Drivers and Barriers For the Adoption of Precision Irrigation in Europe

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Summary

In European agriculture, the changing environmental and institutional context is setting the path for the development of new technologies and relevant patterns of diffusion. This is particularly the case for irrigation practices. The present study explores new frontiers for optimizing the use of water resources in agriculture through "Precision Irrigation" (PI). The main purpose of the study is to develop a theoretical framework to assess the adoption of PI. This framework has been validated and integrated through a Delphi study involving a structured group of experts. The experts provided insights into where and when PI can be considered a promising innovation and regarding the actions that should be undertaken to overcome barriers to its diffusion. Thereafter, a methodology was designed in light of the economic theory of information. An empirical example is offered to illustrate the circumstances in which the adoption of PI is more likely to be of benefit according to crop growth and soil water balance model rules. The paper concludes with a discussion of the extent to which PI can be considered an instrument capable of meeting the main concerns addressed by the WFD and the new CAP reform.

Keywords: Precision Irrigation, Value of Information, Adoption, Delphi Study

JEL Classification codes: Q5

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1. INTRODUCTION

In Europe, the agricultural sector is facing new challenges driven by climate change and environmental and agricultural policy reforms. In Northern Europe, climate change may produce positive effects on agriculture through the introduction of new crop species and varieties, higher crop production and the expansion of suitable areas for crop cultivation. In Southern Europe, the possible increase in water shortage and extreme weather events may cause lower harvestable yields and higher yield variability. These effects may reinforce the current trends of intensification of agriculture in Northern and Western Europe and extensification in the Mediterranean and south-eastern parts of Europe (Olesen and Bindi, 2002; AEA, 2007). The new CAP reform explicitly addresses this aspect, dedicating funds for advisory weather services and training and for supporting investments to adapt farm structures and production methods (EC, 2013). This is the changing environmental and institutional context that is setting the path for the development of new technologies and relevant patterns of diffusion, with particular reference to irrigation practices.

A new frontier for optimizing the use of water resources is sought in the concept of "Precision Irrigation" (PI). PI is a practice rather than a technique that can be applied to any type of irrigation technique in any region of the world. PI is a system that supports end users' decisions with regard to how much to irrigate and when and is uniformly applied across the field through data acquisition from monitoring devices (local field sensors, regional meteorological information) and forecasting tools, data interpretation, system control, and evaluation mechanisms (Battilani, 2013). PI has the potential to increase certain economic efficiencies of operations by optimally matching input to yields in each area of a field and reducing costs (Sadler et al., 2005).

Yet the effect of this promising innovation is still unclear due to limited diffusion. The European Union recently funded the FIGARO project under the FP7 program the objective of which is to create an innovative virtual platform able to combine and manage information from sensors, meteorological stations, and crop growth models to advise farmers when, and how much, to irrigate. In the context of FIGARO, real-time micro-weather stations, plant-based sensors (e.g., reflectance, infrared temperatures or video) and numerous real-time soil water sensors scattered around the field at critical locations are coupled with a set of predictive models into a decision support system.

This paper is based on evaluation activities carried out in the first stage of the project and the main purpose is to: 1) assess the viability of PI in a number of European agricultural regions; and 2) explore the existence of policy initiatives (actual or potential) that are capable of overcoming barriers to PI adoption.

In the following, the authors offer a theoretical framework for the adoption of PI. This framework was then adopted to carry out a Delphi study involving a structured group of experts, such as researchers and agronomists, who are already familiar with the concept of PI and its application in the real world and who can provide insights into where and when these practices will likely yield relevant benefits for farmers and for the environment. Thereafter, a methodology including the economic impact of the main factors conditioning the adoption of PI is offered to assess the economic viability of PI. In the final section an empirical example is offered to illustrate the circumstances in which the adoption of PI is most likely to be implemented. The paper concludes with a discussion of the extent to which PI can be considered an instrument capable of meeting the main concerns addressed by the WFD and the new CAP reform.

2. THEORETICAL FRAMEWORK

The transition from traditional to modern irrigation technologies (MIT) appears to be affected by a number of factors that can be clustered into three main spheres: the environmental sphere, the regulatory sphere and the farm sphere. The environmental sphere includes factors such as climate conditions and the main sources of irrigation water in a given region (Caswell and Zilberman, 2004), as well as the quality of land, field capacity and orography (Miranowski, 1993; Sauer et al., 2010; Caswell and Zilberman, 2004; Moreno and Sunding, 2005). The regulatory sphere highlights factors such as subsidies (Bjornlund et al., 2009; Morales et al. 2011), water pricing policies (Green et al., 1996; Sunding and Zilberman, 2001; Lopez-Morales, 2011; Jara-Rojas, 2012), enforcement and monitoring capacity (Molle, 2008; Lopez-Morales, 2011). For its part, the farm sphere addresses factors such as the type of crops (Green et al., 1996; Moreno and Sunding, 2005), farmer networks (Boyd et al., 2000; Genius et al., 2013), farmer skills (Nash et al., 2009; Nikkila et al., 2010), costs of substituting inputs (labour and energy) and output prices (Sunding and Zilberman, 2001), and land ownership (Moreno and Sunding, 2005).

With respect to the environmental sphere, scientists have found that the adoption of modern irrigation technologies (from sprinklers to drip irrigation) is conditioned by the climatic conditions of a region and by the main types of irrigation water sources. For example, most of the crops for which it is possible to apply drip irrigation systems (fruit and vegetables) tend to be concentrated in tropical and temperate climate regions. Moreover, in those regions where underground water is the main source of irrigation water, the adoption of modern irrigation technologies increases as the unit costs for pumping water from wells increase for highly pressurised irrigation systems. Finally, the adoption of modern irrigation technologies tends to decrease when the orography of the field is regular and the field capacity is increased (land quality augmenting). In other words, localized irrigation guarantees a more homogeneous application of water on fields characterised by irregular orography and is particularly suitable for fields with low water holding capacity, requiring small amounts of water per intervention and high frequencies of interventions.

With respect to the regulatory sphere, scientists have addressed instruments such as subsidies on investments, water pricing (tariffs) and rules of use (licensing for drilling wells, turns and quotas, etc.). These instruments can have varying impacts both on the adoption and the resulting water savings and nutrient leaching reductions. Where water saving is considered a public concern, subsidies alone may lead to the so-called Jevons paradox. That is, by shifting from less efficient to more efficient technologies, the risk of incurring water shortages could be reduced, hence favouring the diffusion of water intensive crops with the result of increasing, rather than reducing, the consumption of water for irrigation in a given region. To avoid the risk of such a paradox, the quoted authors addressed the need to combine subsidies with water pricing. However, there is little evidence that water pricing conditions water uses and consequently impacts the adoption of more efficient irrigation management practices (Molle, 2008). In any case, water pricing, which is an instrument commonly adopted by local water authorities to recover supply costs, could benefit from co-financed subsidies on investments to further promote the diffusion of modern irrigation technologies (Lopez-Morales, 2011). Finally, most of the authors agree that the possibility of imposing rules of use, with particular reference to quotas and turns, is another factor contributing to the promotion of the adoption of modern irrigation technologies.

With respect to the farm sphere, the authors found that the type of land ownership conditions the adoption of modern irrigation technologies, as landowners are usually more willing to make long-term investments with respect to tenants. Moreover, the type of crops grown by a farm conditions the farmer's willingness to adopt MIT. The adoption of MIT is conditioned by the type of crop cultivated and this is the main limitation to their diffusion. Moreover, the adoption of MIT tends to increase with the increasing costs of the substituting inputs and output prices and is also conditioned by the quality of human capital, with particular reference to farm skills and networking capacity.

Most of these factors seem to hold also when considering the transition from traditional information technologies for irrigation to modern information and communication technologies (ICT). ICT for irrigation are part of the concept of precision irrigation (PI). At the moment, there is very little literature analysing the factors conditioning the adoption of PI. This implies that, unlike MIT, PI does not have climate or crop constraints limiting its potential diffusion as, theoretically, it can be applied to any type of irrigation system (modern and traditional) and in any area of the world where irrigation is practiced.

Most of these technologies and tools have been developed without considering the knowledge levels, skills and abilities of farmers and service providers to effectively and economically manage them. In addition, the equipment is expensive (Sadler et al., 2005). Accordingly, a farmer's skills and financial capacity, coupled with his/her networking capacity and service providers are considered the main factors conditioning the adoption of PI.

As for MIT, PI should guarantee higher economic returns, mainly thanks to a more rational use of inputs (such as labour, energy for pumping water and fertilizers) and higher yield, minimizing the risk of having areas in the same fields that are either too wet or too dry (Meisinger and Delgado, 2002; Delagado and Bausch, 2005). The adoption of PI may be expected to favour higher economic returns and higher environmental benefits, minimizing nutrient leaching losses and irrigation water wasted, with increased heterogeneity in field characteristics. However, it has not been easy to consistently demonstrate the economic returns from adopting these technologies as the bulk of the scientific reporting refers to pioneer applications of PI at the case study level (Sadler et al., 2005). The limiting factors of this approach are found in the availability of cost effective support tools and instrumentation for decision-making. Current soil moisture monitoring technologies are inconsistent in their ability to measure soil moisture. Low cost tools (e.g., tensiometers) do not provide consistently precise and accurate data on soil moisture status or require considerable maintenance. Tools that provide precise and relatively accurate measurements of soil moisture are generally too expensive for a grower to utilize in multiple locations at multiple depths across a given field (Sadler et al., 2005).

With respect to weather forecasts, the accuracy of seasonal and long-term weather forecasts still remain quite low despite access to satellite data and improved forecasting models. Moreover, the longer the time frame, the higher the possibility of deviance from the forecast (USAID, 2012).

Despite these limitations, a few empirical studies worldwide highlight that farmers who receive quality, up to date information, and who have the ability to use that information, are able to lessen the risk of experiencing adverse impacts on crop production and income (Mittal, 2012; Sadler et al., 2005; McGukin et al., 1992). It is expected that the diffusion of PI will play a role in bridging the information gap and in reducing the information asymmetry that exists between farmers and between regions. In other words, PI can play the role of better informing decision makers with regard to the value of data and information. Willingness to pay for information can be thought of as a derived demand, or demand emanating from the value of services or information (Macaulay, 2006).

3. The Delphi Study

To explore the viability of PI in a number of European countries a two-round Delphi Study was carried out involving 18 experts from four countries (Denmark, Portugal, Italy and Greece).

In the first round respondents were first invited to describe the region in which they operate according to key aspects such as water status, management of water resources for irrigation, main irrigated crops and irrigation techniques. At this stage the respondents were also invited to rank the relevance of the factors collected in the literature review as potential determinants of PI adoption. Specifically, for each region, respondents were asked to highlight the listed factors that , in their opinion, were liable to limit the adoption of PI, foster the adoption of PI and those that were not relevant to the adoption of PI. They were also asked to provide comments and to highlight any other relevant factors not included in the list that might condition the adoption of PI. In the second round both qualitative and quantitative responses were aggregated at the regional level and sent back to the respondents for revised input. This analysis made it possible to identify an ideal scenario highlighting Strengths, Weaknesses, Opportunities and Threats with respect to the potential diffusion of PI, to identify Barriers and to suggest policy initiatives to overcome these barriers.

Table 1 provides a SWOT analysis of the main factors deemed by the group of respondents to condition the adoption of PI. Strengths and Weaknesses are characteristics intrinsic to the technology, whilst Opportunities and Threats relate to external factors that condition the balance between Strengths and Weaknesses. The combination of Threats and Weaknesses helps identify the main barriers to adoption. Based on this, policy suggestions are provided to overcome them.

Table 1 – SWOT analysis of the uptake of PI

STRENGTHS	**WEAKNESSES**
Energy saving: the use of energy to irrigate is a key component for all types of irrigated crops, with particular reference to maize and potatoes. **Water saving**: the possibility of increasing water productivity with PI is particularly evident for southern European regions (SR) as it limits the risk of water shortages and increases irrigation capacity. **Optimizing fertigation**: increasing water productivity as an impact also in reducing nutrient leaching (addressed by the respondents from Denmark - DR).	**Investment costs**: these costs limit the adoption of PI mainly for farmers with low financial capacity (addressed by most of the respondents from SR). **Labour efforts**: this issue was addressed by DR for big farms that are reluctant to the adopt PI due to managerial constraints. **Requirement of highly-skilled labour**: in Southern Europe aging and low educational levels inhibit farmers' attitude to innovation (addressed by most of the respondents from SR).

OPPORTUNITIES	**THREATS**
Low water availability: where water resources are limited, water productivity is important (addressed by SR). **Low levels of Field Capacity**: increasing coarse soil texture increases the frequency of irrigation interventions and the opportunity to save water and	**Absence of, or inefficient, water pricing**: water pricing is not at the debate for most of the European regions. Water pricing affects water uses only for a few regions where irrigation water is in demand. **Lack of Subsidies**: In Southern Europe subsidies are not high enough to overcome the financial constraints

energy using PI. **High irregularity in the orography**: irregular orography seems to foster the adoption of PI, as this technology should guarantees a more homogeneous application of water.	for the adoption of PI. In Northern Europe, financial factors are not significantly limiting adoption. **Lack of compliance with rules**: low levels of regulatory clearing in some EU regions affect the effectiveness of policy initiatives.

BARRIERS	**POLICY SUGGESTIONS**
Absence of incentives	Targeting specific policy measures that enhance the uptake of PI in those regions where the status of water bodies is compromised (combining direct/indirect subsidies, water pricing, rules of use, etc.).
Low PI usability	Investments in research aimed at increasing the ease of use of crop growth models and in-farm monitoring tools.
Low level of networking and absence of extension services	Development of advisory services for supporting farmers in using PI and promoting farmers' networks (capacity building) to contrast farmer's aversion to innovation.

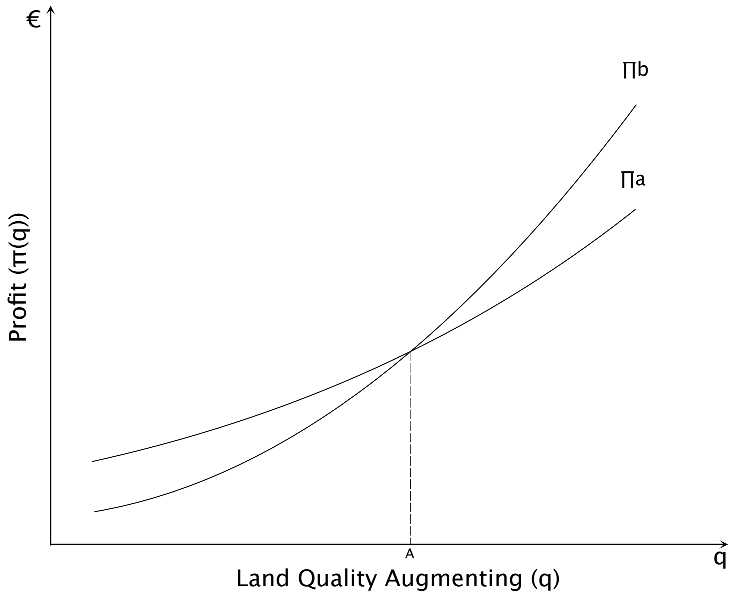
Results from the Delphi study shows key factors that condition both the adoption and performance of PI in different regions also suggesting the way how to overcome weaknesses and threats with dedicated policy initiatives. The study reveals the existence of significant differences between the participating regions. All of the respondents agree that the adoption of PI is conditioned by field capacity, orography and the energy costs for irrigation. With respect to the impact on the environment, whilst the adoption of PI in Denmark is mainly driven by the need to reduce nutrient leaching, in the other countries it is due to the need to increase water use efficiency. With respect to farm characteristics, farm size seems to negatively condition the adoption of PI in Denmark, as farmers need to save labour rather than water, whilst farmers' financial capacity and skills are considered to be the main limitations for most of the other countries. Infrastructural investments, direct subsidies and advisory services are seen to be the most relevant driving forces for the adoption in most of the southern regions, while the imposition of quality standards along the agri-food chain is addressed in the Denmark case study region.

4. THE ASSESSMENT METHODOLOGY

With the following, the authors have combined the findings of some scholars that have contributed to the analysis of the development of modern and new irrigation technologies, respectively Carlson et al. (1993) and Macaulay (2006). Specifically, the former collected a number of studies highlighting the factors that condition the adoption of modern irrigation technologies and, on the basis of this, they developed a methodology that up until recently has provided support their hypothesis (Caswel and Zilberman, 2004; Moreno and Sunding, 2005). From the Delphi study, and according to the relevant literature (Sadler et al., 2005), some of these factors seem to hold also for PI, in particular the quality of the land. For land quality augmenting, PI is less likely in favouring higher performances and reduction in energy and water consumption. Thus, the adoption of PI seems to be more likely to be implemented for low levels of land quality. This rule seems to hold for each type of irrigation system and under different climatic conditions.

Hence, the relevant findings of the above-referenced authors answer the question: ‘under which circumstances does PI affect input uses?’.

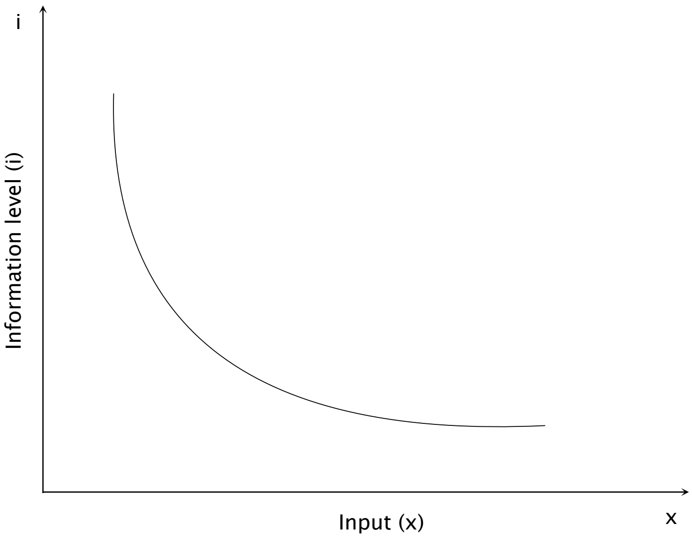
Graph 1 shows the differences in profit function for a land quality augmenting between conventional irrigation technologies, ∏b, and precision irrigation, ∏a. Land quality levels favour the transition to PI up to point A, where the two lines intersect each other. From point A, land quality levels no longer justify the transition to PI. Graph 2 highlights the substituting effects of information with water and energy, two factors which are recognised to be mainly conditioned by the adoption of PI (Meisinger and Delgado, 2002; Delagado and Bausch, 2003; Sadler et al., 2005; Mittal, 2012). There are also some proof that the use of other factors, such as fertilizers (Meisinger and Delgado, 2002; Delagado and Bausch, 2003), pesticides and labour (Sadler et al., 2005), are significantly conditioned by the adoption of PI.



(Authors’ own elaboration based on Miranowsky, 1993)

Graph 1 – Profit trends with land quality augmenting for both conventional irrigation technologies, ∏a, and precision irrigation, ∏b.

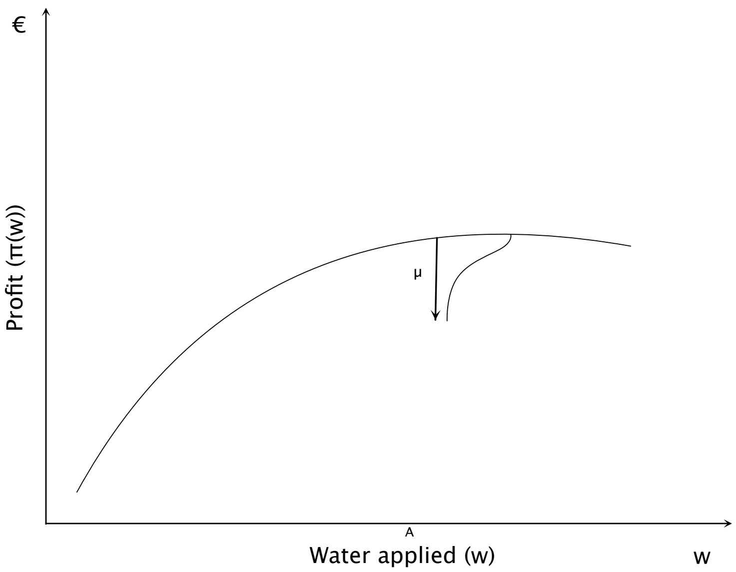
In addition to these findings, Macaulay (2006) introduced the concept of the Value Of Information (VOI) for resource management, highlighting that the performances guaranteed by the adoption of new information systems are conditioned by the quality of the additional information introduced by the new technology. In other words, the performances associated with a new information system vary according to their capacity to condition the users’ prior probabilities, or the probabilities that the user attaches to a given phenomenon by the means of conventional information systems. The value of the information introduced by the new technology is as much higher as much the information brought by the new information system changes the users’ prior probabilities, improving the quality of his/her expectations regarding future events. This conceptual framework also applies for PI, which makes it possible to acquire new information and to better manage available information with respect to conventional information systems (TV weather information, pluviometers, etc.). The relevant findings of Macaulay (2006) answer the question: ‘how it is possible to assess the additional information introduced by PI?’.



(Authors' own elaboration)

Graph 2 – Relationship between level of information, i, and substituting inputs, x (water and energy), with PI keeping profits constant.

Graph 3 shows an ideal production frontier with respect to increasing the amount of water applied. μ is a stochastic factor that captures the effects of information inefficiencies. An improvement in the quality of information should reduce the probability that the farmer will take the wrong decision.



(Authors' own elaboration based on McGuckin et al., 1992)

Graph 3 – Production frontier with respect to increasing amount of irrigation water for precision irrigation, ∏(w). μ is a truncated normal variable ($\mu \leq 0$) that capture the effect of information inefficiency under given climatic condition.

Now, consider a case where for a given irrigation technology (sprinkler, drip, etc.) land is assumed to contribute in conditioning irrigation, and q is a land quality measure, where $0 < q \leq 1$. a(q) is the applied water per hectare for land quality q. The irrigation technology has a fixed per hectare cost denoted by c. Let p denote the output price and w the price of the amount of water applied. The profit, π(q), can then be determined by solving equation (1);

$$\pi(a(q)) = pf(a(q)) - [wa(q) + c] \qquad (1)$$

To assess a farmer's willingness to pay for PI we compare the consequences associated with his decision whether or not to irrigate with and without PI. Farmers are already using traditional message services that condition their expectations regarding future events and, consequently, their strategic decisions. Let $\pi(a_{s.m}(q))$ denote the income associated with the best action, $a_{s.m}(q)$, amount of water applied for a given message *m* in state of the world *s* (where, *s* represents weather conditions). Here, it is assumed that the message service at least improves the farmer's expectations with respect to future events: $\pi(a_{s.m}(q)) \geq \pi(a_{s.0}(q))$, where $\pi(a_{s.0}(q))$ is the profit associated with the best action adopted when there is no additional information. The best action is conditioned by the farmer's prior probabilities, P_s, assuming that there are no message services, or by his/her posterior probabilities, $P_{s.m}$, when the message service is activated. $P_{s.m}$ is the posterior probability that the farmer attaches to state s after receiving message *m*. Prior probabilities are subjective probabilities that incorporate farmers' experiences, skills and risk attitudes, while posterior probabilities represent farmers' expectations about future events once having received the additional information. Now, the expected profit, $E[\pi_i(q)]$, can then be determined by solving equation (2)

$$E[\pi(a_{s.m}(q))] = \sum_{\mu,s} P_{s.m} Q_m \pi\,(a_{s.m}(q)) \qquad (2)$$

where, $P_{s.m} = P_{s.0} Q_{m.s}/Q_m$

Q_m is the unconditional probability of receiving message *m*; $Q_{m.s}$ is the conditional probability of message *m* given state *s*. The relationship between posterior and priori probabilities is known as Bayesian, after Bayes' Theorem (Bikhchandani et a., 2013). $Q_{m.s}/Q_m$ is the marginal informativeness of message m given state s, and the more it differs from 1, the most posterior probabilities will differ from prior probabilities, hence improving the farmer's expectations about future events.

By assumption, PI offers a message service that is an alternative to traditional sources of information, by combining more accurate weather forecasts with more accurate estimations of crop water requirements. The value associated to PI is simply the difference between expected profits with and without the additional message service, $\Omega(\mu)$.

$$\Omega(\mu) = \sum_{\mu(PI),s} P_{s.m(PI)} Q_{m(PI)} \pi\,(a_{s.m(PI)}(q)) - \sum_{\mu,s} P_{s.m} Q_m \pi\,(a_{s.m}(q)) \qquad (3)$$

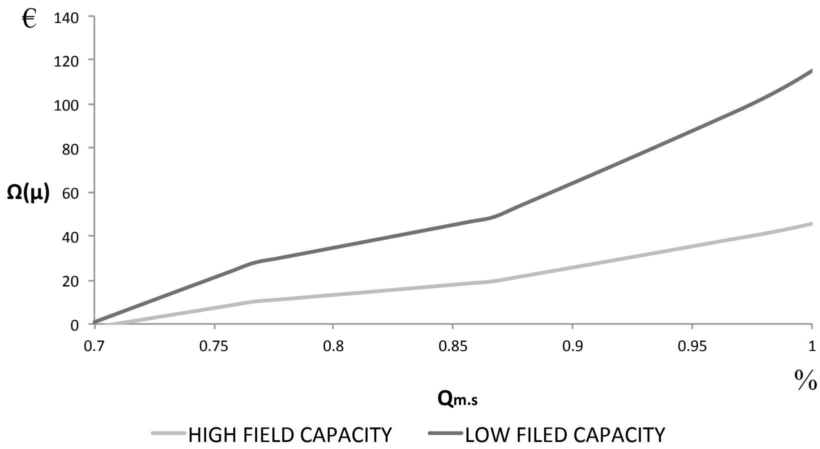
or,

$$\Omega(\mu) = \sum_s P_{s.0} \left[\sum_{\mu(PI)} Q_{m(PI).s}\, \pi\,(a_{s.m(PI)}(q)) - \sum_{\mu} Q_{m.s} \pi\,(a_{s.m}(q))\right] \qquad (4)$$

Equation 4 demontrates that farmer willingness to adopt PI is conditioned by: 1) his/her prior probabilities; 2) the predictability of comparing sources of information, $Q_{m(PI).s}$ and $Q_{m.s}$, given each state of the world, *s*; 3) the consequences associated with a farm's actions. As already stated, the relative gain in irrigation effectiveness associated with the transition from conventional information systems to PI is expected to decrease with land quality augmenting. In other words, with higher land quality the frequencies of irrigation applications during the growing season is reduced and the economic consequences of wrog decisions are also reduced.

Finally, the strategy of profit-maximizing irrigation involves a sequential process. First, optimal expected water use levels under the two informative systems are determined. Then, resulting profits are compared. The new information system is selected if $E[\pi(a_{s.m(PI)}(q))] - \nu \geq E[\pi(a_{s.m}(q))]$ and if $E[\pi(a_{s.m(PI)}(q))] - \nu \geq 0$. The traditional technology is used when $E[\pi(a_{s.m}(q))] > E[\pi(a_{s.m(PI)}(q))] - \nu$ and if $E[\pi(a_{s.m}(q))] \geq 0$. ν is the present cost for the equipment needed to shift from conventional information systems to PI.

In the following we offer an applicative example of the implementation of the former methodology by exploiting an historical series of climatic data from the past 20 years (1993 to 2013) collected by a meteorological station in northern Italy (Mirandola, MO, www.arpa.emr.it). Then, a production function with respect to water uses for tomatoes and sandy and clay soils was estimated through AQUACROP, a well-known FAO crop growth model (http://www.fao.org/nr/water/aquacrop.html). To carry out the simulation, assumptions were made with respect to soil characteristics, ground water table levels, and irrigation technology. In the region in question, tomatoes are both irrigated with sprinkler and drip irrigation systems and cultivated in areas characterised by different types of soils. In the present empirical example, we estimated gross margins combining official accounting data (http://www.rica.inea.it/public/it/index.php) with the production function estimated for tomatoes under low field capacity, sandy soils, and high field capacity, with loamy soils. With the adoption of PI, a message service is activated that improves farmers' expectations about future events. The prediction of traditional information systems is about 60%, while the prediction of PI is unknown. Graph 4 depicts the per hectare value of information trends, which we assume to correspond to farmers' willingness to adopt the technology, with increasing accuracy of information levels.



Graph 4 – Farmer's willingness to adopt PI, $\Omega(\mu)$, with increasing quality of information, $Q_{m.s}$, for processing tomatoes, comparing soils with low and high field capacity.

The differences between the two trends are mainly attributable to differences in the consequences associated with the farmers' decisions whether or not to irrigate. Wrong decisions made for processing tomatoes cultivated in regions characterised by high field capacity do not significantly affect performance. This is not the case for regions characterised by low field capacity levels.

The results confirm that, for a given crop and under given climatic conditions, the willingness to pay for PI increases with increased quality of information and decreases with land quality augmenting. By increasing the quality of the additional information obtained through the adoption of PI the difference in value obtained for low and high land qualities levels is also increased. By comparing the user's willingness to adopt with the costs for the adoption (equipment and licencing) it would be possible to assess under which circumstances, and for which degree of 'informativeness', PI can be considered a valuable practice. Tests from experimental sites in the FIGARO FP7 project will make it possible to verify whether the trend simulated in this study, with regard to the exploitation of water balance models, will be confirmed in the real world.

5. Discussion and Conclusions

PI represents a new technological frontier for optimizing the use of water resources in agriculture. This study is a starting point for investigating the potential of PI in European irrigated agriculture. The theoretical studies discussed in this paper, together with the Delphi study, made it possible to carry out a SWOT analysis on its uptake and to define a methodology for the assessment of the viability of the innovation. The main limitation of the Delphi study is the limited representation of European contexts, potentially resulting in biases in the generalizations presented in this study. The other limitation is the absence of studies highlighting the circumstances under which PI guarantees higher performance and water saving. The present study offers a methodology to partially fill this gap, and also introduces a simulation that nests a water balance model in an economic model. The simulation confirms that the willingness to adopt PI decreases with land quality augmenting.

The study highlights that the adoption of PI is strongly conditioned by the environmental, economic and regulatory framework of a region. Indeed, the regions considered in this study displayed very different endowments, infrastructures and rules. These differences affect the type and priorities of interventions aimed at improving irrigation efficiency and saving water in those contexts that should benefit from the diffusion of PI. However, unlike past irrigation innovations, PI can be applied to any type of irrigation system and in any region of the world. Moreover, PI is considered to be a promising innovation for irrigated agriculture in Europe because it facilitates the accomplishment of current policy tasks. Indeed, the new CAP reform explicitly addresses the need to save water, dedicating funding to advisory weather services and training and supporting investments aimed at adapting farm structures and production methods (EC, 2013). This is subject to a number of conditions: 1) the existence of a river basin management plan (RBP); 2) the inclusion of specific measures dedicated to the agricultural sector in the RBP; 3) the existence of water bodies characterised by a bad status. All of these aspects concur in substantiate the activation of specific CAP measures for targeting regions where the status of water bodies is undermined (Viaggi, 2011).

To enhance the uptake of PI, the stakeholders participating to the Delphi study emphasised the need to set up an advisory service that supports farmers in using PI. This concern is also confirmed in literature with scholars reporting that farmers encounter significant problems in using current agricultural information management systems notably in terms of functionality, interfaces and the parties involved (Reichardt and Juergens, 2009; Nash et al., 2009; Nikkilä et al., 2010).

In light of the upcoming policy scenario, further research is required to determine: a) if and for which type of regions/areas the diffusion of PI could be considered a valuable instrument for the achievement of environmental goals; b) for which type of users the adoption of PI is more likely to ensure economic benefits; and c) which type of economic and regulatory instruments are more likely to guarantee the adoption of PI and the expected impact on the environment and on the farm economy.

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