The largest effect on the proportion of farm incomes used to cover water costs was found in farms that specialized in grazing livestock, followed by those with mixed crops and livestock (Graph 2).

A comparison of the type of water costs assigned to the farms (C_A or C_S), the highest difference was found in farms that specialized in permanent crops. Scenario 1 and 3 resulted in higher ratios than did Scenario 2 and 4. For the other TF categories, the values were below the average and differed between the two sets of data. However, the sample sizes for these TF categories were too small to render a statistical evaluation.

Graph 2 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by TF

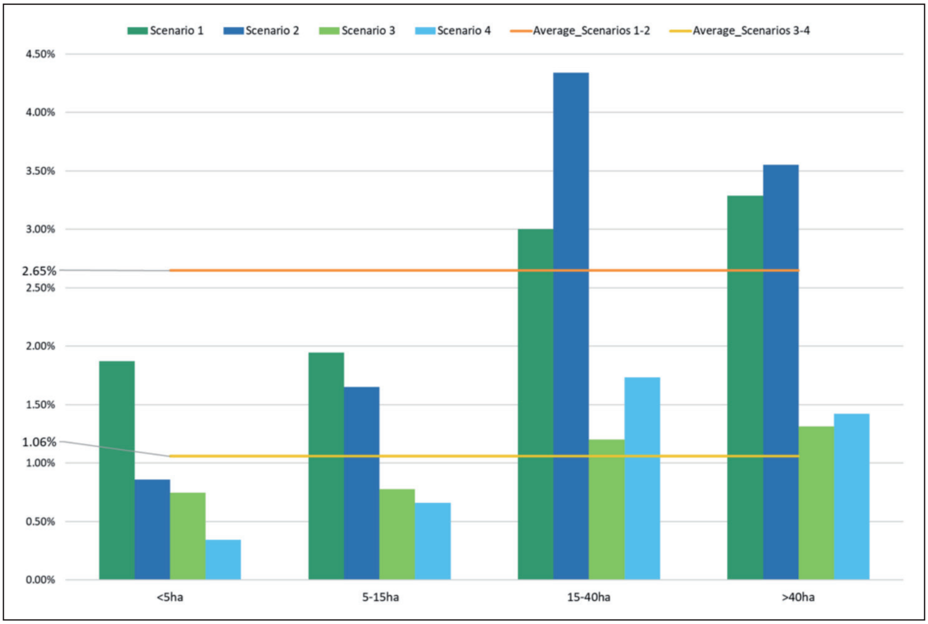


Source: our elaboration on FADN and SDI data.

Aggregating farms by UAA class (Graph 3) demonstrated that the changes in the proportion of operating costs in the larger farms (UAA>40 ha) was higher than the average for all scenarios. Moreover, since the ratio between total and irrigated UAA for these farms was very low (Table 6), the recovery of the costs would have applied to just 8% of the total UAA, on average. In Small farms (UAA<5 ha), the opposite held true. That is, the water costs-to-income ratio was not only lower than the average, but the recovery of the costs would have applied to almost all of the UAA (83%).

In Scenario 1 and 3, the water costs-to-income ratio increased as the UAA increased. On the contrary, Scenario 2 and 4 did not trend linearly. In fact, farms of fewer than 5 ha and farms of 15 to 40 ha produced very different values in the two scenarios: in Scenario 2 the water costs-to-income ratio is of 0.86% and 4.34%, respectively in the two groups of farms, and in Scenario 4 is respectively of 0.34% and 1.74%.

Graph 3 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by UAA class



Source: our elaboration on FADN and SDI data.

4. Discussion and conclusions

To date, regional water policy in Valle d'Aosta does not comply with the WFD guideline, since farmers are required to pay only for the management and maintenance service costs borne by the consortia, while environmental and resource costs are waived. Often, even the coverage of the consortia costs is not due because they are partly borne by the regional administration and partly compensated by the work provided by the farmers on a voluntary basis, through the traditional and well-established practice of *corvées*. Specific research should be carried out to estimate the monetary value of farmers' labor devoted to the maintenance of the water network, but also such practices are not sufficient to meet the requirements of the Directive (again, the costs would only be partially recovered).

Based on the currently available data (i.e, the maintenance and service costs borne by the LIC), a scenario where LIC costs were fully borne by farmers was simulated. The consequent changes in the water costs-to-income ratio were modeled under four alternative cost scenarios. Through associating FADN economic and technical data from a significant sample of regional farms with irrigation water cost data extracted from the regional SDI database, a proxy for irrigation water costs was derived and the ratio was estimated. The costs included outlays for management, operation, and ordinary maintenance of land improvement work paid for by the LIC. The approach described provides a novel method on how to integrate FADN data with other administrative data sources as the EU strongly recommends (European Commission, 2020).

Water costs, estimated as a percentage of farm income, averaged 2.65%. In instances in which a portion of the cost is subsidized by the regional administration, then the estimated value falls to 1.06%. Estimations were made under the conservative assumption that all LIC costs were borne by farmers, therefore the share of maintenance and service costs for irrigation is likely to be slightly overestimated. Nevertheless, these values are significant, especially given that in the regional farms the total variable costs (including the cost of casual labor) vary between 25 and 41% of the net farm income, depending on the TFs (Arzeni, 2020). Notwithstanding, based on the WFD guidelines, these ratios are underestimated as they fail to include environmental and resource costs. Hence, it can be assumed that full cost recovery as defined in the Directive might not be economically and socially sustainable. These results seem to confirm the concerns over the affordability of water costs, as farmers may not be able or willing to pay such increase in operating expenses.

Results also showed that the estimates vary when farm data is categorized and aggregated by ES, UAA, and TF class. In general, estimates under different scenarios varied significantly from the average values when farms were aggregated by UAA and TF. Alternatively, ES differences seemed to affect costs less under the different scenarios. In particular, farms larger than 15 ha bore higher irrigation costs (up to 4.34% of farm income). With respect to TF, higher outlays were estimated for grazing livestock farms (up to 3.96%).

The results indicate that extensive farming systems practiced on large farms seem to be most affected by introduction of water pricing policies. For the mountain areas in the Aosta Valley, this is especially important. There, extensive livestock farming is the most widespread and least profitable type of farming; vineyard farming represents a relatively small secondary type of farming. In mountain areas characterized by natural disadvantages, livestock farming is often the only practicable TF that can provide and maintain several ecosystem services, such as biodiversity and water flow regulation, as well as landscape, recreational, and cultural benefits (Herzog *et al.*, 2018; Orlandi *et al.*, 2016; Battaglini *et al.*, 2014). The trade-off between water irrigation for societal and environmental benefits must be carefully weighed against their environmental costs when setting water policy.

High (and underestimated) water costs in extensive TFs and complex estimations in mountain areas raise concerns about WFD implementation in such territories. Indeed, introduction of a water pricing policy in marginal areas, as defined by the Directive, may hasten current traditional farming practice declines and rural depopulation with negative effects on the economic vitality of local communities and on social and environmental benefits related to irrigation.

References

Arzeni, A. (a cura di) (2020). *Le aziende agricole in Italia - Rapporto RICA 2020.*

Battaglini, L., Bovolenta, S., Gusmeroli, F., Salvador, S. & Sturaro, E. (2014). Environmental sustainability of Alpine livestock farms. *Italian Journal of Animal Science*, *13*(2), 3155, doi: 10.4081/ijas.2014.3155.

Bazzani, G.M., Di Pasquale, S., Gallerani, V. & Viaggi, D. (2004). Irrigated agriculture in Italy and water regulation under the European Union water framework directive. *Water resources research*, *40*, doi: 10.1029/2003WR002201.

Bazzani, G.M., Di Pasquale, S., Gallerani, V., Morganti, S., Raggi, M. & Viaggi, D. (2005). The sustainability of irrigated agricultural systems under the Water Framework Directive: first results. *Environmental modelling & software*, *20*, 165e175, doi: 10.1016/j.envsoft.2003.12.018.

Capitanio, F., Di Falco, S., Zucaro, R. & Zilberman, D. (2007). Italian agriculture in the context of climate change: the role of irrigation for sustainable development of rural areas. *IPCC (International Panel on Climate Change).*

European Commission (2000). Communication from the Commission to the Council, the European Parliament and the economic and social committee. Pricing policies for enhancing the sustainability of water resources. Brussels, 26.07.2000, COM (2000) 477 final.

European Commission (2019, last-modified). Introduction to the EU Water Framework Directive. -- Available online: https://ec.europa.eu/environment/water/water-framework/info/intro_en.htm (accessed on 19 December 2020).

European Commission (2019). Report from the commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans. Brussels, 26.2.2019, COM(2019) 95 final.

European Commission (2020). Data management for the assessment of RDP effects. Report of the Good Practice Workshop, 13-May 2020. -- Available online: https://enrd.ec.europa.eu/sites/default/files/evaluation_publications/gpw13_online_0.pdf (accessed on 03 May 2021).

FADN (2018). Farm Accounting Data Network An A to Z of methodology. -- Available online: https://ec.europa.eu/agriculture/rica/pdf/site_en.pdf (accessed on 20 November 2020).

Florio, M. (2013) Corvée versus money: micro-history of a water infrastructure in the alps, the rû courtaud 1393-2013 Working Paper n. 2013-02, doi: 10.13140/RG.2.1.1081.4481.

Francois, A. & Garello, A. (2004). *Sistemi Idrici Alpini, Identità e Problemi di Conservazione Antichi Canali Irrigui in Valle D'Aosta e in Valle Di Susa*, Print.

Galioto, F., Marconi, V., Raggi, M. & Viaggi, D. (2013). An assessment of disproportionate costs in WFD: the experience of Emilia-Romagna. *Water*, *5*, 1967-1995, doi: 10.3390/w5041967.

Gòmez-Limòn, J.A. & Riesgo, L. (2004). Water pricing: Analysis of differential impacts on heterogeneous farmers. *Water resources research*, *40*, doi: 10.1029/2003WR002205.

Herzog, F. & Seidl, I. (2018). Swiss alpine summer farming: current status and future development under climate change. *The Rangeland Journal*, *40*, 501-51, doi: 10.1071/RJ18031.

Istat (2010). Datawarehouse agricultural census 2010. -- Available online: http://dati-censimentoagricoltura.istat.it/Index.aspx (accessed on 20 January 2021).

Kampas, A., Petsakos, A. & Rozakis, A. (2012). Price induced irrigation water saving: Unraveling conflicts and synergies between European agricultural and water policies for a Greek Water District. *Agricultural Systems*, *113*, 28-38, doi: 10.1016/j.agsy.2012.07.003.

Massarutto, A. (2003). Water pricing and irrigation water demand: economic efficiency versus environmental sustainability. *European Environment*, *13*, 100-119, doi: 10.1002/eet.316.

Orlandi, S., Probo, M., Sitzia, T., Trentanovi, G., Garbarino, M., Lombardi, G. & Lonati, M. (2016). Environmental and land use determinants of grassland patch diversity in the western and eastern Alps under agro-pastoral abandonment. *Springer Science+Business*, *25*, 275-293, doi: 10.1007/s10531-016-1046-5.

RAVA (2019). *Progetto di aggiornamento del Piano di Tutela delle Acque, Relazione generale, Assessorato opere pubbliche, territorio ed edilizia residenziale pubblica*. Aosta Valley.

Regione Valle d'Aosta (2018). SCT, GeoPortale. -- Available online: https://geoportale.regione.vda.it/informazioni/progetto-sct (accessed on 15 January 2021).

Regione Valle d'Aosta (2021, last-modified). Consorzi di Miglioramento Fondiario. -- Available online: www.regione.vda.it/agricoltura/CMF/default_i.aspx (accessed on 13 May 2021).

Seroglia, G. & Zucaro, R. (2009). *Monitoraggio dei sistemi irrigui delle Regioni centro settentrionali, rapporto sullo stato dell'irrigazione in Valle d'Aosta*. Rome: INEA.

Trione, S. (2020). *L'agricoltura nella Valle d'Aosta in cifre 2020*. Rome: CREA.

Vrolijk, H. & Poppe, K. (2020). Impact of off-farm income and paid taxes on the composition and volatility of incomes and wealth of dairy farmers in the Netherlands. *Studies in Agricultural Economics*, *122*, 57-65, doi: 10.7896/j.2046.

Zucaro, R. (2014). *Condizionalità ex-ante per le risorse idriche: opportunità e vincoli per il mondo agricolo*. Rome: INEA.

Patrizia Borsotto
Researcher - CREA, Council for Agricultural Research and Economics, Research Centre for Agricultural Policies and Bioeconomy
Strada delle Cacce, 73 - 10135 Torino, Italy
E-mail: patrizia.borsotto@crea.gov.it

Patrizia Borsotto is a researcher with a degree in Agricultural Science and a PhD in Agricultural economics at CREA, Research Centre for Agricultural Policies and Bioeconomy. She has been involved in scientific research since 2001, following four main research fields:

- agricultural policies at EU and national level: with a special focus on organic agriculture, innovation, peri-urban and urban agriculture, cooperative and interactive strategies to improve local agricultural systems;
- microeconomic analysis of agriculture: farm level economic analysis to evaluate sustainability using also FADN data;
- the Agricultural Knowledge and Innovation System (AKIS) and its implications on agricultural productivity and sustainability;
- social agriculture both for the inclusion of vulnerable people in agricultural activities and for the improvement of social capital at local level (policies, land use, products);

At international level, she spent a 6-months working period at the DG AGRI – L1 Agricultural Policy Analysis and Perspectives, 4-months at the ICAAM (Institute for Mediterranean Agrarian and Environmental Science) of University of Evora and she collaborates in international projects in Polonia, North Macedonia and Algeria. Currently, she is actively involved in several H2020 projects: like Excalibur, Agrobridges projects.

Francesca Moino
Intern - CREA, Council for Agricultural Research and Economics, Research Centre for Agricultural Policies and Bioeconomy
Strada delle Cacce, 73 - 10135 Torino, Italy
E-mail: francesca.moino@crea.gov.it

Francesca Moino graduated in September 2020 in Agricultural Science with a thesis entitled "Analysis of social benefits of irrigation water use and estimation of a water payment impact on farmers' income in Aosta Valley". After her graduation, she continued to follow the project of her thesis thanks to an internship at CREA, Research Centre for Agricultural Policies and Bioeconomy started in February 2021.

Silvia Novelli
Assistant Professor - University of Turin - Department of Agricultural, Forest and Food Sciences (DiSAFA),
Largo Paolo Braccini, 2 - 10095 Grugliasco (TO), Italy
E-mail: silvia.novelli@unito.it

Silvia Novelli graduated in 1996 in Forest Science at the University of Torino. PhD student in 'Agricultural, Forest and Food Sciences' at the University of Torino. Between 1998 and 2003 held some research grants for different research institutes in Italy: National Research Council (CNR) - Institute for Agri-silviculture, University of Torino - Dept. of Agricultural, Forestry and Environmental Economics and Engineering, and National Institute of Agricultural Economics (INEA). Employed as a Research Technician at the Research Centre for Rural Development of Hilly Areas (University of Torino) from 2003 to 2011, she was appointed as Director in-charge of the Centre in 2005 and reconfirmed up to 2016. From 2012 up to now she is researcher (Assistant professor) in 'Agricultural Economics and Rural Appraisal' at the Dept. of Agriculture, Forest and Food Sciences (University of Torino). Her teaching experience includes 'Forest and environmental policy instruments and valuation of ecosystem services', 'Environmental economics' and 'Farming system sustainability evaluation'. Her current main research interests focus on consumer/producer behavior, alternative food networks and economic evaluation of environmental goods and services.