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FOREWORD

Olbassali et al. explore the determinants of administrative and organizational amendments in the general rural administration during the economic crisis. Data were gathered through a qualitative survey with public officers and stakeholders and were gauged through a Delphi policy framework. The results indicated that public administration was neither prepared to confront the crisis nor the changes that followed. On the other hand, stakeholders claim that despite all the changes that have occurred, the bureaucracy was unaffected and that there is a need for public services to be enhanced.

The authors *Kerras et al.* analyze the world situation in terms of training and gender gaps to see if these elements affect the achievement of four of the sustainable development goals (SDG 2, 4, 5 10) in 87 countries. The results of the multiple linear regression show the existence of a positive relationship between these elements is demonstrated. Then, as a real example, Spain is chosen as a country reference and analyzed in terms of training by gender, digital gender gap and labor gap. Finally, some advice and recommendations that allow the achievement of the inclusion of women in the improvement of the countries are suggested.

The efficiency level of cereal-dairy sheep production systems in the Mediterranean Basin dealt with by *Morantes et al.* They studied the Protected Designation of Origin “Manchego Cheese”, located in Castilla-La Mancha (Spain). This work evaluates technological levels by means of synthetic indexes. Two different groups were defined. Technical efficiency was estimated using Data Envelopment Analysis with metafrontier models. The higher the technological level, the higher the efficiency level. Low technology farms could increase their production at least around 23% using the technologies of the high-technology group. Increase farm size is a way to implement these technologies. Special attention to managerial functions, mainly organisation and planning, is also advisable.

Belaidi et al. aim to identify and analyze the major determinants that affect the adoption choice, rate and intensity of water-saving irrigation technologies (sprinkler and drip irrigation techniques) available in the western part of the irrigated perimeter of Mitidja Plain, Algeria. A sample of 136 farmers (28.75%) was randomly selected and surveyed using a structured questionnaire. Three econometric models were used, namely the Logit, Tobit and Poisson regression models. The main findings of the resulted models indicated that capital constraints (credit access, investment costs and subsidies) along with some human capital aspects (age, educational level) and water extraction cost, are the main determinants expected to influence the technological adoption choice, rate, and intensity in the study area.

Fagioli and Viganò used Principal Component Analysis and Logit model to analyse the Self-Efficacy (SE) of young aspiring entrepreneurs and to evaluate its effects on the promotion of personal entrepreneurial projects in the Tunisian region of Kroumerie-Mogods. The study shows that past involvement in business key activities, as commercial experiences, social commitments, and sustainable waste management, represent a decisive element for the promotion of personal business projects in agri-food sector.

Mahdhi et al. analyze the individual strategies and determinants of adaptation to climate change (CC) of irrigators in south-eastern Tunisia. A survey questionnaire was administered to 157 randomly selected farm managers in Tunisia, and descriptive statistics and a multinomial logistic model were used to analyze the data collected from farmers. The climate variability felt by farms is explained by a decrease in precipitation and by an increase in temperature. To address this, two adaptation strategies are distinguished. The main determinants of adaptation are given by the perception of CC, by the diversification of sources of income, by the farmers' age, by education and by access to extension services.

In Ethiopia, where a large proportion of rural households depend on livestock for livelihood, food security remains a significant concern for large portions of the population. *Kasim and Ozkan* evaluate the effect of livestock market participation on household's food security and welfare using a nationally representative cross-sectional survey data of rural households in Ethiopia. The results indicate that participation in livestock market improved food security and welfare of the participating households. Furthermore, in rural areas where alternative income possibilities are scant, livestock market participation has smoothed food consumption by providing income in times of harvest failure or other shocks striking households.

Bekkis et al. examine empirically the dependency issues of the wheat sector in Algeria on the international market, using time series and prediction techniques. The study investigates the adjustment process of supply to price disequilibria to assess the functioning of the wheat sector in domestic production and import sectors. The main results of the model show a growing inability to meet domestic demand for durum wheat, a total disappearance of local production of common wheat, and a more exaggerated resort of the import option for the wheat. Implications for public policy are derived in terms of food security.

Koussani and Khamassi deal with the negative effect economically and socially in Tunisia by Covid-19. The main cause of this situation is the quarantine and the sudden halt of several activities resulting in the drop in domestic demand and the loss of Tunisia's main trading partners. The agricultural sector, and particularly small and family farms, forced to align with the quarantine measures since March 2020, have suffered the full impact of Covid-19. Indeed, the pandemic crisis put a strain on food supply chains: a complex network of interactions involving farmers, agricultural inputs, processing plants, retailers, and others.

Crisis management in rural public organizations: What it takes to evolve?

VASSILIKI OLBASSALI*, CHRISTOS KARELAKIS*, KONSTADINOS MATTAS**

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Abstract

The vortex of the financial crisis that struck European countries did not impact them as it has primarily affected the Mediterranean periphery. Instead, Greece was the prominent victim, both in terms of duration and size of crisis, with radical changes implemented. The present study explores the determinants of administrative and organizational amendments in the general rural administration during the economic crisis. Data were gathered through a qualitative survey with public officers and stakeholders and were gauged through a Delphi policy framework. The empirical study focuses on implementing crisis management and change management practices in the public sector. The results indicated that public administration was neither prepared to confront the crisis nor the changes that followed. On the other hand, stakeholders claim that despite all the changes that have occurred, the bureaucracy was unaffected and that there is a need for public services to be enhanced. The lessons derived suggest more profound shifts in the administrative practice, culture, implementation of organizational knowledge and tools to deal with crises and changes combined with organizational learning.

Keywords: Economic crisis, Crisis management, Organizational change, Rural public administration, Delphi.

1. Introduction

The globalized financial system has led to relations of dependence and interaction of markets, economies, and countries to such an extent that countries' economic crises are transferred in a short time to the international financial system, and vice versa (Claessens and Kose, 2013). This acknowledges the crisis that began in 2007 in the U.S. financial system and soon spread internationally as a capital market crisis that provoked a global economic recession (Kollintzas *et al.*, 2012). In 2008 the financial crisis hit Greece, which led to a recession of the Greek economy and severe consequences for society. The eco-

nomic crisis resulted in rising public debt, rising tax evasion, absence of investments negatively impacting business growth, production, market prices, and increasing unemployment (Giannakis and Bruggeman, 2015). Significant effects came on public finance such as high budget expenditures and large revenue deficits that entrapped the Greek government in a situation unable for growth rates and forced it in 2015 to proceed with capital restrictions, cash withdrawals and a full bank holiday that lasted six working days (Harari, 2015). Individuals or/and social groups had difficulties covering their daily needs and experienced misery or even absolute poverty.

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Wage cuts, 9.5% increased inflation, increases in indirect and direct taxation describe the suffocating and adverse climate for Greek society (European Bank, 2016; Kapiki, 2011).

The European member states were not affected in the same way. Those suffering from high public debt and deficit were forced to take serious austerity measures, leading to a deep recession and substantial fiscal cuts. The implementation of fiscal adjustment programs primarily affected Southern Europe's countries, especially Greece (Artelaris, 2017; Loizou *et al.*, 2019). Greece's economic downturn had consequences in many sectors, like education, health, environment, logistics, immigration, construction, tourism, shipping, entrepreneurship and agriculture (Zmas, 2015; Artelaris, 2017). Especially for agriculture, austerity measures led to lower commodity prices, a rise in production cost, and lower agricultural income (Karelakis *et al.*, 2013a; Micha *et al.*, 2015). The severe impact of crisis combined with factors like the aged population employed in the agricultural sector, low educational qualifications and lack of training, migration of young people, indifference by policymakers exacerbated poverty (Zografakis and Karanikolas, 2012; Anthopoulou *et al.*, 2017). The situation especially aggravated by corruption in public administration and the country's complicated legal framework (Micha *et al.*, 2015). Still, it is stressed out that given the proper policy intervention, the agricultural sector could boost other sectors related to agriculture, the regional economy, as well as playing a pivotal role for Greece to overcome recession (Karelakis *et al.*, 2013a; Lampiris *et al.*, 2018; Loizou *et al.*, 2019).

To regain its credibility, Greece had to take a series of measures under the tutelage of the European Commission, the International Monetary Fund (IMF) and the European Central Bank (ECB). Aberrations of fiscal policy affected almost any policy sector regarding its institutions, values, goals and processes. New regulatory forms and structures, new principles and approaches were introduced. According to Lane (2000), public administration implements political decisions based on laws that employees fol-

low. Therefore, the link between public administration and government policy is inevitable, making it clear that crisis management directly affects both interconnected parties, requiring the mobilization of public administration mechanisms and implementing models and strategies.

All this external pressure came to proliferate to the already existing issues that troubled Greece's public administration. Greece's public administration had to deal with problems even before the time of crisis: Lack of a clear hierarchy, corruption, absence of effectiveness, multifaceted structures, bureaucracy, difficulties in integrating human resource management, limited-service efficiency (OECD, 2011; 2012a; 2018; Papavassiliou, 2014; Tsekeris *et al.*, 2015; Makrydmetres *et al.*, 2016; European Union, 2017; Spanou, 2019). The severe consequences of the economic crisis inevitable affected public organizations.

Bearing those mentioned above, this study aims to map the context in which crisis was addressed and implement changes in rural public organizations, identifying critical factors that acted as catalysts or not in the public system. Also, it examines whether the operation of the Greek rural administration can be linked to the existing theory of crises and change management. The discussion attempts to determine when and under which circumstances crisis was perceived and challenged, whether changes were implemented, the driving forces behind these transformations, and the impact on stakeholders. The study's findings may contribute to comprehend better the relationship between crisis and change and the influence they had in a particular management system. Besides, it offers evidence for a possible correlation between management theory and practice, as the rural public administration denotes an attention-grabbing case study on the effects of the debt crisis on public administration.

Accordingly, the remainder of the paper presents the theoretical background on crisis management and public organizations in section two and the materials and methods employed in section three. Further on, the fourth section delivers and discusses the results, and the final section concludes.

2. Theoretical background

Various scholars defined the organizational crisis as an event that threatens an organization's normality (Coombs and Holladay, 1996). Mitroff *et al.* (1987) argued that organizational crises affect people, organizational structures, finance, technology and can cause extensive damage to human life, the physical and social environment. Pearson and Clair (1998) stated that the organizational crisis threatens the organization's vitality, but at the same time, the cause, the effects and the resolution of a crisis seem unclear. t' Hart (1993) provided a definition connected to the public sector and defined crisis as irregular breakdowns of well-known symbolic frameworks that substantiate the existing socio-politic order.

Literature also points out that crises often lead to change, having an unpredictable outcome for better or worse (Barnett and Pratt, 2000). According to Stern (1997), crisis causes changes in the way people think and forces them to question their previous beliefs and perceptions about the social and natural environment and the acceptability of the existing organizational structures and processes. Antonacopoulou and Sheaffer (2014) also referred to leaders' role in organizational learning and crisis management, emphasizing that learning combines a range of social, psychological, political, emotional, and cognitive parameters and leads to practical crisis management (Shrivastava, 1983). In other words, dealing with a crisis is manifested in daily activities and how an organization's members and leaders act.

There is also a relationship between crisis and organizational learning based on the assumption that better understanding of crises can prevent the recurrence of future ones (Kovoov-Misra *et al.*, 2000), can increase preparedness to deal with it (Mitroff *et al.*, 1988) or can assist in decision-making during crises (Pearson and Clair, 1998). Nevertheless, for organizational learning resulting from crises to be effective, it requires amendments in the beliefs and values of the members of the organization, which means organizational culture change that will lead to changes in the behaviour of members and es-

pecially leaders (Pergel and Psychogios, 2013). Scholars agree that if an organization's culture includes learning readiness and overall acceptance of new ideas, focuses on preparedness, it is probably more comfortable managing and dealing with a crisis (Elsubbaugh *et al.*, 2004; Parnell *et al.*, 2010). However, Christensen *et al.* (2016) and Broekema *et al.* (2017) point out that organizational culture can contribute both to the favourable outcome and the negative outcome when it limits the prevention, preparedness, and recovery of organizations crisis. Furthermore, successful changes require vision, strategy, and a culture of sustainable and shared values (Gill, 2002). Culture is also expressed in less conscious and operational matters between members of an organization (Schein 1990). Therefore, if the cultural assumptions favour change, it becomes easier to implement it. Three crucial factors lead to functional changes: organizational culture, operating climate and administrative policies (McNabb and Sepic, 1995), and according to Dent and Goldberg (1999), the key to change is managing organizational behaviour.

In response to a crisis, organizations need to recognize that internal and external stakeholders may be involved in the crisis as it may have severe implications for the organization itself and its relationships with stakeholders (Bundy *et al.*, 2017). It is possible that stakeholders take distance from the organization in crisis because of fear of being involved or even turning against its interests (Pearson and Mitroff, 1993; Pearson and Clair, 1998). Thus, it becomes vital for them to maintain positive relations or even more engage stakeholders in preventing and mitigating the determinants of a crisis (Alpaslan *et al.*, 2009). On the other hand, when the crisis expands, it is in its best interests to identify all stakeholders involved (Ulmer and Sellnow, 2000).

According to the consolidation programs imposed regarding Greece's public administration reform interventions between 2007 and 2019, a great effort was made to upgrade the administrative mechanism. In 2007, the Special Secretariat for Administrative Reform undertook the execution of the Operational Program entitled "Administrative Reform 2007-2013". The Pro-

gram followed the European Social Fund (ESF) guidelines and the Revised Lisbon Strategy to strengthen the efficiency of public administration. With a holistic approach to public administration and strategic interventions, the Program sought to offer friendlier and more comfortable services to the citizen. Furthermore, it aimed at training public sector executives with an emphasis on women's participation in decision-making centres, institutional reforms in the organization and operation of public services, and the strengthening of central, regional administration, and local government (Ministry of Interior, n.d.).

The "National Strategy for Administrative Reform 2016-2018" followed more long-term planning by documenting public administration's long-term weaknesses. Weaknesses include the lack of coordination of services, the irrational distribution of human resources, the labyrinthine regulatory framework, the lack of e-government issues, the lack of targeting, and the lack of introduction of acceptable practices administration. For implementing the strategy, key pillars of action were developed, which concerned the administrative structures, tools, functions, processes, human resources, transparency,

accountability and open governance (Ministry of Administrative Reconstruction, 2017).

Despite all efforts, the labyrinth of public administrative organization remained unalterable. The Greek Ministry of Rural Development and Food (GMADF) has to deal with every issue concerning the primary sector. Greece covers an area of 13,196,887 Ha of which 97.1% are classified as agricultural areas (73.9% mainly rural and 23.2% intermediate rural), inhabited by about 2/3 of the total population of the country (64.4%) (Ministry of Rural Development and Food, 2009). The central administration of the Ministry (Figure 1) is located in the country's capital. At the same time, several decentralized administration offices are located in the capital cities of the administrative districts, others in the capital cities of prefectures and some offices in other cities all over the country. In addition, there are also companies, institutes and legal entities supervised by the GMADF (Figure 2) that deal with issues about consumer protection by ensuring import, production and distribution of healthy food, the development of Greek agriculture, the rise of the professional and cultural level of farmers, geotechnical issues, research on

Figure 1 - Administrative structure of the Greek Ministry of Rural Development and Food.

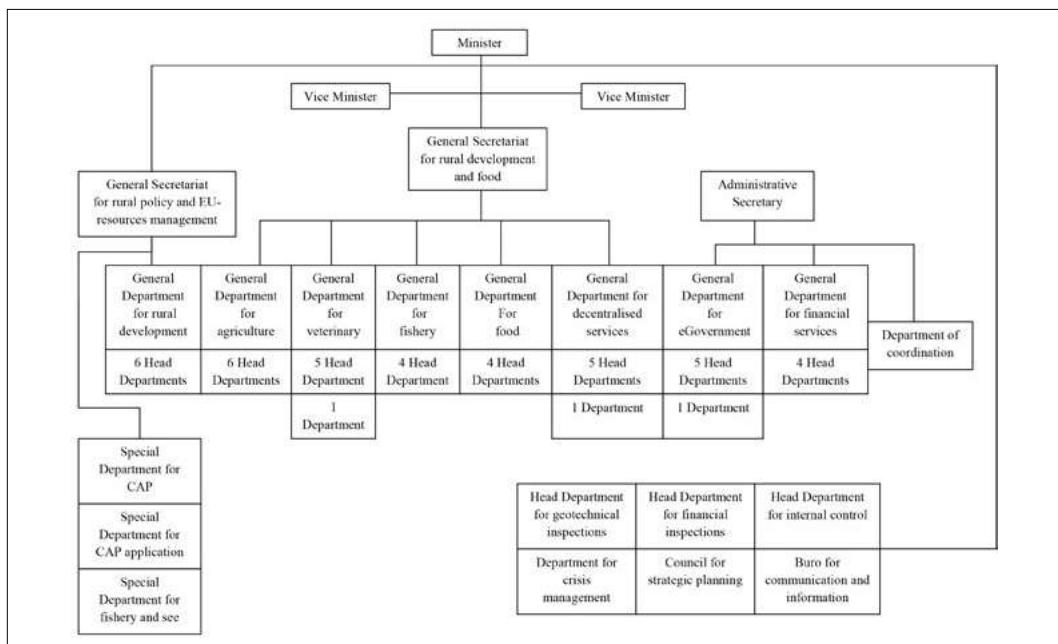
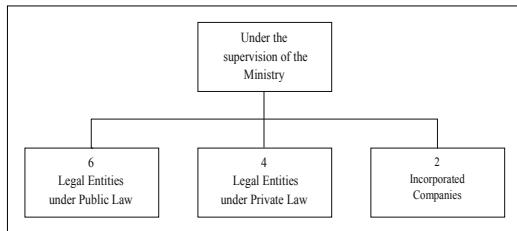


Figure 2 - Companies and legal entities supervised by the Greek Ministry of Rural Development and Food.



diseases and damage to crops, measures to prevent the occurrence and control of pests and other animals or plant pests, insurance of crop and animal production and livestock of agricultural holdings from damage caused by natural hazards, diseases and illnesses, training of executives capable of contributing to the development of the agricultural output, and many other issues.

Considering those mentioned previously, three research questions arise as follows:

- RQ1: Did Greece's financial crisis (2008-2018) force changes in the rural public administration?
- RQ2: Did parameters such as leadership, organizational culture, and learning play a role in dealing with crisis and introducing change?
- RQ3: What is the opinion of stakeholders as recipients of the services offered to them during the time of crisis by the Greek Ministry of Rural Development and Food?

3. Materials and methods

The Delphi Method is a qualitative method for gathering data from a panel of participants within a domain of expertise. The technique aims to reach consensus among the panellists upon the research subject and was developed in the 50s by Dalkey and Helmer (Dayé, 2012). The method's key feature is the use of multiple rounds of questionnaires to collect data and consensus-building from a panel (Young and Jamieson, 2001).

In the present research, study experts invited to participate from all over Greece were members of the Greek Parliament, managers and state employees of the GMADF, managers and state employees of public services supervised by the GMADF, professors in faculties of rural development, agri-

culture, crop production, rural environment, and agricultural technology. The expert panel consisted of 25 participants in the first round and 29 participants in the second round. In addition, to increase reliability, another parallel research panel of stakeholders was invited to participate in the research. The stakeholders' panel consisted of 25 participants in the first round and 19 participants in the second round. Stakeholders were identified as people who conducted any act that required the services offered by the GMADF. The Delphi process lasted for two months, starting from April 2020 to June 2020. Each panel of experts was given two weeks for each round, and all the questionnaires were distributed via email. Alongside the questionnaires, there was a letter of invitation to the experts to participate as members of the Delphi panel, a brief explanation of the procedure and instructions on how to complete the questionnaire.

Delphi studies' significant statistics are measures of central tendency, the level of dispersion and the frequency distributions to present information concerning the collective judgments of participants (Hallowell and Gambatese, 2010). The criteria for consensus used in this research were the mean, the median, the interquartile range and the measure of 75% of participants' opinions that coincide in the same two categories on the Likert scale.

In the first round, the panellists were given a structured questionnaire with closed-ended 5-point Likert scale questions to elicit their level of agreement with a series of statements regarding the economic crisis, organizational change and culture (Table A see Appendix). Participants were asked to rate a scale of 1 to 5 if they agree to the statement with 1= strongly disagree; 2= disagree; 3= neutral; 4= agree; and 5= strongly agree. After receiving participants' responses, questionnaires were analyzed by applying CHIC Analysis (Correspondence and Hierarchical Cluster Analysis) version 1.1 (Markos *et al.*, 2010). The data analyzed from round one was used to form the questionnaire for the second round of data collection. In the second round, panellists received a questionnaire and feedback on the results of the first round. In the second round, the panellists were asked whether they agree with the statements and clarify opinions expressed in the first round that needed further explanation (Table B see Appendix).

Table 1 - Determination of consensus.

	<i>high consensus</i>	<i>moderate consensus</i>	<i>no consensus</i>
IQR	≤ 1	≤ 1	≥ 1
	<i>and</i>	<i>or</i>	<i>and/or</i>
%	≥ 75	≥ 75	≤ 75

Regarding the participants of the stakeholders' panel, they were given a structured questionnaire (Table C see Appendix) with closed-ended, 5-point Likert scale questions in the first round regarding economic crisis, organizational change and culture and they were asked to rate on a scale of 1 to 5 if they agree to the statement with 1= strongly disagree; 2= disagree; 3= neutral; 4= agree, and 5= strongly agree. Responses were analyzed through the CHIC Analysis, and in the second round, another 5-point Likert scale questionnaire was distributed together with feedback of the statements analyzed in the first round. The questionnaire was about expressing an opinion on suggestions about improving public services (Table D see Appendix).

The degree of consensus was considered after each round. The consensus is determined as "high" when the quartile deviation range is less than or equal to 1, and a presentence of $\geq 75\%$ of opinions coincide in two statements. A "moderate" consensus is reached when either the quartile deviation range is less than or equal to 1 or when a presentence of $\geq 75\%$ of opinions coincide in two statements. There is no consensus if the quartile deviation range is more than one or when opinions do not coincide for equal or more than 75% on two statements (Table 1).

4. Results and discussion

In the first round, panellists were given a structured questionnaire with 45 statements, where eighteen reached a consensus. Out of the eighteen statements, eight reached a high consensus, ten moderate consensus and twenty-seven of the statements reached no consensus (Table 2). In the second round, panellists received a questionnaire of fourteen statements and were asked their level of agreement. A 100% consensus was reached in this round, and notably, eight statements reached a high agreement, while six of them a moderate (Table 3). Median and mean

scores were used to define on which statements consensus was expressed.

The analysis of the results showed that public officers agree that the financial crisis during the period 2008-2018 led to changes in public services provided by the GMADF. This statement answers the first research question, clearly identifying the relation between crisis and change. Likewise, it is determined that despite the type of the crisis, in the case of Greece, the financial crisis forced administrative, operational, and functional issues in public services. Although the crisis introduced modifications that led to a radical restructuring of the public services, it seems that changes were too many to be implemented. Managers seemed not to lead with efficiency and competitiveness or promote teamwork, cooperation, innovation, creativity and professionalism. During the crisis period, the public services climate was characterized by formal, bureaucratic procedures and rules. On the other hand, state employees were not negatively affected by changes, even though they had no training dealing with crisis or alterations.

Greece's economic crisis had no triggering effect, and that might be the reason why most people did not realize they were living in a financial crisis until two or more years than it started in 2008. It is evident to all participants that there was no proper training for supervisors, managers and employees, no plan, no political or administrative instructions on implementing changes during the ten years of crisis. There was no time given to employees to adjust to all changes occurring. They only had to follow standardized formal procedures and regulations, so introduced modifications were not fixed as new procedures.

The statements, as mentioned above, offer insights for the second research question to be answered. If parameters such as leadership, organizational culture and learning have had a role in dealing with crisis and introducing change. Leaders and employees followed standardized norms

Table 2 - Consensus measurements: first-round experts.

Statements	Median	Mean	IQR	%	Statements	Median	Mean	IQR	%
1	4	3,958	2	≥75	24	3	3,042	2	
2	4	3,875	2		25	3	2,625	1	≥75
3	4	4,167	1	≥75	26	4	3,25	1,75	
4	4	3,5	1,75		27	4	3,792	1	
5	2	2,125	2		28	3	2,875	1	≥75
6	3	2,542	1		29	2	2,333	1,75	
7	3	2,875	2		30	3	2,708	1,75	
8	3	2,917	2		31	4	3,833	2	
9	4	3,375	2		32	2	2,167	2	
10	2	2,125	2		33	2	2,333	1,75	
11	2	2,083	2		34	2	2,25	2	
12	4	3,667	1,75		35	3	2,917	1,75	
13	4	4,042	1,75	≥75	36	3	2,583	1	≥75
14	4	3,5	1		37	2	2,208	1	≥75
15	2	2	2		38	3	2,708	1,75	
16	4	3,667	1		39	2	1,958	1,75	≥75
17	4	3,583	1	≥75	40	4	4,208	1	≥75
18	4	3,25	2		41	3	3,25	1,75	
19	3	2,583	3		42	3	2,583	1	
20	2	2,458	3		43	4	3,708	1,75	
21	1	1,75	1	≥75	44	4	3,542	1	
22	2	2,167	1		45	3	3,125	2	
23	3	3,125	2						

and procedures, the culture of the organization was to the maximum consolidated, and there was no training at all in dealing with crisis or change. Thus, the importance of these parameters is highlighted to efficient confront crisis and change.

Table 3 - Consensus measurements: second-round experts.

Statements	Median	Mean	IQR	%
1	1	1,345	1	
2	1	1,414	1	
3	4	3,31	1	≥75
4	2	1,552	1	
5	1	1,379	1	
6	2	1,931	0	≥75
7	2	2	0	≥75
8	1	1,138	0	≥75
9	1	1,138	0	≥75
10	2	1,724	1	
11	1	1,069	0	≥75
12	1	1,103	0	≥75
13	2	1,759	0,5	≥75
14	1	1,31	1	

As for the stakeholders' panel participants, they were invited in the first round to answer a structured questionnaire with fifteen statements (Table D see Appendix) in which a 100% consensus was reached. Specifically, eight statements reached a high consensus, and six achieved a moderate agreement (Table 4). Therefore, the need for a second round with eight statements (Table E see Appendix) was to assure that consensus was not random, in which a 100% consensus was reached, marking all eight statements with high consensus (Table 4).

Stakeholders ascertain that public services had not as a goal to serve better during the economic crisis. There were no optimizing or modernizing services, and even though many services were provided via the internet, still there were delays. It was for stakeholders to easily communicate with public services, and they had friendly service, but bureaucratic procedures did not lead to fast and sufficient services. It is in their healthy believes that things need to be changed.

Table 4 - Consensus measurements: first and second-round stakeholders.

Statements	Median	Mean	IQR	%	Statements	Median	Mean	IQR	%
1	2	2,4	1	≥75	1	2	1,737	1	≥75
2	2	2,44	1	≥75	2	1	1,421	1	≥75
3	2	2,28	1	≥75	3	2	1,842	1	≥75
4	3	2,88	2	≥75	4	2	1,789	1	≥75
5	2	2,44	1	≥75	5	1	1,316	0	≥75
6	3	3,08	1,5	≥75	6	1	1,368	1	≥75
7	4	3,8	2	≥75	7	2	1,632	1	≥75
8	4	4	1	≥75	8	1	1,684	1	≥75
9	3	2,96	2	≥75					
10	3	2,72	1	≥75					
11	2	2,52	1	≥75					
12	3	2,76	2	≥75					
13	3	2	1	≥75					
14	3	2,8	2,5	≥75					
15	4	3,32	2,5	≥75					

Therefore, they suggest that there is a need for modernization of the services provided by the GMADF. Minimization of time required to fulfil citizens requests, friendlier service, improvement of services efficiency, more expanded electrical services, training of the employees, but most of all overcoming bureaucracy are some of the stakeholders' suggestions for public service enhancement. Answering the third research question, stakeholders argue mostly about more changes that need to be done and that changes in times of crisis were not enough or not in the right direction that would help a public organization improve itself. According to Szpirglas *et al.* (2008), a new perspective on the stakeholder's role in crisis management should be considered moving the balance from mapping stakeholders to involvement and acting. Likewise, researchers highlight that a bottom-up approach that involves stakeholder's opinions as well as offering specialized and targeted services would lead to more concentrated policy and the use of private and decentralized public advisory and extension services, measures that could ensure the success of management efforts while supporting new strategies in the primary sector (Karelakis *et al.*, 2013b; Pascucci and De Magistris, 2012). Contrary to what researchers suggest, stakeholder's role in Greece is linked just to the acceptance of services, and it is not sure that there is even

mapping of stakeholders by the administration.

However, despite the planning, there have been difficulties in implementation due to the suffocating context created by the financial crisis, with the administration running to anticipate the fiscal adjustment changes. Besides, the public sector's contraction created significant shortages in human resources and resistance within the administration. One reason for the not so good performance of the efforts for consolidation of the public administration seems to be the power of politics, which manages to maintain its relationship with the administration (Spanou, 2019). Another reason is that the central government does not have good management, oversight, and coordination structures to support and carry out the required reforms and procedures. There is also minimal cooperation and coordination between the ministries, whose organizational structures - each of which has, on average, 439 internal structures – which does not at all help in any way to achieve the necessary changes. The administrative culture of modern public administration seems to have been an additional reason for its rigidity. Its unique feature is that it focuses mainly on fulfilling formal responsibilities, as defined by law (OECD, 2012b).

International literature identifies the critical role of organizational learning in dealing with crises when they occur (Elsubbaugh *et al.*, 2004)

and crises likely to occur (Antonacopoulou and Sheaffer, 2013). The importance of proper training has also been noted by experts and stakeholders who participated in this research. It can be considered that the lack of appropriate crisis management training in public organizations has led to the loss of potential for optimizing operation and efficiency, for more modernization, for faster service and reduction of bureaucracy, for facilitating citizens in communicating with services and for expanding electronically provided services to citizens. Moreover, bureaucracy and pyramid schemes of leadership combined with non-existent in-service training may have led to uncoordinated stakeholder interventions, high staff turnover, poor communication between services and departments, ultimately expressed in late adoption. Still, appropriate training may have created opportunities for cooperation between ministries, departments and other public offices to help improve the efficiency and effectiveness of services. Unfortunately, these opportunities have not been exploited. It is also concluded that through administrative and operational transformation or even a review of the structure of public services, it would be possible to provide better services, resulting in more tangible benefits for those involved. Respectively, opportunities for consolidation of solid values, strengthening of responsibility towards stakeholders, and developing the organizations' strengths were lost as examples of renewal. In the case of the services of the Ministry, the lack of training and knowledge on the subject failed to seize the advantage of the opportunities that may have arisen.

Results show an absolute lack in the use of crisis management and change management tools, confirming that structural reforms depend to no small extent on a well-functioning rural public administration. Real change to an efficient, accountable and inclusive administration is still required, as its adherence to the past is likely to jeopardize the broader reforms needed for the country's sustainable development (OECD, 2012b). A source of concern is the fragmented and complex rural public administration in handling the reform framework's coordination and monitoring. Insufficient cooperation between public bodies, irrationality in procedures, lack of use of new technologies,

resistance to change, and other administration weaknesses, as mentioned above, lead to ineffective administration actions (OECD, 2012b). Thus, maintaining old management frameworks, which tend to become routine, combined with the inconsistent implementation of new ones, jeopardizes any change's viability (Spanou, 2019).

Overall, Greece's administrative changes were sporadic without any coherent managerial tool and any theoretical or practical managerial context. Thus, despite the substantial external influence, the administrative pattern has not changed much.

5. Conclusions

Greece's financial crisis of the years 2008-2018 forced changes in public administration. This research study made apparent that Greece's public administration, mainly the public services of the GMADF, were neither prepared to confront the crisis nor the changes it led to efficiently. Administrative and organizational changes were introduced to public administration, but no change management models or culture change. Stakeholders claim that despite all the changes that have occurred, the bureaucracy level seems to be unaffected and that there is a need for public services to be enhanced. The research results demonstrate that a critical factor for successfully dealing with the crisis is to deal with organizational changes and culture successfully. Organizational learning related to the scope of changes and confronting crisis was of total absence.

Results highlighted the requisite framework for crisis, culture and change management, implementing crisis management models. In addition, it is required to embed into the public management system ongoing risk and issues assessment, sound and tested processes, adjusted training and practice. What would furthermore help public organizations to evolve is strong leadership and communicating and managing stakeholders' perceptions effectively to strengthen the primary sector in Greece, at least in terms of administrative adequacy and facilitation of processes that will support it as a vital sector for the country to return to economic stability and productivity.

Authors conclude that neither leaders nor state employees can hope to deal with crises through

legislation, written policies, or procedures. The only way is to adopt organizational crisis and change management in their lives. Greece seems to have overcome the financial crisis though it now must confront a health one, this of the pandemic of Covid-19. Thus, organizations must adopt processes that successfully avert and manage the crisis.

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Appendix

Table A - Statements first-round experts.

1	The financial crisis caused administrative problems in public services
2	...caused financial difficulties for public services
3	...caused operational problems in public services
4	...led to staff reduction in public services
5	...led to a reduction in bureaucracy
6	...led to corruption/lawlessness/disobedience within public services
7	...caused problems between employees in public services
8	...caused issues between employees and officers in public services
9	...caused problems between public services and citizens served
10	...led to better service by public services
11	...led to a decline in the efficiency of public service employees
12	...led to changes in the management of public services
13	...led to changes in the operation of public services
14	...dictated changes in the service of citizens

15	The effects of the financial crisis have been adequately addressed by management using crisis management models
16	During the period 2008-2018, there were changes in the structure of the public service
17	..., there were changes in the procedures followed by the public service
18	..., the requirements to the employees from their supervisors were increased
19	..., the structures of the public service and the services offered were modernized.
20	..., there was an improvement in the productivity and efficiency of the public service
21	..., there was an improvement in the training of public service employees
22	The administration followed a plan to introduce changes
23	Changes were introduced violently, abruptly
24	The employees of the public service reacted to the introduction of a change
25	Changes introduced led to a radical restructuring of public services
26	Employees responded positively to the changes
27	Changes in public services were introduced during the financial crisis without consequences being predicted
28	Changes negatively affected the performance of employees
29	Supervisors cooperated with the employees to introduce a change
30	Changes were too many to be implemented
31	Bureaucratic, standardized procedures prevailed in the public service
32	During the period of the financial crisis in the public service, innovative, alternative procedures prevailed
33	Supervisors acted as consultants and supporters for the employees
34	Supervisors operated innovatively and took initiatives
35	Supervisors operated to organize and coordinate the work
36	Supervisors operated with the aim of efficiency and competitiveness
37	The climate in public service promoted teamwork and cooperation
38	The climate was individualistic and dividing with a focus on goals and productivity
39	The climate was characterized by innovation, dynamism, readiness and initiative.
40	The climate in the public service was characterized by formal, bureaucratic procedures and rules
41	There was a mild and humane working climate.
42	There was a strict and competitive climate
43	Employees adopted and implemented changes introduced in the service
44	Despite the changes, the employees continued to operate as they did before them
45	The changes introduced during the period 2008-2018 did not affect the operation of the public service and its employees

Table B - Statements second-round experts.

1	Before 2008, did you consider the occurrence of an economic crisis possible?
2	Did you notice any „signs” that there would be a financial crisis shortly before its occurrence in 2008?
3	When did you realize that you were experiencing a financial crisis?
4	Have you noticed that management did systematic actions to deal with the financial crisis 2008-2018 and its consequences in the service?
5	Do you think that there was a plan into introducing changes during the financial crisis 2008-2018?
6	Do you think that proper training of employees would help introduce and implement changes during 2008-2018?
7	Do you think that managers’ proper training would help introduce and implement changes during 2008-2018?
8	Do you think that there were clear instructions for implementing the changes introduced in the period 2008-2018 by the leadership (political/administrative)?
9	Do you think that employees were given some time to adapt to the changes introduced?

10	Do you think that the changes introduced have been consolidated as procedures?
11	Do you think that during the period of the financial crisis 2008-2018, the public service had focused its functions on promoting the cooperation, teamwork of its employees?
12	Do you think that in the period 2008-2018, the service operated with innovation, creativity, professionalism?
13	Do you think that during the period of the financial crisis 2008-2018, the service focused on formal procedures, regulations and internal control?
14	Do you think that during the financial crisis, the public service operated with efficiency, productivity, goal achievement?

Table C - Statements first-round stakeholders.

1	During the period of economic crisis, public services operated with the aim of citizens better service
2	...., public services utilised to optimize services
3	...., the public services operated to modernize services
4	...., public services operated more with the use of technology
5	...., the public services utilised to reduce the time of service
6	...., the public services were friendly to the citizens
7	...., public services operated with a long delay in the provision of services
8	...., public services conducted through bureaucratic procedures
9	...., public services were not working proper
10	...., it was easy to contact with services
11	...., the public services operated according to the needs of the citizens
12	The financial crisis has helped make services more effective in accomplishing demands
13	During the financial crisis, the services operated quickly and adequately enough to citizens' demands
14	Public services operated better before the crisis
15	Public services operated the same as before the crisis
Table 8: Statements for the stakeholders' 2nd round	
1	How necessary do you consider the modernization of the Ministry of Agricultural Development and Food services?
2	How necessary is the reduction of the service time by the Ministry of Agricultural Development and Food services?
3	How necessary is it for the services of the Ministry of Agricultural Development and Food to be friendlier?
4	How necessary do you think it is to facilitate citizens in their contact with the Ministry of Agricultural Development and Food services?
5	Do you think it is necessary to reduce bureaucracy?
6	Do you think it is necessary to improve efficiency in handling citizens' requests?
7	Do you think it is necessary to train the Ministry of Agricultural Development and Food services staff?
8	Do you consider it necessary to expand the services provided electronically by the Ministry of Agricultural Development and Food?

Table D - Statements second-round stakeholders.

1	How necessary do you consider the modernization of the Ministry of Agricultural Development and Food services?
2	How necessary is the reduction of the service time by the services of the cultural Development and Food?
3	How necessary is it for the services of the Ministry of Agricultural Development and Food to be friendlier?
4	How necessary do you think it is to facilitate citizens in their contact with the services of Agricultural Development and Food?
5	Do you think it is necessary to reduce bureaucracy?
6	Do you think it is necessary to improve efficiency in handling citizens' requests?
7	Do you think that it is necessary to train the staff of the Agricultural Development and Food services?
8	Do you consider it necessary to expand the services provided electronically by the Ministry of Agricultural Development and Food?

Does women's techno-education impact the agri-food sustainability?

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Abstract

Women contribute decisively to the economy and have an important participation in agricultural exploitation in the world, providing their labor. But if they had better access to technology and training in a more equitable way, they could contribute much more. In effect, the rapid technological changes that have occurred in the sector pose an even greater challenge to achieve equalizing the role of women to that of men in the agri-food sector. The limitation of the female gender to training and empowerment prevents them from taking advantage of the technology that are contributing to the achievement of a world free of hunger and malnutrition, which is one of the sustainable development goals (SDG). Therefore, this work analyzes the world situation in terms of training and gender gaps to see if these elements affect the achievement of four of the sustainable development goals (SDG 2, 4, 5 10) in 87 countries. The results of the multiple linear regression show the existence of a positive relationship between these elements is demonstrated. Then, as a real example, Spain is chosen as a country reference and analyzed in terms of training by gender, digital gender gap and labor gap. Finally, some advice and recommendations that allow the achievement of the inclusion of women in the improvement of the countries are suggested.

Keywords: Sustainable development goals, Digital divide, Training gap, Gender equality, Food security.

1. Introduction

According to the FAO (2020), currently 690 million people in the world suffer from hunger, which represents 8.9% of the world population. This source indicates that, in 2019, about 750 million people, or almost one in 10 people in the world, were exposed to serious levels of food insecurity. These figures could be reduced considerably, by investing in the necessary material and human resources, and it is the reason why three elements are considered essential for this: a) access and proper use of technology, b)

adequate training and the guarantee of equality and c) the participation of women in this area (Women inclusion).

Likewise, the International Labor Organization (ILO, 2017) indicates that fighting against the gender gap would have an added benefit of 5.8 trillion dollars to the global economy. And it specifies that the increase in the participation of the female gender as a labor force, including the ICT sector, would provide capital, in the form of taxes for the countries. This same study explains that, in the case of Spain, GDP could grow by

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34 billion dollars if the employment gender gap is closed by 25% (ILO, 2017). Another study by the European Union (2018) confirms that the incorporation of women in the digital innovations sector could bring up a benefit of 16 billion euros per year to the GDP of the European Union.

Research shows that if women farmers had the same access to productive resources as men, they could increase yields by 20% to 30% and total agricultural production by 2.5% to 4%, taking out from hunger to between 100 and 150 million people (FAO, 2011). These statistics indicate that the contribution of women to agricultural production is fundamental and that they represent up a large rate of the workforce employed in cultivation and production of basic food products for domestic consumption and for sale, since they grow vegetables that are important for family nutrition.

These figures show us the attention that should be accorded to women to achieve various sustainable development goals (SDGs), including those who can contribute to the promotion of agriculture and the guarantee of food security, that represent a priority for all governments concerned with the achievement of food self-sufficiency, the fight against hunger and the improvement of nutrition in their countries.

Also, everyone's involvement is a necessity since the equitable participation of both genders can increase the benefits of world economies by 34% (IMF, 2018). This implication is closely linked with the degree of education, training, and employability, so that women bring added value to this sector.

In this sense, the UN (2015) indicates that women and men are actors and beneficiaries of development. Women's participation in it is not only a matter of justice and human rights, but also a matter of economic calculation, because ignoring half of humanity would not allow achieving the desired sustainable development.

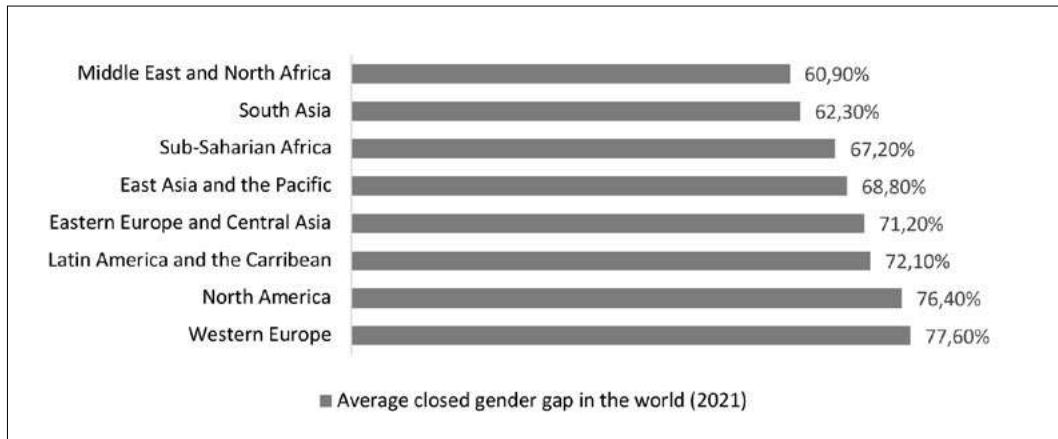
For this purpose, the objective of our study consists in analyzing the world situation of women in terms of education, the digital divide and technological education, with the aim of confirming or denying whether these variables: Inclusive Internet Index, Gini Index, Gender Digital Index and Gender Gap Index

affect the achievement of sustainable development goals, which are SDG 2 main objective of this study, SDG 4 related to education, SDG 5 related to equality and SDG 10 related to infrastructure and technology. This study is applied to 87 countries selected according to the availability of the same information of the same year in the database used. and then further a specific analysis of Spain is proposed as an example. The choice of these sustainable development goals is since they are closely related to the empowerment of women and their role in the agricultural sector, which almost never positions them as protagonists, and limits them to a role of assistant or subordinate, due to ignorance of the performance capabilities in this development (Mason *et al.*, 2016). This is the reason why there is a need to pay a particular attention to equity at work, on family farms, in the household and in the apportionment of resources between cash crops and subsistence, since the benefit of women is not yet being recognized in the rural environment (Kizilaslan and Yamanoglu, 2010). Which prompts us to ask ourselves the following question: if education on the one hand and technology on the other hand contribute to the achievement of the SDGs, how would this achievement be if the two are achieved together equally between men and women?

2. State of the art

Women play a decisive and fundamental role in the agri-food sector, which today has become a strategic sector for the economy and constitutes one of the most important assets in the economic recovery (Hidalgo García, 2013). In fact, Women and especially rural women play a key role in supporting their households and communities to achieve food and nutrition security, generate income, and improve rural livelihoods and general well-being. As such, they are active players in achieving the SDGs. We must also recognize that through local knowledge and experience, women often understand their environment and the needs of their community better than anyone. They transmit traditional knowledge in medicinal plants and contribute significantly to the mainte-

Figure 1 - Average closed gender gap in the world (2021).



Source: Own elaboration from Statista (2021).

nance of agriculture, food security,¹ nutrition, and health (UNEP WCMC, 2020).

Unfortunately, nowadays, rural women and girls face persistent structural constraints that prevent them from fully enjoying their human rights and hamper their efforts to improve their lives and those of those around them. Evidence indicates that if these women had the same access to productive resources as men, they could increase yields on their farms by between 20 and 30 percent, increasing total agricultural production in these countries by between 2.5 and one 4 percent. This would reduce the number of hungry people in the world by between 12 and 17 percent (UN WOMEN, 2021). It is important to highlight that the right to food was recognized as a human right in 1948 in the Universal Declaration of Human Rights. In this year, the world started to give greater importance to ensuring the access to food. Some years later, this right led to other new notions, such as the concept of food security in the 1970s (Mechlem, 2004).

Although women are gaining ground a little more every day, gender gaps continue to exist throughout the world and especially in developing or underdeveloped countries (Benabdallah *et al.*, 2020), which today prevents the respect

of the general commitment expressed by all the countries of the world, and that it consists of the achievement of the 17 sustainable development objectives (Agarwal, 2018). These gaps could be observed in Figure 1.

In fact, although women are considered as an important target group for the achievement of SDGs, their participation in agriculture is generally unpaid and they are considered as auxiliary family workers (Rahman *et al.*, 2020). It should be noted that, today, more than three-quarters of the world's extreme poor live in rural areas, and 70% of the world's poor are women. What it emphasizes the importance of developing policies and programs that address the needs, interests and limitations of women and men in the agricultural sector. This includes renewing and strengthening extension systems to be more responsive and inclusive to women, addressing structural barriers to women's access to productive resources such as the access to education or the access to ICTs (Information and Communication Technologies), and improving financial systems to respond to the needs of rural women producers and entrepreneurs (Adinolfi *et al.*, 2020), even to get out of the least productive segments of the rural economy.

¹ The term of “food security” was defined by Andersen (2009) as the availability of enough food at a global, national, community, or household level.

Indeed, ICTs contribute to improving food security and promoting agricultural sustainability by offering opportunities that benefit farmers, connecting them to remote areas and helping them to improve their cultivation methods and productivity (better production, information on prices of market, environmental conditions control, food supplies monitoring, delivery efficiency) (Awuor *et al.*, 2013).

Technology stands out as an important element since it allows organizations to provide targeted information to reduce food waste and contributes towards the realization of this sustainability development goal. In this regard, FAO (2017) specifies that apart from contributing to the agrarian field closely related to food security, the technology not only allows its users to plan and manage the purchase and use of food, but also receive alerts on the expiration dates of the purchase and propose solutions to avoid food waste. However, it is not enough to have the technological tools and infrastructures for desired result to be obtained in this sector and in several others, but it is necessary to multiply its use and allow it to be widely used. This is done through training and empowerment, managing to take advantage of its benefits in the best possible way (Kumar *et al.*, 2015).

In recent years, there has been a wide recognition of the vital roles played by women in the agrarian sector because of the need for women to have access, through formal and non-formal training, to get knowledge and necessary skills to improve agricultural production, processing, and marketing. Wiig (2013), comments in this purpose that, among all legal rights, the right to land is the most fundamental and describes it as a permanent source of income for stable financial security, food security and well-being, but not all women have access to the training and economic capacities to access this right. Whereby it is important to highlight that the future of the rural environment involves creating more opportunities, improving the employment situation of women, and supporting their educational capabilities and access to new technologies, services, and infrastructures (Lahiri-Dutt and Adhikari, 2015). All these elements show us the need to focus more efforts to achieve the 17 sustainable development

goals, which, have not been achieved as originally planned for 2020, a date that has been set after to 2030. This achievement has not been achieved by the most involved countries such as Spain that although it is well positioned in terms of achieving the sustainable development goals, since it occupies rank 21 among 162 countries, with a score of 77.8. However, there are still sustainable development goals that can be improved, including SDG 2 where its score is still far away (56.2), SDG 4 and 5 even if it has a good score (95.4 and 82.7 respectively) and SDG 10 where there are still many efforts to contribute (69.2) (Bertelsmann Stiftung, 2019).

3. Materials and methods

3.1. Analysis of the world situation

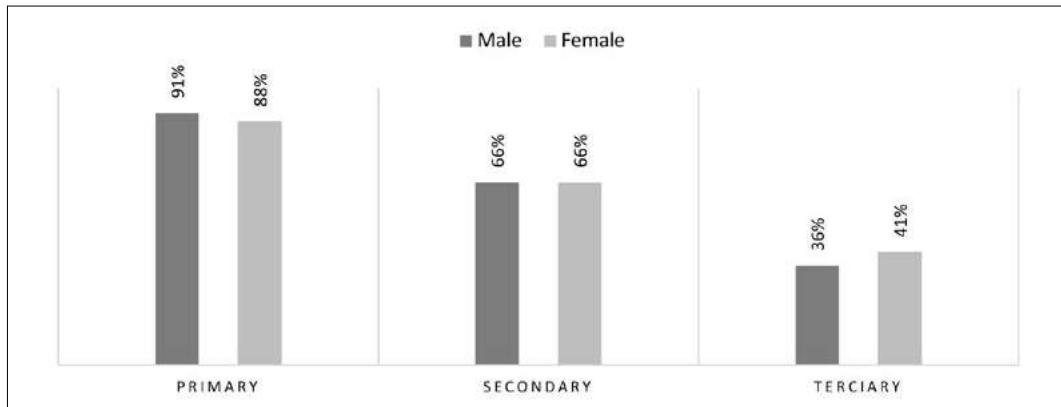
In the 21st century, education is a basic human right, but persistent inequalities in education paralyze the lives of millions of women and girls around the world. Indeed, according to world statistics, women make up more than two-thirds of the world's 796 million illiterates, and only 39 percent of rural girls attend secondary school. This is much less than rural boys (45 percent), urban girls (59 percent), and urban boys (60 percent) (UN WOMEN, 2021).

This difference in education can be observed in Figure 2, where it is clearly seen that at the time of integrating primary education, it is children who predominate 91% compared to 88%, however perfect equality is achieved in the secondary studies, until reaching a predominance of women in tertiary studies (university) at 41% compared to 36%.

UN WOMEN (2021) indicates in this way that if women had the same access to agricultural assets, education, and markets as men, it could lead to an increase in agricultural production and a reduction in the number of hungry people by 150 million. This is because women reinvest up to 90% of their income in their homes, an investment in nutrition, food, health care, school, and income-generating activities for their family, helping to break the cycle of intergenerational poverty (UNEP WCMC, 2020).

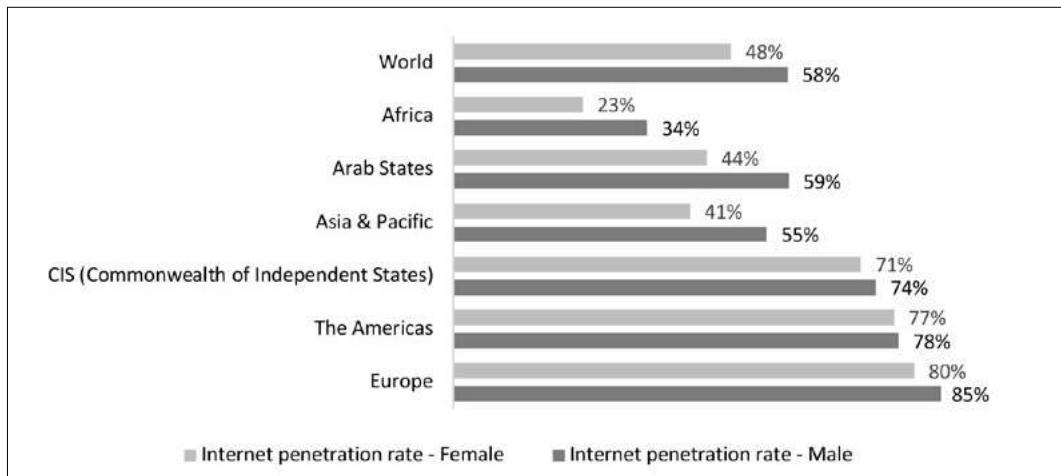
The Technoserve report (2016) reveals that tech-

Figure 2 - Educational achievements by gender around the world (2020).



Source: Own elaboration from Statista (2021).

Figure 3 - Digital gender gap in terms of internet penetration (2019).



Source: Own elaboration from ITU (2019a).

nology is also enabling significant progress: since connecting farmers to multinational agribusinesses, and facilitating payments, to increasing the productivity, incomes, and resilience of farmers.

Investing in the training of rural women is, today, an indisputable necessity, and promoting their technological skills even more so. If one wishes to fight against the digital gender gap² in this sector.

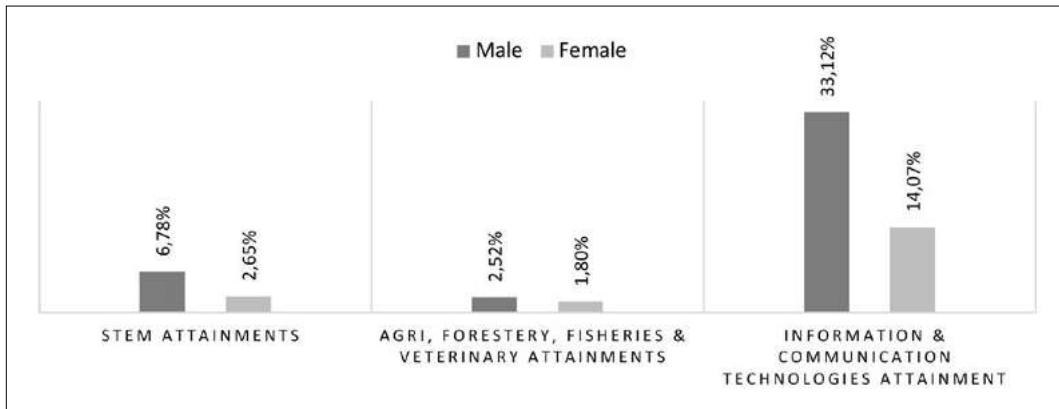
Indeed, inequalities in access to and use of tech-

nology constitute a huge disadvantage for those who are left out or behind and do not get to take advantage of it. These inequalities are observed in various aspects of daily life and range from the use of the internet (see Figure 3) to egalitarian training in ICTs or professional insertion in the technology sector itself or in other sectors that use technology such as it is the agriculture sector.

In fact, technology has been mentioned by the

² The gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities. The digital divide reflects various differences among and within countries (OECD, 2001).

Figure 4 - Educational specialties by gender (2019).



Source: Own elaboration from World Economic Forum (2020).

World Summit (UN, 2006) as one of the elements that affected the empowerment of women in rural areas. It was indicated that guaranteeing equality in access to ICTs contributes to breaking the glass ceiling that prevented, and in some cases still prevents, women from reaching certain positions in the field of technology.

On the other hand, Stock (2017) has shown in her studies that women are often excluded from training programs in new technologies and sustainable agricultural practices, which makes it difficult for them to contribute on an equal footing with men in this sector. This gap in technological and agricultural education is also reflected in the workplace, creating another gender gap and demonstrates the existence of a glass ceiling that prevents the development of women's professional careers in the same way as men.

This technology training imbalance can be seen in Figure 4, which compares the level and training preferences of men and women in terms of STEM attainment, Agri, Forestry, Fisheries & Vererinary attainment and Information & Communication Technologies attainment.

UNDESA (2012) commented about that, that Women make up at least half of the world's farmers and tend to have different needs and approaches that most policy is not sensitive to and is therefore likely to be less effective in reaching its objectives. Some Women, for example, often do not have access to land tenure or credit and financial services. They lack access to education and extension services as well, making it hard

for them to implement new technologies, this is due to the affordability and lack of digital skills. In this way ITU (2019b) indicates that less than half population has basic computer skills, such as copying a file or sending an email with an attachment, and that an estimated 3.6 billion people remain disconnected, and that the number of households with a home computer is only 49.7%.

Finally, it could be said that there are a lot of factors that affects the achievement of the sustainable development goals, and especially those studied in this research investigation, and it is the reason why a multiple regression is proposed in the following part to check the existence of a correlation between our variables and this SDG's attainment.

3.2. Metodology

In this work, we want to analyze the influence of the digital gender gap in achieving the sustainable development goals related to food security and determined by the following SDGs: 2, 4, 5 and 10.

To do it we use information from some international databases, such as the Global Gender Gap Report (World Economic Forum, 2020), the Inclusive Internet Index report (The Economist Intelligence Unit, 2020) and Bertelsmann Stiftung (2019), which provides detail information regarding the variables used. We obtained the available information form 87 countries. To address the aim of this work, a linear regression model is proposed (Equation 1) in which the dependent variable is

Table 1 - Independent variables statistics.

Variable	Description	Mean/ Percent.	Sd.	Min.	Max.	Expected Effect
Inclusive Internet Index	(0 =Total exclusive. 100 = Total inclusive)	66.96	15.14	26.70	86.00	+
Gini Index	(0 = Total equality. 100 = Total inequality)	38.64	7.42	26.50	63.00	-
Gender Digital Divide Index	(0 =Total equality. 100 = Total inequality)	9.77	12.33	0.00	69.40	-
Gender Gap Index	(0 = Total equality. 100 = Total inequality)	29.55	5.54	17.80	45.00	-

Source: Produced by the author.

a measure of SDG achievement. As regressors, variables which measure the distance between the levels of access and use of ICTs for women and men are considered. The definitions of these variables would be as follows and summary statistics are presented in Table 1:

- *Inclusive Internet Index*: This index is made up of four elements that define the degree of inclusion (Availability, affordability, relevance, and availability) of all Internet-related services in a country. The measure expresses a percentage between 0 and 100, where 0 corresponds to total exclusivity and 100 to total inclusivity.
- *Gini Index*: This index measures inequality in terms of wealth within a country. The measure expresses a percentage between 0 and 100, where 0 corresponds to total equality (everyone has the same wealth) and the value 100 corresponds to total inequality (inequality in the distribution of wealth). The objective of this variable is to see if the availability of financial resources influences the achievement of these SDGs or not.
- *Gender Digital Divide Index*: It is a percentage that represents the distance between the levels of access to ICTs by gender, and expresses values between 0 and 100, where 0 corresponds to total equality in the use of ICTs and 100 corresponds to the total inequality or the empowerment of men in the use of ICT.
- *Gender Gap Index*: This is the distance between women and men, made up of four categories of information, which indicate the degree of integration of women in par-

ticipation and economic opportunity, educational level, health and survival and empowerment political. It should be noted that this variable does not consider the technological aspect. The measure expresses a percentage between 0 and 100, where 0 corresponds to total equality and 100 corresponds to total inequality between men and women.

The desired linear regression is as follows:

$$SDG_{ji} = \beta_0 + \beta_1 GDD_i + \beta_2 IINT_i + \beta_3 GINI_i + \beta_4 GD_i + \varepsilon_i \quad (1)$$

Where:

IINT = Inclusive Internet Index

GINI = Gini index

GDD= Gender Digital Divide Index

GG = Gender Gap Index.

ε = Error term

j = Sustainable development goal in which we focused on (j=1...4).

4. Results

In this section you can see the result for each of the four sustainable development objectives considered (Table 2).

It can be observed that at the *Model a* is estimated without considering the Gender Gap variable, and later it is included, to make a more sensitive analysis of the gender element. The objective of this is to find out if the estimated parameters of “The digital gender gap” change or not with its inclusion.

In Table 2, it can be observed that the variables

Table 2 - Results of the ordinary least squares regression analysis for the effects of the set of indices in each ODS considered.

Variables	Model a				Model b			
	SDG 2	SDG4	SDG 5	SDG 10	SDG 2	SDG4	SDG 4	SDG 5
IINTI	0.226*** (3.43)	0.873*** (7.54)	0.065 (0.54)	-0.282* (-1.98)	0.228*** (3.45)	0.877*** (7.61)	0.084 (1.20)	0.281** (-2.00)
GINI	-0.307*** (-2.90)	0.054 (0.29)	0.136 (0.70)	-2.79*** (-12.29)	-0.314*** (-2.96)	0.038 (0.21)	0.050 (0.45)	-2.82*** (-12.53)
GDD	-0.209*** (-2.74)	-0.312** (-2.33)	-0.546*** (-3.92)	-0.334** (-2.07)	-0.185** (-2.33)	-0.254* (-1.84)	-0.235*** (-2.81)	-0.236 (-1.38)
GG					-0.142 (-1.03)	-0.346 (-1.44)	-1.885*** (-13.04)	-0.539* (-1.67)
F-Valor	26.34	53.35	10.77	55.20	20.04	41.05	67.06	43.08
(prob.)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R ²	0.48	0.66	0.28	0.69	0.49	0.67	0.76	0.70
Adj. R ²	0.47	0.65	0.25	0.67	0.47	0.65	0.75	0.68

Source: Own elaboration.

that have been included have the expected effect. In other words, as the “Digital Gender Gap” increases, the proportion of the SDG that the country has reached decreases. On the other hand, an increase in the “Inclusive Internet” index has a positive effect on most of the SDGs analyzed.

Regarding the variable of “Gender Gap” it is observed that it has a negative effect on the analyzed SDGs, also, the impact of its inclusion in the *Model b* on the variable “Digital Gender Divide” stands out this effect when the variable “Gender gap” (DG) is included in the models. In view of these results, we can say that, although the “Digital Gender Gap” has a negative effect on the achievement of the SDGs, there are other dimensions of the gender gap, in addition to the technological dimension, that further compromise achievement of these objectives for the different countries.

Regarding SDG 2 (Essential objective of our study), we can see that an increase of one percentage point in the “Inclusive Internet Index” increases by 0.226 perceptual point (p.p.) the proportion of SDG 2 that this country can achieve. On the other hand, an increase of one unit in the “GINI” index (one p.p.) reduces by 0.307 p.p. the percentage reached of said SDG. In the same way, we observe that an increase of

one percentage point (pp) of the “Gender Digital Divide Index” reduces the percentage reached of SDG2 by 0.209 p.p., this effect being statistically significant.

In the same way, we can observe that an increase of one p.p. in the first variable (IINTI) increases by 0.873 p.p. the proportion of SDG4 achieved. Regarding the variable GINI, one p.p. increases by 0.054 p.p. the percentage of this SDG. Similarly, the precedent SDG, we can see that an increase of one percentage point of the Gender Digital Divide reduces the percentage achieved of SDG 4 by 0.312 p.p.

In the case of SDG 5, the statistics are also significant, since the positive variation of IINTI by 0.065 p.p. increase the proportion of this goal but not at the same level as SDG 2 and 4. As for the GINI Index, we can see that one p.p. increases the percentage of this SDG too. Also, we observe that the increase of one percentage point pf the Gender Digital Divide reduces the percentage of SDG5 by 0.546 p.p.

Finally, we notice that an increase of one p.p. in IINTI reduces by 0.282 p.p. the proportion of this goal 10, and one p.p. in the GINI reduces by 2.79 p.p. the percentage of SDG 10, and that the variable Gender Digital Divide reduces the percentage reached of SDG 10 by 0.334 p.p.

5. Discussion

5.1. Discussion of the results

The significance of the result observed in this study confirms the impact that technology has on the need for food security, as well as the need to incorporate and, above all, prepare women in this field and offer them the resources necessary to carry out their tasks and contribute of added value. Therefore, investing in male and female smallholder farmers is an important way to increase food security and nutrition for the poorest, as well as food production for local and global markets. Also, it is recommended to promote the development of new technologies as an essential tool to improve the personal and employment situation of rural women, as a dynamic measure of the rural economy, and articulate measures that promote conciliation and co-responsibility, to be able to help rural women access to the labor market and information (Hidalgo García, 2013).

The results demonstrate the complementarity that exists between the four SDGs and equality what Ukeje (2004) says that females have the capability of increasing agricultural production given the roles they play in the production process, but they require to be empowered through training and the provision of the appropriate ICTs to reach it.

5.2. Discussion about the situation of Spain

To project these results on a specific case, the situation in Spain can be analyzed, since in this country the agri-food sector represents one of the most important assets in the economic recovery and what makes Spain a power world order food. In fact, the Spanish agri-food sector represents 10% of GDP, generates more than 2.5 million jobs and exports worth more than 50,000 million euros, with an increase of 50% over the figures of 2011. This achievement has been possible thanks to the role played by women, who contribute to the solidity of agricultural and fishing activity, the quality of products from the countryside and the sea (FEAGAS, 2018).

The Spanish rural environment is made up of a total of 6,678 municipalities, in which 7.6

million people are registered, 16.1% of the population. 50.8% of its inhabitants are men and 49.2% women (Ministry of Agriculture, Fisheries and Food, 2019). According to Alonso and Trillo (2014), rural gender issues in Spain focuses on three social problems: rural exodus and, consequently, depopulation (especially among better-educated women), masculinization and ageing. Adding to these problems, a decisive element which influences this segregation. That element is the difficulty of conciliation between family and professional responsibilities, which cause income gaps and occupational segregation. In fact, the choice of occupation is expected as an important determinant of women's earnings and a key factor which underline the gender wage gap. Gammage *et al.* (2020) also stipulate that the pregnancy and childbearing affect women's ability to pursue different types of economic opportunities and even the choice of sectors in which they seek to work.

There are also various other factors that can be mentioned, such as society being convinced that a certain profession is "a man's job". This could be because of the stereotypes instilled in minds from childhood, or the lack of self-confidence due to not having training or not having the necessary technological capabilities to assume more responsibilities (UPA, 2019). Effectively, in the case of Spain, some differences could be observed between academic capacities, university orientations and technological aptitudes between men and women, which demonstrate the existence of a digital gender gap. These differences are due to several socio-economic factors that can be summarized as follows in Table 3.

In this table, the presence of women and men is not the same at all levels of study, nor in all specialties. In fact, we see that the literacy and enrolment rate in the first two cycles is almost the same for both genders, but enrolment in high school shows a clear difference between the two with a prevalence of women almost double. These statistics may be women are more educated and can reach higher educational levels if given the opportunity.

However, the effect of the social factors of the stereotypes of selection of the formations, previously indicated in the different specialties, is ob-

Table 3 - Comparison of training level and specialities by gender in Spain.

<i>Indicators (2020)</i>		<i>Spain</i>	
<i>Training levels and specialities</i>		<i>Male (%)</i>	<i>Female (%)</i>
<i>Educational attainment</i>	Literacy rate	99.00	98.00
	Enrolment in primary education	98.50	97.60
	Enrolment in secondary education	94.00	97.80
	Enrolment in tertiary education	58.70	97.00
<i>Graduates by degree type</i>	<i>Agri, forestry, fisheries and veterinary, attainment</i>	1.91	0.99
	Arts and humanities, attainment	6.56	9.60
	Business, admin and law, attainment	31.11	18.94
	Education, attainment	2.12	22.35
	Health and welfare, attainment	9.14	21.30
	Engineering, manufacturing and construction, attainment	25.08	6.78
	<i>Information and comm technologies, attainment</i>	5.77	0.92
	Natural Sci, mathematics and statistics, attainment	8.87	4.73
	STEMS, attainment (Science, Technology, Engineering and Mathematics)	39.72	12.44
	Services, attainment	3.52	6.10
<i>Social sci, journalism and information, attainment</i>		5.89	8.11

Source: *The global gender gap report (World Economic Forum, 2020)*.

served, since women are more present in sectors such as education, health, journalism, the arts and humanities and services, while men predominate in the scientific, technological and agricultural sectors, which clearly demonstrates the reason for the masculinization of these sectors and justifies this need for investment in the fields of training, education and provision solid infrastructure. In fact, the orographic and geographical conditions in regions make it difficult to install and access quality infrastructure. These connectivity problems affect all people, but are especially relevant among women, especially among older women and those with fewer socioeconomic resources. They are the ones that find the greatest problems when it comes to accessing the use of the Internet with mobile or digital devices of quality. In any case, it should be noted the existence of network drops or gaps in connectivity also in current cities with certain frequency (Vico-Bosch and Rebollo-Catalán, 2018).

Another factor that influences the digital divide is the labor inequality between men and women. The delay in the incorporation of wom-

en into the workplace also creates a difference in the understanding and use of new technologies between genders (Herrero Pulgar, 2012). Additionally, women are already disproportionately responsible for housework and care, so they have less time on their farms, compared to men. With the expectation of caring for out-of-school children or sick relatives, women farmers are more likely to carry the burden of additional household responsibilities. This situation shows a difference between in the case of rural areas and urban areas where the adoption of the technology is not the same (see Figure 5).

This gap in technological and agricultural education is reflected in the workplace, creating another gender gap and demonstrates the existence of a glass ceiling that prevents the development of women's professional careers in the same way as men. In this sense, Eurostat data (2019) shows that the presence of Spanish women in the Food and beverage industry represents 45.5% in front of 54.5% of men, the same gap is showed in the food industry where women represent 28.7% in front of 71.3% of men, and in the agriculture and

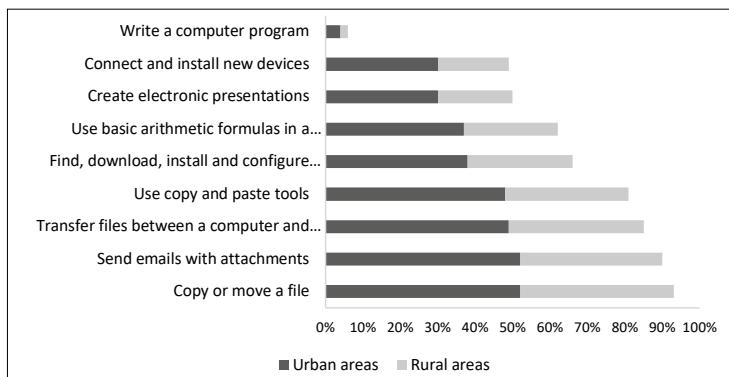


Figure 5 - Average proportion of the population in rural and urban areas with a specific digital aptitude in Spain (2017).

Source: FAO (2019).

fishery industry where women represent 23.8% in front of 76.2%, which indicate a male predominance of the labor market of this sector.

Furthermore, women farmers generally have less access to savings and credit than their male counterparts. In the case of Spain, Law 35/2011 on Shared Ownership in Agricultural Holdings recognizes that gender equality in rural areas evolves slowly and that farms whose owners are women tend to be of smaller economic dimensions and low profitability (Hidalgo García, 2013). In addition to this law, the Spanish Government has approved on September 28, 2021, a royal decree to encourage equality for women in jointly owned agricultural holdings (Ministry of Agriculture, Fisheries and Food, 2021). It must be said that this royal decree comes to regularize and equalize the alarming statistics showed in Table 4. For this reason, awareness about joint land titling is encouraged through socialization campaigns that focus on women to inform them of their rights and duties regarding land ownership.

The digital divide in rural areas is also caused by age. It is evident that younger people who

have been born in the era of new technologies are more used to using them and considering them as part of their daily lives. However, older people have much more difficulty handling gadgets or equipment that have not been around for much of their lives. There are even many cases in which the older population directly avoids these technologies of their own free will. This aging of the population increases the situations of coexistence with people in a position of dependency in rural areas, which affects the workload of caregivers, generally women, reducing their possibilities of labor, political or social participation (Ministry of Agriculture, Fisheries and Food, 2020a)

6. Conclusion

“Every man, woman, and child have the inalienable right not to suffer from hunger or malnutrition to fully develop and maintain their physical condition and mental faculties”, said Gifra Durall and Beltrán García (2013: 26). Therefore, it is necessary to raise awareness among the population about the world food

Table 4 - Presence of Spanish women in the rural world.

Comparative element	Men (%)	Women (%)
Employment rate in Agriculture, livestock, forestry and fishing (2017)	75.13	24.87
People who have received aid in rural development (2019)	67.00	33.00
Farm owners (2016)	67.58	32.42
People with high positions - Heads of farms (2016)	74.21	25.78
Entrepreneurship in rural areas (2019)	46.00	54.00

Source: Own elaboration based on data from the information system of public employment services (SISPE, 2018), Ministry of Equality (2019), INE (2016).

problem and strengthen solidarity in the fight against hunger, malnutrition, and poverty.

Today, the contribution of women in the fight against this malnutrition is more than essential since they are among the actors in the agricultural and agri-food sector. However, it is only recently that their key role as food producers and suppliers and their decisive contribution to household food security began to be recognized, for which they have a long way to go before reaching fair equality in this environment.

However, today, development and globalization have allowed the achievement of this objective through technological innovation and the inclusion of women as labor, which has been complementary and not primary for a long time.

The results of this study demonstrate the complementarity that exists between these two elements and the effect they have on the achievement of sustainable development, especially those referred to in this research namely the eradication of hunger through education, equality, and accessibility to the necessary infrastructure. As a matter of fact, the reproductive roles that women play could be considered as an added factor to pay more attention to topics gender. And this is not only for the need to achieve equity between men and women, but also the need to achieve structural changes oriented to reduce poverty and food insecurity.

The inclusion of women has been confirmed to be a decisive element in many of the SDGs, because it allows duplicating efforts and contributions in all sectors and countries and having them on the top management team, specifically in the rural world represents a windfall.

Also, it should be noted that the differences in the female and male mental faculties make it necessary to resort to this complementarity. In this sense, Slyke *et al.* (2010) indicate that technology is not used in the same way by the two genders, but the association of both creates a certain synergy that leads to a better productivity.

Therefore, it is recommended, to sensitize both genders, all agencies, and senior decision-makers on the absolute need to guarantee equal opportunities, whether in training, employment or in the acquisition of strategic tools, to achieve financial independence and autonomy. This will

allow to conciliate between the professional and the personal life and get women involved in many areas and activities.

In this way, the General Director of Rural Development, Innovation and Agrifood Training, Isabel Bombal, has also highlighted the importance of a fair, balanced, sustainable, and inclusive development of the rural environment. She has pointed out the importance of designing an action plan for rural women, to guarantee their real and effective equality, and to make visible the fundamental role they play (Ministry of Agriculture, Fisheries and Food, 2020b).

Several measures can also be applied for the integration of women in careers related to food security, whether in agricultural specialties or in other more technological ones that are considered complementary in this sector.

The inclusion of women in general meetings, which are decisive in this area, can also be useful to guarantee equal opportunities, in addition to the application of laws that promote their integration, such as inheritance, land ownership or granting aid.

Moreover, the promotion of intelligent work (telework, remote management, web training, tele-administration, etc.) represents a good option to face the obstacles that prevent women from participating in the agrarian world, not only due to the issue of conciliation, but also to the issue of rurality in some cases. The difficulty for women to move to urban areas to seize some opportunities, oblige them very often to take flights (rural exodus), which weakens their social fabric and productivity and encourages the creation of an unpopulated and empty Spain.

Women must be sensitized to the different technical careers they may be eligible to and to the importance of being in harmony with their decisions, regardless of the influences they may have. ICTs can improve rural livelihoods and empower smallholder farmers in developing countries by expanding access to agricultural and market information and can also contribute to the development of social justice and equity by empowering less protected groups in rural communities.

Empowering women, providing them fair access to land, financing, seeds, agricultural training, food within the home, access to markets and

decision-making processes is therefore a condition essential to eradicate hunger in the world. Without pro-active policies in favor of gender equality, it is impossible to guarantee the sustainable future of our agri-food systems and end that infamous scourge of malnutrition. Equality between men and women is, first and foremost, a matter of fundamental justice but it is also a basic prerequisite for achieving food security for all.

Lastly, it must be specified that this work has had limitations in terms of the sample, since the initial idea was to consider all the countries of the world, but the availability of the same data for all variables and in the same years has not been possible, for which has been limited to the 87 countries. It would also have been interesting to apply this same regression on the autonomous communities of Spain that has been selected as the reference country in the discussion part. These limitations could be considered for further future research in which a specific survey could be elaborated to determine the achievement of this sustainability between rural and urban areas.

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Efficiency and technology of dairy sheep production systems in Castilla-La Mancha, Spain. A metafrontier approach

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Abstract

This paper deals with the efficiency level of cereal-dairy sheep production systems in the Mediterranean Basin. It studies them in the Protected Designation of Origin “Manchego Cheese”, located in Castilla-La Mancha (Spain). Previous studies have alerted to the low productivity levels in these farms, suggesting conducting an efficiency analysis. This work evaluates technological levels by means of synthetic indexes. Two different groups were defined. Technical efficiency was estimated using Data Envelopment Analysis with metafrontier models. The higher the technological level, the higher the efficiency level. Low technology farms could increase their production at least around 23% using the technologies of the high-technology group. Thus, it could be wise to apply new technologies, as new feeding techniques, and the use of troughs of cement, dungheaps, flushing and selective breeding. Increase farm size is a way to implement these technologies. Special attention to managerial functions, mainly organisation and planning, is also advisable. The government must improve the agricultural policies. These actions could increase efficiency, resiliency and sustainability of the farms.

Keywords: *Dairy sheep production systems, Data envelopment analysis, Efficiency, Management, Metafrontier.*

1. Introduction

There are approximately 2,200 million sheep and goats in the world. The 20.8% aim for dairy production, producing about 3.5% of the world's milk. The population size of sheep and goats in the European Union (EU) is approximately 74 million heads, of which sheep represent round about 83%. Three quarters of

these sheep live in Spain (24.8%), Romania (16.6%), Greece (13.5%), France (11.4%) and Italy (11.2%) (Eurostat, 2020). Four countries – France, Greece, Italy, and Spain – lead the international markets in sheep and goat dairy products. The productive models of these countries have also characteristic features. In general, they are based on the use of specific breeds and Protected Designation of Origin (PDO)

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cheeses, which are usually produced following traditional recipes.

The dairy sheep-cereal production systems are multifunctional and have a crucial historical, economic and social importance (Arzubi *et al.*, 2009; Vagnoni *et al.*, 2018). Nevertheless, Mediterranean dairy sheep production farms have limits to their productivity, like weather and land conditions (de Rancourt *et al.*, 2006; Rivas *et al.*, 2014; Morantes *et al.*, 2017).

According to national census (MAPA, 2019), there are 15.5×10^6 millions of sheep in Spain, and Castilla-La Mancha has the 15.11% of this amount. The most frequent production systems are concerned with the autochthonous breed called “Manchega” breed.

The observed tendency of the farms to disappear from Europe is an important fact in the dairy sheep production economic sector in Spain. Many farmers left their production systems due to low productivity levels obtained from the herds (Ripoll-Bosch *et al.*, 2012). Morantes *et al.* (2014) studied the socio-economic characteristics of these production systems. These authors, and García-Díaz *et al.* (2012), indicated that agriculture and livestock farms maintenance requires an increase in profitability.

In other previous research, Morantes *et al.* (2017) dealt with the importance of management in dairy sheep production systems in Castilla-La Mancha. They designed and created four indexes of the management functions: planning, organisation, management and control. The results showed that the managerial levels were not optimal, and proved that the productivity levels were low. The conclusions proposed performing an in-depth study on the farms efficiency level, to reach a general improvement of all the processes.

As it is well known, technical efficiency and technological level are productivity determinant factors. The firms' technological level is important for their efficiency analysis. Kompas and Che (2006) have studied the technical efficiency on Australian dairy farms and its relation with the technology. Mukherjee *et al.* (2012) estimated the dairy farms' technical efficiency in Florida and Georgia, with a stochastic frontier analysis considering the technological level as external factors in the production frontier.

One of the main objectives of this paper is to conduct an efficiency analysis of the dairy sheep production systems in Castilla-La Mancha. To do it, we first estimated the firms' efficiency level applying Data Envelopment Analysis (DEA) techniques. Then Truncated Regression analysis was also applied, in order to detect the influential variables on the farm efficiency levels. However, this methodology requires the sample to be homogeneous in technology. For this reason, we previously analysed the dairy-sheep-production-system technological level.

There are management techniques that require substantial investment for a long time. The present paper assesses farm technological levels depending on these implemented technologies and the productivity levels in a long-term period, and performs a long-term technological index. The firms are classified into two groups according to their different technologies. This fact can originate different production frontiers. These groups have diverse technologies, then suitable approaches for the efficiency analysis are required, and two production frontiers should be taken into account. The appropriate methodology is called Metafrontier Production Function (Battese *et al.*, 2004; O'Donnell *et al.*, 2008; Latruffe *et al.*, 2012; Ozden and Dios-Palomares, 2016; Melo-Becerra and Orozco-Gallo, 2017).

On the other hand, the knowledge of the relevant factors to the technical efficiency levels is crucial. These factors relate to the short-term technologies and the management practices.

There are management technologies implemented in a short time term. Thus, they could be easily modified to improve results, if necessary. These techniques, and several aspects of the management functions, could be determinants for the technical efficiency (Urdaneta *et al.*, 2013). In the present paper, a short-term technological index is also performed. This index resumes all these technologies.

The organisation and the control indexes, previously calculated by Morantes *et al.* (2017), has been also used as an explicative variable in the analysis.

In this paper, we used the same sample of Morantes *et al.* (2017), and we applied diverse approaches as survey, index calculation, mul-

tivariate analysis, DEA-metafrontier models, statistical tests, regression methods, bootstrap techniques, etc.

As a relevant added value, we evaluated the technological and efficiency levels. In addition, the main influential factors of both technological and efficiency levels were found.

The detection of these factors allows the decision-makers to perform improvement actions, to relieve the existing problems. It is important to achieve sustainability in these systems, which currently has originated changes in the type and intensity of land utilization, and led to environmental and landscape degradation (Rivas *et al.*, 2015).

All these findings enable us to offer advice on the strategies to implement, to improve the farm production systems, and the performance of the overall economic sector. Indeed, it will be able to extrapolate these advices and conclusions to other similar firms in the Mediterranean Basin.

2. Materials and methods

2.1. Descriptive aspects

This paper works with data, which come from our previous research (Morantes *et al.*, 2014; Rivas *et al.*, 2014; Morantes *et al.*, 2017). The study was conducted in the region of Castilla-La Mancha (Spain), characterised by a Mediterranean climate (Caballero, 2009).

These production systems are usually family-run. The majority of them are agriculture and livestock farms (mixed farms). These farms provide multiple products (milk, lamb, and cheese). They are mainly oriented to produce milk products as Manchego cheese. A detailed description of these farms can be seen in Rivas *et al.* (2014). The Protected Designation of Origin (PDO) “Manchego Cheese” consists of 869 farms located in the natural region called “La Mancha”.

Table 1 - Stratified Random Sample.

<i>Province</i>	<i>Stratum</i>	<i>Sheep</i>	<i>Farms</i>	<i>Sample Size</i>
Albacete	I	(0, 366]	38	7
	II	(366, 1033]	58	10
	III	(1033, 1700]	24	5
	IV	(1700, 2366]	12	3
	<i>Mean</i>	958.32	<i>Total</i>	25
Ciudad Real	I	(0, 200]	56	10
	II	(200, 600]	260	44
	III	(600, 1000]	75	14
	IV	(1000, 1400]	20	4
	V	(1400, 1800]	11	3
	<i>Mean</i>	532.42	<i>Total</i>	75
Cuenca	I	(0, 244]	29	5
	II	(244, 688]	90	15
	III	(688, 1133]	33	6
	IV	(1133, 1577]	9	2
	<i>Mean</i>	617.89	<i>Total</i>	28
Toledo	I	(0, 133]	7	2
	II	(133, 466]	87	15
	III	(466, 800]	45	9
	IV	(800, 1133]	15	3
	<i>Mean</i>	499.71	<i>Total</i>	29
	<i>Total Mean</i>	609	869	157

A representative stratified random sample with proportional allocation was selected in accordance with two classification criteria (province and census) (Table 1).

The farms of each province were divided in strata according to the number of sheep of the farm. The number of strata of each province was selected following the Sturges rule taking into account the proportional allocation, and a random sample was selected from each stratum with sampling fraction of $p = 0.15$. The sample size was 130 farms. In addition, in order to guarantee a suitable effective sample size even in the cases where some instances of the sample must be removed from it, 27 extra farms were selected using the same sampling design. No instance removing was necessary. Thus, the final sample size was 157 (Table 1). The experimental error was 7.82% with a significant level of 5%. (Cochran, 1977).

A survey of 226 questions was designed, to get data from the farms regarding 12 relevant aspects: (1) situation and use of the land, (2) equipment, (3) livestock size, (4) labour (family members and employees), (5) feeding management, (6) grazing, (7) breeding management, (8) health management, (9) milking management and milk quality, (10) economic issues, (11) social issues, and (12) attributes of the management functions: planning, organisation, direction and control.

This research also deals with some results of Morantes *et al.* (2017) regarding the indexes of organisation and control. In that paper, the organisation index was built including several issues, like the manager's ownership, the organisational chart, and the personnel selection method. On the other hand, two aspects were considered for the control index: if the farmer provides records or not, and the evaluation of the objective. Table 2 collects descriptive values of both indexes.

2.2. Evaluation of the long and short term management strategies

Two types of technological synthetic indexes were designed and made, in order to analyse the management strategies: long-term technological index (LTTI), and short-term technological index (STTI). The LTTI considers strat-

Table 2 - Descriptive values for the organisation and control indexes.

Statistics	Organisation index (OI)	Control index (CI)
Total sample		
Valid data	138	138
Mean	0.50	0.53
Standard deviation	0.20	0.39
Minimum	0.19	0.00
Maximum	1	1
HTG Group		
Valid data	32	32
Mean	0.53	0.62
Standard deviation	0.22	0.39
Minimum	0.19	0.00
Maximum	0.88	1
LTG Group		
Valid data	106	106
Mean	0.50	0.50
Standard deviation	0.19	0.38
Minimum	0.19	0.00
Maximum	1	1

gies where the techniques involved require plans of investment and revenue during several years (Table 3).

On the other hand, the STTI incorporates strategies, which could be easily modified or cancelled (Table 4).

Several methods to build synthetic indexes have been described in the literature. The common objective is to quantify some issue in a set of individuals or firms.

In this paper, we have applied the budget allocation process (BAP). All the management variables are dichotomous (the value belongs to the set $\{0, 1\}$), where the value 0 means absence and the value 1 means presence. A panel of experts was consulted in order to assign the weights to the variables in the synthetic indexes designed. This panel of specialists consists of 12 people: 7 vets, 3 agronomists and 2 farmers. Likert scale was applied (Likert, 1932; Cuervo, 2009), and the assessed values were: 1 for total disagree, 2 for disagree, 3 for indifference, 4 for agree, and 5 for total agree.

The formula for each technological index is the following:

$$I = w_1 MS_1 + w_2 MS_2 + \dots + w_n MS_n = \sum_{i=1}^n w_i MS_i \quad (1)$$

where I is the index (LTTI or STTI), w_i is the weight assigned by the experts to the variable i -th included in the index, MS_i (Management Strategy) is the value of such dichotomous variable (0 or 1).

Table 3 - Weights of the variables that compose the long-term technological index (LTTI) and proportion of livestock farms where the strategy is developed in practice.

Management strategy	Weights	Strategy developed in practice % (n)		
		Total sample	HTG Group	LTG Group
Manage grazing lots by productive group	0.13	54.8 (86)	54.8 (23)	54.3 (63)
Uses genetic value as criterion for replacement of males	0.13	41.4 (65)	64.3 (27)	32.8 (38)
Uses genetic value as criterion for replacement of females	0.12	43.9 (69)	66.7 (28)	35.7 (41)
Has mechanical milking	0.12	86.0 (135)	92.9 (39)	82.8 (96)
Has cement screed	0.10	24.8 (39)	38.1 (16)	19.8 (23)
Has dung	0.10	29.3 (46)	45.2 (19)	23.5 (27)
Has silo	0.11	30.6 (48)	35.7 (15)	28.7 (33)
Has hayloft	0.10	29.9 (47)	35.7 (15)	27.8 (32)
Has feed belt	0.09	12.1 (19)	23.8 (10)	7.8 (9)

n: number of farms.

Table 4 - Weights of the variables that compose the short-term technological index (STTI) and proportion of livestock farms that develop the practices.

Variable	Weights	Developed strategy % (n)		
		Total sample	HTG	LTG
Has Unifeed	0.05	63.7 (100)	71.4 (30)	60.9 (70)
Manages lots of feed in the milking	0.06	38.9 (61)	54.8 (23)	33.0 (38)
Manages lambing season	0.06	82.8 (130)	90.5 (38)	80.0 (92)
Assisted copulation	0.05	29.9 (47)	57.1 (24)	20.0 (23)
Male effect	0.05	30.6 (48)	38.1 (16)	27.8 (32)
Flushing	0.05	14.6 (23)	19.0 (8)	13.0 (15)
Artificial insemination	0.03	36.3 (57)	61.9 (26)	27.0 (31)
Voluntary losses in female sheep	0.06	95.5 (150)	100.0 (42)	93.9 (108)
Voluntary losses in male sheep (ram)	0.05	93.0 (146)	90.5 (38)	93.9 (108)
Applies mastitis vaccine	0.03	24.8 (39)	33.3 (14)	21.7 (25)
Applies vaccine agalactia contagious	0.04	91.7 (144)	92.9 (39)	91.3 (105)
Applies intramammary drying treatment in ewes	0.05	47.1 (74)	50.0 (21)	46.1 (53)
Applies drying treatment to the whole flock	0.04	43.3 (68)	47.6 (20)	41.7 (48)
Vitamins and minerals applied to lambs	0.05	15.3 (24)	19.0 (8)	13.9 (16)
Has milk tank	0.03	96.8 (152)	100.0 (42)	95.7 (110)
Milking parlor with low line	0.05	45.9 (72)	38.1 (16)	48.7 (56)
Use water cleaner	0.04	42.7 (67)	57.1 (24)	37.4 (43)
Has vacuum valve	0.05	73.9 (116)	85.7 (36)	69.6 (80)
Has electricity	0.05	96.2 (151)	97.6 (41)	95.7 (110)
Division of stockyards by production lots	0.06	86.6 (136)	95.2 (40)	83.5 (96)
Has area of lambing	0.05	84.7 (133)	92.9 (39)	81.7 (94)

n: number of farms.

2.3. Technical efficiency: analysis and determinants

The technological heterogeneity was studied using factorial and cluster analyses. They were performed based on the variables, which are determinants of the different technological levels. These variables were the LTTI, and the following productivity indicators: Milk/E (Litre/Ewe), IMS/E (€/Ewe) (Income from Milk Sales / Ewe), TSI/E (€/Ewe) (Total Sales Income / Ewe), GM/E (€/E) (Gross Margin / Ewe), L/UAW (Litres of Milk / Unit of Agricultural Work), IMS/UAW (€/UAW) (Income of Milk Sales / Unit of Agricultural Work), TSI/UAW (€/UAW) (Total Sales Income / Unit of Agricultural Work), GM/UAW (€/UAW) (Gross Margin / Unit of Agricultural Work), L/ha (Litres / hectare), IMS/ha (€/ha) (Income Milk Sales / hectare), and GM/ha (€/ha) (Gross Margin / hectare). A factorial analysis with all the variables was performed in order to detect the factors with a high impact on the sample total variance. Then, a cluster analysis with the found factors was applied with the K-means methodology. The significant difference among groups was tested for each variable (t-Student because there are two groups).

Previously to the efficiency analysis, a statistic method to detect atypical values (outliers) was applied.

The TE (Technical Efficiency) analysis was performed with one output: milk production (litres); and five inputs: ewes (number), land (ha), labour (units of agricultural work) (UAW), fixed capital (€) (revenues from buildings, facilities, equipment, and animals), working capital (€) (feeding costs, National Insurance payments, health costs, interest from capital).

Data Envelopment Analysis is a powerful way for the technical efficiency analysis, and determines the efficient firms. These firms make optimal use of the resources for the production of outputs (milk in this case) (Cooper *et al.*, 2007). This methodology has been applied by many studies to diverse sectors (Dios-Palomares *et al.*, 2020).

The estimation of a firm's efficiency is defined by its distance to the production frontier. However, all the firms taken in consideration to esti-

mate the frontier must use the same technology for fair comparison.

In our case, to estimate efficiency, the Data Envelopment Analysis (DEA) methodology was applied with a metafrontier approach (Coelli, 1995; O'Donnell *et al.*, 2008; Ozden and Dios-Palomares, 2016), and dealing with two frontiers corresponding to the two technological groups considered. This metafrontier methodology implies, in our analysis, the estimation of three production frontiers, as will be seen below.

The DEA methodology is applied to each frontier and consists of calculating, by mathematical programming, the distance from each point (firm) to the envelope formed by all the others. It is necessary to solve the DEA model for each company in the sample. (Cooper *et al.*, 2007).

The formulation of the DEA mathematical model starts with the definition of the n decision making units (DMU) under study. The j -th DMU is denoted by DMU_j with $j = 1, \dots, n$. DMU_j uses m inputs (indexed $i = 1, \dots, m$) to produce s outputs (indexed $r = 1, \dots, s$). The production possibility set will be estimated on the basis of the sample values of n DMUs. Thus, if $x_j \in \mathbb{R}_+^m$ is the vector of inputs of DMU_j , and $y_j \in \mathbb{R}_+^s$ is its vector of outputs, for every $j = 1, \dots, n$, then the problem data are characterised by the matrix of inputs $X = (x_j) \in \mathbb{R}_+^{m \times n}$, and the matrix of outputs $Y = (y_j) \in \mathbb{R}_+^{s \times n}$. For each fixed DMU_o (with o varying $o = 1, \dots, n$) the output-oriented BCC model envelopment form (Banker *et al.*, 1984), is written in the way:

$$\max_{\eta, \lambda} \eta \quad (2)$$

subject to

$$X\lambda \leq x_o \quad (3)$$

$$\eta y_o - Y\lambda \leq 0 \quad (4)$$

$$e\lambda = 1 \quad (5)$$

$$\lambda \geq 0 \quad (6)$$

where the scalar η measures the efficiency related to the DMU_o , λ is a column vector ($n \times 1$) which weighs the sample DMUs, and the constraint $e\lambda = 1$ means $\sum_{j=1}^n \lambda_j = 1$ and characterises variable return of scale models.

Firstly, pure efficiency (BCC-efficiency) was estimated with this BCC model. Then, technical efficiency (CCR-efficiency) was estimated

with a CCR model with constant returns to scale (Charnes *et al.*, 1978). In this CCR model, the constraint $e\lambda = 1$, i.e., $\sum_{j=1}^n \lambda_j = 1$, is omitted. Then, scale efficiency (SE) was computed as the ratio between pure and technical efficiencies.

The metafrontier concept, developed by O'Donnell *et al.* (2008), was applied. This model considers that technical efficiencies, related to farms with different technologies, are not comparable under the same production frontier. Figure 1 shows a methodological simplification with two inputs (X_1 and X_2) and one output (Y). The frontiers associated to the two technological groups (HTG – High Technological Group – and LTG – Low Technological Group –) were estimated separately. The intra-group efficiency $TE_{j_k}^k$, with K groups, n_k units (DMUs) in each group k , and $k = 1, \dots, K$, with $n = \sum_{k=1}^K n_k$ the total number of DMUs and $j_k = 1, \dots, n_k$, is the technical efficiency of the DMU_{j_k} , of the group k , respect to the DMUs of its group k .

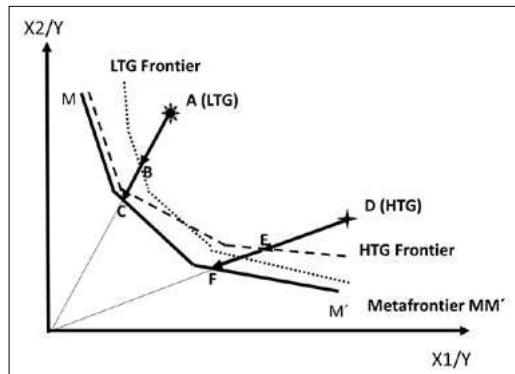
In addition, the metafrontier (MM') is estimated taking into account all the n DMUs, i.e., all the DMUs of both technological groups. The efficiency of the DMU_{j_k} regarding this metafrontier is denoted by $TE_{j_k}, j_k = 1, \dots, n_k$, and $k = 1, \dots, K$.

The meta-technology ratio (MTR_{j_k}) is the ratio between both efficiencies, i.e., $MTR_{j_k} = \frac{TE_{j_k}}{TE_{j_k}^k}$, when the DMU_{j_k} belongs to the technological group k . This ratio represents the ratio between the distances to both frontiers.

After compute the different efficiency indexes, their distributions were compared. To do that, the test of Simar-Zelenyuk (Simar and Zelenyuk, 2006) was performed with 1000 replications, as it is required to compare distributions of technical efficiency scores. In addition, the Two-sample Kolmogorov-Smirnov equality test for distribution functions, and the Kruskal-Wallis equality-of-populations rank test were applied.

Besides the efficiency estimation, additional analysis was conducted, in order to detect the management effect on the dairy-sheep production-system efficiency in Castilla-La Mancha. It is a well-known general result that, if the endogenous variable is bound, truncated regression

Figure 1 - Production Metafrontier.



and bootstrap techniques are suitable to its estimation (Simar and Wilson, 2007). Thus, truncated regression models were estimated, with 1000 bootstrap samples, to explain the calculated efficiency index TE with a set of L efficiency factors by the F function, i.e. $TE = F(\beta, f) + \varepsilon$, with $\varepsilon \in N(0, \sigma^2)$, and $0 < TE < 1$.

For this model estimation, the Simar and Wilson (2007) algorithm #1 was applied, using Stata software, and the package "simarwilson" developed by Badunenko and Tauchmann (Badunenko and Tauchmann, 2016).

A firm is inefficient because it obtains less output than its target, which is on its production frontier, using the same inputs and similar technology. If it used the inputs optimally, it would be efficient. Its inefficiency may be due to factors that are modifiable in the short term, and are mainly related to management.

The variables, which can influence the farm efficiency, were included as explanatory variables. These variables have been selected based on our own knowledge of the sector and those considered in previous works (Ozden and Diós-Palomares, 2016; Urdaneta *et al.*, 2013).

The following variables were selected:

- The variable TG (Technological Group), which indicates the farm technological group. It is equal to 0 for (LTG) and equal to 1 for (HTG). The group is included so that the two different groups are considered in the independent term. In principle, it is to be expected that the companies in the HTG group, in addition to being more productive, are also more efficient.

- The variable STTI. Its value lies between 0 and 1. The STTI index consists of the technologies listed in Table 4. All of them refer to actions that can be changed in the short term. Preliminary studies have established a positive relationship between efficiency and farm intensification through the implementation of technologies (Cabrera *et al.*, 2010; Álvarez *et al.*, 2008). These short-term technologies include the acquisition of equipment and the adoption of good farming practices. They also ensure proper management of inputs available on farms during the different seasons of the year, resulting in better reproductive performance and milk yields of ewes. Their application is expected to favour productivity and, thus, technical efficiency.
- The associative index, which takes the value 1 when the farmers are members of associations, and 0 otherwise. The percentage of associative farms was 37.7%. The farms that are members of associations should receive information and have advantages that could favour efficiency. Better planning is directly related to production success (Morantes *et al.*, 2014)
- The indexes of organisation (OI) and control (CI). Both indexes are valued between 0 and 1. These indices contain variables that cover organisational and control aspects, as expressed in section 2.1 of this paper. The implementation of these aspects may imply an improvement in efficiency (Morantes *et al.*, 2014).

The data were analysed with the following software: Banxia FRONTIER 3.0 (2003), SPSS (2013), STATA (2015), FEAR (Wilson, 2008) and R (R Development Core Team, 2010). In addition, we have developed a program based on the *np* routine of R, to apply the Simar-Zelenyuk test in this paper.

3. Results and discussion

3.1. Evaluation of long and short term technological strategies

Table 3 collects the management strategies taken into account in the long-term technological index (LTTI) and their percentage of

use in the studied systems. These percentages show that the more implemented technologies are mechanical milking, and separate sheep herding by production group. The other collected strategies are less implemented in the studied systems.

Many farmers do not follow genetic criteria for the breeding and replacement of flocks and herds. This lack could be negative for the farms productivity level. This issue was pointed out by researchers like Solano *et al.* (2000). There are only a few farms with technical feeding procedures. Equipment as feeding belts, silos, and haylofts usually lacks. Diverse research suggests incorporating automatic feeding due to its positive effect in cow milk production (Van Asseldonk *et al.*, 1998). In addition, it is also verified that the use of hay store strategies and silage have a positive relation with scale production in dairy sheep production systems (Gabbi *et al.*, 2013; Bernardes and do Rêgo, 2014).

The study indicates that a low proportion of the farms have implemented the use of troughs of cement and dungheaps. The implementation of these technologies is directly related to ammonium emissions in livestock production systems (Monteny and Erisman, 1998). Thus, these technologies could be indicators of the animal wellbeing, environmental conditions, and job performance of the workers and farmers.

Table 3 also shows the weights assigned by the experts to each strategy. The results indicate that the experts have similarly weighted management practices included in the LTTI. Shepherding and the use of genetic criteria for breeding and ram replacement were technologies better assessed and they received higher weights by the experts.

The results of the descriptive analysis of the Long Term Technological Index (LTTI) are collected in Table 5.

The LTTI has a low average value of 0.41 points with standard deviation s.d. = 0.24. However, the values vary between the minimum value 0 and the maximum value 0.90. This large range of variability illustrates a great heterogeneity of the technological development of the studied farms. Thus, it is convenient to detect homogeneous groups regarding technology before the estimation of the technical efficiency.

Table 5 - Description of long-term technological index (LTTI) and short-term technological index (STTI).

Variable	Mean	Standard deviation	Minimum value	Maximum value
<i>Total sample</i>				
Long-term technological index	0.41	0.24	0	0.90
Short-term technological index	0.59	0.16	0.23	0.89
<i>HTG Group</i>				
Long-term technological index	0.49	0.20	0	0.89
Short-term technological index	0.67	0.16	0.29	0.89
<i>LTG Group</i>				
Long-term technological index	0.38	0.24	0	0.90
Short-term technological index	0.57	0.16	0.23	0.89

Table 4 has the same structure that Table 3, but concerning the strategies of management in a short term included in the Short Term Technological Index (STTI). They are the management practices that could be easily changed. Third column shows that there are eight strategies applied in a proportion greater than 80%. However, it could be also checked that the less developed feeding strategy is the use of batches of animals, where batches are done taking into account the nutritional requirements at milking times. Despite the fact that they are easy to implement and do not require high investment, some breeding strategies, like male effect and flushing, are performed in a low proportion. A high proportion of farms does not apply mastitis vaccines, and does not provide vitamins and minerals for the lambs.

The values of the weights proposed by the experts are quite similar among the different management practices. They are collected in Table 4 and vary between 0.03 and 0.06.

The descriptive values of the STTI are shown in Table 5. The results indicate an average value around 0.60 (with s.d. = 0.16). Thus, the level of application of these practices is medium-high, although a large dispersion exists. This variability shows that a relation could be present between the medium-high level of application of these practices and the technical efficiency. Such relation deserves to be studied and analysed. In fact, it is interesting to know if the farms that apply these strategies are more efficient than the other farms.

3.2. Technical efficiency and metafrontiers

Before the analysis of the technical efficiency, the heterogeneity of the technology is studied. To do it, the multivariate methodology described in Section 2.3 is applied.

A factorial analysis was done to the partial productivity indicators and the LTTI. Two factors were obtained and they explain the 78.6% of the variance.

A cluster analysis of K means was performed. In accordance with the results obtained, the farms were divided into two groups.

The group 1 (with $n_1 = 42$ farms) with a high technological level (HTG); and the group 2 (with $n_2 = 115$ farms) with a low technological level (LTG). Table 6 shows the productivity values. Average and standard deviation are detailed in the two groups separately. Mean-difference tests were performed with the t-Student test. Significant differences ($p < 0.01$) were found between the two technological groups.

In Tables 3 and 4 we can see the percentages of use of the strategies that make up the LTTI and STTI indices, respectively, separated by groups.

Regarding the LTTI index, only the strategies of mechanical milking, and separate shepherding by production group have similar percentage of application in both groups. We found interesting differences in the rest of strategies between the two technological groups. The greater percentage of application of the strategy occurs in the high technology group HTG. This difference is especially relevant in the use of genetic values as criterion for

Table 6 - Productivity and long-term technological index (LTTI) by technological group.

Variable	HTG n = 42	LTG n = 115	t- student
	Mean (sd)	Mean (sd)	
Long-term technological index	0.49 (0.20)	0.38 (0.24)	2.75*
Milk (L)/Ewe	197.39 (50.23)	126.34 (42.95)	8.76*
Income from Milk Sales (€)/Ewe	241.15 (75.89)	153.99 (66.32)	7.01*
Total Sales Income (€)/Ewe	392.99 (107.67)	306.25 (112.99)	4.31*
Gross Margin (€)/Ewe	194.92 (96.89)	116.55 (109.39)	4.09*
Milk (L)/UAW	49519 (19344)	30969 (17190)	5.79*
Income from Milk Sales (€)/UAW	59715 (23674)	36945 (21749)	5.67*
Total Sales Income (€)/UAW	99568 (46025)	73889 (39653)	3.44*
Gross Margin (€)/UAW	50973 (35237)	30526 (30476)	3.57*
Milk (L)/ha	303.97 (157.70)	94.84 (52.52)	12.50*
Income from Milk Sales (€)/ha	369.22 (201.01)	111.20 (56.22)	12.55*
Gross Margin (€)/ha	299.08 (249.15)	83.28 (76.26)	8.32*

HTG: high level technological group, LTG: low level technological group, sd: standard deviation, n = number of farms, L: litres, €: euros, ha: hectares, UAW: unit of agricultural work, *: P < 0.01.

replacement and the use of feed belt. These results confirm the definition of the groups considering their technological level, and suggest the presence of a technological gap. This gap is also shown in Table 5. The mean of the LTTI index is 0.49 in the HTG group and 0.38 in the LTG group.

There are also important differences in the application of the strategies included in the STTI index when we compare between the two technology groups (Table 4). For almost all strategies, the percentage of application is higher in the HTG group than in the LTG group. The largest differences (around 35%) are found in assistant copulation, and artificial insemination. About the management strategies named manages lots of feed in the milking, having vacuum valve, and applying mastitis vaccine; their percentage of presence in the HTG group was around 12% higher than in the LTG group. These results indicate that firms with higher technology in the long term have also applied more technology in the short term. Furthermore, Table 5 shows that the average STTI index for HTG firms is 0.67, and for LTG firms it is 0.57.

In our research, two production frontiers are expected. Taking into account this structure of

two technological groups, metafrontier methodology is applied for the efficiency analysis.

The analysis of the atypical data (outliers) by the method of Wilson (1993) identified 10 outliers in the HTG group and 9 outliers in the LTG group. These outliers were removed. As a result, the HTG group was reduced from 42 to 32 farms, and the LTG group from 115 to 106 farms.

Descriptive values of the variables considered in the Data Envelopment Analysis (DEA) are shown in Table 7.

These values are reported separately in the two technological groups. Differences are observed between the two technological groups. In average, the farms of the HTG group use greater values of the following inputs: ewes (n), unit of agricultural work (UAW), fixed capital (€), and working capital (€). These farms also produce, in average, greater levels of output. In addition, the farms with low technological levels (LTG group) present lower levels of output. However, they use more amount of land (ha). This fact indicates that the production system of the farms of this group is more extensive, considering the ewe/land ratio.

Table 8 shows the descriptive measures (mean and standard deviation) of the Meta-frontier es-

Table 7 - Mean, standard deviation, minimum and maximum of output and inputs for groups of farms of high and low technological levels.

	HTG				LTG			
	Mean	sd	min	max	Mean	sd	min	max
<i>Output</i>								
Milk (L)	174050	107811	31000	456000	81875	57729	6500	246000
<i>Inputs</i>								
Ewe (n)	843	541	267	2512	623	367	81	1751
UAW	3.66	2.15	1.33	9.67	2.65	1.22	1	6
Land (ha)	758	567	39	2200	939	670	100	3200
Fixed capital (€)	41677	29334	12191	142019	28357	18561	1622	83133
Working capital (€)	103765	67063	21113	257652	71825	47134	5477	230639

HTG: high level technological group, LTG: low level technological group, sd: standard deviation, min: minimum, max: maximum, L: litres, €: euros, ha: hectares, UAW: unit of agricultural work.

timation results, the statistics, and the statistical significance of the three tests applied. Second column indicates the size of each technological group. Columns 3 to 5 collect the corresponding technical efficiency (TE) indexes obtained by the classical CCR (Charnes *et al.*, 1978) and BCC (Banker *et al.*, 1984) DEA models and the scale efficiency SE, i.e., the efficiency indexes TE-CCR, TE-BCC and SE, respectively. The efficiencies of each technological group $TE_{j_k}^k$ are presented in the first set of rows in a separate way taking into account the corresponding frontier. The second set of rows show the efficiencies TE_{j_k} with respect to the metafrontier of each technological group. Note that the metafrontier is a unique frontier for all the firms. The third set of rows presents the metafrontier technological ratios MTR_{j_k} , also separated by technological groups. The statistics and the statistical significance of the three tests are reported in each set of rows in order to test the distribution differences between the two technological groups (HTG and LTG). These statistical tests are Kolmogorov-Smirnov, Kruskal-Wallis and Simar-Zelenyuk tests.

Regarding intra-group efficiencies, the results show that the farms of the high technological group (HTG) are, in average, significantly more efficient than the farms of the low technological group (LTG), and their distributions are significantly different. These differences are significant both, concerning the CCR-efficiency (CCR) and the pure technical efficiency (BCC). This result

suggests that the farms with higher technological levels are closer each other regarding the management of the resources than the farms with lower technological levels. It is important to know that these values compute the distance of the farms to the frontier of their technological group. These scores are independent of the proximity of their group to the metafrontier. These results are consistent with those of Kompas and Che (2006). They concluded that the more efficient firms are those that also use forward technologies, like rotary or swing-ever dairy shed, and a greater amount of land under irrigation. Likewise, Ozden and Dios-Palomares (2016) applied metafrontier models and found similar results. The more productive firms were in turn more efficient.

In addition, the results also show a high level of scale efficiency (SE), equal for both technological groups. This indicates that, concerning their own technology, the majority of the firms of this economic sector work in their optimal size. Similar results were obtained regarding the dairy cattle to produce milk with scale efficiency values (SE) around 94.7% (Hansson, 2008).

The farms with lowest level of inputs (sheep (n), UAW = unit of agricultural work, fixed capital (€), and working capital (€)) have lowest values of CCR- and BCC-efficiencies. This result coincides with the previous results about dairy farms obtained by Kirner *et al.* (2007). These authors pointed out that the farms with low inputs present low levels of efficiency, due to their great reliance on the agrarian policy.

Table 8 - Indexes of technical efficiency, scale and meta-technological ratio.

	<i>n</i>	<i>CCR (sd)</i>	<i>BCC (sd)</i>	<i>SCALE (sd)</i>
Efficiency by group TE_{jk}^k				
HTG	32	0.83 (0.13)	0.90 (0.12)	0.92 (0.09)
LTG	106	0.70 (0.21)	0.76 (0.19)	0.92 (0.09)
K-S		0.42*	0.37*	0.09
K-W (χ^2)		9.70*	12.47*	0.04
S-Z		4.86*	3.90*	4.9
Metafrontier TE_{jk}				
HTG	32	0.83 (0.13)	0.89 (0.12)	0.93 (0.08)
LTG	106	0.52 (0.17)	0.59 (0.19)	0.88 (0.13)
K-S		0.79*	0.71*	0.17
K-W (χ^2)		54.40*	46.76*	2.42
S-Z		12.90*	12.87*	-0.83
Meta-technological ratio MTR_{jk}				
HTG	32	1.00 (0.00)	0.99 (0.03)	1.00 (0.04)
LTG	106	0.74 (0.09)	0.77 (0.11)	0.96 (0.09)
K-S		0.99*	0.85*	0.63*
K-W (χ^2)		71.83*	56.46*	14.05*
S-Z		14.66*	21.44*	13.34*

HTG: high level technological group, LTG: low level technological group, sd: standard deviation, n = number of farms, K-S: Kolmogorov-Smirnov test, K-W: Kolmogorov-Wallis test, S-Z: Simar-Zelenyuk test, *: P < 0.01.

The estimates of the efficiency concerning the metafrontier show greater differences between the two technological groups than the differences pointed out by the separate and independent frontiers, as it was expected. However, in the scale efficiency, SE, it is observed only small differences between the means of both groups, and their distributions are not significantly different. These metafrontier estimations clearly show for the low technology group (LTG) lower values of the efficiency than the values computed with separate frontiers. In contrast, the estimated levels for the high technological group (HTG) in the metafrontier do not differ too much from the values estimated with separate frontiers. That is because the HTG-frontier is closer to the metafrontier than the LTG-frontier. In fact, in a great proportion, the metafrontier is defined by the HTG-frontier.

The meta-technology ratio takes the value 1 for the HTG. This means that the HTG-frontier of this high technology group practically coincides with the metafrontier. On the other hand, the values 0.74 and 0.77 for the LTG with the models

CCR and BCC, respectively, show the distance between the LTG-frontier and the metafrontier.

Table 9 indicates the number of efficient and inefficient farms for the indexes TE-CCR, TE-BCC and SE, respectively. It is also shown the two approaches, the measures with respect to the separate frontiers and concerning the metafrontier. The results collected in this table also show that the majority of the efficient farms of the LTG are inefficient regarding the metafrontier. However, this estimated distance to the metafrontier is mainly due to the lack of technology, and not truly to a real lack of efficiency. Similar results are reported in dairy cattle in New Zealand, where the agrarian technology is more developed in the south of the island than in the north (Jiang and Sharp, 2015).

The results of our study indicate that the production frontier for the farms of the LTG is far from the metafrontier. Therefore, there is a technological gap in the sector. About this conclusion, different studies propose the implementation of agrarian policies to help with the reduction of this technological gap. These pa-

pers suggest that the available technology must be applied to the local conditions for extending the production frontier of the group (Gatti *et al.*, 2012; Alem *et al.*, 2017; Melo-Becerra and Orozco-Gallo, 2017). To this aim, it would be necessary to increase investment in research and development to implement the new technologies. Also, Jiang and Sharp (2015) dealt with this problem and propose to promote actions of training and formation for the farmers.

Regarding our research, Rivas *et al.* (2015) studied the canonical correlation of technological innovation and performance in the same sample in Castilla-La Mancha. They agree with Dhraief *et al.* (2019) in pointing out the main determinants of the technological gap in these farms. Improvement in technology requires a minimum threshold production structure to ensure profits for the firm. Large companies implement innovation more easily than small ones. Large companies have more sheep, more land and are less dependent on external resources. They also have greater availability of capital. The use of these technologies has an impact on structural costs, but also increases output. Therefore, their impact on unit cost is lower.

Therefore, it is important that companies grow in size. In addition, it is also necessary for small companies to understand the process of technol-

ogy adoption. Change involves managing systems with more complexity, considering a complete view of the process.

Thus, in order to reduce the technology gap, it is essential for companies to receive information, training and coaching. But especially, these companies need financial support and funding. This could prevent the abandonment of young entrepreneurs who are more willing to innovate. To this end, they could benefit from the aid provided by the agricultural policy measures that affect Castilla-La Mancha. The second pillar of the Common Agricultural Policy (CAP) of the European Union contemplates these measures. It is the current Rural Development Policy (EU Regulation No. 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD)), (ref. Official Journal of the European Union, 2013). One of the six priorities of this policy is “transfer of knowledge and innovation”. This priority is articulated in a series of measures that seek to promote innovation and the knowledge base in rural areas (Article 14) thereby improving the competitiveness of all types of agriculture and the viability of farms.

Specifically, the RDP (Rural Development Programme) of Castilla La Mancha 2014–2020 includes among its measures the “M01: Knowl-

Table 9 - Frequency of efficient and inefficient production units.

	<i>n</i>	<i>CCR</i> <i>n (%)</i>	<i>BCC</i> <i>n (%)</i>	<i>SCALE</i> <i>n (%)</i>
Efficiency by group				
HTG	32			
Efficient		6 (18.75)	16 (50.0)	6 (18.75)
Inefficient		26 (81.25)	16 (50.0)	26 (81.25)
LTG	106			
Efficient		13 (12.3)	26 (24.5)	25 (23.6)
Inefficient		93 (87.7)	80 (75.5)	81 (76.4)
Metafrontier				
HTG	32			
Efficient		6 (18.75)	15 (46.9)	6 (18.75)
Inefficient		26 (81.25)	17 (53.1)	26 (81.25)
LTG	106			
Efficient		1 (0.9)	7 (6.6)	14 (13.2)
Inefficient		105 (99.1)	99 (93.4)	92 (86.8)

HTG: high level technological group, LTG: low level technological group, *n* = number of farms.

edge transfer and information actions (art. 14)" (ref. Rural Development Programme European Union, 2015).

Figure 2 draws the Kernel estimation of the density function for the TE-CCR index. It illustrates the results previously indicated. The distribution of the efficiency of the HTG is right-slid with respect to the distribution of the efficiency of the LTG. There is a greater proportion of farms of the HTG group with high level of efficiency.

Figure 3 shows the Kernel estimation of the density function for the TE-BCC index. A considerable proportion of the farms of the LTG group are low of the efficiency level of 0.85. The farms of the HTG group have efficiency levels substantially higher, and a large proportion of these HTG farms have efficiency level greater than 0.6.

The Kernel estimation of the density function for the SE index is drawn in Figure 4. It is observed high values and with a similar distribution for the farms of the groups LTG and HTG.

3.3. Determinants of technical efficiency

Besides the estimation of the efficiency levels, it is necessary a research work looking for the crucial factors that influence the efficiency, in order to solve the problem and improve efficiency.

The estimated truncated regression models obtained following Simar-Wilson (2007) methodology for the TE-CCR, TE-BCC and SE in-

dexes for all the farms are reported in Tables 10, 11 and 12.

The estimated values for the parameters of the variable TG (Technological Group) in the technical efficiency CCR (TE-CCR) efficiency model are significant and positive (Table 10). Then, the HTG group is, in mean, more efficient than the LTG group. This fact confirms the obtained results in the efficiency analyses by group.

This model also presents positive values for the STTI. Thus, the farms with greater values of this index are more efficient. The company organises the production process better throughout the livestock cycle if it has lambing facilities and carries out controlled mating, male effect, flushing and artificial insemination. These technologies make optimal use of feed resources and available labour, due to the reduction of the seasonal effect.

A key determinant of farm performance is feeding. The use of technologies such as unifeed is associated with higher dry matter intake, better regulation of rumen function, and higher milk production. It also reduces the labour required to feed the herd (Bargo *et al.*, 2002; Cabrera *et al.*, 2010). Likewise, organising the milking herd by batches based on their productive level is a practice that enables farmers to serve animals with different nutritional needs, and the strategic use of feed resources.

A successful genetic programme must include the discard of females and males from the herd for voluntary causes. The prevalence

Figure 2 - Kernel estimator of density function for technical efficiency-CCR for high (HTG) and low (LTG) technological level farm groups.

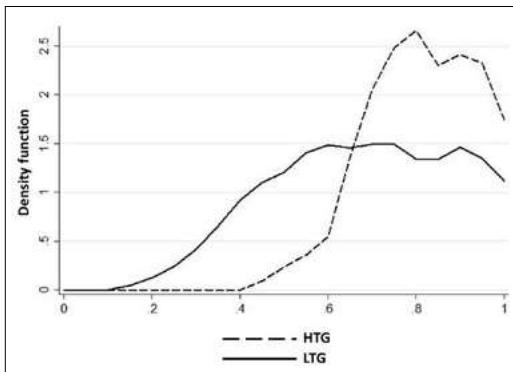


Figure 3 - Kernel estimator of density function for technical efficiency-BCC for high (HTG) and low (LTG) technological level farm groups.

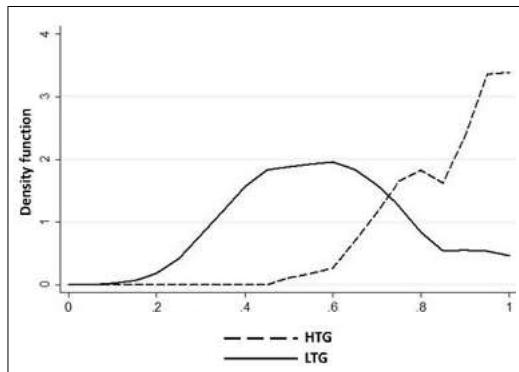
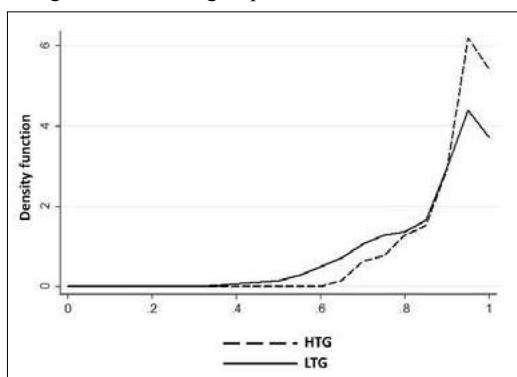


Figure 4 - Kernel estimator of density function for scale efficiency for high (HTG) and low (LTG) technological level farm groups.



of involuntary discards such as disease, injury, death, and infertility can limit the selection process, and negatively affect the productive performance of the farm.

Technologies related to herd health improve the efficiency levels of production systems. They comprise a correct milking routine, e.g. udder drying, cleanliness of facilities, etc. They ensure proper mammary gland health and milk quality, and are positively related to technical efficiency (Hansson *et al.*, 2011; Yilmaz *et al.*, 2020). In addition, vaccination protocols are necessary to avoid animal mortality and morbidity problems.

Concerning the organization and control indexes (OI and CI), Tables 10, 11 and 12 collect the results obtained. They are similar to the above commented results for the TG varia-

ble and STTI index. This means that the firms that pay more attention to these management functions are technically more efficient. In this respect, it is interesting to comment the conclusion of Bahta *et al.* (2015). These authors, in a study of beef cattle in Botswana, indicate that it is needed to promote services to the farmers in order to guarantee the implementation of breeding control methods in the herds, to improve efficiency of the farms.

Regarding the technical efficiency BCC (TE-BCC) (Table 11) the results are similar. There are observed significant differences of 6% between the two groups. TE-BCC efficiency values are used to compare farms of the same or similar size. Therefore, the technological level differences influence the productive level of the two frontiers, but not their TE-BCC efficiency. This last efficiency is higher in the farms where more attention is paid to managerial functions.

It is noticeable the negative and significant estimated coefficient for the variable which shows if the farmers are membership of association. In fact, the associated farms are about 15% less efficient than the others. This is a rare result because the associations are sources of important and useful information for the managerial functions. This result could be related to the fact that the associations promote investment for genetic improvement strategies of livestock, and such strategies could have a negative effect in production, if they are not implemented with a simul-

Table 10 - Models of the determinants of technical efficiency-CCR.

	Coefficient	Standard error	Confidence interval 95%		P>z
By group					
Constant	0.2914	0.0778	0.1462	0.4461	0.000
TG	0.1601	0.0497	0.0644	0.2693	0.001
OI	0.3188	0.0969	0.1359	0.5127	0.001
CI	0.1879	0.0592	0.0702	0.3033	0.002
STTI	0.3861	0.1484	0.0998	0.6758	0.009
Membership of association	-0.2168	0.0512	-0.3207	-0.1210	0.000
Sigma	0.1680	0.0144	0.1353	0.1918	0.000

Wald chi2 = 48.20

Prob > chi2 = 0.000

TG: Technological group, OI: Organisation index, CI: Control index, STTI: Short term technological index.

Table 11 - Models of the determinants of technical efficiency-BCC.

	<i>Coefficient</i>	<i>Standard error</i>	<i>Confidence interval 95%</i>		<i>P>z</i>
By group					
Constant	0.3978	0.0815	0.2386	0.5563	0.000
TG	0.1154	0.0619	0.0028	0.2529	0.062
OI	0.1981	0.0968	0.0106	0.3982	0.041
CI	0.1779	0.0599	0.0625	0.3013	0.003
STTI	0.3158	0.1570	0.0100	0.6297	0.044
Membership of association	-0.1494	0.0500	-0.2548	-0.0532	0.003
Sigma	0.1557	0.0145	0.1244	0.1800	0.000

Wald chi2 = 31.16

Prob > chi2 = 0.000

TG: Technological group, OI: Organisation index, CI: Control index, STTI: Short term technological index.

Table 12 - Models of the determinants of scale efficiency.

	<i>Coefficient</i>	<i>Standard error</i>	<i>Confidence interval 95%</i>		<i>P>z</i>
By group					
Constant	0.2517	0.1979	-0.1438	0.6048	0.203
TG	-0.1108	0.0807	-0.2708	0.0442	0.170
OI	1.1556	0.4288	0.4921	2.1257	0.007
CI	0.0853	0.1062	-0.1100	0.3114	0.422
STTI	0.7666	0.3501	0.1565	1.5532	0.029
Membership of association	-0.1694	0.1083	-0.4126	0.0240	0.118
Sigma	0.1640	0.0334	0.1037	0.2287	0.000

Wald chi2 = 8.72

Prob > chi2 = 0.1208

TG: Technological group, OI: Organisation index, CI: Control index, STTI: Short term technological index.

taneous improvement of the management. Similar results were found by Manevska-Tasevska and Hansson (2011) in their analyses of the key determinants factors in the efficiency of grape production farms. These authors showed that the membership of the farmers had a negative influence in the technical efficiency *TE*. They also conclude that these farmer associations do not fulfil their main objective to be a forum where the producers exchange ideas, share experiences, and work together to achieve better farm performance. In addition, Ozden and Dios-Palomares (2016) applied metafrontier models to olive oil firms in Turkey. They also considered the variable of membership of association, but,

in this case, such variable did not present statistical significance. We also observe in our study that, actually, the associations do not influence to move the managers to start actions to achieve optimal results.

About these results, Siafakas *et al.* (2019) studied the dairy farms in Greece. They concluded that increasing available time spent, especially the farmer's own working hours, in effectively monitoring and managing livestock, and investing more in animal farming, would improve the farms' *TE*. Soliman and Djanibekov (2021) suggested that adopting on-farm management practices could be an option to improve dairy efficiency.

4. Conclusions

This paper investigates the efficiency level in dairy sheep systems in the Protected Designation of Origin (PDO) "Manchego Cheese" ("Denominación de Origen Protegida" (DOP) 'Queso Manchego') in Castilla-La Mancha, Spain, taking into account the heterogeneity related to the technological levels of the farms. Synthetic indexes are designed and computed in order to provide a proper and realistic assessment of the existing technologies.

The long-term technological index, wherein technologies that require considerable investment are included, shows that there is a great heterogeneity. Based on this index, and the partial productivities, two different groups were found. These two groups, with different and contrasting technological levels, are called High Technological Group (HTG) and Low Technological Group (LTG). The HTG has an average value of the LTTI of 0.49, while the average value of this index for the LTG is 0.38. Concerning the value of the Gross Margin by hectare, the LTG achieves, in average, about 72% lower than the HTG does. The former group includes farms with an area around 24% greater than the mean surface.

Efficiency is estimated with the Data Envelopment Analysis (DEA) methodology with metafrontier models considering these two technological groups. The obtained results show that the farms of the HTG are more productive, work with higher technological levels, and report, in average, a value of technical and pure efficiency about 18% greater than the farms of the other group.

If HTG technologies were applied to the farms of the LTG group, a production increase greater than 23% could be obtained. Concerning the scale, however, new technologies could offer only a reduction of the 4% in the average scale-inefficiency value. In addition, the results indicate the influence of the technological group. This fact also advises that the metafrontier approach applied is suitable to estimate efficiency. The analysis of the efficiency with metafrontier models guarantees that inefficiencies are not misleading with technological gap.

Short-term managerial strategies, which are evaluated with the synthetic index STTI (Short

Term Technological Index), influence the efficiency levels of both technological groups. Similarly, farms that pay special attention to managerial functions achieve better efficiency results. However, farmers who are members of associations present lower levels of efficiency than others do. This shows that the associations are not working in an appropriate way, as it could be expected.

The efficiency level of the dairy sheep systems in Castilla-La Mancha could be improved, mainly in the farms with low technological level. Therefore, it could be very interesting to provide to these farms the investment and required means to implement the new technologies. Among them, it could be remarked the application of automatic feeding techniques like feed belt, the use of troughs of cement, dungheaps, silos, silage and hayloft. In addition, flushing and directed breeding are required practises which are not too much applied in the studied farms. One means of implementing these technologies is to increase the size. Finally, a special attention to the managerial functions, mainly organisation and planning is also advisable.

It is very important for entrepreneurs to inform themselves and to apply for the agricultural subsidies currently in force. However, these subsidies do not reach the companies easily. The associations should provide the farmers with the necessary means to obtain these subsidies. On the other hand, we urge the government to improve the agricultural policies that this economic sector needs.

These actions will increase the efficiency of these farms, and, consequently, their resilience and sustainability.

These conclusions can be applied to these Spanish farms and, in addition, to similar farms in the Mediterranean Basin.

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The adoption of water-saving irrigation technologies in the Mitidja plain, Algeria: An econometric analysis

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Abstract

This study aims to identify and analyze the major determinants that affect the adoption choice, rate and intensity of water-saving irrigation technologies (sprinkler and drip irrigation techniques) available in the western part of the irrigated perimeter of Mitidja Plain, Algeria. A sample of 136 farmers (28.75%) was randomly selected and surveyed using a structured questionnaire. Three econometric models were used, namely the Logit, Tobit and Poisson regression models. The main findings of the resulted models indicated that capital constraints (credit access, investment costs and subsidies) along with some human capital aspects (age, educational level) and water extraction cost, are the main determinants expected to influence the WSIT adoption choice, rate and intensity in the study area. These results will help to prioritize the factors that affect adoption decisions and provide insights for improving the crop and water productivity.

Keywords: Water-saving technologies, Water productivity, Irrigated perimeter, West Mitidja, Algeria.

1. Introduction

For all of its consumers, including farmers, residential customers and industrial producers, water is a vital and scarce resource. The agricultural sector in Algeria is by far the largest user of total water¹ and has the most important contribution in the Algerian economy. It accounts about 12.2 percent of the GDP and employs 25 percent of the country's labor force (Bessaoud *et al.*, 2019). Algeria is one of the southern Mediterranean countries having at the Northern part a Mediterranean humid climate, whereas the rest is located in arid and semi-arid

zones. All over the country, average rainfall is 89 mm/year (FAO, 2015). It became a well-established fact that an insufficient irrigation is one of the major constraints of agricultural productivity in Algeria.

Irrigation technologies such as sprinkler or drip irrigation may significantly boost the efficiency of water use in crops production. The adoption of irrigation technologies in agriculture is an important process for both economic and environmental reasons such as increasing farm productivity and saving water resources. Efficient water supply systems, such as drip irrigation, can contribute to increasing crop yield

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¹ Based on FAO (2015).

potential and enhancing crop water and fertilizer use efficiency (Badr *et al.*, 2010). They are techniques that improve efficiency and productive use of inputs. Particularly, the drip irrigation technology has been found to have a significant impact on resource savings, cultivation costs, crop yields and farm profitability (Shrestha & Gopalakrishnan, 1993; Kumar & Palanisami, 2010). The adoption of irrigation technologies is frequently considered as a key to improve the efficiency of water usage in agriculture and reducing the use of scarce inputs (Cason & Uhlaner, 1991), consequently maintaining current output levels. Moreover, such irrigation technologies can increase the overexploitation of groundwater resources. Hence, new irrigation technologies reduce the use of water locally, but the subsidies push towards an extension of the irrigated surface, with negative impacts on the sustainable use of groundwater, more than half the aquifers in Algeria and Morocco, and about one quarter of the aquifers in Tunisia are overexploited (Kuper *et al.*, 2016, Bouarfa *et al.*, 2020).

Policy makers in developing countries have been attempting to promote, by several means, the adoption of new irrigation technologies. In Algeria, the change in irrigation technologies has been supported since 2000 by subsidies between 50% and 60% of the investment amount for drip and sprinkler irrigation (MADR, 2018). The design of these incentives sought to reduce the financing effort required by farmers when adopting new irrigation technologies. It assumed that the farmer's ability to finance investment in water-efficient irrigation equipment is the major constraint to the adoption of modern irrigation technologies. Nevertheless, the area equipped with water-saving equipment has not been able to achieve the objectives set by the government programs through this strategy, which means that the public subsidy alone is not the driving force behind the adoption of water-saving irrigation technologies. Several adoption studies were conducted around the world, although studies on the adoption of drip and sprinkler irrigation techniques have been found to be limited in Algeria (with special refer-

ence to recent few studies such as: Belaidi, 2013; Benmihoub *et al.*, 2016; Akli *et al.*, 2019; Belaidi *et al.*, 2019; Oulmane *et al.*, 2020).

Despite the advantages of Water-Saving Irrigation Technologies (WSIT), as compared to the traditional irrigation systems, and the government's commitment and support to diffuse these technologies, the speed of diffusion is found to be far below expectations. Nevertheless, most of the irrigated area in Algeria remains irrigated with the traditional gravity technique. For example, in 2018, the area equipped with drip irrigation represents less than 25% of the total irrigated agricultural area (1.33 million hectares).² Gravity technique is gradually giving way to irrigation by pressurized systems (sprinkler and drip irrigation techniques) which has indeed increased from 21% in 2000 to 42%, of which 23% for sprinkler and 19% for drip irrigation in 2012, and then to 49% in 2014, and 43.07, 33.42 and 23.50 percent for gravity, sprinkler and drip irrigation respectively (FAO, 2015; MADR, 2018). Therefore, the present paper has addressed the following important issues: (*i*) what factors limit or enhance the adoption of water-saving irrigation technologies? (*ii*) what factors influence the intensity (area under WSIT) of adoption of water-saving irrigation technologies? and (*iii*) what policy actions must be taken to speed up the adoption of water-saving irrigation technologies?

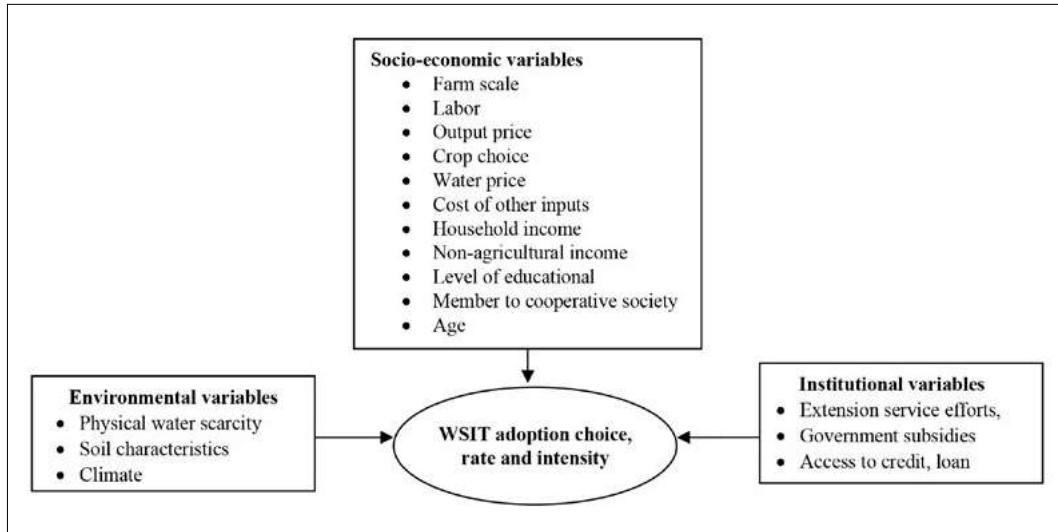
The paper is organized as follows: Section 2 presents the conceptual framework and a brief review of the literature on the adoption of WSIT. Section 3 explores the research methodology (data, variables and modeling procedures). Section 4 presents the main results with discussion. Section 5 concludes

2. Adoption of water saving irrigation technology: conceptual framework and literature review

Different factors and their relationships influence the adoption decisions of various technologies across space and time (Arega, 2009). These may include credit, land and labor constraints,

² According to MADR (2018) statistics.

Figure 1 - Conceptual framework for the determinants of WSIT.



risk aversion coupled with uncertainty about the impact on yields and prices of new technologies, restricted knowledge, lack of markets for farmers' produce, and tenure arrangements (Feder *et al.*, 1985). Other adoption determinants include education, experience and other socioeconomic characteristics along with structural characteristics of the farm such as soil quality and climate. Different studies have been conducted to find out the direction and the magnitude of the influence of different factors on farmers' adoption decision of agricultural technologies (Feder *et al.*, 1985; Feder & Umali, 1993; Sunding & Zilberman, 2001; van Oorschot *et al.*, 2018). Although some factors may have general applicability, it is not usual to develop a universal conceptual model that captures the process of technology adoption in all environments. The dynamic nature of the factors and the distinctive nature of socio-economic environment make it difficult to generalize about the causal relationship between determining factors and technology adoption.

The adoption of agricultural innovations results from a complex process characterized by the interdependence of several factors related not only to the availability of the innovation, its accessibility and its economic potential, but also to the farm-specific characteristics and its socio-economic, technical and institutional en-

vironment (Namegabe, 2006). Irrigation technologies are commonly divided into two groups in most previous studies: conventional irrigation, such as floods, border, and furrow irrigation, and modern irrigation, such as sprinkler and drip irrigation techniques. The variables used within the framework of our analysis are grouped according to three categories of factors: environmental, institutional, and socio-economic variables can be classified as the major factors influencing farmers' choice of water-saving technologies. Environmental variables affecting a WSIT choice include physical water scarcity, soil characteristics, and climate. Institutional variables include agricultural extension efforts, government subsidies or financing for the adoption of new technology, and demonstration projects (Wang, 2008). Socio-economic variables analyzed in previous studies include farm scale, output price, crop choice, water price, cost of other inputs, household income, non-agricultural income, and the educational level. The conceptual framework is shown in Figure 1.

As explained above, the decision to adopt an irrigation technology depends on a variety of factors including farm household characteristics, characteristics of the technology proposed, perception and the risk behavior of the farmer. In this study, we hypothesized that the most important

factors affecting a WSIT adoption at farm level are as follows: Farmers' use of an irrigation technology is considered as a dependent variable. The major explanatory variables that are expected to affect farmer decision to adopt a WSIT are considered based on the empirical literature in many contexts. The previous empirical studies showed that numerous factors related to household characteristics, physical factors and socio-economic conditions are expected to affect the adoption of different irrigation technologies. The farmers' decision to adopt a WSIT was hypothesized to be influenced by a number of variables. In order to verify the existence of an effect of the three categories of factors on the adoption of WSIT, we propose the following hypotheses.

Farm size and human resources are the main variables that have an empirical relationship with farmers' decisions about whether or not to implement technology (Caswell, 1991; Dinar *et al.*, 1992). In empirical studies, age, as a proxy for the experience, is one of the characteristics of farmers frequently studied. It is not possible to predetermine the path of the influence of this variable, but several empirical studies have found a negative relation between the technology adoption and the decision makers' age. Many studies have shown that variables of human resources, such as age and education level are positively associated with the adoption of irrigation technologies (Koundouri *et al.*, 2006; Genius *et al.*, 2014; Olen *et al.*, 2015; Hunecke *et al.*, 2017). For the WSIT adoption, the level of farmers' education is expected to play a crucial role. Trained farmers are more aware of (and able to learn) new technologies that are useful for their agricultural practices (Cason & Uhlaner, 1991). Producer characteristics, such as age and education, are also associated to decisions on irrigation techniques adoption (Koundouri *et al.*, 2006). The study of Schuck *et al.* (2005) showed a positive relationship between the achievement of education and the adoption by Colorado farmers of sprinkler irrigation technology. Moreover, Zhou *et al.* (2008) also demonstrated that the level of education has an impact on the adoption of water-efficient technology by Chinese farmers, and Karami (2006) showed that a positive relationship exists between education and

the adoption of sprinkler irrigation technique by Iranian farmers. Education is often argued as a variable that influences rates of adoption (Alcon *et al.*, 2011). Human capital variables, such as education and years of experience, are indirect indicators of a farmer's ability to acquire and use information on new agricultural production technologies effectively. The higher is the age of a farmer; the lower is the probability to adopt new technology. Although older farmers have relatively richer experience of the social and physical environments, thus they are reluctant to new technologies than young farmers. Furthermore, another consideration could be raised which is the risk aversion that characterizes aged population with respect to younger one. Therefore, it is hypothesized that age of the farmer and WSIT adoption to have negative relationship. Therefore, it is expected that young farmers and high educational level will have significant effects on farmers' WSIT adoption.

Another major factor considered in adoption-diffusion research is farm size which affects adoption in several ways. Other factors interlinked with farm size are adoption costs, risk preferences, human capital, credit constraints, labor requirements, and tenure arrangement. Farm size is one of the key explanatory factors investigated by many empirical adoption studies. Although, theory provides few indications of the relationship between farm size and investment in new technologies. The theoretical literature suggests that large fixed costs reduce the tendency to adopt or slow down the rate of adoption by smallholder farmers. Farm size can have positive, negative or neutral effects on the adoption decisions of farmers. These effects depend on type and characteristics of new technology and the institutional settings in which the new technology is introduced. According to Richefort (2008), the relationship between farm size and adoption depends on fixed costs, risk preferences, knowledge, budget constraints, work time requirements, etc. The effects of farm size on the adoption are not always clear. Therefore, the effect seems ambiguous and depends on other factors. However, it can also be expected that farmers with small plots of land can be more interested to adopt drip irrigation to compensate

their disadvantaged position with increased productivity using drip-irrigation technology. Nevertheless, empirical studies often show that large farms are more likely to adopt new technologies than small farms (Green *et al.*, 1996; Shrestha & Gopalakrishnan, 1993; Marra & Carlson, 1987; Feder & O'Mara, 1981; Just & Zilberman, 1983). Hence, farm size is hypothesized to have positive relationship with WSIT adoption because households with larger farmland size can allot small plots for trial than those having small plot. On the other hand, large scale is an indication for wealth status of farmers and therefore it is expected that better-off farmers are likely to take risk than poor farmers.

The on-farm diversification is one the major factors studied in the empirical literature on agricultural technologies adoption. For the purposes of WSIT adoption, the effect of on-farm diversification may be harder to identify. A farmer with diversified crop portfolio may be more likely to adopt a risk-reducing technology. Likewise, a risk-averse farmer may both be better diversified and be more likely to adopt a risk-reducing technology (de Sousa *et al.*, 2017; Li *et al.*, 2020; Dzanku, 2018). If the new technology reduces yield risk, the probability of adoption will increase (Just & Zilberman, 1983). Irrigation equipment reduces dependence on variable rainfall, which reduces risk. Empirical results from Koundouri *et al.* (2006); Torkamani & Shahri (2008) and Salazar & Rand (2016) conclude that there is a positive and significant effect of production risk on adoption decisions, arguing that new irrigation technology is an input that reduces production risk. Therefore, it is hypothesized that on-farm diversification affects positively the WSIT adoption.

Technological characteristics, particularly installation costs, are also studied and are considered relevant to producers' choice of available technologies (Moreno & Sunding, 2005). Therefore, the cost of irrigation technology plays a significant role in farmers' ability to invest in irrigation equipment (Dinar & Yaron, 1992). Some studies show that a subsidy from an irrigation district can have an impact on adoption (Feder & Umali, 1993; Tiwari & Dinar, 2002). Government financial assistance is a policy instrument that the

government uses as an incentive to adopt new agricultural technologies. Cost sharing between farmers and the government effectively reduces the price of irrigation technology and should lead to higher levels of use than without cost sharing. This relationship could be seen as tautological in the sense that cost sharing is conditioned by the use of irrigation technology. A conclusion that cost-sharing leads to a greater adoption effort, *ceteris paribus*, would confirm the expected response to lower prices. Therefore, it is expected that access to government subsidies will have a significant effect on WSIT adoption.

Another consideration discussed in a variety of adoption studies is the availability of labor. The number of family workers is an important production factor in family farming (Bainville, 2000; Hermelin & Lagandré, 2009). Therefore, a farm with a large workforce is more likely to introduce new technology. It is also argued that the availability of labor affects decisions in agriculture to implement technology (Feder *et al.*, 1985). A farm with a large workforce is therefore more likely to introduce new technology. The direction of the labor effect on adoption decisions depends on the characteristics of the technology and the labor requirements of the technology. Some new agricultural technologies are labor-saving, while others may require more work compared to old technology. The WSIT is known for its labor reducing advantage in irrigation, thus it is more suitable for families with less labor force than households having more labor. Households with less labor are motivated to adopt WSIT to compensate their scarce labor. It is therefore hypothesized that farms with less labor are more likely to adopt the WSIT technology.

The degree of farmers' involvement in professional organizations acting in the agricultural sector can influence farmers' decisions. Agricultural cooperatives, extension clubs and other agricultural interest groups can raise awareness and influence their members to adopt new irrigation technologies. Based on much of the available theoretical evidence, farmers affiliated with agricultural cooperatives and extension clubs may be more aware of adoption and may therefore be more likely to adopt irrigation technologies. Participation in a cooperative allows farmers

to join knowledge flow social networks, which tend to improve the adoption of new agricultural technologies (Bandiera & Rasul, 2006). Membership of farmers to cooperatives enables them to have broader access to information about new technologies. Moreover, cooperatives may have the voice to get assistance from different sources to encourage their members adopt new technologies. Thus, it is hypothesized that farmers who are members in professional organization are more likely to adopt WSIT than non-members.

If we consider the extraction cost of water as an economic determinant in the adoption of irrigation technologies, we can see that in all regions where the extraction cost of water is higher, the diffusion of resource-efficient technologies has been much faster than in regions where farmers have to pay less for water. This is widely corroborated with a high degree of consensus in the literature (Caswell & Zilberman, 1985, 1986; Dinar & Yaron, 1990; Caswell *et al.*, 1990; Negri & Brooks, 1990; Schaible *et al.*, 1991; Shah *et al.*, 1995; Green *et al.*, 1996; Green & Sunding, 1997; Schuck & Green, 2001; Carey & Zilberman, 2002; Foltz, 2003). In the case of groundwater pumping, the use of drip irrigation may increase over time as aquifers levels decline and water extraction cost rise (Shah *et al.*, 1995). Caswell & Zilberman (1985) showed that farmers using groundwater were more likely to adopt sprinkler and drip technologies than those using surface water. Farms with access to surface water sources are more likely to opt for a gravity irrigation technique. The authors suggest that this result is not surprising since surface water is supplied by water districts that, in most cases, have adapted their distribution system to traditional technology. For wells, it is the depth and number of wells that are the most decisive factor in the cost of water supply. The depth and number determine the

initial investment in drilling and pumping equipment, but also the energy costs. Accordingly, the following hypothesis has been derived: Using groundwater will have a significant effect on farmers' adoption of WSIT, and the likelihood of adoption increased with number of drilled wells.

3. Research methodology

3.1. Data and variables

To study the behavior of farmers regarding their adoption of a WSIT, as well as the factors that influenced this behavior, a well-structured questionnaire was designed to interview the heads or representatives of the collective EAC, EAI and private farms.³ Using a method of stratified random sampling, we divided the ONID⁴ farms database of scheme into three different strata with respect to land ownership type, and then a random selection of farms is proceeded for each stratum. This ensured a sufficient number of observations for each landownership group. Therefore, 136 farms were selected from the West Mitidja irrigation scheme, and the size of the sample selected from each group is shown in Table 1.

Data about the adoption of irrigation techniques are collected as the focus of study. Besides, farm and farmers' characteristics are collected. In addition, other information such as the number of drilled wells, production system, and policy subsidies also recorded. The data used in this study were collected from field surveys via face-to-face interviews in Mitidja Plain (Algeria) between January and November 2020. The agricultural domains of Mitidja Plains (T1), started functioning in 1989 with an area of 8 600 ha (of which 7 872 ha are irrigable), is divided into three sectors, South sector with 2 297 ha, East sector with 2 741 ha, and West sector with

³ In 1987, socialist agricultural domains were divided into two types of agricultural units: State-owned collective farms (EACs) with at least three members and State-owned individual farms (EAIs) with infrastructure rights (equipment, buildings, livestock, orchards, citrus, etc.) except for land (Decree No. 87-19 of 8/12/1987). The State restituted the Algerian Revolution's nationalized land to its former owners in 1990 (under decree 90-25 of 18/11/1990). Under the 2010 Land Law, the perpetual use of public land, which was granted to beneficiaries under the 1987 Decree, has been transformed into a 40-year renewable concession. (in: *Journal Officiel de la République Algérienne*, no. 46 of 18/08/2010, no. 10-03 of 15/08/2010).

⁴ For National Office of Irrigation and Drainage.

Table 1 - Selected sample of irrigation farms in the West Mitidja irrigation scheme.

Farm status	Total farms	Percentage (%)	Sample size	Sample percentage	Stratum percentage
EAC	376	79.49	114	83.82	30.32
EAI	26	5.50	11	8.09	42.30
Private farms	70	14.80	11	8.09	15.71
Pilot farms	1	0.21	0.00	0.00	0.00
Total	473	100.00	136	100.00	28.75

Table 2 - Definition and descriptive statistics of variables of the adoption model.

Variables	Data type	Definition	Mean	S.D.
WSIT adoption	Binary	Farmer's adoption of water-saving irrigation technologies, 1 if adopted, 0 for non-adoption	0.471	0.501
WSIT rate	Censored data	Ratio of irrigated area under WSIT to operated land area and expressed as a percentage	0.291	0.370
WSIT intensity	Count data	Irrigated area under WSIT in hectares	3.279	4.578
Farm size	Continuous	Total operated farmland in hectares	22.913	15.374
On-farm diversification	Continuous	Herfindahl Index for on-farm diversification	0.040	0.074
Labor force	Continuous	The number of on-farm labor workers	10.161	3.519
Credit access	Dummy	1 if farmer has an access to credit, 0 for no access.	0.272	0.445
Investment	Dummy	1 if the cost of investment is a reason for not investing or equipping the whole farm area under WSIT, 0 otherwise	0.478	0.499
Age	Continuous	Age of the farmer in years	62.323	10.090
Education level	Categorical	Level of education of the farmer measured on a scale where 0 for none; 1 for Primary; 2 for Middle; 3 for Lyceum; 4 for University	0.786	1.104
Information source	Dummy	0 if the information is from other farmers, 1 if the information is from extension services such as the Agricultural Services Department, agricultural Chamber, the irrigation agency ONID and technical institutes or other private sources such as private agricultural consulting firms, inputs suppliers.	0.279	0.450
Organization membership	Dummy	Dummy variable for membership of Water User Association, Farmer Cooperatives, The National Union of Algerian Farmers: 1 for members, 0 for non-members	0.117	0.323
Public subsidies	Dummy	1 if the farmer has an access to public subsidies of irrigation technology; 0 otherwise	0.323	0.469
Drilled wells ratio	Continuous	Ratio between the number of drilled wells and the surface of the farm	0.0814	0.0778

2 889 ha (Messahel & Benhafid, 2007). The study was conducted in the West Mitidja irrigated perimeter, located in the Blida Province. The irrigated area in Blida Province is 32 280 ha whose irrigation systems are distributed as follows 76.52, 11.04 and 12.44 percent for gravity, sprinkler and drip respectively (MADR, 2018). The irrigation water in the West Mitidja scheme (T1) is supplied from the Bouroumi Dam and is still an eminently agricultural zone. Most agricultural land in the West Mitidja perimeter belongs to the State domain but is cultivated by farmers holding land-use rights in the form of collective farms and individual farms. Many crop productions are practiced in the perimeter, where farmers earn their income from those farm products. The dominant types of crops cultivated in the region are cereals, citrus, orchards (peach, apricot, apple and pear), vegetable and greenhouse crops.

The data are considered to be representative of the overall rural population of the entire study region. The definitions and descriptive statistics of variables used in the adoption modeling are presented in Table 2. On average, farmers were 62.32 years old, 54.41% of them were illiterate, and have approximately ten workers. The mean farm size was 22.91 ha. The mean number of drilled wells was 1.15. Only 11.76% of farmers have been members of agricultural organizations, 27.2% with credit access and 19.87% had access to policy subsidies.

3.2. Empirical modeling procedures

The econometric models for the WSIT adoption decision can be specified as: $y_i^* = \beta X + \varepsilon_i$. First, the study uses a binary variable for WSIT adoption, as a common measure in the empirical literature. In practice y^* is not observed, but is estimated through the discrete variable Y_i such that:

$$\begin{aligned} Y_i &= 1 \text{ if } y_i^* \geq 0 \\ Y_i &= 0 \text{ if } y_i^* < 0 \end{aligned}$$

where ε_i is assumed to be distributed according to a logistic distribution (with mean of zero and standard deviation of $2\pi/\sqrt{3}$). This assumption allows for the use of Logit estimation in the

econometric model. Therefore, the general Logit model for the WSIT adoption decision is:

$$Y_i = \sum_k \beta_k X_{ki} + \varepsilon_i$$

where Y_i is the indirect utility difference and is underlying latent variable that indexes the adoption choice of irrigation technology on a given parcel; X_k is the vector of explanatory variables; β is a column vector of parameters to be estimated and the stochastic error term ε_i is distributed logistically with mean zero and variance normalized to $2\pi/\sqrt{3}$. The variable Y_i is not observed but the adoption decision is, such that:

$$ADOPT_i = 1 \quad si \quad \sum_k \beta_k X_{ki} + \varepsilon_i \geq 0$$

$$\text{and } ADOPT_i = 0 \quad si \quad \sum_k \beta_k X_{ki} + \varepsilon_i < 0$$

Another dependent variable is used to analyze the WSIT adoption. It is a censored variable reflecting the farmland area fraction under WSIT, i.e. adoption rate. Its values are comprised between 0 and 1. Accordingly, the suitable econometric model is the Tobit regression (Gouriéroux, 2000; Greene, 2003). The Tobit model is specified as follows:

$$E(Y_i | \mathbf{X}) = \begin{cases} Y_i^* & \text{if } 0 < Y_i^* < 1 \\ 0 & \text{if } Y_i^* \leq 0 \\ 1 & \text{if } Y_i^* \geq 1 \end{cases}$$

For both Logit and Tobit models, the marginal effects (M.E.) at means are computed and reported.

The factors affecting the intensity of WSIT use are considered empirically by a third dependent variable, namely: the number of hectares under WSIT in the farmland, which is counted data in nature. In this case, the Poisson regression is appropriate for analyzing such data.

Using the quasi-maximum probability method, the Poisson regression model can be estimated because it overcomes the problems associated with over-dispersion, which results in grossly deflated standard errors and inflated t -statistics in the output, and is consistent under this condition (Cameron & Trivedi, 2005; Wooldridge, 2015). Therefore, Poisson maximum likelihood

estimation is used to estimate the regression coefficients, with the following specification:

$$E(Y=y) = \frac{e^{(-\mu)\mu^y}}{y}$$

where y is number of hectares under WSIT, μ is the intensity or rate parameter. The distribution is stated as $p(\mu)$. The distribution of the Poisson regression model assumes equi-dispersion, meaning that the mean and variance of the outcome are equal for a given covariate pattern, i.e. mean $E(Y) = \mu$ and variance $V(Y) = \mu$ (Hardin & Hilbe, 2015; Wang & Famoye, 1997). The standard approach of the Poisson regression is to use the exponential mean parameterization:

$$\mu_i = e^{x\beta}$$

where μ_i is the predicted number of hectares under WSIT, X is a vector of explanatory variables and β is a vector of unknown coefficients to be estimated. For the Poisson regression, the incidence rate ratios (I.R.R.) are computed and reported. Many adoption studies have employed Poisson models in determining intensity of adoption of technologies. For instance, Azumah *et al.* (2017) and Mensah-Bonsu *et al.* (2017) used Poisson to explain adoption intensity of climate change coping strategies and land and water management practices respectively; Jordán & Speelman (2020) used Poisson to explain adoption of irrigation technologies and the underlying diversity in terms of intensity of adoption; Mahama *et al.* (2020) also employed Poisson to estimate the determinants of adoption intensity of sustainable soybean production technologies.

Some robustness parameters should be considered for models assessment.⁵ The study uses some relevant criteria for each model, namely Pseudo-R², adjusted R², log-likelihood, and likelihood ratio tests and F-statistic for overall significance.

4. Results and discussion

As preliminary analysis, the study of the WSIT adoption suggests a descriptive presentation of the use of water-saving technologies in

the selected sample (Table 3). In the sample of 136 surveyed farmers, only 64 use WSIT, which represents about 47%. Indeed, in such choice studies, it is preferable that the favorable and unfavorable responses to a given criterion are in the proportions of 50%, but this only affects the affinity of the results and hardly intervenes in the global significance of variables estimated in the modeling results. The adoption of irrigation in Algeria is considerably encouraged by the government, which adopters benefit from subsidies that can go up to 60% of the equipment investment. However, constraints may limit access to this subsidy, such as land tenure. In the selected sample, 46.8% of the WSIT adopters received the subsidy.

The estimation results for WSIT adoption determinants of through Logit and Tobit models are shown in Table 5, whereas the OLS and Poisson regression results are shown in Table 6. The OLS use is just by way of comparison. The first column is for the explanatory variables. The regressions results are displayed in the remained columns. The chi-squared test statistic was significant at the 1% level for three models, implying joint significance of the variables. The correlation coefficient values have relatively high values for a multivariate analysis focused on cross-sectional data analysis. Notably, many of the 10 selected explanatory variables were statistically significant in the different models. Therefore, the models resulted are effective and explain appropriately the farmers' WSIT adoption phenomenon.

In order to test the existence of multi-collinearity, both continuous and discrete explanatory variables were checked using a Variance Inflation Factor (VIF). If the largest VIF is greater than 10 (or the tolerance is below 0.1) then this indicates a serious problem of multicollinearity (Bowerman & O'Connell, 1990). For the case of our study, the results of the tolerance and VIF tests (Table 4) indicate that the lowest observed value for tolerance is 0.131 and the highest value for VIF is 7.62. Furthermore, the correlation matrix results showed that there was no problem of strong association among the selected explana-

⁵ The three models are estimated by using STATA 14.0 software.

Table 3 - Farmers' status of WSIT adoption.

<i>Variables</i>	<i>WSIT adopters</i>	<i>WSIT non-adopters</i>
Number of farmers (%)	64 (47%)	72 (53%)
WSIT area in percentage	61.87%	0
Mean WSIT area in ha	7 ha	0
Farm size (mean)	19.35 ha	21.55 ha
Labor force by farm	9.67 workers/farm	10.45 workers/farm
Land area per worker	2.02	2.06
The percentage of farmers that accessed a credit on the total number of farmers of this group	53.12%	4.16%
The percentage of farmers who reported that the capital cost of investment is a reason for not investing or equipping the whole farm area under WSIT on the total number of farmers of this group	29.68%	63.88%
Age (mean)	55 years	69 years
Education level (median)	2 i.e. middle school	0 i.e. illiterate
The percentage of farmers are members in agricultural organizations on the total number of farmers of this group.	17.18%	6.94%
The percentage of farmers by sources of information on the total number of farmers of this group.	46.90 % i.e from extension services	88.90 % i.e. from other farmers
The percentage of farmers that received a subsidy on the total number of farmers of this group	46.8%	19.45 %
The total number of drilled wells of this group	78	79

Table 4 - Variance Inflation Factor (VIF) for continuous explanatory variables.

<i>Variables</i>	<i>Variance Inflation Factor (VIF)</i>	<i>Tolerance</i>
Farm size	7.62	0.131
On-farm diversification	4.50	0.222
Labor force	2.30	0.434
Credit access	1.90	0.526
Investment	1.41	0.710
Farmers' age	2.03	0.491
Education level	2.11	0.474
Information sources	2.24	0.446
Organization membership	1.30	0.770
Public subsidies	1.73	0.578
Drilled wells ratio	1.56	0.642

tory variables (Appendix Table 1). The data have no serious problem of multicollinearity based on the tests outcomes.

Results from Tables 5 and 6 show that the explanatory variables are relevant in explaining the adoption decision. From the z-test statistics of

the coefficient estimates in the models, it seems that generally, the selected farm structural characteristics, capital constraints, human capital aspects and extraction cost of water are significant considerations in the WSIT adoption choice in the study region.

The farm size, reflecting the wealth status of the farmers, is expected to influence WSIT adoption positively as WSIT involves large initial investment. This study shows that the farm size has negative relationships with the probability on WSIT adoption choice but is not statistically significant. The reason may have to do with the fact that cropping systems are heterogeneous in the study area. Thus, large or small farms are equally likely to be candidates for the choice of a WSIT.

Crop diversification is a measurement of the number of different crops under cultivation. To measure crop diversification, the Herfindahl-Hirschman index (HHI)⁶ was used as a measure of diversification. It is possible that the decision to use saving technology is influenced by a farmer's decision to diversify and vice versa. The Herfindahl index is a variable included to measure farmers' risk exposure. It measures the amount of farmer diversification among crops as measured in cropping area. This Herfindahl index takes a maximum value of 1 for mono-cropping and decreases for better diversified farms. In other words, the measure of crop diversification has a value of 1 when there is a complete on-farm specialization and approaches 0 as the number of crops produced by the farmer gets larger. A low Herfindahl index indicates a diversified and less risky portfolio of crops. Farmers with higher levels of diversification would tend to be more risk-averse farmers. The results of Logit, Tobit and Poisson regression show that the crop diversification positively affected the adoption and negatively the intensity and rate of WSIT without statistical significance. The insignificant coefficients on "Herfindahl Index," used as a measure of on-farm diversification, provide little evidence to support the idea that farmers would adopt the technology to reduce risk.

Labor force affects WSIT intensity adoption positively and significantly at 1% level. Farms with larger labor force are more likely to adopt on a larger part of their irrigated area under

WSIT. The I.R.R ratio indicates that, holding all other independent variables constant, the I.R.R of adopting saving irrigation technologies increases by a factor of 1.105 as the number of farm workers increases by one unit. The finding could be attributed to the fact that the sprinkler systems require significantly more labor than surface irrigation methods because the sprinkler lines must be moved at regular intervals to irrigate large fields and drip irrigation requires significant human capital for design and management. Farm workers are required to supervise the operation of the sprinklers, drippers and the booster pump. It should be noted that in study area, in general the technique of fertilization under WSIT is not well-known. It is therefore at an early stage, although the potential for use. The fact that farmers often manually fertilize their crops, WSIT is mainly used to convey water i.e. these farmers did not use all fertilizers under WSIT, which would imply a low impact on the economies of the irrigation labor. However, this result revealed that availability of labor would increase the intensity of adoption.

Based on estimation results, the coefficient of credit access is significantly positive in the models, implying that there is a positive relationship between credit access and the adoption choice, rate and intensity of a WSIT. In other words, as shown by Logit model results, if farmers had access to credit, the possibility that they will adopt WSIT increases by 83.1%. The marginal effect of Tobit model indicated that compared to other farmers, the likelihood of WSIT adoption rate by farmers with access to credit for irrigation technologies increased by 58.7%. From Poisson model results, as compared to the sample farmer who has not accessed to credit, the farmer who has access was higher, at a rate of 1.834 times, to increase their area with WSIT, *ceteris paribus*. Based on these results, it can be concluded that an attenuation of the financial constraints facing farmers may help to encourage the adoption of WSIT.

⁶ This concentration ratio sums the squared shares of each crop in total area operated and can be expressed as follows: $HHI = \sum_{i=1}^N (p_i/P)^2$ where p_i is the proportion of cultivated land area devoted to crop i , P is the area's total operated, N is the total number of crops. This index was chosen, among many other concentration indices, to measure on-farm diversification because of its simplicity of implementation, its adaptability to different types of crop diversification and because it possesses most of the characteristics of a good concentration index.

Table 5 - Estimation results for WSIT adoption determinants through Logit and Tobit models.

Explanatory variables	Logit Model		Tobit Model	
	Coef.	M.E.	Coef.	M.E.
Cons.	22.602 (4.01)***	---	3.918 (6.12)***	---
Farm size	-0.042 (-0.62)	-0.010 (-0.62)	-0.006 (-0.05)	-0.006 (-0.05)
On-farm diversification	12.79 (1.51)	3.164 (1.50)	-0.111 (-0.05)	-0.111 (-0.05)
Labor force	-0.013 (-0.10)	0.003 (0.1)	-0.023 (-0.92)	-0.023 (-0.92)
Credit access	5.643 (3.77)***	0.831 (10.39)***	0.587 (3.41)***	0.587 (3.41)***
Investment	-2.485 (-3.16)***	-0.544 (-4.07)***	-0.365 (-2.73)***	-0.365 (-2.73)***
Farmers' age	-0.345 (-4.17)***	-0.085 (-4.22)***	-0.055 (-5.85)***	-0.055 (-5.85)***
Information sources	-2.519 (-1.71)*	-0.504 (-2.55)*	-0.071 (-0.38)	-0.071 (-0.38)
Organization membership	-2.292 (-1.63)	-0.417 (-2.53)	-0.104 (-0.49)	-0.104 (-0.49)
Public subsidies	-0.906 (-0.90)	-0.215 (-0.95)	-0.188 (-1.19)*	-0.188 (-1.19)*
Drilled wells ratio	-2.27 (-0.43)***	0.562 (0.43)***	-1.747 (-1.67)*	1.747 (1.67)*
Number of obs.	136		136	
Pseudo-R ²	0.591		0.449	
Adjusted R ²	0.474		/	
Log likelihood	-38.40		-72.52	
LR chi ² (df)	111.24***		118.21***	
Cases correctly predicted	89.0%		/	

Note: Values in parentheses represent z-ratio for M.E. and Logit coefficient estimates, t-ratio for Tobit coefficient estimates. Asterisks *, ** and *** are significant at 10%, 5%, 1% level respectively.

Moreover, the results confirmed that the investment costs⁷ significantly decreased the likelihood of WSIT adoption choice, rate and intensity. Investment costs influenced negatively the farmers' adoption of a WSIT. The coefficient for the judgment from the farmer about the fact that the investment cost is a reason for not investing was significant and negative for the Logit, Tobit and Poisson models estimated at the level 1%, sug-

gesting that farmers who have judgment of the high costs were less likely to adopt WSIT. Results of Logit model show that the probability of WSIT adoption was 54.4% lower when the cost increased by one unit. Tobit model also shows that the judgment of the high cost of adoption decreases the probability of the adoption rate by 36.5%. Finally, Poisson regression results demonstrate that area installed by WSIT was 51% lower when

⁷ According to MADR (2018) statistics: The investment cost of one hectare of drip irrigation is estimated at 4 020.40 USD for open field vegetable crops, 3 885.34 USD for greenhouse and 1 740.79 USD for orchards or citrus. Screen and disc filtration costs 531.19 USD. A geomembrane basin with a capacity of 1 500 m³ costs 7 439.61 USD. Rotary drilling well costs 148.79 USD by linear meter. The cost of investment of one hectare for vegetable crops in the integral sprinkler cover system costs 5 837.20 USD.

Table 6 - Estimation results for WSIT adoption determinants through OLS and Poisson models.

Explanatory variables	OLS Model		Poisson Model	
	Coef.	M.E.	Coef.	I.R.R.
Cons.	5.087 (1.78)*	---	3.015 (5.85)***	---
On-farm diversification	-2.398 (-0.56)	-2.398 (-0.56)	-0.181 (-0.18)	0.834 (-0.18)
<i>Labor force</i>	0.289 (2.96)***	0.289 (2.96)***	0.100 (5.89)***	1.105 (5.89)***
Credit access	1.212 (1.42)	1.212 (1.42)	0.606 (4.88)***	1.834 (4.88)***
Investment	-0.938 (-1.43)	-0.938 (-1.43)	-0.671 (-4.51)***	0.510 (-4.51)***
Farmers' age	-0.090 (-2.32)**	-0.090 (-2.32)**	-0.051 (-6.79)***	0.950 (-6.79)***
Education level	2.314 (6.37)***	2.314 (6.37)***	0.413 (8.86)***	1.512 (8.86)***
Information sources	-0.299 (-0.33)	-0.299 (-0.33)	-0.311 (-2.21)**	0.732 (-2.21)**
Organization membership	-0.947 (-0.97)	-0.947 (-0.97)	-0.356 (-2.34)**	0.700 (-2.34)**
Public subsidies	-0.825 (-1.07)	-0.825 (-1.07)	-0.315 (-2.55)**	0.729 (-2.55)**
Drilled wells ratio	-3.317 (-0.82)	-3.317 (-0.82)	-1.689 (-2.22)**	1.184 (-2.22)**
Number of obs.	136		136	
F	14.88***		/	
Pseudo R ²	/		0.410	
Adjusted R ²	0.506		0.375	
Log likelihood	-346.71		-315.70	
LR chi ² (df)	/		438.74***	

Note: Values in parentheses represent z-ratio for M.E. and I.R.R for OLS and Poisson coefficient estimates. Asterisks * , ** and *** are significant at 10%, 5%, 1% level respectively.

the cost increased by one unit. It means high costs are a truly key barrier of adoption with respect to capital input. This result implies that it is necessary to reduce the cost of the initial investment of a farmer for the adoption of WSIT to encourage effectively the promotion and the implementation of irrigation technologies.

The farmers' age significantly influenced the WSIT adoption choice, rate and intensity at 1% significance level and influences the adoption negatively, keeping other variables constant. As expected, older farmers had a lower probability of adoption of a WSIT. In terms of marginal effect, a unit increase in farmers' age resulted in a 8.5 % decline in the probability of WSIT adop-

tion. Tobit model also shows that farmers' age decreases the probability of the adoption rate by 5.5%. In terms of WSIT use intensity, keeping other variables constant, the I.R.R. of this variable indicates that if the farmers' age increased by 1 year, the intensity of the number of hectares used by the farm would decrease by a factor of 0.95. This result could be explained by the fact that age is a factor of risk aversion, and reduces the choice of adoption of new technologies. It is possible that young farmers are more willing to engage in risky activities like to invest in WSIT than older farmers. Besides, older farmers often have shorter planning horizons, resulting in a higher actualization rates that reduces the pres-

ent-value of their returns investment, and they are likely to be hostile to change.

The information sources variable is significant at 10% and 5% level for Logit and Poisson models respectively and negatively related with WSIT adoption. The result is not consistent with the hypotheses that those farmers who get information from extension services and other institutions should have a higher probability to adopt such technologies. Our result corroborates the finding of (Dhehibi *et al.*, 2018), who found a negatively significant relationship between extension services and adoption of soil and water conservation techniques. According to Evenson & Westphal (1995), the transmission of information cannot be accomplished solely through the use of rules of thumb primarily employed by extension personnel; rather, it requires the formation of strong social networks among growers engaged in learning-by-doing. In fact, we don't know if extension personnel (from either private, or public extension agencies) target specific farmers who are recognized as being peers exerting a direct or indirect influence on the entire population of farmers in their respective areas. More specifically, the variable cannot assess whether the information was too theoretical, and not practical in applications. Equally important is a realization that this variable does not indicate the quality of information or the extension services. Further research is required in this regard to provide an explanation for this counterintuitive result.

Being a member in agricultural organizations affects the intensity decision of farmers negatively and significantly at 5% level. Membership in agricultural organizations decreases the probability of adopting irrigation saving technologies. Although a direct causation between membership in farm organizations and adoption of WSIT cannot be asserted, the variable may be considered mainly as a proxy for social networks and interaction between farmers. This most probably indicates that members do not support each other in the decision to adopt WSIT, a social network and exchange of personal knowledge on the benefits are low. A study of agricultural cooperatives in the Mitidja showed that the reasons for this disaffection of farmers are to be found

in the fact that the leaders of these cooperatives only partially respect the management principles stipulated in the regulatory texts governing this type of institution. The value of the I.R.R indicates that by holding all other explanatory variables constant, each increase in the membership in agricultural organizations score by one unit would generate a decrease of the I.R.R of adoption by 0.70 times.

The educational level of the farmers, as expected, had a significant and positive relationship with the WSIT intensity at a 1% statistical significance in Poisson regression results. The education level improved the likelihood for more use of WSIT in farmland, *ceteris paribus*. Therefore, this implies that education is one of the key determinants for WSIT adoption. The results showed that the greater the farmers' education level, the greater the chance of high WSIT use, such as hypothesized and observed in other empirical studies. Farmers with high schooling level are more likely to have additional information concerning the WSIT use and more capacity to process information related to new technologies. In the same direction, the more educated farmers tend to have higher levels of managerial skills, which can lead to better resource allocation. According to the calculated results on the I.R.R., a one-unit increase of schooling led to a 1.52 times increase in the likelihood of more WSIT use intensity in the operated farmland.

The results from Tables 5 and 6 indicate that subsidy variable is at best significant at 10%, and negatively associated with WSIT adoption rate and intensity. Based on estimation results, the coefficient of policy subsidies is significantly negative in the model results, implying that there is a negative relationship between policy subsidies and the adoption of WSIT, in one case, the sign is the opposite of what is predicted. In other words, if farmers had access to policy subsidies, the possibility that they will adopt WSIT decreases. This is in contrary to the finding of Dinar & Yaron (1992) who found a positively significant relationship between subsidies for equipment, and adoption of WSIT. However, the study of Malik *et al.* (2018) found a negative impact of subsidies on the adoption of irrigation technology.

The negative and significant correlation between subsidies and WSIT adoption can be explained by the defection of a large part of the installed networks and subsidized because the lack of monitoring and control of irrigation networks subsided by equipment suppliers and the administration in charge of the subsidy. In 2005, the Agricultural Services Department carried out a verification operation on all the farms that had benefited from the irrigation technologies subsidy. The findings revealed the following: (i) a large part of the equipment supplied by the operators, particularly the distribution ramps, was of much lower quality, which accelerated their deterioration, agents often encourage farmers to purchase lower-quality systems with higher margins for dealers or manufacturers; (ii) Some networks were completely clogged and subsequently abounded by the farmers. The defection rate of subsidized networks has been estimated at 70% of the total installed. This explains the significant regression recorded in the allocation of subsidies or their suspension in 2008. The government supported farmers to acquire the WSIT, with an investment subsidy of 100%⁸ initially (in 2000), as of 2004 the value of the subsidy was revised downward because the value of the subsidy was found to be higher than the prices practiced by suppliers for much of the equipment. At the end of 2006⁹ the rate of subsidy was only 60% of the cost, a low rate of subsidy less than 40% between 2006-2009 (subsidy system was removed in 2008), and subsidy is 50% of the cost from 2014.¹⁰ This may lead to the conclusion that the government programs' subsidies predict lower probabilities for WSIT. Such a conclusion would not be supported by the findings of previous studies that government programs providing financial

or technical assistance are strong determinants of the adoption of conservation technologies (Amosson *et al.*, 2009).

Finally, the use of irrigation water through a drilled well is one of the characteristic features in the study region (West Mitidja). Other types of access were observed in the study region, but different types of access coexist in the majority of farms (irrigation through drilled wells and dams). The variable of the drilled wells ratio reflects the use of groundwater from the Mitidja aquifer and the cost of extracting irrigation water. The results of the three models show that this variable has a negative and significant effect on the WSIT adoption, rate and intensity. In other words, as the farm area and number of drilled increases that imply the ratio of drilled wells on farm area decreases,¹¹ thus the probability of adoption WSIT increases. According to the computed marginal effects, results of Logit model show that the probability of WSIT adoption was 56.20 % lower when the drilled wells ratio increased by one unit, a one-unit increase of the drilled wells ratio leads to a 1.74 times decrease in the probability of WSIT adoption rate, and in terms of the I.R.R., lead to 1.78 times decrease in the likelihood of more WSIT use intensity in the operated farmland. We can conclude that the higher number of drilled wells (i.e ratio of drilled wells decreases) and therefore the higher the cost of extracting irrigation water affects positively the adoption, rate and intensity of WSIT. This result could be explained by when the extraction cost of water is relatively high¹² (usually because of expensive investment in drilled wells) the farmer has a greater incentive to use water-saving techniques. Conversely, all those who benefit from the very low cost of water from the ONID and obtained from the

⁸ Ministerial decision no. 599 of 08/07/2000.

⁹ Ministerial decision no. 259 of 26/05/2006.

¹⁰ Ministerial decision no. 943 of 02/10/2014.

¹¹ It should be noted that bivariate correlations are made between the pairs of farm size and drilled wells with a Pearson correlation of 0.311, and farm size and ratio of drilled wells on farm size with a Pearson correlation of -0.173. The correlation is significant at the 0.01 and 0.05 level respectively. There is also a negative correlation between the pairs of drilled wells and ratio of drilled wells on farm size with a Pearson correlation of -0.132 (see Appendix Table 2).

¹² According to the ONID (2020), the cost of a m³ of water from a Drilled Wells in the Matija is 0.037 USD by m³, while the administered price of a cubic meter of water supplied by the ONID is set by law at 0.0148 USD/m³, for water distributed by gravity and 0.0185 USD by m³ for water distributed after pumping. (1 DA= 0.0074 USD).

irrigation networks connected to the dam, have little interest in investing in these same techniques. The main significant variables in both OLS and Poisson models point to the farmers with the highest probability of intensity adoption of WSIT are those who have the labor force and high level of education and the younger ones.

5. Conclusion

The study aimed to analyze empirically the factors that affect farmers' adoption choice, rate and intensity of water-saving irrigation technologies in West Mitidja, Algeria, among a sample survey of 136 farmers. Three econometric models of regression were used, namely: the Logit model (for a binary adoption choice of a WSIT), the Tobit model (for censored values of WSIT area) and Poisson models (for count data of WSIT area). The econometric models seemed to have very high levels of robustness and they are effective and explained the farmers' WSIT adoption phenomenon.

The main findings of the resulted models are as following: In terms of adoption choice, two factors that significantly and positively affect farmers' choice of WSIT adoption are: credit access and extraction costs of water. This is corroborated by findings of Genius *et al.* (2014); Alcon *et al.* (2011); Namara *et al.* (2007); Foltz (2003); Dinar & Yaron (1992) and Caswell & Zilberman (1985), who found a positive significant relationship between irrigation with drilled wells and access to credit. However, other factors such as investment and farmers' age have significant and negative effect technology adoption. The study confirms the finding of Zhang *et al.* (2019) and Hunecke *et al.* (2017), who found that investment and age had a significant negative relationship with technology adoption. Nevertheless, in terms of WSIT intensity, labor force, credit access and education level affect significantly and positively the WSIT intensity at farm level, whereas investment, ratio of drilled wells on farm size, information sources, organizations membership, subsidies and farmers' age have significant and negative effect on WSIT intensity.

The analysis presented in this study could

provide useful policy implications for decision makers with intervention levers, which permit to improve the public action to preserve such common valuable resource, the irrigation water. Policy makers frequently are not well-informed about factors that could influence the adoption of new irrigation technologies. Nonetheless, this study provides some insights for the Algerian policymakers. The age and educational status of farmers were the key determinants for the WSIT adoption. The unexpected negative correlation between information sources, membership in agricultural organizations, subsidies and adoption remains unclear. This finding could be explained by a low efficacy, or low relevance, of the policy subsidies, agricultural organizations and information provided. This indication should be evaluated by the local agricultural institutions. Thus, the extension and training services should be more targeted and possibly supported by the efficient identification of the farmers' influential peers to promote WSIT. Besides, the establishment and maintain of demonstration farms and areas, where the benefits of the promoted WSIT could be shown, and assessed with the farmers' participation, would raise awareness of WSIT. Even if capital costs are a significant barrier, there are alternatives to the current subsidy system that would avoid some of its current shortcomings. For example, the government could, alleviate the eligibility conditions, ease administrative process to obtain subsidies and increase it rates, which requires verification of product purchase and use. Alternatively, farmers can either be provided with interest-free loans for the entire cost of WSIT, administered through existing financial institutions, or provided with conditional cash transfers.

Although, whether or not adopting modern water-saving technologies (such as sprinkler or drip irrigation techniques) conserves water is still an ongoing controversy. The public policy about the irrigation water permits the increase of the agricultural production, to better value the water as well at the level of the farms as at the national level, on the other hand, one increases involuntarily, and against the expectations, the global consumption of water, at the expense of the groundwater, especially in Algeria.

ria where nearly 90% of the irrigated farmland areas depend on groundwater. The recent literature shows that even when water is saved at plot-level, water demand is generally increased at other scales, such as the farm or regional scale (Ward & Pulido-Velazquez, 2008; Batchelor *et al.*, 2014). Caswell & Zilberman (1986) confirm that switching to sprinkler or drip irrigation techniques from border or furrow irrigation saves water at the field level under certain circumstances. Therefore, under some hydrologic conditions, adopting water-saving technologies, either traditional or modern, lead to water saving on farm-level fields. Additional regulatory mechanisms are needed parallel with the subsidy policy of WSIT, for example, contracts between the Government and farmers on the implementation of WSIT and the extension of the irrigated area, the regulation of individual groundwater withdrawals through incentives in which farmers undertake to declare their drillings, particularly in the case of illegal drillings, and install meters. The implementation of a tax on underground withdrawals according to the risk of overexploitation of the water table.

This study has clearly some limitations that offer many research perspectives. In addition to the influence of socio-economic and financial factors, other determinants related to the profitability of the investment, production risk, and agricultural product prices, land tenure issues may influence farmers to adopt WSIT. In addition, results of our static models using cross-sectional data do not capture changes in adoption decisions over time. Dynamic models using panel data might be in order to effectively describe the adoption and diffusion across both time and space. Future research would adequately describe these factors and how they related to the adoption process. These ambitions would be difficult to accomplish with the current data set. They require a larger data set and the inclusion of time dimension in the data. Besides, this research was limited to the Mitidja region, but it will be enlarged to other irrigated areas with different climatic zones and cropping systems in order to compare with our case study and to be able to generalize our findings.

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Appendix

Table 1 - Correlation matrix of explanatory variables.

<i>Variables</i>	<i>Investment cost</i>	<i>Credit access</i>	<i>Education level</i>	<i>Organization membership</i>	<i>Information sources</i>	<i>Public subsidies</i>
Investment cost	1.0000					
Credit access	-0.3203	1.0000				
Education level	-0.4431	0.5086	1.0000			
Organization membership	-0.2123	0.3922	0.2366	1.0000		
Information sources	-0.3006	0.5399	0.4779	0.1286	1.0000	
Public subsidies	-0.2841	0.4249	0.3909	0.0890	0.6202	1.0000

Source: Author's elaboration from field survey (2020).

Table 2 - The Pearson correlation coefficient.

<i>Correlations</i>	<i>Farm size</i>	<i>Drilled wells</i>	<i>Ratio of drilled wells on farm surface</i>
Pearson Correlation	1	0.311**	-0,173*
Sig. (bilateral)		0.000	0.044
N	136	136	136
Pearson Correlation	0.311**	1	-0.132
Sig. (bilateral)	0.000		0.126
N	136	136	136
Pearson Correlation	-0,173*	-0.132	1
Sig. (bilateral)	0.044	0.126	
N	136	136	136

Source: Author's elaboration from field survey (2020).

Promoting Tunisian agri-food start-up. A study on the self-efficacy of aspiring entrepreneurs

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Abstract

In 2011, Tunisia went through a revolution which transformed its modern history. Currently, the country is experiencing a moment of transition in which it faces problems, both on a social and economic level. The region Kroumerie-Mogods, in the northwest, includes the three Governorates of Jendouba, Beja and Bizerte, is strongly affected by past economic policies. Despite having great potential in terms of both natural resources and economic opportunities, the local population appears to be among the poorest in the country, suffering from high level of unemployment, widespread poverty and substantial inequalities. In this context, a Development Cooperation project was implemented with the aim of creating new employment opportunities, especially for young people and women, through the enhancement of the territory and its agricultural products with the support of new entrepreneurial initiatives. Principal Component Analysis and Logit model were used to analyse the Self-Efficacy (SE) of young aspiring entrepreneurs and to evaluate its effects on the promotion of personal entrepreneurial projects. The study shows that past involvement in business key activities, as commercial experiences, social commitments and sustainable waste management, represent a decisive element for the promotion of personal business projects in agri-food sector.

Keywords: Tunisia, Start-up, Development cooperation, Agri-food, Sustainable development, Self-efficacy.

1. Introduction

The path for a sustainable development represents a real challenge for the countries of the Mediterranean area, particularly exposed to the effects of climate change and, at the same time, characterized by strong social and territorial inequalities. The ability of the African continent to tackle many of the serious challenges it faces, depends strongly on its capacity to promote new kinds of entrepreneurs, adopt new technologies, and build institutions to manage those changes (Ben Youssef *et al.*, 2018).

These issues are even more relevant in Tunisia which in 2011 experienced a revolution that transformed its modern history. Ten years later, the country is facing a complex transition which closely involves the Tunisian population, afflicted by a high degree of unemployment, a low level of education, and a difficult social situation caused by a serious economic crisis.

Most of the jobs created by the economy are in low-value added activities and mostly in the informal sector, offering low wages and no job security, and such conditions do not meet

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the aspirations of the highly educated population (World Bank, 2014). Currently, the global unemployment rate in the country stands at 15.1% with a strong gender gap. Female unemployment is 22% while male unemployment is 12.3%. These percentages rise respectively to 38.1% (female) and 15.7% (male) if higher education graduates are considered (INS, 2020). High emigration historically relieved some of the labour market pressures in the country but the global crisis has made access to foreign job markets more difficult, further increasing internal social tensions as well as accentuating persistent gender discrimination (IILS, 2011).

Thus fighting unemployment and reducing inequalities between different regions are crucial for the development of a country like Tunisia where agriculture plays a strategic role in the management of territorial and environmental balances contributing to 13.3% of GDP, and about a third of the population living in rural areas (World Bank, 2018).

The complex economic situation is also reflected in the country's entrepreneurship branch, which is becoming increasingly poor. According to Antonelli *et al.* (2020) the country ranks lower in terms of global entrepreneurship compared to its regional neighbours such as Egypt, Jordan, but also compared to United Arab Emirates, and Saudi Arabia, scoring in 2019, the loss of 13 positions in the Global Entrepreneurship Index (Acs *et al.*, 2020).

The aim of this work is to present the results of the analysis carried out on the Self-Efficacy (SE) of young aspiring entrepreneurs.

This paper is structured as follows. Section 2 presents a literature review on selected keywords, followed by an analytical description of the region in which the development project has been implemented and its lines of action. Section 3 describes the questionnaire used to collect data and methods applied for the study of the SE and its effects on the development of entrepreneurial projects, including Principal Component Analysis (PCA) and Logit model (Section 3.4). Section 4 presents a discussion about results followed by conclusions in Section 5.

2. Background

In 1977 Albert Bandura introduced his Self-Efficacy theory, in which he proposed that self-efficacy and outcome expectancies are key to behaviour initiation and maintenance. The fundamental characteristic of this theory is its multidimensionality, which has allowed its application in many scientific fields, starting from the psychological ones, with the studies on motivation (McCarthy *et al.*, 1985; Schunk, 2003) and healthcare (Wong *et al.*, 2005), including those on performance outcomes (Pajares and Johnson, 1994).

The Self-Efficacy construct is able to explain various cognitive and motivational aspects, including the impact of positive experiences and successes, perseverance in commitment, optimism and the development of interests in specific cultural and professional areas. While there is broad consensus among researchers on the importance SE in entrepreneurial motivation, intentions, and behavior, few studies however deal with Self-Efficacy in rural contexts like North Africa and especially in Tunisia, where entrepreneurship is considered one of the keys to sustainable development.

In order to conduct a rigorous literature review, six keywords related to the topic were identified and a search was carried out on the Scopus database, which allowed researchers to consult papers, books, abstracts and articles from both academic and professional publishers. Four subject areas have also been chosen: (i) Business, Management and Accounting; (ii) Economics, Econometrics and Finance; (iii) Environmental Science; (iv) Agricultural and Biological Sciences. The final list of keyword combinations used and the number of articles found is shown in Table 1.

The literature review shows some important evidence. It is interesting how there are no papers related to the agri-food sector in combination with the Self-Efficacy keyword as well as with the keyword Development Cooperation.

Only five papers deal with SE in Tunisia, but none of them concern start-up or young entrepreneurs. For example, Guo *et al.* (2013) have studied the common values of consum-

Table 1 - Keywords interaction table – Performed using Scopus September 2020.

<i>Keywords</i>	<i>Tunisia</i>	<i>Start-up</i>	<i>Development Cooperation</i>	<i>Agri-food</i>	<i>Sustainable Development</i>	<i>Self-Efficacy</i>
Tunisia	-					
Start-up	11	-				
Development Cooperation	4	0	-			
Agri-food	9	9	0	-		
Sustainable Development	122	166	70	215	-	
Self-Efficacy	5	54	0	0	68	-

ers in terms of financial needs, while Nasri and Charfeddine (2012) have examined several factors that affect the adoption of Internet banking by Tunisian bank customers. Mosbeh and Soliman (2008) and Khelil *et al.* (2018) are more oriented towards large company analysis, using self-efficacy to investigates the effect to the support and independence of internal auditor and to identify factors that are perceived to affect the decision to adopt corporate intranet in a developing country.

The topic of start-ups in Tunisia is addressed by several authors. Arouri *et al.* (2016) have analysed the impact of small firms' entry and exit dynamics on net job creation, pointing out how small firms in Tunisia have a strong social impact on job creation, but a weak economic impact in terms of wealth creation. In this context, small firms' entry rates in the job market are driven mostly by necessity entrepreneurs, while the skilled workforce, which currently is largely unemployed, does not contribute to this process through the creation of innovative start-ups.

Khefacha *et al.* (2012) developed an econometric model of entrepreneurship which allow for the identification of factors influencing transitions into self-employment at the regional level in the country. In this case the authors have shown that the direct knowledge of people who have started their own business and the presence of good opportunities to create business, positively stimulate the creation of new start-ups.

The literature concerning the study of SE in the broader context of Start-ups is quite varied and develops in the so-called Entrepreneurial Self efficacy (ESE). In this context, SE involves individuals' beliefs regarding their capabilities

for attaining success and controlling cognitions for successfully achieving challenging goals during the business start-up developing process (Drnovšek *et al.*, 2010).

From the Sustainable Development (SD) point of view, Sher *et al.* (2020) argue that the promotion of sustainable ventures and behaviours among aspiring entrepreneurs could lead to an effective solution to reduce ecological footprints and help achieve the Sustainable Development Goals (SDGs). An SE study on the drivers of sustainable start-up among university students, point out how the attitude towards sustainable entrepreneurship is a complement of sustainability-driven entrepreneurial intentions. In addition, St-Jean and Labelle (2018) use SE to study the effect of entrepreneur sustainable orientation and motivation on entrepreneurial behaviour.

This literature review allowed us to clarify two crucial points of this work. First of all, SE is a valid analysis tool in the study of the behaviour of aspiring entrepreneurs. In addition, there is a lack of literature on the use of this method for the analysis of start-ups in the agro-food sector, and especially in Tunisia.

3. The territorial context

The past centralized approach and a strong regional inequality have caused a large gap between the development of coastal areas and the rest of the country, demonstrated by a poverty rate of inland areas that has now reached alarming levels (African Development Bank, 2020).

The north western region of the country, called Kroumerie-Mogods, the main humid area of Tunisia, leading to the development

Table 2 - Socio-economic indicators of Beja, Bizerte, Jendouba Governorates. Tunisia Regional Data (INS, 2015).

<i>Index (%) /Governorates</i>	<i>Beja</i>	<i>Bizerte</i>	<i>Jendouba</i>
Total population*	303.032	568.219	404.203
Population in rural areas	55,7	34,7	68,8
Employees in the agricultural sector	11,7	4,5	10,8
Total unemployment rate	18,0	12,9	26,0
Unemployment rate (15-29 years)	13,7	11,9	20,1
Female unemployment rate	29,0	20,6	38,7
Total illiteracy rate	29,4	20,0	32,1
Illiteracy rate (15-29 years)	22,0	14,8	22,4
Female illiteracy rate	37,0	26,0	41,2

* total unit.

of a dense forest (Zielhofer and Faust, 2008). The area, consisting in three Governorates of Beja, Bizerte and Jendouba, is characterized by a strong delay in terms of development, with high rates of unemployment and illiteracy (see Table 2).

Past policies had a strong effect on the regional economy, with a clear advantage for the service sector, especially tourism, over the primary sector. After the collapse of tourist presences, in recent years, the Regions suffered a very disadvantageous economic situation, relying almost exclusively on the agro-pastoral economy. The businesses, generally small and family-run, practice subsistence agriculture, which includes the cultivation of wheat and crops for livestock, but also the production of fruit and vegetables, legumes, cheese and honey. Although the forests extend for more than 483,000 hectares, their exploitation is rather limited and includes the craftsmanship of wood, the distillation of plant essences (rosemary, myrtle, mint) and the collection of mushrooms.

Those who work in agriculture and in the connected sectors have limited training, with scarce skills, both in terms of the management of production and in terms of relations with the market and distribution networks. In addition, the absence of a vertical integration along the supply chain and the poor efficiency of regional institutions and logistic systems logistic makes it very difficult for the economy of the region to develop.

4. Development Cooperation actions

Improving the quality of life of the most disadvantaged communities is one of the most ambitious objectives of the international strategy for SD. Addressing this issue in the countries bordering the Mediterranean sea, means strengthening and making the fight against poverty more effective, contributing to the reduction of inequalities, ensuring an adequate level of training and decreasing the exposure of the most vulnerable classes to economic, social and environmental shocks.

In the rural context characteristic of North African countries, agriculture plays a strategic role in achieving these objectives, which require a growing commitment to collaboration, cooperation and integration between different political and economic systems.

Lin and Si (2014) pointed out that the government can enhance the entrepreneurial intention of rural individuals by updating entrepreneurial policies, by training and education in entrepreneurial activities that target the rural masses, and by promoting a successful entrepreneurial mode.

The “Start-Up Tunisie” Project, co-founded by Italian Agency for Development Cooperation (AICS) and composed of a broad partnership of public bodies and agri-food business, aims to create new job opportunities for young people and women, supporting the establishment of new start-ups in the fields of agriculture, livestock and agri-food products processing, with a focus on organic supply-chain development,

building better trading conditions and promoting sustainability through the creation of collaborative networks (Mariani and Viganò, 2013).

Tunisia is the African country with the largest organic cultivation area, following the implementation of organic regulations, in the broader context of the national strategy to reform agriculture (Willer and Lernoud, 2019), but main productions are located in other regions than Kroumerie-Mogods. On the other hand, it is necessary to consider that organic products are booming in Tunisia, as well as dietetics and fair trade (Kamoun *et al.*, 2015; Callieris *et al.*, 2016). This constitutes a good premise for the reorganization of production and distribution activities, to promote a better management of common goods (Sturla *et al.*, 2019), and to create relationship that increase the “connectedness” of several stakeholders (public institutions, consumers) to food production, by different types of local supply chain (Seyfang, 2007; Goodman *et al.*, 2012; Blasi *et al.*, 2016).

Across the world the creation of micro, small and medium enterprises (MSMEs) are seen as a way of driving economic development and transformative growth, and for some, a route out of absolute and relative poverty (Holt, 2020). Apostolopoulos *et al.* (2018) highlight the role of entrepreneurship as a transformational driver offering the scaffolding for both attaining and delivering the SDGs, and fuelling economic growth led by the principle of SD.

After a first mapping of the agri-business in the Region aimed at defining their dimensional profile, the type of production activated and the relations between producers and markets, the project has undertaken various lines of action.

Some companies have been selected to benefit by interventions to improve production and economic efficiency. In particular, financial support has been provided for the acquisition of specific equipment or for the purchase or improvement of production facilities, but also for training and assistance on production techniques. Next to this line of action, the Project design includes the activation of literacy courses and vocational training to reduce the level of illiteracy and improve the skills of young people and women, who could be included as employees and consultants of the selected companies.

The training activity was preparatory to the formulation of project proposals, in the form of the Business Plan (BP), by the participants, among which the most appropriate were selected for receiving the necessary funding to start production activities. Participants had the option to choose whether to submit the business plan for evaluation or not and thus, to be excluded from the programme.

In this context, each participant was given a questionnaire containing questions relating to different aspects of their business idea and certain questions were aimed at analysing the motivation of the individual participants for starting their own business. This study is the result of the analysis of their responses.

5. Materials and methods

From the development cooperation point of view, Pajardi *et al.* (2020) point out the role of SE in the context of international projects and its importance in determining the attitude of people towards promoting change and improving their living conditions by themselves.

In social psychology theory, SE refers to an individual's self-belief that they can successfully accomplish a certain task and overcome the challenges associated with it (Bandura, 1977, 1997). SE has been recognized as one of the main aspects which can affect psychological empowerment (Zimmerman, 2000) aspirations, motivation and achievements (Bandura, 1993). It can be manifested through various elements of personal behaviour, such as how well a person perseveres in the face of adversity or their will to engage in behaviours or tasks that may be perceived as challenging (Roy *et al.*, 2018).

The current study is based on a model similar to Hedonic Contingency Theory (HTC) (Wegeener and Petty, 1994). With this approach, we assume that individuals in a positive mood try to maintain this mood by engaging in a task where they feel efficacious. Therefore, these individuals will be strongly motivated to perform such a task and achieve better results.

In our case study, we expect that there is a positive relationship between the Self-Efficacy of the subjects who participated in the pro-

Table 3 - Items, variables explanation and sentences for Self-Efficacy measurement.

Fields (aggregated variables)	Variable	Item	Sentences
Economic (EC)	Ec1	Commercial	I am able to use the skills I have acquired in the commercial field to face the challenges that arise building my start-up
	Ec2	Self-consumption	I had experiences of self-consumption that will be useful in the development of my business
	Ec3	Local material and buildings	Skills in using local materials, including building construction, are very useful for the development of my start-up
Social (SO)	So1	Social	My commitments in the social sphere have allowed me to have the sensitivity necessary to develop my idea while respecting others
	So2	Cultural	My traditions will be useful to me to develop my business idea
	So3	Awareness of the local population	The skills acquired in raising awareness of the environmental issues of local populations are very useful for the development of my start-up
Environmental (EN)	En1	Waste Management	Waste management skills acquired are very useful for the development of my start-up
	En2	Water waste	The skills acquired to avoid water waste are very useful for the development of my start-up
	En3	Wastewater collection	The skills acquired in wastewater collection are very useful for the development of my start-up
	En4	Renewable energy	The skills acquired in the field of renewable energy are very useful for the development of my start-up
	En5	Sustainable exploitation of protected areas	The skills acquired in the sustainable exploitation of protected areas are very useful to me for the development of my business

ject, and their decision to create and submit the BP for evaluation and possible admission to the financing.

In this context, SE is considered as the belief of individuals that they can use their past experiences and cognitive resources to face the challenges that the implementation of their entrepreneurial projects puts before them.

Entrepreneurship is the result of the interaction between entrepreneurs' attributes and the surrounding environment (Capelleras *et al.*, 2013; Wennberg *et al.*, 2013). According to Malebana and Swanepoel (2014), who highlight the role of entrepreneurial SE in the context of rural areas of south, this study cannot be separated from an analysis of the phenomenon in the rural context that characterizes the region in which the project operates.

Rural entrepreneurs experience more difficulties accessing key financial, technological, human and knowledge related resources than urban entrepreneurs, and lack certain benefits related to a low density population such as a lower density of markets and a greater distance to resources (Malecki, 2018). Despite this, Capelleras *et al.* (2013), analysing links between individual characteristics of entrepreneurs and the urban/rural environment, argued that individuals who perceive an opportunity in rural areas are more likely to become a nascent entrepreneurs.

At the same time, from the environment perspective, Wu and Mweemba (2010) evaluate farmers' awareness and attitude toward environmental degradation and their self-efficacy beliefs in Zambia, finding that farmers have a strong belief about their capacity to take action

to reduce land degradation on their farms. In this context, Shepherd and Patzelt (2011) define sustainable entrepreneurship as the activities performed by entrepreneurs in the pursuit of opportunities which do not undermine the ecological and social environments in which they operate. By contrast, when possible, they must restore or nurture such environments towards recovering the balance between nature, society and economic activity (Parrish, 2010).

In the literature, there are many examples of questionnaires aimed at the study of SE in different fields of research (Garaika and Margahana, 2019; Malandrakis *et al.*, 2019; Tannady *et al.*, 2019; Zuhir *et al.*, 2019). The economic-social situation typical of Tunisia, the project's objective, and the attention to environmental issues with a view to sustainable development, have led to the creation of questions specific to the present study.

The study was based on the assumption that SE consists in project participants' beliefs that they could utilize past experiences in economic, social and environmental fields, to mobilize cognitive resources, motivation, and courses of action needed to meet situational demands about their business project (Wood and Bandura, 1989). Thus, the questionnaire contained 11 items relating to economic (3 items), social (3 items) and environmental (5 items) aspects. Participants had to rate to what extent they related to these statements using a five-point Likert Scale from 0 "I definitely disagree" to 4 "I definitely agree" (Table 3).

The score of each question was assigned to the corresponding variable. Furthermore, an aggregate variable was created intended as the sum of the scores relating to a specific field.

6. Data collection

Data collection was carried out through a multi-step process. A group of aspiring entrepreneurs from the region were identified using lists provided by the technical partners on site, official administrations and other local partners involved in the project. An initial general interview was then carried out with all the individuals identified, useful for verifying:

Table 4 - Sample characteristics.

Attributes	n.	%
<i>Gender</i>		
Male	25	62,5
Female	15	37,5
<i>Age</i>		
Below 30	7	17,5
30-35	16	40,0
36-40	15	37,5
Over 40	2	5,0
<i>Education Level</i>		
Primary school	4	10,0
Secondary School	5	12,5
University	31	77,5
Total	40	100,0

- general information, education level and age;
- business sector of the project;
- type of company to be built or type of company that has already been officially registered;
- any activities implemented for the preliminary development of the business project.

As a result of this first contact, 40 aspiring entrepreneurs were selected who accepted to take part in the project (Table 4).

Only 32 of the 40 participants submitted the BP, which was then evaluated for financial aid.

The economic sectors influenced by the projects were seven, with a clear predominance of the productive sector over services (Figure 1).

Figure 1 - Sectors affected by start-up projects.

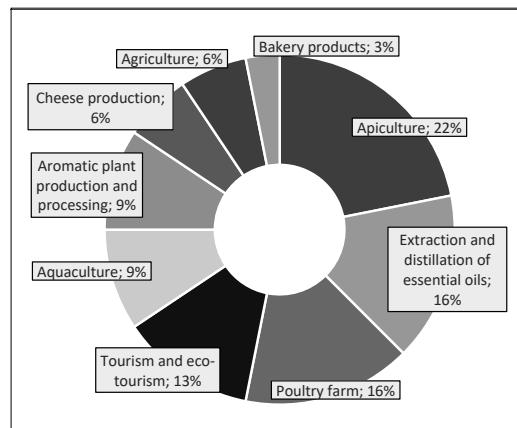


Table 5 - Correlation of items and aggregated variables.

Variable	<i>Ec1</i>	<i>Ec2</i>	<i>Ec3</i>	<i>So1</i>	<i>So2</i>	<i>So3</i>	<i>En1</i>	<i>En2</i>	<i>En3</i>	<i>En4</i>	<i>En5</i>
<i>Ec1</i>	—										
<i>Ec2</i>	0.071	—									
<i>Ec3</i>	0.100	0.122	—								
<i>So1</i>	0.409 **	0.097	0.225	—							
<i>So2</i>	0.251	0.189	0.354 *	0.357 *	—						
<i>So3</i>	0.379 *	0.020	0.262	0.531 ***	0.605 ***	—					
<i>En1</i>	0.500 **	-0.135	0.171	0.357 *	0.303	0.534 ***	—				
<i>En2</i>	0.059	0.053	-0.123	0.298	0.407 **	0.354 *	0.280	—			
<i>En3</i>	-0.036	0.105	-0.051	0.264	0.394 *	0.348 *	0.260	0.602 ***	—		
<i>En4</i>	0.221	0.029	0.336 *	0.380 *	0.472 **	0.485 **	0.372 *	0.369 *	0.477 **	—	
<i>En5</i>	0.102	-0.110	0.483 **	0.285	0.439 **	0.464 **	0.268	0.148	0.055	0.096	—
<i>Aggregated Variable</i>	<i>EC</i>	<i>SO</i>	<i>EN</i>								
<i>EC</i>	—										
<i>SO</i>	0.521 ***	—									
<i>EN</i>	0.356 *	0.734 ***	—								

Statistical significance * $p < .05$, ** $p < .01$, *** $p < .001$

7. Correlation matrix and reliability test

A first analysis was carried out on the correlation of items to measure the degree of connection between the variables. The analysis was conducted on a dual level. The correlation was calculated at the level of individual items of the questionnaire and at the level of the three aggregate variables (Table 5).

To complement this analysis, a measure of the internal consistency was performed using Cronbach's alpha (1951), which indicates the stability of the form, and estimates to what extent the responses of a questionnaire, or parts of it, are reliable (Bujang et al., 2018). The value of Cronbach's alpha ranges from 0 to 1, with the higher values indicating that items are measuring the same dimension. By contrast, when it is approximately close to zero, it means that some or all of the items are not measuring the same dimension (Leontitsis and Pagge, 2007). Nunnally (1978) considers a level of 0.7 to be acceptable. Furthermore, in this case the analysis was carried out on two different levels. The first is the one that examines each item without considering whether it belongs to a specific field or

Table 6 - Reliability of scales.

Reliability	Items	Cronbach's alpha
Variables	11	0,814
Aggregated variables	3	0,749

not, and the second one examines the measure of the reliability of the questionnaire based on the three aggregated variables (Table 6). The results achieved up to this point have served as a reliable foundation for further testing and subsequent analysis.

8. Principal Component Analysis (PCA) and Logit model

Principal Component Analysis (PCA) is a powerful method with which to explore datasets that feature multiple variables (Jollife and Cadima, 2016). In the literature, there are many examples which use this methodology in various fields of research (Jeon et al., 2006; Capitano et al., 2009; Naseri and Sharifi, 2019; Luo et al., 2020).

PCA analysis was performed to identify a few

Table 7 - Matrix of component loadings.

Variable	PC1	PC2	PC3	PC4
<i>Ec1</i>		1.130		
<i>Ec2</i>				0.940
<i>Ec3</i>			0.990	
<i>So1</i>		0.578		
<i>So2</i>			0.496	
<i>So3</i>				
<i>En1</i>		0.747		
<i>En2</i>	0.980			
<i>En3</i>	1.044			
<i>En4</i>	0.535			
<i>En5</i>			0.949	

Note: Applied rotation method is PROMAX.

complex indicators that mostly characterize the differentiations among entrepreneurs' answers and synthesize the original variables with a minimal loss of information. New variables, called principal components (PCs), are linear functions of those in the original dataset (Jackson, 2005).

Table 7 shows the matrix of component loadings (highlighted > 0.39), i.e. the correlations between the initial variables and each of the principal components (eigenvalues > 1). An oblique rotation method (PROMAX) was applied. We extracted four factors that explain more than 71 per cent of the initial variance.

The first component is directly linked to various SE environmental aspects, in particular it is correlated to the elements of responsible use of water (*En2*), the reduction of water waste (*En3*) and to the knowledge and use of energy from renewable sources (*En4*). The second and third components are more transversal, taking into account all three subjects of the SE. The variable *PC2* refers to the commercial skills of the participants (*Ec1*), to their involvement in social relations (*So1*) and to their experiences in the field of waste management (*En1*), while *PC3* refers to participants' skill in terms of building with local materials (*Ec3*), knowledge of traditions (*So2*) and the sustainable exploitation of protected areas (*En5*). The variable related to awareness of the local population about

environmental issue, appears to be uncorrelated to any of the principal factors.

The last principal component (*PC4*) is strongly related to only one element of the economic field, that is self-consumption (*Ec2*). However, the systemic approach adopted in the formulation of the SE framework which takes into account the multidimensionality of the individuals' self-beliefs, has led to the exclusion of this last component for further testing, since it refers to the only one variable that has no correlation to all the other elements considered, as seen in Table 5. In this formulation, the model still explains 61 percent of the total variance.

To determine the effect of SE on the propensity to submit the BP for the financial aid assessment and verify whether the effect differs according to different PCs, a logit regression model is used. In this case, the dependent variable takes a value of 1 when the observed participant submitted a BP, and 0 otherwise. The logit specification provides a model of the probability as follows:

$$P_i = \Pr(Y_i = 1|X_i) = E(Y = 1|X_i) = \frac{1}{1 + e^{-(\alpha + \beta X_i)}} = \frac{1}{1 + e^{-z_i}} \quad (1)$$

that indicates the impact of independent variables on the probability that a participant submits the BP for the financial aid evaluation. The last part of the equation:

$$P_i = \frac{1}{1 + e^{-z_i}} \quad (2)$$

represents the logistic distribution function, which ranges from 0 to 1, and thus ensures that for every estimated X_i , P_i can be interpreted as a probability. According to Wooldridge (2010), it fulfils the requirement $0 \leq E(Y_i|X_i) \leq 1$ and it is one of the main reasons for choosing a logit model for this analysis.

The equation (2) needs to be rewritten so that it becomes linear in X_i and β , to be used to estimate P_i and transform the logit model as follows:

$$\ln(P_i/1 - P_i) = \alpha + \beta X_i + \varepsilon_i \quad (3)$$

where the dependent variable is the logarithms of the odds ratio of BP submitted by participants and ε_i represents the stochastic disturbance term. Despite the fact that this estimation should be interpreted cautiously for relatively small samples such as ours (Stock and Watson, 2014), the

Table 8 - SE Principal Component affecting participant BP submission.

	<i>Estimate</i>	<i>Standard Error</i>	<i>Wald Statistic</i>	<i>p</i>
PC1	-0.094	0.176	0.285	0.593
PC2	0.198 *	0.093	4.508	0.034
PC3	0.096	0.185	0.268	0.605

Statistical significance * $p < .05$.

estimated parameters β , can be interpreted as the change in the odds for the probability the participants will submit their BP for financial aid evaluation. Positive values for β , implies that increasing X_i will increase this probability; negative values implies the opposite (Gujarati, 2004).

The variables included in the model are those identified by the previous PCA analysis, and in particular, the sum of the scores assigned by the participants to the questions corresponding to the individual items.

Hence the corresponding equation is:

$$BP = \beta_1 PC1 + \beta_2 PC2 + \beta_3 PC3 \quad (4)$$

where $PC1 = \sum_{i=0}^n En2_i + En3_i + En4_i$, $PC2 =$

$$\sum_{i=0}^n Ec1_i + So1_i + En1_i$$

$$\text{and } PC3 = \sum_{i=0}^n Ec3_i + So2_i + En5_i.$$

Table 8 summarizes the results of the estimates and therefore the factors of the SE that influence participants to submit BPs for the financial aid assessment.

9. Results

The analyses carried out on the sample of participants in the Development Cooperation project made it possible to clarify many aspects related to self-efficacy in rural contexts such as the Kroumerie-Mogod region. The correlation table of the questionnaire items that have been developed, shows a strong correlation between social and environmental items. It is surprising how the economic elements are, on the other hand, much less significantly correlated to all the others (Table 5).

However, the questionnaire was found reliable, both considering the set of all items, and considering the aggregates in the three main ar-

eas of investigation, economic, social and environmental (Table 6).

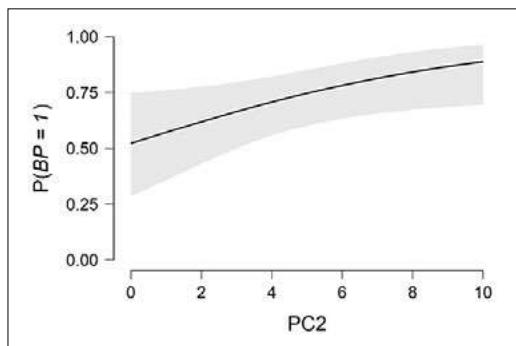
As for the PCA analysis, it was possible to highlight the existence of four different main components, with an explanation of the variance of over 70 percent. The first of the three considered, concerns the environmental sphere, which is related to water management and the use of energy from renewable resources. This denotes how the experiences and skills acquired in environmental issues represent great importance for participants in promoting their own entrepreneurial project.

The second and third principal components are however more transversal and take into consideration all three dimensions of sustainability (economic, social, environmental) investigated by the questionnaire. The participant's experiences related to commercial, social and waste management issues on the one hand, and to building with local materials, knowledge of local traditions and skills regarding the sustainable exploitation of resources on the other hand, allow them to face the challenges related to the development of their own business project.

At the same time, it is interesting how the experiences regarding the awareness of environmental issues do not emerge as a principal component of the participant's SE.

The second of these three variables analysed, is the one with a statistically significant influence on the probability of an individual promoting a personal business project. This result confirms the hypothesis that a strong SE positively affects the participants' decision to submit the BP. Figure 2 shows how an increase in the ag-

Figure 2 - Probability to submit the BP based on PC2.



gregate scores of the items of PC2 positively affects the probability that the young entrepreneur promotes and submits the BP.

This result offers the key to understanding how SE can affect the entrepreneurial initiative of rural populations. The experiences in the commercial field and in the social commitments sphere, together with skills acquired in the field of waste management, have a decisive and significant impact in the promotion of personal entrepreneurial projects in agri-food sector.

10. Conclusions

In the rural context characteristic of African countries, agriculture can make a decisive contribution to a sustainable development of the Mediterranean area. Tunisia is one of the major countries in north Africa but the agri-food sector, despite the great opportunities offered by the territory, still remains afflicted by a strong lack of private investment and infrastructure, which limits Tunisian farming productivity (Boughzala and Tlili Hamdi, 2014).

Young entrepreneurship in agri-food sector is considered as one of the main elements for embarking on a path towards sustainable development that can significantly contribute to improve the lives of the inhabitants of the African countries. This study proposed an unprecedented analysis in Tunisia, investigating the self-efficacy of the participants in the “Start-up Tunisie” project and identifying a positive relationship between some of their experiences, and their willingness to effectively promote own entrepreneurial projects.

In the North African context, Development Cooperation projects plays a crucial role in knowledge transfer and in the adaptation of tools, methodologies, practices or organizational models, to support decisively new start-ups. This investigation represents a first step towards a more in-depth analysis of the self-efficacy in rural context and its relationship with the effectiveness of Development Cooperation (Picciotto, 2002).

The project financed fifteen start-ups and the results of the activities were satisfactory. The improvement of the production, processing and

distribution structures has resulted in an increase in revenues and employees, as well as in a general emergence of informal jobs. A year after the start of the project, all the companies implemented their activities and improved their economic outlook. In the year following the financing, 10 out of 15 companies exceeded the estimated revenues at the start of the project, while 7 companies hired new employees.

Some companies represent clear examples of good practices with respect to the standards of the socio-economic contexts in which they operate and commercial relationships have been created among the various beneficiaries, which amplify the positive effect at the local level.

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Changement climatique et stratégies d'adaptation des exploitations irriguées privées dans le Sud-est Tunisien : Cas de la zone de Gabès-nord

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JEL codes: Q25, Q54, R15

Abstract

The objective of this study is to analyze the individual strategies and determinants of adaptation to climate change (CC) of irrigators in South-Eastern Tunisia. A survey questionnaire was administered to 157 randomly selected farm managers in the Gabès-North area, and descriptive statistics and a multinomial logistic model were used to analyze the data collected from irrigants. The climate variability felt by irrigants is explained by a decrease in precipitation and by an increase in temperature. To address this, two adaptation strategies are distinguished. A first category is called defensive. It aims to adapt production systems to the water available on the farm taking into account existing wells and boreholes. The second category is called offensive. It consists of investing in acquiring the water needed to maintain the farm's production system. The main determinants of adaptation are given by the perception of CC, by the diversification of sources of income, by the farmers' age, by education and by access to extension services.

Keywords: Climate change, Adaptation strategies, Determinants, Multinomial logit model, South-Eastern Tunisia.

1. Introduction

Dans un contexte d'exploitation croissante des ressources en eau et des risques de changements climatiques, la gestion de la ressource en eau est devenue une préoccupation majeure du monde entier (Blinda et Thivet, 2009). Particulièrement concernée, la Tunisie se place dans la catégorie des pays les moins dotés en ressources en eau et les plus exposés aux impacts des changements climatiques (MAE et GIZ, 2011 ; Grami et Ben Rejeb, 2015) dans le bassin méditerranéen. Au-

jourd'hui, l'agriculture est l'un des secteurs les plus directement affectés par le changement climatique. À l'échelle du pays, les changements climatiques se traduisent par une augmentation de la fréquence et de l'intensité des années extrêmes sèches et une baisse de la pluviométrie moyenne de 11 à 29% du nord au sud par rapport à la période de référence (1961-1990). Ces changements entraîneront également une réduction des ressources en eau disponibles pouvant aller jusqu'à 30% pour les eaux souterraines et 5%

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pour les eaux de surface (MAE et GIZ, 2011 ; Ben Nouna *et al.*, 2018).

L'accroissement très prononcé de la variabilité spatiale et temporelle du climat et de la fréquence et de l'ampleur des phénomènes extrêmes de sécheresse, conséquences directes des changements climatiques, sont déjà une réalité dans le Sud-est tunisien (Jeder *et al.*, 2013 ; Sghaier et Ounalli, 2013). L'impact de ces événements sur l'agriculture irriguée est multiforme (Frija *et al.*, 2016 ; Mahdhi *et al.*, 2019). Il pèse sur les ressources en eau souterraine (épuisement et salinité), sur l'augmentation des besoins d'irrigation, sur la baisse de la production des cultures et de leurs rendements, mais également sur l'accroissement de la vulnérabilité du secteur irrigué, en particulier, de petites exploitations familiales, qui ont de capacités limitées pour s'adapter (Jeder *et al.*, 2013 ; Frija *et al.*, 2016). Face à ces évolutions, dans plusieurs régions les irrigants se trouvent obligés à investir toujours plus pour continuer de disposer d'eau douce en quantité suffisante pour leurs cultures, soit à modifier leurs systèmes de cultures pour s'adapter à la rareté et la surexploitation des ressources en eau souterraine (Frija *et al.*, 2016 ; Mahdhi *et al.*, 2019). Les petites exploitations familiales, qui ont des capacités limitées de creuser toujours plus profond ou de partir pour continuer leurs activités dans d'autres régions, sont aujourd'hui les plus vulnérables au changement et à la variabilité climatique. Aujourd'hui en l'absence d'intégration de la volatilité climatique à la politique nationale de l'eau du pays les différences s'accroissent entre les exploitations agricoles qui ont les moyens d'investir toujours plus pour avoir suffisamment d'eau et celles qui doivent adapter leurs cultures à la pénurie (Faysse *et al.*, 2011 ; Mahdhi *et al.*, 2019). Ainsi, des voies alternatives doivent donc être trouvées, à la fois en termes de conception et de viabilité des mesures d'adaptation innovantes à mettre en œuvre pour atténuer les effets des changements climatiques et soutenir la durabilité du secteur irrigué en zones arides.

Aujourd'hui l'ampleur des enjeux des changements climatiques sur l'agriculture sont inévitables et soulèvent la question de l'adapta-

tion à la rareté des ressources en eau en zones arides (Iglesias et Garrote, 2015 ; Leroy, 2019). L'adaptation a été considérée par beaucoup comme le moyen le plus efficace de réduire les impacts négatifs du changement climatique (De Perthuis *et al.*, 2010). En agriculture l'adaptation au changement climatique se réfère à l'ajustement dans les systèmes agricoles en réponse aux stimuli climatiques réels ou prévus ou à leurs effets, ce qui modère les dommages ou exploite des opportunités bénéfiques (GIEC, 2001). La perception et l'adoption des stratégies d'adaptation étaient les deux composantes clés de l'adaptation en agriculture (Yegbemey *et al.*, 2014) où toutes perceptions faussées peuvent conduire à des comportements inappropriés en termes d'adaptation. Cela signifie que les agriculteurs doivent d'abord percevoir un changement dans les conditions climatiques et ensuite mettre en œuvre un ensemble de stratégies pour y remédier. En revanche, en agriculture la majorité des études d'adaptation à ce jour mettent l'accent sur le changement climatique et la variabilité en général à travers un large éventail de mesures d'adaptation privées établies et innovantes (Wheeler *et al.*, 2013 ; Alam, 2015). Les études portant spécifiquement sur l'adaptation à la rareté des ressources en eau et les déterminants d'adaptation dans un contexte de changement climatique restent très peu documentées (Faysse *et al.*, 2011 ; Van Steenbergen *et al.*, 2015). Ce qui soulève les questions suivantes : Comment les acteurs du monde agricole ; les irrigants perçoivent-ils ces changements climatiques et comment réagissent-ils dans une zone tel que le Sud-est tunisien à forte contrainte climatique, très vulnérables aux risques de surexploitation des ressources en eau souterraine et d'intrusion marine (Minoia et Guglielmi, 2008 ; Frija *et al.*, 2016). A cette fin, l'objectif de cette étude est d'explorer d'une part, les perceptions concernant les changements à long terme des variables climatiques vécus par les irrigants et d'autre part, d'identifier et d'hierarchiser les pratiques d'adaptation individuelles préférées et les déterminants socioéconomiques d'adaptation ainsi que les contraintes d'adaptation. Deux hypothèses sont avancées. (i) les irrigants perçoivent clairement les changements climatiques

à travers les modifications d'un ou de plusieurs facteurs climatiques qui se répètent dans leur terroir, (ii) les irrigants adoptent des stratégies diversifiées pour s'adapter et réduire leur vulnérabilité aux conséquences des changements climatiques qu'ils ont observés. Le reste de ce travail est structuré de la manière suivante : la section 2 présente les aspects méthodologiques. Celle-ci comprend une clarification du cadre conceptuel, une présentation de la zone d'étude et des données collectées, une présentation du modèle empirique et conceptuel ainsi que des variables explicatives. La session 3 présente l'analyse des résultats. La conclusion et les enseignements sont présentés dans la session 4.

2. Matériels et méthodes

2.1. Cadre théorique

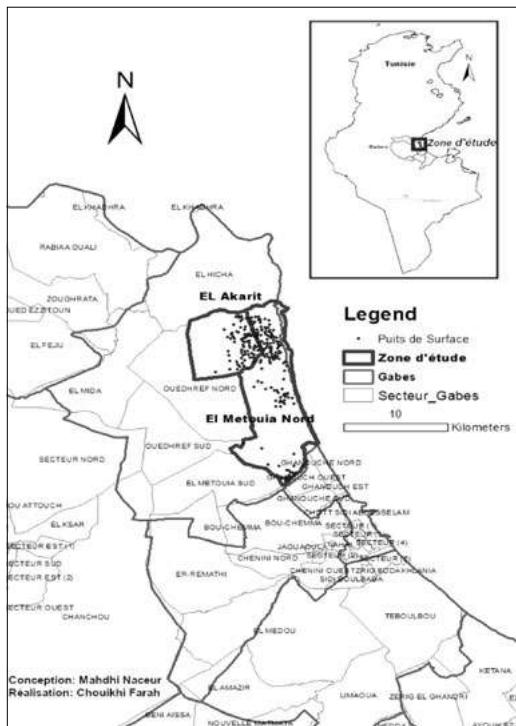
L'adaptation au changement climatique a reçu une attention accrue dans le débat scientifique et politique et est de plus en plus un sujet d'intérêt tant pour les producteurs que pour les décideurs (GIEC, 2001 ; Vissoh *et al.*, 2012). L'adaptation à la rareté des ressources naturelles est essentielle, en particulier à la lumière du changement climatique, et peut être poursuivie sous la forme d'une adaptation individuelle, collectif ou publique (Mendelsohn, 2000 ; Leroy, 2019). Dans le contexte des eaux souterraines, ils concernent la réduction de la vulnérabilité des systèmes tributaires des eaux souterraines au changement climatique et à la variabilité hydrologique. La perception des effets du CC et l'adoption des stratégies d'adaptation sont les deux composantes clés de l'adaptation en agriculture (Yegbemey *et al.*, 2014). Elles sont généralement liées. Bien que les perceptions ne soient pas nécessairement cohérentes avec les analyses climatologiques, elles doivent être prises en compte pour relever les défis socioéconomiques (Omar *et al.*, 2015). Cela signifie que les agriculteurs doivent d'abord percevoir un changement dans les conditions climatiques et ensuite mettre en œuvre un ensemble de stratégies d'adaptation, qui restent influencées aussi par les caractéristiques socio-économiques des ménages et par

leurs environnements physique et institutionnel (Hassan et Nhémachena, 2008 ; Deressa *et al.*, 2009). Cette étude repose sur une mise en perspective des relations entre les perceptions du CC, les caractéristiques socio-économiques des ménages et les stratégies d'adaptation individuelles des irrigants. Plusieurs approches théoriques et empiriques permettent de caractériser les facteurs influençant les décisions des producteurs dans l'adoption des technologies en agriculture (Nhémachena *et al.*, 2014 ; Elum *et al.*, 2017). La mise en perspective entre les différentes variables s'est faite à l'aide des méthodes de statistiques descriptives et de régression logistique multinomiale, qui permettent d'analyser la perception, les stratégies d'adaptation et les facteurs déterminants d'adoption dans le sud-est Tunisien.

2.2. Zone d'étude et collecte de données

L'étude a été réalisée dans la zone de Gabès-Nord située dans le Sud-est Tunisien. Il s'agit d'une plaine côtière. Administrativement, elle relève des délégations de Ghanouch et de Mettouia (Figure 1). Le choix de cette zone a été justifié par sa forte vulnérabilité aux contraintes climatiques et aux problèmes de surexploitation des ressources en eau souterraine et de risque d'intrusion marine (Minoia et Guglielmi, 2008 ; Frija *et al.*, 2016 ; Hamed, 2017). L'agriculture irriguée constitue l'activité économique principale dans cette région. Elle couvre une superficie de 2004 ha soit 33,6% de la superficie totale des périmètres irrigués privés du Gouvernorat de Gabès (ODS, 2018). Sur le plan climatique, cette zone se trouve dans l'aire isoclimatique méditerranéenne (à pluie hivernale et été sec). Les ressources en eau souterraine représentent le principal potentiel hydrique exploitable dans cette zone. Ces ressources sont formées par deux types d'aquifères ; une nappe phréatique se trouve dans l'aquifère sédimentaire mio-plio-quaternaire sur une épaisseur de 20 à 60 m et la nappe profonde de la Djeffara. Les deux aquifères subissent de fortes pressions qui ne cessent de s'accroître à la suite d'un accroissement et d'une extension remarquable du potentiel irrigable aux dépens des terres des parcours et de l'accroissement incon-

Figure 1 - Présentation de la zone d'étude.



trôlable des puits de surface « sondés » et illicites qui dépassent 453, malgré l'instauration de la zone d'interdiction en 1987 et la création de GDA d'irrigation en 1999 dans cette région (Abidi et Ghoudi, 2011 ; Leghrissi, 2012). Les niveaux de salinité sont relativement élevés : environ 4 g/l au plus pour la nappe phréatique, et de 2,9 à 4,9 g/l pour la nappe profonde

(DRE, 2016). Ces facteurs mettent en exergue la vulnérabilité du sud-est Tunisien aux changements climatiques et la nécessité d'adaptation des agriculteurs.

Une combinaison d'approches qualitatives (des interviews semi structurées de groupes informels et individuels, des observations participantes et des transects participatifs) et quantitatives, moyennant des enquêtes approfondies, ont été utilisées. Deux périmètres irrigués privés ont été choisis de façon raisonnée pour l'étude approfondie en fonction de leur vulnérabilité au changement climatique, de surexploitation des ressources en eau souterraine et de risque d'intrusion marine. Il s'agissait des périmètres irrigués privés de Gannouch et de Bsissi Oued El Akarit. La collecte de données a été faite grâce à un questionnaire portant sur 157 exploitants sélectionnés d'une manière aléatoire et proportionnel à l'effectif total des puits de surface par périmètre irrigué au cours de la campagne agricole 2016-2017. Le Tableau 1 montre la structure de l'échantillon par périmètre.

Les principales données collectées ont concerné les caractéristiques démographiques et socioéconomiques des ménages, les perceptions de changements des facteurs climatiques (température, précipitations, etc.) et les perceptions de la rareté des ressources en eau souterraine (niveau de profondeur des puits, salinité). Des informations sur les mesures d'adaptation individuelles adoptées et leur priorisation moyennant une échelle de Likert à quatre points de 0 à 3², et sur

Tableau 1 - Structure de l'échantillon d'étude.

Zone géographique	Nappe phréatique	Périmètres irrigués	Nombre des puits de surface	Taille de l'échantillon	Taux de sondage (%)
Délégation de Metouia	Gabes Nord	Bsissi	303	105	67
Délégation de Gannouch	Gabes Nord	EL Eroug	150	52	33
Total			453	157	100

DRE, 2016 ; ODS, 2018.

¹ La majorité des puits de surface ont été « sondés » leurs profondeurs ont progressivement augmenté, allant généralement au-delà de 50 mètres, pour atteindre les couches à 70-80 m et même à 130 m, traversant ainsi l'aquifère phréatique pour atteindre le plus profond (DRE, 2016).

² Le score « 0 » indique le niveau d'importance le plus bas et le score « 3 » indique le niveau d'importance le plus élevé.

les contraintes d'adaptation ont également été collectées. Ces données ont été obtenues à partir des focus group et des entretiens semi-structurés et informels. Le traitement et l'analyse statistique des données collectées ont été réalisés avec les logiciels Word, Excel et SPSS.

2.3. Déterminants d'adaptation au changement climatique : modèle empirique et variables explicatives (titre changé et texte reformulé)

Face à la variabilité du climat, lorsque le choix d'un agriculteur est de s'y adapter, l'ajustement consistera à utiliser une stratégie ou une combinaison de stratégies parmi un ensemble fini et exhaustif de possibilités mutuellement exclusives. Il s'agit d'une modélisation du comportement des producteurs suivant plusieurs alternatives. Du point de vue économétrique, un modèle de choix discret apparaît donc approprié pour appréhender les aspects rationnels du comportement de l'agriculteur et identifier les facteurs explicatifs de chaque alternative qu'il choisit. Ainsi les modèles multinomiaux sont donc les plus indiqués. Plusieurs approches théoriques et empiriques permettent de caractériser les facteurs influençant les décisions des producteurs dans l'adoption des technologies en agriculture (Yegbemey *et al.*, 2014 ; Nhémachena *et al.*, 2014). Les approches analytiques le plus souvent utilisées dans les études de décision portant sur l'adoption à choix multiple sont le logit multinomial (LMN) et le probit multinomial (PMN) (Hassan et Nhémachena, 2008 ; Yegbemey *et al.*, 2014). L'utilisation d'un modèle logit LMN pour analyser les déterminants des décisions des agriculteurs dans des études de décision d'adoption impliquant des choix multiples et plus facile à calculer que son alternative, le PMN. Ce modèle fournit une forme fermée pratique pour les probabilités de choix sous-jacentes, sans avoir besoin de l'intégration la méthode multivariée, ce qui facilite le calcul des situations de choix caractérisées par de nombreuses alternatives (Bryan *et al.*, 2009 ; Uddin *et al.*, 2017). C'est ainsi que dans le cadre de cette étude un modèle de régression logistique multinomial (MNL) est utilisé.

2.3.1. Cadre d'analyse et modèle économétrique

Face à la variabilité du climat, lorsque le choix d'un agriculteur est de s'y adapter, l'ajustement consistera en l'utilisation d'une stratégie ou d'une combinaison de stratégies parmi un ensemble fini et exhaustif de possibilités mutuellement exclusives. Du point de vue économétrique, un modèle de choix discret apparaît donc approprié pour appréhender les aspects rationnels du comportement de l'agriculteur et identifier les facteurs explicatifs de chaque alternative qu'il choisit. Dans le cadre de cette étude, nous utilisons le modèle Logit Multinomial (MNL) après avoir pris soin de vérifier la validité du modèle, c'est-à-dire qu'il y a indépendance des alternatives non pertinentes.

Le modèle LMN est basé sur la maximisation d'une fonction d'utilité aléatoire (Nhémachena *et al.*, 2014). La variable dépendante est une variable multinomiale et à modalités non ordonnées. Désignons par $j = 0, 1, \dots, h$; les différentes alternatives (stratégies) possibles ; par $X = 1, 2, \dots, t$; les variables explicatives et par i l'individu. Dans cette étude, les options d'adaptation ou les probabilités de réponse sont de deux, comme décrit dans la section ci-dessous (Tableau 1). Pour chaque choix j , l'individu i perçoit une utilité

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \quad (1)$$

ou $\beta_j X_{ij}$ est la partie déterministe de la fonction d'utilité et ε_{ij} la partie aléatoire. β_j , représente les paramètres associés à la variable explicative X_i pour une alternative j donnée ; la variable explicative étant un facteur déterminant de l'adoption des stratégies. Soit Y_{ij} une variable qui prend la valeur 1 si l'individu i choisit l'alternative j et zéro si non. Ainsi la probabilité que le choix j de l'individu se réalise est :

$$P(Y_{ij} = 1) = P(U_{ij} \geq U_{in}), \text{ avec } j \neq n \quad (2)$$

La probabilité que l'agriculteur i choisisse la stratégie j est traduite dans le modèle logit multinomial par (Uddin *et al.*, 2017) :

$$\begin{aligned} P(Y_i = j/X_i) &= \frac{\exp(X_i\beta_j)}{\sum_{k=0}^m \exp(X_i\beta_k)} = \\ &\frac{\exp(X_i\beta_j)/\exp(X_i\beta_0)}{[\sum_{k=0}^m \exp(X_i\beta_k)]/\exp(X_i\beta_0)} = \\ &\frac{\exp[(X_i(\beta_j - \beta_0)]}{\sum_{k=0}^m \exp[(X_i(\beta_k - \beta_0)]} \end{aligned} \quad (3)$$

Avec $\beta_j \in R^k$ le vecteur des coefficients des variables explicatives x pour la stratégie j.

En posant $\beta_j^* = \beta_j - \beta_0, \forall j$, on obtient $\beta_0^* = 0$. Ce changement de variable donne une expression de la probabilité similaire à celle de l'équation (2).

$$(P(Y_i = j/X_i) = \frac{\exp(x_i \beta_j^*)}{\sum_{k=0}^m \exp(x_i \beta_k^*)} = \frac{\exp(x_i \beta_j^*)}{1 + \sum_{k=1}^m \exp(x_i \beta_k^*)} \quad (4)$$

Cette transformation conduit à normaliser les paramètres et à lever l'indétermination du modèle. Les paramètres du modèle correspondent désormais aux différences entre les paramètres originaux β_j et le vecteur de paramètre de la modalité de référence β_0 . Les coefficients estimés ne sont pas directement interprétables, ils servent plutôt à donner une orientation sur la nature de la relation entre la variable dépendante et les variables explicatives. Seuls les effets marginaux doivent être interprétés. On doit donc calculer les effets marginaux. Les effets marginaux sont obtenus en dérivant les probabilités par rapport aux variables explicatives.

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j(\beta_j - \sum_{k=1}^m P_k \beta_k) = p_j(\beta_j - \bar{\beta}_k) \quad (5)$$

L'évaluation du modèle s'est faite à partir des tests de vraisemblance (la moins double logvraisemblance) et le niveau d'adéquation. Les paramètres des régressions sont testés par la statistique de Wald qui se distribue selon la loi Chi2 à un degré de liberté.

2.3.2. Sélection des variables explicatives

Les variables explicatives de la régression logistique (modèle LMN) ont été sélectionnées en fonction de l'analyse de la littérature et de la disponibilité des données (Deressa *et al.*, 2009 ; Tun Oo *et al.*, 2017). Les variables explicatives sont données par la perception des ménages du changement climatique et par leurs caractéristiques socio-économiques. Le Tableau 2 présente la liste des variables explicatives et les signes attendus des paramètres.

Ainsi deux stratégies d'adaptation ont été modélisées. Il s'agit d'une stratégie défensive et offensive. Les variables explicatives sont données par la perception des ménages du changement climatique et par leurs caractéristiques socio-économiques. Les variables de perception sont des variables dichotomiques qui prennent la valeur 1, si l'irriguant perçoit le CC et les risques climatiques (rareté et surexploitation des ressources en eau) et 0 sinon

Tableau 2 - Liste des variables du modèle et les signes attendus des paramètres.

Variables	Types ^a	Description des variables	
Adoption	D	Variable dépendante : prend la valeur 1 s'il y a adoption d'une stratégie d'adaptation et 0 sinon	
<i>Variables explicatives du modèle</i>			
Perception	D	Perception de CC (1= si l'agriculteur perçoit le CC et le risque climatique et 0 sinon).	+
<i>Variables socio-économiques</i>			
Age du chef de ménage	C	L'âge en années du chef d'exploitation	+/-
Niveau d'éducation	D	Prend la valeur 1 s'il s'agit d'un niveau d'étude secondaire et 0 si non	+
Taille du ménage	C	Nombre de personnes en charge dans le ménage	+/-
Encadrement technique	D	Prend la valeur 1 si il y a accès aux services de vulgarisation et 0 sinon	+
Taille de l'exploitation	C	Superficie irrigable	+
Activité secondaire	D	Prenant la valeur 1 si l'individu a une activité secondaire et 0 si non	+
Contrainte financière	D	La contrainte de l'exploitation est le manque de moyen financier (1oui, 0non)	-
Revenu agricole	C	Revenu annuel agricole	+

Tableau 3 - Caractéristiques socio-économiques et démographiques des agriculteurs interrogés.

<i>Variables qualitatives</i>	<i>Valeurs absolues</i>	<i>Fréquences relatives (%)</i>
Droit de propriété sur la terre	135	86
Education	72	46
Activité secondaire	50	32
Contact avec un vulgarisateur	55	35
Contrainte financière	57	36
Accès facilité au crédit	31	20
Variables quantitatives	Moyennes	Écarts types
Age	51	15,7
Expérience agricole	23	9
Taille de ménage	4,6	2,34
Superficie irriguée	12,2	10,6
Revenue annuel agricole	19900	27050

Résultats de nos enquêtes.

(Percep.). L'effet attendu de cette variable est positif. Les variables socio-économiques sont : le niveau d'instruction (instruction), l'âge de l'exploitant (âge), la taille du ménage (ménage), la taille de l'exploitation (superficie), le revenu annuel agricole (Rag), la pratique d'une activité secondaire, l'accès à l'encadrement/vulgarisation (encadrement) et la contrainte financière (CF). L'effet de ces variables varie selon la stratégie adoptée. L'encadrement et le revenu devraient avoir un effet positif car ils devraient stimuler l'adoption des stratégies adaptatives. La régression logistique multinomial a été faite avec le logiciel STATA 13.0.

3. Résultats et discussion

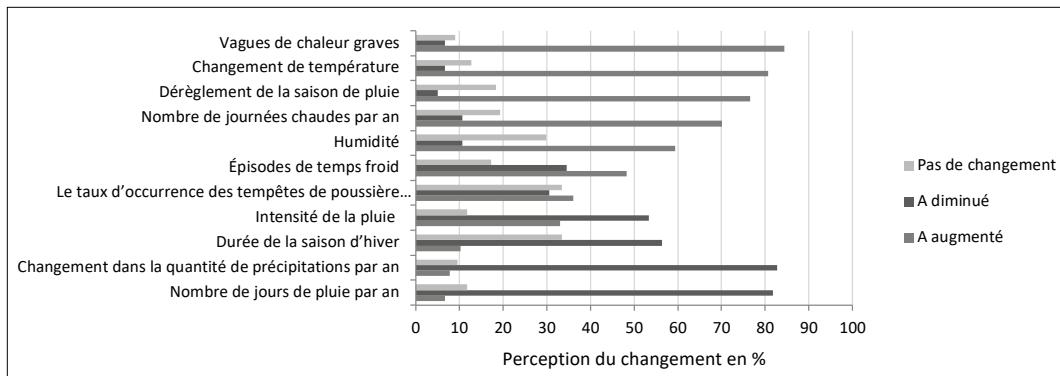
3.1. Caractéristiques des agriculteurs enquêtés

Les caractéristiques démographiques et socio-économiques des irrigants interrogés sont résumées dans le Tableau 3. L'âge moyenne de chef d'exploitation familiale est de l'ordre de 51 ans,

dont le plus jeune est à l'âge de 30 ans et celui le plus âgé est de l'ordre de 78 ans. Le niveau d'instruction reste relativement faible avec 41% de la population ayant atteint le niveau secondaire et 14% seulement de l'échantillon ayant fait des études supérieures, l'un tiers s'arrêtant au primaire. Le pourcentage des individus n'ayant reçu aucune instruction dans les exploitations enquêtées est de l'ordre de 11%. Les modes de faire-valoir de la terre dans la zone d'étude sont l'héritage, le don, l'achat, et la location. L'accès à la terre à travers ces modes confère différents droits de propriété. Ainsi, 86% des personnes interrogées ont affirmé être propriétaires de leurs terres. L'agriculture est l'activité principale de 80% des personnes interrogées. Il s'agit d'une agriculture essentiellement irriguée. En plus de l'agriculture, 32% des producteurs interrogés possèdent une activité secondaire. Le commerce et les petits métiers sont les activités secondaires les plus exercées³. Le nombre d'actifs agricoles par mé-

³ D'abord, le commerce représente une activité phare de ces producteurs : 25% de ceux qui sont interrogés le font au moins durant une partie de l'année. Ce secteur est lié à l'agriculture. Les transactions commerciales restent dominées par les produits agricoles (oignon, carotte, courge, courgette, etc.) et ces producteurs vendent leurs propres récoltes. C'est ainsi que le commerce de fruits et légumes est très prospère dans la région de Gannouch. Cette activité peut générer des revenus pouvant aller de 4000 DT à 6000 DT/an. Mais, le développement des transactions commerciales est, souvent, tributaire d'une bonne production agricole, donc les effets de la péjoration climatique peuvent impacter négativement sur ce secteur. L'autre activité que nous avons relevée est l'exercice d'autres métiers par 7% des producteurs enquêtés comme la maçonnerie, les tailleurs, les artisans, les mécaniciens... etc. Ces secteurs sont moins développés. Mais, ils permettent tout de même aux producteurs de diversifier leurs revenus.

Figure 2 - Perception des changements de facteurs climatiques en (%).



nage est en moyenne de 1,5 ($\pm 0,7$) personnes et l'expérience en agriculture est de 24 (± 9) ans. Les enquêtés emblavent en moyenne 12,2 ha ($\pm 10,6$) et consacrent à l'agriculture une moyenne de 963,8HJ par an. Par ailleurs, il ressort également du Tableau 2 que 65% des exploitants n'ont pas bénéficié des services d'encadrement et de vulgarisation et 80% n'avaient pas un accès facilité au crédit agricole à cause de risque d'endettement, de conditions d'accès difficiles (bureaucraties, formalités administratives, garanties) et des taux d'intérêts élevés (de 14% à 16%) pour les crédits de moyen à long terme.

3.2. Perceptions du changement climatique

La quasi-totalité des irrigants interrogés dans la zone d'étude (98%) a perçu des changements de facteurs climatiques durant les vingt dernières années qui ont eu des répercussions directes sur le secteur irrigué et sur la rareté des ressources en eau souterraine. Les perceptions les plus citées étaient une baisse des précipitations, un dérèglement de la saison des pluies, une plus grande irrégularité des pluies, une augmentation des températures et des vents plus violents et par l'augmentation du taux d'occurrence des phénomènes météorologiques extrêmes (Figure 2).

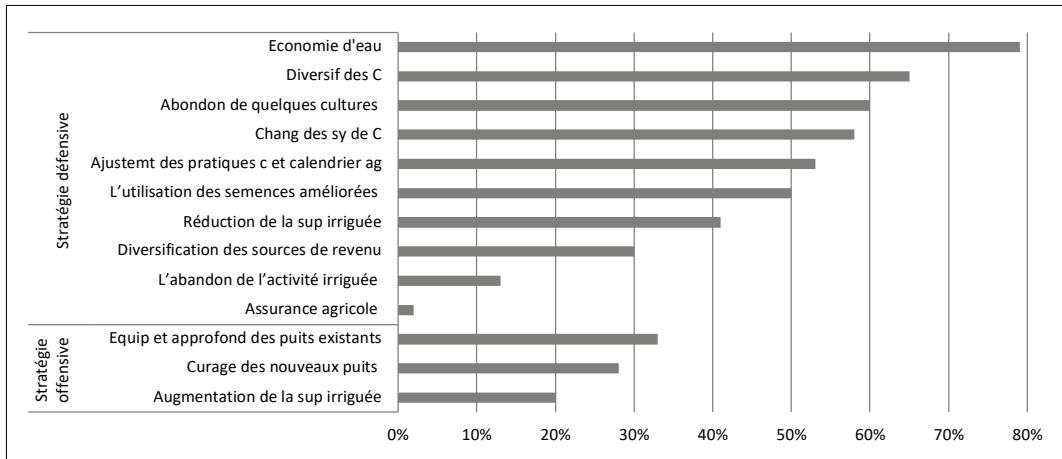
Les irrigants perçoivent clairement les changements climatiques. Ainsi, 90% des irrigants

perçoivent que les précipitations ont changé. La diminution des pluies (83%) et des pluies de plus en plus aléatoires et sporadiques (75%) sont les principales perceptions des changements liés aux précipitations. Le dérèglement de la saison des pluies est perçu par 76,6% des exploitants. Ce phénomène se manifeste par une diminution de la durée de la saison des pluies, la réduction du nombre de jours de pluie (82%) et la réduction de l'intensité journalière des précipitations (53%). Viennent ensuite le décalage des saisons avec une tendance à la réduction de la saison d'hiver (56%). Quant à la température, 87% des enquêtés perçoivent des variations thermiques se manifestant par l'augmentation du nombre de jours chauds (70%), l'augmentation des vagues de chaleur (84%) et le changement des extrêmes de températures (87%) qui se traduit par des périodes plus chaudes ou plus froides. Enfin, 67 % des producteurs interrogées percevaient d'autres changements tels que des vents plus forts (36%) et une augmentation de l'humidité (59%).

L'étude a également révélé que les agriculteurs avaient des perceptions différentes de l'impact du CC sur la rareté des ressources en eau souterraine dans la zone d'étude. Les impacts mentionnés par plus de 85% des irrigants comprenaient l'augmentation des prélèvements et besoins d'irrigation (80%), la baisse des niveaux piézométrique de la nappe phréatique suite au déficit de la recharge (75%)⁴, diminution du débit artésien

⁴ Dans les années 1970 et 1980, le niveau piézométrique de l'aquifère côtier de Gabès Nord se trouvait sur l'isopique entre 20 et 25 mètres. En 1998, en raison de l'augmentation du nombre de puits illégaux, le niveau piézométrique a chuté de 10 mètres, ce qui était la valeur seuil pour éviter l'intrusion maritime (CRDA Gabès, 2003).

Figure 3 - Pratiques et stratégies d'adaptation répertoriées.



(50%)⁵ et de la dégradation de la qualité de l'eau d'irrigation (35%). Les perceptions identifiées concordent avec les études mentionnées dans la littérature qui s'accordent sur une augmentation de la fréquence et de l'intensité des années extrêmes sèches et une baisse de la pluviométrie moyenne qui se traduirait par une réduction des ressources en eau disponibles (West *et al.*, 2008 ; Sarr *et al.*, 2015). Les résultats obtenus ont par ailleurs corroboré ceux d'Ouédraogo *et al.* (2010) et Omar *et al.* (2015) et qui révèlent que les populations se rendent compte de la variabilité du climat.

3.3. Pratiques et stratégies d'adaptation individuelles diversifiées

Les mesures et pratiques d'adaptation aux changements climatiques sont diverses et individuelles dans la zone d'étude. Quatre-vingts pour cent (80%) des irrigants interrogés, dans la zone de Gabès-Nord, ont développé une gamme très variée de pratiques et mesures d'adaptation (Figure 3). Les réponses spontanées les plus courantes comprenaient le recours à l'économie de l'eau (79%), la diversification des cultures (65%), l'abandon de quelques cultures (60%), le changement du système de culture (58%) et

l'ajustement des pratiques culturales et du calendrier agricole (53%). Les autres réponses incluaient, l'utilisation des semences améliorées à cycle court (50%), la réduction de la superficie irriguée (41%), équipement et approfondissement des puits existants (33%), la diversification des revenus par l'exercice d'autres métiers (32%) et creusage de nouveaux puits d'une manière illicite (28%). Les autres réponses incluaient l'augmentation de la superficie irriguée (20%) moyennant l'achat ou la location des terres plus riches en eau, l'orientation vers l'agriculture pluviale (13%) et le recours à l'assurance agricole (2%).

En termes de stratégies d'adaptation les différentes mesures d'adaptation peuvent être classées en deux types de stratégies (Figure 3).

Une première catégorie est dite offensive (S1). Elle est conçue pour la gestion de l'offre en eau d'irrigation et accroître la production. Elle comprend, principalement, le creusage de nouveaux puits, l'équipement et l'approfondissement des puits existants, et l'augmentation de la superficie irriguée à travers la location des terres plus riches en eau. Elle est adoptée par 34% des irrigants de notre échantillon qui ont montré une forte capacité d'adaptation. Cette catégorie d'agriculteurs est principalement constituée de gros agriculteurs.

⁵ L'augmentation des puits équipés du moteur a des impacts évidents, en particulier en termes de diminution du débit artésien, qui passe de 10-25 l/s à 4 l/s, avec des valeurs moyennes de 0,5 et à 1 l/s (CRDA Gabès, 2003).

teurs (70%) de notre échantillon qui investissent à la fois dans l'appropriation de l'eau et dans les technologies d'économie d'eau. Ce groupe d'agriculteurs irrigue de grandes superficies qui dépassent les 10 ha. Les cultures maraîchères et les cultures fourragères consommatrices d'eau ont laissé la place à des plants d'olivier à huile qui occupent 73% de la superficie irriguée. Ce groupe d'agriculteurs a suffisamment de moyens financiers pour investir dans d'autres zones. L'acquisition ou la location des terres agricoles dans d'autres zones sont pratiquées par 20% des cas qui ont choisi de se déplacer vers les régions de Temoula (Gabès-sud), Matmata et Ouedhref pour s'y installer soit par le biais de la location ou carrément l'achat de nouvelles terres. Dans ces zones, les agriculteurs ont choisi de se spécialiser dans la culture de l'olivier surtout la variété « Chemlali » et, plus récemment, des variétés espagnoles telle que « l'Arbequina » et « l'Arbosana » avec une densité moyenne de 270 pieds par hectare et un effectif moyen de 2589 pieds par exploitation. En moyenne ces actions sont considérées comme des mesures d'adaptations positives dans la mesure où elles améliorent la capacité des irrigants à une telle variabilité climatique. Néanmoins leur généralisation est susceptible d'aggraver les impacts des changements climatiques et d'engendrer des pressions sur les ressources en eau souterraine et met en question la durabilité de ses pratiques sur le plan économique et environnemental et accroître le risque pour le secteur irrigué et de la vulnérabilité en particulier des petites exploitations familiales, qui ont des capacités limitées pour s'adapter.

La deuxième catégorie est dite défensive ou « adaptative » (S2). Elle est conçue pour la gestion de la demande en eau d'irrigation à l'échelle de l'exploitation. Elle vise à adapter les systèmes de production à l'eau disponible sur l'exploitation compte-tenu des puits et forages existants. Elle comprend l'économie de l'eau d'irrigation (irrigation goutte à goutte), les ajustements du

calendrier agricole, l'abandon des cultures maraîchères consommatrice en eau (pomme de terre, tomate, laitue et melon) et arboricoles très vulnérables à la variabilité climatique (pommier, d'abricotier et de pêcher)⁶ et l'introduction de la culture de l'olivier (variétés locale « Chemlali » et espagnoles « l'Arbequina » et « l'Arbosana » pour une densité de 270 pieds/ha et une moyenne de 749 pieds par exploitation). Elle est adoptée par 66% des exploitations dont 72% sont des exploitations de taille moyenne comprise entre 5 et 10 ha. En moyenne ces actions sont considérées comme des mesures d'adaptation positives et générales que les exploitations devront continuer d'adopter à l'avenir pour améliorer la capacité d'adaptation des irrigants à une telle variabilité climatique et maintenir la productivité du secteur irrigué.

Les différentes mesures et stratégies d'adaptation identifiées apparaissent pertinentes et concordent avec les stratégies d'adaptation individuelles avancées par la littérature. Ces stratégies montrent à la fois des points communs et des spécificités par rapport à d'autres stratégies d'adaptation au changement climatiques avancés par Berahmani *et al.* (2012), Wheeler *et al.* (2013), Alam (2015), et Faysse *et al.* (2011). Néanmoins, le nombre et la diversité des adaptations mises en place par les irrigants indiquent une réelle volonté de minimiser la pénurie des ressources en eau souterraine et les impacts des changements climatiques. Cependant, si certaines sont bien adaptées aux changements décrits (diversification des sources d'irrigation, conservation de l'eau d'irrigation), d'autres apparaissent comme des réponses générales (diversification des cultures et les ajustements du calendrier agricole) dénotant l'insuffisance d'efficacité des premières mesures. Le courage et l'approfondissement des puits a été également montré comme une réponse commune aux changements climatiques en Afrique du Nord et en Asie (Berahmani *et al.*, 2012 ; Alam,

⁶ Selon un responsable de la cellule Territoriale de vulgarisation de Gannouch « l'augmentation de la température ces dernières années a causé la réduction des superficies emblavées en rosacées fruitières telles que le pommier, l'abricotier et le pêcher. Ces cultures étaient assez répandues entre les années 1980 et les années 1990 puisque le nombre d'heures de froid nécessaire à la production des fruits était suffisant. Actuellement, avec l'élévation des températures, ces cultures ne reçoivent plus les heures de froid nécessaires et leur production se trouve alors affectée ».

2015). La généralisation de telles adaptations est susceptible d'aggraver les impacts des changements climatiques et d'engendrer des pressions sur les ressources en eau souterraine et accroître le risque pour le secteur irrigué et de la vulnérabilité en particulier des petites exploitations familiales, qui ont des capacités limitées pour s'adapter (MAE et GIZ, 2011 ; Iglesias et Garrote, 2015 ; Frija *et al.*, 2016 ; Jeder *et al.*, 2013). En absence de politiques spécifiques, les différences s'accroissent entre les exploitations agricoles qui ont les moyens d'investir toujours plus pour avoir suffisamment d'eau et celles qui doivent adapter leurs cultures à la pénurie d'eau (Faysse *et al.*, 2011 ; Frija *et al.*, 2016).

3.4. Priorisation et indice d'adaptation

Par ordre de priorité, moyennant une échelle de Likert à quatre points, l'économie de l'eau d'irrigation a été classée en premier rang (Tableau 4) et comme la tactique la plus sollicité. Cette priorité peut être expliquée par les subventions accordées par les pouvoirs publics pour ce type d'investissement (60% du coût d'investis-

sement), ainsi, que par la rareté très prononcée des ressources en eau souterraine dans cette zone où la mise en œuvre de techniques d'économie d'eau permettrait d'assurer une disponibilité suffisante et un accès fiable à l'eau. Toutefois, les options telle que l'irrigation goutte à goutte sont à forte intensité de capital, bien qu'elles soient la stratégie idéale contre la raréfaction des ressources en eau. Pratiquer la diversification des cultures a été identifié comme la deuxième stratégie d'adaptation. C'est une stratégie d'adaptation potentiellement viable car le fait de disposer différents types de cultures dans une ferme peut réduire le risque agricole global contre l'échec ou les pertes des rendements, et élargit les opportunités de profit. De nombreuses études ont également mis en évidence les options de diversification des cultures comme mesures d'adaptation appropriées (Uddin *et al.*, 2017 ; Evelyn *et al.*, 2017). Le changement des systèmes de cultures, l'ajustement des pratiques culturelles et du calendrier agricole, l'utilisation des semences améliorées viennent en troisième lieu et figurent également parmi les pratiques d'adaptation possibles dans la région. Cela pourrait être proba-

Tableau 4 - Priorisation des pratiques d'adaptation aux changements climatiques (n =157).

<i>Pratiques d'adaptations</i>	<i>Fréquence par niveau d'importance (%)</i>				<i>Indice de poids moyen</i>	<i>Rang</i>
	<i>Très important</i>	<i>Important</i>	<i>Moins important</i>	<i>Aucune importance</i>		
Economie d'eau	83	17	-	-	2,83	1
Diversification des cultures	75	22	13	-	2,79	2
Changement des systèmes de cultures	66	17	17		2,50	3
Ajustement des pratiques culturelles et du calendrier agricole	H64	25	8	3	2,48	4
Utilisation des semences améliorées	67	17	8	8	2,42	5
La diversification des revenus	33	25	25	17	1,75	6
Augmentation de la superficie irriguée	17	25	25	33	1,25	7
Equipement et approfondissement des puits existants	13	20	22	45	1,02	8
Réduction de la superficie irriguée	-	17	50	33	0,83	9
Assurance agricole	-	8	17	75	0,33	10

blement le résultat des changements perçus par l'agriculteur dans les régimes pluviométriques qui affectent directement la recharge des nappes phréatiques et par la suite la disponibilité des besoins en eau des cultures. La diversification des sources de revenus vient en sixième rang suivie de la location des terres plus riches en eau dans d'autres zones (Temoula (Gabès sud), Matmata et Ouedhref). Même si l'agriculture continue à être l'unique activité de 80% des producteurs rencontrés, la pluralité des sources de revenus par l'exercice d'autres métiers (commerce et petit métiers) reste l'une des pratiques recherchées et qui présente un gage de sécurité en cas de mauvaises récoltes, en particulier, pour les petites exploitations qui ont des capacités limitées pour s'adapter. Le recours à l'approfondissement des puits existants et le creusage de nouveaux puits restent parmi les pratiques les moins recherchées et restent d'une manière illicite à cause des restrictions légales imposées dans cette zone (Abidi et Ghoudi, 2011). En dernier lieu l'assurance a été classée comme la stratégie d'adaptation la moins recherchée. Cela pourrait être expliqué par l'absence de mécanismes efficaces d'assurance agricole contre les catastrophes naturelles (sécheresse et sirocco), la complexité des procédures et la lenteur de règlement des sinistres ainsi que le coût élevé des primes d'assurance, et du nombre limité des institutions financières (FAO, 2013).

3.5. Contraintes d'adaptation aux changements climatiques

Le manque d'information sur les stratégies d'adaptation, contrainte d'accès aux crédits agricoles, pénurie et coût élevé des intrants, contraintes d'accès à d'autre sources d'eau, et du manque d'accès aux marchés ont été soulevés comme principales barrières à l'adaptation (Figure 4). Le manque d'informations (44% des interrogés) porte sur un accès limité des agriculteurs à l'information provenant de sources privées ou publiques sur les mesures d'adaptation appropriées d'adaptation, en cas d'événements météorologiques extrêmes, y compris de fortes précipitations, des températures extrêmement élevées ou des températures extrêmement basses qui sont fréquemment mentionnés comme indicateurs du changement climatique. L'accès non facilité aux crédits agricoles (22%) a été identifié par les agriculteurs comme une autre contrainte majeure de l'adaptation. L'utilisation du crédit agricole dans la zone d'étude est limitée, en plus de l'accès aux facilités de micro-crédit disponibles au niveau de la ville. Le risque d'endettement et les conditions d'accès difficiles (bureaucraties, formalités administratives, garanties) à côté des taux d'intérêts élevés (de 14% à 16%) pour les crédits de moyen à long terme peuvent expliquer le moindre intérêt des agriculteurs pour les établissements de crédit formels. Enfin, l'accès à d'autres sources d'eau d'irrigations (réseau pu-

Figure 4 - Contraintes d'adaptation soulevées.

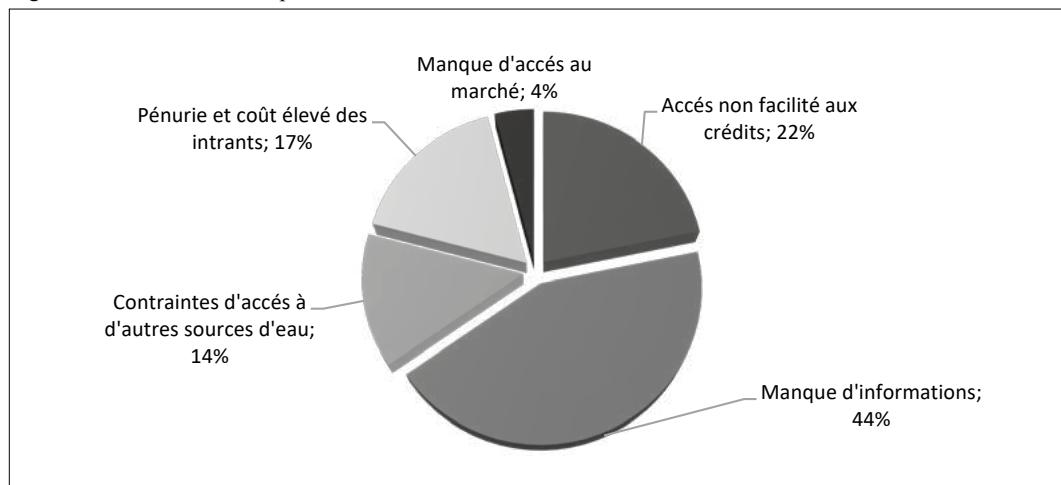


Tableau 5 - Effets marginaux des variables explicatives de l'adaptation des agriculteurs aux changements climatiques (estimation du Modèle Logit Multinomial).

Variable	Stratégie offensive			Stratégie défensive		
	coef.	Écart Type	Effet Marg.	coef.	Écart Type	Eff. Marg.
Age	0,31	0,021	-0,001	0,050	0,021	0,006*
Taille de famille	0,168	0,130	-0,009	0,273	0,130	0,035
Niveau d'éducation	1,72	0,584	0,215**	1,08	0,605	-0,066
Superficie irriguée	0,29	0,163	0,010	0,327	0,163	0,026
Revenu agricole	0,0001	0,0000	3,95e-6*	3,23e-6	0,000	3,31e-6
Activité secondaire	0,042	0,656	0,07**	1,88	0,967	0,09***
Contrainte financier	-0,236	0,771	-0,062	-0,672	0,547	-0,118
Vulgaris.	0,185	0,66	-0,057	1,99	0,798	0,221**
Perp. de CC	-0,288	0,742	-0,217**	0,843	0,692	0,240**
Observations			157			
Log pseudo-vraisemblance			-119,47			
Pseudo R ²			0,12			
Wald chi2(16)			39,49***			
Prob > chi2			0,0009			

La catégorie de base est la non-adoption d'au moins une de ces deux stratégies. Les niveaux de significativité sont respectivement : 1% (***) , 5% (**) et 10% (*).

blic et nappes profondes) et aux marchés constituent d'autres contraintes soulevées, respectivement, par 14% et 4% des producteurs.

Ces résultats ont corroboré les observations faites par d'autres études en Afrique (Gebrehiwot et van der Veen, 2013 ; Yegbemey *et al.*, 2014 ; Harmanny et Malek, 2019) qui révèlent que l'adaptation peut être limitée par de nombreux facteurs, tels que les obstacles socioéconomiques, institutionnels, biophysiques, et financiers, et, par conséquent, l'adaptation privée ne peut pas être entièrement autonome.

3.6. Déterminants des stratégies d'adaptation : Estimation du modèle économétrique

Les facteurs influençant l'adoption des stratégies d'adaptation ont été examinés à l'aide du modèle de logit multinomial (LMN). Les stratégies que nous étudions, notamment (i) l'adop-

tion d'une stratégie offensive et stratégie adaptive sont analysées en comparaison avec l'option de référence qui est la non-adoption d'au moins une de ces deux stratégies. Avant d'exécuter le modèle, le problème de multi colinéarité entre les variables explicatives a été testé moyennant respectivement le test du Facteur d'Inflation de la Variance (VIF)⁷. Le modèle a été également testé pour la validité des hypothèses de l'indépendance des alternatives non pertinentes (IIA) à l'aide du test Hausman, et il a été constaté que le modèle LMN est approprié pour cette étude. Par conséquent, la probabilité d'utiliser une certaine méthode d'adaptation par un ménage donné est supposée indépendante de la probabilité de prendre une autre méthode d'adaptation. Le Tableau 5 présente les coefficients estimés du modèle LMN, l'Écart Type, les effets marginaux et leurs niveaux de signification pour les deux stratégies d'adaptation étudiées. Les résultats montrent que le modèle estimé est globalement

⁷ Les valeurs du VIF pour l'ensemble des coefficients associés aux variables explicatives sont comprises entre 1.03 et 1.43 avec une moyenne de 1.12. Ceci indique qu'il n'y a pas de problème de multi colinéarité dans les modèles que nous allons estimer en utilisant ces variables.

statistiquement valide. En effet, la log-vraisemblance (-119,47) est satisfaisante, ainsi que le Khi-deux du modèle ($\text{Khi}^2=39,49$) qui est significatif à 1%. Au niveau des paramètres estimés, on trouve globalement six variables ayant une influence significative sur la probabilité d'adoption des stratégies d'adaptation. Ces variables sont entre autres : l'âge, le niveau d'éducation, la vulgarisation, le revenu agricole, l'exercice d'une activité secondaire et la perception du CC. En outre, l'analyse de la sensibilité de la probabilité d'adoption par rapport aux variables explicatives montre que certaines variables ont des effets marginaux les plus forts. En plus, certaines variables affectent positivement et d'autres négativement la propension à l'adoption des stratégies d'adaptation. Une analyse singulière des variables ayant des effets significatifs sur la probabilité de choix nous permettra de mettre en évidence ces effets.

3.6.1. L'âge

L'âge du chef de ménage a une relation positive et significative avec la probabilité de choisir une stratégie d'adaptation défensive (0,006) au seuil de 10%. Cet effet indique qu'une augmentation d'une unité de l'âge du ménage accroît la probabilité d'utiliser cette stratégie de 0,6%. Les agriculteurs les plus âgés auront tendance à plus adopté cette stratégie que les plus jeunes. La raison probable de cette association positive est due au fait que l'âge peut probablement doter les agriculteurs de l'expérience requise qui leur permettra de mieux évaluer les risques liés aux décisions d'investissement dans l'adaptation au changement climatique. Ces résultats ont confirmé les résultats des travaux de Deressa *et al.* (2009) et Davis et Ali (2014) qui sont parvenus à la conclusion selon laquelle l'expérience en agriculture est un potentiel déterminant d'adaptation du producteur au changement climatique. Concernant la stratégie offensive, bien que le coefficient associé à l'âge de l'irrigant soit non significatif, le signe négatif peut nous conduire à dire que les agriculteurs plus âgés sont moins susceptibles de prendre ce type de stratégie. La probabilité d'adapter ce type de stratégie diminue plus un agriculteur est âgé.

3.6.2. Niveau d'instruction

L'éducation du chef de ménage a un effet positif et significatif pour l'adoption d'une stratégie offensive au seuil de 5%. Cet effet indique que les chefs de ménage qui ont un niveau d'instruction au moins égal au niveau secondaire, ont 21,5% plus de chance d'adopter une stratégie offensive par rapport aux chefs de ménage moins éduqués. Diverses études parviennent à cette même conclusion selon laquelle la relation entre l'éducation et l'adaptation au changement climatique est positive (Ouédraogo *et al.*, 2010 ; Yegbemey *et al.*, 2014). Les agriculteurs plus instruits sont en général plus capables d'évaluer les technologies disponibles et le climat car il existe une différence majeure avec les agriculteurs moins éduqués en termes d'accès aux actifs, au crédit, à la technologie et à l'approvisionnement en intrants (Hassan et Nhémachena, 2008). Concernant la stratégie adaptative le niveau d'éducation influence négativement le choix de cette stratégie mais non significative. Plus le niveau des agriculteurs est élevé, moins ils auront tendance à adopter cette stratégie d'adaptation. La non significativité de niveau d'éducation sur l'adoption de la stratégie adaptative peut s'expliquer par le fait que dans nos provinces, avec l'évolution dans le domaine de la vulgarisation (partage d'expérience entre producteur, accès à l'information dans la langue locale, etc.), les producteurs arrivent à comprendre les mesures à prendre dans un contexte de changement climatique dont notamment les stratégies adaptatives.

3.6.3. Revenu annuel

Le revenu annuel agricole présente une relation positive pour l'ensemble des stratégies d'adaptation et significative à 10% pour la stratégie offensive. Ces résultats sont en accord avec Abid *et al.* (2014), Yong (2014) et Tun Oo *et al.* (2017) où une association positive significative entre l'adoption de stratégies d'adaptation au changement climatique et le niveau de revenu a été obtenue. Cela signifie que les agriculteurs qui ont gagné plus de revenus grâce à leurs activités agricoles avaient vraisemblablement plus de ressources sous forme d'économies de secours à investir dans l'infrastructure d'adaptation et ont plus de chances d'adopter

des stratégies d'adaptation au changement climatique que les agriculteurs qui ont un petit revenu agricole annuel. Ces résultats concordent avec les conclusions de Bryan *et al.* (2009) et Ado *et al.* (2019) qui ont rapporté que la production agricole et les revenus annuels des ménages avaient une incidence significative sur les niveaux d'adaptation des ménages.

3.6.4. Activité secondaire

En plus du revenu agricole, l'exercice d'une activité secondaire augmente également considérablement la probabilité d'adopter des stratégies d'adaptation. L'exercice d'une activité secondaire est positivement et significativement corrélé avec la décision d'adaptation au changement climatique au seuil de 5% pour la stratégie offensive et de 1% pour la stratégie adaptative. Une activité secondaire constitue une autre source de revenus pour les irrigants. Une augmentation unitaire du revenu non agricole augmente la probabilité d'adopter des stratégies offensives et défensives de 7% et de 9%, respectivement. Ainsi, les revenus issus de l'activité secondaire peuvent être mis à profit pour augmenter le niveau d'investissement dans les intrants tels que la main-d'œuvre, les engrains et pesticides, les nouvelles variétés et surmontées ainsi les contraintes financières à l'échelle d'exploitation. Ce résultat est conforme à ceux de Gnanglè *et al.* (2012) et Piya *et al.* (2013) qui trouvent que la diversification des activités est aussi une stratégie d'adaptation au changement climatique. En ce sens, les producteurs qui possèdent déjà une activité secondaire auraient une plus forte probabilité à s'adapter au changement climatique.

3.6.5. Vulgarisation

La vulgarisation présente une corrélation positive et significative avec la probabilité de choisir une stratégie adaptative au seuil de 5%. Une augmentation d'une unité du contact avec les services de vulgarisation est susceptible d'augmenter la probabilité pour l'agriculteur d'adopter la stratégie adaptative de 9,8% plus élevées que celles des ménages qui n'ont pas accès aux services de vulgarisation. Les contacts avec les agents de vulgarisation peuvent faciliter la sen-

sibilisation et l'anticipation des agriculteurs au changement climatique et aux options d'adaptation disponibles pour y faire face. L'importance de la vulgarisation dans l'adaptation des producteurs au changement climatique est déjà mise en exergue dans les travaux de Nhémachena et Hassan (2007), Gbetibouo (2009) et Deressa *et al.* (2009) qui ont remarqué que les agriculteurs qui obtiennent des informations par l'intermédiaire des agents de vulgarisation sont plus susceptibles d'être informés de la situation climatique et des réponses suivies. Concernant la stratégie offensive l'encadrement technique influence négativement le choix de cette stratégie mais non significative. L'encadrement technique semble ne pas avoir d'effet sur la probabilité d'adopter des stratégies offensives parce que ses types d'adaptation restent hors de la portée des services de vulgarisation et restent guidés par des initiatives privées. Ce résultat est similaire à celui de l'étude de Ouédraogo *et al.* (2010), qui a constaté que l'accès aux services de vulgarisation n'était pas un déterminant de l'adaptation des technologies de CES, de la fumure et de la date de semis où le principal canal de diffusion des technologies de CES reste les projets et les organisations non gouvernementales de développement.

3.6.6. Perception de changement climatique

La perception de CC et du risque climatique est l'une des variables explicatives qui influent sur le choix des mesures d'adaptation des agriculteurs. La perception des irrigants des effets de CC s'est trouvée positivement et significativement corrélée avec le choix de la stratégie adaptative au seuil de 1%. Ce résultat révèle que les agriculteurs qui percevaient le CC et le risque climatique liée à la rareté et à la surexploitation des ressources en eau souterraine sont plus susceptibles de s'adapter au CC de 24 fois plus que ceux qui ne perçoivent pas un CC. En revanche, la perception de risque de CC a un effet négatif relativement plus fort (-0,217) et significatif au seuil de 5%, pour le choix de la stratégie offensive. Cet effet montre qu'un accroissement de la pénurie d'eau de 1% réduit la probabilité d'adoption des stratégies offensive de 21,7% et accroît la probabilité d'adoption des stratégies

adaptative. Ce résultat peut être expliqué, d'une part, par les mesures législatives appliquées dans cette région⁸ qui limitent l'adoption de ce type de stratégie offensive (Abidi et Ghoudi, 2011 ; Le-ghrissi, 2012) et encourage le recours aux stratégies adaptatives. D'autre part, cette stratégie requiert des charges de production élevées devant des capacités limitées d'adaptation des irrigants dans le sud-est tunisien (Mahdhi *et al.*, 2019). Ces résultats confirment les résultats d'Alaud-din et Sarker (2014) et Rezaei *et al.* (2017) et qui montrent que la perception des agriculteurs à l'égard de la rareté des ressources en eau est l'une des variables explicatives qui influent sur le choix des mesures d'adaptation des agriculteurs. Les résultats obtenus ont par ailleurs corroboré ceux de Mertz *et al.* (2009) et Ouédraogo *et al.* (2010) qui révèlent que les populations qui se rendent compte de la variabilité et de CC ont plus de chances de prendre des mesures d'adaptation en réponse aux changements observés.

Notons enfin que, d'autres variables bien qu'ayant été citées comme influençant positivement ou négativement le choix des producteurs, n'ont aucun effet statistiquement significatif dans le modèle. Il s'agit notamment de la superficie de l'exploitation, la taille de famille et de la contrainte financière.

La taille de famille introduit dans le modèle d'adaptation, n'est pas significativement corrélée avec l'adaptation du producteur au changement climatique (probabilité > 0,10). Cela se trouve justifié, car la quasi-totalité des producteurs interrogés ont affirmé que la main-d'œuvre familiale disponible était suffisante pour exécuter toutes les activités de production, y compris les éventuels ajustements ou adaptations au changement climatique.

Pour la taille de l'exploitation, les régressions effectuées présentent des coefficients non significativement différents de zéro au seuil de 5%. La taille ne constitue donc pas un facteur significatif d'adoption des stratégies d'adaptation. La raison probable de cette relation non significa-

tive pourrait être due au fait que l'adaptation est spécifique à la parcelle. Cela signifie que ce n'est pas la taille de l'exploitation, mais les caractéristiques spécifiques de l'exploitation qui dictent la nécessité d'une méthode d'adaptation spécifique au changement climatique. Dans la littérature il y a une controverse sur la relation entre la superficie de l'exploitation et l'adaptation aux changements climatiques (Deressa *et al.*, 2009 ; Nhemachena *et al.*, 2014). Cependant, étant donné que la taille des exploitations agricoles est associée à une plus grande richesse, on émet l'hypothèse qu'elle permet d'accroître l'adaptation aux changements climatiques (Bradshaw *et al.*, 2004 in Deressa *et al.*, 2009).

Enfin, les résultats de l'estimation permettent aussi d'observer une influence négative et non significative de la variable contrainte financière sur le choix des stratégies. Ce résultat suggère que plus cette contrainte est déclarée forte moins les producteurs ont tendance à prendre de décisions d'adaptation. Cela se trouve justifié par l'accès non facilité aux crédits agricoles selon les usagers. Ce résultat corrobore les résultats de Nguyen *et al.* (2021) qui montre que le manque des moyens financiers et le risque d'endettement des agriculteurs réduisent de manière significative l'adoption des stratégies d'adaptation au changement climatique.

4. Conclusion et recommandations

Le changement climatique est une réalité qui devrait avoir des impacts significatifs sur l'agriculture tunisienne avec des pluies moins incertaines, des températures plus élevées et par l'augmentation du taux d'occurrence des événements extrêmes comme les inondations, les sécheresses. Aujourd'hui, l'agriculture irriguée est plus susceptible d'être affectée par le changement climatique. Par conséquent, l'adaptation de l'agriculture au changement climatique est nécessaire au niveau micro. Cette étude montre que les agriculteurs perçoivent et s'inquiètent

⁸ Instauration de la zone d'interdiction en 1987 et la création d'un Groupement de Développement Agricole (GDA) de Bsissi-Oued El Akarit en 1999 pour contrôler le nombre de puits et de forages et limiter l'extension des superficies irriguées.

des effets du changement climatique et de la pénurie des ressources en eau souterraine dans le sud-est Tunisien. L'analyse des perceptions du changement climatique dans la région d'étude a fait ressortir la prise de conscience d'une baisse des précipitations, dérèglement de la saison des pluies, de l'augmentation des températures, de la variabilité de la température moyenne et des précipitations et de la rareté des ressources en eau souterraine à cause de l'augmentation des prélèvement et besoins d'irrigation au cours des 20 dernières années. Pour y faire face, treize mesures et pratiques d'adaptation ont été adoptées par les irrigants allant du recours à l'économie de l'eau à l'abandon de l'activité irrigué et l'orientation vers l'agriculture pluviale. En termes de stratégies d'adaptation, les différentes mesures d'adaptations peuvent être classées dans deux types de stratégies potentiels : Une première dite offensive. Elle comprend, principalement, l'équipement et l'approfondissement des puits, et location de terres plus riches en eau dans d'autres zones. La deuxième catégorie est dite défensive. Elle vise à adapter les systèmes de production à l'eau disponible sur l'exploitation compte-tenu des puits et forages existants. Elle comprend la diversification des cultures, les ajustements du calendrier agricole, le changement du système de culture et l'économie de l'eau d'irrigation à l'échelle de l'exploitation. La connaissance et la prise en compte de différentes pratiques et stratégies d'adaptation permet d'identifier des options d'adaptation à la fois réalistes du point de vue de leur mise en œuvre et ambitieuses du point de vue de leurs objectifs et aider à élaborer des priorités pour l'adaptation des ressources en eau pour l'irrigation. Néanmoins, leurs adaptations restent limitées, d'une part, par des contraintes informationnelles, financières et techniques, et d'autre part, la généralisation des stratégies offensive est susceptible d'aggraver les impacts des changements climatiques et d'engendrer des pressions sur les ressources en eau souterraine et met en question la durabilité de ses pratiques sur le plan économique et environnemental et accroît le risque pour le secteur irrigué et la vulnérabilité en particulier des petites exploitations, qui ont des capacités limitées pour s'adapter.

L'étude des déterminants d'adoption montre que l'âge, l'éducation, la vulgarisation, le revenu agricole, diversification des sources de revenu et la perception du risque de CC sont les principaux déterminants de l'adaptation des irrigants au changement climatique et à la rareté des ressources en eau souterraine. En somme, la capacité d'un irrigant à s'adapter au changement climatique dépend de sa perception du phénomène, de la nécessité d'apporter des solutions et des possibilités qui lui sont offertes. Dans une perspective d'adaptation aux changements climatiques, des recherches futures doivent être menées afin d'améliorer les stratégies existantes ou développer de nouvelles stratégies. Pour ce faire, une bonne connaissance et analyse des stratégies endogènes et de déterminants d'adaptation constitue un bon point de départ pour orienter les politiques publiques et améliorer efficacement la résilience des agriculteurs aux changements climatiques en zones arides. En outre, des voies alternatives doivent donc être trouvées, en fonction de la prévision de climat futur, à la fois en termes de conception et de viabilité des mesures d'adaptation innovantes à mettre en œuvre pour atténuer les effets des changements climatiques et soutenir la durabilité du secteur irrigué en zones arides. Dans ce sens, des mesures d'adaptation doivent être prises dans différentes conditions agro-écologiques et climatiques à travers l'encouragement de la recherche en matière d'évaluation et d'identification des options d'adaptation (paquet technologique agricole adapté aux changements climatiques, diffusion de nouvelles variétés tolérantes et de variétés précoce adaptables aux changements climatiques, etc.) à la fois réalistes du point de vue de leur mise en œuvre et ambitieuses du point de vue de leurs objectifs. Dans le court et le moyen terme, les possibilités d'adaptation du pays doivent passer par la collecte des eaux de ruissellement, la recharge de la nappe, tarification incitative, amélioration de l'efficacité d'usage de l'eau d'irrigation à travers la généralisation de l'irrigation goutte à goutte et la réduction des pertes en eau. D'autres mesures peuvent être liées aux pratiques culturales telles, l'optimisation des dates de semis en fonction des changements du climat, l'utilisation de semences sélectionnées et de variétés à cycle court et résistantes à la sécheresse, la recon-

version et le repositionnement des cultures selon l'évolution du contexte bioclimatique, et enfin la refonte progressive des calendriers agricoles traditionnels. Ce choix serait cependant cautionné par un accompagnement technique et financier des agriculteurs. Enfin, des mesures d'accompagnement (formation, encadrement, infrastructure) doivent être prises pour faciliter l'adaptation et aider à élaborer des priorités pour l'adaptation des ressources en eau pour l'irrigation en zone aride.

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Analysis of the effects of livestock market participation on food security and welfare of smallholder farmers in Ethiopia

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Abstract

In Ethiopia, where a large proportion of rural households depend on livestock for livelihood, food security remains a significant concern for large portions of the population. The commercialization of the livestock sector is expected to play an important role in stimulating economic growth, reducing poverty and achieving food security. This study evaluates the effect of livestock market participation on household's food security and welfare using a nationally representative cross-sectional survey data of rural households in Ethiopia. The endogenous switching regression model which accounts for both the selection and endogeneity bias is employed to examine the effect of livestock market participation. The robustness of the results is checked using propensity score matching. The results indicate that participation in livestock market improved food security and welfare of the participating households. Participation in the market also would have increase food security and welfare of non-participants had they decided to participate in the market. Furthermore, in rural areas where alternative income possibilities are scant, livestock market participation has smoothed food consumption by providing income in times of harvest failure or other shocks striking households. However, building a more sustainable market-oriented production system is critical for the improvement of household food security and welfare.

Keywords: Food security, Livestock, Market participation, Endogenous switching regression, Ethiopia.

1. Introduction

In Africa, livestock is central to the livelihoods of rural population and is strategically important to the continent's food and nutritional security. It is estimated that the livestock sector contributes between 20 to over 80 percent of the agricultural value added in African countries, averaging at 35% across the continent (LiDeSA, 2015). It is noted that in many developing countries, achieving the UN Sustainable Development Goals

(SDG) would depend greatly on how livestock production systems are managed to meet the needs of massive surges in the human population (Herrero & Thornton, 2013). The subsector has the potential to deliver both agricultural-led growth and socio-economic transformation for improved livelihoods (LiDeSA, 2015). In this regard, livestock represents a potential pathway out of poverty and food insecurity for many of the poor in developing countries (Aklilu & Cat-

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ley, 2014; Herrero & Thornton, 2013). It enables poor people to secure current and future assets, improve the productivity of agricultural systems in which livestock are important and facilitate greater participation of the poor in livestock-related markets (Njuki & Singa, 2013). Moreover, livestock offers an alternative source of capital that the poor can accumulate as a ‘savings account’ to hedge against income fluctuations (Kazianga & Udry, 2006). Keeping livestock is then considered as an alternative form of insurance, providing the household with assets that can be sold in times of shocks (Mogues, 2011).

The livestock sector in Ethiopia occupies an important place in the economy and pro-poor development strategies of the country (Kuma *et al.*, 2015). The country has the largest population of livestock in Africa (Kuma *et al.*, 2015). In 2014, 18% of the total cattle population and 8.2% of the sheep and goat population in Africa are found in Ethiopia (Enahoro *et al.*, 2019). With these figures, livestock account to about 40-50% of agricultural GDP. It is also an important contributor to export earnings, accounting for 15% of total export earnings (FAO, 2017). Furthermore, at the household level, the livelihoods of a large proportion (70%) of rural households in the country depends on livestock (FAO, 2019). Hence, any shocks that affect livestock will have an adverse effect on the overall economy and on household welfare (Kuma *et al.*, 2015).

Food insecurity (22.7 percent) and poverty (27.1 percent) remains a significant concern for large portions of the population in the rural areas of the country (WFP & CSA, 2019). In this case, significant number of the country’s rural population (28.36 percent) were classified as livestock keepers living under the national poverty line (Enahoro *et al.*, 2019). In addition, there is also a significant interrelationship between mixed crop and livestock farming in the country (FAO, 2017). This shows that, with appropriate management interventions, livestock have an important role in improving food security and reducing poverty in Ethiopia (Shapiro *et al.*, 2015). Therefore, the sector needs to be considered among any options aimed at transforming present and future welfare outcomes at the household, sectorial and national levels (Enahoro *et al.*, 2019).

In all Ethiopian government agricultural policies and strategies, prioritization of livestock development is pursued for stimulating economic growth, reducing poverty and achieving food security (MoA and ILRI, 2013). Under the Ministry of Agriculture, Ethiopia launched a Livestock Master Plan for the transformation of the livestock sector in July 2015. By strengthening the livestock sector and spurring growth, the goals were to enhance nutrition and food security and to lift 2.36 million households out of poverty by 2030 (Shapiro *et al.*, 2015). Besides raising their productivity, the plan has adopted market participation of smallholder agriculture as a strategy for its economic transformation (Shapiro *et al.*, 2015). This is because unless smallholder linkages to markets are strengthened simultaneously, the mere attempts to raise productivity will have limited success (Arias *et al.*, 2013). Besides its impact on rural people, the commercialization of the livestock sector has also potential impact on urban dwellers through enhancing supply of agricultural inputs for industrial production (Enahoro *et al.*, 2019).

Hence, the potential contribution of the livestock sector for economic development and welfare improvement in low income countries depends on the extent to which the livestock sector is thriving at the marketing level (IGAD, 2017). When market access is guaranteed, the general welfare of smallholding farm households is improved through increased productivity and income and better consumption choices (IFAD, 2010). It is also noted that, besides inadequate entitlements, lack of access to reliable markets for farm produce and inputs are equally important in defining the food security status of the farm households (Burchi & Muro, 2012). This shows that increasing participation of farm households in agricultural markets is a key factor to lift rural households out of poverty. As a result, the role of market participation as the determinant of the household food security and welfare has attracted the attention of researchers in different parts of the world. The results of Gani & Adeoti (2011) indicated that poor market participation was found to have positive correlation with poverty in Nigeria. Interventions reducing the barriers of market participation and

facilitating the improvement of productivity to generate consistent levels of marketable surplus will often have greater payoffs in living standards of smallholder farmers and poverty reduction (Arias *et al.*, 2013).

Other studies have also indicated that enhancing smallholder participation in markets has significant potential to increase the income potentials, especially for poor and land-constrained farmers (Hichaambwa *et al.*, 2015). According to their results, income gains were more pronounced for small and poor households. In addition, market participation was an important instrument to alleviate extreme poverty. Participation in markets was also seen to reduce the gender gap in rural household income (Hichaambwa *et al.*, 2015). Results also showed that household commercialization was associated with a reduced risk of being chronically food poor (Kirimi *et al.*, 2013). Expansion of smallholder market participation and ensuring that farmers are not trapped in low productivity and low return farming activities are crucial in helping households graduate out of food insecurity (Kirimi *et al.*, 2013). Furthermore, different studies (Abdullah *et al.*, 2019; Mmbando *et al.*, 2015) have also indicated a positive and significant impact of market participation on household food security and welfare.

Most of these studies in smallholder market participation have models on the decision of smallholder market participation in staple crops. Among the few works modeling the impact of livestock market participation, Mulford (2013) studied the welfare effects of smallholder market participation on Kenya's dairy sector. By analyzing households' asset dynamics, the study highlights a strong association between high milk sales levels and improved welfare. But due to the qualitative nature of the work, the causal direction was not evident. Lubungu (2013), by employing propensity score matching and decomposition techniques on data collected from smallholder farmers in Zambia, examined the effect of participation in cattle markets on cattle-raising households' incomes. The findings showed that on average participation in cattle markets raises household income by over 50%. However, the propensity score matching

approach may underestimate the magnitude of the effects leading to a downward bias relative to methods which also account for unobserved heterogeneity (Tesfaye & Tirivayi, 2018). In addition, the model fails to account for the potential systematic difference between participants and non-participants (Khonje *et al.*, 2015). Furthermore, the empirical studies that evaluated the impact of livestock suffer from the absence of control groups and endogeneity problems associated with the selection bias (Jodlowski *et al.*, 2016). Hence, the objectives of this study would be filling these gaps by estimating the food security and welfare effects of livestock market participation using a different set of identification and estimation strategies that address the selection and endogeneity problems.

The rest of the paper is organized in three sections. The next section describes the impact estimation problems, conditional expectations, and treatment and heterogeneity effects, data and the description of the variables. The third section presents and discusses the empirical results of the study. Finally, the conclusion and the implication of the results are presented.

2. Materials and methods

2.1. Impact estimation problems

The estimated impact of market participation on the selected outcome variables can be calculated by directly comparing the average treatments between the participants and nonparticipants if the farmers were randomly assigned to each group (Khonje *et al.*, 2015). However, participation in livestock markets by smallholder farmers is non-random as the farmers themselves decide (self-select) whether to participate or not in the market. In addition, these decisions are influenced not only by observable characteristics but also by non-observable characteristics (such as a farmer's innate abilities) that may be correlated with the outcome variables (Olwande & Smale, 2014). In the regression framework, this means that the error terms in the decision and outcome equations are correlated (Ma & Abdulai, 2015) and the mean outcomes of the two groups may differ even in the absence of treat-

ment. Consequently, the non-randomness poses a well-known dilemma of missing data in which the counterfactual outcome cannot be observed for both groups (Olwande & Smale, 2014).

Estimation of the impact of market participation without considering the problem of missing data will result in biased estimates. Different approaches for dealing with this problem include propensity score matching (PSM), the Heckman selection method, Instrumental variables (IV) and Endogenous switching regression models (ESR) (Khonje *et al.*, 2015; Olwande & Smale, 2014). Among these models, the ESR model has some advantages over the other models. First, the method addresses the issues of selection bias by accounting for both observable and non-observable characteristics. Second, the ESR approach simultaneously estimates the participation decision and outcome equation for both participants and non-participants and calculates the actual and counterfactual expected values of outcome variables for both groups (Lokshin & Sajaia, 2004). However, the results from ESR model may be sensitive to selection of instrumental variables (Khonje *et al.*, 2015). Thus, as each model has its own limitations which cannot be corrected individually, the estimates are not robust by using a single model (Khonje *et al.*, 2015). Therefore, the effect of market participation on the binary and continuous outcome measure of food security and welfare was estimated by using the Endogenous Switching Probit Model (ESP) and Endogenous switching regression model respectively. The robustness of the results is checked by using the PSM model. These models were widely applied in the literatures and general specifications of these models can be seen in Lokshin & Sajaia (2004), Wooldridge (2010) and Maddala (1983).

2.2. Conditional expectations, and treatment and heterogeneity effects

Though the endogenous switching regression models can be estimated using a two stage method, the more efficient version of the models is obtained by using the full information maximum likelihood method (FIML) (Lokshin & Sajaia, 2004). Consequently, the study used the FIML method which estimates the decision and

outcome equations simultaneously. After estimating the model's parameters, the conditional expectations are computed as follows (Lokshin & Sajaia, 2004).

For participants who participated:

$$E(y_{1i}|P_i = 1, x_{1i}) = x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma Z_i)/F(\gamma Z_i) \quad (1a)$$

For participants had they decided not to participate (counterfactual):

$$E(y_{1i}|P_i = 0, x_{1i}) = x_{1i}\beta_1 - \sigma_1\rho_1 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} \quad (1b)$$

For nonparticipants had they decided to participate (counterfactual):

$$E(y_{2i}|P_i = 1, x_{2i}) = x_{2i}\beta_2 + \sigma_2\rho_2 f(\gamma Z_i)/F(\gamma Z_i) \quad (1c)$$

For nonparticipants who did not participate:

$$E(y_{2i}|P_i = 0, x_{2i}) = x_{2i}\beta_2 - \sigma_2\rho_2 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} \quad (1d)$$

Equations 1a and 1d represent the actual expectations observed in the sample while equations 1b and 1c represent the counterfactual expected outcomes. Table 1 presents the summary of the conditional expectations, and treatment, and heterogeneous effects. Following Di Falco *et al.*, (2011) and Heckman *et al.*, (2001), the effect of market participation on outcome variables of households that actually participated in the market was computed by calculating the difference between a and c:

$$\begin{aligned} TT &= E(y_{1i}|P_i = 1, x_{1i}) - E(y_{2i}|P_i = 1, x_{2i}) \\ &= x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma Z_i)/F(\gamma Z_i) - x_{2i}\beta_2 \\ &\quad + \sigma_2\rho_2 f(\gamma Z_i)/F(\gamma Z_i) \end{aligned} \quad (2)$$

Similarly, the difference between b and d was used to calculate the treatment effect on households that did not participate in the market:

$$\begin{aligned} TU &= E(y_{1i}|P_i = 0, x_{1i}) - E(y_{2i}|P_i = 0, x_{2i}) \\ &= x_{1i}\beta_1 - \sigma_1\rho_1 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} - \\ &\quad x_{2i}\beta_2 - \sigma_2\rho_2 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} \end{aligned} \quad (3)$$

The effect of base heterogeneity for households that participated in the market (BH_1) was computed by calculating the difference between a and b:

$$\begin{aligned} BH_1 &= E(Y_{1i}/P_i = 1) - E(Y_{1i}/P_i = 0) \\ &= x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma Z_i)/F(\gamma Z_i) - x_{1i}\beta_1 - \\ &\quad \sigma_1\rho_1 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} \end{aligned} \quad (4)$$

Table 1 - Conditional expectations, and treatment, and heterogeneous effect.

Sub-samples	Decision stage		Treatment effects
	To participate	Not to participate	
Households that participated	(a) $E(y_{1i}|P_i = 1, x_{1i})$	(c) $E(y_{2i}|P_i = 1, x_{2i})$	TT
Households that did not participated	(b) $E(y_{1i}|P_i = 0, x_{1i})$	(d) $E(y_{2i}|P_i = 0, x_{2i})$	TU
Heterogeneity effects	BH ₁	BH ₂	TH

Note: Y_{1i} = outcome variables if households participated

Y_{2i} = outcome variables if households did not participate

TT = the effect of the market participation on the households that participated

TU = the effect of the market participation on the households that did not participate

BH = the effect of base heterogeneity for households that participated ($i = 1$), and did not participate ($i = 2$)

TH = (TT-TU), i.e., transitional heterogeneity.

Similarly, the effect of base heterogeneity (BH₂) for households that did not participate in the market was calculated by taking the difference between c and d:

$$\begin{aligned} BH_2 &= E(Y_{2i}/P_i = 1) - E(Y_{2i}/P_i = 0) \\ &= x_{2i}\beta_2 + \sigma_2 p_2 f(\gamma Z_i)/F(\gamma Z_i) - x_{2i}\beta_2 - (5) \\ &\quad \sigma_2 p_2 f(\gamma Z_i)/\{1 - F(\gamma Z_i)\} \end{aligned}$$

Another important statistic is transitional heterogeneity (TH) which is the difference between TT and TU and measures whether the effect of market participation is larger or smaller for households that participated or for households that did not participate, in the counterfactual case that they did participate (Di Falco *et al.*, 2011). Similarly, the treatment effect of binary outcome variables was calculated in the framework of the endogenous switching probit model (Lokshin & Sajaia, 2004).

For the ESR and ESP models to be properly identified, a variable that has a direct effect on the decision to participate in the market but does not have direct effect on the outcome variables of interest (i.e., food security and welfare) should be included in the decision model. Consequently, following the studies on the impact of market participation (Mmbando *et al.*, 2015; Muricho *et al.*, 2018), the information source variables were hypothesized as candidates for the instruments. This is based on the fact that access to reliable sources of marketing information either through formal or informal institutional arrangement is critical for commercialization of agriculture (Jagwe *et al.*, 2010). In this regard, extension services, by linking households with

markets and providing the right marketing information (Rehima *et al.*, 2013), enables the households to commercialize their agricultural products. In addition, a household's ownership of a mobile phone is also an important determinant of marketing participation (Mmbando *et al.*, 2015). However, the mere access of farmers to marketing information without participating in the market does not affect the outcome variables of interest (Mmbando *et al.*, 2015). Information variables are thus expected to affect the outcome variables only when the households are participating in the market. However, according to the results of a simple falsification test conducted for the statistical admissibility of these selection instruments (Di Falco *et al.*, 2011), only access to the extension service was found as a valid instrument significantly explaining the market participation decision but not the outcome equation of the households that did not participate in the market (Table A.4). Consequently, access to extension services was used as the instrument in both ESR and ESP models.

2.3. Data

The study used data from the Ethiopian Socio-economic Survey (ESS), a nationally representative cross-sectional survey of rural households of Ethiopia in 2015/16. The data were collected under the Living Standards Measurement Study-Integrated Surveys on Agriculture Initiative (LSMS-ISA) in collaboration with Central Statistical Authority (CSA). In the collection of these data a two-stage probability sampling

technique was used. The first stage of sampling entailed selecting primary sampling units, or CSA enumeration areas (EAs). A total of 433 EAs were selected based on probability proportional to size of the total EAs in each region. For the rural sample, 290 EAs were selected. A total of 43 and 100 EAs were selected for small town and urban areas, respectively. The second stage of sampling involved the selection of households from each EA. For rural and small town EAs, a total of 12 households were sampled from each EA. However, 15 households were selected in each large town EA. Finally, a total of 4,954 households were interviewed. As the study is interested in the rural farmers in Ethiopia, by excluding the capital and the provincial capital cities and deleting some missing observations, the analysis here is based on a sample of 2655 households. The survey questionnaire collected information on basic demographics; education; food and nonfood expenditures; household non-farm income-generating activities; food security and shocks; safety nets; assets; credit; and other sources of household income. The community questionnaire gathered information on access to infrastructure and community organizations. The post-planting and post-harvest agriculture questionnaires focused on farming activities and solicited information on land ownership and use and crop harvest and utilization. The livestock questionnaire collected information on animal holdings and sales of livestock.

2.4. Variables and descriptive statistics

2.4.1. Outcome variables

Different proxy indicators were used to measure the outcome variables of interest including food security and welfare of households. The household dietary diversity score (HDD) measuring the number of different food groups

consumed over a given reference period (FAO, 2013) is the first proxy indicator used to measure the household's food security. It reflects the economic ability of the household to access a variety of foods (Swindale & Bilinsky, 2006). In addition, as HDD is strongly related to other measures of food security (FAO, 2013), it is an efficient proxy measure widely employed to measure food security (FAO, 2013; Headey & Ecker, 2013).

Following FAO (2013) and Swindale & Bilinsky (2006), the food groups chosen to create the HDD were categorized into 12 food groups.¹ The results of the descriptive statistics tests presented in Table 2 show that the average dietary diversity score of 6.972 for the market participating households was significantly higher than the score of 6.649 for the nonparticipants. In addition, the experience based proxy indicators reflecting the household's subjective feelings about food insecurity were used to complement dietary diversity measures (D'Souza & Jolliffe, 2016). These proxy measures were developed from coping strategies used against food insecurity² and self-reported food insecurity. Following the work of D'Souza & Jolliffe (2016) and Tesfaye & Tirivayi (2018), two dummy variables were created and labeled "negative change in diet" and "reduced food intake". The first two questions of coping strategies used against food insecurity were used to create a negative change in diet variable while the remaining questions were used for the construction of the reduced food intake variable. The descriptive statistics for both the negative change in diet and reduced food intake show that there is no significant difference between the market participant and non-participant households (Table 2).

The self-reported food insecurity dummy variable was created based on the household's response to the question, 'In the last 12 months,

¹ The twelve food groups used for the calculation of the HDD include cereals; white tubers and roots; vegetables; fruits; meats; eggs; fish and other seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments; and beverages (FAO, 2013).

² Questions used to derive the two indicators from the coping strategies include (1) relied on less preferred foods, (2) limited the variety of foods eaten, (3) limited portion size at mealtimes, (4) ate fewer meals in a day, (5) restricted adult consumption to benefit small children, (6) borrowed food or relied on help from a friend or relative, (7) had no food of any kind in the household, and (8) went a whole day and night without eating anything (D'Souza & Jolliffe, 2016).

Table 2 - Outcome variables.

Outcome Variables	Participants (N= 1,432)	Non-participants (N= 1,223)	t/X ² -value
	Mean (St.dev.)	Mean (St.dev.)	
Household Dietary Diversity	6.972 (0.047)	6.649 (0.0535)	4.539***
Negative change in diet (%)	29.469	29.354	0.0649
Reduced food intake (%)	17.2486	15.454	-1.2443
Self-reported Food insecurity (%)	28.581	27.892	0.1544
Per-capita consumption expenditure	224.981 (457.375)	209.704 (494.656)	3.48**

Note: *** and ** denotes significance at 1% and 5% level, respectively. Values in the parenthesis represent the standard deviation. Per capita consumption is expressed in Ethiopia Birr.

have you been faced with a situation when you did not have enough food to feed the household'. The results in Table 2 show that more than one quarter of both the market participants and non-participant households have reported facing the problem of food insecurity. Finally, per capita consumption expenditure, constructed by adjusting the summation of the food consumption expenditure and non-food consumption expenditure by per month, was used as a proxy measure of the household's welfare. Average per capita consumption expenditures by participating household was significantly higher than that of nonparticipating households.

2.4.2. Independent variables

The important variables of interest were selected based on the empirical studies on market participation and the impacts of market participation on food security and welfare (Gani & Adeoti, 2011; Gebremedhin *et al.*, 2015; Seng, 2016; Lubungu, 2013; Mmbando *et al.*, 2015; Muricho *et al.*, 2018; Olwande & Smale, 2014). Variables were categorized as household characteristics and assets (age, gender, education level of the household head, household size, land size, asset ownership, access to non-farm income opportunities and household commercialization index); herd characteristics and shocks (number of livestock owned by type (TLU), number of dead animals and shocks in the households); transaction cost variables (distance to main road and livestock market); institutional variables (access to social safety nets and access to credits); and information variables (mobile ownership and

access to extension). The results of the descriptive statistics tests are presented in Table A.1. Most market participants were male and their households owned a significantly larger herd than nonparticipants (Table A.1). There was also significantly more livestock lost for market participants than for nonparticipants. This was expected to increase the likelihood that the household became food insecure by decreasing the marketable surplus of the household. The results presented in Table A.1 also showed that there was a statistically significant difference between the household crop intensification index (HCI) of the two groups, suggesting that nonparticipants rely more on the sale of crops. Furthermore, about 65% of market participants were negatively affected by shocks (usually the death of family members or drought). Access to major roads and markets were used to capture the effect of transaction costs on the smallholder farmers' market participation and food security as higher transaction costs often arise from the problems of poor infrastructure (Takeshima 2008). Accordingly, the results presented in Table A.1 show that participants were closer to major roads and markets than nonparticipants.

3. Results and discussion

In this section, results of the econometric model estimations are presented and discussed. The first section is devoted to the discussion of the propensity score matching results and the sensitivity analysis of the treatment effects to the hidden bias. Following this, the results of the

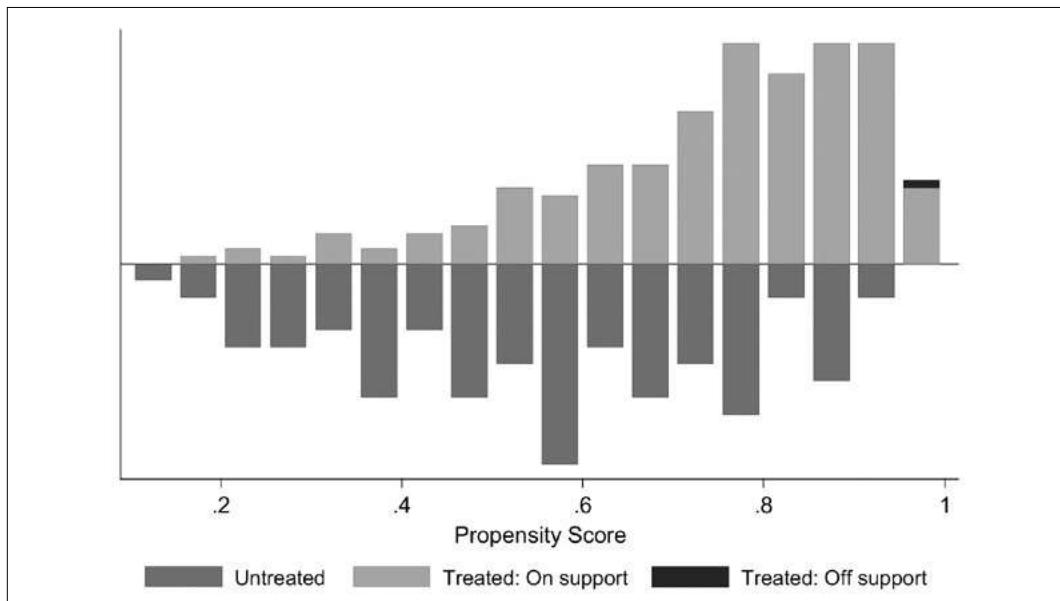
determinants of market participation and the estimation results of the treatment effects obtained by using the endogenous switching regression model and endogenous switching probit model are discussed.

3.1. Propensity score matching results and sensitivity analysis of the treatment effects

In the current study, the PSM model is used as a robustness check (Caliendo & Kopeinig, 2008). However, the validity of the model must first be examined by verifying the common support or overlap condition. This is important to ensure that households with the same x-values have positive probability of being both market participants and nonparticipants (Caliendo & Kopeinig, 2008). Consequently, the distributions of the propensity scores for both groups were estimated and are presented in Figure 1. A visual inspection of the propensity score distribution in Figure 1 indicates that the common support condition is satisfied as there is a substantial overlap in the distribution of the propensity scores for both market participants and nonparticipants.

After verifying the overlap condition, the next step is checking the balancing of propensity scores and covariates in the groups of participants and nonparticipants. This was done by implementing a variety of diagnostics tests (Leuven and Sianesi, 2003). The results of the diagnostic tests are presented in Table A.2. According to the results, the standardized mean difference for overall covariates used in the estimation process reduced from 21% before matching to a range of 3.1- 3.3% after matching. The total bias was also reduced significantly through the matching process which clearly indicates that the matching process effectively reduced biases in the estimates. In addition, the p-values of the likelihood ratio tests also showed that the joint significance of covariates was rejected after matching while it was not rejected before matching. Moreover, the pseudo-R² was decreased significantly from 17 percent before matching to 2.1 percent after matching. This low value of the pseudo-R² indicates that there was no systematic difference in the distribution of covariates between the two groups after matching. These results indicated that the matching quality was fairly good. There-

Fig. 1 - Propensity score distribution and common support for propensity score estimation.



Note: Treated on support indicates individuals participating in the market that have a suitable match. Treated off support indicates individuals participating in the market that have no suitable match.

fore, the proposed specification of the propensity scores is successful in terms of balancing the distribution of propensity scores and covariates between the two groups and it can be used to evaluate the effect of market participation.

After verifying both matching and balancing tests, the PSM model was used to evaluate the effect of market participation on outcome variables. The estimates of the average treatment effects (ATT) obtained by using Kernel Based Matching (KBM) and Nearest Neighbor Matching (NNM) techniques are presented in Table A.3. The propensity score matching results could be sensitive to the hidden bias if selection is affected by unobserved characteristics (Smith & Todd, 2005). Hence, the results of the sensitivity analysis obtained by using the Rosenbaum bounds tests (DiPrete & Gangl, 2004) and the Mantel-Haenszel (MH) bounding approach (Becker & Caliendo, 2007) for binary and continuous outcomes are presented in the last columns of Table A.3. These are the critical levels of gamma (Γ) at which the causal inference of a significant effect of participation in the market may be questioned. Accordingly, the estimates showed that farmers who participated in the market have a 20 to 22% higher HDDs compared to nonparticipants. However, this conclusion of the market participation effect on HDD would be questioned at the critical level of Γ falling in the range of 1.15-2.35. The results also showed that per capita consumption expenditures increased in the range of 5% to 7% for market participants. These results would also be questioned for Γ values falling in the range of 1.40 to 1.90. Similarly, though the results showed market participating households have better food security status than nonparticipants as manifested by the low percentage of negative changes in diet and reduced food intake for market participants compared to nonparticipants, the results would be questioned for value of Γ ranging between 1.1-1.35 and 1.1-1.85, respectively. A value of Γ closer to 1 show that the impact estimates are highly sensitive to hidden bias while a larger value of Γ indicates less sensitivity of the impact estimates to the hidden bias. These results of PSM model suggest that the estimated average treatment effects of market participation on outcome indi-

cators are sensitive to the hidden bias and there is a need to control for the hidden selection bias through endogenous switching regression models. The ESR and ESP models, which account not only for the observable characteristics but also for the effect of the unobservable characteristics, are presented in the next sections.

3.2. Determinants of market participation

The estimated results of market participation jointly estimated using the FIML procedure is presented in Table A.5. The results showed that the likelihood of participating in the market is significantly affected by the gender of the household heads. Male-headed households have a higher probability of participating in the market than female-headed households. The descriptive results also supported this result. This is due to the fact that male-headed households have better access to productive assets to increase the chances of producing a marketable surplus, which in turn increased the chance of participating in the market (Awotide *et al.*, 2016). In addition, as men are more responsible for providing cash incomes to the households, male-headed households are more market oriented than female (Sigei *et al.*, 2014). Furthermore, as opposed to their counterparts, female-headed households are more negatively affected by the transaction costs of searching for buyers and enforcing a sale transaction (Jagwe *et al.*, 2010). The finding in this study is consistent with the results of different studies (Awotide *et al.*, 2016; Sarma *et al.*, 2014). However, the finding is different from the finding of other studies (Asfaw *et al.*, 2012; Olawuyi & Mushunje, 2018), which found a higher probability of participating in the market for female-headed households than their male counterparts. These could be because production of some goods is an important source of income for women smallholders.

Household size is significantly and positively correlated with the likelihood of participating in the market. This shows that the probability of participation in the livestock market increases as household size increases. This could be because livestock's most important contribution to food security is more in income generation than in

food production (Njuki & Singinga, 2013). In this case, a large household size implying availability of cheaper labour can also help households increase the possibility of producing marketable surplus which in turn increase the likelihood of farm households participation in the market (Alene *et al.*, 2008). In this regard, livestock is a crucial source of income for poor households to access their food. This suggests that more family members encourage households to sell their livestock, which in turn is used to meet the increased needs of the family. However, according to the findings of Awotide *et al.* (2016) larger household size reduced the probability of households participating in the rice market. They reasoned that larger households consume most of the rice output in the home and this tends to reduce the tendency to produce a marketable surplus as rice is the most important staple food crops in Nigerian diets. Similarly, the findings of Olawuyi & Mushunje (2018) also indicated that an increase in household size tends to decrease the likelihood of participating in the output market, which could be a result of overdependence on the limited resources of farmers.

The household crop commercialization index has a significant and negative correlation with the likelihood of participating in the market. This suggests that households getting the needed income from the sale of their crops have less incentive to sell their livestock. The result is consistent with the findings of Lubungu (2013) who found that high crop commercialization dampens the farmers' likelihood of participating in the livestock market.

Distance to roads and market have a significant and negative correlation with the likelihood of participating in the market. The further the household resides from the nearest road and livestock market, the less likely it will be involved in the selling of the livestock. Increased distance to roads and the market increase transaction costs and discourage the household from entering the market (Umar & Baulch, 2007). These transaction costs will be more significant especially in the marketing of live animals from distant areas because transaction charges are not limited to transport alone but include local taxes and the costs of holding, fodder, and water (Umar

& Baulch, 2007). Therefore, farmers are more inclined to build larger herds as drought-coping mechanisms than to build a large herd for increased commercial off-take (Asfaw *et al.*, 2012). In this case livestock would be taken to the market at times when their value has decreased significantly as a result of their age added to the shocks like drought. Consequently, improving market infrastructure by building the marketplace and constructing and improving roads to reduce transportation cost should be an important consideration in promoting market-oriented production (Gebremedhin *et al.*, 2015). The result of the study is consistent with the findings of Asfaw *et al.* (2012) and Mmbando *et al.* (2015) who found for households located far away from market were less likely to participate.

Access to extension services and mobile ownership as a source of marketing information affected the likelihood of participating in the market positively and significantly. This suggests that households with better access to marketing information are more likely to participate in the market. The extension service provides required technical assistance and marketing information and can link households with markets (Rehima *et al.*, 2013). These services help households to improve their productivity and to produce a marketable surplus. This suggests that, inadequate access to extension services are among the hindrances to participation in the market (Ndoro *et al.*, 2014). Mmbando *et al.* (2015) obtained similar results in which farmers with better access to extension services and mobile phones as the sources of market information were more likely to participate in markets.

Herd size is the other important variable significantly and positively affecting the likelihood of participating in the market. Households with larger herd size are more likely to produce a marketable surplus, as there will be more potential in the stock to participate in the market. The result suggests the significant importance of helping the households to increase their herd size. The result is consistent with the results of different studies (Gebremedhin *et al.*, 2015; Lubungu *et al.*, 2012; Ndoro *et al.*, 2014) stating that households with bigger livestock herd sizes are more likely to sell their livestock than those

with smaller herds. Related to this, the results of the study indicated that the numbers of dead animals in the year have a significant and negative correlation with the likelihood of participating in the market. The more livestock that the households are losing, the less marketable surplus is available for the market. The finding is consistent with the finding of another study (Gebremedhin *et al.*, 2015) which found a negative correlation between the number of dead animals in the year and the probability of market participation in the market.

Shocks the household faced positively and significantly affected the likelihood of participation in the market. This implies that households facing shocks like death, illness and other asset-related shocks have a higher probability of participating in the market. Livestock is a form of insurance that provides the household with assets that can be sold in times of shocks (Do *et al.*, 2019; Mogues, 2011). Andersson *et al.* (2011) indicated that shocks appear to lead households to disinvest in livestock. In addition, the results of Börner *et al.* (2015) also indicated that households tend to deplete financial and durable assets in response to death, illness or asset-related shocks. Remittances were found to affect the likelihood of households participating in the market negatively and significantly. Farmers regularly receiving more unearned incomes such as remittances from their family members and friends are not likely to participate in the market (Ndoro *et al.*, 2014; Olawuyi & Mushunje, 2018).

3.3. Endogenous switching regression model

The estimated parameters of the endogenous switching regression model are presented in Table A.6. In the second and third columns of Table A.6, determinants of HDD are presented. These results indicate that there is a systematic difference between market participants and nonparticipants. In this case, household size was negatively and significantly affected HDD for non-participant households. This suggests that the household's food security declines with the increase in its size. This could be because larger households have higher consumption, which

requires more food and generates food security issues. Seng (2016) found that household size negatively and significantly affected HDD of both market participants and non-participants, though the effects were greater among nonparticipating households. The coefficient of the age of the household head was significantly negative for both the market participants and nonparticipants. This implied that an older household head might be associated with lower labor force participation in other income generating activities, which in turn increases the exposure to food insecurity. Farm size, reflecting the ownership of important resources, significantly and positively affected the HDDS of only market participants. This could be because, households with large farms are less likely to become food insecure through minimizing their production risk and increasing productivity. In the findings of Seng (2016) the coefficient of farm size was significantly positive for the participants but negative for the non-participant, suggesting that nonparticipants use their own land in a less productive way than do the participants.

Distance to road and market was found to negatively affect the HDD of both the market participants and nonparticipants. This suggests that the further the household is from main road and market the higher the likelihood that it is food insecure. This could be because proximity to main roads and a major market by creating access to additional income through providing non-farm employment and easy access to inputs, extension and transportation enhances households' food security. Distance to the administration center affected significantly and negatively the HDD of only non-participants.

The herd size was significantly positive for the both the market participants and nonparticipants, indicating that households with more livestock have a better chance to be food secure. A large herd size contributes to the household's food security and dietary diversity through their use as food, a source of income, as a hedge against risks and as a means of capital accumulation that can be exchanged for food in times of deficit (Do *et al.*, 2019). However, the number of animal deaths in the year and shocks the household faced affected the HDDs signifi-

cantly and negatively. In this case, the potential of households to cope with shocks and smooth households' consumption and incomes would decline. The implication of this result is that the government and private sector can increase food security by controlling the high livestock mortality rate in the smallholder farmers (Do *et al.*, 2019; Lubungu, 2013). Muricho *et al.* (2018) also found that the coefficient of the herd size was positive and significant supporting the argument that livestock can provide a pathway out of poverty or at least a way to reduce the poverty gap for livestock owners (Do *et al.*, 2019). Though access to a safety net was significantly positive only for nonparticipants, the results indicate that a safety net program could play a positive role in reducing asset depletion and enhancing productive investment for food insecure households (Adimassu & Kessler, 2015). Access to remittances was positive and significant for both market participants and non-participants. This indicates that, households with access to remittances are more likely to be food secure. The result is consistent with the findings of Seng (2016) who suggested the importance of remittances in reducing rural poverty.

Table A.6 also reports the results when per capita consumption expenditures are used as a proxy for the household welfare. The results indicated that household size affected the welfare of the households negatively and significantly for both the market participants and non-participants. This suggests that farmers with large households have lower welfare due to a higher number of dependents requiring higher consumption and more expenditure (Abdullah *et al.*, 2019). In addition, large households are more likely to expand farming operations by using available family labor, which could lead to over-dependency on limited resources of farmers (Olawuyi & Mushunje, 2018). The findings are in conformity with findings of different studies (Abdullah *et al.*, 2019; Awotide *et al.*, 2016; Olawuyi & Mushunje, 2018). The age of the household head was also revealed to be negatively and significantly correlated with the household's welfare. In the finding of Awotide *et al.* (2016), the age of the household head was obtained positively and significantly affecting

the household welfare. Distance to roads and market were also found to significantly and negatively affecting the welfare of the households for participants and nonparticipants. The finding is consistent with results of different studies (Abdullah *et al.*, 2019; Mmbando *et al.*, 2015). The herd size owned and access to remittances was also significant for both the market participants and nonparticipants. However, the number of dead animals in the year and the farm size owned was significant only for nonparticipants. Access to nonfarm income opportunities affected positively and significantly only the welfare of participants.

In the ESR estimation, the likelihood ratio test and correlation coefficients of the covariance terms between the error terms in decision and outcome equations also have important economic interpretations (Fuglie & Bosch, 1995). The estimation results are presented in the lower part of Table A.6. The results of likelihood ratio test for joint independence of the participation and outcome equations were significant, suggesting that the participation and outcome equations are jointly dependent and endogeneity needs to be controlled in the specification of the outcome equations. The correlation coefficients were also statistically significant which indicates the presence of the selectivity bias. These results thus confirmed that both observable and unobservable characteristics influenced both the decision to participate in the market and the outcome variables. Failing to account for these factors may result in biased estimates. The sign of the correlation coefficients between market participation and outcome variables had the same sign in the case of HDD equation. This suggests that the HDDs for participants are above the average level whether they participate or not, but farmers are better off by participating. On the other hand, the HDDs of nonparticipant are below the average level in both cases, but farmers are better off by not participating (Fuglie & Bosch, 1995). In the case of per capita consumption expenditures, the opposite signs of correlation coefficients indicated that both the participant and nonparticipant households had an above-average value of the outcome by participating in the market.

Table 3 - Treatment and heterogeneity effects based on endogenous regression models.

Outcomes	Households/Treatment effects	Decision to		ATE
		Participate	Not to participate	
Household Dietary Diversity score	Participating households (ATT)	6.985	6.735	0.250 (0.058)***
	Non-participating households (ATU)	7.800	7.661	0.139 (0.040)***
	Heterogeneous effect (BH)	-0.815	-0.926	0.111
Per capita consumption expenditure (ln)	Participating households (ATT)	8.740	8.423	0.311 (0.035)***
	Non-participating households (ATU)	9.11	8.45	0.667 (0.023)**
	Heterogeneous effect (BH)	-0.37	-0.027	-0.349

Note: Ethiopia Socio-economic Survey (ESS) (2015-2016); ATT-Average Treatment Effect on the Treated, ATU-Average Treatment Effect on the Untreated, ATE- Average Treatment Effect, *** $p < 0.01$.

3.4. Estimation of treatment effects based on endogenous regression models

The ESR model results of the average treatment effects (ATT), accounting for selectivity bias arising from both the observable and unobservable characteristics, is presented in Table 3. The results reveal that the expected HDD score for the participant household was 6.985. The score would be 6.735 had they decided not to participate in the market. Thus, the participant households' dietary diversity score would decline by 0.250 units had they decided not to participate in the market. For non-participants the dietary diversity score was 7.661. The households' dietary diversity score would have increased by 0.139 had they decided to participate in the market. In this regard, livestock being a key income source for the poor plays an important role in improving the dietary diversity of households, as dietary diversity increases with income (Sandford & Ashley, 2008). Livestock also affects dietary diversity through the increase in total consumption expenditures (Rawlins *et al.*, 2014) that can contribute to their owner's ability to access food of all kinds. The result of model thus shows that participation in the market is the important determinants of households' food security. The result was consistent with the other finding (Seng, 2016) who showed that by participating in markets, farm households enjoyed higher dietary

diversity scores. However, Asfaw *et al.* (2012) found that although participation in the output market has a positive and significant effect on reducing food insecurity, there was no significant impact on dietary diversity.

Table 3 also shows that market participation positively and significantly affected households' welfare. The increase in per capita consumption expenditure was 31 percent for participants and households that did not participate in the market would gain 67 percent had they decided to participate in the market. These results show that participation in the market increased the welfare of the participants and would have helped households that did not participate. The result was consistent with the findings of Mmbando *et al.* (2015) who found that participation in the maize and pigeon pea market increased per capita consumption expenditures by 19.2-20.4% and 28.3-29.4%, respectively. Results from Lubungu (2013) also indicated that participation in cattle markets raises household income by over 50%, though poor households derive relatively smaller benefits from participation than their non-poor counterparts. A study conducted in South Africa (Chaminuka *et al.*, 2014) also showed that commercialization of cattle and cattle products increased total household cash income by 29%.

The results of the base heterogeneity were negative for both HDDs and per capita consumption expenditures indicating that house-

holds are better off by participating in the market (Table 3). However, the transitional heterogeneity effect was positive for HDDS implying that the effect was greater for farm households that did participate in the market than to the ones that did not. But this result was negative for per capita consumption expenditures which indicates that the effect was higher for nonparticipants had they decided to participate in the market. Thus, these results suggest that with appropriate interventions, participation in livestock markets can enhance both food security and welfare of farm households. One possible strategy is to promote livestock production because increasing livestock ownership may increase the number of animals sold, thus increasing household income (Lubungu, 2013). In this case, intervention aimed at increasing production in the livestock sector should emphasize the farmers use of the innovative livestock technologies (Dhraief *et al.*, 2019).

3.5. Endogenous switching probit regression model

The results of the endogenous switching probit model obtained by using FIML method are presented in Table A.7. In this section, for the brevity, we discuss only the impact of market participation on the binary outcome of food security. According to the results presented in Table 4, market participation reduces the probability of reporting food insecurity by 32% for market participating households. The likelihood of reporting food insecurity would be 29% for non-market participants had they participated in the market. In this instance, the sale of livestock being an important outlet for smallholders households (Saxena *et al.*, 2017)

reduces the hardest challenges of food insecurity by ensuring that households can have a way to purchase food when volatile economies and natural disasters make already weak livelihoods even more unstable (FAO, 2017).

The results also show that market participation reduces the probability of a negative change in diet by 49% for market participant households. Similarly, the probability that the household would reduce food intake during the period of food shortage declines by 71%. The probability of reducing food intake would decline by 15% for nonparticipants in the market had they participated in the market. This implies that, despite the fact that households usually smooth their consumption using variety of methods, the substantial food gap remaining would force households to liquidate their assets (especially livestock) during times of food shocks (Hänke & Barkmann, 2017). Livestock thus plays an important role in contributing to food security through providing cash income from livestock sales that can be used to purchase food, especially during times of food deficit (Dorward *et al.*, 2005; Hatab *et al.*, 2019; Njuki & Sanginga, 2013).

This suggests that livestock serve as a financial source, that can be drawn upon in the season when lower production and income are insufficient to support consumption needs (Dorward *et al.*, 2005). Studies conducted in rural Ethiopia also indicated that livestock is an alternative coping mechanism as it provides the household with assets that can be sold in times of shocks (Mogues, 2011; Yilma *et al.*, 2014). The study in Niger further indicated that 60% of the households relied on livestock sales to cope with food shortages or unexpected medical expenditures (Alary *et al.*, 2011). Sim-

Table 4 - Treatment effects based on switching-probit model.

Outcome	ATT	ATU	ATE	MTE
Self-reported food insecurity	-0.325***	0.296***	-0.042***	-0.017***
Negative change in diet	-0.488***	-0.279***	-0.389***	-0.327***
Reduced food intake	-0.711***	-0.148***	-0.450***	-0.139***

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016); ATT-Average Treatment Effect On The Treated, ATU-Average Treatment Effect On The Untreated, ATE- Average Treatment Effect and MTE-Marginal Treatment Effect, *** denotes significance at 1% level.

ilarly, Hänke & Barkmann (2017) also found that approximately 54% of total cash income came from livestock sales and accounted for around 57% of cash food expenditures on average. Thus, livestock, by providing products for income generation and quick cash when emergencies and shocks occur, occupies an integral part of smallholder farming systems.

4. Conclusion

In Ethiopia, where a large proportion of rural households depend on livestock for livelihood, food security remains a significant concern for large portions of the population. However, with a significant number of poor people depending on livestock production for their livelihood and incomes, the livestock sector is expected to play an instrumental role in achieving sustainable food security in the country. The sector has the potential to improve food and nutrition security and to promote more inclusive agricultural sector growth (Aklilu & Catley, 2014, ILRI, 2019). Furthermore, the potential size of livestock population in the country also implied that livestock sector intervention in Ethiopia will have significant socio-economics importance not only for the country but also for the region at large (Enahoro *et al.*, 2019). Hence, the livestock sector in Ethiopia, after several years of neglect, was recently recognized as one of the key sectors in the broader economic development plans of the country (Shapiro *et al.*, 2015). In this plan of development, market participation of the smallholder agriculture was adopted as a strategy for the economic transformation of the country.

The current study uses an endogenous switching regression model framework combined with the propensity score matching strategies to evaluate the determinants of livestock market participation and their subsequent effect on household's food security and welfare in Ethiopia. As the study had used a nationally representative household survey data, the results of the study have the most favorable scale for the strategic orientation of policy makers (Jeder *et al.*, 2020). The results of the study indicate that livestock market participation by smallholder farmers in Ethiopia has increased household food security

and welfare, with both outcomes substantially greater for households participating in the market. In addition, livestock sales have smoothed out food consumption by providing income in times of harvest failure or other household shocks. This is very important in rural areas of Ethiopia where households with few social protections frequently experience economic hardship. Consequently, the results of the study suggest the transformation of livestock production system into a more sustainable, market-oriented production system would benefit farmers.

In this endeavor, the important variables for the transformation of livestock production system were also identified in the results of the study. As indicated in the results, most of the farmers are far from market centers and major roads, indicating the absence of an assured effective livestock market near the farmers' residence. The absence of assured markets for the farmers produces lead to distress sales and thus reduces revenues from sales by increasing the transaction cost of marketing. These circumstances would in turn hinder the effort of the transformation of livestock production system into a sustainable market-oriented system. Besides poor market infrastructure, the results of the study also indicated that control of animal disease would help households increase their herd size. Systems for better disease control are important policy considerations in promoting both the market orientation and the food security of the households. In addition, as illiteracy among the producers was prevalent, provision of market information through strengthening the extension system is desirable. Furthermore, though the institutional factors like cooperatives and credit are insignificant in the current study, formations and strengthening of farmers' institutions are critically important to improve the market orientation and market linkages of the smallholder farmers. Otherwise, individual livestock producers may find it difficult to use the improved market linkages. Therefore, the effort to improve market linkages for livestock producers should integrate the market-oriented livestock production system with a system of livestock health, breeding and marketing services. Finally, since livestock sales not only provide

cash income for farm households but also generate a significant number of jobs, especially in rural areas where other income opportunities are limited, the future research of interest in livestock marketing should consider the effect of livestock market participation on other elements of livestock value chains.

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Appendix

Table A.1 - Descriptive statistics of the independent variables used in the study.

Variables	Participants (N= 1,432)		Non-participants (N= 1,223)		t/X ² -value
	Mean	St.dev.	Mean	St.dev.	
<i>Households' characteristics and asset ownerships</i>					
Gender (=1 if male)	82.47		75.72		-4.301***
Age (in Years)	47.70	0.37	48.02	0.43	0.590
Educational level (in Years)	0.448	0.448	0.392	1.889	0.4671
Adult equivalent household size	4.55	0.048	4.33	0.05	-3.044***
Household size (Numbers)	5.61	0.059	5.34	0.07	-3.051***
Nonfarm (=1 if it owns non-farm enterprise)	21.51		21.51		-0.002
HCI (%)	10	0.005	21.7	0.0819	2.150**
Asset index ³	0.26	0.04	0.039	0.04	-3.742***
Farm size (hectare)	1.64	0.08	1.27	0.05	-3.852***
<i>Transactions cost factors</i>					
Distance to road (Km)	15.04	0.54	17.16	0.61	2.490**
Distance to market (Km)	65.83	1.29	68.25	1.49	1.212
Distance to administration (Km)	175.42	3.66	156.25	3.43	-3.837***
<i>Information variables</i>					
Mobile phone ownership (=1 if head owned)	58.14		52.51		-2.906***
Access to extension (=1 if it has access)	45.87		41.62		-2.203**
<i>Herd characteristics and shocks</i>					
Herd size owned in TLU	6.817	0.204	4.085	0.135	-10.781***
Dead animals (No.)	4.37	0.18	2.74	0.07	-7.867***
Shocks (= if HH affected negatively by shock)	65.36		60.75		-2.458**
<i>Institutional factors</i>					
Access to social safety net (=1 if received)	7.12		4.82		-2.476**
Access to remittance (=1 if received)	10.55		8.26		-2.004*
Cooperative (=1 if available in the community)	15.57		14.96		-0.435
Credit (=1 if received credit)	18.65		17.33		-0.875

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016); ***, ** and * denotes significance at 1%, 5% and 10 % level respectively.

³ The asset index was computed by applying the first principal component to household assets' including farm implement, furniture, personal items and other assets.

Table A.2 - Matching quality test indicators before and after matching.

Matching algorithm	Pseudo R2		LR X ² (p-values)		Mean standardized Bias		Total % bias reduction
	Before matching	After matching	Before matching	After matching	Before matching	After matching	
Kernel based matching (KBM)	0.168	0.02	247.40 (0.000)	9.84 (0.971)	21.3	3.1	85
Nearest neighbor Matching (NNM)	0.167	0.04	229.23 (0.000)	14.78 (0.737)	21.2	3.6	83

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016).

Table A.3 - Results of average treatment effects (ATT) and sensitivity analysis.

Matching algorithms	Outcomes variables	Participants	Non-participants	ATT (S.E)	Critical value of the hidden bias(Γ)
Kernel based matching (KBM)	HDD	6.972	6.754	0.218 (0.081)***	1.15-2.35
	Self-reported food insecurity	0.286	0.279	0.007 (0.018)	1.05-1.15
	Negative change in diet	0.259	0.297	-0.037 (.020)*	1.05-1.1
	Reduced food intake	0.144	0.172	-0.037 (0.022)*	1.05-1.25
	Percapita consumption Expenditure (ln)	8.508	8.448	0.059 (0.03)**	1.45-1.9
Nearest neighbor Matching (NNM)	HDD	6.972	6.769	0.203 (.086)**	1.2-2.0
	Self-reported food inssecurity	0.288	0.256	0.030 (0.028)	1.05-1.35
	Negative change in diet	0.240	0.297	-0.057 (.028)**	1.05-1.35
	Reduced food intake	0.120	0.172	-0.052 (0.021)**	1.25-1.85
	Percapita consumption Expenditure (ln)	8.519	8.444	0.075 (0.033)**	1.40-1.80

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016); ***, ** and * denotes significance at 1%, 5% and 10 % level respectively. The Number in brackets show bootstrapped standard errors with 100 replication samples.

Table A.4 - Test for the validity of selection instruments for endogenous regression model.

Variables	(1) Market participation	(2) Percapita consumption expenditure (ln)	(3) HDDS	(4) Self-reported food insecurity
Extension services	0.103 (0.050)**	0.026 (0.024)	0.011 (0.074)	0.114 (0.070)
Mobile ownership	0.038 (0.0057)***	-0.169 (0.025)***	0.416 (0.076)***	0.095 (0.071)
Other variable	Yes	Yes	Yes	Yes
Constant	0.242 (0.139)*	9.182 (0.059)***	7.496 (0.181)***	(1.513) (0.169)***
Wald chi2(2) F	254.62***	F = 16.55	19.90	235.26***
Observations	2655	1223	1223	1223

Note: Models (1) and (4) are Probit model, Models (2) and 4) are Ordinary least squares; ***, ** and * represents the significance level of p value at a probability of 1, 5 and 10 respectively; values in the parenthesis are the standard errors. The reports of control variables included in the model were not reported to save the space.

Table A.5 - The determinants of market participation.

<i>Variables</i>	<i>Coefficients</i>	<i>Std. Err.</i>	<i>P>z</i>
Gender	0.234 ***	0.067	0.000
Age	-0.002	0.002	0.185
Educational level	0.017	0.013	0.191
Household size	0.028 **	0.013	0.027
Nonfarm	0.002	0.063	0.975
HCI	-0.135 ***	0.072	0.0063
Farmsize	0.022	0.012	0.162
Cooperative	0.003	0.003	0.355
Distance to road	-0.001 ***	0.002	0.004
Distance to market	-0.002 ***	0.001	0.002
Distance to administration	0.002	0.002	0.296
Extension	0.094 *	0.054	0.085
Mobile ownership	0.102 **	0.048	0.032
Asset index	0.091	0.022	0.482
TLU	0.047 ***	0.008	0.000
Dead animals	-0.117*	0.067	0.083
Shocks	0.195 *	0.113	0.083
safety net	0.041	0.054	0.447
Remittance	-0.149 *	0.089	0.093
Credit	0.004	0.009	0.624
_cons	0.017	0.161	0.918

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016); ***, ** and * denotes significance at 1%, 5% and 10 % level respectively.

Table A.6 - Endogenous switching regression model for continuous outcomes.

Variables	Household dietary diversity (HDD)				Per capita consumption expenditure (ln)			
	Participants (N= 1,432)		Non-participants (N= 1,223)		Participants (N= 1,432)		Non-participants (N= 1,223)	
	Coef.	P>z	Coef.	p>z	Coef.	p>z	Coef.	p>z
Gender	0.069 (0.137)	0.611	0.163 (0.139)	0.240	0.067 (0.043)	0.114	0.038 (0.046)	0.408
Household size	-0.004 (0.023)	0.856	-0.049 (0.027) *	0.068	-0.090 (0.008)***	0.000	-0.103 (0.009)	0.000
Age	-0.013 (0.003) ***	0.000	-0.011 (0.004) ***	0.002	-0.002 (0.001)*	0.084	-0.004 (0.001)***	0.001
Educational level	0.005 (0.023)	0.839	0.042 (0.027)	0.128	0.006 (0.007)	0.400	0.009 (0.009)	0.344
Nonfarm	-0.002 (0.004)	0.571	0.006 (0.002)	0.722	0.141 (0.037)***	0.000	0.063 (0.043)	0.141
HCI	0.006 (0.001)	0.346	0.370 (0.127) ***	0.004	-0.0022 (0.001)	0.239	-0.0073 (0.0001)	0.188
Asset index	0.318 (0.114) ***	0.005	0.350 (0.040) ***	0.000	0.097 (0.011)***	0.000	0.100 (0.013)***	0.000
Farmsize	0.336 (0.034) ***	0.000	0.034 (0.033)	0.295	0.003 (0.001)	0.825	0.032 (0.013)	0.015
Distance to road	-0.004 (0.002)**	0.067	-0.006 (0.003)**	0.041	-0.002 (0.001) ***	0.004	-0.002 (0.001)*	0.064
Distance to market	-0.004 (0.001)***	0.000	-0.004 (0.001)***	0.002	-0.002 (0.004)***	0.000	-0.003 (0.000)***	0.000
Distance to administration center	-0.003 (0.004)	0.946	-0.01 (0.001)*	0.064	-0.002 (0.001)***	0.053	-0.003 (0.000)*	0.060
TLU	0.034 (0.009)***	0.000	0.030 (0.017)*	0.069	0.012 (0.004)***	0.002	0.029 (0.007)***	0.000
Dead of animals	-0.001 (0.010)	0.909	-0.041 (0.024)*	0.084	-0.006 (0.003)***	0.065	-0.022 (0.008)***	0.004
Shocks	-0.333 (0.130)**	0.010	-0.045 (0.108)	0.679	-0.065 (0.033)***	0.048	-0.061 (0.037)***	0.099
safety net	-0.086 (0.193)	0.656	0.287 (0.151)*	0.057	-0.002 (0.063)	0.974	-0.095 (0.049)***	0.053
Remittance	0.585 (0.155)***	0.000	0.420 (0.191)**	0.028	0.173 (0.051)***	0.001	0.221 (0.064)***	0.001
Mobile ownership	0.415 (0.101)	0.000	0.428 (0.120)	0.000	0.168 (0.033)	0.000	0.152 (0.040)	0.000
Credit	-0.094 (0.124)	0.447	-0.192 (0.140)	0.171	-0.064 (0.040)	0.114	-0.121 (0.047)***	0.010
Cooperative	0.094 (0.101)	0.351	0.017 (0.249)	0.945	-0.083 (0.043)	0.052	0.013 (0.081)	0.878
_cons	6.930 (0.382)	0.000	7.464 (0.364)	0.000	9.247 (0.105)	0.000	9.505 (0.117)	0.000
σ	0.580 (0.050)	0.000	0.620 (0.047)	0.000	-0.587 (0.036)	0.000	-0.514 (0.068)	0.000
ρ	0.539 (0.1949)	0.006	0.494 (0.163)	0.002	-0.416 (0.152)	0.006	0.590 (0.223)	0.008
LR test of indep. eqns.: chi2(1) = 25.95 Prob > chi2 = 0.0147								
Wald X^2	=	187.57***				315.35***		
LR test of indep. eqns.:			chi2(1) = 22.86			Prob > chi2 = 0.0000		

Note: Ethiopia Socio-economic Survey (ESS) (2015-2016); * p<0.01, ** p<0.05, *** p<0.01.

Table A.7 - Endogenous switching probit regression model.

Variables	<i>Self-reported food insecurity</i>		<i>Negative change in diet</i>		<i>Reduced food intake</i>	
	<i>Participants</i> (N= 1,432)	<i>Non-participants</i> (N= 1,223)	<i>Participants</i> (N= 1,432)	<i>Non-participants</i> (N= 1,223)	<i>Participants</i> (N= 1,432)	<i>Non-participants</i> (N= 1,223)
	<i>Coeff.</i> (<i>Std. Err.</i>)	<i>Coeff.</i> (<i>Std. Err.</i>)	<i>Coeff.</i> (<i>Std. Err.</i>)	<i>Coeff.</i> (<i>Std. Err.</i>)	<i>Coeff.</i> (<i>Std. Err.</i>)	<i>Coeff.</i> (<i>Std. Err.</i>)
Gender	-0.035 (.088)	-0.093 (0.112)	-0.083 (0.092)	0.153 (0.093)*	-0.194 (0.111)*	-0.203 (0.079)**
Age	-0.001 (.002)	-0.0022 (0.003)	-0.001 (0.002)	-0.002 (0.02)	-0.005 (0.003)*	-0.004 (0.002)*
Education level	-0.04 (.015)***	-0.037 (0.018)**	0.056 (0.015)***	0.024 (0.017)	-0.026 (0.021)	0.016 (0.015)
Household size	-0.003 (.015)	-0.006 (0.021)	0.006 (0.016)	-0.010 (0.018)	0.013 (0.018)	-0.005 (0.017)
Cooperative	0.126 (.090)	-0.093 (0.104)	-0.140 (0.094)	0.102 (0.10)	-0.661 (0.151)	0.06 (0.090)
Distance to road	0.008 (.002)***	0.009 (0.003)***	0.08 (.002)***	0.010 (0.003)***	0.006 (0.002)***	0.005 (0.002)**
Distance to market	0.0001 (.001)	0.003 (0.002)*	0.004 (0.001)	0.002 (0.001)*	0.001 (0.001)	0.009 (0.001)
Distance to administration center	0.001 (.000)***	0.0008 (0.0003)**	0.002 (0.003)***	0.001 (0.003)***	0.002 (0.003)***	0.001 (0.003)***
Mobile ownership	0.131 (0.064)**	0.150 (0.090)*	0.105 (0.067)	0.144 (0.088)	0.311 (0.077)***	0.033 (0.067)
safety net	-0.316 (.120)***	-0.258 (0.160)	0.373 (0.124)***	0.329 (0.150)**	0.360 (0.138)***	0.349 (0.137)**
Remittance	-0.182 (.098)*	-0.177 (0.127)	0.202 (0.101)**	0.105 (0.123)	0.221 (0.117)*	0.105 (0.109)
Nonfarm	0.099 (.076)	0.063 (0.088)	-0.122 (0.080)	-0.024 (0.082)	-0.093 (0.095)	-0.065 (0.077)
Credit	-0.147 (.081)*	-0.038 (0.105)	0.243 (0.085)	0.059 (0.096)	0.162 (0.107)	0.093 (0.083)
HCI	-0.001 (.0004)	0.0003 (0.0004)	-0.343 (0.174)**	-0.036 (0.117)	-0.234 (0.212)	-0.304 (0.140)
Dead animals	-0.012* (.007)	-0.028 (0.020)	0.007 (0.007)	0.012 (0.016)	0.016 (0.007)**	0.021 (0.016)
TLU	0.012 (0.008)	0.00247 (0.033)	-0.002 (0.009)	-0.023 (0.029)	0.006 (0.009)	0.007 (0.018)
Farmsize	-0.004 (.003)	0.057 (0.042)	-0.025 (0.016)	-0.051 (0.037)	-0.062 (0.028)**	-0.033 (0.034)
Shocks	0.497 (.075)***	0.524 (0.149)***	0.448 (0.076)***	0.467 (0.135)***	0.497 (0.095)***	0.285 (0.107)***
Asset index	0.084	0.057	0.015	0.021	0.074***	0.024
_cons	1.285 (.161)***	0.403 (0.479)	-1.425 (0.169)***	-0.346 (0.366)	-1.424 (.201)***	-0.248 (0.245)
Wald chi2	= 276.09***		280.63***			
LR test of indep. eqns. (rho1=rho0=0): chi2(2) = 21.26 Prob > chi2 = 0.0000		LR test of indep. eqns. (rho1=rho0=0): chi2(2) = 18.12 Prob > chi2 = 0.0001		LR test of indep. eqns. (rho1=rho0=0): chi2(2) = 14.61 Prob > chi2 = 0.0007		

Source: Ethiopia Socio-economic Survey (ESS) (2015-2016); * p<0.01, ** p<0.05, *** p<0.01.

Les enjeux de la dépendance de la filière de blé en Algérie : Analyse par asymétries de réponses de l'offre dans la chaîne de valeur

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Abstract

The aim of this study is to examine empirically the dependency issues of the wheat sector in Algeria on the international market, using time series and prediction techniques. The study investigates the adjustment process of supply to price disequilibria in order to assess the functioning of the wheat sector in domestic production and import sectors. The time interval for the study runs from 1965 to 2019 using official data. The asymmetric error correction model is used highlighting asymmetries in the response of supply to prices. The main results of the model and the predictions made for 2040 explicitly stipulate that the challenges facing the wheat sector in Algeria are: a growing inability to meet domestic demand for durum wheat, a total disappearance of local production of common wheat, and a more exaggerated resort of the import option for the wheat. Implications for public policy are derived in terms of food security.

Keywords: Wheat sector, Food security, Error correction model, Asymmetric adjustment, Algeria.

1. Introduction

Le blé et ses produits dérivés est le principal aliment de la population sud-méditerranéenne, ce qui lui confère un rôle stratégique dans les politiques nationales. Dans tout le Maghreb, la base de l'alimentation en céréales demeure le blé dur, étant un produit traditionnel ancré dans la tradition (avec la semoule) mais qui est de plus en plus concurrencé par le blé tendre (pain). Ce qui n'est pas sans poser de problème, car le blé dur est beaucoup mieux adapté au contexte agro-climatique méditerranéen que le blé tendre (Abecassis & Bergez, 2009 ; Rastoin & Benabderrazik, 2014 ; Abis, 2015 ; Charmet *et al.*, 2017).

D'après Chabane & Boussard (2012), il s'avère que le degré de déficit de la balance commerciale agricole depuis près d'un demi-siècle démontre que l'Algérie présente un profil de dépendance alimentaire structurel qui interpelle sérieusement sur le devenir de la sécurité alimentaire du pays. Aujourd'hui, l'Algérie ne couvre qu'environ 25% de ses besoins en blés. Assurer la sécurité alimentaire de l'Algérie constitue donc une priorité pour la politique publique. Le gouvernement algérien n'a cessé, depuis 1962, de se considérer comme responsable de l'alimentation de base de la population (Bencharif *et al.*, 1996). En conséquence, le rôle nourricier de l'État a suscité une politique céréalière qui est restée constante dans les objec-

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tifs, quels que soient les changements dans les orientations économiques (Talamali, 2000). De ce fait, le pays continue d'importer massivement les céréales de l'étranger pour couvrir des besoins domestiques (Feliachi, 2000). Ceci à travers l'Office Algérien Interprofessionnel des Céréales (OAIC), considéré comme instrument important de la politique céréalière du gouvernement. Il est doté de l'autorité pour coordonner et gérer les mécanismes de l'ensemble des dispositifs de l'importation et de la régulation du marché des céréales. Il avait toujours bénéficié de subventions importantes allouées par le trésor public pour le soutien des prix payés tant au producteur qu'au consommateur (Talamali, 2000).

Les besoins nationaux en céréales, et en particulier le blé, ne cessent d'augmenter à cause de l'accroissement démographique, passé de 12,09 millions d'habitants en 1966 à 43,42 millions en 2019 (ONS, 2019). Cette croissance démographique s'est accompagnée d'une très forte urbanisation. Selon les produits, les céréales occupent la première place dans le budget alimentaire des ménages algériens (17,5% de la dépense alimentaire totale). Aussi, la part budgétaire des produits céréaliers est d'environ 20% dans les zones rurales contre 16,3% dans les zones urbaines (ONS, 2011).

Selon Bencharif *et al.* (1996), ce qui reste vrai jusqu'à nos jours, la filière algérienne des céréales se distingue des autres filières agroalimentaires nationales et des filières de céréales d'autres pays par les caractéristiques suivantes : l'existence d'une importante capacité de production agricole nationale, même si elle n'a pas pu suivre le triplement du nombre des consommateurs, le poids devenu de plus en plus écrasant des importations, les constantes interventions de l'État, un modèle de consommation alimentaire dans lequel les blés tiennent une place essentielle. De nos jours, les blés durs et tendres constituent la principale base du régime alimentaire pour les consommateurs algériens. Ils se consomment principalement sous forme de pain et de couscous.

L'industrie de première transformation des blés représente, quant à elle, un taux d'utilisation des capacités de production de 79,5% en 2019 (ONS, 2019) en raison de l'importance relative de ses capacités de trituration. À ce titre, la capacité virtuelle de trituration annuelle installée a enregistré au cours de la dernière année une augmentation de plus de 76,08%. Elle est en nette proportion avec les politiques agricoles et alimentaire adoptées par le gouvernement algérien, notamment la politique du renouveau agricole et rural (PRAR). De plus, l'adoption d'un modèle de consommation alimentaire de type occidental est une tendance qui accentue cette dépendance bien que ce type de consommation n'ait pas de justification sur le plan nutritionnel. Dans une certaine mesure, ce modèle de consommation se trouve inadapté aux conditions de production locale (Arif & Zga, 1988 ; Le Mouél & Schmitt, 2017). D'après Bedrani *et al.* (1993), les importations alimentaires avaient commencé à augmenter de façon très forte dès les années soixante-dix, et ce dans le cadre de la politique alimentaire. Ce choix stratégique était conjoncturel et motivé par la disponibilité en devises.

En conséquence de ces faits explorés, la problématique actuelle stipule qu'il est devenu impérieux d'atténuer la croissance des importations par l'augmentation de la production locale afin de soulager la balance commerciale du pays. La démarche méthodologique adoptée consiste à présenter un bref diagnostic de la filière de blé en Algérie depuis l'indépendance jusqu'à nos jours. Ensuite, nous utilisons des outils d'analyse élaborés afin de comprendre les déséquilibres encourus à l'amont de la chaîne de valeur de blé et apercevoir les enjeux de la dépendance alimentaire en Algérie. Nous utilisons une analyse par les asymétries de réponses de l'offre aux prix à travers le modèle de correction d'erreur asymétrique (AECM)¹ sur la période de 54 ans (1965-2019)². L'analyse est faite sur la réponse des structures internes de production et pareillement sur les réponses par rapport aux

¹ Abréviation de *Asymmetric Error Correction Model*.

² L'étude de Benmehai (2021) a utilisé le ECM sur 19 cultures, dont les céréales ont été exclues à cause de l'usage de prix à la production (qui sont subventionnés dans son cas). Dans notre cas, nous contournons cette difficulté en utilisant des prix de collecte calculés de l'amont de la filière, et en plus cette étude supposera une réponse asymétrique.

flux d'importation. Il s'agit de savoir à quelle mesure l'ajustement aux déséquilibres est-il plus efficient dans les deux cas de figure. Nous envisageons aussi d'élaborer des perspectives sur la base des prévisions jusqu'à 2040.

Le papier est organisé comme suit. La section 2 présente un cadre conceptuel pour l'analyse de la filière de blé (les structures de l'offre et de son organisation). La section 3 présente la méthodologie utilisée dans cette recherche. La section 4 explore et discute les résultats. La section 5 conclue.

2. L'organisation de la filière de céréales en Algérie : cadre conceptuel

2.1. La structure de production

La filière de céréales et en particulier la filière de blé est une filière stratégique et représente un poids considérable dans l'économie algérienne. Elle constitue l'un des maillons les plus importants du système alimentaire du pays. Elle représente la première industrie agroalimentaire en Algérie. Cependant, elle connaît une dépendance vis-à-vis de l'étranger pour satisfaire la demande interne en céréales, principalement les blés, mettant ainsi en péril la sécurité alimentaire et la souveraineté du pays.

De l'époque coloniale à ce jour, les moyennes décennales de la superficie cultivée en céréales indiquent qu'annuellement sont entre 2,4 et 3,2 millions d'hectares, soit 28% à 40% de la SAU. La plus grande superficie revient au blé dur qui occupe une moyenne de 1,39 million d'hectares durant la période 1965/2019 (DSASI, 2020). Ceci est dû à l'instauration des prix de vente attractifs, soit 4 500 DZD/Qx. Le blé tendre se classe en troisième position après l'orge. Sa superficie moyenne reste stable et faible durant la même période 1965-2019. En effet, la surface moyenne 1965-2019 de blé tendre avoisine 624,7 milles d'hectares. Elle représente 33% de la superficie moyenne des blés durant la période 1965/2019 et 23,51% de la superficie moyenne des céréales durant la même période (1965-2019). Le prix de vente pratiqué sur le blé tendre est de 3 500 DZD/Qx.

Par ailleurs, la céréaliculture algérienne est

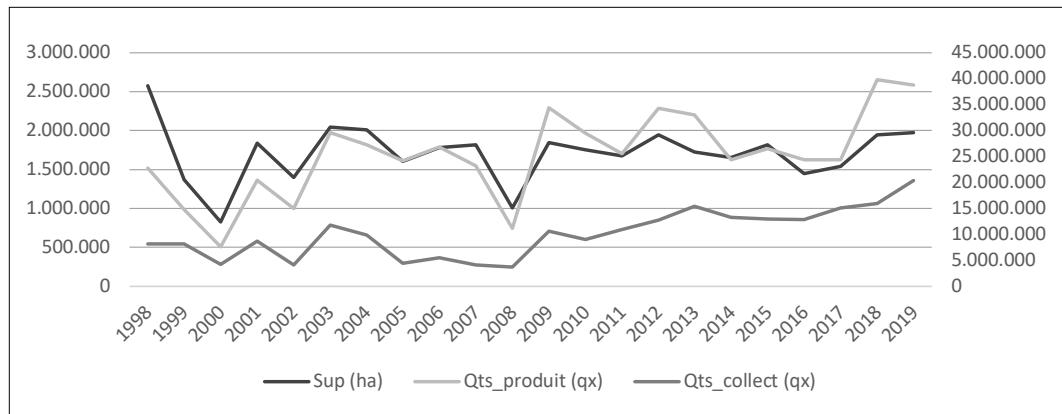
conduite en mode pluvial, engendrant une production dépendante de la précipitation (Tabet-Aoul, 2008 ; Chabane & Boussard, 2012 ; Benmehaia *et al.*, 2020), ajoutant les problèmes de l'itinéraire technique inadéquat, la faible mécanisation et la non-application des facteurs d'intensification (ITGC, 2010). Également, le volume annuellement produit en semences réglementaires (certifiées et ordinaires) est insuffisant et ne couvre que de 30% en moyenne des besoins nationaux en semences.

La production, malgré ses fluctuations, n'a pas cessé de croître, démontrant ainsi des capacités potentielles de production et des réserves existantes pour réduire la dépendance du pays vis-à-vis de l'extérieur. À ce titre, et d'après la DSASI (2020), la moyenne de production décennale 2009-2019 des blés a connu une amélioration des performances, soit une production moyenne des blés de 3,04 millions de tonnes sur une superficie de 1,7 million d'hectares, où le rendement moyen des blés enregistré est de 1,73 tonne/ha. Alors que dans la période 1998-2008, la production moyenne des blés enregistrée est évaluée à 2,02 millions de tonnes sur une superficie de 1,6 million d'hectares, où le rendement moyen décennal des blés enregistré est de 1,21 tonne/ha.

Pour ce qui est de la collecte des blés, elle est toujours inférieure par rapport à la production. L'écart moyen enregistré entre la production et la collecte des blés durant 2009-2019 est de 44,53%. Alors que durant 1998-2008, l'écart moyen enregistré était de 32,70%. Cet écart représente généralement l'autoconsommation : une quantité des céréales importante est exclue du programme de régulation. Malgré les efforts consentis par le gouvernement, l'écart entre la production et la collecte est toujours observé depuis l'indépendance. Les performances sont montrées dans la Figure 1 ci-après.

Ces performances en matière de production et de rendement sont les conséquences des politiques agricoles qui ont été mobilisées par le gouvernement algérien à partir de 2000. Le programme d'intensification céréalier a été initié en 1998 et il est poursuivi avec l'arrivée du Plan National du Développement Agricole et Rural (PNDAR), de 2000 à 2008, qui a donné

Figure 1 - Évolution de superficie, production et collecte des blés durant 1998-2019.



également des résultats prometteurs en matière de production et de rendement. Le programme de Renouveau Agricole et Rural (PRAR) en 2009-2015 avait l'objectif d'amélioration de la productivité des céréales par l'utilisation d'irrigation d'appoint. Ensuite, le programme *Filaha* 2016-2019 a permis d'achever les programmes par filière initiés par la politique PRAR, surtout la filière de blé. À ce titre, cette politique a permis d'initier un programme de sécurisation de la production des céréales par la diffusion de l'irrigation d'appoint. En effet, la superficie irriguée moyenne des céréales pour la décennie 2000-2019 reste très faible, dans la mesure où elle ne représente que 5,25% de la surface moyenne des céréales durant la même période (Bencharif *et al.*, 2010 et Estimation par les auteurs sur la base des statistiques du DSASI, 2020).

L'industrie de transformation des céréales, quant à elle occupe en Algérie la première place dans le secteur des industries agroalimentaires après l'industrie du lait, en raison de l'importance relative de ses capacités de trituration, soit un taux d'utilisation des capacités de production de 79,5 (ONS, 2019). L'importance de la demande en produits céréaliers, notamment en semoule et en pain, a conduit le gouvernement à libérer le marché de première transformation aux opérateurs privés, soit 80% du circuit de distribution des produits céréaliers assuré par les opérateurs privés

(plus de 540 semouliers-minotiers). Le reste du marché est assuré par les filiales du groupe public AGRODIV (plus de 50 semouliers-minotiers). Aussi, d'après le rapport de l'ONS (2011), la production brute des industries agroalimentaires est de 1,4 milliards DZD représentées pour une grande partie par le secteur de grains générant une production de 1,2 milliards DZD.

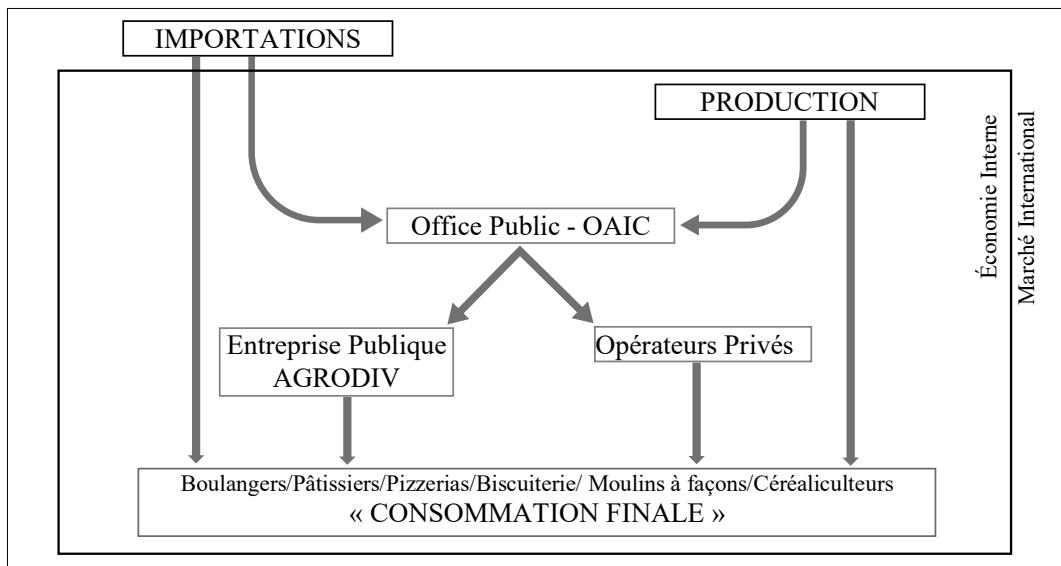
De l'indépendance à ce jour, les unités de première transformation ont connu un accroissement en nombre, soit 949% et un accroissement en capacité de trituration, soit 2 086%. Ces performances en matière de transformation des grains ont été poussées par les prix incitatifs et réglementés adoptés par le gouvernement. Le blé dur est cédé aux transformateurs à un prix de 2 280 DZD/Qx³, alors que le prix réel dépasse largement le prix cédé, soit plus de 4 000 DZD/Qx. Le blé tendre est cédé aux transformateurs à 1 285 DZD/Qx⁴, alors que le prix réel dépasse largement le prix cédé, soit plus de 3 000 DZD/Qx.

D'autres résultats montrent qu'avec l'avènement du PNDAR (de 2000 à 2008), les rendements en blés sont passé en moyenne de 9,5 à 13 Qx / Ha, soit un accroissement de 34%. Cependant, les importations ont connu, durant la même période, une augmentation en quantité (soit 34%) et en valeur (soit 77%). Ceci s'explique par l'augmentation des quantités livrées aux unités de transformation qui sont passées en

³ Conformément au décret exécutif n° 07-402 du 25 décembre 2007.

⁴ Conformément au CIM du 26 juin 2004.

Figure 2 - Représentation systémique de la filière de blé et de leur positionnement dans leur contexte socio-économique en 2020.



moyenne de 2,3 millions de tonnes à 3,2 millions de tonnes pour satisfaire la demande nationale, malgré les efforts consentis par l’État en matière de soutien des prix à la production nationale (1900 à 2 100 DA/Quintal pour le blé dur et de 1 700 à 1950 DA/Quintal pour le blé tendre). Pour ce qui est des impacts de programmes PRAR (2009 à 2015) et *Filaha* (2016 à 2019), les rendements en blés ont continué à augmenter pour atteindre une moyenne nationale de 17 Qx/Ha à fin 2019. En même temps, l’importation a aussi continué à accroître en quantité (soit 15%) et en valeur (soit 24%) en raison d’une forte demande en aval (6,5 millions de tonnes de blé tendre et environ 3 millions de tonnes de blé dur ont été livrées aux industriels). Dans cette optique, il faut noter que les pouvoirs publics ont toujours privilégié le soutien à la production nationale du blé dur (4 500 DA/Quintal) au détriment de celle du blé tendre (3 500 DA/Quintal) malgré que ce dernier connaît une forte demande sur le marché.

2.2. L’organisation actuelle de la filière de blé

La Figure 2 représente un schéma de l’organisation actuelle de la filière de blé en Algérie. Nous pouvons la décrire comme suit. Sur les

8,4 millions d’hectares de sols arable, la céréaliculture occupe ces dernières années 40%, dont 23% destinée à la filière de blé (18% pour le blé dur et le reste, soit 5% pour le blé tendre). Sur le plan de la production et malgré les fluctuations dues à la diversité agro climatique des zones de production, les performances sont restées relativement stables puisque la production moyenne 2009-2019 en blé enregistrée au cours de la dernière décennie est de 3,04 millions de tonnes sur une superficie de 1,75 millions d’hectares. Il est important de signaler que la part de la production nationale consacrée à l’industrie de première transformation (collecte entrée dans le processus de transformation) est relativement faible. Par ailleurs, l’autoconsommation des blés (quantités non collectées) utilisée pour diverses raisons (semences ordinaires, moulins à façon et alimentation animale) représente une moyenne décennale 2009-2019 de 45%.

Les approvisionnements de l’industrie céréalière sont assurés de plus en plus par le blé d’origine importée. C’est qu’on peut l’appeler la filière d’importation des blés (FIB). Devant cette situation, l’OAIC occupe une place prépondérante dans la réalisation de l’ajustement entre la production nationale et l’importation. L’OAIC importe annuellement 80% des besoins

en céréales à partir du marché international, et ce à travers la chaîne logistique d'importation dont elle dispose à travers 9 ports d'importation des céréales, la réception des céréales importées par l'OAIC, la participation au contrôle et à la réalisation de l'agréage des céréales importées, le déchargement, le stockage et la distribution des importations des céréales aux CCLS⁵ (44 coopératives). Il y a lieu de signaler aussi que les importations réalisées par d'autres opérateurs privés ne représentaient que 20% des quantités totales importées. Les CCLS assurent les opérations de la gestion, la collecte et la distribution des céréales aux industries de première transformation ainsi que les réserves des stocks des céréales.

L'industrie de première transformation des céréales est assurée pour une grande partie par les opérateurs privés (plus de 540 semouliers-minotiers), produisant 1 079 millions de kg/an de semoule et 4 097 millions de kg/an de farine. Quant aux issus de meuneries (son des blés triturés), destinés à l'alimentation de bétail, l'industrie de première transformation produit annuellement une quantité de 1 781 millions de kg/an. Le groupe public AGRODIV (6 filiales et 56 complexes industriels et commerciaux rattachés) produit quant à lui une quantité importante en semoule, soit 472 millions de kg/an et en farine, soit 767 millions de kg/an. Une quantité importante du son des blés triturés, soit 437 millions de kg/an est destinée à l'alimentation du bétail. L'emploi dans la filière de céréales notamment dans la filière de blé est considéré comme un marché du travail important. D'après OAIC (2020), l'activité de la production des céréales吸orbe la plus grande part de l'emploi de la filière, soit plus de 700 000 emplois directs.

D'après toutes ces performances, la filière de blé en Algérie reste toujours d'actualité en raison de son déficit structurel qui semble être chronique présageant un avenir sombre pour ce

secteur. Une remise en question de mécanismes de régulation de ce marché s'impose pour mettre en évidence explicitement les dangers encourus.

3. Méthodologie de recherche

3.1. Sources des données et variables

Dans la mesure où la filière de blé en Algérie comporte deux chaînes d'approvisionnement, l'une est basée sur la production locale et l'autre sur l'importation depuis le marché international, cette étude utilise plusieurs sources de données collectées auprès des organisations officielles du pays. L'intervalle de temps pour cette étude s'étale de 1965 jusqu'à 2019 où les données sont disponibles.

Concernant la filière nationale, deux variables sont sélectionnées, à savoir la production agrégée et le prix. Les données sur la production et le prix du blé sont disponibles pour les deux variétés : blé dur et blé tendre. En fonction du propos de cette étude, l'usage de superficie cultivée est préconisé⁶. La série de production, représentée par la variable de la superficie (mesurée en 1 000 ha) est obtenue de la DSASI (2020), tandis que la série des prix de collecte exercés (en DZD) entre les céréaliculteurs et l'OAIC, étant l'office de régulation concerné, est obtenu de l'OAIC (2020) et sont calculés sur la base de ses rapports. Pour le secteur de l'importation de blé, les données sont disponibles seulement pour les deux variétés unies. En conséquence, cette étude utilise aussi deux variables, à savoir la quantité importée de blé et son prix de collecte. Les séries de quantité importée (en 1 000 tonnes) et de prix (en DZD) entre les entités d'importation et l'OAIC sont obtenues de la direction générale de la douane (CNIS, 2020). Les données ont été converties en logarithmes afin d'interpréter les coefficients d'intérêt comme des élasticités.

⁵ L'abréviation de Coopérative des Céréales et Légumes Secs.

⁶ L'usage de la superficie au lieu de la production en quantité est motivé par le fait de la présence de plusieurs facteurs qui déterminent la production. Depuis Nerlove (1956, 1958), l'approche traditionnelle de la réponse de l'offre pour les produits agricoles implique l'utilisation de la superficie cultivée ou récoltée pour représenter la production planifiée (Seale *et al.*, 2013). Néanmoins, Chabane & Boussard (2012) insiste sur l'importance du rendement qui est plus approprié dans ce cas. Vu la contrainte de la disponibilité des données, nous préconisons l'usage de la superficie, justifié pleinement dans les études de réponse de l'offre.

3.2. La procédure de modélisation empirique

En vue d'analyser les asymétries de réponse de l'offre de blé par rapport aux prix, cette étude utilise un modèle de correction d'erreur asymétrique (AECM), variante du fameux modèle de correction d'erreur (ECM). Ce modèle a été conçu et appliqué par certains auteurs, tels que par exemple Hallam (1984), Burton (1985), Jaforullah (1993), Kandil (1998), Kennedy & Schmitz (2009), Yoon & Brown (2017) dans différents contextes dans l'agriculture, comme il est appliqué ailleurs (consommation de différents produits, politique monétaire, etc.). L'idée de ce modèle est de chercher la magnitude d'une réponse (supposée symétrique ou asymétrique) d'une variable par rapport à un déséquilibre à court terme d'une autre variable.

En se basant sur une période de 54 ans (1965-2019), nous établissons une régression reflétant la relation d'équilibre à long terme entre l'offre et le prix. L'équation de l'équilibre à long terme est comme suit :

$$Y_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 T + \varepsilon_t \quad [1]$$

où Y_t représente la production de blé, la superficie étant son proxy, P_t le prix exercé, T la tendance (qui reflète très approximativement l'influence des autres variables telles que la fluctuation de la demande, changement de goûts, aléas climatiques, avancés technologiques, etc.), et ε_t représente le terme d'erreur résiduelle.

Dans la mesure où la relation [1] existe, et afin d'éviter le phénomène des régressions fallacieuses, d'après le théorème de Engle & Granger, les variables devront être cointégrées, I(1). Cela implique l'existence d'un modèle valide de correction d'erreur décrivant la relation (Engle & Granger, 1987 ; Apostolopoulos & Stoforos, 1995). Cela est conçu comme étant une condition préalable au modèle de correction d'erreur (Hallam & Zanoli, 1993 ; Seale *et al.*, 2013). Afin de vérifier la cointégration des séries, cette étude adopte le test de cointégration de Johansen (1988, 1995).

Le ECM fait reproduire la régression de l'équation [1] en utilisant l'opérateur de la première différence (Δ) pour la variable dépendante (Y_t) et la variable indépendante (P_t) avec l'inclusion de la variable décalée de terme d'erreur,

c.-à-d., ε_{t-1} . Son coefficient, λ , sera traité comme étant la vitesse d'ajustement aux déséquilibres dans le processus de réponse. Cette version représente l'équation de l'équilibre de court terme. L'ajustement dans ce cas précis est supposé symétrique, c.-à-d., la réponse de l'offre au changement positif de prix serait similaire en magnitude quant au changement négatif. Cette étude adopte une démarche qui annule cette présupposition, où la magnitude d'ajustement varie selon la direction du changement, c.-à-d., la réponse est asymétrique. Pour cela, le AECM sera décrit donc par l'équation suivante :

$$\Delta Y_t = \alpha_0 + \alpha_1^+ D^+ \Delta P_t + \alpha_1^- D^- \Delta P_t + \lambda^+ D^+ \varepsilon_{t-1} + \lambda^- D^- \varepsilon_{t-1} + \alpha_2 T + \varepsilon_t \quad [2]$$

où D^+ est variable muette qui prend la valeur de 1 si le changement de prix ΔP (ou le terme d'erreur, ε_{t-1}) est positif, et 0 s'il est négatif. De même pour D^- pour les changements négatifs de ΔP (ou le terme d'erreur, ε_{t-1}). Dans ce cas, α_1^+ et α_1^- représentent la réponse (l'élasticité à court terme) pour un changement positif ou négatif respectivement de prix, tandis que λ^+ et λ^- représentent les vitesses d'ajustement aux déséquilibres positifs ou négatifs respectivement de prix. Ce modèle empirique, à travers l'équation [2], sera reproduit 3 fois pour les chaînes de blé. Le premier pour le marché interne de blé dur, le second pour le marché interne de blé tendre, le troisième pour le marché international (le secteur de l'importation) des blés (dur et tendre unis). Dans le dernier cas du marché international, une variable supplémentaire sera introduite, celle de taux de change (coefficient α_3), vue sa pertinence dans ce cas.

Enfin, sur la base des résultats des trois modèles obtenus, cette étude procède le calcul des prévisions de prix et des quantités pour une perspective de prochaines 20 années. Nous émettons des prévisions à partir de 2020 (c.-à-d. de 2020 au 2040) sur la base d'une prédiction dynamique en dehors de l'échantillon en utilisant 54 observations de pré-prévision.

4. Résultats et discussion

Les résultats des modèles empiriques de cette étude sont récapitulés dans les tableaux suivants. Le Tableau 1 représente la réponse de l'offre de

Tableau 1 - Résultats pour la réponse des prix du blé dur sur le marché intérieur.

Test de Johansen pour la cointégration Nombre de vecteurs cointégrents				L'équilibre à long terme Résultats de la régression					
Rang	Eigenvalue	Trace	Lmax	Estimations des paramètres					
0	0,280	33,17***	17,76***	β_0	6,73	(30,5)	***		
1	0,248	15,41***	15,41***	β_1	0,162	(3,21)	***		
<i>Vecteurs de cointégration</i>				β_2	-0,028	(-4,2)	***		
<i>Y</i>	5,496	-1,635		\hat{R}^2	0,373				
<i>P</i>	-1,473	-1,661		<i>F</i>	17,07 (0,000)		***		
				<i>D.W.</i>	1,166				
<i>Les modèles de correction d'erreurs</i>									
<i>Réponse symétrique</i>				<i>Réponse asymétrique</i>					
<i>Estimations des paramètres</i>				<i>Estimations des paramètres</i>					
α_0	-0,028	(-0,57)		α_0	-0,023	(-0,42)			
α_1	0,142	(2,94)	***	α_1^+	0,161	(1,88)	*		
α_2	0,002	(0,14)		α_1^-	0,145	(1,34)			
λ	-0,591	(-4,37)	***	α_2	0,004	(0,27)			
\hat{R}^2	0,329			λ^+	-0,786	(-2,35)	**		
<i>F</i>	9,68 (0,000)		***	λ^-	-0,497	(-2,42)	**		
<i>D.W.</i>	1,935			\hat{R}^2	0,307				
				<i>F</i>	5,70 (0,000)		***		
				<i>D.W.</i>	1,969				

Remarque : Les valeurs entre parenthèses représentent la statistique *t* pour les estimations de paramètres et les valeurs *p* pour la statistique *F*. Astérisques pour les niveaux de signification : *** pour le niveau de 1%, ** pour le niveau de 5% et * pour le niveau de 10%.

blé dur des céréaliculteurs vis-à-vis des prix de collecte auprès de l'OAIC, tandis que le Tableau 2 représente la réponse de l'offre de blé tendre des céréaliculteurs vis-à-vis de son prix de collecte. En revanche, le Tableau 3 représente la réponse de la quantité importée du total de blé par rapport aux prix de collecte. Pour chacun des trois tableaux, le premier segment (en haut à gauche) représente les résultats de test de Johansen pour la cointégration des séries en niveaux entre *Y* et *P*. La partie du tableau à côté représente les résultats de régression de l'équation [1] de l'équilibre de long terme. Le premier segment de la partie inférieure de chaque tableau représente les résultats de ECM dans le cas où la réponse est supposée symétrique (le cas standard). Tandis que le segment à côté (en bas à droite) est le vif du sujet de cette étude, cela représente les résultats de l'AECM.

Les résultats de tests de Johansen (sur les vecteurs cointégrés) montrent pour les trois cas de figure que les séries de production des blés (*Y*) et les prix exercés de chacun sont cointégrés d'ordre 1, I (1), à travers les tests de valeurs propres et les tests de Trace. Les valeurs résultantes montrent une signification statistique très élevée (au niveau de 1%). Le fait qu'on a assuré une cointégration entre les deux séries, le phénomène de régression fallacieuse est dument évité. En conséquence, les modèles de correction d'erreur peuvent être implémentés et interprétés en toute sûreté.

Les élasticités à long terme (β_0) dans chaque modèle, ayant un niveau élevé de signification statistique, montrent que le marché interne se caractérise par des élasticités faibles (0,16 et 0,14 pour le blé dur et tendre respectivement). Tandis que le marché d'importation est caractérisé par

Tableau 2 - Résultats pour la réponse des prix du blé tendre sur le marché intérieur.

Test de Johansen pour la cointégration Nombre de vecteurs cointégrants				L'équilibre à long terme Résultats de la régression					
Rang	Eigenvalue	Trace	Lmax	Estimations des paramètres					
0	0,431	51,29***	30,49***	β_0	6,009	(23,08)	***		
1	0,319	20,80***	20,80***	β_1	0,146	(2,59)	**		
Vecteurs de cointégration				β_2	-0,022	(-4,17)	***		
Y	-5,020	-0,429		\hat{R}^2	0,386				
P	0,894	-1,987		F	17,98 (0,000)		***		
				$D.W.$	1,521				
Les modèles de correction d'erreurs									
Réponse symétrique				Réponse asymétrique					
Estimations des paramètres				Estimations des paramètres					
α_0	0,012	(0,21)		α_0	-0,050	(-0,76)			
α_1	0,100	(2,03)	**	α_1^+	0,265	(3,26)	***		
α_2	-0,008	(-0,50)		α_1^-	-0,113	(-1,13)			
λ	-0,808	(-6,04)	***	α_2	-0,001	(-0,66)			
\hat{R}^2	0,441			λ^+	-0,879	(-2,78)	***		
F	14,94	(0,000)	***	λ^-	-0,744	(-3,75)	***		
$D.W.$	2,062			\hat{R}^2	0,484				
				F	10,97 (0,000)		***		
				$D.W.$	2,154				

Remarque : Les valeurs entre parenthèses représentent la statistique t pour les estimations de paramètres et les valeurs p pour la statistique F . Astérisques pour les niveaux de signification : *** pour le niveau de 1%, ** pour le niveau de 5% et * pour le niveau de 10%.

une élasticité plus élevée (0,48). En dépit de leur caractère significatif (à travers le test de F), les résultats sont moins fiables à cause de certains problèmes de multi-colinéarité présente dans ce type de régression. Cela se manifeste par des niveaux élevés de facteur d'inflation de la variance (supérieur à 10), en plus, une corrélation élevée à travers le coefficient de corrélation ajusté et un niveau faible des valeurs de la statistique de Durbin-Watson ($D.W.$), c.-à-d., significativement loin de 2. Cela nous amène à procéder l'étape suivante, produire un ECM standard.

Les résultats des ECM (le cas symétrique) montrent que, la réponse étant symétrique, la statistique $D.W.$ présente ici des valeurs proches de 2, c.-à-d., absence de problèmes de multi-colinéarité. Les valeurs des coefficients d'ajustement sont négatives, entre 0 et 1 et avec une forte signification (à un niveau de 1%). Ils sont

de 59,1% pour le marché interne de blé dur, 80,8% pour le marché interne de blé tendre et 77,7% pour le marché de l'importation. La vitesse d'ajustement aux déséquilibre passés des prix (dans les deux sens) est moins faible dans le marché interne de blé dur que dans le blé tendre ou le marché d'importation.

Quant à l'élasticité à court terme, la réponse de prix qui est supposée symétrique, elle reste faible pour le marché interne (0,146 et 0,10 pour le blé dur et tendre respectivement) et forte pour le marché d'importation (0,52). Ces valeurs dans ces trois ECM ne représentent que des moyennes de magnitudes de réponse à savoir la direction en allant au-dessus ou au-dessous des valeurs d'équilibre. Pour en savoir plus sur cet aspect, les résultats des AECM montrent qu'effectivement les magnitudes ne sont pas les mêmes quant à la direction du changement.

Tableau 3 - Résultats pour la réponse des prix du blé sur le marché des importations.

Test de Johansen pour la cointégration Nombre de vecteurs cointégrents				L'équilibre à long terme Résultats de la régression					
Rang	Eigenvalue	Trace	Lmax	Estimations des paramètres					
0	0,480	55,26***	35,31***	β_0	4,485	(12,2)	***		
1	0,308	19,94***	19,94***	β_1	0,480	(6,29)	***		
Vecteurs de cointégration				β_2	0,010	(1,29)			
Y	3,779	0,380		β_3	-0,420	(-4,7)	***		
P	-1,327	-2,318		\hat{R}^2	0,897				
				F	159,01 (0,000)		***		
				D.W.	1,591				
Les modèles de correction d'erreurs									
Réponse symétrique				Réponse asymétrique					
Estimations des paramètres				Estimations des paramètres					
α_0	0,129	(1,58)		α_0	0,155	(1,68)	*		
α_1	0,523	(7,55)	***	α_1^+	0,194	(2,07)	**		
α_2	0,016	(2,74)	***	α_1^-	0,866	(8,12)	***		
α_3	-0,206	(-3,00)	***	α_2	0,014	(2,89)	***		
λ	-0,777	(-6,58)	***	α_3	-0,186	(-3,02)	***		
\hat{R}^2	0,670			λ^+	-0,328	(-1,37)	*		
F	27,97 (0,000)		***	λ^-	-0,971	(-7,19)	***		
D.W.	2,208			\hat{R}^2	0,761				
				F	29,14 (0,000)		***		
				D.W.	2,073				

Remarque : Les valeurs entre parenthèses représentent la statistique t pour les estimations de paramètres et les valeurs p pour la statistique F. Astérisques pour les niveaux de signification : *** pour le niveau de 1%, ** pour le niveau de 5% et * pour le niveau de 10%.

Pour le marché interne de blé dur, la réponse aux changements positifs de prix reste à 0,16 avec un niveau élevé de signification, tandis que pour un changement négatif est à 0,14, néanmoins sans signification. La vitesse d'ajustement aux déséquilibres positifs monte à 78,6% tandis qu'elle est moins faible pour les déséquilibres négatifs (à 49,7%). Pareille logique se manifeste pour le marché interne de blé tendre. L'écart de réponse de l'offre aux changements de prix est plus grand (0,26 pour le changement positif et 0,11 pour le changement au sens négatif) avec un taux d'ajustement aux déséquilibres positifs de 87,9% et il est plus faible aux déséquilibres négatifs de 74,4%.

Ces résultats empiriques exhibent un dysfonctionnement au niveau du processus d'ajustement

de la production des blés au niveau du marché interne par rapport aux prix, signalant un faible rattrapage des équilibres négatifs dans ces deux produits (blé dur et blé tendre). Cette faiblesse d'asymétrie dans les réponses conduit, au niveau agrégé, à l'abandon graduel des activités de production des blés au niveau national. Cela remet en question l'efficacité des mécanismes de régulation pour ces deux produits.

La faiblesse de l'ajustement de l'offre aux déséquilibres négatifs des prix signale un danger futur qui peut survenir dans les années prochaines et qui réside dans l'incapacité de satisfaire de moins en moins la demande interne. Ces résultats se montrent très informatifs pour la politique publique, et l'office de régulation en sujet, afin de réexaminer et d'implémenter

des mécanismes plus incitatifs pour les céréaliculteurs dans ce pays.

L'alternative à la rescousse est, comme il est toujours, le marché d'importation qui, d'après les résultats de l'AECM, malheureusement est relativement plus efficace. La réponse au changement positif des prix est faible à 0,19, mais quant au changement négatif elle est à 0,86. Cela signale une élasticité à court terme relativement forte pour le blé d'importation. Une réduction de 1% dans les prix de blé importés entraîne une réponse moyenne de 0,86%. Quant à la vitesse d'ajustement, elle est à 32,8% pour les déséquilibres positifs de prix et à 97,1% pour les déséquilibres négatifs. La faiblesse d'ajustement aux déséquilibres positifs ne fait que pousser vers l'augmentation accrue de la facture d'importation des blés, le recours à l'importation étant une option commode.

D'après ces résultats de l'analyse des différentes réponses asymétriques dans cette filière particulière, les prévisions établies ne présagent rien d'agréable. Pour se maintenir à la rigueur, les prévisions de production et de prix sur les prochaines 20 années sont joliment illustrées dans les figures suivantes.

La Figure 3 montre les prévisions de la production nationale et du prix du blé dur jusqu'au 2040. La Figure 4 pareil pour le blé tendre, tandis que la Figure 5 représente les prévisions des quantités à l'importation et ses prix jusqu'au 2040. Il s'avère que les prix dans les trois cas de figure sont déterminés à la nette hausse sans le moindre espoir qu'ils se varient autrement. En fonction d'intervalles de confiance (établis à 95%), le prix de blé dur sera en moyenne de 188 milliards de DZD, soit une augmentation de

Figure 3 - Prévision de la production nationale et du prix du blé dur 2020-2040.

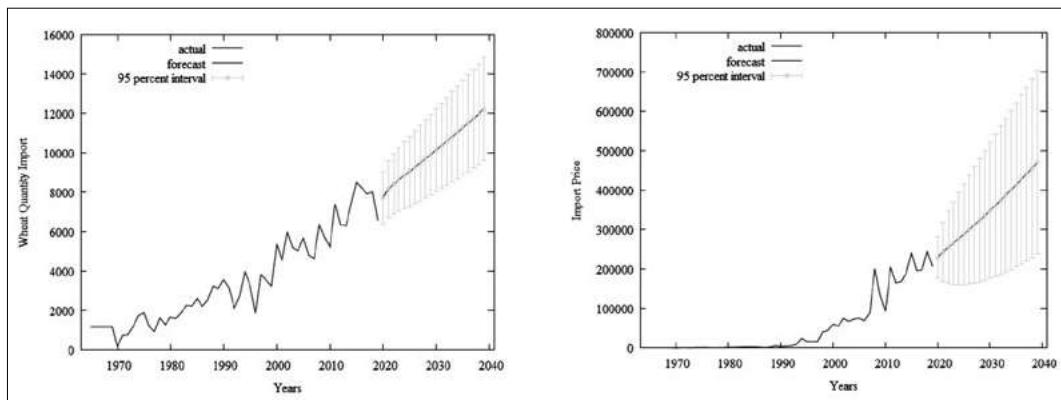


Figure 4 - Prévision de la production nationale et du prix du blé tendre 2020-2040.

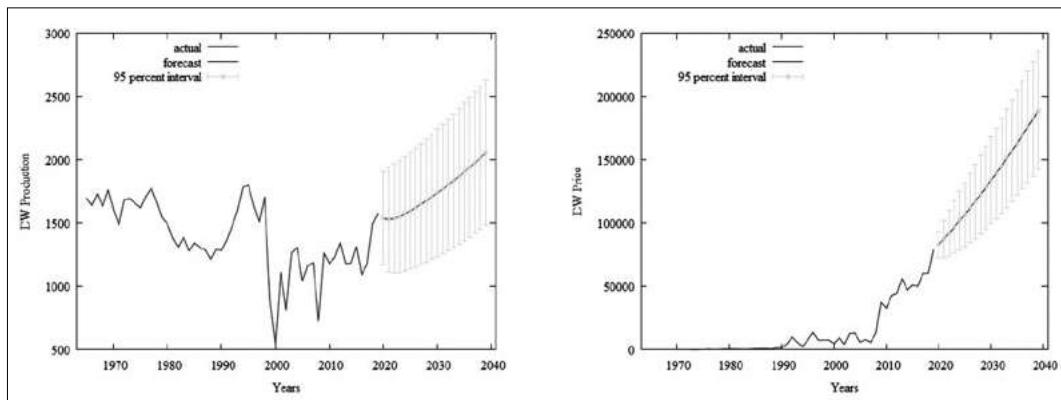
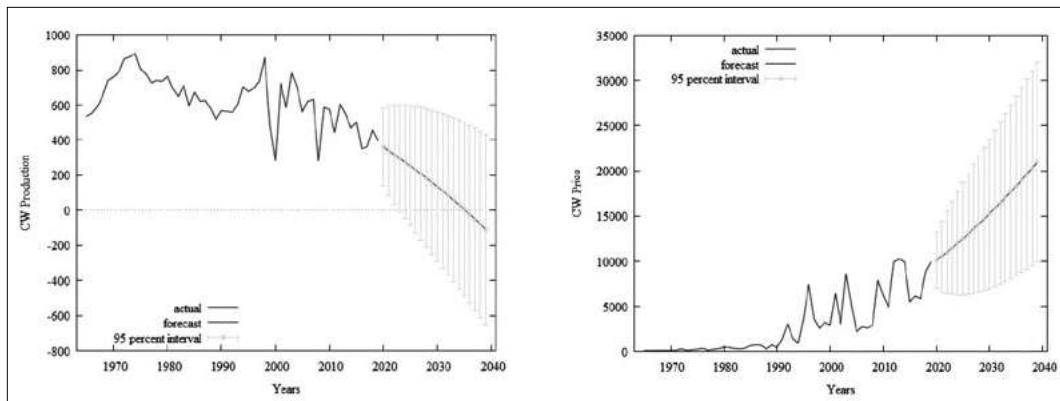


Figure 5 - Prévisions d'importation et de prix du blé 2020-2040.



239%, tandis que le prix de blé tendre sera en moyenne de 21 milliards de DZD, soit une augmentation de 211%. Le prix des blés à l'importation sera en moyenne de 470 milliards de DZD, soit une augmentation de 227%.

D'un autre côté, la production va se comporter autrement. La nette hausse n'est réservée qu'à la quantité importée, allant jusqu'à 12 millions de tonnes en 2040, soit une augmentation de 186%. Tandis que la production de blés sur le territoire national va connaître une régression. La superficie cultivée de blé dur va maintenir une légère hausse moins significative tenant compte les intervalles de confiance établis. Elle ne va atteindre que presque 2 millions ha, soit une augmentation de 130% (166% dans les meilleurs cas). En outre, la superficie de blé tendre va régresser de façon dramatique. Elle va s'annuler complètement en 2036. Pour être moins pessimiste, en tenant compte des intervalles de confiance, elle gardera une relative constance. Tous ces résultats supposent le fameux postulat de *ceteris paribus*. Si on prend en compte seulement l'évolution future de la demande alimentaire de la population, actuellement estimée à 43,05 millions d'habitants, d'ici 2040, la population totale de l'Algérie devrait atteindre 57,63 millions d'habitants, soit un taux de croissance de 134%. Par ailleurs, si la politique reste la même, et le taux de couverture de la demande interne se maintient au tiers, le pays assistera à une incapacité paralysante à nourrir la population en blé dans les meilleurs cas avant même l'arrivée de 2040. Autrement dit, le taux de couverture interne s'annulera.

D'après les différents résultats de cette étude, les enjeux que fait face la filière de blé en Algérie sont : une incapacité croissante de satisfaire la demande locale en blé dur, une disparition totale de la production locale de blé tendre et un recours plus exagéré à l'option de l'importation de blés qui ne fait qu'alourdir la facture alimentaire. Vu la forte présence de l'État dans cette filière stratégique, une remise en question de l'historique des interventions et les mécanismes de régulation s'impose aux instances concernées. Cela débouche du fait qu'une régulation efficiente exige une coordination verticale plus étroite entre les acteurs de la filière (Benmehaia & Brabéz, 2018 ; Xhoxhi *et al.*, 2019 ; Solazzo *et al.*, 2020). Cependant, la construction d'un véritable secteur céréalier et l'atténuation de sa dépendance vis-à-vis des marchés internationaux exigent un engagement crédible de la part du gouvernement, engagement dont la logique n'est pas celle du marché et qui ne peut porter sur le seul prix payé aux producteurs, mais une logique protectionniste qui tient en compte la durabilité d'une telle filière et une stratégie à long terme afin de faire face à de tels enjeux. Cela impliquerait des améliorations sur certains niveaux, principalement de la recherche, de la distribution, de la qualité, de la disponibilité des intrants et du crédit. Cela supposerait aussi une politique de conservation des sols, de lutte contre le changement climatique, d'intégration de l'agriculture à l'aménagement du territoire et de prise en charge par l'autorité publique des risques financiers entraînés par l'intensification.

En guise de recommandations pour la politique publique ayant les fins d'augmenter la production des blés et réduire les importations, on peut suggérer les éléments suivants : une révision des politiques des prix, du crédit et de la fiscalité s'impose de manière à les rendre incitatives aux producteurs locaux ; l'encouragement de la recherche et de la vulgarisation orientés vers la substitution des blés par les légumes frais et les produits d'origine animale ; la promotion réfléchie de l'irrigation d'appoint lors des périodes de sécheresse pour atténuer les effets des risques climatiques ; l'implémentation des programmes de restitution et de sélection des semences plus productives et résistantes ; une révision élaborée des barèmes de réfaction et de bonification de la qualité de la production des blés ; une extension de la superficie agricole utile là où les potentialités naturelles sont favorables ; et sur le plan organisationnel, un encouragement du mouvement coopératif pour une meilleure organisation de la filière de blés.

5. Conclusion

L'objectif de cette étude était de mettre en lumière, sur le plan empirique, les enjeux de la dépendance de la filière de blé en Algérie. Pour cela, cette étude s'est basée sur des techniques élaborées de séries temporelles et de prédiction afin de parvenir à cette fin. L'étude a diagnostiqué les processus d'ajustement aux déséquilibres des prix afin d'évaluer le fonctionnement de la filière de blé, mettant en évidence les deux chaînes d'approvisionnement présentes, celle de la production nationale qui reflète l'autonomie relative de la filière et le secteur de l'importation qui reflète la dépendance de cette filière au marché international.

L'intervalle de temps d'observation s'étalait de 1965 jusqu'à 2019 (54 ans). Les données sur la production des blés et son prix de collecte sont obtenus des organisations officielles concernées (MADR, MIPI, OAIC, Direction Générale de Douane). Concernant la méthode, une variante de modèle de correction d'erreur (ECM) a été utilisée et qui met en évidence les asymétries de réponse de l'offre aux prix. Il s'agit du modèle de correction d'erreur asymétrique (AECM).

Les résultats obtenus peuvent être récapitulés comme suivant : Pour le marché interne, le blé dur enregistre une réponse aux changements positifs de prix à 0,16, tandis que pour un changement négatif est à 0,14. La vitesse d'ajustement aux déséquilibres positifs à 78,6% tandis qu'elle est moins faible pour les déséquilibres négatifs, soit 49,7%. Pour le blé tendre, l'écart de réponse de l'offre aux changements de prix est plus grand, soit 0,26 pour le changement positif et 0,11 pour le changement au sens négatif, avec un taux d'ajustement aux déséquilibres positifs de 87,9% et il est plus faible aux déséquilibres négatifs de 74,4%. Pour le marché d'importation, la réponse au changement positif des prix est faible à 0,19. Quant au changement négatif, elle est de 0,8. La vitesse d'ajustement est à 32,8% pour les déséquilibres positifs de prix et à 97,1% pour les déséquilibres négatifs.

Ces résultats dévoilent un dysfonctionnement au niveau du processus d'ajustement de la production de blé en marché interne aux prix, signalant un faible rattrapage des équilibres négatifs dans ces deux produits. Cette faiblesse d'asymétrie dans les réponses conduit, au niveau agrégé, à l'abandon graduel des activités de production de blé au niveau national. Cela remet en question l'efficacité des mécanismes de régulation dans ces deux marchés. Les prévisions sur les prochains vingt ans ne présagent rien d'agréable. La situation va s'aggraver au détriment de la sécurité alimentaire du pays, dont l'insécurité alimentaire est un danger latent aux conséquences redoutables (Berdai, 2016). La production de blé dur va stagner et celle de blé tendre s'annulera au plus tard en 2040 dans les meilleurs cas. D'après les institutions internationales, notamment la FAO et l'OCDE (in Abis *et al.*, 2014), la production agricole devra augmenter de 60% à l'horizon 2050, mais cette augmentation sera contrainte par une possibilité limitée d'extension des surfaces cultivées, où la très grande majorité des terres arables d'ores et déjà exploitée, surtout dans la région d'Afrique du Nord et de Moyen Orient. Aussi, la baisse probable des précipitations et la hausse des températures vont accroître les tensions qui pèsent sur les perspectives de développement de la production nationale en blé. À ce titre, les travaux

récents ont attiré l'attention sur les effets du changement climatiques sur la région méditerranéenne et ses récoltes agricoles. Ajoutons à cette situation l'augmentation de la population qui va compliquer encore l'équation de l'offre et de la demande (Abis *et al.*, 2014).

Au final, les enjeux que fait face la filière de blé en Algérie s'énoncent explicitement comme suivant : une incapacité croissante de satisfaire la demande interne en blé dur, une disparition totale de la production locale de blé tendre et un recours plus exagéré à l'option de l'importation de blés qui ne fait qu'alourdir la facture alimentaire. L'impératif de la sécurité alimentaire du pays ainsi que la réduction de notre dépendance vis-à-vis de l'extérieur exigent de réexaminer les dispositifs actuels et les efforts entrepris par les autorités publiques en matière de régulation, d'organisation et de coordination de la production et de la collecte des blés.

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Impact de la crise sanitaire Covid-19 sur les petites exploitations agricoles et perspectives pour un système alimentaire durable en Tunisie

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Abstract

Covid-19 had a negative effect economically and socially in Tunisia, as illustrated by the highest mortality rate recorded in Africa in March 2020 and the economic growth rate estimated at -9.3% by the Central Bank of Tunisia in 2020. The main cause of this situation is the quarantine and the sudden halt of several activities resulting in the drop in domestic demand and the loss of Tunisia's main trading partners. The agricultural sector, and particularly small and family farms, forced to align with the quarantine measures since March 2020, have suffered the full impact of Covid-19. Indeed, the pandemic crisis put a strain on food supply chains: a complex network of interactions involving farmers, agricultural inputs, processing plants, retailers, and others. This study proposes to analyze the impact of the sanitary crisis, and of the national lockdown measures imposed since March 22, 2020, on small farms in the most vulnerable rural areas of Tunisia and on the functioning of small local chains. A survey based on the approach of the Participatory Systemic Rapid Diagnosis (PSRD) was conducted during the month of June 2020 just after 2 months of containment, with a sample of 240 farmers operating in local channels and distributed from north to south of Tunisia on 6 governorates the poorest and most vulnerable, according to the economic development indicator and poverty line. The results of this survey have shown that the health crisis has resulted in major disruptions to agricultural activities mainly at the level of supply chains of raw materials (treatment products, fertilizers, seeds, animal feed, ... etc.), and marketing channels due to the closure of weekly markets (leafy vegetables, small livestock, ... etc.). This dysfunction of the production system and local agricultural sectors has not only had an impact on farmers' incomes, which have dropped significantly compared to a normal year, but has also disrupted the functioning of the entire food system at the local level. Consequently, the need for a new model of production, processing, and marketing of food products is necessary.

Keywords: Covid-19 impact, Health containment, Small farms, Local agricultural chains, Food system, Tunisia.

1. Introduction

La crise sanitaire due à la Covid-19 a conduit au confinement de plus de 3 milliards de personnes à la fin du premier trimestre 2020 entraînant, par des effets systémiques et des drames

sanitaires, un chômage massif, une baisse importante du Produit Intérieur Brut (PIB) et un accroissement des inégalités sociales. Cette pandémie constitue un choc remarquable qui devrait inciter à un changement radical des

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politiques publiques partout dans le monde (Rastoin, 2020). La pandémie a engendré une crise économique mondiale la plus grave depuis la 2ème guerre mondiale, elle questionne la sécurité alimentaire et les modes de production et de consommation de masse suite aux perturbations enregistrées dans les chaînes logistiques d'approvisionnement des produits alimentaires. En Tunisie, la pandémie Covid-19 a pris une dimension sociale, alimentaire et économique touchant l'ensemble de la société, essentiellement la frange la plus vulnérable. Le renforcement des capacités des petits agriculteurs s'avère indispensable pour surpasser cette crise, en particulier du fait de leur contribution à la sécurité alimentaire et à la constitution des revenus au niveau local et national. Ces agriculteurs ont rencontré des difficultés multiples de déplacement, d'accès aux intrants, de récolte (par manque de main d'œuvre suite à la restriction de déplacement entre gouvernorats) et d'accès aux marchés vu qu'ils sont éloignés (i) des grands marchés et des grandes zones de consommation urbaine, (ii) des grands marchés d'approvisionnement en intrants et matières premières... etc. De ce fait le confinement a dû les toucher plus durement. De plus leur trésorerie et leurs stocks (engrais, semences, aliments du bétail...) sont généralement faibles, et ne leur permettraient pas de subvenir à leurs besoins pendant une assez longue période de confinement décrété par le gouvernement le 22 mars 2020 et qui a duré presque deux mois.

Au-delà des études abordant l'impact de la crise covid-19 sur l'agriculture tunisienne (FTDES, 2020 ; El Kadhi *et al.*, 2020 ; ONAGRI, 2020 ; ITES, 2020), ce travail vient appuyer celui conduit par Elloumi (2020) et propose d'analyser l'impact de la crise sanitaire particulièrement sur les petites exploitations agricoles des zones rurales les plus vulnérables de la Tunisie et sur le fonctionnement des petites filières locales, ce qui nous ramène à lancer une discussion sur les systèmes alimentaires territoriales durables (Rastoin, 2020).

2. Contexte de la crise pandémique Covid-19 en Tunisie et problématique de recherche

Durant la période de confinement, la disponibilité au niveau national en produits alimentaires

de base a été globalement assurée mais l'accès à ces produits reste une préoccupation majeure, aussi bien pour les décideurs que pour la population en général, en milieu rural pauvre en particulier (Gurbuz et Ozkan, 2021). Selon Elloumi (2020), quatre type de facteurs ont pu affecter la sécurité alimentaire et le revenu des ruraux les plus pauvres : i) la perturbation des circuits de distribution des produits alimentaires, d'approvisionnement en intrants et de commercialisation des récoltes ii) l'augmentation conjoncturelle de la demande globale en produits alimentaires sous forme de stock de sécurité chez les ménages les plus aisés, iii) l'insuffisance des revenus, surtout pour les couches vulnérables et les employés du secteur privé et informel, particulièrement les employés occasionnels et journaliers du secteur agricole, iv) la réduction relative de l'offre en produits agricoles frais commercialisés sur le marché, surtout au début du confinement total suite à la fermeture des marchés hebdomadaires. Devant cette situation, le gouvernement tunisien a pris des mesures conjoncturelles de compensation pour réduire l'impact de la pandémie sur la sécurité alimentaire, à travers i) *des mécanismes financiers exceptionnels* qui ont touché les familles nécessiteuses et à revenus limités : un programme d'aides sociales a été mis en place pour cibler 470 000 familles vulnérables. Il s'agit d'accorder des aides financières à hauteur de 400 DT en deux tranches pour chaque famille. Ce programme déboursera 188 Millions de Dinars au total. Les allocations budgétaires mobilisées par l'Etat pour alléger les dégâts socio-économiques du Covid-19 s'élèvent à 2,5 milliards de Dinars Tunisien, ce qui représente 5,3% du budget 2020 (Ministère des Finances, 2020), ii) *des mécanismes de distribution et de rapprochement des produits alimentaires* aux couches de la population les plus affectées par la crise sanitaire et ses conséquences socio-économiques, et enfin iii) *des dons en nature et des aides qui ont été évalués à 17.947 MD jusqu'au 17 mai 2020* aux personnes vulnérables, suite à la mobilisation de la société civile, d'institutions étatiques et des ONG. Ces interventions ont contribué à répondre conjoncturellement à la pression sociale, avec un coût économique élevé pour la Tunisie qui connaît depuis la révolution de 2011 un déséquilibre budgétaire (Soussi, 2020).

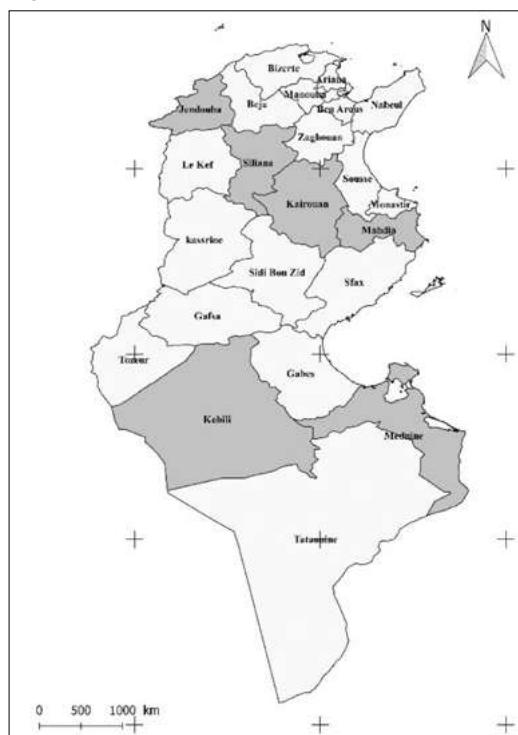
Devant la perturbation des circuits nationaux et internationaux de distribution, en amont et en aval de la production et la situation fragile des petites exploitations agricoles qui risquent la décapitalisation, les filières agricoles locales vulnérables risquent-elles de disparaître ? Ces filières sont stratégiques par les rôles socio-économiques qu’elles assurent notamment en matière de création de revenus et aussi par la mise à disposition d’aliments d’origine animale et végétale pour l’autoconsommation et pour l’approvisionnement des populations en milieu rural et périurbain tributaires des marchés hebdomadaires (FAO, 2020a). A travers ce papier, nous cherchons à mettre l’accent sur les problèmes rencontrés par les petites exploitations agricoles durant la période de confinement (accès difficiles aux intrants, circuits de commercialisation des récoltes défaillants...), les stratégies de résilience développées par les producteurs et par conséquent l’impact sur le fonctionnement des petites filières locales.

3. Méthodologie

Le ministère de l’agriculture, des ressources hydrauliques et de la pêche a lancé une enquête dans les zones rurales vulnérables auprès de 240 exploitations agricoles. Cette enquête financée par le Fonds International de Développement Agricole (FIDA) a été coordonnée par l’Institution de la Recherche et de l’Enseignement Supérieur Agricole (IRESA) au mois de juin 2020. Nous allons nous baser sur les résultats de cette enquête pour analyser l’impact de la crise pandémique sur la résilience des systèmes de production et sur le mode de gouvernance local par la mise en lumière des impacts sur les filières les plus touchées par cette crise sanitaire ainsi que sur le fonctionnement de tout le système alimentaire.

La démarche utilisée est celle du Diagnostic Rapide Participatif Systémique (DRPS) qui comprend un ensemble d’outils d’enquêtes (études monographiques de recueil de données essentiellement qualitatives, à partir d’un questionnaire administré à un échantillon issu d’une population cible) permettant de comprendre une situation et de dégager des enjeux liés à la zone d’étude (Burte, 2016), dans notre cas, l’impacts

Figure 1 - Carte des zones d’étude.



Source : Rapport Impact COVID-19 sur les filières locales et les petits producteurs dans les zones vulnérables de la Tunisie, IRESA, 2020.

du COVID-19 sur les exploitations agricoles familiales et les petites filières locales. L’enquête a été réalisée auprès d’un échantillon de 240 exploitants opérant dans des filières locales et répartis du nord au sud de la Tunisie sur 6 gouvernorats (Jendouba, Siliana, Kairouan, Mahdia, Kébili et Médenine) comme illustré par la Figure 1. Ces exploitations ont été identifiées en collaboration avec les Commissariats Régionaux de Développement Agricole (CRDA) de chaque région et qui répondent aux critères de sélection :

- Régions pauvres identifiées selon l’indicateur de développement économique et le seuil de pauvreté établi par l’Institut National des Statistiques (INS, 2020) ;
- Taille de l’exploitation allant de 1 à 7 hectares (système extensif de production) ;
- Diversité des systèmes de production (arboriculture, cultures maraîchères, petite élevage, ... etc.) ;
- Exploitation familiale ;

- Produits agricoles écoulés sur les marchés des produits frais, hebdomadaires et de proximité.

Cette enquête a été complétée par des entretiens conduits en face à face auprès des acteurs des petites filières locales, au premier rang desquels figurent les petits producteurs eux-mêmes, mais aussi les acteurs de l'amont et de l'aval des filières ainsi que les structures de conseil et d'accompagnement du secteur agricole. Le diagnostic a porté sur les différents types de systèmes de production et en respectant l'aspect genre avec un pourcentage de femmes enquêtées de l'ordre de 25% au Nord (Siliana et Jendouba), 35% au centre (Kairouan et Mahdia) et 28% au Sud (Kébili et Médenine). Le questionnaire d'enquête renferme des questions ouvertes et d'autres fermées et comporte différentes rubriques qui permettent de repérer, outre la présentation générale de l'exploitation (superficie, statut foncier, activité agricole pratique, main d'œuvre familiale ou salariale, ...):

- L'impact de la crise sur le déroulement de l'activité agricole ;
- Les différents maillons des filières agricoles qui ont été le plus touché par la crise (approvisionnement, stockage, commercialisation) ;
- Les stratégies de résilience mises en œuvre par les exploitants pour surpasser la crise ;
- La perception des agriculteurs par rapport à l'efficacité des mesures prises par l'Etat pendant le confinement.

L'enquête est conduite avec « une posture d'entretien », c'est-à-dire que l'enquêteur est toujours en train d'observer, d'écouter, de questionner et d'analyser les observations obtenues. Les entretiens sont conduits de manière progressive, plus comme des « discussions » (entretiens ouverts) en partant de thèmes larges dans la présentation pour aller progressivement vers des thèmes spécifiques (entretien semi-directif) puis vers des questions plus précises (entretien directif). La phase « ouverte » est importante pour identifier « ce qui est important pour la personne enquêtée, faire ressortir sa perception, sa vision de la réalité et créer un lien de confiance avec la personne enquêtée ». La phase semi-directive permet d'avancer sur les thèmes d'intérêt de

l'enquête. La partie plus « directive » de l'entretien permet d'affiner des éléments, préciser des informations et collecter des données précises exigées par l'enquête. Cette démarche permet d'assurer une certaine qualité de l'information collectée.

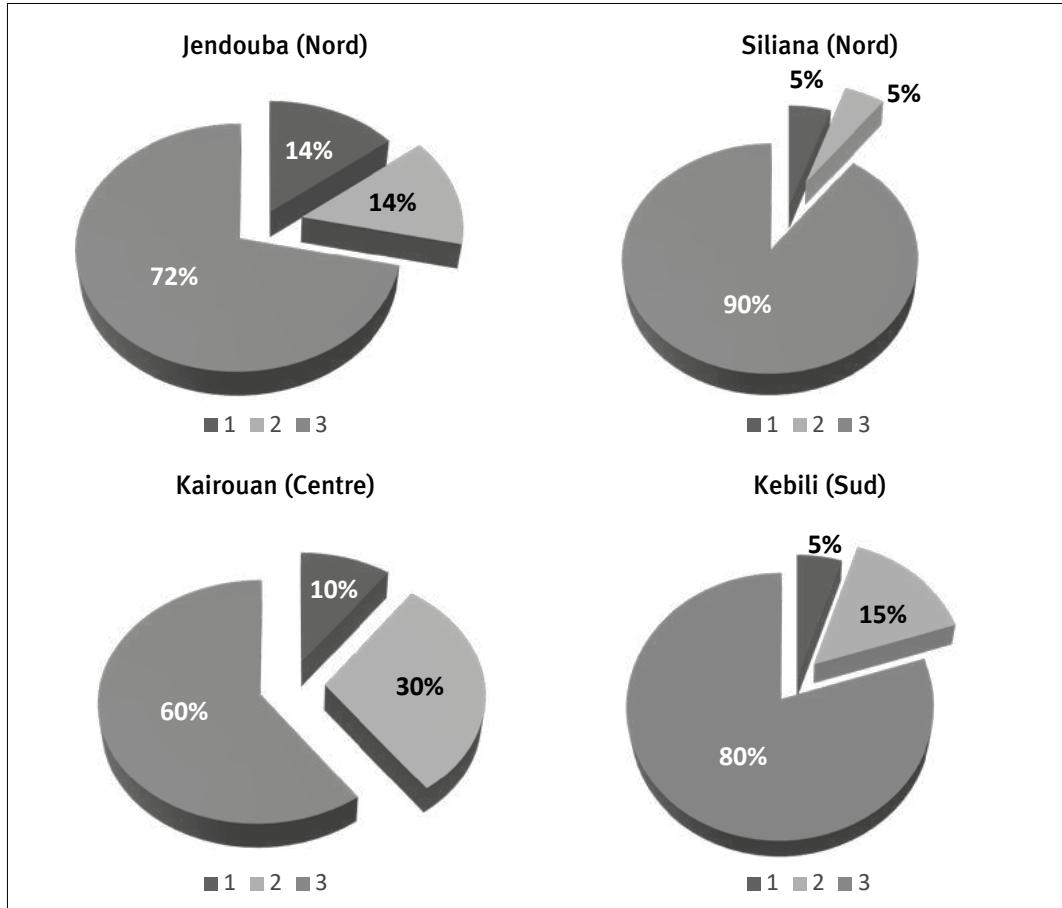
4. Résultats

4.1. Impact du confinement sur l'activité dans les exploitations agricoles

Comme le montre la Figure 2, la crise sanitaire et économique a touché, selon les déclarations des producteurs enquêtés, 82,5% de producteurs au nord (Siliana et Jendouba), 79% des producteurs au centre (Kairouan et Mahdia) et 83,5% des producteurs au Sud (Kébili et Médenine).

Comme le montre le tableau ci-dessous, cette crise s'est traduite par de fortes perturbations des activités agricoles, essentiellement l'arrêt de la commercialisation des produits agricoles à cause de la fermeture des marchés hebdomadaires et l'interruption du transport dans tous les gouvernorats notamment pendant les deux premières semaines du confinement (du 15 mars au 4 avril 2020) avec une intensité variable entre gouvernorats et par type d'activité agricole pratiquée (60% d'arrêt à Kairouan et 90% à Siliana). Parmi les activités les plus touchées figurent le maraîchage et l'élevage. En effet, pour les cultures maraîchères, notamment les légumes à feuilles (comme les salades qui ne se conservent pas longtemps aux champs et encore moins après la récolte), l'activité a été bouleversée suite à la difficulté d'approvisionnement en intrants et également par la non-disponibilité de la main d'œuvre à cause de l'interdiction de circulation des personnes et l'arrêt des transports. Quant à l'élevage, c'est surtout l'approvisionnement en aliments de bétail et l'assistance vétérinaire qui ont entravé l'activité. Toutefois, l'impact de la COVID-19 sur les petites exploitations agricoles dépend essentiellement du moment de l'instauration du confinement par rapport au calendrier agricole qui diffère d'une culture à une autre : la céréaliculture en pluvial et la culture de l'amandier dont les opérations de préparation du sol, de

Figure 2 - Impact de la Covid-19 sur l'activité agricole des petites exploitations (période mi-mars, fin avril 2020).



Légende : 1. Continuité de l'activité / 2. Arrêt partiel de l'activité / 3. Forte perturbation de l'activité.
 Source : Elaboration des auteurs.

plantation, de traitement, etc. étaient en grande partie déjà réalisées, se sont trouvées moins affectées par le confinement.

4.2. Des perturbations variables d'une filière à une autre

Les résultats des entretiens avec les acteurs des différentes filières agricoles locales témoignent d'une grande variabilité des effets de la crise sanitaire sur ces filières ainsi qu'à différents niveaux d'une même filière comme indiqué par la Figure 3. Il s'agit essentiellement de :

- La non disponibilité et/ou de la hausse des prix des intrants et des matières premières ou aliments du bétail ;

- La fermeture des marchés hebdomadaires ;
- La difficulté et l'absence de moyens de stockage des produits agricoles ;
- L'arrêt définitif de l'activité agricole essentiellement celles demandant beaucoup de main d'œuvre venant d'autres villes.

Le premier mois de la crise sanitaire a abouti à une dégradation des revenus des petits exploitants à cause de la baisse des prix de vente des produits agricoles sur le lieu de production ou plus généralement, l'absence de débouchés pour la production. Les revenus issus des petits élevages, tels que les poules et les lapins dans la région de Siliana, ont enregistré selon nos enquêtés, une baisse de 65% durant les deux mois de confinement. Pareillement, les reve-

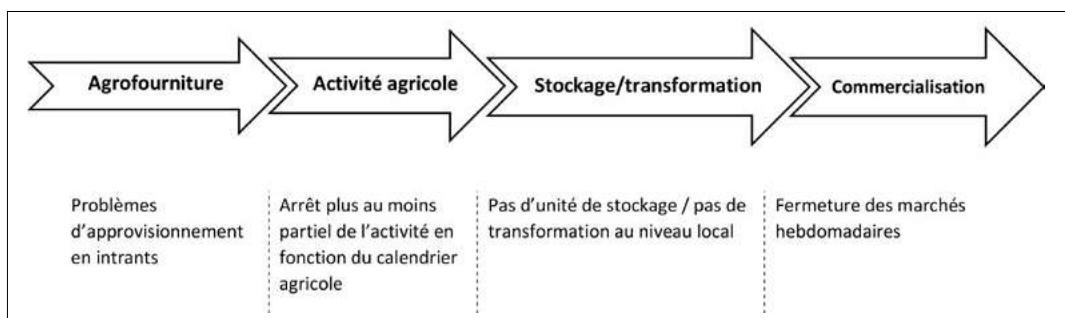
Tableau 1 - L'effet d Covid-19 à court, moyen et long terme sur les systèmes de production.

Régions	Systèmes de production	<i>Impact de la Covid-19 sur la production de l'année selon les producteurs enquêtés</i>	<i>Impacts de la crise, constatés par les agriculteurs enquêtés, à court/moyen terme</i>
<i>Nord / Gouvernorat de Jendouba</i>	Apiculture	<i>Elevé (60 - 80%)</i>	Difficulté pour obtenir une autorisation et un moyen de transport Difficulté à se procurer le sucre alimentaire / quantité limitée Elevage interrompu et baisse de la production. Essaimage et partition des ruches non effectués
<i>Nord/ Gouvernorat de Siliana</i>	Exploitation de la forêt (PAM)	<i>Elevé (100%)</i>	Chômage des exploitants Fermeture des unités de transformation des produits Perte des sources de revenu supplémentaire (chasse illicite des lapins dans les forêts)
	Engrissement de caprins	<i>Moyen (50%)</i>	Non disponibilité des aliments du bétail Perte de quelques têtes (pas de médicament, manque d'aliment)
	Petite arboriculture	<i>Elevé (65%)</i>	Production faible de cerise suite à la non disponibilité des produits de traitement (en mars/avril, il faut traiter au moment où les bourgeons commencent à gonfler ou quand les pétales commencent à tomber) Prix de vente bas des cerises suite à la fermeture des marchés et la vente uniquement sur la route principale aux passagers qui se font rare (restrictions des déplacements)
	Engrissement de bovins	<i>Moyen (56%)</i>	Fermeture des marchés aux bestiaux Manque d'aliments (concentrés ...) suite à la fermeture des points de vente des aliments du bétail Prix de vente bas des veaux
	Petite agriculture maraîchage/ Légumineuses	<i>Elevé (65%)</i>	Perte de la moitié de la production de tomate (de primeurs et d'arrière-saison) suite à l'indisponibilité de la main d'œuvre et des produits de traitement (pesticides essentiellement). Fermeture du marché, perte de la production
<i>Gouvernorat de Kairouan</i>	Exploitation forestière et cultures fourragères	<i>Moyen (60%)</i>	Interdiction d'exploiter la forêt Perte de la production des cultures fourragères suite au non-traitement de la production du foin-avoine et de l'ensilage essentiellement
	Petite arboriculture	<i>Elevé (97%)</i>	Chute de la production des abricots et qualité médiocre des fruits (pas de traitement)
	Petit élevage	<i>Moyen (83%)</i>	Chute des ventes (lapins, poules,) Manque de médicaments pour les animaux
	Petite agriculture maraîchage/ légumineuses	<i>Elevé (100%)</i>	Chute de la production (tomate, piment, petit pois, ...) et qualité médiocre des fruits.
<i>Gouvernorat de Mahdia</i>	Petit élevage ovin et caprin (engraissement) en sec	<i>Moyen (35%)</i>	Augmentation des dépenses liée à la hausse de prix des aliments de bétail (orge et aliments concentrés)

Régions	Systèmes de production	Impact de la Covid-19 sur la production de l'année selon les producteurs enquêtés	Impacts de la crise, constatés par les agriculteurs enquêtés, à court/moyen terme
<i>Gouvernorat de Kébili</i>	Cultures sous serre ; tomate, melon...	Elevé (80%)	Problèmes de commercialisation des produits comme le melon, le concombre, la pastèque
	Production par les femmes de dérivés des dattes, artisanat...	Elevé (80%)	Pas de foires pour vendre les produits et donc pas de revenu pour les femmes productrices
	Agriculture mixte (oasis, CF, caprin)	Moyen (60%)	Pas d'ouvriers pour la pollinisation des palmiers dattiers (mars, avril) Absence de fleurs mâles sur le marché Prix bas des dattes stockées suite à l'arrêt des exportations.
	Petit élevage (engraissement de caprins, poulets, élevage des camélidés)	Elevé (71%)	Arrêt de la campagne de vaccination des cheptels (donc pas de subvention pour les aliments, puisque ces deux opérations sont combinées) Pas de marché de vente du bétail Prix bas des têtes de bétail (diminution de 500 DT/tête à 280 DT/tête). Les éleveurs se trouvent obligés de vendre à prix bas pour payer leurs dettes auprès des fournisseurs... Absence d'aliments sur le marché
<i>Gouvernorat de Médenine</i>	Cultures maraîchères irriguées en intercalaire avec l'olivier	Moyen (30 - 45%)	Écoulement limité / marché fermé (pas de point de vente) Accès limité aux points de vente des engrangements Ressources financières limitées
	Petit élevage d'ovins et de caprins (engraissement) en sec	Moyen (25 - 35%)	Aliments non disponibles (concentré et orge) ou plus cher (paille, concentré (de 1,5 à 2 DT/kg) et orge (à 24 DT/kg), Augmentation des dépenses estimées liées à la hausse de prix des aliments de bétail mais aussi à l'allongement de la durée d'engraissement

Source : Elaboration des auteurs.

Figure 3 - Les différents types d'impact au niveau des filières locales.



Source : Elaboration des auteurs à partir des données de l'étude.

nus des éleveurs ont été touchés par la crise, en particulier ceux qui font l'engraissement des caprins et des ovins. Le revenu par tête ovine est passé de 200 à 100 dinars à Médenine et celui des caprins a chuté de 500 à 280 dinars à Kairouan. La crise n'a pas épargné les arboriculteurs, ceux produisant l'abricotier à Kairouan, ont enregistré une chute de 70% environ de leur revenu par rapport à une année normale, le revenu est passé de 12 milles dinars par hectare à 400 dinars par hectare et ce à cause de la fermeture des marchés en pleine période de récolte, de l'augmentation des prix des produits de traitement et l'absence de lieux de stockage des fruits. « Je n'ai pas mis de pesticides ni fongicides pendant les mois de mars et avril. J'ai perdu à peu près 10 tonnes d'abricots par rapport à l'année dernière à cause de la fermeture du marché et la difficulté de commercialisation des abricots » a affirmé un agriculteur de Khit El Oued (Kairouan-Haffouz).

En amont, les perturbations enregistrées au niveau de l'approvisionnement en intrants (semenes, engrais, produits de traitement, aliments de bétail, etc.) et la hausse importante de leur prix ont freiné le démarrage de plusieurs activités comme le maraîchage ou leur maintien tel que l'engraissement ovin et bovin. Les prix des engrains de fond comme l'ammonitrat et le Diammonium Phosphate ont passé respectivement de 50 à 75 dinars par quintal et de 62 à 92 dinars par quintal. Ajoutons à cela l'arrêt des services de conseil aux agriculteurs en particulier les soins vétérinaires et de vulgarisation, primordiaux pour assurer la continuité des activités agricoles. Face à cette situation, l'agriculteur s'est trouvé isolé et sans appui, ce qui a conduit à la perte du cheptel. A l'aval de ces petites filières locales, la fermeture des marchés hebdomadaires et l'interdiction des déplacements ont empêché le commerce de différents produits en particulier des produits périssables qui ne peuvent pas être conservés plus que quelques jours (persil, abricot, cerise, tomate, etc.). Cette crise sanitaire a touché aussi les produits de l'élevage comme le fromage frais et le lait qui sont aussi périssables. Par ailleurs, la baisse de revenu de ces petites exploitations a amené les producteurs à brader

les prix, en particulier du cheptel, pour assurer leurs dépenses familiales.

Au Nord de la Tunisie, en particulier à Jen-douba, l'impact de la crise sur les apiculteurs a été remarquable car l'aliment de base des abeilles pour cette période de l'année, à savoir le sucre alimentaire, n'était plus disponible et les déplacements dans les parcours et forêts étaient interdits par les autorités locales. Un jeune apiculteur de la région de Fernana a ainsi expliqué : « j'ai 20 ruches et j'espérais doubler le nombre de ruches pour augmenter mon capital, mais je me suis retrouvé, après le confinement, avec le même nombre de ruches et avec un nombre très réduit d'abeilles par ruche ». A Siliana, l'impact de la crise sur les petits élevages tels que la cuniculture, l'apiculture, l'aviculture et l'élevage des caprins a été élevé, plus de 75% des exploitants enquêtés ont été touché. « Suite à la non disponibilité du concentré pour le bétail, j'ai perdu 8 brebis » a témoigné une productrice à Siliana. Ces perturbations impactent directement le revenu des agriculteurs pour la campagne (2019-2020) ainsi que celle des campagnes suivantes par la réduction de la taille des cheptels ou leur mauvais état.

Également à Mahdia, cette situation a poussé les petits éleveurs à vendre leur cheptel pour subvenir à leurs besoins en matière d'alimentation de base, un jeune éleveur de la région El Dbara-Essouassi a témoigné : « j'ai vendu un veau, une chèvre et deux bœufs pour payer mes crédits en aliments auprès du collecteur. J'ai accumulé 1000 dinars de perte et les prix sont toujours bas. Je n'ai pas trouvé d'autres solutions que de contracter des emprunts auprès de ma famille ». Cependant, l'adhésion aux Sociétés Mutuelles de Services Agricoles de collecte de lait a permis de sauver la production laitière bien que les aliments soient restés plus chers et moins disponibles durant le confinement pour les ovins et les caprins.

Au Sud de la Tunisie, dans les régions de Kébili et de Médenine, la fermeture des unités de conditionnement de dattes a imposé un chômage sans revenu aux femmes qui travaillent dans ces unités. Pendant le confinement, plusieurs producteurs ont eu recours au stockage

de leur production de dattes (récoltée en 2019) dans l'espoir de la vendre en période grande consommation, en l'occurrence, le mois de Ramadan (avril 2020) à un prix plus intéressant ; mais suite au confinement, la production est restée dans les frigos selon la déclaration des producteurs enquêtés. « J'ai 25 tonnes de dattes dont je ne sais pas quoi faire. J'ai commencé à vendre à 3 dinars le kilo au lieu de 10 dinars l'année dernière. Je donne le reste des dattes aux animaux comme aliments » a affirmé un agriculteur de Kébili.

4.3. Une demande croissante de la part des citoyens et une offre déstabilisée de produits agricoles

L'arrêt de l'activité agricole au niveau de la quasi-totalité des exploitations enquêtées, allant jusqu'à 90% au gouvernorat de Siliana, est la conséquence de la perturbation des chaînes d'approvisionnement en matières premières (produits de traitement, engrains, semences, nourriture animale, ... etc.), l'absence de stockage de certains produits (l'abricot à Kairouan) et la perturbation des circuits de commercialisation due à la fermeture des marchés hebdomadaires (légumes à feuilles, petit élevage, ... etc.). Ce dysfonctionnement de l'appareil productif et des filières agricoles locales a eu des effets non seulement sur les revenus des exploitants, qui a nettement baissé par rapport à une année normale, mais a aussi bouleversé le fonctionnement de tout le système alimentaire au niveau local ce qui démontre les limites du mode de gouvernance publique dudit système (Rastoin, 2009). La crise a entraîné une baisse des revenus d'une majorité de citoyens et une hausse des prix de certains aliments de base : en avril 2020, les prix à la consommation augmentent de 0,9% sur un mois. Le taux d'inflation augmente légèrement à 6,3% en avril contre 6,2% en mars et 5,8% en février 2020. Cette progression est due essentiellement à l'accélération du rythme des hausses des prix de l'alimentation à 6,2% contre 5,1% le mois dernier (INS, Avril 2020). Ceci a rendu la nourriture inaccessible pour un grand nombre de

personnes (FAO-CSA, 2020). En effet, cette situation a été aggravée par le comportement d'achat de sécurité de consommateurs craignant des pénuries alimentaires. Les images d'achats compulsifs, « de rayons d'épicerie vides et de files d'attente de plusieurs kilomètres dans les banques alimentaires nous ont soudain rappelé l'importance des systèmes alimentaires dans nos vies ainsi que leur déséquilibre » (Batini *et al.*, 2020). Ainsi les dynamiques complexes provoquées par le confinement, destiné à contenir la maladie, perturbent fortement les systèmes alimentaires (FAO, 2020b).

En Tunisie, des pénuries de produits alimentaires de base dans les commerces de détail ont été observées pendant les semaines de confinement auxquelles s'ajoute un grave ralentissement de l'activité économique, d'une part, et une grande perturbation des chaînes d'approvisionnement, d'autre part. Ces comportements se sont traduits par une pression forte sur les circuits d'approvisionnement et ils ont mis en exergue le dysfonctionnement du système alimentaire remettant en surface la problématique de la sécurité alimentaire et nutritionnelle de la population, de la défaillance du mode de gouvernance publique de tout le système fortement dépendant des importations pour de nombreux produits alimentaires de base.

5. Discussions

5.1. La sécurité alimentaire entre disponibilité et accessibilité économique des produits alimentaires

En Tunisie, l'enquête réalisée par l'Institut National des Statistiques avec l'appui de la Banque Mondiale (INS-BM, 2020) révèle que près des deux tiers des ménages ont subi les conséquences de la Covid-19, essentiellement par l'augmentation des prix des produits alimentaires et par la perte d'emplois. Ainsi, plus d'un tiers des enquêtés ont déclaré avoir appréhendé de manquer de nourriture pour des raisons financières. En mars 2020, les prix des denrées alimentaires ont augmenté de 5,1% : cette hausse est expliquée par l'augmentation des prix des fruits de 13,8%, des poissons de

9,3%, des légumes de 5,7% et des viandes de 5,1% (INS, 2020). Les résultats de notre enquête auprès des 240 exploitations agricoles confirment cette tendance : en effet, pour faire face à l'augmentation des prix des produits alimentaires ou à la perte d'emploi, plus de 25% des répondants ont puisé dans leurs économies « l'épargne des ménages ». Une autre partie significative d'entre eux, plus de 25%, a reçu de l'aide ou a emprunté de l'argent à des proches, 15% d'entre eux ont recouru à un paiement différé de leurs obligations.

Cette mise en lumière des divers faits ayant impacté les budgets des ménages, les activités agricoles, la commercialisation des produits alimentaires de base et les circuits de distribution, ont bien dévoilé le dysfonctionnement du système alimentaire en Tunisie, et par conséquent, il est urgent de repenser son mode de gouvernance au niveau territorial et au niveau national, d'autant plus que la pandémie a éclaté à un moment où la sécurité alimentaire et les systèmes alimentaires étaient déjà mis à rude épreuve au niveau mondial. En effet, les conflits géopolitiques, la pression croissante sur les ressources naturelles, l'impact du changement climatique, la malnutrition et son impact sur la santé humaine, l'instabilité des marchés ont précédé la Covid-19 et touchent déjà la sécurité alimentaire dans de nombreux endroits. Toutes les analyses et les études des organismes internationaux (FAO, Banque Mondiale, OMS, etc.) confirment que les impacts de la Covid-19, ne seront pas conjoncturels et ne se limitent pas au court terme, et que le monde post-Covid ne sera plus le même. Des bouleversements du modèle économique et des échanges internationaux sont attendus ainsi que des bouleversements de la structure et des pratiques de consommation et, d'autre part, du modèle technico-économique de production agricole et de commercialisation des aliments essentiellement pour un pays comme la Tunisie, ayant une forte dépendance aux importations (céréales, aliments de bétail, intrants et produits de traitement) et une spécialisation à l'exportation (huile d'olives et dattes).

La reconstruction des économies après la crise Covid-19 offre une occasion unique de

transformer le système alimentaire et de le rendre plus résistant aux chocs futurs, en assurant une nutrition saine et durable pour tous (Batini *et al.*, 2020). Cette crise devrait être pour tous l'occasion de rééquilibrer et de transformer les systèmes alimentaires, afin de les rendre plus inclusifs, plus durables et plus résistants. Il est urgent de repenser rapidement la manière dont nous produisons, transformons, commercialisons et consommons nos aliments ainsi que la gestion de nos déchets. Ce qui nous amène à poser une question de fond sur le rôle de la petite agriculture familiale dans le système alimentaire local en Tunisie.

5.2. Quelles perspectives pour une alimentation durable à travers la promotion des systèmes alimentaires en Tunisie

Le mode de consommation alimentaire résultant d'un patrimoine naturel et culturel porté par les territoires, constitue les fondations de systèmes alimentaires plus résilients aux crises économiques, sociales, sanitaires et environnementales (Capone *et al.*, 2021). De tels systèmes ont la capacité d'assurer un développement local durable par la reconquête du marché intérieur, mais aussi par l'exportation sur un marché international très porteur pour les produits de terroir (Rastoin, 2020). Cette notion met l'accent sur une triple proximité, par opposition aux filières longues de la mondialisation agroalimentaire : il s'agit en premier lieu d'une proximité dans l'écosphère, par diversification des productions agricoles, en « reconnectant » les filières locales à leurs territoires. La seconde proximité concerne le rapprochement entre agriculture, transformation et consommation sur les territoires de production. La troisième proximité se fait à travers une réorientation de la demande alimentaire vers une production locale plus diversifiée et de qualité. Ceci permettra d'offrir aux petits producteurs en particulier des zones marginales la capacité de s'affranchir des contraintes de leurs activités principales. De plus, les circuits courts, la valorisation des produits typiques locaux (Appellations d'Origines Contrôlées, Indications Géographiques Protégées), l'approvisionnement

en intrants au niveau local et le développement de l'économie de proximité favorisent le développement de filières courtes et performantes. Les aliments produits localement peuvent être distribués plus efficacement, ce qui pourrait réduire les risques d'insécurité alimentaire au niveau local et régional, de malnutrition et d'augmentation des prix des denrées alimentaires, tout en créant des emplois locaux. Cela nécessite une transformation rurale afin de donner aux petits producteurs et aux détaillants les moyens d'agir et de les intégrer dans l'économie des systèmes alimentaires (Rastoin, 2020).

En Tunisie, la question centrale de la dépendance aux marchés extérieurs pour certains produits alimentaires (blé tendre, orge, soja, maïs) montre la fragilité de la sécurité alimentaire, basée sur les échanges internationaux, face aux crises politiques et sanitaires et surtout face aux changements climatiques qui risquent d'aggraver la dépendance alimentaire de la Tunisie dans un futur proche (Elloumi, 2020). La crise actuelle de la Covid-19 doit être saisie comme une opportunité pour repenser le mode de gouvernance du système alimentaire tunisien, le faire sortir de ses difficultés actuelles, de ses faiblesses structurelles et le préparer pour l'avenir en mettant au centre de ce système les petites exploitations agricoles qui représentent presque 80% des exploitations agricoles au niveau national et les filières agro-alimentaires locales au niveau territorial.

6. Conclusion

Avec la perturbation des circuits nationaux et internationaux de distribution, en amont et en aval de la production et la situation fragile des petites exploitations agricoles qui risquent la décapitalisation, les petites filières agricoles locales vulnérables risquent de disparaître. Ces dernières sont stratégiques par leur rôle socio-économique majeur notamment par la création de revenus pour les différents intervenants à tous les niveaux de la chaîne et par la mise à disposition d'aliments d'origine animale et végétale pour l'autoconsommation et l'approvisionnement des populations au niveau des territoires ruraux et périurbain tributaires des

marchés hebdomadaires de fruits et légumes et produits d'origine animale.

Afin de soutenir ces filières, il y a lieu tout d'abord d'intervenir en amont à travers le renforcement de l'accès aux intrants produits au niveau du territoire (aliments du bétail, semences, plants, fertilisants, pesticides...), aux savoir-faire locaux et aux équipements produit d'une économie de proximité (matériels de labour, de transformation des produits, de traitement...) pour stabiliser les filières locales et garantir leur durabilité. En aval des filières agricoles, la commercialisation des produits doit être renforcée moyennant des circuits courts de commercialisation connectés avec des plateformes de vente en ligne tels que JUMIA, Founa-Shop, ... etc. qui ont joué un rôle très important pendant la période de confinement. Ces plateformes numériques de vente en ligne, même si elles restent encore limitées, ont renforcé la résilience des petits producteurs qui y sont connectés, à l'instar des femmes produisant le miel de montagne dans la région de Jendouba, des producteurs de dattes à Kébili et à Médenine et des producteurs de cerises à Siliana.

Toutefois, un changement de paradigme s'impose. Celui-ci mettra en avant un référentiel de développement durable par rapport au référentiel de la valeur unique du marché qui a démontré ses limites et dans lequel la souveraineté alimentaire est privilégiée à toute forme de dépendance alimentaire pour assurer une sécurité alimentaire durable au niveau territorial. Ce changement de paradigme donnera lieu à un nouveau cadre institutionnel permettant d'assurer la durabilité des systèmes de production et d'orienter le comportement des consommateurs vers une alimentation saine, de réduire les asymétries entre acteurs des filières au plan national et international, et de stimuler l'action collective des porteurs de projets d'alimentation responsable et durable (Rastoin *et al.*, 2016).

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