# Water management for agriculture in a Mediterranean area: The case of processing tomatoes in Italy

ROBERTO HENKE*, EMANUELA BURGIO**, CRISTINA VAQUERO-PIÑEIRO***

DOI: 10.30682/nm2502h
JEL codes: C31, O13, Q12


### *Abstract*

*Unpredictable climate variations, including severe droughts and heat waves, pose significant challenges to agricultural water management and threaten the economic sustainability of farmers. This study examines the effects of different irrigation methods and water supply services on the economic performance of farmers in the processing tomato sector, using micro-level data from the Italian Farm Accountancy Data Network (FADN) from 2008 to 2021. The analysis reveals economic benefits generated by adopting a self-supply water management strategy and more sustainable irrigation techniques (micro-irrigation), especially in regions experiencing acute droughts and higher temperatures. Findings emphasize the importance of considering the region-specific context when implementing policy interventions, technological innovations, and governance structures, particularly in Mediterranean countries where water scarcity increasingly restricts agricultural output.*


***Keywords***: *Agricultural water management, Processing tomato industry, Adaptation measures, FADN, Italian agriculture.*

## 1. Introduction

Agriculture remains one of the main sectors in Mediterranean countries that face binding limits on water scarcity. Climate change and warm heat are exacerbating water stress, highlighting more and more that irrigated agriculture will be essential to guarantee food security and farmers' income sustainability in the future (World Bank, 2022a). Even if rainfed agriculture remains the predominant agricultural production system worldwide – 78% of world agricultural land (FAO, 2021) –, a permanent source of irrigation is becoming necessary to maintain productivity and sectorial competition also in temperate zones. According to the Food and Agriculture Organization (FAO, 2021), in the Mediterranean basin, 17% of agricultural land is irrigated in West and Central Europe, compared to 31% in North Africa. The challenges posed by climate change are, in fact, constantly increasing the demand for agricultural water, especially for water-intensity crops.

Water scarcity, affecting agricultural produc-

* CREA – Centre for Policies and Bioeconomy, Rome, Italy.
** University of Tuscia, Viterbo, Italy.
*** Department of Economics and Rossi-Doria Research Centre, Roma Tre University, Rome, Italy.
Corresponding author: roberto.henke@crea.gov.it

tivity, is limiting the capacity of local systems to respond to consumers' demand while increasing the import dependence from other countries. As a result, sustainable irrigation strategies will be pivotal not only to climate change adaptation and mitigation but also to support the economic competitiveness of local agrifood systems and farmers' income. The economic resilience of local systems will depend on the adoption of water management models and irrigation systems capable of considering all the sustainability dimensions comprehensively and harmoniously. The relationship between economic activities and water consumption is, thereby, emerging as a central concern within the broader environmental issues, positioning it as a strategic objective in the green transition of Mediterranean agri-food systems. To improve the efficiency of water governance in the agriculture sector policies should consider both demand and supply side (Behera *et al.*, 2023; Shiferaw *et al.*, 2023; Tran & Cook, 2023), looking also at the non-conventional grey solutions (e.g., Tran & Cook, 2023).

Irrigation schemes and water governance strategies are the main channels along which policy interventions may build economic resilience to water shocks and stresses, indeed.

On the one hand, the adoption of different irrigation technologies (e.g., micro-irrigation *vs* sprinkler) will operate at the farm level and affect how water resources are managed by farmers. On the other hand, the establishment of efficient and harmonised regional/national water distribution services may guarantee the availability of water and its fair allocation by crops' irrigation water requirements and their economic returns. As recently described by Scatolini *et al.* (2024) irrigation water requirements affect crops' economic value and "*the estimation of the socio-economic effects of specific irrigation techniques should be addressed by agricultural economists*" Scatolini *et al.* (2024, p. 18). Evaluating the economic impacts of agricultural water management and irrigation strategies is, however, a complex task, and there is currently no consensus on the appropriate methods or criteria for such assessment.

In this context, this paper aims to investigate the relationships between different irrigation schemes, supply irrigation services and the economic sustainability of Italian farmers specialised in a water intensity specialisation: the processing tomato industry.

Italy is the ideal empirical setting for several reasons. First, Italy is the EU country with the highest number of irrigated plots which are watered at least once a year, with peaks in the spring and summer seasons (Wriedt *et al.*, 2009; CREA, 2023). Second, it is one of the Mediterranean countries most actively engaged in high-value-added production, due to its leadership in both the processing and processed agrifood sectors. Among them, the processing tomato industry (e.g. tomatoes used for pulp, peeled tomatoes, purees and ready-made sauces), is a strategic market for the Italian agrifood sector competitiveness, at both national and international levels. In 2023, Italy dedicated approximately 68,500 hectares to cultivating tomatoes for processing, with an increase of around 5% compared to 2022. However, in the same year, the production (5.4 million tonnes) registered a decrease of 1.3% mainly due to the extreme climatic events and an unfavourable climate that have led to a decline in the production yield per hectare (Cammarano *et al.*, 2022).

Over the years, the literature demonstrated that environmental production inputs, like water, represent a key factor for economic sustainability, given their higher volatility and dependence on climate change in comparison with other artificial inputs (e.g., fertilizers). In the case of water, it is a necessary input, very often characterised by low substitution rates, which might yearly determine the land productivity rate, the amount of production and its economic value and the productivity rate. In this sense, adopting different irrigation techniques and water management strategies may generate economic value and prosperity for farmers. The economic sustainability of agriculture holdings is nowadays constantly endangered by climatic conditions, which are exacerbating farmers' entrepreneurial risks. In Italy, over the last few years, agriculture has faced threats from unpredictable climate variations, especially in temperature and precipitation. Overall, all regions have witnessed a rise in severe drought profoundly affecting crop yields in some of the most agriculturally crucial areas of the country. These climatic conditions have affected irrigation strategies and local water availability, posing location-specific challenges for agricultural production, and affecting prices and economic outputs (ISTAT, 2021). Several are the economic variables that the literature has defined as good proxies of economically sustainable targets (Sardone *et al*., 2023), such as Gross Sealable Production (GSP) and Value Added (VA), and all of them might be, at least theoretically, affected by the availability of water.

From the EU policy perspective, keeping together economic and environmental objectives is becoming a target goal, with a growing integration of economic and environmental tools, as shown in the new Green Deal, the Farm to Fork strategy and the 2023-2027 Common Agricultural Policy (CAP) programming period (Henke *et al*. 2018; Henke *et al*., 2023). All these documents advocated for new adaptation and mitigation strategies, with the general aim of improving the resilience of agriculture, while fostering the economic competitiveness of the sector (Seneviratne *et al*., 2015).

The main contribution of the paper is providing evidence about the adoption of micro-irrigation, which seems to positively support the economic sustainability of farmers involved in the tomato industry. This evidence is in line with the goal of the new CAP of reducing the volumes of water while keeping in or even increasing, the economic performance of farmers thanks to more efficient use of water.

However, some regional heterogeneity emerges suggesting the need to reflect on the territorial dimension of water governance efficiency. The approach to tailor interventions to crop and territorial species, which is already implemented for other agricultural policy measures, may, in fact, lead to more sensitive strategies that contribute to implementing a more rational and sustainable use of water for irrigation.

Products, such as ready-made tomato sauces and pulp, represent a key driver of the Italian economic value and competitiveness for the agrifood sector, in both domestic and international markets. Given the water intensity requirement of this crop (i.e., tomato), addressing water scarcity and extreme precipitation events is becoming not only an agronomic challenge (Donati *et al*., 2023) but also an economic one (Mantino *et al*., 2018). In the long run, a production reduction may lead to an increase in terms of prices and, consequently, determine a change in the economic nature of this good, from a normal good to a luxury one. On the one hand, converting this farming activity into a niche market may help Italian producers differentiate and diversify their products based on their quality and geographical origin. On the other hand, however, the risk may be to be crushed by the cheaper international competitiveness. However, the positive relation between new irrigation techniques and the GSP, found in this study, leaves some optimism about the possibility of not excessively limiting production.

The paper is structured as follows. Section 2 introduces the literature and contextual framework, with a specific focus on the sector under analysis. Section 3 presents the empirical setting, data and methodology, while Section 4 describes the results. The conclusion provides some final remarks and policy advice.

## 2. Literature review and contextual framework

Agriculture is responsible for 24% of the current extraction of water in Europe, with Italy, Spain, Greece, France, and Portugal accounting for 96% of the total extraction (European Environmental Agency Water Resources Across Europe, 2021). Considering the projected increases in temperatures and droughts in the coming years (Mirra *et al*., 2023; Fallon *et al*., 2010), water stress has now become a more permanent condition rather than an occasional event, making irrigation a necessary condition for the sector. Contrasting water stresses through governance and management strategies and irrigation techniques are becoming, therefore, a crucial topic in the political and academic debate about the sustainability of agrifood systems (Martin-Ortega *et al*., 2011; European Environmental Agency Water Resources Across Europe, 2021)[1].

### 2.1. *Water management and irrigation techniques*

The economic sustainability of farmers could be affected by the implementation of different water management strategies and irrigation techniques. Water represents, in fact, not only a cost but also a necessary production factor without which tomato production cannot be guaranteed. The uneven distribution of water in different regions of the world, including Europe, and the growing competition for water use, call for sustainable management of available water resources, at different territorial levels considering specific strategic options: from "virtual water" to improved efficient use of irrigation water, to recycling and depollute water making it available again for irrigation and drinking uses (Qadir *et al*., 2003). Research on water management and efficiency has improved substantially in the last years and is more and more oriented to better understand how the complex interactions between different uses of water and agriculture productions may develop over the coming decades and the consequent social, political, and environmental implications (Cosgrove and Loucks, 2015).

Among others, Mendicino *et al*. (2008) underlined how a reactive approach to prolonged water shortage is not particularly appropriate in a context where water is scarce, such as the Southern regions. Conversely, adopting a proactive approach, based on mitigation measures with the direct and constant involvement of all the stakeholders, should reduce the levels of subjectivity, while increasing transparency and participation by leading to optimistic results in terms of water management. Vanino *et al*. (2015) studied the implementation of Earth Observations (EO) techniques which result to be highly responsive to irrigation issues and water management in water scarcity territories. These techniques combine technical information, such as weather parameters and crop characteristics, with management and environmental factors, helping to implement more efficient water use. Staccione *et al*. (2021) investigated water retention ponds in the North and demonstrated that investment costs and running costs are relatively modest, considering the benefits in terms of an increase in agricultural production and the provision of ecological services. Water retention ponds are, in fact, not only water stocks but also a potential ecological source of biodiversity and micro-habitats.

From the governance perspective, the strategies adopted are characterised by different strengths and weaknesses. Collective supply services are more suitable to manage water distribution and respond more efficiently to water scarcity crises. These services are assumed capable of achieving higher levels of distribution efficiency (Manganiello *et al*., 2022; Scardigno *et al*., 2011) and environmental sustainability (Dono *et al*., 2014), thanks to their centralised nature and top-down management. Economies of scale can, in addition, reduce extraction and distribution costs. Planned collective supply management allows farmers to use surface water, rather than deep water from the aquifer, which significantly reduces the risk of subsidence. However, the quantity of water provided by *Consortia* is often not sufficient, so farmers need to obtain water also from private wells, with significant effects on the impoverishment of the aquifers and the unsustainable use and distribution of water (Giannoccaro *et al*., 2019). The implementation of collective services, however, needs to be implemented with caution, given that, the increasing extreme climatic events that are affecting Mediterranean areas may require a

[1] Water scarcity implies a condition of seasonal, annual, or multiannual stress, caused by anthropic activities, due to a systematic excess of demand compared to the supply capacity of a natural system, which in turn depends on the relationship between renewable reserves and the extraction and use of water. Drought, instead, is a natural and temporary phenomenon occurring when the average water availability reduces due to a scarcity of rainfall (European Environmental Agency Water Resources Across Europe, 2021). Drought can be aggravated in a situation where water scarcity is frequent and the unbalance between water demand and the supplying capacity of the natural system.

just-in-time response, which a collective supply of services is always not capable of providing.

Conversely, farmer-led water provision, for which users are not subject to *Consortia* regulations and timelines, leads to lower costs, guarantees just-in-time provisions and offers high-quality water, especially in the short run (Sardaro *et al*., 2020; Tauro *et al*., 2024). This difference in water quality may be capitalised in land value, becoming an additional source of economic benefit for farmers (Tauro *et al*., 2024). In sum, the choice between collective and self-supply irrigation from private wells represents a key challenge for both farmers, who would like to reduce the time of provisions, and policymakers, who must design efficient and inclusive market regulations.

At the same time, the adoption of different irrigation techniques has also become crucially important. Producers of processed tomato production mainly adopted sprinkler irrigation and micro-irrigation (Manganiello *et al*., 2022)[2]. On the one hand, sprinkler irrigation is particularly useful in areas where water is scarce or where the terrain is not suitable for traditional surface irrigation methods. Sprinkler irrigation can be automated and adjusted to supply precise amounts of water, making it an efficient and effective irrigation technique. On the other hand, micro-irrigation is suitable to address water scarcity given that it minimises evaporation and runoff, making it more water-efficient than traditional surface irrigation methods. A relevant stream of studies focused on this issue, and in particular on the improvement in irrigation efficiency at the field level, analyzing the so-called "rebound effect", according to which an improvement in efficiency does not necessarily translate into a reduction of the consumption of water (Berbel *et al*., 2018). Following these authors, to properly study the relationship between efficient irrigation and water consumption a set of tools needs to be considered, such as the potential area irrigated, the crop changes and also market forces.

## 2.2. *The economic effects of water use*

With specific regard to the economic effects of water scarcity, some papers exist that looked at the relationship between water issues and economic performances in Mediterranean countries. Babovic *et al*. (2009) worked on the economic efficiency of irrigated and dry crops in a local area in Serbia (Vojvodina), comparing data and analysing the economic performance before and after the introduction of irrigation. Results show a positive effect of irrigation on production yield and farm profitability. Ruberto *et al*. (2022) looked at the use of water in agriculture in the Veneto region in Italy with microdata (source: FADN), showing that irrigation increased the value of agriculture turnover. Lopez-Serrano *et al*. (2021) assessed the use of reclaimed water in greenhouses used in agricultural production in a region of Southern Spain (Almeria), which has positive effects not only on the quantity of water saved but also on the quality of soils. Other studies have investigated the economic benefits of water requirements and irrigation strategies. Lopez-Mata *et al*. (2019) built an integrated framework to predict the direct economic impacts of drought on irrigated agriculture, concluding it is relevant in terms of production loss. Giannoccaro *et al*. (2019) empirically assessed the impact of the reduction of water availability on tomato production in the *Capitanata* area in the Italian Apulia region showing that drought has caused losses of 30% compared to years with regular water availability. Alobid *et al*. (2022) worked on the efficient allocation of water in Southern Italy, looking at farmers' productivity and comparing scenarios aimed to achieve the most suitable set of decisions that fulfil the best goal in terms of efficient use of water. More recently, Scatolini *et al*. (2024) estimated the impact of crops' irrigation water requirements on economic value (i.e. yields and gross saleable production) in the Emilia-Romagna region sug-

[2] Sprinkler irrigation is a method of distributing water to crops like natural rainfall through a system of pipes, usually by pumping, and then sprayed into the air through sprinklers so that it breaks up into small water droplets that fall to the ground. Conversely, micro-irrigation is a method of distributing water directly to the root zone of plants.

gesting that, in water scarcity conditions, the allocation of water to permanent crops generates economic benefits also for small quantities of water.

Looking at the tomato sector, existing papers about the evaluation of the effects of different irrigation systems are even more scant and rarely focus on economic outcomes.

While Giannoccaro *et al*. (2019) investigated the impact of the reduction of water availability on the quantity of production, Rinaldi *et al*. (2009) estimated the effect on biomass, berry production and water use efficiency. They also included an analysis of the consequences on net agricultural income. Cammarano *et al*. (2022) studied the effect of climate change on the quantity of water used in processing tomatoes in South Italy (Campania region), showing that an increase in irrigation water does not translate into a growth of production and yields. In a different context, Rogers *et al*. (2014) worked on the choices of irrigation systems in the production of processing tomatoes in Florida, US. They showed how the switch to more efficient irrigation systems led to increases in production and quality, at the same time reducing energy costs and the quantity of water.

Other studies combine the sectoral analysis of the processing of tomatoes with the application of specific methods of irrigation and techniques. This is the case for Pandey *et al*. (2018), who investigated the economic effect of wire and wire drip irrigation on tomato crops in India, showing the economic advantages of the former compared to the latter, all other terms being equal. El Chani *et al*. (2023) focused on a water management issue, focusing on the optimization of applied irrigation water for different high-quality products, including processing tomatoes, concluding that low-cost wireless soil moisture sensors are effective in managing the level of irrigation by optimising the processing tomato yield and the economic benefits for farmers.

Despite the growing literature, a detailed empirical analysis of the relationship between the localisation of crops, sources of water, on-field irrigation systems and economic performance of farms does not exist so far. In this paper, we try to disentangle these complex relations, which are particularly relevant for a crop that is one of the most important Italian value chains.

## 3. Processing tomato growing, and water needs in Italy

Italy is firmly confirmed to be the third-world producer and processor of tomatoes, after the USA and China, with 6.6 million tons and a total value of 1.3 billion euros in 2021-2022 (Cammarano *et al*., 2022). The Italian sector maintains the leadership also in terms of international competition, with 2.8 million euros of exports in 2023 (ISMEA, 2024). Over the years, there has been, however, a decline in production, influenced by various factors. First, there was a progressive replacement of lower service-content products (pulp and peeled tomatoes) with higher service-content products (purees and ready-made sauces), which include a lower percentage of tomatoes. Second, changes in consumer behaviours have led to a gradual reduction in the number of meals consumed at home, in the time dedicated to preparing meals and in the use of tomato sauces, replacing them with other types of condiments. Third, even if the level of CAP funds destined for this sector in Italy remains the highest among EU countries, there was a decrease in absolute terms of the amount of public support (Arfini *et al*., 2011; Kierczynska, 2015)[3]. Lastly, the recent increasing temperatures and water stress conditions have even more affected the production capacity. Tomato is, in fact, a

[3] At the EU level, Italy remains the main beneficiary of the CAP support for the sector, through two main channels: the common market organisation (CMO) measures and the rural development programmes [28]. Funds from the CMO are mainly oriented to producer support and consumer behaviour (e.g. *Fruits in the school* EU programme (*Commission Implementing Regulation (EU) 2017/39 of 3 November 2016 on rules for the application of Regulation (EU) No 1308/2013 of the European Parliament and of the Council about Union aid for the supply of fruit and vegetables, bananas and milk in educational establishments (OJ L 5, 10.1.2017, p. 1)*). Conversely, resources coming from the rural development programmes mainly address support quality productions (e.g. quality schemes) and innovation diffusion.

water-intensive crop that requires to be irrigated and that is negatively reacting to climate changes and extreme events (e.g., precipitations) (ISTAT, 2023). Unconventional water use is not allowed (e.g., wastewater), leaving water allocation and management decisions strategic for this sector.

In Italy, Piacenza is the area where at the turn of the twentieth century the industry of processing was born, becoming a virtuous example of a localised agri-food system characterised by the interaction between private and public actors. Nowadays, the production is mainly concentrated in two regions: Emilia-Romagna in the North (provinces of Piacenza, Parma and Ferrara) and Apulia in the South (province of Foggia) (Table 1)[4].

These two regional systems differ quite substantially in terms of agricultural water needs, consumption, and distribution (Zucaro, 2011). For example, Apulia requires large amounts of irrigation due to the scarcity of water and the higher temperatures. From the irrigation governance perspective, the main difference regards the distribution services adopted. While in Emilia-Romagna the distribution of agricultural water is mainly managed collectively, in Apulia it relies on self-supply services, despite an increase in the water provided by *Consortia.* In Italy, the institutional bodies responsible are the so-called *Consorzi di Bonifica e Irrigazione* (Land Reclamation and Irrigation Consortia), which manage the distribution and allocation of water, whereas in the case of farmer-led irrigation farmers who have obtained the concession to pump water are responsible for all the process and all the costs for the sourcing, catchment and distribution of the resource. The diffusion of *Consortia* in Italy can be assumed as a good practice of institutional references for water management that could create the conditions in which farmers can adopt more sustainable practices on a large scale, obtain training and technical assistance, establish incentives for rational irrigation, and promote water-efficient practices through shared regulations and standards.

Table 1 - Processing tomatoes in Italy (2021).

| | *Area (thousand ha)* | *Production (tons)* | *Yield (kg/ha)* |
|---|---|---|---|
| North | 38,621 | 3094 | 80.1 |
| South | 32,569 | 2484 | 91.2 |
| Italy | 71,19 | 5578 | 85.2 |

*Source: Authors' elaboration from Eurostat and OI Processing Tomato data.*

Regarding irrigation technologies, while in Emilia-Romagna sprinkler irrigation is the most common irrigation system, in Apulia micro-irrigation prevails, confirming the preference for micro-irrigation as a suitable approach to contrast higher temperatures. At the same time, the water scarcity affecting the Southern part of the country is reflected by the fact that the average number of irrigation days in Apulia is lower than in Emilia-Romagna, 5 days and 20 days respectively[5].

Due to the economic value of tomato processing production for Italy, its high-intensity water requirements and the actual water scarcity challenge, understanding the potential consequences of different water management strategies with a broader spectrum of analysis, is crucial as never before. The new Italian strategic plan of the CAP 2023-2027 is the first attempt in this direction. It explicitly underlines how in the case of: "*the standard cultivation technique* [for processing tomato production] *involves the use of irrigation methods aimed at conserving water resources (micro-irrigation)*"[6]. However, how supporting farmers to achieve this objective is not mentioned, and there are no funds specifically targeting this issue to compensate for the economic discrepancy (i.e., fixed costs and initial investments).

## 4. Research design

To conduct the study, this paper uses a micro-level dataset at the farm level and exploits panel-fixed effects models to isolate the effect of irrigation schemes and water services on

[4] Province corresponds to the NUTS3 level according to the EU territorial nomenclature.
[5] Data on irrigation water days is available only from 2019 to 2021.
[6] IT 628 IT PD 06 - CIS(04) - *Sostegno accoppiato al reddito per superficie - Pomodoro da trasformazione*.

the economic performance of farms, measured through three key indicators: (i) Gross Sale Production (GSP), (ii) Value Added (VA), and (iii) net income (NI). Unlike previous research, which has primarily concentrated only on a single specific case (e.g., Giannoccaro *et al.*, 2019) or not EU countries (Benmehaia and Brabez, 2018), this analysis encompasses all major production regions in Italy, thereby utilizing a substantially larger sample and providing more comprehensive insights into the sector's economic dynamics.

### 4.1. *Data and sample*

Data have been collected from the Italian Farm Accountancy Data Network (FADN), which is the primary source of annual micro-economic data for agricultural holdings within the EU[7]. This dataset allows us to account for the socio-economic dimension of farming and to obtain the needed information to account for the economic performances of farmers[8]. Data on climatic conditions have been collected from the ISTAT database, which provides information for temperature and precipitations at the NUTS3 level[9]. The climate context by which a farmer is affected has been determined by the *Provincia* (NUTS3) where the farmer is located.

Starting from the entire Italian FADN sample, we intentionally constructed our sample by selecting for each year all the farms involved in the tomato for industry production (>=1 ha) and located in Emilia-Romagna (North) and Apulia (South). The final sample is an unbalanced panel from 2008 to 2021 that includes for each year around 50 farms (734 observations in total)[10]. The regional distribution accounts for 68 per cent of farms in Emilia-Romagna, while 32 per cent in Apulia, with Foggia (Apulia) and Piacenza (Emilia-Romagna) as the NUTS3 with the highest concentration of farms[11].

Overall, over the years under analysis, there was an overall increase in the absolute value of UAA-dedicated tomatoes for procession in the sample, with, however, a constant average value by farms. If we look at regional statistics, both the absolute and the mean values had been higher in Emilia-Romagna than in Apulia. The absolute value of irrigated UAA for processed tomatoes increased, as well as the share of irrigated UAA (i.e., the share of the irrigated UAA dedicated to tomato for the procession on the UAA dedicated to this production). While Emilia-Romagna accounted for the highest average absolute value of irrigated land, the share of irrigated land for processed tomatoes is higher in Apulia.

The farmers' specialisation (i.e., the share of UAA dedicated to tomato for procession) remained quite constant over time, with an average value of 30 per cent. Regarding water, the total amount of water used for this crop increased by 32 per cent[12]. The average amount of water used in the regions under analysis is

[7] The Italian name is *Rete di Informazione Contabile Agricola (RICA)*.

[8] The Italian FADN includes all farms that achieve a threshold of standard output of a minimum of 8,000 EUR. Consequently, smaller farms are excluded from the sample. The economic dimension is defined as the sum of the standard output values of all agricultural activities carried out on the farm, and its value is expressed in euros. More information is available at: https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html.

[9] More details: https://www.istat.it/tavole-di-dati/temperatura-e-precipitazione-nei-comuni-capoluogo-di-provincia-anno-2022-serie-storica-2006-2022/.

[10] Unfortunately, the structure of the FADN dataset is not suitable for balanced panel data analysis, as the farmers surveyed change from year to year. Regarding the production specialisation, limiting the sample only to those farms specialised in tomato for processing (a threshold of 75 per cent of the share of UAA dedicated as defined by the EU) would result in a significant loss of observations: from 734 to 12.

[11] This regional difference in sample size is due to the FADN database construction. It relies, in fact, on a stratification based on three dimensions: Region, year and OTE (i.e., *Orientamento Tecnico Produttivo*). In this sense, the specific crop production is not considered in the EU sample stratification procedure. As a result, it could happen that there is heterogeneity in the regional location of farms if we focus on specific production.

[12] For FADN construction, this information is available only from 2011.

quite similar, with Apulia accounting for the highest values for all the years under analysis[13].

Regarding water management strategy, in our sample, collective management is more used in Emilia-Romagna, together with sparkling irrigation. Conversely, in Apulia private management and micro-irrigation are predominant. This evidence confirms sample validity.

The descriptive evidence can be attributed to several factors and anticipates some reflections. First, a potential increasing need to irrigate in a region characterized by severe drought, such as Apulia. Apulia accounts, in fact, not only for the highest number of hectares irrigated but also for the highest share of irrigated land. However, while the drought conditions in the Southern region are more severe, irrigation in Apulia is predominantly managed on an individual basis. Authorized farmers can withdraw groundwater and surface water as needed, without adhering to a collective plan like the one in place in Emilia-Romagna. Given that water is not entirely unavailable, farmers in Apulia likely responded to increasing droughts by extracting and using more water. In contrast, the less severe drought conditions in Emilia-Romagna may not have created such an urgent need for irrigation. The highest water need of Apulia is also confirmed by the increasing adoption of micro-irrigation techniques, which help face overall water scarcity.

Apart from the differences mentioned above, in these regions, there are some common trends related to farmers' characteristics that might affect the adoption of irrigation approaches that roll out possible sources of endogeneity making the results comparable. In both regions, family-owned is the most common ownership type of farmers, large farmers are the highest number, as well as farms with strong specialisation in comparison with diversified farms. The number of farms involved in organic production increases in both the regions under analysis. In addition, the average VA per hectare is quite similar (2.6 EUR/ha in Emilia-Romagna vs 3.3 EUR/ha in Apulia).

### 4.2. *Methodology*

To evaluate the economic effects of water supply methods and irrigation systems, this study adopts a panel-data approach with fixed effects[14]. The following model has been estimated with the constant:

$$\begin{gathered} \textit{Economic Performance}_{it} = \\ \alpha + \beta_1 \text{Collective-supply}_{it-1} + \beta_2 \text{Self-supply}_{it-1} + \\ \beta_3 \text{Sparkling}_{it-1} + \beta_4 \text{Micro-irrigation}_{it-1} + \\ \text{Controls}_{it-1} + \mu_t + \delta_{jt} + \varepsilon_{it} \end{gathered} \qquad (1)$$

where *i* is the single farm and *t* is the year of the reference.

*Economic Performance* is declined through three variables, which literature has defined as good variables to register the economic dynamics at the farm level (Sardone *et al.*, 2023)[15]: (i) the farm's Gross Sale Production (GSP) of tomatoes for the processing industry, (ii) the overall farm's Value Added and (iii) the overall farm's Net Income (NI). While the GSP refers solely to tomato production, VA and NI refer to overall farm, indeed[16].

*Collective supply* and *Self-supply* are calculated by weighting the number of Utilised Agricultural Area (UAA) hectares managed by different agricultural water supply methods (self- *vs* collective supply) on the UAA dedicated to processing tomatoes. *Sparkling* and *Micro-irrigation* are also calculated by weighting the number of UAA hectares irrigated with different irrigation systems (micro- *vs*

[13] In 2021, the difference is only 1 thousand cubic meters.

[14] Based on the Hausman specification test.

[15] For an analysis of the microeconomic variables in agriculture see the FADN website on the EU Commission portal: https://agriculture.ec.europa.eu/data-and-analysis/farm-structures-and-economics/fadn_en.

[16] Unfortunately, the FADN database does not collect VA and NI separately for different crops. Conversely, the GSP is available for each specific crop produced by farms.

sparkling irrigation) on the UAA dedicated to processing tomatoes[17].

The model is augmented by a matrix of control variables with a one-year time lag (*Controls*) that includes: the farm's physical dimension (UAA - ha), the number of workers employed, the total amount of CAP funds received (EUR), the total costs specific for water consumption in proceed tomato farming (EUR), the percentage of UAA dedicated to tomato for industry, a dummy taking value 1 for organic farms (0 otherwise) and a dummy with value 1 for diversified farms (0 otherwise). In addition, we consider the annual average (°C) of temperature and precipitation (mm) of the NUTS3 where the farm is located to account for climatic conditions that vary at the provincial level. See Tables A1 and A2 in the Appendix for definition, source and descriptive statistics. In the model, we also include year-regional fixed effects ($\delta_{jt}$) accounting for yearly cross-sectional changes varying at the regional level and year-fixed effects ($\mu_t$) for yearly cross-sectional changes such as general shocks affecting agriculture production in a specific year (e.g., economic crisis, wars)[18].

Standard errors are clustered at the NUTS3 level (Abadie *et al*., 2017).

## 5. Results and discussion

Results of the model (1) are reported in Table 2.

Starting from the governance of irrigation services, findings reveal a statistically significant effect only for self-supply irrigation services, which are positively correlated with the Net Income (*Column 3*). According to the estimations, an additional point of the share of UAA supplied through a farmer-led source, and dedicated to processing tomato, is associated with an average increase in NI value of 13.940 euros, *ceteris paribus*. There seems to be, therefore, an economic advantage in using this type of irrigation supply, rather than managing water allocation and distribution through a collective approach, confirming what literature finds for arboreal crops (olive trees) (Tauro *et al*., 2024).

The significance of the NI is particularly relevant as it reveals a channel trough which seems to be possible to positively affect the structurally weaker economic position of farmers along the supply chain. The upstream position of farmers in the supply chain based on transformation and logistic activities, such as the processing of tomatoes, tends, to reduce their market power and negatively affect their economic performances. The increasing effect of self-supply irrigation services leaves, in addition, an open door to some reflections on the efficiency of the collective management strategy implemented so far, and on the opportunities of reforming them toward a more profitable solution.

Moving to irrigation methods (sprinkler irrigation *vs* micro-irrigation), findings reveal that micro-irrigation increases the GSP of proceed tomatoes (*Column 1*). The estimate indicates that, all else being equal, an additional point of hectare irrigated with a sprinkler system, and dedicated to farming tomatoes for the processing industry, is expected to generate an average increase of around 17,110 EUR in GSP. Conversely, there are no significant effects on VA and NI.

The results presented so far seem to be promising for the transition towards more sustainable agricultural systems of proceed tomato, even if, limited at the GSP. A decreasing trend in production is, in fact, one of the criticalities that Italian

[17] Regarding the empirical strategy adopted, we would like to clarify the following. First, unfortunately, FADN does not provide hectares irrigated by crops and the related specific water sources and irrigation systems. For this reason, we decided to weigh the related variables. Second, we decide to exclude the option of accounting for different water management strategies and irrigation techniques by a dummy. Even if this choice excludes the possibility of conducting interaction analysis, from the database, we cannot isolate, the number of hectares irrigated by micro /sparkling irrigation using water coming from collective/private supply. In this way, therefore, we would have lost the detail about the magnitude of the phenomenon, reducing the analysis only in the presence of it (i.e., yes/no) and capturing the effect at an aggregate level difficult to unpack. An additional analysis has been conducted to test our hypothesis and the results confirm the relevance of using more detailed variables. However, results are available upon request.

[18] The inclusion of these variables, at least partially, reduces the omitted variables bias that can be associated with the presence of inflation and responsible for changes in production and productivity.

Table 2 - Estimation results – entire sample.

| | *Gross Sale Production (1)* | *Value Added (2)* | *Net Income (3)* |
|---|---|---|---|
| Collective supply | -1.790 | 7.770 | 3.356 |
| | (4.016) | (4.573) | (4.216) |
| Self-supply | -1.783 | 16.16 | 13.94* |
| | (4.157) | (9.533) | (7.433) |
| Sprinkler irrigation | 5.250 | -0.996 | 3.038 |
| | (4.289) | (3.575) | (6.322) |
| Micro-irrigation | 17.11*** | 1.679 | 4.473 |
| | (5.122) | (7.981) | (9.296) |
| Controls | Yes | Yes | Yes |
| Year-NUTS2 fixed effects | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 377 | 377 | 377 |
| R2 | 0.35 | 0.38 | 0.35 |

*Note: *** p<0.01, ** p<0.05, * p<0.1. The outcome variables are: (i) Gross Sale Production of tomatoes for processing (GSP), (ii) Value Added of farming activities (VA), and (iii) Net Income from farming activities (NI). They are expressed in thousands of euros. Controls include one-year time lag of the following variables: Utilised Agricultural Area, the number of workers employed, the amount of CAP funds received, the total costs specific for water consumption in proceed tomato, the percentage of UAA dedicated to tomato for industry, the percentage of UAA dedicated to tomato for industry, a dummy taking value 1 for organic farms (0 otherwise) and a dummy with value 1 for diversified farms (0 otherwise), the annual average of temperature of the NUTS3, the annual average of precipitation of the NUTS3, year-NUTS2 fixed effects and year fixed-effects. Robust standard errors in parentheses (NUTS3). The model has been estimated with constant and fixed effects.*

agriculture is facing (CREA, 2024) and, it seems that could be mitigated by new irrigation techniques. Conversely, when we extend the focus to the overall economic performance of farming, the effect is no longer significant. This evidence highlights the difficulties of achieving general spill-over economic benefits at the farm level by the adoption of more sustainable practices, suggesting a reflection on how to convince farmers to adopt innovations, given the potential limited economic benefits, at least in the short run. In the long run, a constant upward trend of GSP could compensate the highest cost of innovation and induce an increase also in farmers' remuneration and incomes.

However, the efficiency of specific policy interventions, or innovation strategies, may be affected by the institutional characteristics of the territory where it is implemented. In Italy, in fact, administrative regions maintain a certain level of legislative autonomy in water management. For this reason, we decided to investigate the regional heterogeneity by re-estimating the model separately for each region. Findings are reported in Table 3.

Looking at the agricultural water supply services, results show that in Apulia the collective supply services generate an overall higher negative effect on both VA (*Column 2*) and NI (*Column 3*) than self-supply. The effect is conversely not significant in the case of GSP (*Column 1*). In Emilia-Romagna, the only significant, and positive, effect is related to the self-supply services on NI (*Column 6*). The economic advantage of such an approach in a region mainly characterised by collective water governance can be ascribed to the just-in-time nature of farmer-led services. Starting from a baseline condition with water allocated in advance and by *Consortia* criteria, an additional positive effect can be driven

Table 3 - Estimation results – regional samples.

| | *Apulia* | | | *Emilia-Romagna* | | |
|---|---|---|---|---|---|---|
| | *Gross Sale Production (1)* | *Value Added (2)* | *Net Income (3)* | *Gross Sale Production (4)* | *Value Added (5)* | *Net Income (6)* |
| Collective supply | 17.06 | -20.84* | -27.71** | -1.879 | 5.430 | 2.160 |
| | (9.210) | (8.086) | (6.703) | (4.723) | (4.757) | (3.554) |
| Self-supply | 13.75 | -17.83* | -20.96** | -1.509 | 16.50 | 14.40* |
| | (7.280) | (7.550) | (7.361) | (5.185) | (10.03) | (7.541) |
| Sprinkler irrigation | -6.369 | 35.04*** | 37.09*** | 4.460 | -0.843 | 2.759 |
| | (4.512) | (4.835) | (6.609) | (4.877) | (4.078) | (5.840) |
| Micro- irrigation | 0.344 | 41.39*** | 47.35*** | 15.55 | -2.729 | -0.590 |
| | (4.229) | (5.697) | (7.401) | (8.413) | (7.017) | (8.924) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 147 | 147 | 147 | 230 | 230 | 230 |
| R2 | 0.46 | 0.42 | 0.37 | 0.34 | 0.41 | 0.37 |

*Note: *** p<0.01, ** p<0.05, * p<0.1. The outcome variables are: (i) Gross Sale Production of tomatoes for processing (GSP), (ii) Value Added of farming activities (VA), and (iii) Net Income from farming activities (NI). They are expressed in thousands of euros. Controls include one-year time lag of the following variables: Utilised Agricultural Area, the number of workers employed, the amount of CAP funds received, the total costs specific for water consumption in proceed tomato, the percentage of UAA dedicated to tomato for industry, the percentage of UAA dedicated to tomato for industry, a dummy taking value 1 for organic farms (0 otherwise) and a dummy with value 1 for diversified farms (0 otherwise), the annual average of temperature of the NUTS3, the annual average of precipitation of the NUTS3 and year fixed-effects. Robust standard errors in parentheses (NUTS3). The model has been estimated with constant and fixed effects.*

by the opportunity to extract water when it is needed and obtain it in a short time.

From a policy perspective, overall, looking at the potential social and environmental advantages of using collective services, this evidence suggests that, when well-managed, collective supply systems may function as an effective alternative without, however, generating substantial economic benefits. In a region such as Emilia-Romagna, historically managed through a collective approach, this governance model may become a standard governance framework that, even if without a positive impact, does not negatively affect the farmers' economic sustainability (as in Apulia).

Moving to the type of irrigation systems, findings reveal a positive and significant effect of micro-irrigation on farms' economic performances in Apulia: each additional point of the share of tomato for processing irrigated through a micro-irrigation result in an increase of 41,390 euro in VA, while of 47,350 euro in NI. Due to the highest level of drought that characterises this region, this evidence can be considered as an encouraging result for claiming in support of the positive economic consequences of the adoption of more sustainable irrigation technologies for the entire farm. The observed impact justifies and supports, the effort made by EU and international organizations towards the adoption of more sustainable irrigation services, recognised as essential to climate change mitigation (World Bank, 2022b).

The no significant impacts found in the case of Emilia-Romagna may be, at least partially, explained by the fact that large-medium farms, such as those that characterised this region, tend to be economically more robust and, therefore, potentially less financially dependent on water scarcity through new irrigation techniques. In this case, even though the adoption of more sustainable technologies does not contribute to economic value, it forever helps reduce environmental impact. The shift from more conventional irrigation techniques to micro-irrigation ones will lead to more environmentally sustainable agricultural systems, at both local and national levels (Mirra *et al*., 2021; Tauro *et al*., 2024).

## 6. Conclusions

Under the conditions of climate change, water management and irrigation practices have emerged as central issues in political and academic discussions regarding the sustainability of food production and agricultural systems (Scatolini *et al*., 2024; Donati *et al*., 2023; Martin-Ortega *et al.*, 2011). This study contributed to this debate by looking at the economic dimension of sustainability and highlighting how water issues (i.e., management and irrigation strategies) impact the economic performances of Italian farmers involved in processed tomato production.

In sum, our analysis highlighted the economic effects for farmers consequence of different agricultural water management and technologies adopted leaving two main general takeaways, which might be extended also to other crops.

First, it highlights that the adoption of different irrigation techniques became relevant for the economic consequences in territories characterised by higher temperatures, more severe water scarcity and lower levels of local added value systems (agriculture *vs* agrifood) and socio-economic development, as in the case of Apulia.

Second, the significance of self-supply services leads us to reflect on the potential diffusion of this approach in future, given the natural resources' vulnerability driven by the absence of top-down coordination. Although the study revealed that farm-led water supply is more economically advantageous for farmers, it could have negative environmental and social implications. Self-supplied irrigation is, in fact, not regulated by institutional plans and may generate quantitative and qualitative depletion of water as well as not fair management of water crisis (i.e., first comers). To avoid inefficient overexploitation of water, national and international policies might, therefore, promote the efficiency of collective services in tandem with the adoption of more innovative and efficient irrigation technologies.

This paper is fully supported by the EU and international policy debate[19]. First, agricultural water management may be ascribed as one of the policy channels through which local and national institutions may effectively shape the transition of local agrifood systems toward a more sustainable, resilient and economically fair approach. In doing this, the promotion of more innovative irrigation techniques should support practitioners and farmers in making evidence-based irrigation decisions (World Bank, 2022b). Second, both messages recall the relevance of considering where policy interventions, innovation technologies and governance structures are implemented. Our study underscores, in fact, the need for designing "water strategies" with a place-sensitive and crop-led approach. As for other objectives of political economy (Henke and Vaquero-Piñeiro, 2023; Crescenzi *et al*., 2022), the logic of simple compliance and one-sized policies, summarised as the so-called "*one-size-fits-all*", does not work (Morisson and Doussineau, 2019). This aspect is particularly relevant within the international water law and regulation framework. At the EU level, the 2024-2027 CAP programming period is going towards this new direction, developing a policy closer to territories, societal needs and social equity and inclusion, enhancing the multifunctional role of agriculture and rural areas (Wilson, 2008; Tohidyan and Rezaei-Moghaddam, 2019). A sustainable use of water not only implies a more efficient use of on-farm resources but encourages also the provisions of eco-systemic services linked to the efficient and ration-

[19] The Agenda 2030 framework fixes the sustainable management and provision of clean water (SDG 6) as one of the goals, together with the promotion of sustainable agriculture (SDG 2) and terrestrial ecosystems (SDG 15). To achieve these goals, it is needed to address water scarcity issues, while guaranteeing agricultural production and food access.

al use of water as well as agro-biodiversity for more sustainable agricultural activities.

This paper is a starting point for future research on the economic sustainability consequences of water challenges under climate change. The extension of the analysis to other crops and EU countries, also in a comparative mode, is on our future research agenda.


### *Acknowledgement*

Part of this work was funded by the Next Generation EU – Italian National Recovery and Resilience Plan (NRRP), Mission 4, Component C2, Investment 1.1, "Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale (PRIN)" (Directorial Decree n. 2022/1409) - under the project "MUlti-scale modelization toward Socio-ecological Transition for Water management (MUST4Water)", n. P2022R8ZTW. This work reflects only the authors' views and opinions, neither that of the Ministry for University and Research nor the European Commission's.


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## Appendix

Table A1 - Variables: definition, sources and units of measurement.

| | *Definition* | *Source* | *Units of measurement* |
|---|---|---|---|
| *Outcome variable* | | | |
| Gross Sale Production | Revenues strictly connected with processing tomato farming activity | Italian FADN database | EUR - thousand |
| Added Value | Added value of total farming activities | Italian FADN database | EUR - thousand |
| Net income | Net income for total farming activities | | EUR - thousand |
| *Control variables* | | | |
| Collective supply | Share of hectares managed by collective supply dedicated to processing tomatoes | Italian FADN database | Ha |
| Self-supply | Share of hectares managed by farm-led self-supply dedicated to processing tomatoes | Italian FADN database | Ha |
| Sprinkler irrigation | Share of hectares irrigated by sprinkler irrigation dedicated to processing tomatoes | Italian FADN database | Ha |
| Micro-irrigation | Share of hectares irrigated by micro-irrigation dedicated to processing tomatoes | Italian FADN database | Ha |
| Utilised Agricultural Area | Hectares of Utilised Agricultural Area | Italian FADN database | Ha |
| Number of workers | Number of people employed on the farm | Italian FADN database | Number |
| CAP funds | Amount of Common Agricultural Policy funds received by the farm | Italian FADN database | EUR |
| Water costs | Amount of cost for agricultural water dedicated to processing tomatoes | Italian FADN database | EUR |
| Specialisation | Percentage of UAA dedicated to processing tomatoes | Italian FADN database | |
| Organic farms | Dummy =1 for organic farms (0 otherwise) | Italian FADN database | |
| Diversification | Dummy =1 for the presence of diversification practices | Italian FADN database | |
| Annual average temperature | Annual average temperature for the NUTS3 where the farm is located | Authors' elaboration on ISTAT dataset | °C |
| Annual average precipitation | Annual average precipitation for the NUTS3 where the farm is located | Authors' elaboration on ISTAT dataset | mm |

Table A2 - Descriptive statistics.

| | *Mean* | *Std. dev.* | *Min.* | *Max.* |
|---|---|---|---|---|
| *Outcome variables* | | | | |
| Gross Sale Production | 136.83 | 147.90 | 0 | 1138.32 |
| Added Value | 238.16 | 509.87 | 4.36 | 10928.71 |
| Net income | 134.25 | 281.32 | -319.16 | 6358.39 |
| *Control variables* | | | | |
| Collective supply | 1.21 | 3.24 | 0 | 42.71 |
| Self-supply | 1.02 | 1.95 | 0 | 20.39 |
| Sprinkler irrigation | 1.20 | 2.88 | 0 | 42.71 |
| Micro-irrigation | 1.01 | 2.15 | 0 | 32 |
| Utilised Agricultural Area | 90.08 | 132.32 | 1.83 | 1659.24 |
| Number of workers | 4.14 | 8.09 | 0.50.50 | 131.61 |
| CAP funds | 57492.34 | 81428.2 | 0 | 787030 |
| Water costs | 1540.95 | 4369.75 | 0 | 43631 |
| Specialisation | 27.56 | 17.63 | 0.16 | 100 |
| Organic farms | 0.094 | 0.29 | 0 | 1 |
| Diversification | 0.08 | 0.27 | 0 | 1 |
| Annual average temperature | 430.83 | 700.09 | 13.78 | 1797 |
| Annual average precipitation | 2575.76 | 7418.573 | 271.7 | 78625 |

Table A3 - Estimation results with coefficients – the entire sample.

| | *Gross Sale Production (1)* | *Value Added (2)* | *Net Income (3)* |
|---|---|---|---|
| Collective supply | -1.790 | 7.770 | 3.356 |
| | (4.016) | (4.573) | (4.216) |
| Self-supply | -1.783 | 16.16 | 13.94* |
| | (4.157) | (9.533) | (7.433) |
| Sprinkler irrigation | 5.250 | -0.996 | 3.038 |
| | (4.289) | (3.575) | (6.322) |
| Micro-irrigation | 17.111*** | 1.679 | 4.473 |
| | (5.122) | (7.981) | (9.296) |
| Annual average temperature | -0.009 | 0.003 | 0.015 |
| | (0.010) | (0.038) | (0.039) |
| Annual average precipitation | 0.0001 | 0.001** | 0.0004** |
| | (0.0001) | (0.0002) | (0.0002) |
| Utilised Agricultural Area | 1.471*** | 1.712** | 1.485** |
| | (0.361) | (0.708) | (0.682) |
| Number of workers | 1.367 | -4.662 | -8.795** |
| | (3.001) | (3.841) | (3.653) |
| CAP funds | -0.0005 | -0.001* | -0.0009** |
| | (0.0004) | (0.001) | (0.0004) |
| Water costs | -0.002*** | -0.001 | -0.0005 |
| | (0.0004) | (0.001) | (0.001) |
| Specialisation | 1.592* | 2.007*** | 1.725*** |
| | (0.844) | (0.447) | (0.514) |
| Organic farms | -26.000* | 1.786 | -82.930 |
| | (13.280) | (28.980) | (63.300) |
| Diversification | -1.932 | -10.240 | -0.369 |
| | (41.410) | (45.480) | (26.960) |
| Year-NUTS2 fixed effects | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 377 | 377 | 377 |
| R2 | 0.35 | 0.38 | 0.35 |

Table A4 - Estimation results with coefficients – regional sample.

| | *Apulia* | | |
|---|---|---|---|
| | *Gross Sale Production (1)* | *Value Added (2)* | *Net Income (3)* |
| Collective supply | 17.06 | -20.84* | -27.71** |
| | (9.210) | (8.086) | (6.703) |
| Self-supply | 13.75 | -17.83* | -20.96** |
| | (7.280) | (7.550) | (7.361) |
| Sprinkler irrigation | -6.369 | 35.04*** | 37.09*** |
| | (4.512) | (4.835) | (6.609) |
| Micro-irrigation | 0.344 | 41.39*** | 47.35*** |
| | (4.229) | (5.697) | (7.401) |
| Annual average temperature | 81.87* | -39.77 | -79.10 |
| | (38.25) | (74.05) | (69.66) |
| Annual average precipitation | 0.180 | -0.116 | -0.202 |
| | (0.0878) | (0.171) | (0.158) |
| Utilised Agricultural Area | -2.916*** | 0.156 | 1.365* |
| | (0.224) | (0.328) | (0.570) |
| Number of workers | 13.43*** | 1.096 | -8.494 |
| | (0.628) | (3.325) | (6.207) |
| CAP funds | 0.000175 | -0.000782*** | -0.000766*** |
| | (0.000107) | (8.29e-05) | (4.30e-05) |
| Water costs | -0.00252*** | -0.000430 | 0.000430 |
| | (0.000453) | (0.000662) | (0.000570) |
| Specialisation | 1.009 | 1.620*** | 1.538*** |
| | (0.509) | (0.261) | (0.0550) |
| Organic farms | -63.62*** | -35.83*** | -35.14*** |
| | (9.640) | (5.622) | (0.926) |
| Diversification | -1.932 | -10.240 | -0.369 |
| | (41.410) | (45.480) | (26.960) |
| Year-NUTS2 fixed effects | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 147 | 147 | 147 |
| R2 | 0.464 | 0.418 | 0.372 |

| | *Emilia-Romagna* | | |
|---|---|---|---|
| | *Gross Sale Production (1)* | *Value Added (2)* | *Net Income (3)* |
| Collective supply | -1.879 | 5.430 | 2.160 |
| | (4.723) | (4.757) | (3.554) |
| Self-supply | -1.509 | 16.50 | 14.40* |
| | (5.185) | (10.03) | (7.541) |
| Sprinkler irrigation | 4.460 | -0.843 | 2.759 |
| | (4.877) | (4.078) | (5.840) |
| Micro-irrigation | 15.55 | -2.729 | -0.590 |
| | (8.413) | (7.017) | (8.924) |
| Annual average temperature | -0.00851 | 0.00141 | 0.0154 |
| | (0.0133) | (0.0455) | (0.0440) |
| Annual average precipitation | 0.000109 | 0.000456* | 0.000307 |
| | (0.000136) | (0.000198) | (0.000181) |
| Utilised Agricultural Area | 1.914*** | 2.143** | 1.704** |
| | (0.188) | (0.701) | (0.729) |
| Number of workers | -7.865 | -15.96* | -13.79* |
| | (7.487) | (8.246) | (6.925) |
| CAP funds | -0.000253 | -0.000795 | -0.000745 |
| | (0.000531) | (0.000595) | (0.000435) |
| Water costs | -0.00257 | -0.00657** | -0.00575*** |
| | (0.00325) | (0.00254) | (0.00128) |
| Specialisation | 1.755 | 2.202** | 1.972 |
| | (1.481) | (0.705) | (1.092) |
| Organic farms | -12.12 | 20.79 | -112.0 |
| | (13.36) | (29.48) | (93.30) |
| Diversification | 6.298 | -8.098 | -4.439 |
| | (36.45) | (34.89) | (22.70) |
| Year-NUTS2 fixed effects | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 230 | 230 | 230 |
| R2 | 0.339 | 0.410 | 0.369 |