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Forecasting deficit irrigation adoption using a mixed stakeholder assessment methodology

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ABSTRACT

Although Deficit Irrigation (DI) can help farmers achieve significant water savings, its adoption is still limited. This study aims to identify the factors that affect DI adoption decisions in a water-scarce area, namely, south-eastern Spain, and to evaluate the importance of these factors. The factors were derived from the literature and personal interviews with regional irrigation water managers and other stakeholders. First, Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was used as the overarching framework to evaluate the various technical, social–political and environmental factors influencing DI adoption in an integrative manner. Second, a two-round Delphi survey was used to validate the SWOT items. The results reveal that the strengths and opportunities of DI adoption are given more weight than its weakness and threats. The technique's capacity for water saving and the specific water scarcity context appear to be the most important reasons for DI implementation. However, knowledge and awareness levels are low across different stakeholder groups, implying a need for improved promotion of the adoption of DI through scientific knowledge transfer. Water policies that promote the adoption of DI are considered an important way forward to ensure the long-term availability and sustainable use of water in agriculture in extreme drought-prone areas.

1. Introduction

Water is becoming scarce globally, and demand for its sustainable management is increasing rapidly. In this context, policy-makers in the Mediterranean regions are forced to focus on water conservation measures to ensure sustainable use of water resources in the long term. Stakeholders involved must carefully consider the optimal balance of water allocation for consumption and maintaining environmental and ecological requirements at the same time [1].

Several policy initiatives have been considered to achieve the sustainable use of water from both the supply and demand side. Currently, the measures to increase water availability on the supply side in Spain are focused on the use of recycled water and desalinated seawater. On the demand side, various options associated with new water policies and the uses of water saving technologies are under consideration. The application of water saving technologies is generally used in mature water management systems where little room exists for future expansion or development

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[2]. The adoption of modern water saving techniques or technologies that increase water use efficiency (and reduce irrigation input requirements) while maintaining production levels are considered the key to managing scarce water resources in arid and drought-prone areas [3,4].

At the farm level, increased water use efficiency can be achieved, for example, through the use of drip irrigation systems, which are currently widely adopted in water-scarce areas [5]. However, additional water savings can be achieved through the optimisation of controlled water dosage and timing of irrigation, commonly referred to as deficit irrigation (DI) [6,7]. DI is defined as irrigation supply below the full crop water requirements [8]. In areas where water is the limiting factor for cropping, the use of DI to regulate the amount of irrigated water has been shown to be economically more profitable for farmers than to maximise yield because water productivity is maximised [9–12].

The application of DI also stabilises yield and farm income, making it easier for farmers to make economic planning decisions [13]. DI has been more successful so far in fruit crops and vines than in field crops [14,15]. Other studies have demonstrated that the application of DI also increases crop quality [16,17] and advances the harvesting seasons [18]. Consequently, farmers are able to sell their crops at a higher average price. DI could also be used to control excessive foliage growth when applied during a plant's vegetative growth period [19].

Despite the advantages of this technique, its use is still limited, possibly due to the uncertainties and risk that DI introduces in farming. The use of DI requires [13]: a) precise knowledge of crop response to drought stress, b) a constant minimum quantity of water available for application and c) unrestricted access to irrigation water in sensitive periods. Moreover, the identification of the different phonological phases through expertise or the use of sensors is critical, and additional risks are assumed when low quality water is used [20]. The level of management required is high to achieve a modest gain of water productivity [21], and the risk of damaging the crop by accidental over-stressing can be significant [22].

This study aims to identify the factors that influence DI adoption decisions in a water-scarce area, namely south-eastern Spain, and to evaluate the importance of these factors. To identify the factors, a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is first conducted through personal interviews with stakeholders involved in irrigation water management in the region. The SWOT items are subsequently evaluated using a two-round Delphi survey of a panel of stakeholders. The Delphi method allows for the analysis and comparison of different stakeholder group responses on the relevance of the factors affecting DI adoption, whereas the use of the SWOT framework allows for a comprehensive analysis of the technical advantages and disadvantages of DI and the surrounding factors affecting its adoption. The current literature on DI adoption is fragmented, with studies focusing either on the technical aspects that enable or hinder the adoption of DI (as evidenced by field experiments) or on policy issues evaluating how social and economic factors motivate or restrict adoption. This study represents the first time that both technical and policy components have been consolidated and analysed under one framework (the SWOT) to obtain a more comprehensive and comparative perspective on the key factors in DI adoption. Findings from this research will assist policy makers to make more informed decisions about establishing guidelines that facilitate the adoption of DI techniques by farmers.

2. Background

The adoption of irrigation technologies has been previously studied in water-scarce areas such as the western United States (US) and Mediterranean countries. Specifically, these studies examined the impact of farmers' and farm' characteristics, technology characteristics and policy settings on the adoption of different irrigation technologies, including DI.

In the western US, Caswell and Zilberman [23] found that higher water prices foster the adoption of water-saving technologies. They [24] also found that technology adoption is affected by soil properties. Subsequent studies in the US [25–29] confirm that input costs (particularly the cost of water), topography, soil characteristics, and climate influence the type of irrigation technology adopted. Moreno and Sunding [30] also found a correlation between land allocation and technology choice, indicating that financial incentives, such as technology subsidies or water prices, have a stronger influence on adoption behaviour than suggested by previous studies. These studies confirm that the transition to water-saving technologies is relatively slow in the absence of policy-induced changes.

In the Mediterranean region, Foltz [31] examined the adoption of drip irrigation technology in Tunisia observing that information and credit constraints had the strongest effects on technology adoption choices. He also found that better-informed farmers and those with farms situated closest to the areas where drip irrigation was first introduced had a higher probability of adopting drip irrigation.

Fishelson and Rymon [32] identified that the total drip irrigation adoption effect in Israel was guided by yield differences between technologies. Caswell and Zilberman [23] found similar results for the western US and Dinar and Yaron [33] for citrus growers in Israel. In Crete, Koundoury et al. [34] suggested that farmers adopted new irrigation technology to hedge against production risk, but human capital also plays a significant role in the decision to adopt modern irrigation technology. Alcon et al. [35] obtained similar results in southern Spain, where the speed of adoption of drip irrigation technology was studied using a duration model. This work highlights the importance of educational factors, technological trialability (i.e., the technology can be tried and tested by farmers), credit availability and institutional factors such as water availability and price, information networks and policy factors. Contrary to expectations, they found that higher yearly water allotment increased the speed of new technology adoption because increasing the amount of water allocated to farmers may reassure them that the investment in irrigation technology will be profitable.

Thus, previous studies on irrigation technology adoption have compared the different characteristics between adopters and non-adopters (i.e., farmer characteristics, technology characteristics, farm characteristics and policy settings) and identified which characteristics influence the rate of adoption. Despite the benefits of water productivity maximisation and yield stabilisation in water-scarce areas [13], DI has not achieved widespread adoption. Geerts and Raes [13] argued that greater knowledge of crop response to drought stress from