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Vineyard irrigation and assessment of ecosystem service: Experimental trials on “Catarratto” cultivar for the production of “Bianco di Alcamo” DOC wine

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ABSTRACT

Water is an important resource for humans both for drinking and for irrigation. In the case of irrigation, the use of water resources leads to many direct benefits for farmers. The use of irrigation water, in addition to having consequences for those directly involved, determines positive externalities on the ecosystem in general. In this research the value of the ecosystem service that determines water for irrigation was estimated. The method used was that of the gross margin method which determined a value of 200.10 €/ha. The research results are very important in relation to climate change which makes water increasingly important as an element of production in Mediterranean environments.

1. Introduction

Water in agriculture is an important resource for increasing the productivity and profitability of businesses. The water allows for high-income crops such as vegetables and fruit trees. Water resources represent public goods [1,24,25] and as such are subject to market failure, since the latter fails to report their real value and, consequently, to allocate the resource efficiently. Most market failures are related to the existence of incomplete markets. This also applies to the water used in agriculture, in fact, not having a market price it is, inevitably, exploited, with repercussions on the collective well-being and on future generations [2]. Information asymmetry also plays a particular role in the market failure for this resource. In fact, the absence of precise information both on the annual availability of rainwater to be collected in the reservoirs (conditioned by rainfall in the winter months) and the absence of the effective demand for irrigation water by entrepreneurs (which depends on summer temperatures) determines the failure of the market left free to operate. It is therefore necessary to have a correct water management policy as a public good. In order to ensure the efficiency of the irrigation activity of agricultural crops, it is important to consider, in addition to the direct benefits that its use entails, also the externalities it produces or the positive or negative changes in well-being on individuals in the agri-food chain (of the specific territory) and not or on the productivity of firms that do not directly intervene in the activity of consumption or production of that good [26–29]. Considering the water used for irrigation, this produces a series of environmental externalities, both positive and negative, and these externalities depend on the pedo-climatic characteristics of the cultivation environment, the efficiency of exploitation of water resources and the preferences of all those who receive recreational, hedonistic or evocative benefits, linked to the existence of particular landscapes characterized by the presence of irrigation activities. Among the negative externalities caused by irrigation, the problems associated with the salinization of groundwater resources are relevant. In addition, a negative externality is due to the arrangement of the land and irrigation methods which, if not suitable for the arrangement of the land, cause soil erosion. In the near future, with the increasing increase in temperatures in the summer months, there will be a progressive increase in water demand. As a function of this, an efficient management of the water resource is required. The efficiency of water management begins with a correct assessment of the ecosystem service provided by irrigation water deriving from reservoirs specially created by man for irrigation purposes. In agriculture, the use of these waters determines an increase in production yields, greater company competitiveness, a diversification of the production offer and therefore an increase in collective well-being for operators who are located in the area served by the water network. Estimating the value of this externality can be useful to institutions as a support to the management choices of control, taxation or subsidies relating to agricultural activity. The following work aims to estimate the economic value of the ecosystem service provided by irrigation water.

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Through this paper we want to evaluate the ecosystem service provided by water for irrigation. Many studies in the literature have addressed the problem without looking at a systemic situation, however. In fact, the works present in the literature appear to be limiting with respect to the problem as a whole. One of the best methods in the literature is that of estimating the value of the ecosystem service through the difference between the gross margins between the ex-ante situation and the ex-post situation. However, the literature looks at the problem in a limiting way as it looks at only one year of investment. In agriculture as it is known and especially for tree crops, which are multi-year, the gross margin referred to one year does not make much sense as it would be affected by the climatic situation or by a possible market appreciation or a possible unfavorable market (low product prices). Through this study, with the average annual gross surplus for the entire investment cycle, we obtain a value of the ecosystem service that is more suited to the real market conditions and represents a correct estimate of the ecosystem value of the use of water for irrigation purposes.

2. Ecosystem services and economic literature

The use of water for irrigation determines social, economic and environmental benefits [3]. Social benefits are linked to social well-being in terms of livability of the irrigated area. In fact, irrigation, determining the increase in production, determines a greater demand for work in the area both in agriculture and in related industries. Among the economic benefits that the water used in agriculture produces, we have the increase in productivity, greater food security and the increase in the supply of agricultural products [4–9]. Regarding the positive effects on the environment, the use of water in agriculture prevents soil degradation. In fact, maintaining irrigated areas prevents structural infertility of the soil, especially in arid, sub-arid and dry areas. Other positive effects on the environment are given by the characterization of landscapes, the use of irrigation allows the choice of crops that can provide the landscape with a particular hedonistic and evocative value, thus increasing the usefulness of subjects who come into contact with it. Think of the landscapes planted with vines in the plains, or those with olive trees, but also the plains planted with vegetables: in all cases, the landscape also becomes a resource for rural tourism. Furthermore, the water availability of dams has positive effects on flood control. However, there is a problem of estimating the value of these benefits since probabilistic aspects should also be considered. In other words, when designing a dam it is not possible to predict in which years the floods will occur and what will be the extent of the damage they will produce [2]. Water produces positive social and environmental effects, think of the possibility of increasing productivity which undoubtedly determines an increase in the need for work (human and mechanical). From this point of view we can say that there are effects that can determine a possible development trajectory for the farm. Furthermore, the presence of water in the territories favors the permanence of man on it [10]. Negative social and environmental aspects are also associated with the use of irrigation water. With regard to environmental issues, irrigation can facilitate the spread of some diseases that spread in the aqueous medium. In particular, irrigation water can be a vehicle for the spread of some pathogens. According to a study carried out in Pakistan, the main vectors of malaria are found in the areas of irrigation water accumulation, connected, consequently, to the distribution channels of the resource. And again, irrigation also causes soil degradation problems such as salinization and erosion. Soil salinization can be the consequence of an excessive or insufficient use of irrigation water [11]. Finally, irrigation can cause pollution related to the use of polluted surface water for irrigation purposes but also to the occurrence of pollution due to the solubilization and/or transport of fertilizers and pesticides used in agriculture.

In light of the foregoing, the protection of water resources is considered one of the major challenges to be faced in order to achieve an increasingly sustainable development, both in terms of protection from pollution and improvement of management. The rational and efficient use of water resources in agriculture can therefore represent an important factor in curbing the processes of land degradation, alongside a more decisive reconversion towards environmentally friendly agricultural practices and the need to support the continuation of the activity. agricultural where an abandonment of the land would cause serious risks for the territory, with an increase in the level of hydrogeological risk or desertification processes [12,13]. In consideration of the context exposed, improving the efficiency of irrigation uses of the resource is, therefore, an essential objective. Precisely in this perspective it becomes increasingly important that agricultural and irrigation practices, in particular, are carried out in full efficiency and in compliance with all the components environmental since, although good levels of efficiency in the use of the resource by the primary sector have been achieved in recent years, it is equally true that there is further room for improvement. In the light of the described picture, therefore, it is clear that the evaluation of the externalities produced by the irrigation use of water represents a theme that has had a great theoretical, methodological and application development in recent years. In fact, the methods proposed on the evaluation of externalities have made it possible to tackle several studies also on the evaluation of externalities produced by irrigation use of water. Therefore, irrigation contributes to the production of eco-systemic services and increases the availability of environmental goods for free use [14,15]. In order to estimate these externalities related to the use of irrigation water, in the economic literature there is what consists in estimating the value of an externality by observing the behavior of economic agents on the real goods market; it is a question of investigating the equivalence between the lost utility and the amount of money capable of restoring it by analyzing the spending function of individuals or the production costs of companies [16]. Other methods are present in the literature such as that of "declared preferences" which tries to grasp the value of externality by observing the behavior of economic agents on hypothetical or experimental markets built on purpose. All these methods, although valid from a theoretical point of view, must find application in dempirical verification. In fact, in the present work we propose a method where the value of the ecosystemic service is evaluated by analyzing two scenarios separately: the first represents the current situation, in which irrigation water is supplied by private wells with excessive exploitation and, consequently, with the fact that the salt concentration progressively increases over time, causing a reduction in yields; the second presupposes the use of public water by the reclamation consortium and, therefore, the maintenance of the quality of the resource and respect for environmental sustainability.

3. Methodology

The need to evaluate the ecosystem service of irrigation water provided by the reclamation consortium arises from the need to protect natural resources for future generations and thus make resources sustainable. According to the FAO [17], in order to achieve full sustainability, there are five key actions, on which to insist in the coming years: improving the use of resources, especially water; undertake actions aimed at the conservation and protection of nature; guaranteeing equity and social welfare in the agricultural sector; increase the resilience of our ecosystems; guaranteeing governance mechanisms based on transparency and accountability. In other words, social and economic development must be implemented in such a way as to minimize the effects of economic activity if the costs are to be borne by future generations. The principles of FAO are aimed at rebalancing the relationship between man and the environment both in terms of long-term environmental and economic sustainability. In fact, in the recent past, the agricultural production activity aimed at obtaining maximum yields and maximum profit has caused negative effects that are transferred to future generations on the capital stock. On the other hand, according to the principle of strong sustainability, some natural resources, not being replaceable, represent a critical natural capital and for this reason they must be conserved [18–20]. The problem of the excessive exploitation of groundwater resources in agriculture derives from the fact that, since there are no protection rules for future generations, agricultural entrepreneurs tend to draw a level of water higher than the sustainable one, entailing, in fact, a cost external social for those who will operate in the sector and that the free market is unable to compensate [21–23]. A simple way to estimate the ecosystem service is to consider the loss of benefits due to the occurrence of negative externality. In the case under study, two scenarios are analyzed separately: the first represents the current situation, in which water for irrigation is supplied by private wells with excessive exploitation and, consequently, with the fact that the salt concentration it progressively increases over time, causing a reduction in crop yields; the second assumes a use of the water of the reclamation consortium and therefore, the maintenance of the quality of the resource. It should be noted that currently in this area there is no Reclamation Consortium network, so in our study we assume that the company is served by the reclamation consortium. The difference in gross margins, without prejudice to the other company variables (ceteris paribus), over time will represent the estimate of the water ecosystem service of the reclamation consortium. Therefore:

$$VSE = ML_a - ML_b \tag{1}$$

$$ML_a = RT_a - Cv_a \tag{2}$$

$$ML_B = RT_b - Cv_b \tag{3}$$

Where:

MLa = Gross Margin with water supplied by the Reclamation Consortium (public water from artificial reservoir)

MLb = Gross Margin under current conditions (private wells)

RTa = Total revenues with water supplied by the Reclamation Consortium (public water from artificial reservoir)

Cva = Variable costs with water supplied by the Reclamation Consortium (public water from artificial reservoir)

RTb = Total revenues in current conditions (private wells)

Cvb = Variable costs in current conditions (private wells)

For the purposes of this work, a viticultural company was considered in the territory of the Gulf of Castellamare (Invaded Poma on the Jato Valley), an area particularly suited to viticultural culture, located in the municipality of Partinico, in the province of Palermo, falling within the production area of the Bianco di Alcamo Denomination of Controlled Origin (DOC). Irrigation is to be understood as emergency irrigation and consists of one or at most two irrigations per year. The cultivar is bred is the Catarratto reared with espalier, guyot pruning, with a planting density of 4,444 plants/ha (2.50 m x 0.90 m) and with a yield of 10 t/ha. The irrigation system is localized by drop. From a strictly economic point of view, in the case of the vineyard, since it is an investment where there are variable outlays and monetary revenues depending on the years of the investment, for the purposes of this study we have transformed formula (1) into a difference of Continuous average annual gross margins over the investment period. This aspect is particularly relevant as it allows to eliminate any years of particularly high revenues (due to a good season or due to an increase in the market price of the grapes) or any years where costs are excessive (due to adverse climatic conditions which can lead to an increase in treatments. plant protection products to do to the plant). Furthermore, the determination of the continuous average annual gross margin allows you to express an opinion on the value of the ecosystem service without looking at the year of investment, since as mentioned above, depending on the year of investment, the costs exceed the revenues (first years life of the investment).

Therefore:

$$VSE = ML_{ma} - ML_{mb} \tag{4}$$

Where:

$$ML_{ma} = \left(\sum_{0}^{n} (RTa - CVa) \right) x \;\; r/q^n - 1 \tag{5}$$

$$ML_{mb} = \left(\sum_{0}^{n} (RTb - CVb) \right) x \;\; r/q^n - 1 \tag{6}$$

The duration of the investment was determined according to the ordinariness in the area of the Gulf of Castellammare of production of the Bianco di Alcamo DOC grapes and for the cultivar under consideration. In particular, to determine it, we asked several entrepreneurs the duration of their previous investments in the same cultivar and for the same type of soil (medium mixture). Based on the information gathered, the duration of the investment chosen was 14 years. The year of the estimate of the economic values refers to the year 2020. The interest rate used is 3% and was chosen by observing alternative investments for equal risk and duration. The estimate of gross margins, as highlighted in formulas (5) and (6), was carried out by making the values homogeneous over time through the annual discontinuous compound interest, which as we know from the mathematical literature is a divisible law. In particular, we brought all monetary values to the end of year n and then we determined the annual average gross margin over the investment period. In this study, it must be remembered that the formulas used to estimate the value of the ecosystem service and gross margins must be considered with the limits imposed in the estimate of the same, therefore the estimated values correspond to reality the more the researcher knows the territory subject to study. This method, compared to the existing literature on the subject, is particularly innovative as it considers the annual average gross margin for the duration of the investment. In this way, any very positive years in terms of margins or particularly negative years, always in terms of margins, are eliminated from the estimate.

4. Results and discussions

According to the proposed methodology, we first collected the empirical data that were used to estimate the ecosystem service. The farm examined is a reality that reflects, for methods of cultivation and management of the vineyard, that typical of the Mediterranean and the procedures foreseen by the Community Agricultural Policy (PAC). In particular, depending on the density of the plant, there is a production yield adequate for the production of quality wines. The empirical results of the research provide an important indication both for the analysis of the crops in the area under study and for the estimation of the externality due to the use of groundwater for the Reclamation Consortium (public water from artificial reservoir). In the specific case under study, as regards the production of wine grapes, the area is currently not served by the Reclamation Consortium (public water from artificial reservoir). This causes excessive exploitation of groundwater with an increase in the salinity of the water. The estimate of the externality due to excessive use of groundwater is 495.62 €/ha against 695.72 €/ha if the water is supplied by the reclamation consortium (Table 1). The lowest gross margin in the case of water supplied by wells is due to the loss of productivity of the investment. The difference between the two gross margins provides the value of the ecosystem service which amounts to 200.10 €/ha.

The result of the estimate highlights the considerable value that the

Table 1
Results of the estimate of the value of the ecosystem service of irrigation water (€/ha).

Margin/Value of ecosystem service	*€*
Gross margin with artificial reservoir water	695.72
Gross margin with groundwater (private wells)	495.62
Value of the ecosystem service	**200.10**

consortium water network has for the territory. The positive effects are both for entrepreneurs (acquisition of a competitive advantage, increase in production yields and increase in income) and for consumers (security in supplies for local production). This result also makes us reflect on the lowering of the availability of water resources due to the decrease in rainfall. In fact, over time, even in the area under study, from information gathered, for some years there have been problems with the water availability of the reservoir managed by the reclamation consortium. This aspect, in addition to having direct economic effects on company profitability (decreasing it), has a negative effect on the environment, the water from wells and their excessive use, determines a decrease in productivity. The Value of the ecosystem service provided through the use of water from reservoirs highlights a fundamental aspect of the ecosystem service. With a view to environmental, economic and social sustainability to which the objectives of the Economic Policy are currently aimed, they allow us to affirm that the use of water from reservoirs is an economically, socially and also from an environmental sustainable point of view.

5. Conclusions

Irrigation water makes it possible to increase the profitability of farms and to increase the need for work in farms that produce irrigated crops. As we have seen in this study, there are several positive and negative environmental externalities related to the use of water for irrigation purposes. It is important to underline that, since these externalities depend on the specific characteristics of the soil and the territory, in order to better manage the water resources it is necessary to consider the peculiarities of the reference context. The choice to estimate the value of the ecosystem service arose from the need for greater environmental, economic and social sustainability. Without a doubt, as highlighted, the irrigation water provided by the Reclamation Consortium determines the conditions of sustainability and longevity of the company in the long term. This statement is highlighted through the proposed study methodology which leads to an estimate of an ecosystem service value of 200.10 €/ha on an annual basis. Considering the negative externalities created in the case of tapping wells, the solution of extending the water network to these areas subject to estimation becomes of fundamental importance also considering the collective well-being. The lack of the consortium water network determines a decrease in the wealth assessed in monetary terms of the territory under study, as well as from the point of view of the environment in general. For the near future, also in the light of this study, the importance of collecting rainwater in reservoirs and efficient management of public water is emphasized. Only in this way will it be possible to guarantee balanced long-term growth for companies and for the territory in general. The proposed estimation method is innovative in that it considers the entire investment over its duration and not a single year. In this way, any effects due to the climate or to exceptional market events that could affect the result of the estimate of the value of the ecosystem service are eliminated. As demonstrated in this study, water in agriculture is a very important resource both at the company and at the territorial level. On the first aspect, water determines positive effects on the profitability of the company but also on the environment as a function of its own benefits deriving from the cultivation of agricultural products and from the ecosystem that is produced. On the second aspect, the presence of water favors a better distribution of resources. In conclusion, we can affirm that the correct management of water in the territory has a positive impact both on a social and environmental level.

Declaration of competing interest

I have submitted the manuscript entitled "Vineyard irrigation and assessment of ecosystem service: experimental trials on "Catarratto" cultivar for the production of "Bianco di Alcamo" DOC wine" to Journal of agriculture and food research.

I declare not to be in conflict of interest Journal of agriculture and food research.

We hope that this manuscript can be taken into consideration for publication in to Journal of agriculture and food research.

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