Chapter 14
Drip Irrigation Technology: Analysis of Adoption and Diffusion Processes

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Abstract Increasing concerns about water scarcity have promoted the adoption and diffusion of irrigation technologies, such as drip irrigation, which allow farmers to use water in a more efficient way, while saving water resources. While some dry regions have embraced drip irrigation, this technology remains scarcely deployed on a global scale. In this chapter we provide an overview of the processes underlying the adoption and diffusion of innovations, with a focus on the specific context of the adoption and diffusion of drip irrigation technology within the agricultural community of Cartagena, in Southeast Spain. Our final aim is to inform policy makers charged with the designing of initiatives aimed at saving water and at increasing climate change resilience in agricultural contexts. Our main insights suggest that effective policies focused on irrigation technology uptake should consider social, economic, technological and environmental factors affecting adoption and diffusion dynamics, and specifically those factors that define perceptions of water scarcity, such as water prices and availability of water.

Keywords Review · Analytic framework · Irrigation water · Water-saving technology · Spain

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14.1 Introduction

Water is an ever-scarcer key resource, necessary to sustain ecosystems as well as economic and social activities. Worldwide, agriculture accounts for 70% of all water withdrawal. Irrigated agriculture thus plays a crucial role in the global food production system (WWAP 2012) and agricultural water management has become an international priority. Water availability for agriculture has reached critical levels in arid and semi-arid regions, where water shortages are predicted to worsen due to climate change and its derived effects, such as increased frequency and intensity of droughts, lower precipitation, as well as foreseeable increases in water demand for irrigation (IPCC 2007).

In water-scarce areas, where limited water resources must be allocated to various productive uses while preserving the environment and ecosystems, the sustainable use of water resources is perhaps the major policy challenge of our times (Falkenmark 2000). To address this challenge, policy initiatives have been promoted from the two perspectives of supply and demand (Alcon et al. 2014). Supply-focused initiatives aim at increasing water resources availability. On the other hand, demand-focused initiatives foster water-saving management practices through the adoption of irrigation technologies of improved but variable water use efficiency, such as furrows (50–60% efficiency), sprinklers (70–80%) and drip irrigation (90%) (Dasberg and Or 1999).

Relative to traditional irrigation systems, drip irrigation, defined as the application of water through point or line sources at small operating pressures, has the potential to conserve water, improve crop quality, and increase crop production by using controlled irrigation doses and frequencies (Dasberg and Or 1999). Drip irrigation enhances water use efficiency by reducing water losses caused by deep percolation, soil evaporation and runoff. Through drip irrigation weed growth can be reduced, salinity problems mediated and the use of fertilisers optimised. Drip irrigation is generally more energy-efficient than sprinklers, and is adaptable to difficult soils and terrains (Skaggs 2001). At the same time, drip irrigation has a number of limitations, the main constraints for its deployment being the high initial installation costs[1] and the intensive maintenance requirements (emitter clogging, etc.). In addition, drip irrigation limits plant root development, favours salt accumulation near plants and reduce soil capacity to absorb CO_2 (Puy et al. 2016).

Overall, in spite of these limitations, drip irrigation technologies drastically improve the effectiveness of water use in agriculture while maintaining production levels. Thus, drip irrigation can play a key role for the improved use of scarce hydric resources worldwide (Cason and Uhlaner 1991).

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[1] Investment and operational costs are variable depending on the technology selected. As an example, in Spain, investment and maintenance cost was in 5000€ ha^{-1} and 1232€ ha^{-1}, respectively in 2006 for fruits (Alcon et al. 2013), while in Burkina Faso the investment cost reached 7132$ ha^{-1} and the operational was 1544$ ha^{-1} for herbaceous crops (IFC 2014)

Nevertheless, drip irrigation has been scarcely deployed to date. For instance, the OECD countries with the highest share of irrigated land area (Spain, the Czech Republic, Greece and Italy) have drip irrigation adoption rates lower than 40% (OECD 2010). Some countries outside the OECD show higher drip irrigation adoption rates. In Israel for example, over 50% of irrigated land is now under drip irrigation (OECD 2011). In Jordan and Cyprus adoption rates add up to 60% and 95% respectively. In general, arid and drought-prone regions have shown the widest adoption of such water-saving technologies as drip irrigation (Alcon et al. 2011).

After providing an overview of the processes underlying the adoption and diffusion of innovations, this chapter focuses on the specific context of adoption and diffusion of drip irrigation technology within the agricultural community of Cartagena, in Southeast Spain. By identifying the social, economic, technological and environmental factors that affect irrigation technology adoption and diffusion we wish to support the improvement of policy initiatives that foster water saving and increase climate change resilience in agriculture.

14.2 Adoption and Diffusion of Innovation: Concepts and Approaches

Besides bringing competitive advantages to companies (Dieperink et al. 2004), innovations have an impact on social and cultural factors related to economic development (Freeman 1995). Originated is response to demand or as a need, a given innovation reaches the market in the shape of a technology, a technique or an organisational method or process. Over time, the diffusion of such an innovation follows existing communication channels among the members of a social system (Rogers 2003). The adoption of an innovation refers to a single individual decision on the acceptance of an innovation, whereas diffusion refers to the process of acceptance by a group of individuals through time. Diffusion is thus defined as the process of adopting a technology by the members of a social system or the process through which innovations are disseminated within and beyond a productive system (Feder and Umali 1993).

The innovation–decision–diffusion process comprises a set of phases, including knowledge, persuasion, decision, implementation and confirmation. From first exposure to adoption and confirmation, embracing a given innovation may bring a series of benefits to those implementing it (Pannell et al. 2006).

In the agricultural sector, innovations generally reach the market in the shape of new technologies. While becoming familiar with a newly available technology, farmers go through an adaptation process based on a sequence of decisions leading to its adoption or rejection (Gatignon and Robertson 1991). The amount of time it takes for the farmer to make a decision will depend on several factors, including: uncertainties associated to the proposed innovation, formal and informal knowledge gathered on its efficiency, the authority and credibility of the informants, as well as farmer's characteristics and background. Farmers who apply a new technology expect to benefit from its implementation, thus contributing to a global improvement of their social welfare (Rogers 2003).

While most innovations reaching the market are cost-effective, their spreading has often been slower than expected. In most cases, the slow speed for the adoption and diffusion of a given innovation can be attributed to the lack of information on the expectations that it creates among the potential adopting actors and to poor communication regarding its potential contribution to the achievement of their goals (Pannell et al. 2006). One of the main benefits expected from the implementation of an innovation is a significant decrease of collateral risks associated to the development of the business activity. In agricultural contexts, water scarcity and availability is perhaps the major one of such risks, becoming especially relevant in arid and semi-arid climates, where the adoption of water-saving technologies is one of the goals of national irrigation policies aimed at the sustainable and rational use of water resources.

Different approaches exist for the analysis of the adoption and diffusion of technologies (Feder and Umali 1993; Lindner 1987; Pannell et al. 2006; Rogers 2003), which are summarised in Fig. 14.1.

In a first set of approaches the adoption process is classified from the point of view of innovativeness. Here, studies at the micro level (i.e. individual adopters) focus on the characteristics of the potential adopters and their behaviour when facing innovations. Research studies carried out within this approach have been divided into two types depending on the perspective from which the analysis is undertaken: static, focused on intensity, and dynamic, focused on adjustment (Lindner 1987):

- Cross section studies (static) focus on the reasons why an individual accepts or rejects an innovation. They try to explain those factors and processes that have led the individual to the final decision on whether to adopt or reject an innovation.
- Temporal studies (dynamic) focus on the time elapsing between the development of an innovation and its adoption by an individual. They try to explain why some individuals adopt an innovation more quickly than others.

In a second set of approaches, the diffusion process is studied in broader areas of time and space, estimating the adoption rate of an innovation within the community of potential adopters and its dependence on the characteristics of the technology. As for the micro level, these macro level studies have been divided into two types depending on the perspective approached from both static and dynamic perspectives:

- Cross section studies are aimed at finding the diffusion rate of a technology once the imbalance has been readjusted. They try to explain why some innovations are widely adopted, while others are not.

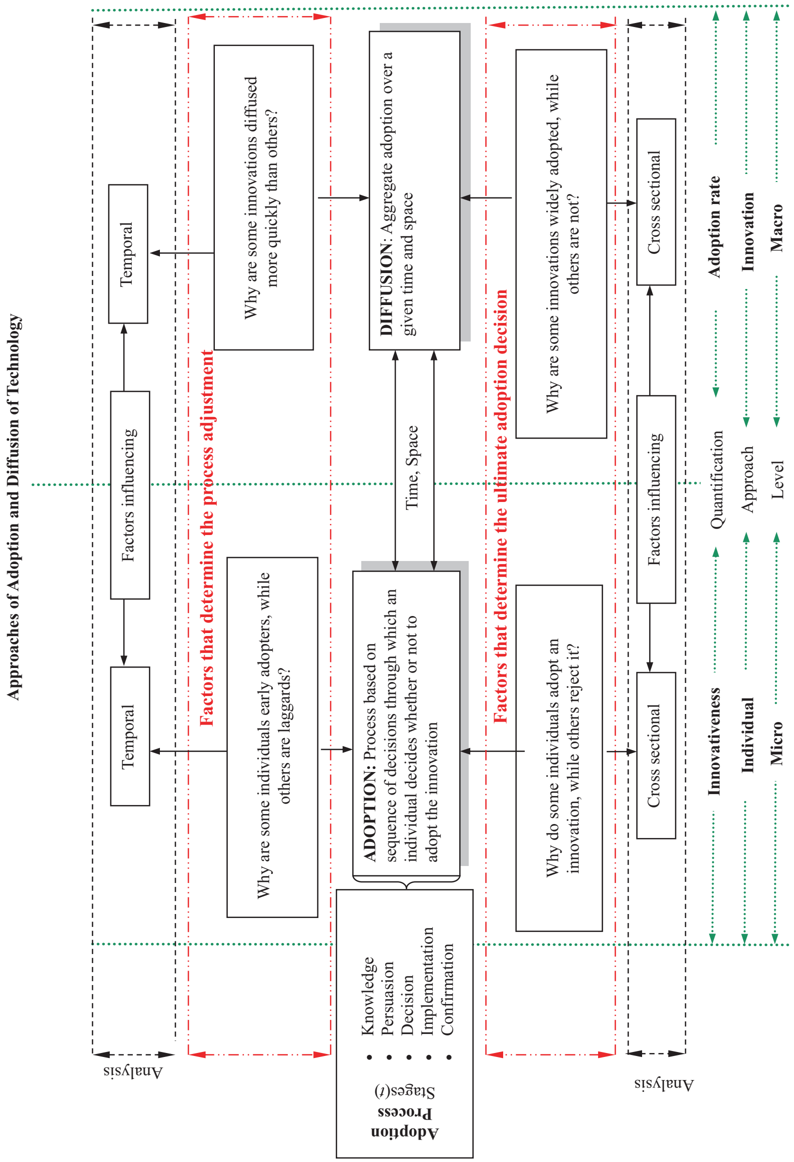


Fig. 14.1 Approaches of adoption and diffusion of technology

- Temporal studies estimate the delay between the first and the last members adopting an innovation within the same group. They try to explain why some innovations diffuse more quickly than others within a given group.

14.3 Adoption and Diffusion of Innovation: Analytical Models

Innovation adoption rates have been analysed mainly using temporal data to describe individuals on the basis of their adoption time. To do so, the density function of adopters can, for example, be divided into five categories using the mean and the standard deviation of the adopters' population, according to the method proposed by Rogers (2003). The resulting adopter categories were: innovators, early adopters, early majority, later majority and laggards. These categories were employed in the irrigation scheme of Cartagena (Murcia, SE Spain) by Alcon et al. (2006) to analyse the diffusion pattern of drip irrigation technology. Although variations of this method have been developed (Bass 1969; Mahajan et al. 1990; Karlheinz and Even 2000), the fundamentals remain the same.

14.3.1 Diffusion Models

Diffusion models aim at describing the number of adopters across time and at predicting the development of the diffusion process. Such models are based on mathematical functions that explain the degree of penetration and the maximum level of adoption of a given technology within a given social system (Van den Bulte 2000). Diffusion models follow the general form:

$$\frac{\mathrm{d}N(t)}{\mathrm{d}t} = g(t)\left[M - N(t)\right] \tag{14.1}$$

where $\mathrm{d}N(t)/\mathrm{d}t$ = diffusion rate in time t, $N(t)$ = cumulative adoption in t, M = total adopters and $g(t)$ = diffusion coefficient that would define the shape of the curve.

Diffusion models can be of internal, external or mix influence. All model equations described below allow plotting the percentage of cumulative adoption $N(t)$ along the time line t, specifying a maximum percentage of adoption. Therefore, different technologies fit better in different contexts.

1. Internal influence diffusion models, also called logistic models, are based on the assumption that the diffusion is produced by information and experience accumulation within the community (autochthonous), reducing the initial uncertainty about the technology. Here, early adopters influence later potential adopters,

similar to the propagation of an epidemic by contagion. The logistic model is defined by Mansfield (1961):

$$N(t) = \frac{M}{1 + e^{-(a+bt)}} \tag{14.2}$$

2. Where, a is the integration constant and b the adoption rate. In these models, the maximum adoption rate is found in correspondence with the inflection point ($dN/dt = 0$), i.e. when the innovation is adopted by 50% of the population. According to Banks (1994) it can be reached at $t^* = a/b$ and $N(t^*) = M/2$. External influence diffusion models, proposed by Fourt and Woodlock (1960), assume that information reaching potential adopters proceeds from external sources (allochthonous), such as social media or external agents. External influence models assume that adoption rate only depends on the number of potential adopters across time and it is defined by:

$$N(t) = M\left[1 + e^{-(a+bt)}\right] \tag{14.3}$$

3. Mix influence diffusion models, also known as "Bass models", include both models previously described, taking into account innovators (external influence) as well as imitators (internal influence) in a sigmoidal function as:

$$N(t) = \frac{M\left(1 - e^{-(p+q)t}\right)}{\left[(q/p)e^{-(p+q)t} + 1\right]} \tag{14.4}$$

   where p is the external influence coefficient and q the internal influence coefficient.

   At higher values of p and q higher diffusion speed is achieved, the maximum adoption being rate reached at time $t^* = \ln(q/p)/p + q$ where the cumulative adoption is $N(t^*) = M(1/2 - p/2q)$ (Mahajan et al. 1990).

14.3.1.1 Innovativeness: Logit and Probit Models

Innovativeness has been approached in individual models where the technology adoption decision is considered at a single moment in time. Such cross-section studies explain the adoption of a new technology as a function of its expected utility compared with that gained from an existing technology. These models have been applied to a number of studies on drip irrigation technology where the variable to be explained was adoption itself (Dinar and Yaron 1990; Feder and Umali 1993; Shrestha and Gopalakrishnan 1993; Green et al. 1996; Green and Sunding 1997).

The most common approach to explain this categorical variable has been the use of logit and probit models, which provide similar results, though based on different error distributions. Logit models allow the endogenous variable Y_i, bounded between 0 and 1, to be related with a series of explicative variables X_{ki} through a logistic distribution function (Cramer 2003). The goal of logit models is to find the relationship between the endogenous variable and a set of independent variables. This model generates the coefficients to predict a logit transformation of the probability of the factors of interest being present:

$$\log\text{it}\left(p\right) = \beta_k X_k + \varepsilon_i \tag{14.5}$$

where p is the probability of adoption and β_k is a vector of regression coefficients. Extensions of this model have been also used to analyse the joint adoption of two complementary decisions. This was explored by Moreno and Sunding (2005) for irrigation technology and land allocation and by Engler et al. (2016) for irrigation technology and scheduling.

14.3.1.2 Duration Models

A different approach, introduced in the 1980s, uses duration models to explain adjustment processes. (In such models, duration analysis explains the time elapsed between the moment when an individual becomes a potential adopter (T) and the moment when the full adoption occurs. In these works, technology adoption is presented as a dynamic process, explained by cross-section and other time-dependent external variables). The adoption is modelled by the hazard function (Lancaster 1990). Assuming that $F(t)$ denotes the cumulative distribution of adoption ($F(t) = Pr(T \leq t)$), then the survival function $S(t)$ is the reverse of the cumulative distribution function of T (i.e. $S(t) = 1 - F(t)$) which defines the probability of not adopting at time t. The hazard function ($h(t)$) specifies the rate at which adoption occurs through time as defined by Jenkin (1995):

$$\begin{aligned} H\left(t\right) &= \operatorname*{Lim}_{\mathrm{d}t\to 0} \frac{P\left(t \leq T < t + \mathrm{d}t \mid T \geq t\right)}{\mathrm{d}t} \\ &= \operatorname*{Lim}_{\mathrm{d}t\to 0} \frac{F\left(t+\mathrm{d}t\right) - F\left(t\right)}{\mathrm{d}t\left(1 - F\left(t\right)\right)} = \frac{f\left(t\right)}{S\left(t\right)} \end{aligned} \tag{14.6}$$

This approach focuses on the timing of innovation adoption, considering the impact of variables which intensity changes over time. As such, duration analysis has been deemed suitable to analyse the adoption of agricultural technologies in general (Burton et al. 2003 and D’Emden et al. 2006) and that of drip irrigation in particular (Alcon et al. 2011).

14.4 Factors Explaining the Adoption of Innovations

In this section we focus on the factors that influence the adoption of innovations and on their relation to the adoption process. We pay special attention to the context of irrigation technology.

Based on existing scholarship, we have proposed above a classification of the different factors that have been used to explain technology adoption (Rogers 2003; Foltz 2003; Pannell et al. 2006; Feder and Umali 1993; Mohammadzadeh et al. 2014). A revised classification is proposed hereafter, clustering all analysed factors under five major groups (Fig. 14.2): (1) farmer characteristics, (2) economic factors, (3) farm characteristics, (4) characteristics of the technology, and (5) environmental factors in which the adoption process develops.

Farmer characteristics have been widely analysed in adoption literature proving significant in many instances over the adoption decision. Regarding irrigation technologies for example, it is expected that young farmers adopt earlier than elder ones (Skaggs 2001; Alcon et al. 2011). More experienced farmers, that are usually the elders in the community, tend to delay the adoption (Dinar and Yaron 1990; Shrestha and Gopalakrishnan 1993; Engler et al. 2016). Farmers with higher levels of education tend to be early adopters (Sidibé 2005). Also, personal inclination to cooperate promotes innovation adoption among individuals as it provides access to collective investment (Dinar and Yaron 1990, Sidibé 2005). Personal beliefs about the technology can also affect the innovativeness level (Skaggs 2001; Sidibé 2005). Finally, the probability of adopting irrigation technologies is proportional to land ownership (Moreno and Sunding 2005).

Economic characteristics arise from farmers' goal to maximise profitability of the farm. In this sense, the adoption of irrigation technology implies an investment and a consequent variation of inputs, use and outputs produced. The size of the business (measured as annual turnover), and the access to capital (e.g. as loans) can be considered the two most important economic variables. Generally, richer farmers have been more innovative thanks to their investment capacity and access to credit (Dinar and Yaron 1990; Skaggs 2001; Foltz 2003). Lower labor costs have also shown a positive effect on the adoption decision (Negri and Brooks 1990). However, the most important economic factor influencing the adoption of irrigation technolo-

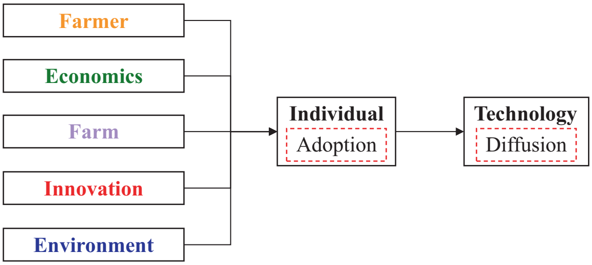


Fig. 14.2 Factors affecting technology adoption

gies has been shown to be water price, increasing as a consequence of water scarcity. Several studies have demonstrated that hydrological scarcity leads to higher shadow prices for water, pushing farmers towards the adoption of water-saving technologies (Dinar and Yaron 1990; Caswell et al. 1990; Negri and Brooks 1990; Green et al. 1996; Green and Sunding 1997; Carey and Zilberman 2002; Foltz 2003; Alcon et al. 2011).

Farm characteristics (physical, technical and locational) may facilitate the adoption of irrigation technologies. Soil characteristics, such as soil slope or texture, as well as microclimatic context have been claimed to influence innovation adoption rate (Green et al. 1996; Green and Sunding 1997; Negri and Brooks 1990). In some cases, crop type preferences have also influenced irrigation adoption decision-making (Moreno and Sunding 2005).

Innovation characteristics defined by Rogers (2003) may be summarised as follows: (1) the *relative advantage* of the innovation over existing alternatives, (2) the *complexity*, understood as the degree of difficulty that is perceived in using the new technology; (3) the *compatibility*, or degree to which an innovation is perceived as being consistent with the cultural values, previous experience, needs and resources of the adopters; (4) the *trialability*, that is the possibility to appreciate with real examples the advantages of the technology; and (5) the *observability*, or the degree to which the results of the innovation can be observed by other potential adopters. For irrigation technologies, relative advantage has been shown to influence adoption decision to the greatest extent (Moreno and Sunding 2005; Engler et al. 2016), together with technology cost (Caswell et al. 1990; Negri and Brooks 1990). Trialability and observability (i.e. the possibility to test) have become increasingly important in the past years in the adoption of several technologies (Pannell et al. 2006; López-Becerra et al. 2016).

Environment factors, other than those related with the farmers, the farm or the technology, may also affect the diffusion of irrigation technologies. These factors refer to the economic, social and political environment within which the farmers are embedded. For example, water allocation and water price policies, defined by political actors, play a key role on the adoption of irrigation technologies. In general, farms with endowments from different water sources, such as rivers or aquifers, have a lower perception of water scarcity and are less likely to adopt irrigation technologies with respect to farmers that depend on a single water source (Moreno and Sunding 2005). In one instance, Alcon et al. (2011) showed that farmers that use surface water, complemented with groundwater resources, tend to adopt early to reach some certainty in water supply. Finally, the contact with change agents (opinion leaders within the agricultural community), the exposure to mass media and access to interpersonal communication channels would also promote early adoption (Rogers 2003). Frequent contact with relevant information sources thus seems to contribute to reducing the degree of uncertainty when deciding on the adoption of new irrigation technologies, favouring early adoption (Engler et al. 2016).

14.5 Drip Irrigation Technology Adoption and Diffusion in Spain

Here we present the example of adoption and diffusion of drip irrigation technology in a water-scarce area of Spain, previously studied by Alcon et al. (2006, 2011), to illustrate the definitions, concepts and approaches used in the analysis of adoption and diffusion processes. The study was developed at *Campo de Cartagena*, a major irrigation community found in one of the most water-stressed areas of Europe. First introduced as early as 1975, drip irrigation technology is presently used by more than 95% of farmers within the Cartagena community (Fig. 14.3).

Diffusion analysis to model the drip irrigation adoption pattern was explored using the logistic model (see above Diffusion model 1, Alcon et al. 2006). Inter-firm diffusion of technology was studied according to individual farmer adoption time. The results obtained highlighted that "word of mouth" and farmer's visual perceptions fuelled the adoption process. In fact, access to knowledge acquired from previous adopters reduces perceived uncertainty around a new technology, motivating later adopters.

Thus, Fig. 14.4 and Table 14.1 present the key points defining the density (n) and cumulative (N) diffusion curves. Diffusion rates reached their maximum growth ratio between 1987 and 1988 (12 and 13 years after first introduction), about two-thirds down the overall diffusion period of 18 years. The percentage of cumulative adoption (N) at density function inflection points refers to the year in which the maximum diffusion speed is reached, i.e. 1982, and the year when the establishment period starts, i.e. 1993.

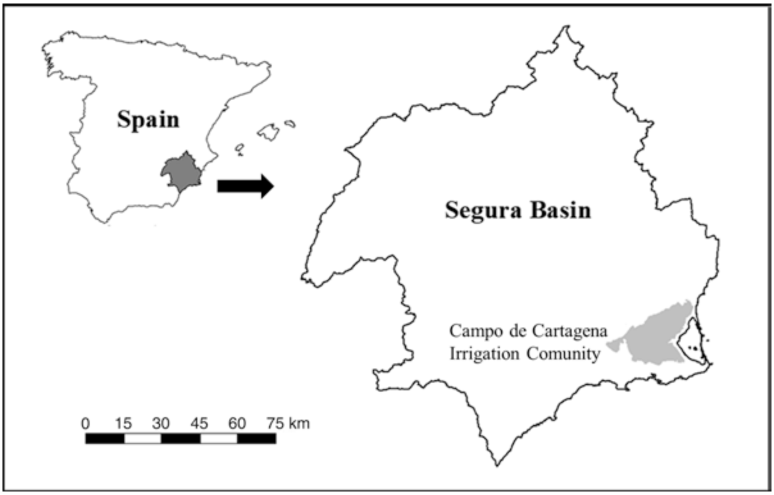
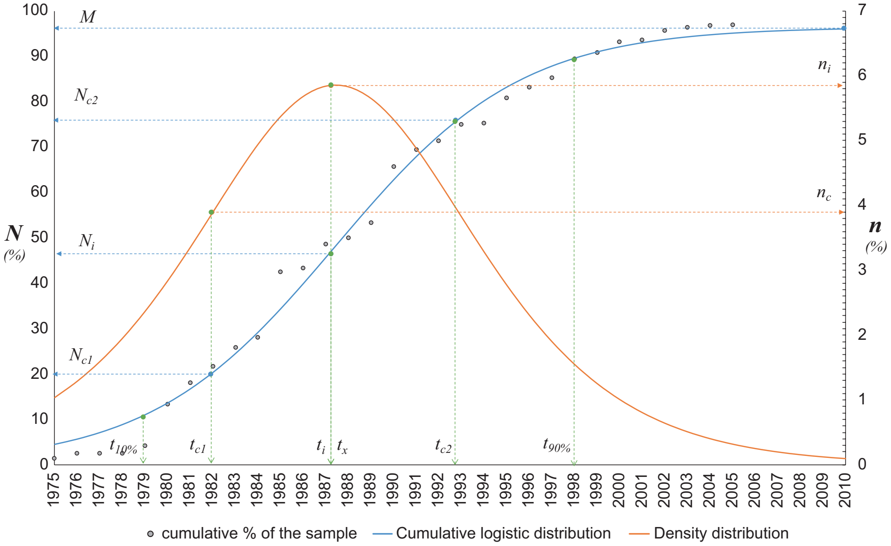


Fig. 14.3 Location of the Campo de Cartagena Irrigation Community in south-eastern Spain



Source: Adapted from Alcon et al. (2006)

Fig. 14.4 Inter-firm diffusion of drip irrigation technology in the Cartagena Irrigation Community Source: Adapted from Alcon et al. (2006)

Table 14.1 Features of the logistic distribution of drip technology adoption

Description	Symbol	Value
Integration constant	a	3.02
Diffusion coefficient	b	0.24
Total adopters (%)	M	96.45
Value of t at cumulative inflection point (year)	t_i	12.44
Value of N at cumulative inflection point (%)	N_i	48.23
Maximum value of n (slope) at cumulative inflection point	n_i	5.86
Value of t at density inflection points	t_{c1} t_{c2}	7.02 17.86
Value of N at density inflection points (%)	N_{c1} N_{c2}	20.38 76.07
Value of n (slope) at cumulative inflection point	n_c	3.91
Mean value of density distribution	t_x	12.44
Standard deviation of density distribution	s	7.46
Diffusion time	$t_{10–90\%}$	18.08

Source: Adapted from Alcon et al. (2006)

A Duration model (see above) that measures proportional hazard was used to analyse the decision-making process followed by farmers in adopting drip irrigation technology (Alcon et al. 2011). Table 14.2 reports the description of the variables used and the maximum likelihood estimation of the variables determining the adop-

Table 14.2 Duration model of drip irrigation adoption

	Coeff.	Std. err.	$P > \|z\|$	Variable definitions
$\alpha 1$	2.45	0.46	0.00	
$\alpha 2$	0.83	0.39	0.03	
Age	−0.03	0.01	0.01	Age of farmer (years)
Study	0.26	0.11	0.02	Study levels: no studies = 0 Left education at 14/16 = 1 Left education at 18 = 2 3 year at university study = 3 5 year at university study = 4
Coop	0.46	0.19	0.01	If a member of a cooperative = 1, = 0 otherwise
Labour	0.04	0.10	0.65	Number of household members working in the farm (persons full time/year)
On-farm income	0.41	0.26	0.12	if income from agriculture is the main source of household income = 1, = 0 otherwise
Water price$_t$	0.11	0.02	0.00	Real price of water (€/100 m^3, constant 2005€)
Credit	0.07	0.03	0.05	If farmer has had credit availability (personal valuation 0–10)
Size	−0.00	0.00	0.31	The size of the farm (ha)
Fruits	0.37	0.18	0.04	If farmer crop fruits = 1, = 0 otherwise.
Trial	0.36	0.21	0.08	If farmer has tested technology in part of his farm prior to adoption or rejection = 1, = 0 otherwise
Info	0.91	0.25	0.00	If main information source is specialized personnel in agriculture (technology suppliers or other inputs, agricultural extension services, cooperative technicians or research centres) = 1, = 0 other farmers
Availaw$_t$	0.00	0.00	0.00	Water availability at time t (m^3/ha)
Groundwater	0.38	0.22	0.09	if farmer has groundwater allocation = 1, = 0 otherwise
Year_85$_t$	0.72	0.18	0.00	Dummy variable to measure the effects of expectations of becoming a European Union member in 1986, = 1 in 1985, = 0 otherwise
$p - 1$	0.97	0.28	0.00	
Ln (λp)	−7.03	0.84	0.00	
U	−0.61	0.33	0.07	
V	0.53	0.19	0.00	
Log likelihood	−827.58			
Number of obs.	326			
LR Gamma test Prob. > =chibar^2	9.84 0.00			
Pseudo R^2	0.18			

Source: Alcon et al. (2011)
t time-dependent variables

tion of drip irrigation technology. Positive coefficients imply that the variable has a positive impact on the probability of adoption and vice versa. The change in probability for a unit change in the exogenous variable is given by the exponential of the coefficient. For example, the hazard ratio for the variable denoting groundwater allocation (GROUNDWATER) is $e^{0.38} = 1.46$, which indicates that farmers with groundwater allocation have a 46% greater probability of adopting drip irrigation than those that use only surface water.

When results are interpreted on the basis of the five major groups described above (farmer, economic, farm, innovation and environment) a number of results from previous studies published within the adoption literature are confirmed. Specifically, age, study, membership of farmer groups, specific information sources, trialability of the technology and credit availability, all contribute to increased innovation uptake.

1. Farmer's characteristics influence the decision to adopt a new technology. Younger and least experienced farmers show more interest in adopting the irrigation technology. More educated farmers are also more likely to adopt.
2. Regarding economic aspects, availability of credit, through association and greater business size, also favours adoption.
3. Farm characteristics did not show any significant difference in adoption decision.
4. As for technological aspects, the trialability has been shown to play an important role on the adoption of drip irrigation technology in Cartagena.
5. Regarding environmental factors, direct knowledge of the information sources and of their reliability also increased the likelihood of adoption. Also, awareness of water availability and knowledge of the existence of an alternative water supply (ensuring benchmark water availability per year) increased adoption probabilities.

In Cartagena, water availability favoured the adoption of drip irrigation technology. Individual preferences and perceptions of agriculture and technology were also crucial in the adoption process. Alcon et al. (2011) confirmed the key role of benchmark water availability and water price in determining the speed of adoption of drip irrigation. However, and somewhat counter intuitively, more water allotment in a given year has been shown to increase adoption speed, possibly highlighting the importance for farmers to be reassured on the economic profitability of investing in the drip irrigation technology. Overall, time and time-dependent variables were shown to have an important influence on the adoption process.

14.6 Conclusions

In this chapter we have reviewed the different methodological and modelling approaches used to investigate adoption and diffusion processes within the framework of irrigation related technologies. We have illustrated the state of the art using the example of drip irrigation uptake at *Campo de Cartagena*, a large community of irrigators in the region of Murcia, Southeast Spain, which has one of the driest climates in Europe. Our proposed interpretation aims at highlighting how the analysis of adoption and diffusion dynamics of drip irrigation technology can provide information to policy-makers that design initiatives aimed to save water and increase climate change resilience in agriculture. In fact, a good understanding of the social, economic, technological and environmental factors affecting adoption and diffusion dynamics is paramount to actually implement technologies that improve water productivity and conservation, reducing environmental externalities caused by agriculture. To be effective, water-saving policies focused on irrigation technology uptake should consider those factors that encourage perceptions of water scarcity, such as water prices and availability of water. An effective adoption of irrigation technology is unlikely when such factors are overlooked.

Some general results that have emerged from Spanish case studies can inform policy makers that aim to spread irrigation technologies in other water-scarce regions of the world. For example, we found that personal relationships between irrigation stakeholders are the key for the transmission of information, reducing perceived uncertainty about newly introduced technologies. We also identified the type of farmers that policies should target to ensure a successful early diffusion of technologies: younger and more educated farmers, with bigger farms, belonging to farmers' associations and with reduced credit constraints. Our results also suggest that the creation of demonstrative plots, where technology can be tested and tried by end-users, would foster the adoption process. Finally, we found that environmental restrictions, such as guaranteed water supply, would contribute to early adoption, as well as paying for the water.

In conclusion, our analysis of adoption and diffusion processes for drip irrigation technologies contributes a better understanding of how to successfully implement the adoption of water-saving technologies to mitigate the negative effects of climate change over water availability for irrigation in agriculture.

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