NEW MEDIT

CIHEAM BARI

MEDITERRANEAN JOURNAL OF ECONOMICS, AGRICULTURE AND ENVIRONMENT

Poste Italiane Spa Spedizione in Abbonamento Postale Periodico ROC Centro Nord aut. N° 0029 - € 15,00.

1
QUARTERLY
VOL. XXIII - N. 1
MARCH
2024

Bologna University Press

ISSN: 1594-5685
www.newmedit.iamb.it

CIHEAM
BARI

NEW MEDIT

MEDITERRANEAN JOURNAL OF ECONOMICS, AGRICULTURE AND ENVIRONMENT

Vol. XXIII - n. 1/2024

Editorial office
Bologna University Press
Via Saragozza, 10
40123 Bologna (Italy)
tel.: +39 051 232882
fax: +39 051 221019
email: newmedit@iamb.it

Paper submission
http://www.newmedit.iamb.it

Publisher
Bologna University Press
Via Saragozza, 10
40123 Bologna (Italy)
tel.: +39 051 232882
fax: +39 051 221019
email: comunicazione@buponline.com

Subscription rate
Print: Italy: € 40; Foreign: € 90.

Subscription office
ordini@buponline.com

Abstract and Index citation
NEW MEDIT is indexed in: SCOPUS, EBSCO, ISI Web Science,
CAB Abstracts, EconLit, AGRIS/FAO database

Web page
http://www.newmedit.iamb.it

ISBN: 979-12-5477-430-4

ISSN: 1594-5685

ISSN online: 2611-1128

DOI: 10.30682/nm2401

Graphic Layout
DoppioClickArt – San Lazzaro (BO)

Cover design
Debora Degl'Innocenti

Registrazione
Tribunale Ordinario di Bari, n. 1546 del 4/1/2002

Direttore Responsabile
Giulio Malorgio

NEW MEDIT è associato alla

Contents

Foreword

Güldal and Ozcelik investigate the impact of ex-ante policy scenarios on conventional farmers' intentions to adopt smart farming applications and identifies influential factors. The findings reveal that financial support significantly boosts farmers' intention to adopt new technologies. Additionally, farm income, knowledge, and inheritor positively influence adoption, while education and age hinder it.

The assessment of different impacts of conservation agriculture compared to conventional agriculture, using a set of agronomic, economic and environmental indicators at the scale of an experimental station are analysed by *Talbi and Sghaier*. Results show the added value of conservation agriculture, which has higher economic and agronomic performance and positive environmental benefits.

Céu and Gaspar focus on the prediction of financial distress of agricultural firms operating in the vineyards and olive crops sectors in Mediterranean countries, specifically in Portugal, Spain, and Italy. The study concludes that there are differences between the two sectors, as well as across countries, and suggests that dedicated models for each country or crop may improve the models' accuracy.

Oğuz et al. aim to calculate the climate-friendly innovative technology usage indexes of sheep farms in Konya and to determine the affecting factors. Results show that 5.96% of the enterprises are low level, 87.42% medium level and 6.62% high level climate-friendly innovative technology users. Providing education and financial support to farmers in the region regarding climate change perception and technology usage will enhance the level of Climate-Friendly Innovative Technology Usage Index in enterprises.

Nawar et al. assess the economic feasibility of wastewater treatment and reuse in irrigation in eastern Tunisia applying an ex-post Cost-Benefit Analysis. The results prove that: the project is economically profitable for all scenarios except the first; farmers are the main beneficiaries of the project which is financially not viable for both the treatment plant company and the public body charged of the distribution of water; the affordability of the treated wastewater price depends on the cropping pattern.

The factors of farmers' willingness form early adoption of enhanced irrigation technologies in Tunisia are investigated by *Chebil et al*. Risk, trust, and perception towards technology are important factors in driving early adoption decision. The findings imply that farmers training on water conservation technologies, financial support for innovation adoption, awareness of young farmers about the opportunities of agricultural innovation, incentives to farmers' associations in order to improve their market access.

The impacts of the Young Farmer Support Program (YFP) in Türkiye are analysed by *Türker*. The results showed that about half of the young farmers were not satisfied with the provided support. The presence of social facilities in the rural areas, crop diversity, agricultural insurance, and investments in the farms were statistically significant and had an impact on the willingness of young farmers to continue their farm activities.

Hammude and Bahşi find out how Syrians with temporary protection status in Turkey live and work. The study used a survey-based approach to collect primary data from 210 Syrian asylum seekers residing in Turkish province. The research brought attention to the vulnerable position of Syrian refugees in the labor market and the need for comprehensive measures to improve their working conditions and overall well-being.

Ameur et al. analyze the technical efficiency of dairy cattle farms in Tizi Ouzou region. Paper found that the average technical efficiency is relatively high, suggesting that farms can reduce their inputs by an average of 17% while maintaining the same level of output. Agricultural advisory system and traditional insemination play an important role in enhancing technical efficiency. practiced on a small scale, increasing herd size can result in reduced performance. The study also recommended that agricultural policies should be adapted to local specificities and that a more supportive strategy should be adopted for small-scale family dairy farms instead of promoting the large farm model.

From conventional to smart: Farmers' preferences under alternative policy scenarios

Hüseyin Tayyar Güldal*, Ahmet Ozcelik*

DOI: 10.30682/nm2401a
JEL codes: Q12, Q16, Q18

Abstract

This study investigates the impact of ex-ante policy scenarios on conventional farmers' intentions to adopt smart farming applications and identifies influential factors. Through survey data collected from 117 conventional farmers, three scenarios (no support, cash support, credit support) were presented to determine their intention to adopt smart farming. The findings reveal that financial support significantly boosts farmers' intention to adopt these technologies. Additionally, farm income, knowledge, and inheritor positively influence adoption, while education and age hinder it. To promote the adoption of smart farming systems, we recommend providing educational programs to increase farmers' knowledge and offering financial benefits to offset the costs of purchasing and installing the systems. Our findings are relevant for developing countries, such as Türkiye, that are transitioning to smart farming and can inform policies that facilitate the adoption of smart farming systems.

Keywords: *Ex-ante policy, Farmers' intention, Innovation, Smart farming, Technology adoption.*

1. Introduction

Since the beginning of human history, agriculture has been one of the oldest and most important occupations. Particularly for developing countries, the agricultural sector plays a pivotal role in driving economic growth (Byerlee *et al.*, 2009). However, there are several challenges facing the sector today, such as the abandonment of agricultural lands (Leal Filho *et al.*, 2017), the increasing demand for food (Elferink and Schierhorn, 2016), rising rural-to-urban migration (Goldsmith *et al.*, 2004), higher input costs (Mottaleb and Mohanty, 2015), and the harmful effects of chemical inputs on the environment (Wu, 2011), particularly in conventional farming.

In addressing the challenges confronting the agricultural sector, new technologies present themselves as promising alternative solutions. The widespread use of technology in agriculture has been found to result in higher productivity (Morantes *et al.*, 2022), lower costs (Bongiovanni and Lowenberg-DeBoer, 2000; Özgüven and Türker, 2010), water-saving (Belaidi *et al.*, 2022), and reduced chemical inputs (Ehlert *et al.*, 2004; Karimzadeh *et al.*, 2011).

In recent years, Agriculture 4.0, also known as Smart Farming or Digital Farming, has started integrating digital transformation with

* Department of Agricultural Economics, Ankara University, Ankara, Türkiye.
Corresponding author: htguldal@ankara.edu.tr

Industry 4.0, combining information technologies with industrial activities. The objective of smart farming is to implement a production model that is more efficient, with reduced input usage, lower cost, and environmentally friendly. While Precision Agriculture (PA) only takes in-field variability into account, Smart Farming (SF) goes beyond that by basing management tasks on location, data, and context situation awareness triggered by real-time events (Wolfert *et al.*, 2014). SF allows a large volume of data and information to be generated by incorporating information and communication technologies into machinery, equipment, and sensors in agricultural production systems, progressively automating the process (Pivoto *et al.*, 2017).

In Mediterranean countries where water scarcity (Iglesias *et al.*, 2007) and arid climate (Tramblay *et al.*, 2020) are prevalent, integrating technology into agriculture is crucial. However, in countries like Türkiye, where conventional farming is widespread, there is ongoing debate regarding the adoption of technology in agriculture, and its utilization remains limited. While agricultural technologies are widely used in some countries (Erickson and Widmar, 2015; Griffin *et al.*, 2017), there are still farmers who are hesitant to adopt the technology (Daberkow and McBride, 2003; Fountas *et al.*, 2005; Reichardt and Jürgens, 2009). At this point, agricultural supports are crucial for the adoption and advancement of technology in agriculture.

Agricultural support impacts farmers in many aspects, such as land use (Demirdöğen *et al.*, 2016) and farm income (Hennessy, 1998). Moreover, the quality and effectiveness of support initiatives significantly influence farmers' adoption of technology (Aubert *et al.*, 2012). In this study, we present support scenarios to the farmers to answer questions such as "Which policies can encourage farmers to use technology?" and "Which factors affect farmers' intentions?". Ex-ante support scenarios are designed because there is currently no policy supporting farmers' widespread use of technology in Türkiye.

The contribution of this article to the literature is the evaluation of policies that can be applied in the transition from conventional to smart agriculture. Our study presents ex-ante support scenarios and aims to provide suggestions to policymakers for encouraging farmers to use technology and contribute to developing countries' policies. Understanding how farmers respond to new technologies and supports that have not been previously utilized is crucial for developing countries to bridge the technological gap with advanced nations in agriculture.

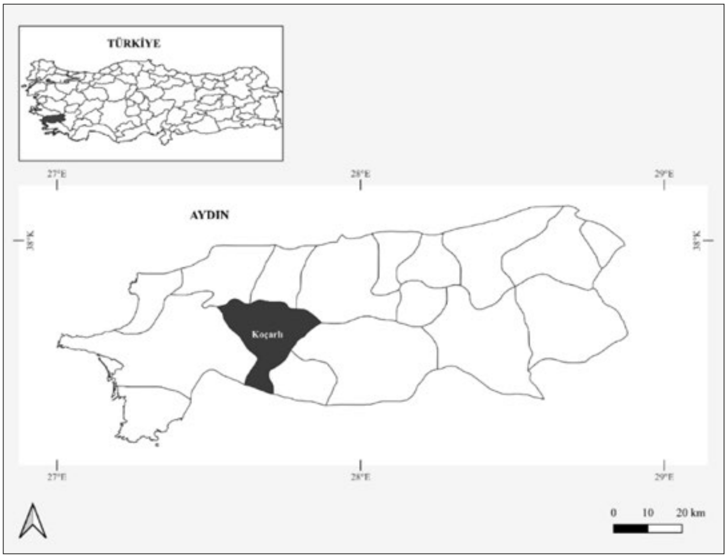


Figure 1 - Map of research area.

2. Research area and dataset

This study focuses on the Koçarlı district in Aydın province, with specific emphasis on Kasaplar village, renowned for its noteworthy smart farming enterprise. To ensure a comprehensive perspective, nine other villages were thoughtfully selected within the research area, considering their production patterns and geographical positions. By limiting the study area to Kasaplar village and its neighboring villages, we also acknowledge the potential awareness among farmers about the nearby enterprise and the benefits it provides (Figure 1).

The chosen smart farm in Kasaplar has been successfully operational since 2014, encompassing a vast land area of 29.8 hectares dedicated to both crop and animal production. This technologically advanced farm is equipped with various smart applications, including a sophisticated smart irrigation system, a comprehensive meteorology station, innovative smart pasture and fruit tools, advanced pest detection mechanisms, an agricultural monitoring center, and automated water tank systems. Notably, the farm has established valuable partnerships with industry leaders such as Vodafone and Tabit, which further contribute to its success.

Informations about the farmers collected through a survey in the 2017-2018 production period. In this period, the smart farm's five products with the largest production area were tomato, pepper, watermelon, melon, and eggplant. Therefore, the selection of conventional farmers that grow these products was considered. A total of 117 farmers in ten villages grow these products. We conducted a field survey with all these farmers.

3. Modeling farmers' responses

This study collects information on changes in farmers' intentions to use smart farming (SF) by directly asking them about various scenarios. The literature presents multiple pros and cons of stated intentions, which offer practical and guiding information, especially for the short term (Gorton *et al.*, 2008). Despite criticisms about the accuracy of stated intentions in revealing actual behavior, this method is widely documented in the literature. For instance, Lefebvre *et al.* (2014) analyzed the stated intentions about investments in land on the part of 171 farmers in 6 EU case study areas and their realized investments between 2006 and 2009. Barnes *et al.* (2016) examined the effect of past reforms on influencing farmers' intentions toward the most recent reform of the EU Common Agricultural Policy (CAP). Additionally, various studies claim that stated intention is not as problematic as previously mentioned and that farmers often behave as stated (Thomson and Tansey, 1982).

We prepare three scenarios to determine farmers' intentions toward SF:

Scenario 1 (S_1) (reference scenario): In case of the same market conditions (input and product price etc.) and probability of being affected by pests in the next five years.

Scenario 2 (S_2): In case of the same market conditions (input and product price etc.) and probability of being affected by pests in the next five years but 50,000 Turkish Lira/ha support to smart farming.

Scenario 3 (S_3): In case of the same market conditions (input and product price etc.) and probability of being affected by pests in the next five years but 0% interest rate agricultural loans given to smart farming by cooperatives or banks.

The minimal use of SF in Turkish agriculture and the absence of existing policies led the study to implement ex-ante scenarios. Ex-ante impact assessment is frequently used in the agricultural literature (Helming *et al.*, 2011; Lopez-Ridaura *et al.*, 2018; Paul *et al.*, 2018; Andrade *et al.*, 2019).

S_1 refers to the reference scenario where farmers are asked if they would prefer to use smart farming practices without any support. These responses to this scenario compare with S_2 and S_3.

In S_2, land-based payments are given to farmers. Agriculture is one of the economic sectors where support is most widespread (Vozarova and Kotulic, 2016). Researchers and policymakers have been interested in the effect of government payments to farms (Huffman and Evenson, 2001; Key and Roberts, 2006).

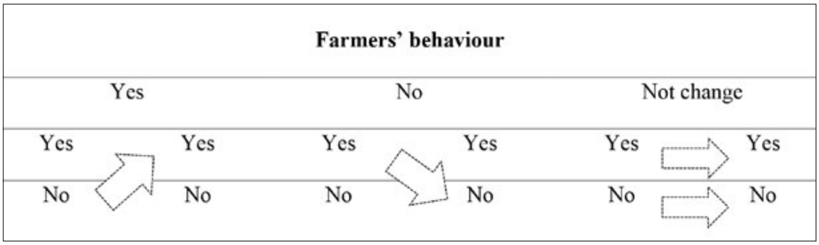


Figure 2 - Framework analysis applied.

Land-based payments are priority support in Turkish agriculture under different subheadings.[1] However, due to the cost of technological investments (Moss and Schmitz, 1999) and criticism of land-based payments (Uslu and Apaydın, 2021), we design the scenario to support farmers at 50,000 Turkish Lira per hectare. This amount is approximately ten times the average amount of support that Turkish farmers received in 2019, which was 5,000 TL per hectare. This scenario aims to provide support that will attract the attention of conventional farmers.

In S_3, a 0% interest rate is offered on agricultural loans to farmers. According to Ellis (1996), agricultural financing policies aim to provide the investment and input supply required for agricultural production, short-term cash needs, and access to new technology. Studies have shown that agricultural loans increase investment (De Rosari *et al.*, 2014). However, not all farmers have access to credit due to high-interest rates, especially small-scale farmers who cannot afford to purchase inputs or other technology (Olagunju, 2007). Similar to S_2, a new financing source is considered in S_3 to attract farmers' attention while they think about their new investment plans.

The model used in this study was inspired by Giannoccaro and Berbel (2013)[2] approach to determining farmers' intentions. We adapt their model to align with the aim of our study, which is to predict whether farmers would adopt smart farming applications based on different scenarios.

The smart farming applications discuss in the scenarios are "Thermo-hygrograph, Smart Irrigation, Yield Mapping, Terrain Monitoring with Drone and Early Warning Systems". These applications are used in the smart farm in this region, so we incorporate them into our scenarios.

The Thermo-hygrograph app measures moisture, temperature, soil moisture, and soil temperature continuously in the field using Internet of Things (IoT) sensors. The Smart Irrigation system records irrigation and fertilization information based on the plant's growth stages, which can be controlled from a computer, mobile, or panels. With the yield mapping system, it is possible to determine the changes in the productivity monitored in the field and thus determine the amount of agricultural input to be used. The drone creates visuals about the land, soil, and product. In addition, pesticides and chemical fertilizers are applied. Finally, the early warning system warns farmers about potential diseases or pests that meteorological conditions may cause on the farm.

To determine the "stated intention" variable, we first present the S_1 (reference scenario) to conventional farmers. Changes in farmer intentions are determined in S_2 and S_3 according to the reference scenario. For example, if the farmer's behavior is "No" in S_1 but "Yes" in S_2, it indicates a change in the stated intention. Conversely, if the farmer's response is "No" in S_1

[1] Land-based payments are provided under the subcategories of small farmer support for crop production, hazelnut land-based income, alternative product support, support for good farming practices, fuel oil and fertilizer support, soil analysis support, and organic farming support (TOB, 2022).

[2] Giannoccaro and Berbel (2013) considered farmers' stated responses to different CAP scenarios, examined the extent to which these plans would be influenced by the abolition of the CAP starting from 2014, and analyzed the implications of such abolition in terms of likely changes, such as increases or decreases in the use of chemicals and water resources on the farm.

Table 1 - Descriptive statistics.

Variables	*Description*	*Mean*	*Std.dev*
Dependent Variable			
Stated Intention	=1 if the farmer's intention changes to yes, not change 0	0.61	0.49
Independent Variables			
Farm Income	1000 TL*	111.58	159.47
Age	1: 15 - 49 years 2: 50 - 64 years 3: ≥ 65 years	1.81	0.63
Education	1: Primary school 2: Primary + secondary 3: High school 4: University	2.11	1.01
Land	1: ≤ 2 ha 2: 2.1 - 5 ha 3: ≥ 5.1 ha	2.29	0.77
Inheritor	=1 if the farmer has someone who will continue their farming in the future, otherwise 0	0.38	0.49
Knowledge	=1 if the farmer knows about smart farming, otherwise 0	0.31	0.46
Livestock	=1 if the farmer engaged in livestock, otherwise 0	0.39	0.49

* *1 $ = 5.70 TL.*

and S_2, it assumes that the stated intention of the farmers is not changed (see Figure 2). We include the stated intention variable as a dependent variable in the econometric model and analyzed the factors affecting farmers' intentions using logistic regression.

The economic theory that underlies stated preferences assumes that the decision maker's highest utility (or profit) is achieved through the most preferred option (Giannoccaro and Berbel, 2013). Initially, we planned to use a multinomial logistic regression model with the dependent variable in the analysis labeled as "0: Not change, 1: Yes, and 2: No". However, since all farmers indicated "No" in response to whether they would use any smart farming applications according to S_1, a binary logistic regression analysis was performed. The dependent variable is labeled as "0: Not change and 1: Yes".

The independent variables in this study include farm income, the age of farmers, farmers' education level, land size, whether the farmer has relatives to continue farming, and the status of livestock (see Table 1).

Our logistic model is specified as below:

$$Prob(Y_i=1)=P_i=F(Z_i)=F(\alpha+\sum_i \beta_i X_i)=\frac{1}{1+e^{-z_i}} \quad (1)$$

where is P_i is the probability that a farmer who wants to use smart farming tools; X_i represents explanatory variables; and α and β are parameters to be estimated.

$$Prob(Y_i=0)=1- Prob(Y_i=1)=(1-P_i)=\frac{1}{1+e^{z_i}} \quad (2)$$

From Equations (1) and (2), we get,

$$\frac{Prob(Y_i=1)}{Prob(Y_i=0)}=\frac{P_i}{1-P_i}=e^{z_i} \quad (3)$$

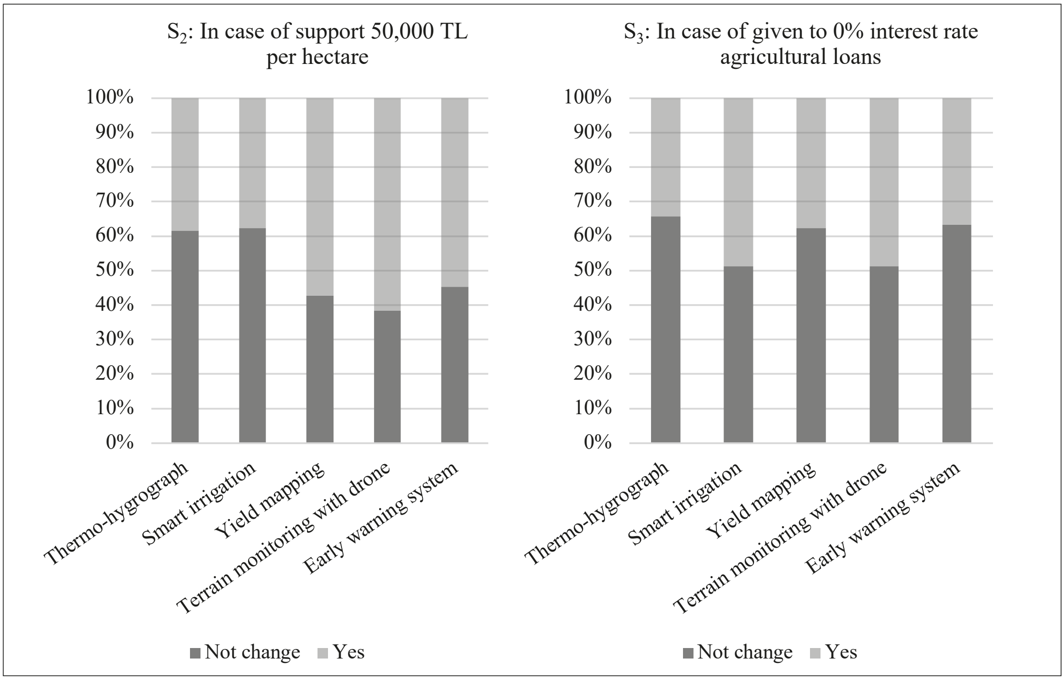
where P_i is the probability that Y_i takes the value 1 and then (1- P_i) is the probability that Y_i is 0, and e is the exponential constant.

Taking the natural log of both sides of Equation (3), we get,

$$Z_i= ln\left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\ldots+\beta_k X_{ki}+u_i \quad (4)$$

A separate model was established for each smart farming application presented to the farmer in the scenarios.

Figure 3 - Farmers' intention to use SF regarding S_2 and S_3.



4. Results

To evaluate whether factors such as the age of the household head and education affect participation in extension programs and adoption of new farm technology, it is essential to consider farm household characteristics (Langyintuo and Mungoma, 2008). This study reveals that a significant portion of farmers in the research area, specifically the Koçarlı district of Aydın province and surrounding villages, fall within the age range of 50-64. Additionally, the level of education among farmers tends to be relatively low. A considerable proportion of farmers have completed primary school, while a smaller percentage have completed both primary and secondary education.

In terms of land ownership, a significant number of farmers own 5.1 hectares or more, with an average land size of 6.59 hectares. Moreover, a substantial portion of farmers lack a potential successor within their family who can continue farming after them. Furthermore, many farmers in the study area have limited or no knowledge about smart farming practices (see Table 1).

Figure 3 illustrates the change in farmers' intentions for smart farming between S_2 and S_3. In the reference scenario (S_1), none of the farmers change their intention. However, changes in farmers' intentions are observed in S_2 and S_3.

Decoupled supports can increase agricultural investments (Westcott and Young, 2004) and change and expand production (Goodwin and Mishra, 2005). In S_2, more than half of the farmers change their intentions to use decoupled supports, particularly in yield mapping, terrain monitoring with drones, and early warning system applications. Specifically, in S_2, 38.46% of the farmers change their intention to use thermo-hygrograph applications, 37.61% to use smart irrigation, 57.26% to use yield mapping, 61.54% to use terrain monitoring with drones, and 54.70% to use the early warning system (see Figure 3).

In S_3, the intention of farmers to use all smart applications, except for smart irrigation, is lower compared to S_2. According to the results, smart irrigation is the costliest smart investment equipment. In S_3, farmers are less likely to use thermo-hygrograph (34.19%), yield mapping (37.61%), terrain monitoring with a drone (48.72%), and early warning system (36.75%), compared to S_2.

Table 2 - Binary logistic regression on smart farming (S_2).

	Thermo-hygrograph			*Smart irrigation*			*Yield mapping*			*Terrain monitoring with a drone*			*Early warning system*		
	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio
Farm income	0.02	0.001	1.002	**0.004****	0.002	1.004	0.002	0.002	1.002	0.002	0.002	1.002	0.001	0.001	1.001
Age															
15 - 49 ages (reference)															
50 - 64 ages	-1.001	0.685	0.368	**-2.123*****	0.802	0.120	**-2.192*****	0.751	0.112	**-2.743*****	0.823	0.064	**-1.955*****	0.726	0.142
≥ 65 ages	-0.778	0.914	0.460	**-3.795*****	1.131	0.022	**-3.093*****	1.008	0.045	**-4.048*****	1.116	0.017	**-3.280*****	1.008	0.038
Education															
Primary school (reference)															
Primary + secondary	0.304	0.698	1.355	-0.845	0.754	0.430	-0.569	0.702	0.566	-0.615	0.714	0.541	-0.708	0.702	0.493
High school	-0.509	0.633	0.601	-0.483	0.646	0.617	-0.808	0.612	0.446	**-1.417****	0.654	0.242	-0.995	0.619	0.370
University	-0.934	1.091	0.393	-1.516	1.248	0.220	**-2.177***	1.143	0.113	**-2.440***	1.255	0.087	-1.558	1.192	0.211
Land															
≤ 2 ha (reference)															
2.1 - 5 ha	0.030	0.627	1.030	-0.787	0.701	0.455	-0.600	0.657	0.549	-0.687	0.702	0.503	-0.475	0.654	0.622
≥ 5.1 ha	-0.402	0.647	0.669	-0.579	0.714	0.560	-0.313	0.662	0.731	-0.472	0.709	0.624	-0.357	0.665	0.700
Inheritor	0.610	0.476	1.840	**2.196*****	0.633	8.993	**1.441*****	0.514	4.224	**1.666*****	0.561	5.292	0.806	0.490	2.240
Knowledge	**1.233*****	0.469	3.431	0.739	0.552	2.095	**0.848***	0.513	2.335	**1.005***	0.544	2.732	**1.446*****	0.525	4.248
Livestock	0.070	0.444	1.072	-0.222	0.489	0.801	-0.385	0.457	0.680	-0.240	0.477	0.787	-0.162	0.453	0.850
Constant	-0.529	0.884	0.589	1.669	1.006	5.308	1.936	0.937	6.933	2.750	1.007	15.648	1.807	0.923	6.092
Level of significance:	$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$														
-2 Log Likehood	135.521			112.888			128.565			118.388			130.769		
Nagelkerke R^2	0.217			0.411			0.314			0.373			0.306		
Percentage of correct predictions (%)	Overall = 73.5 Class "0" = 87.5 Class "1" = 51.1			Overall = 78.6 Class "0" = 70.5 Class "1" = 83.6			Overall = 70.1 Class "0" = 62.0 Class "1" = 76.1			Overall = 73.5 Class "0" = 57.8 Class "1" = 83.3			Overall = 66.7 Class "0" = 60.4 Class "1" = 71.9		

The factors that affect farmers' intentions in S_2 and S_3 are determined by binary logistic regression analysis. We use "Enter" method in the analysis and significance tests (Hosmer-Lemeshow and Omnibus) also perform, and the results show in Tables 2 and 3. The effects of these factors analysis separately for each smart app.

According to S_2, farm income, age, education, inheritor, and knowledge are statistically significant variables that affect farmers' intention to use smart apps. An increase in farm income has a positive effect (0.4% in a unit) on the intention to use the smart irrigation system ($p < 0.05$). However, there is an inverse

Table 3 - Binary logistic regression on smart farming (S_3).

	Thermo-hygrograph			*Smart irrigation*			*Yield mapping*			*Terrain monitoring with a drone*			*Early warning system*		
	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio	Coefficient	Std. Dev.	Odds Ratio
Farm income	**0.004****	0.002	1.004	**0.005****	0.002	1.005	**0.004****	0.002	1.004	**0.003***	0.002	1.003	**0.004****	0.002	1.004
Age															
15 - 49 ages (reference)															
50 - 64 ages	-0.956	0.714	0.384	**-1.997*****	0.735	0.136	-0.935	0.707	0.393	**-2.269*****	0.746	0.103	**-1.262***	0.721	0.283
≥ 65 ages	**-2.241***	1.170	0.106	**-2.341****	1.002	0.096	-0.908	0.996	0.403	**-2.844*****	1.000	0.058	**-1.989***	1.096	0.137
Education															
Primary school (reference)															
Primary + secondary	**-1.652***	0.984	0.192	-0.982	0.786	0.375	**-1.903****	0.940	0.149	-0.385	0.728	0.680	-1.585	0.982	0.205
High school	-0.362	0.681	0.696	-1.009	0.660	0.365	-0.811	0.663	0.444	-0.816	0.644	0.442	-0.335	0.679	0.715
University	-0.464	1.172	0.629	-1.237	1.245	0.290	-0.677	1.137	0.508	**-1.931***	1.159	0.145	0.140	1.248	1.151
Land															
≤ 2 ha (reference)															
2.1 - 5 ha	0.732	0.687	2.080	-0.803	0.658	0.448	0.698	0.662	2.009	-0.712	0.650	0.491	0.571	0.692	1.769
≥ 5.1 ha	-0.842	0.742	0.431	**-1.321****	0.675	0.267	-0.326	0.687	0.721	-0.578	0.652	0.561	-0.572	0.734	0.564
Inheritor	0.774	0.534	2.169	0.514	0.498	1.672	0.784	0.503	2.191	**1.048****	0.493	2.851	0.849	0.535	2.338
Knowledge	**1.796*****	0.555	6.026	**1.259****	0.515	3.522	**1.613*****	0.520	5.020	**1.057****	0.499	2.877	**1.581*****	0.539	4.862
Livestock	0.336	0.505	1.400	**0.940****	0.480	2.560	0.085	0.473	1.088	0.414	0.457	1.512	0.720	0.502	2.055
Constant	-1.408	0.953	0.245	1.056	0.920	2.874	-1.007	0.925	0.365	1.233	0.910	3.431	-1.295	0.949	0.274
Level of significance:	$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$														
-2 Log Likehood	109.647			122.896			121.125			128.966			110.787		
Nagelkerke R^2	0.406			0.380			0.342			0.329			0.421		
Percentage of correct predictions (%)	Overall = 76.9 Class "0" = 84.4 Class "1" = 62.5			Overall = 69.2 Class "0" = 71.7 Class "1" = 66.7			Overall = 73.5 Class "0" = 82.2 Class "1" = 59.1			Overall = 70.9 Class "0" = 73.3 Class "1" = 68.4			Overall = 78.6 Class "0" = 85.1 Class "1" = 67.4		

relationship between farmers' age and intention to use some technological applications. As farmers get older, their intention to use smart irrigation (8.33 times higher for the 50-64 age group and 45.45 times higher for those aged 65+ compared to the 15-49 age group), yield mapping (8.93 times higher for the 50-64 age group and 22.22 times higher for those aged 65+ compared to the 15-49 age group), terrain monitoring with a drone (15.62 times higher for the 50-64 age group and 58.82 times higher for those aged 65+ compared to the 15-49 age group), and early warning system (7.04 times higher for the 50-64 age group and 26.32 times higher for those aged 65+ compared to the 15-49 age group) do not change[3] ($p < 0.01$). Similarly, there is an inverse relationship between education and intention to use technological applications. The higher the education level, the lower the intention to use yield mapping and terrain monitoring with a drone ($p < 0.1$; $p < 0.05$). Those who have inheritors are more likely to use smart irrigation (8.99 times), yield mapping (4.22 times), and terrain monitoring with a drone (5.29 times) compared to those who do not ($p < 0.01$). Additionally, those who know about smart farming are more likely to use a thermo-hygrograph (3.43 times), terrain monitoring with a drone (2.73 times), and early warning system (4.25 times) compared to those who do not ($p < 0.01$; $p < 0.1$) (see Table 2).

According to S_3, there are several statistically significant variables that affect farmers' intention to use smart apps. These variables include farm income, age, education, land, inheritor, knowledge, and livestock. Increasing farm income has a positive impact on the intention to use thermo-hygrograph (0.4% in a unit), smart irrigation system (0.5% in a unit), yield mapping (0.4% in a unit), and terrain monitoring with a drone (0.3% in a unit) ($p < 0.1$; $p < 0.05$). Similarly to S_2, there is an inverse relationship between farmers' age and their intention to use technology. As farmers get older, their intention to use thermo-hygrograph (9.43 times higher for those aged 65+ compared to the 15-49 age group), smart irrigation (7.35 times higher for the 50-64 age group and 10.42 times higher for those aged 65+ compared to the 15-49 age group), terrain monitoring with a drone (9.71 times higher for the 50-64 age group and 17.24 times higher for those aged 65+ compared to the 15-49 age group), and early warning system (3.53 times higher for the 50-64 age group and 7.30 times higher for those aged 65+ compared to the 15-49 age group) do not change ($p < 0.1$; $p < 0.05$; $p < 0.01$). Education similarly affects farmers' intention to use technology in both S_2 and S_3. As the level of education increases, the intention to use thermo-hygrograph, yield mapping, and terrain monitoring with a drone decreases ($p < 0.1$; $p < 0.05$). Knowledge and inheritor variables are also significant in S_3. Farmers with knowledge about smart farming are more likely to use all smart apps ($p < 0.05$; $p < 0.01$). Furthermore, those who have inheritors are more likely to use terrain monitoring with a drone (2.85 times) than those who do not ($p < 0.05$) (see Table 3).

5. Discussion and conclusion

The results show that agricultural support is essential for farmers to consider adopting SF technologies. None of the farmers prefer SF technologies in the unsupported scenario (S_1), while in the supported scenarios (S_2 and S_3), farmers' intentions change significantly towards SF technologies. The cost of SF technologies remains a barrier to their widespread use, and credit and cash support can significantly influence investment preferences among farmers (De Rosari *et al.*, 2014). Especially in smart irrigation system[4], cash support covers only half of the cost, the application with the highest increase in intention to use is the smart irrigation system with credit support. Farmers are more likely to adopt these systems when provided with 0% interest rates and an attractive repayment schedule. It should be noted that the type of technology and its costs may significantly impact farmers' intentions to use SF technologies (Khatri-Chhetri *et al.*, 2017), particularly among those with low net returns (Suri, 2011), who tend to be more resistant to adoption.

Contrary to the expected positive relationship between education level and the adoption of innovations in agriculture (Aydoğan *et al.*, 2022), our study reveals an inverse association. This can be attributed to the high costs of advanced technology. The financial burden associated with implementing and maintaining innovative

[3] Farmers' unchanged intentions indicate their continued non-usage of smart apps, as highlighted in the "Modeling farmers' responses" section where all farmers responded "No" in S_1.

[4] The research also identified the investment costs associated with implementing a smart farm. The most expensive system was the smart irrigation system, with a cost of 102,040.80 TL per hectare.

agricultural practices and equipment appears to hinder adoption among individuals with higher educational attainment. The economic barriers posed by these costs outweigh the potential benefits of education in driving agricultural innovation adoption.

According to Higgins *et al.* (2017), rural sociologists and geographers have long argued that farmers' knowledge, along with the broader social and cultural relations in which such knowledge is embedded, is crucial to understanding farmer engagement with and adoption of new programs, techniques, and technologies (e.g., Oliver *et al.*, 2012; Warren *et al.*, 2016). To increase farmers' knowledge and awareness of SF applications, educational and outreach programs can be developed, which could involve working with agricultural extension services (Hussain *et al.*, 1994; Oyinbo *et al.*, 2019) and other organizations.

According to studies such as Akudugu *et al.* (2012) and Phi *et al.* (2021) that examine farmers' adoption of precision agriculture, younger farmers are more willing to adopt PA than older farmers. In our study, younger farmers are more willing to adopt SF than older farmers, and farmers with inheritors have higher intentions to use smart agriculture than those without. As May *et al.* (2019) suggested, tailored support programs and incentives can be developed to encourage younger farmers to adopt these technologies and promote SF's potential benefits to the next generation of farmers and landowners. This study can aid in designing policies that encourage the adoption of SF while considering farmer conditions in different regions and markets. However, one of the limitations of this study is the lack of support for policies, particularly cash and credit, prior to their implementation. In addition to these policies, training and technical support policies can be created to ensure the proper use of technology.

Currently, the bulk of technological innovation in the Mediterranean region is being developed and deployed by for-profit entities, including private-sector companies (Bedeau *et al.*, 2021). So, exploring additional ways to make smart systems more accessible and affordable to farmers could involve collaborating with technology providers to offer more competitive pricing or exploring alternative financing models, such as leasing or rental arrangements. Public-private partnerships can be formed to support the adoption of sustainable farming practices while considering farmer conditions in different regions and markets.

Acknowledgement

This research be included in Huseyin Tayyar Guldal Ph.D. thesis in Ankara University Graduate School of Natural and Applied Sciences Agricultural Economics Department. In addition, I would like to thank my colleague Alper Demirdogen and valuable jury members for helping develop my thesis.

References

Akudugu M.A., Guo E., Dadzie S.K., 2012. Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions. *Journal of Biology, Agriculture and Healthcare*, 2(3): 1-13.

Andrade J.F., Edreira J.I.R., Farrow A., van Loon M.P., Craufurd P.Q., Rurinda J., Zingore S., Chamberlin J., Claessens L., Adewopo J., van Ittersum M.K., Cassman K.G., Grassini P., 2019. A spatial framework for ex-ante impact assessment of agricultural technologies. *Global Food Security*, 20: 72-81. https://doi.org/https://doi.org/10.1016/j.gfs.2018.12.006.

Aubert B.A., Schroeder A., Grimaudo J., 2012. IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, 54(1): 510-520. https://doi.org/https://doi.org/10.1016/j.dss.2012.07.002.

Aydoğan M., Demiryürek K., Özer O.O., Uysal O., 2022. Factors accelerating agricultural innovation and sustainability: The case of paddy farmers. *Integrated Environmental Assessment and Management*, 18(3): 824-835.

Barnes A., Sutherland L.A., Toma L., Matthews K., Thomson S., 2016. The effect of the Common Agricultural Policy reforms on intentions towards food production: Evidence from livestock farmers. *Land Use Policy*, 50: 548-558. https://doi.org/10.1016/j.landusepol.2015.10.017.

Bedeau J.V., Rezaei M., Pera M., Morrison J., 2021. Towards food systems transformation in the Mediterranean region: Unleashing the power of data, policy, investment and innovation. *New Medit*, Special Issue, 20(3):5-16. https://doi.org/10.30682/nm2103a.

Belaidi S., Chehat F., Benmehaia M.A., 2022. The adoption of water-saving irrigation technologies in the Mitidja Plain, Algeria: an econometric analysis. *New Medit*, 21(1): 53-73. https://doi.org/10.30682/nm2201d.

Bongiovanni R., Lowenberg-DeBoer J., 2000. Economics of variable rate lime in Indiana. *Precision Agriculture*, 2(1): 55-70. https://doi.org/https://doi.org/10.1023/A:1009936600784.

Byerlee D., De Janvry A., Sadoulet E., 2009. Agriculture for development: Toward a new paradigm. *Annual Review of Resource Economics*, 1: 15-31. https://doi.org/https://doi.org/10.1146/annurev.resource.050708.144239.

Daberkow S.G., McBride W.D., 2003. Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture*, 4(2): 163-177. https://doi.org/https://doi.org/10.1023/A:1024557205871.

De Rosari B.B., Sinaga B.M., Kusnadi N., Sawit M.H., 2014. The impact of credit and capital supports on economic behavior of farm households: a household economic approach. *International Journal of Food and Agricultural Economics*, 2: 81-90. https://doi.org/10.22004/ag.econ.186269.

Demirdöğen A., Olhan E., Chavas J.P., 2016. Food vs. fiber: An analysis of agricultural support policy in Turkey. *Food Policy*, 61: 1-8. https://doi.org/10.1016/j.foodpol.2015.12.013.

Ehlert D., Schmerler J., Voelker U., 2004. Variable rate nitrogen fertilisation of winter wheat based on a crop density sensor. *Precision Agriculture*, 5(3): 263-273. https://doi.org/https://doi.org/10.1023/B:PRAG.0000032765.29172.ec.

Elferink M., Schierhorn F., 2016. Global demand for food is rising. Can we meet it. *Harvard Business Review*, April 7.

Ellis F., 1996. *Agricultural policies in developing countries*. Cambridge: Cambridge University Press.

Erickson B., Widmar D.A., 2015. *Precision agricultural services dealership survey results*. Purdue University, West Lafayette, IN, 37 pp.

Fountas S., Blackmore S., Ess D., Hawkins S., Blumhoff G., Lowenberg-Deboer J., Sorensen C.G., 2005. Farmer experience with precision agriculture in Denmark and the US Eastern Corn Belt. *Precision Agriculture*, 6(2): 121-141. https://doi.org/https://doi.org/10.1007/s11119-004-1030-z.

Giannoccaro G., Berbel J., 2013. Farmers' stated preference analysis towards resources use under alternative policy scenarios. *Land Use Policy*, 31: 145-155. https://doi.org/https://doi.org/10.1016/j.landusepol.2011.12.013.

Goldsmith P.D., Gunjal K., Ndarishikanye B., 2004. Rural–urban migration and agricultural productivity: the case of Senegal. *Agricultural Economics*, 31(1): 33-45. https://doi.org/ https://doi.org/10.1111/j.1574-0862.2004.tb00220.x.

Goodwin B.K., Mishra A.K., 2005. Another look at decoupling: additional evidence on the production effects of direct payments. *American Journal of Agricultural Economics*, 87(5): 1200-1210. https://doi.org/https://doi.org/10.1111/j.1467-8276.2005.00808.x.

Gorton M., Douarin E., Davidova S., Latruffe L., 2008. Attitudes to agricultural policy and farming futures in the context of the 2003 CAP reform: A comparison of farmers in selected established and new Member States. *Journal of Rural Studies*, 24(3): 322-336. https://doi.org/https://doi.org/10.1016/j.jrurstud.2007.10.001.

Griffin T.W., Miller N.J., Bergtold J., Shanoyan A., Sharda A., Ciampitti I.A., 2017. Farm's sequence of adoption of information-intensive precision agricultural technology. *Applied Engineering in Agriculture*, 33(4): 521-527. https://doi.org/doi:10.13031/aea.12228.

Helming K., Diehl K., Bach H., Dilly O., König B., Kuhlman T., Pérez-Soba M., Sieber S., Tabbush P., Tscherning K., Wascher D., Wiggering H., 2011. Ex ante impact assessment of policies affecting land use, Part A: analytical framework. *Ecology and Society*, 16(1): 27.

Hennessy D.A., 1998. The production effects of agricultural income support policies under uncertainty. *American Journal of Agricultural Economics*, 80(1): 46-57.

Higgins V., Bryant M., Howell A., Battersby J., 2017. Ordering adoption: Materiality, knowledge and farmer engagement with precision agriculture technologies. *Journal of Rural Studies*, 55: 193-202. https://doi.org/https://doi.org/10.1016/j.jrurstud.2017.08.011.

Huffman W.E., Evenson R.E., 2001. Structural and productivity change in US agriculture, 1950-1982. *Agricultural Economics*, 24(2): 127-147.

Hussain S.S., Byerlee D., Heisey P.W., 1994. Impacts of the training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan. *Agricultural Economics*, 10(1): 39-47.

Iglesias A., Garrote L., Flores F., Moneo, M., 2007. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. *Water Resources Management*, 21: 775-788.

Karimzadeh R., Hejazi M.J., Helali H., Iranipour S., Mohammadi S.A., 2011. Assessing the impact of site-specific spraying on control of Eurygaster integriceps (Hemiptera: Scutelleridae) damage and natural enemies. *Precision Agriculture*, 12(4): 576-593. https://doi.org/https://doi.org/10.1007/s11119-010-9202-5.

Key N., Roberts M.J., 2006. Government payments and farm business survival. *American Journal of Agricultural Economics*, 88(2): 382-392.

Khatri-Chhetri A., Aggarwal P.K., Joshi P.K., Vyas S., 2017. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, 151: 184-191.

Langyintuo A.S., Mungoma C., 2008. The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food Policy*, 33(6): 550-559. https://doi.org/https://doi.org/10.1016/j.foodpol.2008.04.002.

Leal Filho W., Mandel M., Al-Amin A.Q., Feher A., Chiappetta J., 2017. An assessment of the causes and consequences of agricultural land abandonment in Europe. *International Journal of Sustainable Development & World Ecology*, 24(6): 554-560. https://doi.org/10.1080/13504509.2016.1240113.

Lefebvre M., Raggi M., Gomez y Paloma S., Viaggi D., 2014. An analysis of the intention-realisation discrepancy in EU farmers' land investment decisions. *Review of Agricultural and Environmental Studies - Revue d'Etudes en Agriculture et Environnement*, 95(1): 51-75. https://www.persee.fr/doc/reae_1966-9607_2014_num_95_1_2121.

Lopez-Ridaura S., Frelat R., van Wijk M.T., Valbuena D., Krupnik T.J., Jat, M.L., 2018. Climate smart agriculture, farm household typologies and food security: An ex-ante assessment from Eastern India. *Agricultural Systems*, 159: 57-68. https://doi.org/https://doi.org/10.1016/j.agsy.2017.09.007.

May D., Arancibia S., Behrendt K., Adams J., 2019. Preventing young farmers from leaving the farm: Investigating the effectiveness of the young farmer payment using a behavioural approach. *Land Use Policy*, 82: 317-327.

Morantes M., Dios-Palomares R., López de Pablo D.A., Rivas J., 2022. Efficiency and technology of dairy sheep production systems in Castilla-La Mancha, Spain. a metafrontier approach. *New Medit*, 21(1): 33-52. https://doi.org/10.30682/nm2201c.

Moss C.B., Schmitz T.G., 1999. *Investing in precision agriculture*. Morrison School of Agribusiness and Resource Management, Arizona State University, Polytechnic Campus.

Mottaleb K.A., Mohanty S., 2015. Farm size and profitability of rice farming under rising input costs. *Journal of Land Use Science*, 10(3): 243-255. https://doi.org/https://doi.org/10.1080/1747423X.2014.919618.

Olagunju F., 2007. Impact of credit use on resource productivity of sweet potatoes farmers in Osun-State, Nigeria. *Journal of Social Sciences*, 14(2): 177-178.

Oliver D.M., Fish R.D., Winter M., Hodgson C.J., Heathwaite A.L., Chadwick D.R., 2012. Valuing local knowledge as a source of expert data: farmer engagement and the design of decision support systems. *Environmental Modelling & Software*, 36: 76-85. https://doi.org/https://doi.org/10.1016/j.envsoft.2011.09.013.

Oyinbo O., Chamberlin J., Vanlauwe B., Vranken L, Kamara Y.A., Craufurd P., Maertens M., 2019. Farmers' preferences for high-input agriculture supported by site-specific extension services: Evidence from a choice experiment in Nigeria. *Agricultural Systems*, 173: 12-26.

Özgüven M., Türker U., 2010. The production economics of precision farming and its possible application for grain corn in Turkey. *Journal of Tekirdag Agricultural Faculty*, 7(1): 55-70.

Paul B.K., Frelat R., Birnholz C., Ebong C., Gahigi A., Groot J.C.J., Herrero M., Kagabo D.M., Notenbaert A., Vanlauwe B., van Wijk M.T., 2018. Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and trade-offs. *Agricultural Systems*, 163: 16-26. https://doi.org/https://doi.org/10.1016/j.agsy.2017.02.007.

Phi H.D., Dinh P.H., Quang M.B., 2021. Factors influencing new technology adoption behaviors of rice farmers: binary logistic regression model approach. *International Journal of Business and Management Review*, 9(4): 54-71. https://doi.org/https://doi.org/10.37745/ijbmr.2013.

Pivoto D., Waquil P.D., Talamini E., Finocchio C.P.S., Dalla Corte V.F., Mores G.V., 2017. Scientific development of smart farming technologies and their application in Brazil. *Information Processing in Agriculture*, 5(1): 21-32. https://doi.org/https://doi.org/10.1016/j.inpa.2017.12.002.

Reichardt M., Jürgens C., 2009. Adoption and future perspective of precision farming in Germany: results of several surveys among different agricultural target groups. *Precision Agriculture*, 10(1): 73-94. https://doi.org/https://doi.org/10.1007/s11119-008-9101-1.

Suri T., 2011. Selection and comparative advantage in technology adoption. *Econometrica*, 79(1): 159-209.

Thomson K., Tansey A., 1982. Intentions surveys in farming. *Journal of Agricultural Economics*, 33(1): 83-88. https://doi.org/ https://doi.org/10.1111/j.1477-9552.1982.tb00714.x.

TOB, 2022. Ministry of Agriculture and Forestry, Agricultural support items. Accessed date: February 15, 2022. https://www.tarimorman.gov.tr/Konular/Tarimsal-Destekler.

Tramblay Y., Llasat M.C., Randin C., Coppola E., 2020. Climate change impacts on water resources in the Mediterranean. *Regional Environmental Change*, 20: 83.

Uslu H., Apaydın F., 2021. An empirical analysis on agricultural productivity and area-based supports in Turkey. *Hitit Journal of Social Sciences*, 14(2): 477-499. https://doi.org/doi: 10.17218/hititsbd.1002014.

Vozarova I.K., Kotulic R., 2016. Quantification of the effect of subsidies on the production performance of the Slovak Agriculture. *Procedia Economics and Finance*, 39: 298-304. https://doi.org/10.1016/S2212-5671(16)30327-6.

Warren C.R., Burton R., Buchanan O., Birnie R.V., 2016. Limited adoption of short rotation coppice: The role of farmers' socio-cultural identity in influencing practice. *Journal of Rural Studies*, 45: 175-183. https://doi.org/10.1016/j.jrurstud.2016.03.017.

Westcott P.C., Young C.E., 2004. Farm program effects on agricultural production: Coupled and decoupled programs. In: Burfisher M.E., Hopkins J. (eds.), *Decoupled Payments in a Changing Policy Setting*. Agricultural Economic Report, No. AER838. Washington, DC: United States Department of Agriculture, pp. 7-17.

Wolfert S., Goense D., Sørensen C.A.G., 2014. A future internet collaboration platform for safe and healthy food from farm to fork. In: *Proceedings of the 2014 Annual SRII Global Conference*, San Jose, CA, 23-25 April. Woodbridge, NJ: IEEE Publishing, pp. 266-273. https://doi.org/10.1109/SRII.2014.47.

Wu Y., 2011. Chemical fertilizer use efficiency and its determinants in China's farming sector: Implications for environmental protection. *China Agricultural Economic Review*, 3(2): 117-130. https://doi.org/10.1108/17561371111131272.

Etude expérimentale des performances technicoéconomiques et environnementales de l'agriculture de conservation dans les régions semi-arides en Tunisie

Salem Talbi*, Mongi Sghaier

DOI: 10.30682/nm2401b
JEL codes: O32, Q12, Q14

Abstract

Conservation agriculture, based on direct seeding, offers an ecological production method based on an integrated and sustainable management of mulch and soil resources. The techno-economic and environmental impacts of this production alternative are variable depending on the production system and the agroecological zone. This work aims to assess different impacts of conservation agriculture compared to conventional agriculture, using a set of agronomic, economic and environmental indicators at the scale of an experimental station. The experimental device combines a set of crop rotations, in rainfall and irrigated system under conventional and conservation agriculture. The analytical methodological framework used the tools of descriptive statistics and multidimensional analysis, including principal component analysis (PCA). Results show the added value of conservation agriculture, which has higher economic and agronomic performance and positive environmental benefits.

Keywords*: Conservation agriculture, Direct seeding, Sustainable agriculture, Agroecology, Economic and environmental performance.*

1. Introduction

L'agriculture d'aujourd'hui confronte nombreux défis dont notamment satisfaire la demande alimentaire croissante et procurer un revenu économique décent aux agriculteurs à travers la promotion des systèmes de production agricoles durables (Kumar and Pant, 2023). La concrétisation du dernier objectif passe impérativement par l'amélioration de la performance environnementale de l'agriculture, notamment qu'elle est soupçonnée d'être une cause de détérioration de la qualité de l'environnement [11% des émissions mondiales du gaz carbonique] et s'empare de la grande part de la consommation mondiale d'eau [70%] (Brooks *et al.*, 2019).

La demande alimentaire croissante, les évolutions technologiques rapides et la diversité des besoins en denrées alimentaires ont accéléré le processus d'intensification de l'activité agricole et l'exploitation des nouvelles terres écologiquement fragiles (Joumard *et al.*, 2020). Au fil des années et avec l'évolution des préférences des consommateurs, des nouvelles demandes des

* INAT: Institut National Agronomique de Tunis, Tunisia.
** Laboratoire d'Economie et Sociétés Rurales, Institut des Régions Arides de Médenine, Université de Gabes, Tunisia.
Corresponding author: talbi.salem@gmail.com

marchés sont apparues et des pratiques de gestion inappropriées, à l'échelle des exploitations agricoles, sont mises en place. L'interaction de ces nouvelles préférences avec les évolutions technologiques de pointe (mécanique et chimique) détermine aussi le niveau de la performance environnementale de l'agriculture (Guerrero, 2021). Le progrès technique s'est accompagné par des conséquences négatives manifestées par des fortes pressions sur les ressources notamment en sol et en eau. Durant les dernières décennies, un large consensus s'est manifesté sur la nécessité de créer un changement profond au niveau du modèle de production agricole. En effet, les modèles conventionnels de production agricole semblent atteindre des limites, parfois irréversibles sur les plans économique et environnemental (Diogo *et al.*, 2018). C'est pour cette raison que, les orientations vers le renforcement des performances économiques et environnementales du secteur agricole, deviennent de plus en plus des exigences incontournables (Peccia *et al.*, 2017).

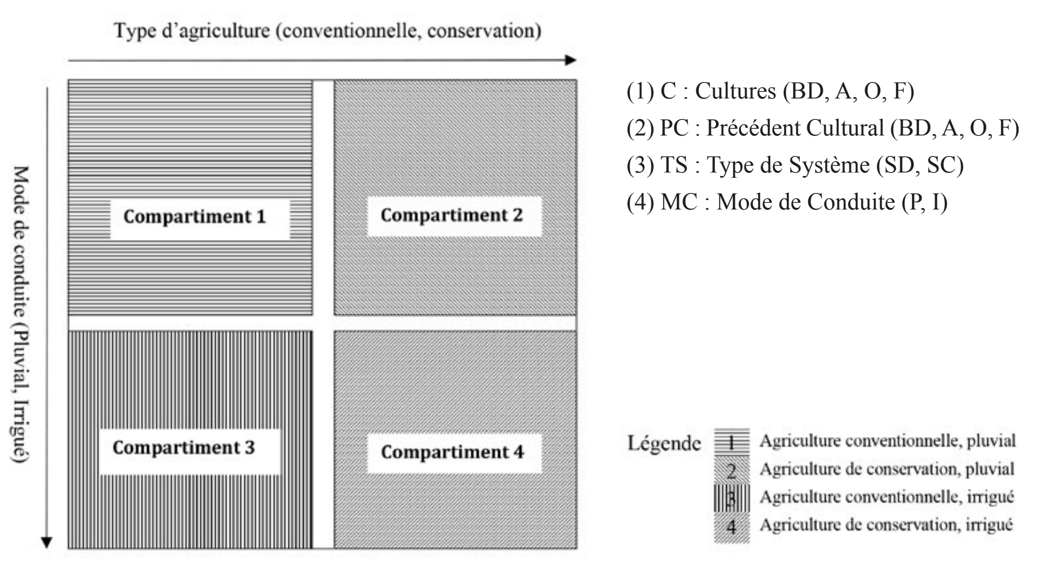
Les perspectives de développement d'une agriculture durable considèrent que l'exploitation agricole devrait inscrire ses stratégies de production dans une démarche socioéconomique et environnementale basée des pratiques écologiques qui protègent l'environnement (Bommarco *et al.*, 2013; Zahm *et al.*, 2019; Muhie, 2022).

L'agriculture de conservation (AC) basée sur le semis direct(SD) fait partie de l'agriculture écologiquement intensive [AIE] (Ghali *et al.*, 2014). Elle est apparue comme une forme d'intensification écologique des systèmes de production qui vise la stabilité de la production agricole et favorise la restauration des milieux dégradés (Laurent, 2015; FAO, 2022). Durant les dernières décennies, les systèmes de production agricole basés sur des pratiques de conservation du sol ont montré leur efficacité, comparativement aux pratiques conventionnelles basées sur le labour, notamment en matière de réduction de l'érosion, de la séquestration du carbone et de la stabilité de la production (Bastiège et Favreau, 2019; Bekin *et al.*, 2021; Chabert et Sarthou, 2020; Mendes *et al.*, 2019).

Les performances agronomiques de l'AC, au niveau d'une parcelle expérimentale, sont assez remarquables et sont en faveur des systèmes de conservation. En effet, 80% des cultures sous les systèmes de conservation présentent des rendements meilleurs qu'en système conventionnel (Thierfelder *et al.*, 2015). A l'échelle de l'exploitation agricole, les résultats économiques et financiers des systèmes de conservation sont confirmés et le revenu additionnel par hectare demeure encourageant (Jacobs *et al.*, 2022; Cusser *et al.*, 2023; Rouabhi *et al.*, 2019). Les vrais impacts économiques ne seront observés qu'à moyen et long terme [équilibre écologique], contrairement aux effets financiers immédiats à court terme (Friedrich *et al.*, 2012). C'est pour cette raison, que la mise en place d'un mécanisme de soutien financier adapté, semble être une priorité afin de surmonter les difficultés financières qui accompagnent généralement l'adoption des nouvelles technologies par les agriculteurs notamment des zones arides (Dhehibi *et al.*, 2023).

Le contexte de développement agricole en Tunisie n'échappe pas au contexte mondial et il est caractérisé par une forte pression sur les ressources naturelles. En effet, la dégradation continue des terres fertiles constitue une vraie menace de la durabilité globale de la production agricole. En revanche, l'appui sur des nouvelles technologies, pour remédier aux problématiques environnementales demeure limité (Bouzaida et Doukali, 2019; Dhehibi *et al.*, 2023). Bien que « *la vraie* » introduction des pratiques écologiques basées sur l'AC chez des agriculteurs pilotes remonte à la fin des années 90, les conclusions préliminaires tirées, en milieu réel, en matière de rentabilité économique sont encourageantes (Ben-Hammouda *et al.*, 2010). En effet, il y a un consensus général, après plus de deux décennies d'expérimentation, que les résultats technicoéconomiques obtenus chez cette catégorie d'agriculteurs leaders ne peuvent pas être considérés comme des résultats finaux et définitifs. Par conséquent, il est difficile d'extrapoler des conclusions confirmées et robustes pour tous les systèmes de production. Même les économies en ressources, issues de la conversion en AC, ne sont pas de la même ampleur pour tous les systèmes de cultures et elles pourraient être absorbées par des coûts additionnels de désherbage ou des réductions potentielles de niveau de rendement.

Figure 1 - Dispositif expérimental.



En revanche, les impacts environnementaux positifs de l'AC demeurent aussi pertinents et plus tangibles sur la ressource sol. La réduction d'émission du gaz carbonique et des terres fertiles arables, en plus des services écosystémiques divers [externalités positives] de cette alternative de production, sont en réalité, sous-évaluées jusqu'à maintenant. Ce type de performances environnementales permet d'atténuer les effets négatifs du changement climatique et accroît, par conséquent, la durabilité des systèmes de production agricole. Dans le contexte tunisien d'adoption des pratiques agrologiques basées sur l'AC, deux questions pertinentes sont posées afin de bien cerner les différentes potentialités de cette approche de production : i) du point de vue technicoéconomique, l'AC basée sur le SD, convient-elle à toutes les cultures sous les systèmes pluvial et irrigué et ii) comment varie l'ampleur des retombées économiques et environnementales, des systèmes de conservation à l'égard des systèmes conventionnels ?

Le présent travail se propose de fournir quelques éléments de réponse pour les questions posées dans un cadre d'une analyse systémique, à l'échelle d'une station expérimentale. Les résultats de cette étude vont servir comme un outil d'aide à la décision pour les agriculteurs de proximité qui désirent expérimenter cette alternative de production. Il ambitionne, également, de présenter des orientations en matière de conduite et des conditions de réussite de l'AC en Tunisie.

2. Approche méthodologique et outils d'analyse

2.1. *Dispositif expérimental et collecte de données*

Les données technico-économiques sont collectées auprès de la station expérimentale de l'École Supérieure de l'Agriculture du Kef (ESAK)[1]. L'objectif de l'expérience est d'évaluer les performances technicoéconomiques et environnementales d'un ensemble de cultures (blé dur [BD], orge[O], avoine[A] et féverole[F]) sous deux systèmes de production différents (système conventionnel *vs* système de conservation), en irrigué(I) et en pluvial(P). Afin de simplifier la lecture et l'analyse des résultats et pour des questions ergonomiques, le *système de conservation* est représenté par SD alors que le *système conventionnel* est représenté par SC.

[1] École supérieure de l'agriculture du Kef [36°07'14.3»N 8°42'56.3»E].

Tableau 1 - Matrice de données et variables d'analyse.

Rotations	*Variables*								
	Dés.	*Ren.*	*ConsEn.*	*HT*	*CDéh*	*MB*	*EmCO2*	*SelDép*	*Irr.*
O.BD.SD.P	R1	0,27	0,151	0,015	2,18	4,6	0,38	0	0
BD.O.SD.P	R2	0,46	0,151	0,015	2,86	23,4	0,38	0	0
A.BD.SD.P	R3	0,29	0,151	0,015	1,6	11,7	0,38	0	0
BD.A.SD.P	R4	0,43	0,151	0,015	2,86	21,9	0,38	0	0
F.BD.SD.P	R5	0,11	0,151	0,015	2,48	3,1	0,38	0	0
BD.F.SD.P	R6	0,5	0,151	0,015	2,86	22,6	0,38	0	0
O.BD.SD.I	R7	0,42	0,151	0,015	2,18	6,2	0,38	16	6,4
BD.O.SD.I	R8	0,48	0,151	0,015	2,86	21,2	0,38	16	6,4
A.BD.SD.I	R9	0,42	0,151	0,015	1,6	12,5	0,38	16	6,4
BD.A.SD.I	R10	0,56	0,151	0,015	2,86	21,5	0,38	16	6,4
F.BD.SD.I	R11	0,25	0,151	0,015	2,48	6,7	0,38	16	6,4
BD.F.SD.I	R12	0,53	0,151	0,015	2,86	21,7	0,38	16	6,4
O.BD.SC.P	R13	0,22	1,306	0,014	1,6	7,9	3,29	0	0
BD.O.SC.P	R14	0,44	1,306	0,014	2,27	25,1	3,29	0	0
A.BD.SC.P	R15	0,25	1,306	0,014	1,01	14,8	3,29	0	0
BD.A.SC.P	R16	0,42	1,306	0,014	2,27	22,7	3,29	0	0
F.BD.SC.P	R17	0,12	1,306	0,014	1,89	2,8	3,29	0	0
BD.F.SC.P	R18	0,43	1,306	0,014	2,27	28,2	3,29	0	0
O.BD.SC.I	R19	0,38	1,306	0,014	1,6	9,6	3,29	18,75	7,55
BD.O.SC.I	R20	0,51	1,306	0,014	2,27	20,3	3,29	18,75	7,55
A.BD.SC.I	R21	0,35	1,306	0,014	1,01	19,4	3,29	18,75	7,55
BD.A.SC.I	R22	0,52	1,306	0,014	2,27	26	3,29	18,75	7,55
F.BD.SC.I	R23	0,25	1,306	0,014	1,89	7,9	3,29	18,75	7,55
BD.F.SC.I	R24	0,52	1,306	0,014	2,27	23,8	3,29	18,75	7,55

Ren. : Rendement, ConsEn. : consommation en énergie, HT : heures de travail,CT : Coût Total, CDéh. : Coût de Désherbage, MB. : Marge Brute, EmCO2 : Emission de CO2, SelDép. : Sel déposé Irr. : Irrigation, Dés. : Désignation.

Le dispositif expérimental est composé de quatre grands compartiments cultivés des mêmes rotations culturales [O/BD, BD/O, A/BD, BD/A, F/BD, BD/F]. Deux types de rotations culturales sont testées : une céréale précédée par une céréale (C/C) et une céréale précédée par une légumineuse (C/L). Chaque culture est représentée par 4 indices [C (1), PC (2), TS (3), MC (4)], comme le montre la Figure 1.

La présente analyse porte sur 9 variables et 24 observations, comme l'illustre le tableau de données (Tableau 1).

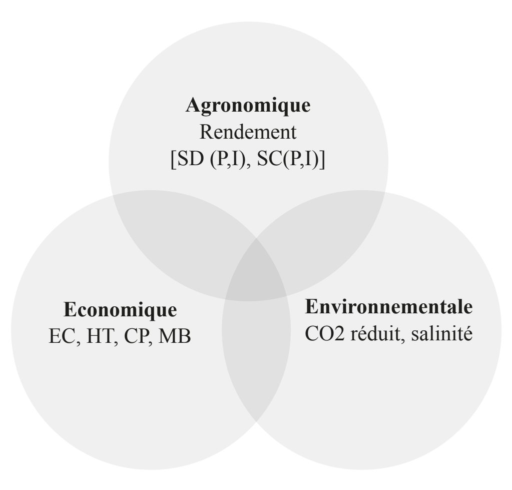
2.2. *Méthodes et outils d'analyse des données*

Analyse descriptive

L'analyse statistique descriptive appliquée, consiste à une comparaison de deux systèmes de production (SD et SC), basée sur des indicateurs [écarts relatifs] (Figure 2) pour les trois dimensions suivantes :

- Agronomique [indicateurs de mesure : rendement des cultures]
- Economique [indicateurs de mesure : heures

Figure 2 - Dimensions d'analyse et indicateurs de mesure.



de travail (HT), énergie consommée (EC), coût de production (CP), marge brute (MB)]
- Environnementale [indicateurs de mesure : dioxyde de carbone émis, sel déposé]

Analyse multivariée

L'objectif de l'analyse multivariée est de synthétiser les liens entre les variables par l'analyse des covariances ou des corrélations, de dresser une « carte » des individus et d'indiquer leurs positions par rapport à ces liens. L'analyse en composantes principales (ACP), proposée comme outil d'analyse, constitue un outil extrêmement puissant de synthèse de l'information et il est préconisé dans le cas de traitement et d'interprétation de données quantitatives complexes, en particulier les données exploratoires multidimensionnelles (Guerrien, 2003). Elle vise, également, à synthétiser les informations de départ seulement en quelques nouvelles variables groupées, appelées *composantes principales* (Helbling, 2018; Saracco *et al.*, 2018).

L'application de l'ACP pour la présente base de données [matrice (24,9)], permet l'extraction et la visualisation des informations importantes sous forme d'un nouvel ensemble plus réduit des variables. La synthèse des variables permet de mieux interpréter les résultats et d'analyser en profondeur les relations de dépendance entre les variables les plus déterminantes.

Afin d'appliquer correctement l'ACP, trois conditions sont bien vérifiées, au préalable [corrélation des variables, indice de KMO et test *de Bartlett*]. L'application de l'ACP permet d':
- étudier et visualiser les corrélations entre les variables qui décrivent les deux systèmes de production (conservation *vs* conventionnel), afin de limiter et de mieux regrouper les variables à mesurer par la suite ;
- obtenir, de construire des facteurs non corrélés, formés par des combinaisons linéaires des variables de départ et d'identifier les variables qui contribuent à chaque facteur. Chaque groupe de variables sera nommé selon le degré d'homogénéité des variables qui le composent ;
- élaborer une typologie des cultures, par type de dimension définie, d'évaluer et d'interpréter les potentialités de chaque système de production à travers la cartographie des cultures.

3. Résultats et discussions

3.1. *Mesure des performances technicoéconomiques de l'agriculture de conservation*

3.1.1. *Effets des pratiques de conservation sur le rendement des cultures*

Comparativement aux systèmes conventionnels, les rendements des cultures sous les systèmes de conservation, sont assujettis à des impacts variables. Les ampleurs de ces impacts mesurées en matière d'écart de rendements[q/ha] ($Ren^{*}_{SD.(I,P)}$-$Ren_{SC.(I,P)}$), dépendent essentiellement du précédent cultural et du régime de la conduite [pluvial ou irrigué].

Il ressort de l'analyse du Tableau 2 que :
- l'impact des pratiques de conservation sur les rendements des cultures, demeure variable, mais plus remarquable en pluvial qu'en irrigué ;
- le rendement de la culture de F/BD [groupe1] est meilleur en conventionnel qu'en conservation dans le régime pluvial ou irrigué. Cette chute de rendement varie de -0,05 q/ha [-4%] à -0,2 q/ha [3,5%] en pluvial et en irrigué, elle est expliquée, en

grande partie, par un problème technique de régalage de semoir ;

- de même, le rendement de la culture de BD/O [groupe 1] est meilleur sous le système conventionnel que le système de conservation, en irrigué, une chute de -1,4 q/ha [-5,7%] est remarquée. En revanche, le rendement de cette même rotation [groupe 2] est légèrement meilleur sous le système de conservation en pluvial. Une augmentation de 1q/ha [4,8%] est obtenue ;
- l'effet des pratiques de conservation sur le rendement demeure légèrement meilleur en pluvial qu'en irrigué pour les rotations suivantes [groupe 2] : O/BD, BD/F. Les améliorations en matière de rendement de ces deux cultures s'élèvent respectivement à 2,6 et 3, 5q/ha, soient respectivement des taux d'augmentation de 25,5% et 17% ;
- en revanche, l'effet des pratiques de conservation est meilleur en irrigué qu'en pluvial, pour les rotations [groupe 2] A/BD et BD/A et BD/F, les taux de variation sont respectivement 3,4 q/ha [20%], 2 q/ha [8,6%] et 0,5 q/ha [2%].

3.1.2. *Effets financiers et économiques*

3.1.2.1. Réduction du temps de travail du sol

Sous les systèmes conventionnels, les besoins en heures de traction mécanique nécessaires pour l'installation d'une culture, allant de la phase de préparation du sol jusqu'au semis, sont variables et dépendent du type de rotations culturales. Le nombre d'heures (h) de traction,

Figure 3 - Comparaison des besoins en heure de traction [h/ha, SD *vs* SC].

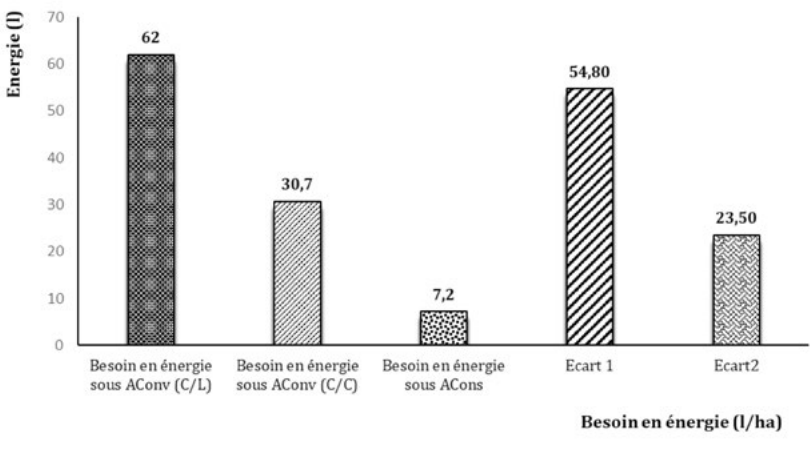


Figure 4 - Comparaison des besoins en énergie [l/ha, SD *vs* SC].

par hectare, s'élève à 3,4[C/C] et 6,9[C/L], alors que le système de conservation, requiert 0,75 h/ha. De ce fait, la conversion vers le système de conservation génère des économies plus importantes en heures de traction mécanique comparé au système cultural en conventionnel type C/L.

A l'échelle d'un hectare, ces économies s'élèvent à 6,15 h [Ecart 1] et 3,4 h [Ecart 2], respectivement pour le type de rotation C/L et C/C, soient des taux de réduction estimés respectivement à 89% et 78% par rapport aux mêmes systèmes en conventionnel, comme le montre la Figure 3.

3.1.2.2. Des économies variables en énergie fossile

La réduction du temps de traction s'est traduite par une moindre consommation en gasoil et les économies en énergie sont corrélées positivement au nombre d'heures de travail. Sous le système de conservation, le besoin d'énergie fossile pour l'installation d'une culture s'élève à 7,2 l/ha, alors qu'en conventionnel les besoins en énergie varient de 62 l/ha pour les rotations C/L et 30,7 l/ha pour les rotations type C/C. Les quantités réduites d'énergie sont respectivement de 54,8 l/ha [rotation C/L, écart1] à 23,5 l/ha [rotation C/C, écart2] (Figure 4). Les économies relatives en énergie sont de l'ordre de 88,4% et 76,5% respectivement pour les rotations C/L et C/C.

3.1.2.3. Coût de désherbage post-semis

Le coût de désherbage post-semis constitue un coût supplémentaire pour les cultures installées sous le système de conservation à l'égard des systèmes conventionnels. Le coût de désherbage additionnel, à base de glyphosate, s'élève à presque +27% du coût total de traitement phytosanitaire.

3.1.2.4. Synthèse des indicateurs de la performance économique des deux systèmes SC et SD

La comparaison des écarts relatifs entre les deux systèmes de production [SD vs SC], en termes des coûts totaux de production (CTP), des produits totaux (PT) et des marges brutes (MB) des cultures montre une certaine performance économique variable, mais en faveur des systèmes de conservation à l'égard des systèmes conventionnels pour l'ensemble des rotations culturales [C/C et C/L] comme le montre le Tableau 3.

Tableau 3 - Synthèse des charges de production [DT/bloc], par mode de semis [P *vs* I].

	Agriculture conventionnelle [P,I]						*Agriculture de conservation [P,I]*					
Culture	O/BD	BD/O	A/BD	BD/A	F/BD	BD/F	O/BD	BD/O	A/BD	BD/A	F/BD	BD/F
Produits Totaux												
P.T $_{[P, (SC, SD)]}$	12,3	33,0	19,9	31,6	9,9	32,2	15,5	34,6	22,9	32,2	9,6	37,7
P.T $_{[I, (SC, SD)]}$	21,5	38,4	28,3	38,6	21,2	38,9	23,7	36,2	33,9	41,9	21,0	39,7
Coûts totaux de production												
CTP $_{[SC (P), SD (P)]}$	7,7	9,6	8,2	9,6	6,9	9,6	6	7,9	6,5	7,9	5,2	7,9
CTP $_{[SC (I), SD (I)]}$	15,3	17,2	15,8	17,2	14,4	17,2	12,4	14,3	12,9	14,30	11,6	14,34
**Vari. relative (%)[P]*	-22	-18	-21	-18	-25	-18						
Vari. relative (%)[I]	-19	-17	-18	-17	-19	-17						
Marges brutes												
DT/bloc $_{[P, (SC, SD)]}$	4,6	23,4	11,7	21,9	3,1	22, 6	9,5	26,7	16,4	24,3	4,4	29,8
DT/bloc[1] $_{[I, (SC, SD)]}$	6,2	21,2	12,5	21,5	6,7	21,7	11,3	21,9	21	27,6	9,4	25, 4
Vari. relative (%)[P]	107	14	40	11	42	32						
Vari. relative (%)[I]	82	3	68	28	40	17						

** Vari.relative : Variation relative: [CTP, MB] (SD-SC)*100/SC; SC représente le système conventionnel, SD représente le système de conservation.*

L'analyse croisée des performances économiques des deux systèmes de production, montre que :

- l'avantage économique global en faveur du système de conservation n'est pas absolu. Il cache des avantages par poste en faveur du système conventionnel, tel que le cas du coût de traitement phytosanitaire ;
- les CTP des cultures [O/BD, de BD/A A/BD et de F/BD] sont réduits respectivement de -22.4%, -17.9%, -20,9% et -25% en pluvial, alors qu'en irrigué les réductions s'élèvent respectivement à -19%, -17%, -18% et -19% ;
- en pluvial, la performance économique [MB] des cultures sous le SD est nettement meilleure qu'en SC. En effet, la MB [O/BD] a presque doublé (107%), alors que les MB [F/BD, A/BD et BD/F] sont améliorées respectivement de 42%, 40% et 32%. En revanche, les MB [BD/O, BD/A] sont légèrement améliorées et elles varient de 14% à 11% ;
- en irrigué, d'une manière générale, la rentabilité économique des systèmes de cultures sous SD est meilleure que celle des systèmes conventionnels. Les rotations O/BD et A/BD sont les plus performantes (82% et 68%), alors que les rotations BD/A et F/BD sont moyennement performantes avec des taux respectivement de 28% et 40% ;
- les rotations culturales BD/O et BD/F sont relativement performantes, leurs améliorations sont respectivement de 3% et 17% ;
- les résultats économiques sont dans la majorité des cas en faveur des cultures sous le système de conservation. L'ampleur de ces résultats s'observe plus pour les systèmes culturaux sous AC en pluvial qu'en irrigué ;
- Finalement, les rendements des cultures sous les deux systèmes (SD *vs* SC) sont presque similaires aux rendements moyens de la région du Kef. Cette similitude est expliquée par l'application du paquet technique le plus répandu dans la région afin de faciliter des éventuelles comparaisons entre la station de la recherche et la réalité des agriculteurs.

3.1.3. *Performances environnementales*

3.1.3.1. Réduction de l'émission du gaz carbonique

Les systèmes conventionnels de production sont plus polluants en dioxyde de carbone gaz carbonique que les systèmes de conservation. Les ampleurs des réductions du gaz carbonique, à l'égard des systèmes culturaux conventionnels, s'élèvent à 147 kg /ha et 73 kg/ha respectivement pour les rotations C/C et C/L, comme le montre le Tableau 4.

3.1.3.2. Efficacité de gestion de l'eau d'irrigation et la salure du sol

L'efficacité des irrigations complémentaires exprimée en économie d'eau d'irrigation, s'élève à 7,85 m^3/bloc, [374 m^3/ha], soit 15,6% à l'égard du système conventionnel grâce à la couverture permanente du sol. Par conséquent, la quantité réduite du sel s'élève à 15,7 kg/bloc, soit 934 kg/ha, comme il est indiqué dans le Tableau 5.

Tableau 4 - Dioxyde de carbone émis par système de production.

	Rotation [C/C]		*Rotation [C/L] céréale/légumineuse*	
	SC	*SD*	*SC*	*SD*
Quantité d'énergie requise	30,7	7,2	62,2	7,2
Emission (Kg CO_2/bloc)	1,73	0,4	3,5	0,4
Emission (Kg CO_2/ha)	82	19	166	19
Réduction [Kg CO_2/ha]	73		147	

* *La combustion d'un litre de gasoil émet 2,67 kg de CO_2 ; SC représente le système conventionnel, SD représente le système de conservation.*

Tableau 5 - Sel déposé sous les systèmes irrigués [SD *vs* SC].

	Compartiments en irrigué		
Mode de semis	*SD*	*SC*	*Ecart*
Eau d'irrigation complémentaire*	42,5	50,35	7,85
Sel déposé (kg/bloc)	85	100,7	15,7
Sel déposé (kg/ha)	4047,6	4795,2	747,6

**Salinité de l'eau est de 2 g/l, bloc de 0.021 ha.*

Tableau 6 - Contribution des variables par axe (après rotation).

Attributs	*Axis_1*		*Axis_2*		*Axis_3*	
-	*Corr.*	*% (Tot. %)*	*Corr.*	*% (Tot. %)*	*Corr.*	*% (Tot. %)*
EmCO2	0,971	94 % (94 %)	-0,077	1 % (95 %)	0,048	0 % (95 %)
ConsEn	0,971	94 % (94 %)	-0,077	1 % (95 %)	0,048	0 % (95 %)
HT	0,834	70 % (70 %)	0,242	6 % (75 %)	-0,014	0 % (75 %)
CDeh	-0,548	30 % (30 %)	0,657	43 % (73 %)	-0,101	1 % (74 %)
MB	0,249	6 % (6 %)	0,924	85 % (92 %)	-0,023	0 % (92 %)
Ren	-0,049	0 % (0 %)	0,894	80 % (80 %)	0,348	12 % (92 %)
SelDep	0,039	0 % (0 %)	0,081	1 % (1 %)	0,994	99 % (100 %)
Irr	0,042	0 % (0 %)	0,081	1 % (1 %)	0,994	99 % (100 %)
Var. Expl.	2,949	37 % (37 %)	2,168	27 % (64 %)	2,111	26 % (90 %)

Source : Output de Tanagra, 2023.

3.2. *Analyse multidimensionnelle : Résultats de l'analyse en composantes principales*

3.2.1. *Vérification de la fiabilité de l'application de l'ACP à la matrice de données*

La méthode de rotation orthogonale utilisée est la méthode de *VARIMAX*. La quantité d'information totale expliquée, est préservée même après rotation (90%), les nouvelles quantités d'informations expliquées par les axes F1, F2 et F3 sont respectivement 37%, 27% et 26%.

- L'analyse de la matrice des contributions des variables montre que les trois premières variables sont fortement corrélées au premier axe. Les variables, qui ont les poids les plus élevés sur ce facteur, sont « *heure de travail* » et « *énergie combustible utilisée* » en plus des « *émissions du gaz carbonique* ». Cette dimension représente l'efficacité d'utilisation de ces ressources et ses impacts sur l'environnement, il peut être nommé « *efficacité d'utilisation des ressources et performance environnementale* ».
- Le deuxième axe est représenté par trois variables de nature différente : une variable technique « *rendement* » et deux variables économiques « *coût de désherbage* » et « *marge brute* ». Cet axe exprime la « *performance technicoéconomique* ».
- Le troisième axe est représenté par deux principales variables « *irrigation »* et « *sel déposé* ». Cet axe exprime « *la performance de pilotage d'irrigation et qualité d'eau* ».

3.2.2. *Carte de représentation des individus*

3.2.2.1. Interprétation du plan Factoriel (F1 *vs* F2)

L'analyse de la carte des individus (cultures), formée du plan factoriel (F1*F2) montre quatre principaux groupes bien distincts (Figure 5).

La répartition des cultures, par composante est synthétisée dans le Tableau 7.

Première composante

Cette composante est formée par des combinaisons culturales uniquement en conventionnel [P et I], les plus exigeantes en ressources, les moins performantes sur le plan environnemental et les plus performantes sur le plan technicoéconomique.

En outre, cette composante est subdivisée en deux sous-composante distinctes : la première sous composante [R12 et R24] est constituée par la culture de BD/F[I,P], alors que la deuxième sous composante [R08, R22, R10 et R20] est constituée par la culture de BD avec des précédents culturaux type graminée (orge et avoine).

Cette classification montre que les cultures de la première sous composante sont les plus performantes sur le plan technicoéconomique et exigeantes en ressources, en plus d'impact négatif sur l'environnement (CO_2) alors que la deuxième sous-composante est formée par des cultures moins exigeantes en ressources avec une performance environnementale relativement meilleure.

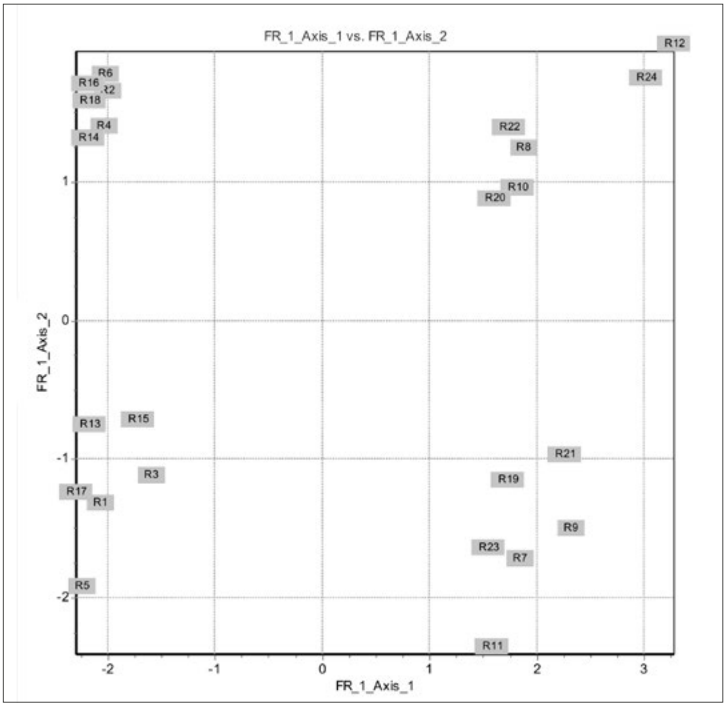


Figure 5 - Cartographie des individus (F1 *vs* F2).

Les résultats obtenus sont en harmonie avec la réalité. La culture de blé dur ayant précédent cultural, type légumineuse[féverole], nécessite plus d'heures de traction et consomme plus d'énergie. Par conséquent, elle émet plus de dioxyde de carbone comparativement à un précédent cultural, type graminée [avoine ou orge].

Deuxième composante

Cette composante est formée par les cultures, uniquement sous les systèmes de conservation [combinaisons de BD (I, P)]. Elles sont les plus performantes sur le plan environnemental et sur le plan technico-économique et les moins exigeantes en ressources. La performance environnementale est exprimée par la faible pollution en dioxyde de carbone alors que la performance économique est exprimée par l'effet du précédent cultural sur le rendement conjugué au prix élevé de ce produit sur le marché.

Troisième composante

Cette composante résulte l'ensemble des cultures, en conventionnel, les moins performantes sur le plan technicoéconomique et les plus émettrices du dioxyde de carbone. Elle est constituée par les cultures d'orge, de féverole et d'avoine en pluvial et en irrigué en conven-

Tableau 7 - Typologie des cultures du plan factoriel (F1*F2).

	Composante 1	*Composante 2*	*Composante 3*	*Composante 4*
Cultures*	R12 : *BD.F.SC.P* R24 : *BD.F.SC.I* R08 : *BD.O.SC.P* R22 : *BD.A.SC.I* R10 : *BD.A.SC.P* R20 : BD.O.SC.I	R06 : *BD.F.SD.P* R16 : *BD.A.SD.I* R02 : *BD.O.SD.P* R18 : *BD.F.SD.I* R04 : *BD.A.SD.P* R14 : *BD.O.SD.I*	R21 : *A.BD.SC.I* R19 : *O.BD.SC.I* R09 : *A.BD.SC.P* R23 : *F.BD.SC.I* R07 *O.BD.SC.P* R11 : *F.BD.SC.P*	R15 : *A.BD.SD.I* R13 : *O.BD.SD.I* R03 : *A.BD.SD.P* R17 : *F.BD.SD.I* R01 : *O.BD.SD.P* R05 : *F.BD.SD.P*

* *SC: désigne le système conventionnel ; SD désigne le système de conservation.*

tionnel. Ces cultures sont caractérisées par des rendements moyens avec des prix de vente relativement faibles. La culture de féverole demeure la moins performante sur le plan économique et environnemental.

Quatrième composante

La dernière composante est formée par les mêmes cultures que la troisième composante, mais en conservation. L'ensemble de ces cultures [avoine, orge avec différents précédents culturaux] est caractérisé par une bonne performance environnementale et une performance technicoéconomique moyenne. En revanche, la culture de féverole demeure un peu éloignée par rapport au reste des cultures de la composante, c'est la plus performante coté environnemental et moins performante coté économique.

Les conclusions qui peuvent être tirées de l'analyse du premier plan factoriel (F1*F2), sont :

- le demi-plan supérieur, formé par les deux composantes 1 et 2, contient uniquement la culture de blé dur, avec différents précédents culturaux. Ces deux composantes sont antagonistes sur le plan système de culture [composante 1 : conventionnel *vs* composante 2 : conservation] et sur le plan besoin en ressources et performances économique aussi. Cette typologie met en évidence que les pratiques de conservation sont moins exigeantes en heures de travail et en énergie fossile, indépendamment du système de production pluvial ou irrigué ;
- le demi-plan inférieur, formé par les deux composantes 3 et 4, contient les cultures d'orge, d'avoine et de féverole. Ces deux composantes sont aussi antagonistes sur le plan système de culture [composante3 : conventionnel *vs* composante4 : conservation] et sur le plan besoin en ressources et performance économique. Cette typologie met évidence que les pratiques de conservation sont moins exigeantes en heures de travail et en énergie fossile, indépendamment du système de production, pluvial ou irrigué. En revanche, les performances technicoéconomiques des cultures d'orge et d'avoine sont nettement meilleurs en conservation qu'en conventionnel.

4. Synthèse et comparaison des performances des systèmes de conservation à l'égard des systèmes conventionnels

Les systèmes de culture basés sur la simplification du travail du sol ne sont pas trop performants sur tous les aspects comparativement aux systèmes conventionnels basés sur le labour, comme il est indiqué dans le Tableau 8.

- *Performance économique* : les systèmes de conservation sont en général, plus performants que les systèmes conventionnels, en termes des coûts totaux de production par type de culture installée. En revanche, les systèmes de conservation nécessitent des coûts additionnels de désherbage et ces coûts sont généralement absorbés par l'amélioration des rendements et les économies en temps de travail du sol. En matière de marges brutes, la performance est en faveur des systèmes de conservation, exception faite pour la culture de féverole qui demeure en conventionnel.
- *Allocation des ressources* : les systèmes de conservation sont distingués par une meilleure allocation des ressources [heure de travail et énergie fossile] que les systèmes conventionnels.
- *Performance technique* : les systèmes de conservation sont caractérisés par une stabilité, voire des améliorations des rendements à l'égard des systèmes conventionnels. A l'équilibre écologique (3 à 7 ans), des améliorations nettes pourraient être mieux constatées.
- *Performance environnementale* : les systèmes de conservation réduisent davantage l'émission du gaz à effet de serre (CO_2) causé par la combustion d'énergie fossile en plus ils favorisent la séquestration du carbone et la réduction du processus de minéralisation de la matière organique. La réduction de la salure des sols compte aussi un point fort de ces systèmes de production en irrigué à l'égard des systèmes conventionnels. En revanche, le désherbant « glyphosate », utilisé en AC, demeure une molécule cancérogène et très polluante et peut-être lessivée facilement par les eaux de pluie et elle risque de contaminer les ouvrages de rétention des eaux (externalité négative).

Tableau 8 - Comparaison des performances des systèmes de conservation à l'égard des systèmes conventionnels.

Performance	*Agriculture Conventionnelle*		*Agriculture de conservation*	*Conclusion*
	Rotations C/C	*Rotations C/L*	*Rotations C/C et C/L*	
Allocation des ressources				
Préparation du sol	2-3 recroisements [2,75 h/ha]	1 gros labour et 2 à 3 recroisements [6,9 h/ha]	Suppression totale du labour	Aération biologique du sol à travers les rotations
Semis	Semis conventionnel [0,66 h/ha]		Semis direct [0,75 h/ha]	Gain du temps de travail sous AC
Besoin en énergie	30,7 l/ha	62 l/ha	7,5 l/ha	Gain d'énergie sous AC
Economique				
Coût de désherbage	Coût réduit de -27%, *vs* l'AC		Coût additionnel de +27% *vs* de l'AC	Coût supplémentaire de désherbage avant semis en AC
Coût de production	Coût total de production varie de +17 à +22% à l'égard de l'AC	Coût total de production de +25% à l'égard de l'AC	Réduction du coût total de production varie de -17% à -25%, à l'égard du SC	Coût de production généralement réduit sous AC
Marge brute	MB [O] réduite de -107% *vs* AC	MB [BD] réduite de -11% *vs* AC	Amélioration de 11 % [O] à 107% [BD] *vs* conventionnel	Marge brute par culture généralement améliorée sous AC
Technique				
Rendement	Rendements réduits de -10% à -25% pour les cultures d'orge et avoine, à l'égard de l'AC	Stabilité ou légère augmentation pour le cas du BD à l'égard de l'AC	Rendements meilleurs, de 10 à 25,5% [O, A] *vs* conventionnel	Stabilité voire amélioration des rendements sous AC
Environnementale				
Emission du CO_2	Emission du dioxyde carbone de 82 kg/ha	Emission du dioxyde carbone de 166 kg/ha	Emission du dioxyde carbone de 19 kg/ha	Réduction du gaz à effet de serre
Salure des sols	Salure des sols en irrigation complémentaire : 4795,2 kg/ha		Salure des sols en irrigation complémentaire : 4048 kg/ha	Dégradation de la qualité du sol plus rapide en conventionnel
Glyphosate	-	-	Glyphosate de 1 à 2 l/ha	Molécule cancérogène

5. Conclusion

L'intensification écologique de l'agriculture tunisienne est apparue comme une nouvelle approche de production agricole qui vise une gestion rationnelle et durable des ressources naturelles et de remédier aux problématiques de l'agriculture intensive conventionnelle. Les pratiques agricoles de conservation, dont l'AC fait partie, cherchent à répondre à un défi majeur : assurer une sécurité alimentaire durable du pays sans dégrader et nuire à la qualité des ressources naturelles. Les travaux de recherche qui ont accompagné la phase d'expérimentation et d'introduction de l'AC chez les agriculteurs sont focalisés, dans la plupart des cas, sur la mesure de diffusion ou des aspects techniques fins. La présente étude s'est proposée d'analyser, de manière systémique, les effets potentiels sur les plans technicoéconomique et environnemental, des systèmes de conservation comparativement aux systèmes conventionnels en pluvial et en irrigué à l'échelle d'une parcelle expérimentale.

Les résultats, en termes d'économie en ressources, sont en faveur des systèmes de conservation à l'égard des systèmes conventionnels, en matière du temps de travail et d'énergie fossile. Les ampleurs de ces économies dépendent des itinéraires de production en conventionnel et elles sont plus perçues en cas des itinéraires complexes de travail de sol [rotations à base de légumineuse]. L'analyse multidimensionnelle appliquée aux résultats des expériences comparatives de deux systèmes de production [SC *vs* SD] à l'échelle d'une station de recherche expérimentale située dans une zone semi-aride, montre une stabilité de la production en faveur de l'AC. En effet, les rendements des cultures sont légèrement meilleurs pour la culture d'orge et d'avoine sous les systèmes de conservation qu'en conventionnel, alors que pour la culture de féverole, le rendement demeure meilleur sous le deuxième système que le premier. En revanche, les effets économiques demeurent variables et sont nettement meilleurs pour les cultures d'orge et d'avoine [+50%] alors pour la culture de blé dur est légèrement meilleur. Le coût supplémentaire de désherbage est généralement absorbé par le gain en consommation d'énergie et parfois par le surplus de la production. Les pratiques de conservation conviennent mieux aux systèmes pluviaux et la gestion intégrée de mulch et du sol permet aux cultures de bien gérer les périodes de stress hydriques. Le bilan environnemental, demeure aussi important et il est manifesté par des réductions considérables des émissions du gaz carbonique dues à la combustion d'énergie fossile. En guise, les résultats technicoéconomiques et environnementaux obtenus à l'échelle de la station de recherche de l'ESA-Kef, pourraient servir comme un outil d'aide à la décision pour les agriculteurs et les décideurs. Ainsi, les résultats du présent travail contribuent à l'élaboration I) d'un référentiel technoéconomique permettant l'amélioration de l'adoption et la diffusion de l'AC chez un nombre plus élevé d'agriculteurs, et II) des nouvelles stratégies d'adaptation au changement climatique qui permettent de renforcer la durabilité des systèmes de production agricole en Tunisie notamment dans un contexte de sécheresse prolongée.

Références bibliographiques

Bastiège M., Favreau F., 2019. Management des ressources naturelles, le retour de l'État régalien ? *Revue Politiques et Management Public*, 4: 353-370.

Bekin N., Prois Y., Laronne J., Egozi R., 2021. The fuzzy effect of soil conservation practices on runoff and sediment yield from agricultural lands at the catchment scale. *Catena*, 207: 105710. https://doi.org/10.1016/j.catena.2021.105710.

Ben-Hammouda M., Thabet B., Talbi S., 2010. *Retombées technico-économiques et environnementale de l'agriculture de conservation*. Presented at the S*éminaire National : Dix ans d'Agriculture de Conservation en Tunisie : Bilan et Perspectives*, Tunis, 28 octobre 2010.

Bommarco R., Kleijn D., Potts S.G., 2013. Ecological intensification: harnessing ecosystem services for food security. *Trends in Ecology & Evolution*, 28: 230-238. https://doi.org/10.1016/j.tree.2012.10.012.

Bouzaida M.A., Doukali H., 2019. Évaluation de la durabilité des exploitations agricoles irriguées en zones arides tunisiennes par la méthode IDEA: cas de la région de Zarzis. *New Medit*, 18(4): 89-104. https://doi.org/10.30682/nm1904g.

Brooks J., Deconinck K., Giner C., 2019. *Three key challenges facing agriculture and how to start solving them*, June 6, OECD. https://www.oecd.org/agriculture/key-challenges-agriculture-how-solve/.

Chabert A., Sarthou J.-P., 2020. Conservation agriculture as a promising trade-off between conventional and organic agriculture in bundling ecosystem services. *Agriculture, Ecosystems & Environment*, 292: 106815. https://doi.org/10.1016/j.agee.2019.106815.

Cusser S., Jha S., Lonsdorf E., Ricketts T., 2023. Public and private economic benefits of adopting conservation tillage for cotton pollination. *Agriculture, Ecosystems & Environment*, 342: 108251. https://doi.org/10.1016/j.agee.2022.108251.

Dhehibi B., Fouzai A., Frija A., Adhim M.A., M'hamed H.C., Ouerghemmi H., Rekik M., 2023. Assessing complementary synergies for integrated crop–livestock systems under conservation agriculture in Tunisian dryland farming systems. *Frontiers in Sustainable Food System*, 6: 1022213. https://doi.org/10.3389/fsufs.2022.1022213.

Diogo R., Adodo P., Nouatin G.S., Djedje M., 2018. Durabilité agroécologique et déterminants du degré d'investissement des producteurs dans la gestion durable des terres au nord-est du Bénin. *Bulletin de la Recherche Agronomique du Benin*, Numéro Spécial Développement Agricole Durable (DAD), pp. 75-86.

FAO, 2022. *L'agriculture de conservation*. https://www.fao.org/3/cb8350fr/cb8350fr.pdf.

Friedrich T., Derpsch R., Kassam A., 2012. Overview of the Global Spread of Conservation Agriculture. *Field Actions Science Reports*, 6. https://journals.openedition.org/factsreports/1941.

Ghali M., Daniel K., Colson F., Sorin S., 2014. L'agriculture écologiquement intensive. Une approche économique. *Economie Rurale*, 341: 83-99. https://doi.org/10.4000/economierurale.4338.

Guerrero S., 2021. *Characterising agri-environmental policies: Towards measuring their progress*. OECD Food, Agriculture and Fisheries Papers, No. 155. Paris: OECD Publishing. https://doi.org/10.1787/41257e3c-en.

Guerrien M., 2003. L'intérêt de l'analyse en composantes principales (ACP) pour la recherche en sciences sociales. *Cahiers des Amériques latines*, 43: 181-192.

Helbling D.J.-M., 2018. *MATH 444 – Statistique multivariée.*

Jacobs A.A., Evans R.S., Allison J.K., Garner E.R., Kingery W.L., McCulley R.L., 2022. Cover crops and no-tillage reduce crop production costs and soil loss, compensating for lack of short-term soil quality improvement in a maize and soybean production system. *Soil and Tillage Research*, 218: 105310. https://doi.org/10.1016/j.still.2021.105310.

Joumard I., Arriola C., Dek M., 2020. *Challenges and opportunities of India's enhanced participation in the global economy*. OECD Economics Department Working Papers, No. 1597. Paris: OECD Publishing. https://doi.org/10.1787/a6facd16-en.

Kumar A., Pant S., 2023. Analytical hierarchy process for sustainable agriculture: An overview. *MethodsX*, 10: 101954. https://doi.org/10.1016/j.mex.2022.101954.

Laurent F., 2015. L'Agriculture de Conservation et sa diffusion en France et dans le monde. *Cybergeo: European Journal of Geography*, 747. https://doi.org/10.4000/cybergeo.27284.

Mendes I.D.C., Souza L.M.D., Sousa D.M.G.D., Lopes A.A.D.C., Reis Junior F.B.D., Lacerda M.P.C., Malaquias J.V., 2019. Critical limits for microbial indicators in tropical Oxisols at post-harvest: The FERTBIO soil sample concept. *Applied Soil Ecology*, 139: 85-93. https://doi.org/10.1016/j.apsoil.2019.02.025.

Muhie S.H., 2022. Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*, 10: 100446. https://doi.org/10.1016/j.jafr.2022.100446.

Peccia T., Kelej R., Hamdy A., Fahmi A., 2017. A reflection on Public-Private Partnerships contribution to the attainment of Sustainable Development Goals. *Science & Peace*, VIII(1): 81-103.

Rouabhi A., Laouar A., Mekhlouk A., Dhehibi B., 2019. Socioeconomic assessment of no-till in wheat cropping system: a case study in Algeria. *New Medit*, 18: 52-64. https://doi.org/10.30682/nm1901e.

Saracco J., Chavent M., Audin-Garcia L., Lespinet-Najib V., Ron-Angevin R., 2018. Classification de variables et analyse multivariée de données mixtes issues d'une étude BCI. *Ingénierie cognitique*, 2(1). https://doi.org/10.21494/ISTE.OP.2018.0311.

Thierfelder C., Matemba-Mutasa R., Rusinamhodzi L., 2015. Yield response of maize (Zea mays L.) to conservation agriculture cropping system in Southern Africa. *Soil and Tillage Research*, 146: 230-242. https://doi.org/10.1016/j.still.2014.10.015.

Zahm F., Alonso Ugaglia A., Barbier J.-M., Boureau H., Del'homme B., Gafsi M., Gasselin P., Girard S., Guichard L., Loyce C., Manneville V., Menet A., Redlingshöfer B., 2019. Évaluer la durabilité des exploitations agricoles. La méthode IDEA v4, un cadre conceptuel combinant dimensions et propriétés de la durabilité. *Cahiers Agricultures*, 28: 5. https://doi.org/10.1051/cagri/2019004.

Financial distress in European vineyards and olive groves

Mário Santiago Céu*, Raquel Medeiros Gaspar**

DOI: 10.30682/nm2401c
JEL codes: G32, G33, Q14

Abstract

This study focuses on the prediction of financial distress of agricultural firms operating in the vineyards and olive crops sectors in Mediterranean countries, specifically in Portugal, Spain, and Italy, which are crucial for the production of these crops. The sample size of the study is 5,057 firms. Twelve models are presented, estimated from subsamples of combinations between countries and crops. Logistic regression is used for the estimation of these models. The accuracy of the models is evaluated, considering the importance of misclassification costs. Additionally, the areas under the ROC curves are calculated and compared in a dynamic of possible combinations between crops and countries. The study concludes that there are differences between the two sectors, as well as across countries, and suggests that dedicated models for each country or crop may improve the the models' accuracy.

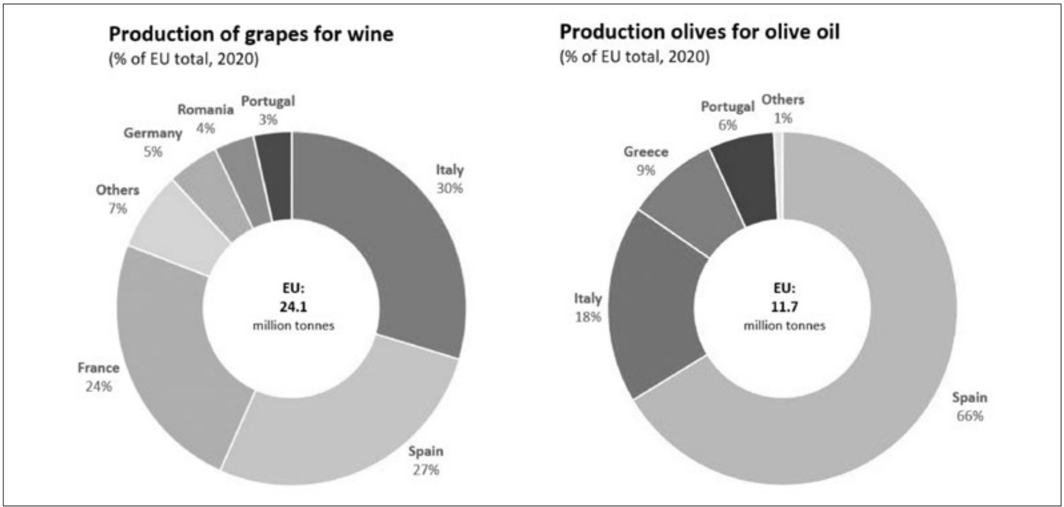
Keywords: *Agriculture, Financial distress, Prediction models, ROC curves.*

1. Introduction

The similarities between the Mediterranean regions in biophysical, climatic and structural conditions are widely recognised. From this similarity, agronomic practices also evolved, predominantly for certain plantations, namely the cultivation of vineyards and olive groves (Caraveli, 2000). "In the Mediterranean basin, the olive along with the vine constituted the equivalent of the rural industries of the North. This equivalence is important, if not for the volume of income, at least for the number of people they engaged, since the 16th century and on, whenever an increase of the cultivation of the olive is observed" (Loumou and Giourga, 2003, p. 90). In 2020, the European Union (EU) explored 3.2 million hectares of vineyards and 5.1 million hectares of olive groves, corresponding to 45% of the world's wine-growing area and 40% of the olive-growing area. From 1962, when the first common market organisation was created, until 2013, when the last reform was revised, the wine sector became more competitive, with simpler and more balanced market rules. European policies over this half century have significantly transformed the sector through diversified interventionist measures, initially supporting divestments (grubbing up) and then supporting firms in financing the restructuring of most of the current vineyards. In 2014, the eight largest EU wine-producing countries accounted for 94% of the EU's wine exports and 65% of global wine exports (Correia *et al.*, 2019). Concerning the production of olives, mainly destined for the extraction of olive oil, the Mediterranean coun-

* ISEG, Lisbon University, Advance/CSG Research Center, Lisboa, Portugal.
** ISEG, Lisbon University, Cemapre/REM Research Center, Lisboa, Portugal.
Corresponding author: mariosantiago@phd.iseg.ulisboa.pt

Figure 1 - Production of grapes and olives in EU.



Source: Eurostat.

tries have had almost absolute dominance in the world due to their unique and highly favourable climate for this culture. In the case of the European Union, Spain, Italy, Greece, and Portugal are the major producers in this market, with a proportion of 99% of the EU-27[1] and 40% of the world, respectively (FAO, 2022). Through Figure 1, it is possible to verify the largest producers of grapes and olives in the European Union.

Despite the importance of these crops in European agriculture and the economy, there are uncertainties about their future. Due to climate change, Fraga *et al.* (2019) refer to risks to the economic sustainability of vineyards and olive groves in these countries. Furthermore, within the olive sector, there is a coexistence of modern and traditional farms, exhibiting significant disparities in productivity, management practices, economic performance, contributions, and sustainable values, raising concerns about the adaptability and survival prospects of traditional family farms (Mokrani *et al.*, 2022). The prevalence of small-scale agriculture also impacts firm viability, wherein farm size and distribution are intrinsically linked to efficiency, with larger farms demonstrating greater productivity and technological advantage, enhancing their survival prospects (Ruz-Carmona *et al.*, 2023).

On the other hand, the Mediterranean countries, compared to Northern Europe, suffer from an ageing agricultural population and poor farm training, which negatively impacts their financial performance. The reformulation of direct payments under the CAP (Common Agricultural Policy), added to the impact of climate change and the liberalization of agricultural trade, places these rural economies in the South more exposed to financial risks (Giannakis and Bruggeman, 2015).

The similarities in the geography and agronomic practices of Portugal, Spain and Italy are widely studied (Arnalte-Alegre and Ortiz-Miranda, 2013; Beopoulos, 2017). However, this does not mean that we can consider a single financial distress prediction model for agricultural firms from different countries and crops.

The paper aims to examine the financial sustainability and risk of agricultural firms, particularly vineyards and olive groves of Portugal, Spain, and Italy. These crops play a vital role in the region's agriculture and economy. However, uncertainties and challenges threaten their future, including climate change risks, disparities between modern and traditional farms, and the impact of policy changes on financial performance. While studying similarities in geog-

[1] The 27 European Union countries after the UK left the EU.

raphy and agronomic practices, a one-size-fits-all approach may not be suitable due to unique economic, social, and environmental factors influencing the financial health of these farms. Hence, are presented financial distress prediction tools for each of these dimensions.

The remainder of the paper is organised as follows. Section 2 addresses the literature on the definition of financial distress, particularly in agriculture, and the relevance of the ROC (receiver operating characteristic) curve to measuring the accuracy of predictive models. Section 3 describes the data and methodology, and section 4 presents and discusses the results. Finally, Section 5 presents the conclusions and limitations.

2. Literature review

After the seminal study by Beaver (1966), the prediction of bankruptcy and financial distress has been a subject of significant interest and research among scholars. While bankruptcy is a legal action that decrees the end of business activity, financial distress results from financial difficulties compromising the firm's ability to honour its commitments. We can define financial distress as a stage before a court decrees bankruptcy. Fitzpatrick (1934) characterizes five moments in the life of a company until bankruptcy: (i) incubation, (ii) embarrassment, (iii) financial insolvency, (iv) total insolvency, and (v) confirmed insolvency. Altman *et al*. (2019) goes deeper into the different concepts and list six reasons that alone or together can contribute to corporate failure, namely (i) poor operating performance and high financial leverage, (ii) lack of technological innovation, (iii) liquidity and funding shock, (iv) relatively high new business formation rates in specific periods, (v) deregulation of key industries, and (vi) unexpected liabilities. The duration between a firm showing signs of financial distress and its bankruptcy being declared is imprecise. However, the years before this failure show predictors of this failure. Chan and Rotenberg (1988) estimated this duration at four years in the Canadian agricultural sector. However, financial distress does not necessarily imply bankruptcy, and many firms prosper after going through moments of financial difficulty.

In the credit risk literature, there are different approaches to defining financial distress, as if it were a singular state dependent on numerous internal or external variables, in addition to different interactions with the local policies and economies in which they operate. "A firm is in financial distress at a given point in time when the liquid assets of the firm are not sufficient to meet the current requirements of its hard contracts" (Hotchkiss *et al.*, 2008, p. 6). Wruck (1990) defines financial distress as an insufficient cash flow to cover current obligations. Asquith *et al.* (1994) bases the entire definition on interest coverage ratios, classifying the firm in financial distress if, for two consecutive years, EBITDA (earnings before interest, taxes, depreciation and amortization) is less than interest expenses or if in one year, EBITDA is less than 80 per cent of its interest expenses. Whitaker (1999) reports this state for the first year in which cash flow is less than current long-term debt maturities. However, one thing is for sure, "distinguishing between financially distressed and healthy companies is more difficult than the traditional comparison between bankrupt and healthy companies" (Platt and Platt, 2006, p. 155).

There are characteristics of the markets and sectors of activity in which firms operate which can compromise the effectiveness of insolvency prediction models. Research on these differences is well known and focuses on various aspects such as cultural, legal, regulatory or macroeconomic. The financial health of firms must be examined in loco within the local macro environment (Khoja *et al.*, 2019). Nevertheless, within similar markets, depending on the sector of activity, there may be variables that stand out as affecting the financial health of firms. In the European Union (EU-27), public policies are shared in the agricultural sector, and even in countries that share similar climates and favourable conditions for the exploitation of certain agricultural products, this does not mean that firms in these countries have similar levels of financial distress.

The lack of a formal definition of financial distress, unlike bankruptcy, which the court defines on a specific date, motivated researchers to propose concepts that somehow characterise the financial strength of firms but emphasise the subjectivity about the most appropriate variables for the definition of this state of the financial health of firms. In the repository of research on financial distress in agriculture, the transnational specificities or the agricultural products cultivated are only sometimes analysed. The data is collected across territories without any differentiation. Klepac and Hampel (2017) tested 250 agriculture business firms in the EU (forestry and logging, fishing and aquaculture), of which 62 reported the default of payment or insolvency proceedings. Vavřina *et al.* (2013) were concerned with homogenizing the data, limiting the choice of 2,581 active and 71 bankrupted agribusiness firms in the Visegrad Group countries (Czechia, Hungary, Poland and Slovakia). Other studies selected firms from agricultural subsectors without proper homogenization criteria. Karas *et al.* (2017) selected 450 active and 25 bankrupt firms. Data were obtained from cereals, rice, grapes, plant propagation, raising of sheep and goats, and mixed farming subsectors. In this selection, they mixed small samples from such subsectors as non-perennial crops, perennial crops and livestock.

Literary approaches that compare predictive models of bankruptcy or financial difficulties in agriculture across various countries and crop combinations are lacking. There is a great diversity of agronomic practices that influence the business structures themselves. The risk of failure for a farmer who produces olives may differ from another farmer who explores vineyards. The same is valid for many other combinations. This research opens a reflection on the subject and aims to contribute to filling this gap.

3. Data and methodology

3.1. *Data and definition of financial distress*

The financial data used in this study is sourced from the Orbis database, provided by Bureau van Dijk. This database is a reputable and widely utilized financial resource, consolidating information from diverse sources, including company reports, regulatory filings, and other publicly available records. It offers extensive financial data for a vast number of companies worldwide. Within the scope of our research, we employed this database to collect financial information about firms operating in the viticulture and oliviculture sectors across European countries. Are considered only firms that did not fail to submit accounts in 2018, 2019 and 2020. We excluded firms that did not have known operating revenue (turnover) in these three years. Of the European countries dedicated to viticulture and oliviculture, only Italy, Spain and Portugal had sufficient financial data available.[2] Table 1 presents the distribution of firms according to the above classifications. We divided data into two groups: just 2018 and both 2019 and 2020. Following the same procedure devised by Platt and Platt (2008), we implemented a two-step procedure to categorize firms according to their financial health. To belong to the healthy group, firms had to register three positive variables in 2019 and 2020. If any of these metrics failed, they would be placed in the financially distressed group; otherwise are categorized as healthy. The variables chosen were (i) EBITDA to interest coverage, (ii) EBIT (earnings before interests and taxes), and (iii) Net income before special items[3]. The financial ratios used to estimate the models are obtained from the 2018 financial statements. This methodology allows us to retrospectively define the status of firms, knowing their performance in the following two years.

Table 2 presents descriptive statistics of applying the two-step procedure to the variables that define the categorization of firms between healthy and financially distressed.

3.2. *Method and hypotheses*

Although the methodology of discriminant analysis gained popularity with Altman (1968), it was from the 1980s onwards that logistic re-

[2] Although there were 399 growing grapes French firms, there were only two firms in olive cultivation. In Greece, only four growing grapes firms were available.

[3] To calculate this last variable and consider the lack of uniformity between the accounting standards, we adopted the formula of extracting extraordinary items (revenue and expenses) from net income.

Table 1 - Distribution of financial statements.

	Vineyards			*Olive Groves*			*Totals*		
	H	FD	% FD	H	FD	% FD	H	FD	% FD
Portugal	738	117	13.7%	351	51	12.7%	1089	168	13.4%
Spain	426	87	17.0%	471	83	15.0%	897	170	15.9%
Italy	1456	399	21.5%	643	235	26.7%	2099	634	23.2%
Totals	2620	603	18.7%	1465	369	20.1%	4085	972	19.2%

Healthy (H), Financial Distressed (FD), (% FD) Proportion of distressed.
Source: Own elaboration.

Table 2 - Descriptive statistics of the firms categorization procedure.

		EBITDA interest coverage[a] 2019		*EBITDA interest coverage 2020*		*EBIT 2019*		*EBIT 2020*		*Net income before special items[b] 2019*		*Net income before special items 2020*	
		Mean	*Median*	*Mean*	*Median*	*Mean*	*Median*	*Mean*	*Median*	*Mean*	*Median*	*Mean*	*Median*
Italy													
Vineyards	FD	-141.92	-60.52	-144.30	-52.19	-216.33	-97.97	-259.77	-95.47	-232.76	-101.58	-263.18	-99.96
	H	260.08	31.70	226.62	21.74	130.41	14.30	92.02	8.06	82.91	3.34	62.69	1.63
Olive grows	FD	-52.73	-16.29	-55.14	-15.86	-82.54	-27.03	-88.73	-27.20	-86.59	-28.66	-89.93	-29.60
	H	31.97	4.41	28.65	3.54	-3.21	1.83	9.40	2.67	10.61	0.45	7.18	0.66
Portugal													
Vineyards	FD	-72.19	-19.13	-70.23	-20.89	-86.52	-27.78	-89.81	-30.40	-104.21	-31.50	-107.81	-31.56
	H	94.85	22.93	81.86	17.97	55.07	9.29	38.15	4.93	35.84	5.74	23.09	2.95
Olive grows	FD	-121.49	-51.84	-177.84	-39.05	-149.69	-102.96	-225.64	-62.55	-177.67	-111.17	-271.99	-64.29
	H	119.01	29.78	114.26	30.63	65.64	12.64	67.43	10.98	23.47	8.54	47.32	7.93
Spain													
Vineyards	FD	-61.54	-28.22	-57.07	-28.99	-94.27	-38.54	-87.15	-43.20	-80.69	-37.36	-74.12	-34.00
	H	125.57	29.35	129.40	19.20	82.78	14.71	86.99	6.91	68.92	8.51	65.37	3.70
Olive grows	FD	-71.36	-28.37	-73.77	-20.01	-85.83	-45.76	-88.40	-34.22	-74.47	-36.71	-79.13	-31.40
	H	88.46	29.52	61.67	20.51	59.51	15.77	31.93	10.68	38.85	9.62	59.20	5.84

Healthy (H), Financial Distressed (FD). Source: Own elaboration.
[a]EBITDA interest coverage = EBITDA - Financial expenses. [b]Net income before special items = Net income + Extraordinary and other expenses - Extraordinary and other revenue.

gression came to be preferred by researchers and is even used in the overwhelming majority of bank scorecards (Nyitrai and Virág, 2019). Ohlson (1980) was at the origin of this popularity with his seminal work in the literature on credit risk. In this study, given the characteristics of the sample, namely the disproportion between healthy firms and firms in financial distress, we use binary logistic regression. In logistic regression or a probit model, the model's predictive capacity also depends on definining a cutoff to separate healthy firms from the rest. There is no single way to determine the optimal cutoff. Ohlson (1980) states that previous prediction studies have two assumptions present. First is the presentation of a (mis)classification matrix. Second, an additive property in which the best cutoff point is the one that minimizes the sum of type I (classify a distressed firm as healthy) and type II (classify a healthy firm as distressed) percentage errors. However, it must be considered that comparing models in different periods, predictors, and data sets is exceptionally difficult. Also, the costs are not equal. The cost of classifying a distressed firm as healthy implies losing the return on investment, and the cost of classifying a healthy firm as distressed means losing the investment opportunity (Agarwal and Taffler, 2008). Other authors have tried other approaches. Hsieh (1993) defines type I error as the opportunity cost of holding a long position in equity securities of failing firms. In turn, the type II error is defined as the opportunity cost of selling short securities of healthy firms. Aware of this importance Dopuch *et al.* (1987) and Koh (1992), studied the misclassification costs of type I and type II Errors through proportions from 1:1 to 20:1 and 1:1 to 500:1, respectively. The analysis of type I and type II Errors is very present in the literature. It is indispensable in this kind of research, having the great advantage of being easy to interpret, even for those who do not have a high level of mathematics and statistics education (Čámská *et al.*, 2016). In short, the accuracy of a model goes far beyond the simple calculation of the correct percentage of observation classifications. Moreover, minimizing total error probabilities is different from minimizing total error costs. In this subjectivity, other powerful tools were adopted, such as the ROC curve representing the universe of possible events (Hanley and McNeil, 1982). In World War II, the ROC curve was first used to detect enemy objects on the battlefield. From then on, its expansion into other areas of knowledge was rapid, being widely recognized for its advantages, namely in biosciences, atmospheric forecasting or finance. The analyzes obtained through the ROC curve are considered powerful tools for validating the discriminatory power of a predictive model (Basel Committee on Banking Supervision, 2005). ROC Curve results from how the scores obtained from the prediction model are distributed between firms considered healthy and in financial distress. A perfect model would not confuse the scores between both financial health categories, but in the real world, there is an overlapping zone in which both coexist. Hence, a broad debate exists about the best cutoff point to consider in a financial distress prediction model.

This methodology, represented as a curve, is represented by an antagonistic relationship between sensitivity (the proportion of correctly classified non-failures) and specificity (the proportion of correctly classified failures) along a continuous scale of cutoff points. In other words, the area under the curve (AUC) summarizes curve performance across all thresholds, and a cutoff point is a defined criterion to separate failed from healthy firms. The greater the AUC, where x corresponds to (1-specificity) and y the sensitivity, the greater the discriminating power of the model. The ROC curve conveys the conjugation of the type I and type II error curves along an axis. In practice, AUC is a measure of prediction accuracy, where 1 will represent a perfect model. On the contrary, an AUC equal to 0.5 will demonstrate the total ineffectiveness of the model in predicting an occurrence (Altman *et al.*, 2010; Hanley and McNeil, 1982). Thus, a larger AUC indicates better predictability of the model.

The ROC curve is widespread in medical diagnosis, where there are demanding precision scales. For example, are expected AUCs between 0.80 and 0.90 for chest x-ray films and 0.80 to 0.90 for mammography. In weather forecasting, are accepted values from 0.75 for rain forecast and 0.65 for temperature intervals or fog (Swets, 1988). In one of the unavoidable references in the literature, Lemeshow *et al.* (2013) does not mention an optimal scale to describe the quality of discrimination, but in general, is used the following rule: (i) no discrimination if AUC is equal to 0.5, (ii) poor, if between 0.5 and 0.7, (iii) acceptable, if between 0.7 and 0.8, (iv) excellent, if between 0.8 and 0.9, and (v) outstanding if it is above 0.9. About financial distress prediction models in agriculture, Klepac and Hampel (2017) mentions 4 classifications: (i) eligible if AUC is between 0.50 and 0.75, (ii) good if between 0.75 and 0.92, (iii) very good if between 0.92 and 0.97, and (iv) perfect if it is above 0.97. Valaskova *et al*. (2020) defines five levels of accuracy: (i) inappropriate for bankruptcy prediction if below 0.6, (ii) poor if between 0.6 and 0.7, (iii) fair if between 0.7 and 0.8, (iv) good if between 0.8 and 0.9, and (v) excellent if above 0.9.

This study analyzes the accuracy of the presented models by examining the areas under the ROC curves and, specifically, the differences between them. Through the interaction between the different subsamples and trying out various combinations, we tested the following null hypotheses:

- Interaction between the *Global Model*[4] and the *Aggregate Models*[5]:
  H_1: Between the Global and Vineyards Models, there are no differences in the AUCs.
  H_2: Between the Global and Olive Groves Models, there are no differences in the AUCs.
  H_3: Between the Global and Portugal Models, there are no differences in the AUCs.
  H_4: Between the Global and Spain Models, there are no differences in the AUCs.
  H_5: Between the Global and Italy Models, there are no differences in the AUCs.
- Interaction between Crop Aggregates:
  H_6: Between the Vineyards and Olive Groves Models, there are no differences in the AUCs.
- Interaction between Country Aggregates:
  H_7: Between the Portugal and Spain Models, there are no differences in the AUCs.
  H_8: Between the Portugal and Italy Models, there are no differences in the AUCs.
  H_9: Between the Spain and Italy Models, there are no differences in the AUCs.
- Combined Interaction of *Individual Models*[6]:
  H_{10}: Between the Portugal Vineyards and Portugal Olive Groves Models, there are no differences in the AUCs.
  H_{11}: Between the Spain Vineyards and Spain Olive Groves Model, there are no differences in the AUCs.
  H_{12}: Between the Italy Vineyards and Italy Olive Groves Models, there are no differences in the AUCs.
  H_{13}: Between the Portugal Vineyards and Spain Vineyards Models, there are no differences in the AUCs.
  H_{14}: Between the Portugal Vineyards and Italy Vineyards Models, there are no differences in the AUCs.
  H_{15}: Between the Spain Vineyards and Italy Vineyards Models, there are no differences in the AUCs.
  H_{16}: Between the Portugal Olive Groves and Spain Olive Groves Models, there are no differences in the AUCs.
  H_{17}: Between the Portugal Olive Groves and Italy Olive Groves Models, there are no differences in the AUCs.
  H_{18}: Between the Spain Olive Groves and Italy Olive Groves Models, there are no differences in the AUCs.

3.3. *Independent variables*

Table 3 contains 12 financial ratios to be tested as potential independent variables in the model according to those most commonly present in bankruptcy and financial distress prediction studies. For this study, we combine four categories of ratios. It is in this structure that they are presented throughout this paper: (i) liquidity ratios that measure the ability of firms to honour their short-term commitments, (ii) solvency ratios /leverage that is associated with the ability to level of indebtedness and the ability to meet its payment obligations, including long-term ones, and continue to operate in the future, (iii) profitability ratios determine the ability to generate income through efficient management of resources and (iv) activity/other ratios that measure the structure of fixed assets and the operational activity of agricultural firms.

We chose to exclude financial ratios that presented inconsistent values with the expected sign in this list by logical intuition. For example, the profitability ratio that measures the relationship between earnings and equity (return on equity) could simultaneously contain negative signals in the numerator and denominator. That would result in a positive and erroneously good ratio, and we found 418 firms in this condition on our preliminary data. Also, the solvency ratio, which measures the relationship between total liabilities and equity (debt-to-equity), could be affected by negative equity found in 489 firms in our data. The result would be contrary to the perception that this ratio will worsen the greater the relationship between the numerator and denominator.

[4] The total sample, all types of crops and countries.
[5] Subsamples by type of crop, or by country.
[6] Individual interaction between crops and countries.

Table 3 - Initial set of financial ratios.

	Ratios	*Description*	*Observations*
Liquidity	CCL	Cash and equivalents / Current liabilities	Cash Ratio
	WCTA	Working capital / Total assets	
	CATA	Current assets / Total assets	
	CR	Current assets / Current liabilities	Current Ratio
Solvency/ Leverage	RETA	Retained earnings / Total assets	
	EQTA	Equity / Total assets	Shareholder Equity Ratio
	TLTA	Total liabilities / Total assets	Debt-to-Assets Ratio
Profitability	EBITTA	EBIT / Total assets	
	CFTA	(Net income + Deprec + Amortiz) / Total Assets	
	ROA	Net income / Total assets	Return on Assets
Activity/Others	STA	Sales / Total assets	Total Asset Turnover
	FATA	Fixed assets / Total assets	

Source: Own elaboration.

3.4. *Model development*

This study presents 12 models divided into two groups. The first group of six is based on aggregated data, considering all data as a whole or aggregating them according to crops or countries. The second group of six subdivides the data by countries and crops. The data considered in estimating these models are from 2018 because 2019 and 2020 only classify firms according to their financial health.

We performed a binary logistic regression, a statistical method in which several assumptions must be observed. The first is that the dependent variable is measured on a dichotomous scale. The probability of a given observation falling into one of two possible categories is predicted, healthy firm or distressed firm. The second assumption is the existence of several independent variables. The third assumption is the independence of observations, thus being mutually exclusive and exhaustive categories. Finally, the fourth assumption is that there must be a linear relationship between any continuous independent variables and the logit transformation of the dependent variable. We performed the Box-Tidwell transformation in SPSS for this last assumption, which confirmed that this assumption is not violated. The logistic model is given by:

$$Pi = \frac{1}{1 + e^{-(\beta 0 + \beta 1\, Xi1 + \beta 2\, Xi2 + \ldots + \beta n Xin)}} \quad (1)$$

where, P_i = probability of financial distress, X_{ij} = j^{th} variable of the i^{th} firm, and β_j = estimated coefficient for the j^{th} variable.

3.5. *Models accuracy*

This article presents several forecasting models and analyses their explanatory power. We use the confusion matrix (Table 4) to analyse type I and II errors and the area under the ROC curve (AUC) for analyzing the occurrence of misclassifications. This matrix shows the number or percentages of false positives (FP, type I error), false negatives (FN, type II error), true positives (TP, sensitivity) and true negatives (TN, specificity). Let us assume that the *negatives* are the healthy firms and the *positives* are financially distressed firms:

The accuracy of the classification process is based on the relationship between sensitivity and specificity, according to the following equations:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (2)$$

$$Sensitivity = \frac{TP}{TP + FN} \quad (3)$$

$$Specificity = \frac{TN}{TN + FP} \quad (4)$$

where, TP = true positive, TN = true negative, FP = false positive, and FN = false negative.

Table 4 - Confusion matrix.

		Predicted	
		Healthy	*Financial Distressed*
Observed	*Healthy*	True negative	False positive
	Financial Distressed	False negative	True positive

Source: Own elaboration.

The AUC equation is given by:

$$AUC = \int_0^1 TPR\left(FPR^{-1}(\theta)\right)d\theta \qquad (5)$$

where, *TPR* represents the true positive rate, *FPR* = false positive rate = (1 − *Specificity*), $FPR^{-1}(\theta)$ represents the classification threshold value that corresponds to a given θ, and θ varies from 0 to 1, representing the proportion of positive samples that are correctly classified out of the total positive samples.

100(1- α)% confidence interval can be calculated using the standard normal distribution, that is:

$$AUC \pm \mathcal{Z}_{\alpha/2} SE(AUC) \qquad (6)$$

According Hanley and McNeil (1982), the standard error of the area under the curve is given by:

$$SE(AUC) = \sqrt{\frac{AUC(1-AUC)+(n_{FD}-1)(Q1-AUC^2)+(n_H-1)(Q2-AUC^2)}{n_{FD}.n_H}} \qquad (7)$$

where, *AUC* = area under the ROC curve, n_{FD} = number of financial distressed firms, n_H = number of healthy firms, *Q*1 = AUC/(2-AUC), and Q2 = $2AUC^2/(1+AUC)$.

The test statistic is given as follows:

$$\mathcal{Z} = \frac{AUC}{SE(AUC)} \qquad (8)$$

Although there is no criterion to determine the optimal cutoff for several reasons (misclassification costs, efficiency, etc.), the Youden Index (*J*) provides a criterion to determine an optimal threshold value (Fluss *et al.*, 2005), which it is maximized the equation:

$$J = Max_c(Sensitivity_c + Specificity_c - 1) \qquad (9)$$

where *c* = optimal cutoff.

In this study, for simplicity, we assume that sensitivity and specificity are equally important or desirable.

We use the same method as Hanley *et al.* (1983) to assess the differences between the AUC of the different models. This method performs a two-sided test for differences between AUCs that analyzes the proportion of positive and negative cases and the respective AUC of each model. The test returns a *p*-value determining the significance of the difference between the two curves. The statistical test is as follows:

$$\mathcal{Z} = \frac{AUC_1 - AUC_2}{\sqrt{(SE(AUC_1))^2 + (SE(AUC_2))^2 - 2.r.SE(AUC_1).SE(AUC_2)}} \qquad (10)$$

where, z = standard normal variate and r = correlation between AUCs.

4. Results and discussion

4.1. *Statistical results*

To understand how variables are revealed when forming different subsamples depending on the financial health of firms and across countries, we present the respective descriptive statistics in supplementary materials (Table S1 and Table S2). The median is the correct measure of central tendency, considering that outliers were not excluded and the sample is not uniformly distributed. As expected, and for the generality of the results, the medians are better in healthy firms, regardless of type of the crops. There are, however, some exceptions that deserve to be highlighted when the analysis considers countries. In Portugal and Italy, all ratios are consistent depending on whether firms are healthy or in financial distress. However, in Spain, CR, EQTA, and TLTA ratios present better results in Spanish financial distress firms than in healthy firms. In Portugal and Italy, all ratios are consistent depending on whether firms are healthy or in financial distress.

Confirming previous studies on the violation of the assumption of normality in the distribution of financial ratios (Deakin, 1976; Frecka and Hopwood, 1983), we performed a standard Kolmogorov-Smirnov Test, where, unsurpris-

Table 5 - Panel A: Aggregate models.

		Global Model	*Crops Models*		*Countries Models*		
			Vineyards	*Olive G.*	*Portugal*	*Spain*	*Italy*
	Constant	-1.055	-0.862	-1.085	-1.309	-1.338	-0.707
	p-Value	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
I	CCL						
	p-Value						
	WCTA						
	p-Value						
	CATA	-0.772	-0.654	-0.796			-0.985
	p-Value	(0.001)	(0.001)	(0.001)			(0.001)
	CR						
	p-Value						
II	RETA					-0.680	
	p-Value					(0.001)	
	EQTA						
	p-Value						
	TLTA	0.159			0.453		
	p-Value	(0.010)			(0.001)		
III	EBITTA	-1.352	-1.658	-1.356		-2.277	-1.587
	p-Value	(0.001)	(0.001)	(0.001)		(0.001)	(0.001)
	CFTA						
	p-Value						
	ROA						
	p-Value						
IV	STA	-1.022	-1.646	-0.321	-2.014	-0.667	-0.980
	p-Value	(0.001)	(0.001)	(0.068)	(0.001)	(0.014)	(0.001)
	FATA						
	p-Value						
	χ^2 Model	274.614	225.754	62.495	69.785	53.647	188.385
	Model *p*-Value	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Nagelkerke R^2	0.085	0.109	0.053	0.099	0.084	0.101
	-2 log Likelihood	4,675.28	2,881.09	1,779.06	918.90	882.22	2,772.31
	N	5,057	3,223	1,834	1,257	1,067	2,733

I (Liquidity), II (Solvency/Leverage), III (Profitability), IV (Activity/Others).
Source: Own elaboration.

ingly, we found that none of the financial ratios presents a normal distribution (Table S3 in supplementary materials).

A Spearman correlation matrix is performed to observe the correlations between covariates (Table S4 in supplementary materials). Considering that we are using a non-uniformly distributed distribution, it is preferable to the Pearson correlation matrix (Bol *et al.*, 2012). The Spearman correlation coefficient uses the order values of the observations. Thus, this coefficient is not sensitive to distribution asymmetries nor the presence of outliers, not requiring that the data come from two normal populations. Given the typology of each ratio, it is intended to select one or at most two ratios in each category. The se-

Table 6 - Panel B: Individual models.

		Vineyards			*Olive Groves*		
		Portugal	*Spain*	*Italy*	*Portugal*	*Spain*	*Italy*
	Constant	-1.695	-1.069	-0.712	-1.496	-1.638	-0.674
	p-Value	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
I	CCL						
	p-Value						
	WCTA						
	p-Value						
	CATA			-0.659			-1.159
	p-Value			(0.008)			(0.001)
	CR						
II	*p*-Value						
	RETA					-0.741	
	p-Value					(0.001)	
	EQTA						
	p-Value						
	TLTA	0.401					
	p-Value	(0.001)					
III	EBITTA			-2.579		-1.457	-0.927
	p-Value			(0.001)		(0.056)	(0.002)
	CFTA		-6.365		-2.565		
	p-Value		(0.001)		(0.023)		
	ROA						
	p-Value						
IV	STA	-1.747	-0.802	-2.240	-3.036		
	p-Value	(0.001)	(0.029)	(0.001)	(0.009)		
	FATA						
	p-Value						
	χ^2 Model	40.732	45.561	191.285	33.915	20.049	31.909
	Model *p*-Value	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Nagelkerke R^2	0.085	0.142	0.151	0.152	0.062	0.052
	-2 log Likelihood	641.88	421.51	1,720.25	271.91	447.97	988.17
	N	855	513	1,855	402	554	878

I (Liquidity), II (Solvency/Leverage), III (Profitability), IV (Activity/Others).
Source: Own elaboration.

lection of ratios to be included in the final model goes through several combinations between variables from different categories to potentially reduce multicollinearity. In the discrimination between healthy and distressed firms, the numerical comparison is expected to be consistent with previous studies.

Performing a Mann-Whitney U-Test (Table S5 in supplementary materials), it is possible to verify that the differences in the financial ratios of healthy firms for those in financial distress are only sometimes consistent across crops or countries. Some ratios only express such differences in one of the crops (example of CCL in vineyards), and others that depend on the country (example of FATA in Olive Groves in Italy).

Table 7 - Prediction accuracy of models.

Model	*AUC*	*Cutoff*	*Confusion Matrix Parameters*				
			Accuracy	*Sensitivity*	*Specificity*	*Type I Error*	*Type II Error*
Global	0.724	0.2405	73.2%	59.3%	76.6%	40.7%	23.4%
Vineyards	0.752	0.2354	71.8%	66.3%	73.1%	33.7%	26.9%
Olive Groves	0.695	0.2397	73.8%	53.9%	78.8%	46.1%	21.2%
Portugal	0.706	0.1778	80.0%	50.6%	84.5%	49.4%	15.5%
Spain	0.694	0.2034	80.4%	49.4%	86.3%	50.6%	13.7%
Italy	0.739	0.2775	69.7%	67.5%	70.4%	32.5%	29.6%
Portugal Vineyards	0.696	0.1838	83.0%	46.2%	88.9%	53.8%	11.1%
Spain Vineyards	0.760	0.2341	80.7%	59.8%	85.0%	40.2%	15.0%
Italy Vineyards	0.788	0.2478	68.0%	79.7%	64.9%	20.3%	35.1%
Portugal Olives	0.762	0.1383	63.7%	78.4%	61.5%	21.6%	38.5%
Spain Olives	0.698	0.1627	78.2%	57.8%	81.7%	42.2%	18.3%
Italy Olives	0.669	0.3125	67.2%	58.7%	70.3%	41.3%	29.7%

AUC - Area under ROC curve.
Source: Own elaboration.

Table 8 - Comparison of differences between areas under ROC Curve.

	Difference between AUCs	*Std. error*	*z*	*p-value*
H1 Global Model ~ Vineyards	0.028	0.0156	1.793	0.0730
H2 Global Model ~ Olive Groves	0.029	0.0191	1.515	0.1298
H3 Global Model ~ Portugal	0.018	0.0255	0.705	0.4808
H4 Global Model ~ Spain	0.030	0.0258	1.164	0.2446
H5 Global Model ~ Italy	0.015	0.0157	0.958	0.3382
H6 Vineyards ~ Olives	0.058	0.0196	2.930	0.0034***
H7 Portugal ~ Spain	0.012	0.0333	0.359	0.7194
H8 Portugal ~ Italy	0.033	0.0257	1.262	0.2068
H9 Spain ~ Italy	0.045	0.0266	1.673	0.0942
H10 Portugal Vineyards ~ Portugal Olives	0.065	0.0455	1.429	0.1530
H11 Spain Vineyards ~ Spain Olives	0.062	0.0454	1.369	0.1711
H12 Italy Vineyards ~ Italy Olives	0.119	0.0246	4.838	0.0001***
H13 Portugal Vineyards ~ Spain Vineyards	0.064	0.0423	1.502	0.1330
H14 Portugal Vineyards ~ Italy Vineyards	0.092	0.0316	2.905	0.0037***
H15 Spain Vineyards ~ Italy Vineyards	0.028	0.0335	0.845	0.3979
H16 Portugal Olives ~ Spain Olives	0.064	0.0485	1.315	0.1886
H17 Portugal Olives ~ Italy Olives	0.092	0.0410	2.254	0.0242**
H18 Spain Olives ~ Italy Olives	0.029	0.0394	0.728	0.4663

*AUCs - Areas under ROC curve. ***. **. * represent .01. .05. and .10 significance levels, respectively.*
Source: Own elaboration.

For countries, and since there are three independent groups, we performed a Kruskal-Wallis Test (Table S6 in supplementary materials), which also dispenses the assumption of normality. We tested whether at least one sample comes from the same population. The null hypothesis was rejected for all financial ratios, which presupposes that there will be significant differences in the distribution of variables by country level.

The estimation of the logit model is summarised in Table 5 and Table 6. Excepted for STA in the Olive Groves aggregate model and EBITTA in the Spain Olive Groves individual model, all covariates were estimated with a *p*-value<0.05. However, with the *p*-value on the significance threshold, we chose to include them in the models as they improve the respective R^2. All estimated models present a Chi-Square goodness of fit test with an associated probability below 0.01 indicating that the current models outperform the intercept models. That is, it is concluded that the independent variables significantly influence the estimated models.

The accuracy and AUC are summarized in Table 7, which expresses the confusion matrix results.

The optimal cutoff point in these models was determined using Youden's index.

Table 8 and Figure 2 present the test results comparing the areas under the Roc curve of the different models. The main result of the differences in the areas under the curve between aggregated models is that only the Vineyards model shows differences with the Olive Groves model. Neither the global model compared with the crop or country models nor the countries themselves showed statistically significant differences. The Vineyards Model is more accurate (AUC of 0.752 against 0.695), despite the covariates chosen to be the same as the Olive Groves Model (CATA, EBITTA and STA).

Analysis of the individual models' differences results in the finding that the models sometimes present pretty significant differences. This is the case of comparing the models in Italy about Vineyards and Olive Groves. The statistical test has a *p*–value of less than 0.0001, the most robust rejection of the null hypothesis. In Italy, the Vineyards Model has an AUC of 0.788, which is even the best AUC of all 12 models. In turn, the Olive Groves Model from Italy has the lowest AUC of all models. In this model, the STA covariate is not included due to a lack of statistical significance, being a model with only two covariates in addition to the constant. Between different countries but with the same crops, there are also differences to be noted. The null hypothesis is also rejected in the Vineyards case between Portugal and Italy. The Italy model has the best accuracy (AUC of 0.788 against 0.696). Although both models contain the variable STA, Portugal only has two covariates, while Italy also has CATA. In the case of Olives Groves, the null hypothesis of differences between Portugal and Italy is also rejected. However, in this case, the opposite situation is registered, with Portugal registering an AUC of 0.762 while Italy is only 0.669. Interestingly, there is no covariate common to both models, highlighting that the Portuguese model uses a variable from the profitability category (CFTA) and another from the category of Activity (STA). In the case of Italy, a covariate of the liquidity category and another of profitability (EBITTA) is used.

4.2. *Discussion*

If, until now, studies dedicated to predicting bankruptcy or financial distress in agriculture generally considered agriculture as a whole, this study demonstrates that there are specificities that are not indifferent to the estimation of the models.

Although the dependent variable that determines the firm's state (healthy or distressed) is not based on variables that measure firms' activity, the STA ratio is a covariate in almost all the models presented. Only in the individual models of Spain and Italy referring to Olives Groves was this variable not shown to be statistically significant.

However, the models show a lower Nagelkerke R^2 compared to other studies. We must also consider that we did not remove outliers and limited the study to the most popular financial covariates in credit risk models. Thus, it is possible to improve the accuracy of the models by including qualitative and categorical variables. The AUCs, not stunning, can be considered eligible and suitable according to other researchers' ratings, so the models are far from useless.

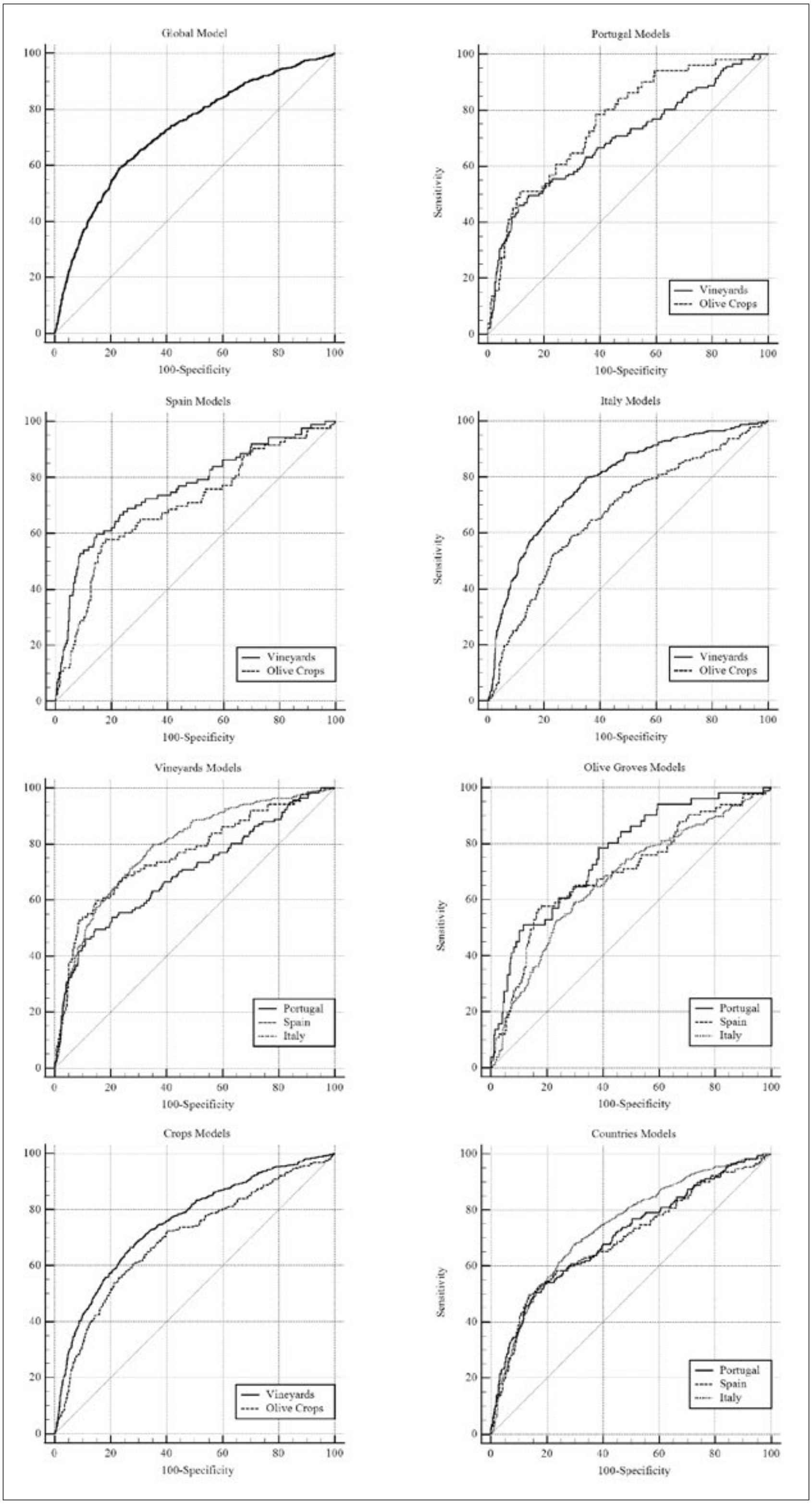


Figure 2 - Comparison of ROC curves.

Source: Own elaboration

Financial costs by an imperfect estimation of the model, namely the cost of classifying a distressed financial firm as healthy, being higher than the inverse, are the backbone of the discussion in this paper. Therefore, and since it is possible to determine a specific cutoff to separate the two categories, it is essential to have a model that, for all possible thresholds, is as accurate as possible. Therefore, the area under curves obtained from the ROC Curve is of essential importance. Moreover, in the case of agricultural activity, in which different cutoffs may be associated depending on the country or crop, it is essential to have a model that presents the best accuracy along with the possible cutoffs.

The best accuracy of the model is only sometimes consistent with the highest AUC. Aggregate models of Portugal and Spain in which the accuracy based on the confusion matrix is among the highest of the aggregate models, but which, ambiguously, have the lowest AUCs. On the contrary, the Italian model has a low accuracy compared to the other aggregate models but has the highest AUC of the country models.

In individual models, we have similar cases. The Italy Vineyards model has the lowest confusion matrix accuracy but has the highest AUC of all the individual models. On the contrary, the Portugal Vineyards model has the highest accuracy of the individual models but the lowest AUC.

In an undetermined optimal cutoff context, the AUC should be a preferable measure. However, when it is possible to determine an optimal cutoff, accuracy has the advantage of minimizing the sum of false positives and false negatives.

In comparing the accuracy of the models, we have identified statistically significant differences in the areas under the ROC curve (AUCs) for the following hypotheses, leading to the rejection of the null hypotheses:

- H_6: The comparison between Vineyards and Olives models showed a statistically significant difference in AUCs.
- H_{12}: The comparison between Italy Vineyards and Italy Olives models exhibited a highly significant difference in AUCs.
- H_{14}: The comparison between Portugal Vineyards and Italy Vineyards models demonstrated a significant difference in AUCs.
- H_{17}: The comparison between Portugal Olives and Spain Olives models resulted in a rejected hypothesis due to a significant difference in AUCs.

It is exciting that in the aggregate models, only between the aggregate model of Vineyards (0.752) against that of Olives groves (0.695), the differences are significant. All other aggregate models show no differences in accuracy. In the individual models, however, there are differences in some models, not only within the same country about crops (Italy) but also between different countries, although with the same crops. There are differences between Portugal and Italy in the AUCs, whether in the Vineyards or the Olive Groves. These results suggest creating specific models if the agriculture practised differs at the level of crops or countries.

5. Conclusion

This study is based on the estimation of forecasting models of financial difficulties in vineyards and olive groves in Portugal, Spain and Italy, Mediterranean countries with similar characteristics and agronomic practices. For this purpose, we analyzed popular financial covariates commonly used in financial distress analysis. Our variables are related to liquidity, solvency, profitability and activity of agricultural firms and are commonly used in credit risk models.

ROC curves and the corresponding areas under the curves (AUCs) allow us to conclude that, depending on the subsamples, significant differences suggest that credit risk in agriculture depends on the specifics of the agricultural activity itself. When comparing the differences in the areas under the ROC curve, we find significant variations between firms that cultivate olive groves and those that cultivate vineyards. The vineyards model is more predictive of financial distress, while the olive groves model is less accurate. However, no significant differences are observed among the various combinations of model comparisons across countries. The models that aggregate firms by country, namely Portugal, Spain, and Italy, show no significant variations. In Italy, the vineyards and olive groves models exhibit statistical differences. At the country and crop level, the difference in AUCs of firms that explore vineyards between Portugal and Italy is noticeable. This suggests that specific prediction models should be adopted in this country depending on the categorization of agricultural firms. The results also show significant differences between Spain and Italy in the case of olive groves.

This study highlights the importance of adopting region-specific predictive models for assessing credit risk in agriculture. Policymakers in Portugal, Spain, and Italy should consider the distinct characteristics of vineyards and olive groves cultivation when designing agricultural policies and financial support programs. Tailoring policies to specific crops can lead to more targeted and effective interventions to address financial distress and promote sustainable agricultural development. The distinct challenges faced by Mediterranean countries, together with the impact of climate change and agricultural trade liberalization, highlight the need for targeted interventions to address financial difficulties and improve the financial performance of rural economies in the South relative to Northern Europe. There is still to consider the likely impacts of applying the new PAC 2023-2027 and its improved sustainability measures based on environmental and climate objectives through ecological schemes. These plans, based on significant budgets, if they consider the different characteristics of agricultural firms in different countries and crops, will certainly mitigate the factors related to financial distress. Farmers and business leaders in the agricultural sector can benefit from the insights provided by the study. Understanding the differences in credit risk prediction between vineyards and olive groves cultivation can help them make more informed financial decisions and risk management strategies. Farmers need to recognise the specific factors influencing their financial health and take appropriate actions to enhance their financial sustain- ability. For the scientific community, this study highlights the importance of considering the specific characteristics of agricultural activities when developing credit risk models for the agriculture sector. This finding could prompt further research into refining and enhancing predictive models for different agricultural activities.

There are limitations to consider when interpreting the results. The first limitation is the very definition of financial distress, which determines the dependent variable of logistic regression. While bankruptcy determines the end of the firm's activity, the severity of financial distress may not put the firm in real danger. Another limitation is that there needed to be an exhaustive exploration of predictor covariates. The study focuses on the dynamics of models between different countries and crops, having selected a few potential model-independent variables. If we had access to a combination of financial variables with others that are more qualitative and even specific to agricultural activity, the predictive power of the models could be better. Also, although this study is based on a large set of data, the business structure of agriculture in these countries is complex and leaves out all farmers who are not legally constituted as a firm. This is the case of individual entrepreneurs representing a broad spectrum of family farms and other small-scale agriculture.

Future research may introduce covariates linked to the rural world, especially those specific to different crops.

References

Agarwal V., Taffler R., 2008. Comparing the performance of market-based and accounting-based bankruptcy prediction models. *Journal of Banking & Finance*, 32(8): 1541-1551.

Altman E., 1968. Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *The Journal of Finance*, 23(4): 589-609.

Altman E.I., Hotchkiss E., Wang W., 2019. *Corporate Financial Distress, Restructuring, and Bankruptcy (Analyze Leveraged Finance, Distressed Debt, and Bankruptcy)*, 4th ed. New York: John Wiley & Sons.

Altman E.I., Sabato G., Wilson N., 2010. The value of non-financial information in small and medium-sized enterprise risk management. *Journal of Credit Risk*, 6(2): 95-127.

Arnalte-Alegre E., Ortiz-Miranda D., 2013. The 'southern model' of European agriculture revisited: Continuities and dynamics. In: *Agriculture in Mediterranean Europe: Between old and new paradigms*. Bingley: Emerald Group Publishing.

Asquith P., Gertner R., Scharfstein D., 1994. Anatomy of financial distress: An examination of junk-bond issuers. *The Quarterly Journal of Economics*, 109(3): 625-658.

Basel Committee on Banking Supervision (2005). *Studies on the validation of internal rating systems*. Working Paper no. 14. Basel: Bank for International Settlements. https://www.bis.org/publ/bcbs_wp14.pdf (accessed on 12 October 2022).

Beaver W.H., 1966. Financial ratios as predictors of failure. *Journal of Accounting Research*, 4(71): 71-111.

Beopoulos N., 2017. Mediterranean agriculture in the light and shadow of the cap. In: Stathakis G., Kasimis C. (eds.), *The reform of the CAP and rural development in Southern Europe*. London: Routledge, pp. 39-51.

Bol G., Nakhaeizadeh G., Rachev S.T., Ridder T., Vollmer K.H., 2012. *Credit risk: measurement, evaluation and management*. Heidelberg: Springer Science & Business Media.

Čámská D. *et al*., 2016. Accuracy of models predicting corporate bankruptcy in a selected industry branch. *Ekonomický časopis*, 64(4): 353-366.

Caraveli H., 2000. A comparative analysis on intensification and extensification in mediterranean agriculture: dilemmas for LFAs policy. *Journal of Rural Studies*, 16(2): 231-242.

Chan M. L., Rotenberg W.D., 1988. Financial distress in the Canadian agricultural sector: A macro analysis. *Canadian Journal of Agricultural Economics/ Revue canadienne d'agroeconomie*, 36(3): 531-538.

Correia L., Behmiri N.B., Gouveia S., 2019. Drivers of wine production in the European Union: A macroeconomic perspective. *New Medit*, 18(3): 85-96.

Deakin E.B., 1976. Distributions of financial accounting ratios: some empirical evidence. *The Accounting Review*, 51(1): 90-96.

Dopuch N., Holthausen R.W., Leftwich R.W., 1987. Predicting audit qualifications with financial and market variables. *Accounting Review*, 62(3): 431-454.

FAO, 2022. *Crops and livestock products*. https://www.fao.org/faostat/en/#data/QCL (accessed on 11 February 2022).

Fitzpatrick P.J., 1934. Transitional stages of a business failure. *Accounting Review*, 9(4): 337-340.

Fluss R., Faraggi D., Reiser B., 2005. Estimation of the youden index and its associated cutoff point. *Biometrical Journal*, 47(4): 458-472.

Fraga H., Pinto J.G., Santos J.A., 2019. Climate change projections for chilling and heat forcing conditions in European vineyards and olive orchards: A multi-model assessment. *Climatic Change*, 152(1): 179-193.

Frecka T.J., Hopwood W.S., 1983. The effects of outliers on the cross-sectional distributional properties of financial ratios. *Accounting Review*, 1(58): 115-128.

Giannakis E., Bruggeman A., 2015. The highly variable economic performance of European agriculture. *Land Use Policy*, 45: 26-35.

Hanley J.A., McNeil B.J., 1982. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*, 143(1): 29-36.

Hanley J.A., McNeil B.J. *et al*., 1983. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology*, 148(3): 839-843.

Hotchkiss E.S., John K., Mooradian R.M., Thorburn K.S., 2008. Bankruptcy and the resolution of financial distress. In: Eckbo B.E. (ed.), *Handbook of corporate finance*, vol. 2. Amsterdam: North-Holland, pp. 235-287.

Hsieh S.-J., 1993. A note on the optimal cutoff point in bankruptcy prediction models. *Journal of Business Finance & Accounting*, 20 (3): 457-464.

Karas M., Reznakova M., Pokorny P., 2017. Predicting bankruptcy of agriculture companies: Validating selected models. *Polish Journal of Management Studies*, 15(1): 110-120.

Khoja L., Chipulu M., Jayasekera R., 2019. Analysis of financial distress cross countries: Us- ing macroeconomic, industrial indicators and accounting data. *International Review of Financial Analysis*, 66: 101379.

Klepac V., Hampel D., 2017. Predicting financial distress of agriculture companies in EU. *Agricultural Economics – Czech*, 63(8): 347-355.

Koh H.C., 1992. The sensitivity of optimal cutoff points to misclassification costs of type i and type ii errors in the going-concern prediction context. *Journal of Business Finance & Accounting*, 19(2): 187-197.

Lemeshow S., Sturdivant R.X., Hosmer Jr D.W., 2013. *Applied logistic regression*, 3rd ed. New York: John Wiley & Sons.

Loumou A., Giourga C., 2003. Olive groves: "the life and identity of the Mediterranean". *Agriculture and human values*, 20(1): 87-95.

Mokrani A., Ben Nasr J., Sai M.B., Bachta M.S., 2022. Sustainability assessment of Tunisian olive growing systems. *New Medit*, 21(4): 3-13.

Nyitrai T., Virág M., 2019. The effects of handling outliers on the performance of bankruptcy prediction models. *Socio-Economic Planning Sciences*, 67: 34-42.

Ohlson J.A., 1980. Financial ratios and the probabilistic prediction of bankruptcy. *Journal of Accounting Research*, 18(1): 109-131.

Platt H.D., Platt M.B., 2006. Understanding differences between financial distress and bankruptcy. *Review of Applied Economics*, 2(2): 141-157.

Platt H.D., Platt M.B., 2008. Financial distress comparison across three global regions. *Journal of Risk and Financial Management*, 1(1): 129-162.

Ruz-Carmona A., Rosa M.P., Colombo S., 2023. Quantification of production inefficiencies as a cost-savings tool for increasing the viability of traditional olive farms. *New Medit*, 22(2): 29-49.

Swets J.A., 1988. Measuring the accuracy of diagnostic systems. *Science*, 240(4857): 1285-1293.

Valaskova K., Durana P., Adamko P., Jaros J., 2020. Financial compass for Slovak enterprises: Modeling economic stability of agricultural entities. *Journal of Risk and Financial Management*, 13(5): 92.

Vavřina J., Hampel D., Janová J. *et al.*, 2013. New approaches for the financial distress classification in agribusiness. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 61(4): 1177-1182.

Whitaker R.B., 1999. The early stages of financial distress. *Journal of economics and finance*, 23(2): 123-132.

Wruck K.H., 1990. Financial distress, reorganization, and organizational efficiency. *Journal of financial economics*, 27(2): 419-444.

Appendices

Table S1 - Descriptive statistics of variables according to crops.

Type	*Ratio*	*Crops*	*Healthy Firms*						*Financial Distressed Firms*					
			N	*Mean*	*Median*	*Std. Dev.*	*Min.*	*Max.*	*N*	*Mean*	*Median*	*Std. Dev.*	*Min.*	*Max.*
I	CCL	V	2592	851.93	0.17	42728.5	-133.8	2175351	595	2.98	0.08	17.15	0.00	260.9
		OG	1438	5.33	0.25	41.2	0.00	975.4	367	6.28	0.19	48.34	0.00	749.9
	WCTA	V	2620	0.09	0.10	0.46	-9.94	1.37	603	-0.05	0.04	0.95	-18.3	1.00
		OG	1465	0.04	0.06	0.47	-5.36	1.00	369	-0.76	0.01	12.68	-243.3	0.97
	CATA	V	2620	0.45	0.40	0.29	0.00	1.00	603	0.33	0.21	0.29	0.00	1.00
		OG	1465	0.37	0.27	0.31	0.00	1.00	369	0.29	0.15	0.30	0.00	1.00
	CR	V	2592	1730.51	1.55	86133.7	-146.8	4385009	595	10.40	1.53	85.70	0.00	1983.4
		OG	1438	17.70	1.46	155.7	0.00	3616.7	367	13.73	1.08	70.58	0.00	1082.1
II	RETA	V	2620	0.18	0.19	1.27	-56.8	1.00	603	0.02	0.06	1.29	-19.57	0.99
		OG	1465	0.16	0.14	0.76	-17.6	1.00	369	-2.12	0.02	40.53	-778.3	0.99
	EQTA	V	2620	0.35	0.32	0.51	-9.94	1.00	603	0.21	0.25	1.19	-17.8	1.00
		OG	1465	0.38	0.36	0.48	-5.34	1.00	369	-0.38	0.23	12.68	-242.9	1.00
	TLTA	V	2620	0.65	0.68	0.51	0.00	10.94	603	0.79	0.75	1.19	0.00	18.79
		OG	1465	0.62	0.64	0.48	0.00	6.34	369	1.38	0.77	12.68	0.00	243.9
III	EBITTA	V	2620	0.02	0.01	0.32	-12.88	2.18	603	-0.09	-0.03	0.29	-4.27	0.61
		OG	1465	0.01	0.01	0.24	-3.27	2.30	369	-0.08	-0.03	0.31	-3.47	0.83
	CFTA	V	2620	0.04	0.03	0.32	-12.88	2.21	603	-0.07	-0.02	0.28	-4.31	0.47
		OG	1465	0.03	0.02	0.25	-4.10	2.40	369	-0.06	-0.02	0.29	-3.47	0.83
	ROA	V	2620	0.01	0.01	0.32	-12.88	2.09	603	-0.09	-0.04	0.29	-4.31	0.46
		OG	1465	0.00	0.00	0.25	-4.11	2.30	369	-0.08	-0.03	0.30	-3.47	0.83
IV	STA	V	2620	0.38	0.21	0.83	0.00	33.19	603	0.16	0.05	0.34	0.00	4.19
		OG	1465	0.30	0.11	0.53	0.00	6.74	369	0.18	0.02	0.62	0.00	7.55
	FATA	V	2620	0.55	0.60	0.29	0.00	1.00	603	0.67	0.79	0.29	0.00	1.00
		OG	1465	0.63	0.73	0.31	0.00	1.00	369	0.71	0.85	0.30	0.00	1.00

I (Liquidity), II (Solvency/Leverage), III (Profitability), IV (Activity/Others); V (Vineyards), OV (Olive Groves).
Source: Own elaboration.

Table S2 - Descriptive statistics of variables according to countries.

Type	Ratio	Country	Healthy Firms						Financial Distressed Firms					
			N	*Mean*	*Median*	*Std. Dev.*	*Min.*	*Max.*	*N*	*Mean*	*Median*	*Std. Dev.*	*Min.*	*Max.*
I	CCL	PT	1071	2057.34	0.38	66471.9	-133.8	2175351	168	4.96	0.28	23.68	0.00	260.9
		ES	892	5.20	0.39	37.96	0.00	860.5	168	9.28	0.31	59.58	0.00	749.9
		IT	2067	3.77	0.10	51.09	0.00	1699.0	626	2.69	0.07	23.33	0.00	522.2
	WCTA	PT	1089	0.16	0.20	0.53	-9.94	1.37	168	-1.49	0.10	18.80	-243.3	0.98
		ES	897	0.10	0.09	0.40	-5.36	1.00	170	-0.10	0.06	1.49	-18.32	0.96
		IT	2099	0.02	0.06	0.44	-4.68	1.00	634	-0.07	0.01	0.46	-3.19	1.00
	CATA	PT	1089	0.46	0.43	0.28	0.00	1.00	168	0.42	0.39	0.31	0.01	1.00
		ES	897	0.37	0.31	0.28	0.00	1.00	170	0.31	0.23	0.27	0.01	1.00
		IT	2099	0.42	0.33	0.32	0.00	1.00	634	0.28	0.16	0.30	0.00	1.00
	CR	PT	1071	4134.04	2.50	133991	-146.8	4385009	168	12.53	2.17	39.12	0.00	335.2
		ES	892	15.59	1.69	137.3	0.00	3616.8	168	18.48	1.77	90.47	0.01	1082.1
		IT	2067	33.61	1.26	953.5	0.00	42821.7	626	9.61	1.08	85.37	0.00	1983.4
II	RETA	PT	1089	0.23	0.27	0.69	-12.88	1.00	168	-4.90	0.02	60.05	-778.3	0.97
		ES	897	0.23	0.18	0.42	-5.39	0.99	170	-0.08	0.01	1.61	-19.57	0.99
		IT	2099	0.11	0.11	1.44	-56.77	1.00	634	0.11	0.05	0.68	-6.43	0.99
	EQTA	PT	1089	0.35	0.37	0.62	-9.94	1.00	168	-1.59	0.20	18.81	-242.9	1.00
		ES	897	0.51	0.55	0.43	-5.34	1.00	170	0.38	0.59	1.49	-17.79	1.00
		IT	2099	0.30	0.24	0.44	-8.22	1.00	634	0.30	0.19	0.40	-3.06	1.00
	TLTA	PT	1089	0.65	0.63	0.62	0.00	10.94	168	2.59	0.80	18.81	0.00	243.9
		ES	897	0.49	0.45	0.43	0.00	6.34	170	0.62	0.41	1.49	0.00	18.79
		IT	2099	0.70	0.76	0.44	0.00	9.22	634	0.70	0.81	0.40	0.00	4.06
III	EBITTA	PT	1089	0.02	0.02	0.44	-12.88	0.93	168	-0.13	-0.04	0.39	-3.47	0.53
		ES	897	0.05	0.02	0.15	-2.21	1.14	170	-0.03	-0.02	0.21	-1.73	0.65
		IT	2099	0.00	0.01	0.23	-3.41	2.30	634	-0.09	-0.03	0.28	-4.27	0.83
	CFTA	PT	1089	0.05	0.05	0.44	-12.88	0.98	168	-0.10	-0.02	0.39	-3.47	0.49
		ES	897	0.06	0.04	0.19	-4.10	1.14	170	-0.01	0.00	0.19	-1.33	0.73
		IT	2099	0.02	0.02	0.24	-3.76	2.40	634	-0.07	-0.02	0.28	-4.31	0.83
	ROA	PT	1089	0.00	0.01	0.44	-12.88	0.92	168	-0.14	-0.05	0.39	-3.47	0.46
		ES	897	0.03	0.02	0.19	-4.11	1.14	170	-0.03	-0.02	0.19	-1.38	0.63
		IT	2099	-0.01	0.00	0.24	-3.76	2.30	634	-0.09	-0.04	0.28	-4.31	0.83
IV	STA	PT	1089	0.34	0.22	0.50	0.00	6.14	168	0.17	0.07	0.25	0.00	1.63
		ES	897	0.38	0.20	0.52	0.00	6.48	170	0.27	0.08	0.54	0.00	4.19
		IT	2099	0.35	0.13	0.91	0.00	33.19	634	0.14	0.02	0.48	0.00	7.55
	FATA	PT	1089	0.54	0.57	0.28	0.00	1.00	168	0.58	0.61	0.31	0.00	0.99
		ES	897	0.63	0.69	0.28	0.00	1.00	170	0.69	0.77	0.27	0.00	0.99
		IT	2099	0.58	0.67	0.32	0.00	1.00	634	0.72	0.84	0.30	0.00	1.00

I (Liquidity), II (Solvency/Leverage), III (Profitability), IV (Activity/Others), PT (Portugal), ES (Spain), IT (Italy).
Source: Own elaboration.

Table S3 - One-sample Kolmogorov-Smirnov Test.

		Normal Parameters		*Test*	*Asymp. Sig.*
	N	*Normal Mean*	*Std. Dev.*	*Statistic*	*(2-tailed)*
CCL	4992	444.698	30789.257	0.499	0.000***
WCTA	5057	-0.001	3.468	0.386	0.000***
CA/TA	5057	0.398	0.303	0.109	0.000***
CR	4992	905.882	62066.191	0.498	0.000***
QR	4992	903.177	62066.195	0.499	0.000***
RETA	5057	-0.015	11.004	0.463	0.000***
EQTA	5057	0.288	3.479	0.419	0.000***
ICR	3710	-9157.657	312569.030	0.483	0.000***
TLTA	5057	0.712	3.479	0.419	0.000***
EBITTA	5057	-0.003	0.296	0.279	0.000***
CFTA	5057	0.016	0.300	0.290	0.000***
ROA	5057	-0.014	0.301	0.289	0.000***
ROS	4462	-13.826	523.149	0.480	0.000***
STA	5057	0.319	0.699	0.324	0.000***
FATA	5057	0.602	0.303	0.109	0.000***

Source: Own elaboration.

Table S4 - Spearman's rho coefficients.

	CCL	*WCTA*	*CATA*	*CR*	*RETA*	*EQTA*	*TLTA*	*EBITTA*	*CFTA*	*ROA*	*STA*	*FATA*
CCL	1.00											
WCTA	0.57	1.00										
CATA	0.22	0.59	1.00									
CR	0.70	0.88	0.36	1.00								
RETA	0.24	0.36	0.08	0.33	1.00							
EQTA	0.35	0.44	0.05	0.42	0.72	1.00						
TLTA	-0.35	-0.44	-0.05	-0.42	-0.72	-1.00	1.00					
EBITTA	0.18	0.28	0.25	0.18	0.40	0.27	-0.27	1.00				
CFTA	0.21	0.29	0.28	0.20	0.41	0.27	-0.27	0.91	1.00			
ROA	0.20	0.30	0.24	0.21	0.42	0.30	-0.30	0.98	0.92	1.00		
STA	0.08	0.24	0.53	0.07	0.18	0.05	-0.05	0.45	0.52	0.42	1.00	
FATA	-0.22	-0.59	-1.00	-0.36	-0.08	-0.05	0.05	-0.25	-0.28	-0.24	-0.53	1.00

For all ratios, the level of statistical significance of Spearman correlation coefficients is relevant at the 0.01 level.
Source: Own elaboration.

Table S5 - Mann-Whitney U-Test according to financial condition.

		Vineyards				*Olive Groves*			
		Mann-Whitney U	*Wilcoxon W*	*Z*	*Asymp.Sig. (2-tailed)*	*Mann-Whitney U*	*Wilcoxon W*	*Z*	*Asymp.Sig. (2-tailed)*
CCL	PT	36889.0	43792.0	-2.347	0.019**	8682.0	10008.0	-0.052	0.959
	ES	15421.5	19076.5	-2.070	0.038**	17343.0	127558.0	-1.583	0.113
	IT	253446.5	330867.5	-3.173	0.002***	70412.0	97673.0	-0.813	0.416
WCTA	PT	38716.0	45619.0	-1.796	0.073*	7277.0	8603.0	-2.158	0.031**
	ES	16068.0	19896.0	-1.955	0.051*	18936.0	22422.0	-0.454	0.650
	IT	249482.0	329282.0	-4.324	0.000***	66464.0	94194.0	-2.732	0.006***
CATA	PT	38170.0	45073.0	-2.016	0.044**	8503.0	9829.0	-0.577	0.564
	ES	14944.5	18772.5	-2.847	0.004***	17622.0	21108.0	-1.431	0.152
	IT	206347.0	286147.0	-8.875	0.000***	57801.0	85531.0	-5.336	0.000***
CR	PT	40615.0	47518.0	-0.828	0.408	7508.0	8834.0	-1.603	0.109
	ES	17028.0	20683.0	-0.769	0.442	18068.0	128283.0	-1.042	0.297
	IT	266428.0	343849.0	-1.778	0.075*	67224.0	94485.0	-1.798	0.072*
RETA	PT	30866.0	37769.0	-4.959	0.000***	6563.0	7889.0	-3.079	0.002***
	ES	15203.0	19031.0	-2.641	0.008***	12434.0	15920.0	-5.290	0.000***
	IT	266071.5	345871.5	-2.574	0.010**	69106.0	96836.0	-1.938	0.053*
EQTA	PT	31448.0	38351.0	-4.724	0.000***	6948.0	8274.0	-2.583	0.010**
	ES	18243.0	109194.0	-0.229	0.819	18680.0	129836.0	-0.644	0.519
	IT	278862.0	358662.0	-1.225	0.221	69389.0	97119.0	-1.853	0.064*
TLTA	PT	31448.0	304139.0	-4.724	0.000***	6948.0	68724.0	-2.583	0.010**
	ES	18250.0	22078.0	-0.223	0.824	18680.0	22166.0	-0.644	0.519
	IT	278862.0	1339558.0	-1.225	0.221	69389.0	276435.0	-1.853	0.064*
EBITTA	PT	20589.0	27492.0	-9.100	0.000***	5291.0	6617.0	-4.720	0.000***
	ES	9995.0	13823.0	-6.775	0.000***	10145.0	13631.0	-6.992	0.000***
	IT	103624.0	183424.0	-19.712	0.000***	39476.0	67206.0	-10.844	0.000***
CFTA	PT	19560.0	26463.0	-9.514	0.000***	4899.0	6225.0	-5.225	0.000***
	ES	9430.0	13258.0	-7.223	0.000***	10893.0	14379.0	-6.436	0.000***
	IT	100853.0	180653.0	-20.004	0.000***	37230.0	64960.0	-11.519	0.000***
ROA	PT	20915.0	27818.0	-8.968	0.000***	5397.0	6723.0	-4.583	0.000***
	ES	10353.0	14181.0	-6.491	0.000***	10892.0	14378.0	-6.436	0.000***
	IT	105609.0	185409.0	-19.503	0.000***	40286.0	68016.0	-10.600	0.000***
STA	PT	29582.0	36485.0	-5.477	0.000***	4979.0	6305.0	-5.146	0.000***
	ES	12173.0	16001.0	-5.046	0.000***	14291.0	17777.0	-3.909	0.000***
	IT	159662.0	239462.0	-13.810	0.000***	52596.0	80326.0	-6.947	0.000***
FATA	PT	38170.0	310861.0	-2.016	0.044**	8503.0	70279.0	-0.577	0.564
	ES	14944.5	105895.5	-2.847	0.004***	17622.0	128778.0	-1.431	0.152
	IT	206347.0	1267043.0	-8.875	0.000***	57801.0	264847.0	-5.336	0.000***

*PT (Portugal), (ES) Spain, (IT) Italy. ***, **, * represent .01, .05, and .10 significance levels, respectively.*
Source: Own elaboration.

Table S6 – Kruskal-Wallis Test[a,b].

	Global data				*Vineyards*				*Olive Groves*			
	Healthy		*Fin. Distressed*		*Healthy*		*Fin. Distressed*		*Healthy*		*Fin. Distressed*	
	Kruskal Wallis H	*Asymp. Sig.*	*Kruskal Wallis H*	*Asymp. Sig.*	*Kruskal Wallis H*	*Asymp. Sig.*	*Kruskal Wallis H*	*Asymp. Sig.*	*Kruskal Wallis H*	*Asymp. Sig.*	*Kruskal Wallis H*	*Asymp. Sig.*
CCL	251.706	0.000***	46.952	0.000***	163.055	0.000***	17.974	0.000***	77.390	0.000***	34.210	0.000***
WCTA	128.879	0.000***	23.143	0.000***	97.105	0.000***	15.246	0.000***	48.545	0.000***	13.816	0.001***
CATA	57.878	0.000***	38.300	0.000***	45.144	0.000***	25.661	0.000***	8.756	0.013**	14.473	0.001***
CR	157.989	0.000***	29.482	0.000***	96.376	0.000***	14.691	0.001***	76.786	0.000***	22.379	0.000***
RETA	62.581	0.000***	13.788	0.001***	37.547	0.000***	8.159	0.017**	32.836	0.000***	6.667	0.036**
EQTA	227.524	0.000***	51.655	0.000***	95.339	0.000***	23.242	0.000***	130.363	0.000***	31.017	0.000***
TLTA	227.524	0.000***	51.470	0.000***	95.339	0.000***	23.111	0.000***	130.363	0.000***	31.017	0.000***
EBITTA	98.068	0.000***	24.208	0.000***	75.460	0.000***	16.903	0.000***	41.038	0.000***	7.173	0.028**
CFTA	147.841	0.000***	37.044	0.000***	149.772	0.000***	26.618	0.000***	32.378	0.000***	12.263	0.002***
ROA	113.206	0.000***	34.662	0.000***	86.118	0.000***	23.242	0.000***	45.545	0.000***	10.149	0.006***
STA	61.860	0.000***	60.946	0.000***	75.855	0.000***	52.227	0.000***	26.313	0.000***	29.245	0.000***
FATA	57.878	0.000***	38.300	0.000***	45.144	0.000***	25.661	0.000***	8.756	0.013**	14.473	0.001***

[a.] *Grouping Variable: Portugal, Spain, Italy.* [b]. *2 degrees of freedom.*
***. **. * *represent .01. .05. and .10 significance levels, respectively.*
Source: Own elaboration.

Determining the factors affecting the climate-friendly innovative technology usage levels of sheep farms

Cennet Oğuz*, Aykut Örs**, Aysun Yener Öğür*, Yusuf Çelik*

DOI: 10.30682/nm2401d
JEL codes: Q16, Q54, Q55

Abstract

Climate-friendly smart agriculture (CSA) describes a set of interventions aimed at sustainably increasing productivity and reducing greenhouse gas emissions from agriculture. The aim of this study was to calculate the climate-friendly innovative technology usage indexes of sheep farms in Konya and to determine the affecting factors. Neyman allocation sampling method was used to determine the 151 sheep farms. As a result of the study, it has been determined that 5.96% of the enterprises are low level, 87.42% medium level and 6.62% high level climate-friendly innovative technology users. The general average of climate-friendly innovative technology usage index (CFITU) of the sheep farms is 52.88% and they are medium level climate-friendly innovative technology users. Ordinal logistic regression analysis was conducted to determine the factors influencing the level of CFITU in sheep farms. The results showed that the dependent variable was explained by 7 independent variables with a percentage of 32.5%. Providing education and financial support to farmers in the region regarding climate change perception and technology usage will enhance the level of CFITU in enterprises.

Keywords: *Sheep farming, Climate friendly smart agriculture, Innovative Technology Usage Index, Konya.*

1. Introduction

Regardless of the state of development, the agricultural sector is indispensable for countries. Although many technological and biological innovations have been developed in agriculture, agriculture is considered to be one of the most sensitive sectors to the negative impact of climate change. It is clear that climate change has a direct impact on agricultural production. Climate change can significantly reduce agricultural productivity, which can affect rural per capita income and poverty levels (Dellal *et al.*, 2011; Li *et al.*, 2013; Masud *et al.*, 2017; Uitto *et al.*, 2017; Azadi *et al.*, 2019; Foguesatto *et al.*, 2019; Ramborun *et al.*, 2020).

The impact of climate change on animal production varies from year to year and increases (Descheemaeker *et al.*, 2018). Changes in death rate, feed consumption rate, live weight gain, milk production and pregnancy rate are expected with the deterioration of the balance between heat production and use of heat in animals with temperature increase (Polat and Dellal, 2016).

* Selçuk University, Faculty of Agriculture Department of Agricultural Economics, Konya, Turkey.
** Agriculture and Rural Development Support Institution, Konya Provincial Coordination Unit, Turkey.
Corresponding author: aykutors@gmail.com

According to Food and Agriculture Organization (FAO, 2015), the global demand for animal products is projected to double by 2050 due to the rising standard of living and population pressure. Because, in parallel with the increase in population and income in the world, the demands for animal food are increasing (Speedy, 2003; Steinfeld, 2003; Godfray and Garnett, 2014; Khan and Sameen, 2018; Tarawali *et al.*, 2018; Lemaire *et al.*, 2019). Therefore, climate change is emerging as one of the biggest threats to the animal food supply (Reilly *et al.*, 1996; Nardone *et al.*, 2010; Gauly *et al.*, 2013).

Agriculture is an area of activity that causes climate change as much as it is affected by climate change. Industrial agriculture practiced worldwide disrupts fundamental ecological processes. This, triggers climate change and causs loss of biosphere integrity, destructive soil system changes, and pollution of the oceans with phosphorus and nitrogen fertilizers (Tilman *et al.*, 2001; West *et al.*, 2014; Liebman and Schulte, 2015; Steffen *et al.*, 2015; DeLonge *et al.*, 2016).

Livestock contributes to 14.5% of greenhouse gas emissions responsible for climate change (Barnes and Toma, 2012; Gerber *et al.*, 2013; Ardakani *et al.*, 2019). In the production of greenhouse gases, sheep and goats have a low rate (Görgülü *et al.*, 2009; Rojas-Downing *et al.*, 2017; Koluman *et al.*, 2017; Koluman and Silanikove, 2018). Ovine breeding has a very important place especially in arid or semi-arid regions (Sejian *et al.*, 2017). It is stated that the methane gas emission in Turkey is approximately 1 million tons and 76% of the total emission originates from cattle, 20.49% from sheep breeding and 2.98% from goat breeding (Görgülü *et al.*, 2009).

Reducing the negative effects of climate change will only be possible by adapting to these effects. The level of knowledge, recognition and perception of climate change by producers is also important in order to know what the effects of climate change are and to reduce these effects (Masud *et al.*, 2017; Somda *et al.*, 2017; Tripathi and Mishra, 2017; Chedid *et al.*, 2018; Wetende *et al.*, 2018). Because, to the extent that the producer has knowledge about climate change and its effects, it will endeavor to reduce the negative effects. It is stated that farmers define climate change knowledge in terms of how it affects them in the context of history, culture and local experiences (Velempini *et al.*, 2018). They develop place-based coping strategies and take part in adaptation studies to alleviate and maintain their livelihoods (Ashraf and Routray, 2013; Roco-Fuentes *et al.*, 2015; Hyland *et al.*, 2016; Daly-Hassen *et al.*, 2019; Ata *et al.*, 2021).

Climate-friendly smart agriculture (CSA) describes a set of interventions aimed at increasing productivity sustainably while helping farmers adapt their agricultural systems to the predicted effects of climate change and manage climate risk more effectively (Mutenje *et al.*, 2019). CSA is a new concept first proposed by the FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010 to address the need for a strategy for managing agriculture and food systems under climate change (Saj *et al.*, 2017). Mutenje *et al.* (2019) used a mixed methodology approach (stochastic dominance) combined with cost-benefit analysis to determine the probability of investment in various CSA technology combinations in their study. As a result of their study, they found that CSA practices are economically viable and should be implemented. Azumah *et al.* (2020) also show that the adoption of CSA is profitable because the average benefits outweigh the average costs.

In their study, Long *et al.* (2016) discussed the barriers to the adoption and diffusion of CSA in Europe. They selected the countries of the Netherlands, France, Switzerland, and Italy as their study areas. The research concluded that there were barriers on both the demand and supply sides. It showed that traditional supply-focused innovation policies alone are unlikely to lead to a sufficient level of technological innovation adoption in CSA practices. Khatri-Chhetri *et al.* (2017b), on the other hand, evaluated CSA implementation options in Nepal in their study. They assessed CSA options that could be applied in different parts of the country and provided recommendations in four areas for the widespread adoption of these technologies. These headings are as follows: Knowledge-transfer approach, Market-based approach, Public-Private Partnership Approach, Community-based Climate-Smart Villages (CSVs) approach. In the study of Everest (2021), factors affecting the adaptation of CSA technologies among farmers in the northwestern Marmara region of Turkey were examined. The study identified factors influencing farmer decisions in this regard as education, participation in agricultural meetings, land size, and agricultural income. In the study by Biró *et al.* (2021), they worked on solutions offered by CSA technologies with farmers and farmer organizations in Hungary. They identified 27 CSA technologies that could be used in Hungary. They recommended integrating CSA goals into agricultural policies with regional characteristics in mind and including CSA technologies in the curriculum of digital agriculture academies.

The use of climate-friendly smart innovative technology by sheep farms is important for the management of agricultural enterprises. Agricultural enterprises have a privileged structure in terms of management. Especially in small-scale businesses, the business and the life of the business manager and his family are spatially integrated. In order for the resources to be used effectively in agricultural enterprises, the characteristics of the resources allocated to production should be known and they should be allocated to production in accordance with their characteristics. In addition, as a result of the activities carried out in the enterprise, income and expense status and profitability analyzes of the enterprise should be made. The importance of *making decisions based on information* is increasing day by day in order for businesses and countries to use their scarce resources effectively and consciously and to create a competitive advantage. That is why the utilization of emerging smart technologies in agricultural production is important (Oğuz and Çelik, 2020).

The aim of the research is to calculate innovative technology usage indexes of sheep farms based on climate-friendly smart technologies and to determine the affecting factors. Within the scope of the study, climate-friendly smart technologies are grouped under six headings and are given. These factors are water, energy, food, carbon, weather, and information-friendly smart technologies. Innovative climate-friendly smart technology usage indices have been calculated by scoring the technologies under the headings. In the research area, farmers who use climate-friendly innovative technology at a high level are defined as a "climate-friendly smart farmers" and are detailed in the research findings and results section below.

2. Materials and method

2.1. *Material*

2.1.1. *Study area*

As the research region, Konya has been chosen as the study area because it is one of the driest provinces in Turkey (Erkan *et al.*, 2009; Cebeci *et al.*, 2019; MGM, 2021), as well as having an important production potential in terms of both plant production and animal production. Konya meets 5% of Turkey's agricultural production

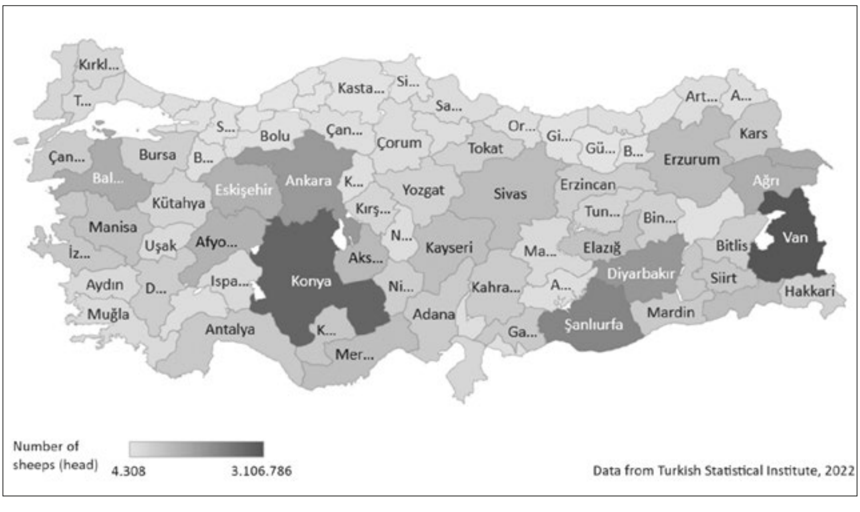


Figure 1 - Turkey sheep population density map.

value and constitutes 6.20% of Turkey in terms of the number of sheep (2,770,980). In the study, the records of the Konya Province Sheep and Goat Breeders' Association were used to determine the population. Districts with the highest number of sheep in the province are Karapınar, Ereğli, Cihanbeyli, Meram, Karatay and Çumra. These districts constituted the main frame of the research, as they constitute 54.92% of the total number of sheep (1,521,822) in Konya. In the selection of the districts, the presence of sheep, drought and precipitation, the presence of pasture land, and the representation of the current production pattern for the ecology of the region were taken into account.

2.1.2. *Data collection*

The main material of the research is the primary data collected from the sheep farms of Konya through a questionnaire. In addition to these data, the publications and websites of the relevant public institutions and organizations in the research region, as well as previous research findings and published statistical data on this subject were also used. In this study, $1 = 14.12 Turkish Liras calculated that was the average exchange rate of the dates of the field study was done.

2.2. *Method*

The methodological framework of the research has been schematized in Figure 2. The methods used at each stage of the research are comprehensively explained below.

2.2.1. *Sampling methods*

Neyman's "stratified random sampling method" was used to determine the sample size due to

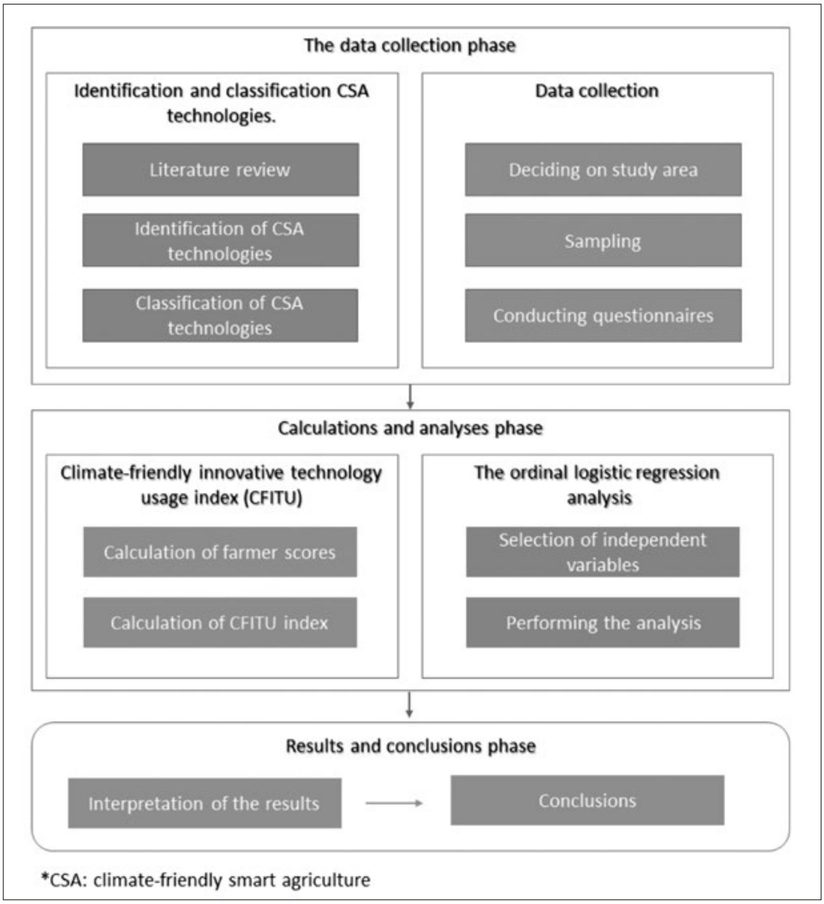


Figure 2 - The methodological framework of the research.

the coefficient of variation of the population was greater than 75%.

$$n = \frac{[\sum(N_h S_h)]^2}{N^2 D^2 + \sum[N_h (S_h)^2]}$$

$$D^2 = d / z$$

In formula; n = sample volume, N = total unit number belonging to the sampling frame, D = d / t, d = derivation from the average, t = standard normal distribution value (Yamane, 1967).

The size of the enterprise was examined by arranging various layers, and it was deemed appropriate to form 3 layers by taking into account the frequency distributions. The boundaries of these strata were determined as holdings with 1-100 head, 101-250 head, 251 head and more sheep. In determining the number of samples drawn from the main population, 5% error and 95% confidence limits were used and determined as 151. The distribution of sheep farms according to layer widths was made with the following formula (Yamane, 1967).

$$n_i = \frac{(N_h S_h) n}{\sum N_h S_h}$$

As a result, the distribution of the farms in the research area according to the size of the farms (number of animals) and the number of sheep farms to be surveyed are given in Table 1.

2.2.2. *Constructing a climate-friendly innovative technology usage index*

Since the diffusion and adoption of innovations requires a certain process, the stages that manufacturers go through during this process are important. These stages are; acquiring knowledge, persuasion, decision making, implementation and adoption. In the first stage, the manufacturer learns about the innovation and its functions. At the stage of persuasion, it evaluates the advantages and disadvantages of innovation for itself and shapes its attitude towards innovation. At the decision stage, it obtains additional information about the innovation and makes a decision to accept or reject the innovation. At this stage, the producer is particularly influenced by his peers around him. The fourth stage, implementation, takes place when the decision to adapt to innovation is made. In the final stage, the manufacturer validates and reinforces the compliance decision (Rogers, 1995). The time spent in each stage varies according to the innovation, the way it is presented and the characteristics of the person (Özçatalbaş and Gürgen, 1998). According to the speed of diffusion of innovations, manufacturers are classified as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and the laggards (16%) (Rogers, 1995). There are many factors that affect people's early or late adoption of innovations. These factors are socio-economic, personal and communication techniques (Özçatalbaş and Gürgen, 1998).

Khatri-Chhetri *et al.* (2017a) gathered climate-friendly smart technologies under six headings in their study titled "Farmers' prioritization of climate-smart agriculture (CSA) technologies". These topics are water, energy, nutrients, carbon, weather and information-friendly smart technologies (Table 2). Farmers were asked to provide one of three responses, "I don't know", "I know", or "I implement", regarding the following technologies and applications in the research field.

Scoring was made according to the farmers' knowledge and application of each of the 25 technologies and applications in the above list. If he knows the technology or application, 2 points are given, if he applies it, 3 points, if he does not know and does not apply it, 1 point is given. The maximum score a farmer can achieve if they know and implement all the technologies is a total of 75 points. After the scoring was completed for each

Table 1 - Distribution of sheep farm numbers by farm size groups.

Farm Size Groups (number of sheep (Head))	*Nh*	*Sh*	*Ort*	*CV*	*Nh*Sh*	*Nh*(Sh)²*	*Sample Volume (n)*
1. Group (1-100)	1636	22.27	64	33	36,429.03	811,170	22
2. Group (101-250)	2103	62.86	163	31	132,189.64	8,309,130	79
3. Group (251 - +)	816	136.16	384	33	83,191.52	11,327,052	50
Total	4,555	221.28	172.72	86.30	251,810.19	20,447,353	151

Table 2 - Climate-friendly smart agriculture (CSA) technologies.

Water Friendly S.A.	*Energy Friendly S.A.*	*Nutrient Friendly S.A.*
Rainwater Harvesting	Zero Tillage/Minimum Tillage	Site Specific Integrated Nutrient Management
Drip Irrigation	Solar Energy Solutions for Agriculture	Green Manuring
Laser Land Levelling	Biofuel Use	Leaf Color Chart
Furrow Irrigated Bed Planting		Intercropping with Legumes
Drainage Management		
Cover Crops Method		
Carbon Friendly S.A.	*Weather Friendly S.A.*	*Knowledge Friendly S.A.*
Agro Forestry	Climate Smart Housing for Livestock	Contingent Crop Planning
Concentrate Feeding for Livestock	Weather Based Crop Agro-advisory	Improved Crop Varieties
Fodder Management	Crop Insurance	Seed and Fodder Banks
Integrated Pest Management		Farmer to Farmer Learning
		Farmer Organizations for Adaptation Technologies

**S.A.: Smart Applications.*

business, the climate-friendly innovative technology usage indexes (CFITU) were calculated with the score they received. By using the index, all businesses are divided into three subgroups as "those using high-level climate-friendly innovative technology", "middle-level climate-friendly innovative technology users" and "low-level climate-friendly innovative technology users" (Oğuz and Yener, 2017). Climate-friendly innovative technology usage indexes (CFITU) were calculated using the formula below.

$$index_{CFITU} = \frac{\text{The total score received by the enterprise}}{\text{Maximum score the enterprise can get}} \text{ x } 100$$

$index_{CFITU}$: Climate-friendly innovative technology usage index (CFITU)

Accoding to CFITU, index scores between 1% and 35% are classified as "low level climate friendly innovative technology users"; index scores between 36% and 70% are classified as "moderate climate friendly innovative technology users" and index scores 71% and above are classified as "enterprises using high level climate friendly innovative technology" (Oğuz and Yener, 2017; Örs and Oğuz, 2018). Within the scope of the study, those higher than 71% were called "climate friendly smart farmers".

2.2.3. *Ordinal logistic regression analysis*

In determining the factors affecting the CFITU levels of farmers in the study, ordinal logistic regression analysis was used instead of linear regression due to the non-normal distribution of variables and the lack of homogeneity (equality) in group variance-covariance. Logistic regression analysis can be examined in three different groups based on the nature of the dependent variable: Binary Logistic Regression, Multinomial Logistic Regression, and Ordinal Logistic Regression (Akın and Şentürk, 2012). In the study, ordinal logistic regression analysis was used due to the categorical and ordinal nature of the dependent variable, CFITU level.

Ordinal logistic regression is a method used to examine the relationship between two or more ordered categories in a categorical response variable. The general representation of the Ordinal Logistic Regression model is based on the odds ratios of the categories and is as follows (McCullagh, 1980; Christensen, 2012):

$$\ln (Y_j) = \ln \left(\frac{P(Y \leq \frac{1}{X_1}, X_2, \ldots, X_i)}{1 - P(Y \leq \frac{1}{X_1}, X_2, \ldots, X_i)}\right) =$$

$$= \alpha_j - (\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_i X_i)$$

The key features of the Ordinal Logistic Regression model can be listed as follows (Ding *et al.*, 2004):

- The dependent variable is a grouped and ordered categorical variable.
- It uses a cumulative function to describe the impact of the independent variables on the ordered and categorical dependent variable, eliminating the need for normality and constant variance assumptions.
- The model assumes that the relationship between the independent variables and the ordered dependent variable is independent of the specific categories. In the field of sheep farms, seven independent variables were considered to determine the factors affecting the level of climate-friendly smart innovative technology usage. These variables include education, perception of climate change, farming experience, livestock presence (in head), total farm land area, access to information, and agricultural income.

3. Results and discussions

3.1. *Climate-friendly innovative technology usage index results*

3.1.1. *Water-friendly smart innovative technology application cases*

Knowing and applying water-friendly smart applications of sheep farms are given in Table 3. It has been determined that 2.65% of the surveyed enterprises started rainwater harvesting practices, 46.36% used drip irrigation systems, 7.95% made laser land levelling, 1.32% made furrow ırrigated bed planting, 7.95% used drainage management, 0.67% applied cover crops method to protect the soil.

It has been determined that 41.06% of the enterprises do not practice rainwater harvesting, 45.03% drip irrigation, and 40.40% drainage management although they know about these methods. Some enterprises do not know these methods at all. When the unknown rates of the methods are examined; rainwater harvesting is 56.29%, laser land leveling is 64.90%, furrow ırrigated bed planting is 90.73%, cover crops management for soil protection is 82.78%, and drainage management is 51.66%.

3.1.2. *Energy-friendly smart innovative technology application cases*

The state of knowing and applying energy-friendly smart applications of the sheep farms is given in Table 4. It has been determined that 10.60% of the examined enterprises perform zero tillage/minimum tillage practices, and 1.99% use solar energy solutions for agriculture. There were no enterprises using biofuels. These rates show that the use of energy-friendly smart innovative technology applications is almost non-existent.

Considering the state of knowing the energy-friendly smart technologies of the enterprises, it is seen that 23.84% of them know zero tillage/minimum tillage, while 65.56% of them do not. These rates are 44.37% to 53.64% for solar energy solutions and 31.13% to 68.87% for biofuels.

3.1.3. *Nutrient-friendly smart innovative technology application cases*

The state of knowing and applying nutrient-friendly smart applications of sheep farms are given in Table 5. Implementation and aware-

Table 3 - Water-friendly smart innovative technology application cases of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Rainwater Harvesting	4	2.65	62	41.06	85	56.29	151.00	100.00
Drip Irrigation	70	46.36	68	45.03	13	8.61	151.00	100.00
Laser Land Levelling	12	7.95	41	27.15	98	64.90	151.00	100.00
Furrow Irrigated Bed Planting	2	1.32	12	7.95	137	90.73	151.00	100.00
Drainage Management	12	7.95	61	40.40	78	51.66	151.00	100.00
Cover Crops Method	1	0.66	25	16.56	125	82.78	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

Table 4 - Energy-friendly smart innovative technology application situations of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Zero Tillage/Minimum Tillage	16	10.60	36	23.84	99	65.56	151.00	100.00
Solar Energy Solutions for Agriculture	3	1.99	67	44.37	81	53.64	151.00	100.00
Biofuel Use	0	0.00	47	31.13	104	68.87	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

Table 5 - Food-friendly smart innovative technology application cases of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Site Specific Integrated Nutrient Management	7	4.64	13	8.61	131	86.75	151.00	100.00
Green Manuring	9	5.96	42	27.81	100	66.23	151.00	100.00
Leaf Color Chart	9	5.96	8	5.30	134	88.74	151.00	100.00
Intercropping with Legumes	8	5.30	59	39.07	84	55.63	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

ness rates in this area are very low. The application rate of site-specific integrated nutrient management is 4.64%, green manuring is 5.96%, leaf color chart is 5.96%, and intercropping with legumes is 5.30%.

When the table is examined, it is seen that 27.81% of the enterprises have knowledge about green manuring and 39.7% of them have knowledge about intercropping with legumes. The rates of those who have not heard of these methods are 66.23% and 55.63%, respectively. The other two methods are unknown at a very high rate of 85%.

3.1.4. *Carbon-friendly smart innovative technology application cases*

The state of knowing and applying carbon-friendly smart applications of enterprises are given in Table 6. We do not have a enterprises that implements the first factor, agro forestry, among the enterprises we surveyed. The rate of those who make concentrated feeding is 57.2% and those who apply fodder management is 62.25%. Only 10.60% of enterprises implement integrated pest management.

While the number of enterprises that know the agro forestry method, which includes sustainable land use management and encourages carbon sequestration, is 31.13%, while the number of those who do not is as high as 68.87%. Concentrate feding and roughage management is widely known and practiced by enterprises. While 23.18% know but do not implement integrated pest management, 66.23% of the enterprises do not know at all.

3.1.5. *Weather-friendly smart innovative technology application cases*

The state of knowing and applying the weather-friendly smart applications of the sheep farms are given in Table 7. It has been determined that climate smart housing and weather-based crop agro-advisory are implemented at a very low rate of 5.30%. The rate of those who have product insurance is 30.46%.

The number of those who know climate smart housing and weather-based crop agro-advisory is very low, with ratios 30.46% and 23.18%. However, the rate of those who know crop insurance but do not apply, is very high with 47.02%.

3.1.6. *Knowledge-friendly smart innovative technology application cases*

Knowledge-friendly smart innovative technology application situations of sheep farms are given in Table 8. When the table is examined, it is seen that contingent product planning is used at very low rates such as 7.28%, improved product varieties 6.62%, and seed and fodder banks 6.62%. While the farmer-to-farmer learning application is applied at a high rate of 59.60%, the application of farmer organizations for adaptation technologies is 21.85%.

Table 6 - Carbon-friendly smart innovative technology application cases of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Agro Forestry	0	0.00	47	31.13	104	68.87	151.00	100.00
Concentrate Feeding for Livestock	87	57.62	46	30.46	18	11.92	151.00	100.00
Fodder Management	94	62.25	43	28.48	14	9.27	151.00	100.00
Integrated Pest Management	16	10.60	35	23.18	100	66.23	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

Table 7 - Weather-friendly smart innovative technology application cases of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Climate Smart Housing for Livestock	8	5.30	46	30.46	97	64.24	151.00	100.00
Weather Based Crop Agro-advisory	8	5.30	35	23.18	108	71.52	151.00	100.00
Crop Insurance	46	30.46	71	47.02	34	22.52	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

The rate of those who do not know the first three factors is 72.85%, 61.59% and 53.64%, respectively. The rate of those who do not know the application of farmer organization for adaptation technologies is relatively lower than the first three factors and is 45.03%. It is seen that the practice of learning from farmer to farmer is common among enterprises, and the rate of those who do not know this practice is only 19.87%.

3.1.7. *Climate-friendly innovative technology usage index (CFITU)*

Climate-friendly innovative technology usage indexes (CFITU) of sheep breeding enterprises are calculated and presented in Table 9.

When the table is examined, it is seen that 9 of the enterprises surveyed in the field are low level, 132 of them are medium level and 10 of them are high level innovative technology farmers. In terms of percentages, the rates are 5.96%,

Table 8 - Knowledge-friendly smart innovative technology application cases of sheep farms.

Factors	*3**	*%*	*2**	*%*	*1**	*%*	*Total*	*%*
Contingent Crop Planning	11	7.28	30	19.87	110	72.85	151.00	100.00
Improved Crop Varieties	10	6.62	48	31.79	93	61.59	151.00	100.00
Seed and Fodder Banks	10	6.62	60	39.74	81	53.64	151.00	100.00
Farmer to Farmer Learning	90	59.60	31	20.53	30	19.87	151.00	100.00
Farmer Organizations for Adaptation Technologies	33	21.85	50	33.11	68	45.03	151.00	100.00

**1=I don't know, 2=I know, 3=I apply.*

Table 9 - Climate-friendly innovative technology usage indexes (CFITU).

Description of farmers applying climate-friendly innovative technology	*1-100*	*101-250*	*251-+*	*Total*
Low-level climate-friendly innovative technology users (1-35%)	2	5	2	9
Middle-level climate-friendly innovative technology users (36-70%)	19	70	43	132
High-level climate-friendly innovative technology users (71-100%)	1	4	5	10
Total	22	79	50	151
Average CFITU (%)	51.27	51.68	55.49	52.88

Table 10 - Distribution of climate-friendly innovative technologies by CFITU groups.

	Average Score of Enterprises			
	Low-level CFITU	*Middle-level CFITU*	*High-level CFITU*	*Overall average*
Water Friendly S.A.	6.00	9.09	12.30	9.13
Energy Friendly S.A.	3.00	4.17	6.40	4.52
Nutrient Friendly S.A.	4.00	5.12	8.00	5.71
Carbon Friendly S.A.	4.00	7.88	9.30	7.06
Weather Friendly S.A.	3.00	4.76	7.40	5.05
Knowledge Friendly S.A.	5.00	8.39	13.00	8.80

**S.A.: Smart Applications.*

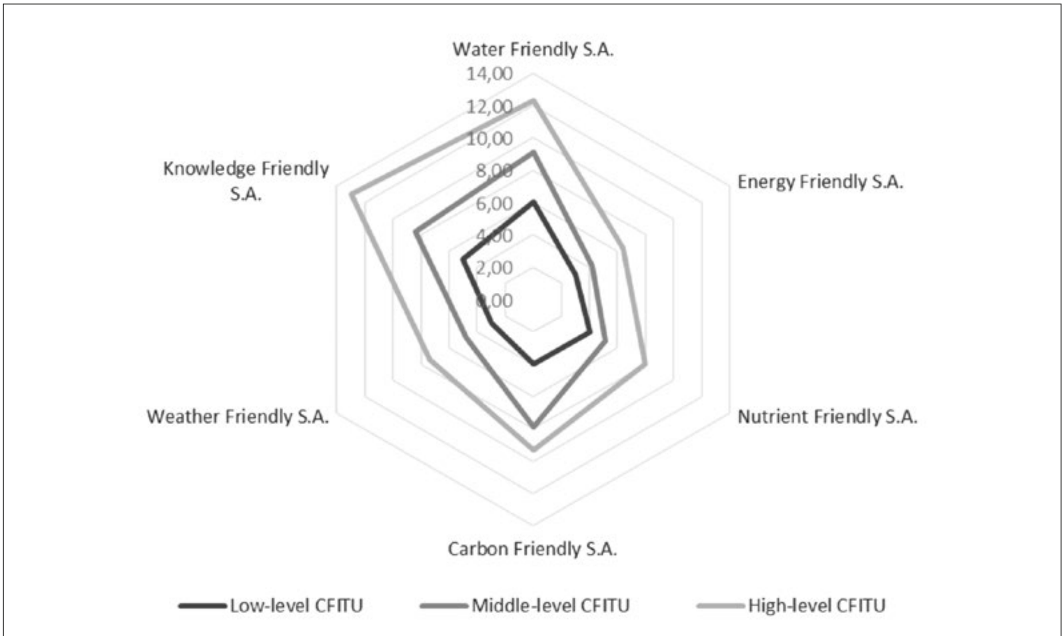
87.42% and 6.62%, respectively. When the averages of the CFITU (%) of the groups are examined, it is 51.27% for the 1-100 head group; 51.68% for the 101-250 head group and 55.49% for the 251+ head group. Sheep farms use moderately climate-friendly innovative technology with a general average of 52.88%.

According to the CFITU score groups, the average scores obtained by the enterprises from each smart application are given in Table 10 and presented graphically in Figure 3.

When the table is examined, it is seen that sheep farms have the highest average score in water, carbon and knowledge friendly smart technology applications. Awareness and application rate are higher in these three areas. The average scores of energy, food and weather friendly smart technology applications of sheep farms are low. The rate of not having knowledge in this field or having knowledge but not applying it is higher.

Before the widespread availability of the internet, smartphones, and similar devices in rural areas, staying informed about innovative

Figure 3 - Distribution chart of climate-friendly innovative technologies by CFITU groups.



technologies often required economically demanding activities such as attending trade fairs or technical trips. However, in the current situation, internet and smartphone usage is high across all socio-economic groups. Therefore, thanks to the internet and social media, the awareness of innovative technologies among all farmers, regardless of their socio-economic background, is at a high level. However, as will be seen in the section on factors affecting the CFITU index, certain factors such as having a specific level of education, recognizing and understanding climate change, having experience, and having the agricultural income to purchase technology are necessary for these technologies to be applied in the field. Consequently, the levels of implementation remain significantly below the level of awareness.

The data in Table 10 are transferred to the radar chart in Figure 3. In the graph, it can be seen visually that all three groups have a higher tendency towards water, carbon and knowledge-friendly smart technology applications.

3.2. *Factors influencing the CFITU in sheep farming*

Ordinal logistic regression analysis was conducted to determine the factors influencing the level of climate-friendly smart innovative technology usage (CFITU). In the model, the dependent variable, CFITU levels, was examined together with the independent variables, and their relationships were explored and established. The relationships between the independent variables and CFITU levels were examined individually. The CFITU levels according to the independent variables are presented in Table 11.

Upon examining Table 11, it can be observed that there is a clustering of medium CFITU level for all independent variables. According to the education levels, it can be observed that farmers with a low CFITU level predominantly fall into the categories of primary-middle school and high school education. Farmers with a medium CFITU level are more prevalent, and as the education level increases, their CFITU levels tend to shift from medium to high. The percentages of farmers with a high CFITU level based on education categories are as follows: 3.45% for primary-middle school, 10.53% for high school, 12.50% for vocational school, 33.33% for bachelor's degree, and 100% for master's and above.

According to the perception levels of climate change, the percentages of farmers with a medium CFITU level are as follows: 91.30% for those with low perception, 86.67% for those with medium perception, and 87.50% for those with high perception. On the other hand, the percentages of farmers with a high CFITU level are: 8.70% for those with low perception, 5.83% for those with medium perception, and 12.50% for those with high perception.

According to the experience level, it can be observed that CFITU levels vary. However, there is no clear trend of CFITU levels increasing or decreasing proportionally with the increase in experience.

According to the livestock presence (head), there is an increase in CFITU level as the number of livestock increases. The percentages of farmers with a low CFITU level are 9.09% for the 1st group, 6.33% for the 2nd group, and 4% for the 3rd group. Correspondingly, as the number of livestock increases, the percentages of farmers with a high CFITU level also increase. The percentages of farmers with a high CFITU level are 4.55% for the 1st group, 5.06% for the 2nd group, and 10% for the 3rd group.

According to the total land area (decares), CFITU levels differ, but it can be said that CFITU level increases as the land size increases. The percentages of farmers with a high CFITU level are 5.32% for 0-250 decares, 4% for 251-500 decares, 10% for 501-750 decares, and 13.64% for 751 and above decares.

According to the agricultural income, there are farmers in all three CFITU levels at each income level. While there is no significant change in CFITU level in relation to low agricultural income, an increase in income is associated with an increase in CFITU level. As income increases, the CFITU level also increases. The percentages of farmers with a medium CFITU level based on income are 89.47%, 85.71%, and 75% respectively, while the percentages of farmers with a high CFITU level are 4.39%, 9.52%, and 18.75% respectively.

Table 11 - CFITU levels by independent variables.

Variables	*Categories*	*Climate-friendly smart innovative technology usage levels*		
		Low	*Medium*	*High*
Education	Can read and write (2)	0.00	100.00	0.00
	Primary-Middle School (3)	6.03	90.52	3.45
	High School (4)	10.53	78.95	10.53
	Vocational School (5)	0.00	87.50	12.50
	Bachelor's Degree (6)	0.00	66.67	33.33
	Master's and above (7)	0.00	0.00	100.00
Perception Level	Low	0.00	91.30	8.70
	Medium	7.50	86.67	5.83
	High	0.00	87.50	12.50
Experience	1-5 years (1)	0.00	87.50	12.50
	6-10 years (2)	11.11	88.89	0.00
	11-15 years (3)	4.35	82.61	13.04
	16-20 years (4)	0.00	100.00	0.00
	21-25 years (5)	7.69	80.77	11.54
	26-30 years (6)	6.90	82.76	10.34
	30 years (7)	7.69	92.31	0.00
Livestock Presence (head)	0-100	9.09	86.36	4.55
	101-250	6.33	88.61	5.06
	251+	4.00	86.00	10.00
Total Land Area (da)	0-250	7.45	87.23	5.32
	251-500	0.00	96.00	4.00
	501-750	0.00	90.00	10.00
	751+	9.09	77.27	13.64
Agricultural Income ($)	20,000 and below	6.14	89.47	4.39
	20,001-100,000	4.76	85.71	9.52
	100,000 and above	6.25	75.00	18.75
Access to Information Level	0-2.50	0.00	95.65	4.35
	2.51-4.00	9.18	83.67	7.14
	4.01 +	0.00	85.71	14.29

According to the access to information score, CFITU levels differ, but it can be said that CFITU level increases as the access to information score increases. The percentages of farmers with a high CFITU level are 4.35% for 0-2.50 points, 7.14% for 2.51-4.00 points, and 14.29% for 4.01 and above points.

The next stage after explaining the CFITU levels in terms of independent variables is modeling. Modeling was performed using the logistic link function. When examining the model fit, the model shows a good fit at a significance level of $p<0.05$ ($X^2=33.096$, $p=0.045$). The parallelism assumption was tested using the chi-square test ($X^2=31.943$, $p=0.059$), and since $p>0.05$, the parallelism assumption is satisfied. This means that the CFITU categories, which are the dependent variable, are parallel to each other, and the pa-

Table 12 - Expressing the significance of model parameters.

		Estimate (β)	*Std. Error*	*Wald*	*sd*	*Sig.*	e^{β}
The dependent variable	[The_technology_level = 1.00]	-26.938	2.223	146.830	1	0.000	
	[The_technology_level = 2.00]	-19.542	2.071	88.997	1	0.000	
The independent variables	Livestock_presence	0.002	0.001	3.731	1	0.053	
	[Education=2.00]	**-25.046**	**4.937**	**25.736**	**1**	**0.133×10^{-10}**	**0.000**
	[Education=3.00]	**-23.837**	**1.341**	**316.180**	**1**	**0.445×10^{-10}**	**0.000**
	[Education=4.00]	**-23.277**	**1.398**	**277.099**	**1**	**0.778×10^{-10}**	**0.000**
	[Education=5.00]	**-21.934**	**1.545**	**201.682**	**1**	**2.978×10^{-10}**	**0.000**
	[Education=6.00]	-20.604	0.000		1		
	[Education=7.00]	0^a			0		
	[Experience=1.00]	1.994	1.378	2.094	1	0.148	
	[Experience=2.00]	-0.367	1.211	0.092	1	0.761	
	[Experience=3.00]	**2.271**	**1.035**	**4.816**	**1**	**0.028**	**9.685**
	[Experience=4.00]	0.766	1.028	0.555	1	0.456	
	[Experience=5.00]	1.227	0.908	1.827	1	0.177	
	[Experience=6.00]	1.209	0.898	1.812	1	0.178	
	[Experience=7.00]	0^a			0		
	[Perception_level=1.00]	0.505	1.303	0.150	1	0.699	
	[Perception_level=2.00]	-0.091	1.158	0.006	1	0.938	
	[Perception_level=3.00]	0^a			0		
	[total_land_code=1.00]	0.800	1.032	0.600	1	0.439	
	[total_land_code=2.00]	0.645	1.099	0.345	1	0.557	
	[total_land_code=3.00]	1.185	1.335	0.788	1	0.375	
	[total_land_code=4.00]	0^a			0		
	[income_code =1.00]	**-1.776**	**0.794**	**5.005**	**1**	**0.025**	**0.169**
	[income_code =2.00]	-2.259	1.176	3.687	1	0.055	
	[income_code =3.00]	0^a			0		
	[info_acces_code =1.00]	-0.506	1.343	0.142	1	0.706	
	[info_acces_code =2.00]	-1.372	1.296	1.122	1	0.290	
	[info_acces_code =3.00]	0^a			0		

rameters are equal in each category. With this assumption satisfied, the next step is to examine the goodness-of-fit measures of the model. The probabilities associated with the test statistics (Pearson p=0.483; Deviance p=1.000) are greater than 0.05, indicating that the model fits well with the data. The goodness-of-fit of the model is also examined through R^2. R^2 indicates the percentage of the dependent variable explained by the independent variables. In the analysis, the Cox and Snell R^2 value is 0.197, while the Nagelkerke R^2 value, which overcomes the limitations of the former, is relatively high at 0.325. Additionally, the McFadden R^2 value is 0.235.

The significance of the model's parameters was evaluated based on the probability values. In this model, there are a total of 7 independent variables. To interpret these variables, the probability values, which are associated with the Wald Test for testing the significance of parameters, were examined. Only the variables with probability values less than 0.05 (statistically significant variables) were interpreted. However, before interpreting the estimated parameter values, these values were transformed by taking the exponent of "e" to facilitate interpretation (Kokthi *et al.*, 2015).

The ordinal logistic regression test is based on the principle of selecting a reference category and interpreting other categories relative to this reference category. In this study, the highest level of CFITU was chosen as the reference category. Similarly, for the independent variables, the last categories were selected as the reference categories. Therefore, the interpretations were made based on these reference categories using odds ratios. The odds ratios were calculated, and the model prediction results are presented in Table 12.

According to the data in the Table 12, out of the 7 independent variables, 3 of them (education, experience, agricultural income) are statistically significant at the $p<0.05$ level. Therefore, these 3 variables have been interpreted with their significant categories.

Education Level: This variable represents the education levels, and the reference category for this variable is the 7th and last category, "master's and above", where farmers have higher levels of CFITU. Looking at the estimate values of the education categories in Table 12, it can be observed that as the education level of farmers in sheep farming enterprises increases, the rates of using climate-friendly innovative technologies also increase. This result can be interpreted as higher education levels being associated with increased awareness of climate change and a higher inclination to adopt climate-friendly innovative technologies to adapt to the changes.

Experience: When looking at Table 12, it can be said that farmers with 11-15 years of experience have approximately 9.685 times higher CFITU levels compared to farmers with 30 years and more experience. Based on these results, it can be observed that young sheep farmers with more than 10 years of experience tend to have higher tendencies in using climate-friendly technologies compared to relatively older sheep farmers, generally aged 55 and above, with 30 years and more experience.

Agricultural Income: The reference category for this variable is farmers with agricultural income "above $100,000". Significant differences can be observed in the income group with agricultural income "below $20,000", where sheep farming enterprises with lower agricultural income have much lower CFITU levels compared to the reference category of those with agricultural income above $100,000. The main reason for this difference is the potential additional cost associated with the establishment and implementation of climate-friendly innovative technologies in sheep farms.

4. Conclusions

As a result of the study, 10 of the sheep farms that made the survey fall into the enterprise class that uses high-level climate-friendly innovative technology. Within the scope of the study, these farmers were named as "climate-friendly smart farmers". The rate of climate-friendly smart farmers remained at a very low level at 6.62%. Similarly, the rate of the number of enterprises at low level is as low as 5.96%. The rate of those who use moderately climate-friendly innovative technology is as high as 87.42%, which is promising for the future. Medium-level enterprises can be transformed into climate-friendly smart farmers with necessary extension studies and support.

During the application of the Ordinal Logistic Regression Analysis, the dependent variable was the level of using climate-friendly innovative technologies (CFITU), and the independent variables education, perception level, experience, livestock presence (head), total land area (da), agricultural income ($) and access to information level. The analysis results indicate that these 7 independent variables account for 32.5% (Nagelkarte R^2) of the variance in the dependent variable. When examining the categories, it can be observed that education, experience, and agricultural income have a significant impact on the CFITU level. The test results indicate a significant increase in the level of using climate-friendly innovative technologies as the education level of sheep farms increases. Sheep farms with low agricultural income have significantly lower investment and utilization rates in climate-friendly innovative technologies compared to those with high agricultural income. The test results also show that sheep farms with more than 10 years of experience have significantly higher levels of using climate-friendly innovative technologies compared to those with over 30 years of experience.

In order to minimize the negative effects of climate change on the agricultural sector, to take precautionary measures and to raise awareness of the agricultural sector on climate change adaptation and mitigation; universities, Ministry of Agriculture and Forestry, relevant institutions and organizations, farmers, farmer representatives, NGOs should develop strategies to enable farmers to use smart practices for adaptation by addressing the issue of climate change together. While there is a need to conduct a comprehensive extension study for each smart application method evaluated under six headings, priority should be given to studies on energy, nutrient and weather friendly smart technology applications where average scores are low.

Climate change, environment, biodiversity and sustainable agriculture are the priority topics within the scope of harmonization with the European Green Deal. These issues are also included as a separate heading in the Eleventh Development Plan of the Republic of Turkey. The Eleventh Plan emphasizes the creation of an efficient, environmentally sustainable agricultural sector *based on advanced technology*. In this context, it will be possible to include climate-friendly smart application technologies as a separate title among the many support tools currently implemented in the field of agriculture and to accelerate their spread with the financial support to be provided.

When we look at CSA technologies, it is clear that these technologies are readily accessible both globally and in our country. Here, the issue is not so much the accessibility of technologies but rather the awareness of the problem (farmers' awareness of climate change and their ability to adapt, which requires education), as well as financial factors. The primary responsibility here lies with national leaders and policymakers. Within the framework of the European Union's green economic development strategy and our country's sustainable agriculture policy, policies that promote digitalization in agriculture and the use of CSA technologies should be developed and urgently implemented.

Acknowledgements

This article has been prepared by making use of the project numbered 121K885, "Determination of Typology of Sheep Enterprises in the Scope of Climate Change Perception and Adaptation, and Comparison of Resource Use Efficiency by Types of Enterprises", supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK).

References

Akın H.B., Şentürk E., 2012. Bireylerin mutluluk düzeylerinin ordinal lojistik regresyon analizi ile incelenmesi-Analysing levels of happiness of individuals with ordinal logistic analysis. *Öneri Dergisi*, 10(37): 183-193.

Ardakani Z., Bartolini F., Brunori G., 2019. Economic modeling of climate-smart agriculture in Iran. *New Medit*, 18(1): 29-40.

Ashraf M., Routray J.K., 2013. Perception and understanding of drought and coping strategies of farming households in north-west Balochistan. *International Journal of Disaster Risk Reduction*, 5: 49-60.

Ata M., Altarawneh M., Al-Masad M., 2021. Climate change perceptions and adaptations for dairy cattle farmers in Jordan: Case study in North East Region-Al-Dhulel Area. *New Medit*, 20(2): 97-105.

Azadi Y., Yazdanpanah M., Mahmoudi H., 2019. Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: Evidence from wheat growers in Iran. *Journal of Environmental Management*, 250: 109456.

Azumah S.B., Adzawla W., Osman A., Anani P.Y., 2020. Cost-benefit analysis of on-farm climate change adaptation strategies in Ghana. *Ghana Journal of Geography*, 12(1): 29-46.

Barnes A.P., Toma L., 2012. A typology of dairy farmer perceptions towards climate change. *Climatic Change*, 112(2): 507-522.

Biró K., Szalmáné Csete M., Németh B., 2021. Climate-Smart Agriculture: Sleeping Beauty of the

Hungarian Agribusiness. *Sustainability*, 13(18): 10269.

Cebeci İ., Demirkiran O., Doğan O., Sezer K.K., Öztürk Ö., Elbaşi F., 2019. Türkiye'nin iller bazında kuraklık değerlendirmesi. *Toprak Su Dergisi*, Special issue: 169-176.

Chedid M., Tourrand J.-F., Jaber L.S., Hamadeh S.K., 2018. Farmers' perception to change and adaptation strategies of small ruminant systems in the West Bekaa of Lebanon. S*mall Ruminant Research*, 167: 16-21.

Christensen R., 2012. *Ordinal: Regression Models for Ordinal Data*. R Package, Version 2011.08-11.

Daly-Hassen H., Annabi M., King-Okumu C., 2019. Social and private profitability of tree-based adaptation options to climate change in a dryland area of Tunisia. *New Medit*, 18(2): 89-104.

Dellal İ., McCarl B.A., Butt T., 2011. The economic assessment of climate change on Turkish agriculture. *Journal of Environmental Protection and Ecology*, 12(1): 376-385.

DeLonge M.S., Miles A., Carlisle L., 2016. Investing in the transition to sustainable agriculture. *Environmental Science & Policy*, 55: 266-273.

Descheemaeker K., Zijlstra M., Masikati P., Crespo O., Tui S.H.-K., 2018. Effects of climate change and adaptation on the livestock component of mixed farming systems: A modelling study from semi-arid Zimbabwe. *Agricultural Systems*, 159: 282-295.

Ding J.H., Xu X., Yang D., Chu P.H., Dalton N.D., Ye Z., Yeakley J.M., Cheng H., Xiao R.P., Ross Jr J., 2004. Dilated cardiomyopathy caused by tissue-specific ablation of SC35 in the heart. *The EMBO Journal*, 23(4): 885-896.

Erkan O., Oğuz C., Kan A., Gültekin U., 2009. *Measuring the Effect of the Change in Climate Condition on Input Use in Agriculture in Konya*. Paper presented at the 1st International Symposium on Sustainable Development, June 9-1, Sarajevo, pp. 26-33. https://omeka.ibu.edu.ba/files/original/fb8e5d0ee7a6d7f92a0423829b18a61c.pdf.

Everest B., 2021. Farmers' adaptation to climate-smart agriculture (CSA) in NW Turkey. *Environment, Development and Sustainability*, 23(3): 4215-4235.

FAO, 2015. *The State of Food Insecurity in the World*. Rome: FAO. Accessed on 07.12.2022. http://www.fao.org/3/a-i4646e.pdf.

Foguesatto C.R., Borges J.A.R., Machado J.A.D., 2019. Farmers' typologies regarding environmental values and climate change: Evidence from southern Brazil. *Journal of Cleaner Production*, 232: 400-407.

Gauly M., Bollwein H., Breves G., Brügemann K., Dänicke S., Daş G., Demeler J., Hansen H., Isselstein J., König S., 2013. Future consequences and challenges for dairy cow production systems arising from climate change in Central Europe–A review. *Animal*, 7(5): 843-859.

Gerber P.J., Steinfeld H., Henderson B., Mottet A., Opio C., Dijkman J., Falcucci A., Tempio G., 2013. *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Godfray H.C.J., Garnett T., 2014. Food security and sustainable intensification. *Philosophical Transactions of the Royal Society. Biological Sciences*, 369(1639). https://doi.org/10.1098/rstb.2012.0273.

Görgülü M., Koluman Darcan N., Göncü Karakök S., 2009. *Goat production and global warming*. 5. National Goat Nutrition Congress, 30 September - 3 October, Çorlu, Turkey.

Hyland J.J., Jones D.L., Parkhill K.A., Barnes A.P., Williams A.P., 2016. Farmers' perceptions of climate change: identifying types. *Agriculture and Human Values*, 33(2): 323-339.

Khan M.I., Sameen A., 2018. *Animal Sourced Foods for Developing Economies: Preservation, Nutrition, and Safety*. Boca Raton, FL: CRC Press.

Khatri-Chhetri A., Aggarwal P.K., Joshi P.K., Vyas S., 2017a. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, 151: 184-191.

Khatri-Chhetri A., Poudel B., Shirsath P.B., Chaudhary P., 2017b. *Assessment of climate-smart agriculture (CSA) options in Nepal*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), New Delhi, India.

Kokthi E., Bermúdez I.V., Limón M.G., 2015. Origin or food safety attributes? Analyzing consumer preferences using Likert Scale. Empirical evidence from Albania. *New Medit*, 14(4): 50-57.

Koluman (Darcan) N., Silanikove N., Koluman A., 2017. Climate Change and Goat Agriculture Interactions in the Mediterranean Region. In: Simões J. Gutiérrez C. (eds.), *Sustainable Goat Production in Adverse Environments*, vol. I. Cham: Springer, pp. 393-405.

Koluman (Darcan) N., Silanikove N., 2018. The advantages of goats for future adaptation to Climate Change: A conceptual overview. *Small Ruminant Research*, 163: 34-38.

Lemaire G., Giroud B., Bathily B., Lecomte P., Corniaux C., 2019. Toward integrated crop-livestock systems in West Africa: a project for dairy production along Senegal river. In: Laire G., De Faccio Carvalho P.C., Kronberg S., Recous S. (eds.), *Agroecosystem Diversity*. Amsterdam: Academic Press, pp. 275-285.

Li C., Tang Y., Luo H., Di B., Zhang L., 2013. Local farmers' perceptions of climate change and local adaptive strategies: a case study from the Middle Yarlung Zangbo River Valley, Tibet, China. *Environmental Management*, 52(4): 894-906.

Liebman M., Schulte L.A., 2015. Enhancing agroecosystem performance and resilience through increased diversification of landscapes and cropping systems. *Elementa: Science of the Anthropocene*, 3: 000041.

Long T.B., Blok V., Coninx I., 2016. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *Journal of Cleaner Production*, 112: 9-21.

Masud M.M., Azam M.N., Mohiuddin M., Banna H., Akhtar R., Alam A.F., Begum H., 2017. Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. *Journal of Cleaner Production*, 156: 698-706.

McCullagh P., 1980. Regression models for ordinal data. *Journal of the Royal Statistical Society: Series B (Methodological)*, 42(2): 109-127.

MGM (Meteoroloji Genel Müdürlüğü), 2021. Accessed on 08.12.2022. https://mgm.gov.tr/veridegerlendirme/kuraklik-analizi.aspx?d=yillik#sfB.

Mutenje M.J., Farnworth C.R., Stirling C., Thierfelder C., Mupangwa W., Nyagumbo I., 2019. A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics*, 163: 126-137.

Nardone A., Ronchi B., Lacetera N., Ranieri M.S., Bernabucci U., 2010. Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science*, 130(1-3): 57-69.

Oğuz C., Çelik Y., 2020. *Technical Assistance for FADN project*. Farm Accounting Data Network (FADN) unpublished tutorials for NGOs and Farmers.

Oğuz C., Yener A., 2017. Konya İli Süt İşletmelerinin Ekonomik Faaliyet Sonuçları Ve Yenilikleri Benimseme Düzeyleri. Selçuk Üniversitesi Bilimsel Araştırma Projeleri Proje, 15401020.

Örs A., Oğuz C., 2018. The Comparison of Innovative Technology Usage Levels of Dairy Farms Supported and Non-Supported by IPARD Program; A Case Study of Konya. *Turkish Journal of Agriculture-Food Science and Technology*, 6(12): 1809-1813.

Özçatalbaş O., Gürgen Y., 1998. *Tarımsal Yayım ve Haberleşme*. Adana: Baki Kitabevi, 385 pp.

Polat K., Dellal İ., 2016. *İklim Değişikliği İle Mücadele Ve Uyumda Tarımın Rolü*. 12. Ulusal Tarım Ekonomisi Kongresi, Isparta.

Ramborun V., Facknath S., Lalljee B., 2020. Moving toward sustainable agriculture through a better understanding of farmer perceptions and attitudes to cope with climate change. *The Journal of Agricultural Education and Extension*, 26(1): 37-57.

Reilly J., Baethgen W., Chege F., Van de Geijn S., Iglesias A., Kenny G., Patterson D., Rogasik J., Rötter R., Rosenzweig C., 1996. Agriculture in a changing climate: impacts and adaptation. In: Watson R.T., Zinyowera M.C., Moss R.H. (eds.), *Climate change 1995; impacts, adaptations and mitigation of climate change: scientific-technical analyses*. Cambridge: Cambridge University Press, pp. 427-467.

Roco-Fuentes L., Engler A., Bravo-Ureta B., Jara-Rojas R., 2015. Farmers' perception of climate change in mediterranean Chile. *Regional Environmental Change*, 15: 867-879.

Rogers E.M., 1995. Diffusion of Innovations: Modifications of a model for telecommunications. In: Stoetzer Mw., Mahler A. (eds.), *Die Diffusion von Innovationen in der Telekommunikation*. Berlin-Heidelberg: Springer, pp. 25-38.

Rojas-Downing M.M., Nejadhashemi A.P., Harrigan T., Woznicki S.A., 2017. Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, 16: 145-163.

Saj S., Torquebiau E., Hainzelin E., Pages J., Maraux F., 2017. The way forward: An agroecological perspective for Climate-Smart Agriculture. *Agriculture, Ecosystems & Environment*, 250: 20-24.

Sejian V., Kumar D., Gaughan J.B., Naqvi S.M., 2017. Effect of multiple environmental stressors on the adaptive capability of Malpura rams based on physiological responses in a semi-arid tropical environment. *Journal of Veterinary Behavior*, 17: 6-13.

Somda J., Zougmoré R., Sawadogo I., Bationo B.A., Buah S., Abasse T., 2017. Adaptation processes in agriculture and food security: Insights from evaluating behavioral changes in West Africa. In: Uitto J., Puri J., van den Berg R. (eds.), *Evaluating climate change action for sustainable development*. Cham: Springer, pp. 255-269.

Speedy A.W., 2003. Global production and consumption of animal source foods. *The Journal of Nutrition*, 133(11): 4048S-4053S.

Steffen W., Richardson K., Rockström J., Cornell S.E., Fetzer I., Bennett E.M., Biggs R., Carpenter S.R., De Vries W., De Wit C.A., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223). DOI: 10.1126/science.1259855.

Steinfeld H., 2003. Economic constraints on production and consumption of animal source foods for nutrition in developing countries. *The Journal of Nutrition*, 133(11): 4054S-4061S.

Tarawali S.A., Enahoro D.K., Pfeifer C., 2018. *Food of animal origin: Demand and diversity*. Presented at the Expert panel: "Food of Animal Origin 2030: Solutions to Consumption Driven Challenges", Global Forum for Food and Agriculture, Berlin, Germany, 18 January 2018. Nairobi, Kenya: ILRI.

Tilman D., Fargione J., Wolff B., D'Antonio C., Dobson A., Howarth R., Schindler D., Schlesinger W.H., Simberloff D., Swackhamer D., 2001. Forecasting agriculturally driven global environmental change. *Science*, 292(5515): 281-284.

Tripathi A., Mishra A.K., 2017. Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, 16: 195-207.

Uitto J., Puri J., van den Berg R., 2017. Evaluating climate change action for sustainable development: Introduction. In: Uitto J., Puri J., van den Berg R. (eds.), *Evaluating Climate Change Action for Sustainable Development*. Cham: Springer, pp. 1-12.

Velempini K., Smucker T.A., Clem K.R., 2018. Community-based adaptation to climate variability and change: Mapping and assessment of water resource management challenges in the North Pare Highlands, Tanzania. *African Geographical Review*, 37(1): 30-48.

West J., Salter A., Vanhaverbeke W., Chesbrough H., 2014. Open innovation: The next decade. *Research Policy*, 43(5): 805-811.

Wetende E., Olago D., Ogara W., 2018. Perceptions of climate change variability and adaptation strategies on smallholder dairy farming systems: Insights from Siaya Sub-County of Western Kenya. *Environmental Development*, 27: 14-25.

Yamane T., 1967. *Elementary Sampling Theory*, 1th ed. Englewoods Cliffs, NJ: Prentice Hall, 405 pp.

Treatment and reuse of water: Economic feasibility and assessment of water pricing policies in Ouardanine irrigation district (Tunisia)

Bechir Nawar*, Alessandra Scardigno*,
Juan Antonio Sagardoy*

DOI: 10.30682/nm2401e
JEL codes: D61, Q1, Q25

Abstract

Treated wastewater reuse is a valuable water source in water scarcity conditions. If its technical feasibility is largely demonstrated, less attention is paid to the economic assessment. By applying an ex-post Cost-Benefit Analysis to Ouardanine irrigation district, in eastern Tunisia, the economic feasibility of wastewater treatment and reuse in irrigation was assessed. Data on costs and benefits were evaluated throughout the lifespan of the project and four scenarios - no treatment, treatment, treatment with reuse, and treatment with reuse without considering the environmental benefits – were considered. The results prove that: the project is economically profitable for all scenarios except the first; it is still profitable with an increase in costs or a decrease of benefits up to 30%; farmers are the main beneficiaries of the project which is financially not viable for both the treatment plant company and the public body charged of the distribution of water; the affordability of the treated wastewater price depends on the cropping pattern: with increased water pricing peach growers will still have substantial benefit while olive growers will reduce significantly their benefits.

***Keywords**: Cost-Benefit Analysis, Wastewater reuse, Wastewater treatment plan, Economic feasibility, Irrigation water pricing, Irrigation system.*

1. Introduction

Reusing water is a valuable solution to stop the loop between water supply and wastewater disposal, turning what was formerly deemed trash into a resource after the necessary treatment (Urkiaga *et al.*, 2008). Reusing water for irrigation has the benefit of providing water and the needed nutrients associated with crop development, and it may replace the usage of fertilizers, which is quite expensive (Alobaidy *et al.*, 2010). Wastewater irrigation can therefore help to lessen environmental carbon emissions while also reducing water shortages and saving money on disposal and pumping expenses (Hanjra *et al.*, 2012). Reusing recovered wastewater is a particularly enticing alternative in these ecolog-

* CIHEAM - International Center for Advanced Mediterranean Agronomic Studies, Mediterranean Agronomic Institute of Bari, Italy.
Corresponding author: scardigno@iamb.it

ically conscious times (Mujeriego *et al.*, 2008) and, to develop strategies to meet the regulatory criteria for direct reuse of recovered wastewater in agricultural, industrial, or urban uses, several wastewater treatment systems have been examined (Meneses *et al.*, 2010).

However, wastewater treatment and management are costly and present challenges in terms of funding (Fernandez *et al.*, 2009) mainly because the benefits of wastewater treatment are less evident to individuals and more difficult to assess in monetary terms. Identifying and evaluating external advantages, which are typically immeasurable, is quite complex. Although several practical approaches and frameworks have been proposed, none are complete or accurate (Kihila *et al.*, 2014). The economic value of these projects is sometimes underestimated due to a failure to adequately account for and quantify the various non-monetary advantages of water reuse (e.g., watershed conservation, local economic growth, and public health improvement) (Godfrey *et al.*, 2009). With the aim of economically evaluating wastewater treatment, this paper will present a scheme to assess the economic feasibility of the "Ouardanine wastewater treatment and irrigation district project" taking both internal and external impacts into consideration. The specific objectives of the present work are to evaluate the economic viability of the wastewater Treatment Plant and irrigation system of Ouardanine under different assumptions and to learn lessons for similar cases in Tunisia.

Estimating the profitability of a public project, such as wastewater treatment plants and water reuse, should be addressed to determine whether the country makes a profit with the planned investment. Therefore, the economic analysis takes a broader view of the project's profitability where external effects such as environmental and health impacts are included, and international prices are applied. For this purpose, by applying the Cost Benefit Analysis (CBA) methodology, we will determine the economic value of the environmental benefits and search for water pricing policies that contribute to a more efficient O&M of the irrigation system and the Waste Water Treatment Plant (WWTP). Although the literature on CBAs of planned or existing reuse project is rather sparse, CBA is now recognized by many researchers as the most suitable appraisal tool of reuse projects (Acampa *et al.*, 2019; Arena *et al.*, 2020).

Of course, since wastewater treatment and reuse projects are either implemented to increase water availability and its use and to enhance the environment or both an improved and extended CBA have recently been intensified by explicitly including environmental costs and benefits.

The technical solutions for those projects are available and well developed, but they come with a huge financial demand since they are very expensive to implement (Fernandez *et al.*, 2009). In general terms, the costs of the investments are well known but not so much the benefits, particularly in the case of environmental benefits where different approaches prevail (Chen and Wang, 2009; Godfrey *et al.*, 2009; Hernández *et al.*, 2006; Molinos-Senante *et al.*, 2010; Ćetković *et al.*, 2022). Previous research focus on water reuse for environmental purposes (Birol *et al.*, 2010; Chen et Wang, 2009; Kihila *et al.*, 2014; Molinos-Senante *et al.*, 2010; Verlicchi *et al.*, 2012) while economic and financial feasibility evaluations are often missing especially when the reuse in irrigation is the main option.

The project's overall performance is mainly evaluated by (European Commission, 2015) three indicators: the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Cost-Benefit Ratio (BCR). The CBA's greatest aspect is that it makes it easier to compare different types of costs and benefits, giving evidence for decision-makers to choose the water reuse plan that is most likely to generate the largest net benefits. In this approach, all costs and benefits must be stated in monetary terms, allowing for comparing cost and benefit items of changeable nature (for example, project market and nonmarket benefits) (Winpenny *et al.*, 2010).

2. Treated wastewater in Tunisia

With an area of 16.361 million hectares, Tunisia is in a semi-arid to an arid climate zone (ONAS, 2017) and is increasingly facing years of drought caused or exacerbated by climate change with both years of heavy rains causing violent floods, and droughts (Benabdallah, 2007).

The long-term average annual rainfall is 207 mm, with inter-annual variance ranging from 70 to 620 mm. Rainfall varies widely across the country, with 600 mm in the north, 300 mm in the middle, 150 mm in the south, and less than 100 mm in the extreme southwest. Tunisia's water resources are projected to be 4700 Mm^3, with 650 Mm^3 of non-renewable resources accounting for 13.8% of total water resources. As a result, in 2015 the annual endowment per capita is around 450 m^3 which is below the absolute water shortage criterion (Drechsel and Hanjra, 2018) and will be 315 m^3 per capita per year in 2030. Annual water consumption in Tunisia is distributed between irrigated agriculture 2,080 Mm^3, drinking water 365 Mm^3, industry 130 Mm^3 and tourism 25 Mm^3. The country will shortly be confronted with a water deficit between its consumptive uses and its water productivity which is pushing the government to turn to non-conventional waters.

The main responsible for WWTP development is the Office National de l'Assainissement, (ONAS). It operates about 115 wastewater treatment plants, only 66 are active. There are essentially (2/3) activated sludge treatment plants with low load and prolonged aeration, 7% use activated sludge with medium load, 12% use lagoons, as well as small rural plants and two wastewater treatment plants for industrial discharges. The flow of wastewater treated, is approximately 905,000 m^3/d, or nearly 330 Mm^3/year.

The reuse of treated water started in Tunisia in 1965 with the project of the irrigated perimeter (IP) of Soukra and Oued Souhil where surface wells were no longer able to satisfy farmers' water needs, causing overexploitation and salinization. New IPs emerged between the 80s and 90s in greater Tunis, the governorate of Sousse, and Sfax. Subsequently, other projects were created in the interior areas and the country's south. Between the 70s and 80s treated wastewater reuse (TWWR) projects also emerged for watering golf courses and green spaces. TWWR in irrigation is considered a necessity and is an integral part of the National Strategy for the Rationalization of the Use of Hydraulic Resources initiated simultaneously with the first Ten-Year Water Mobilization Strategy (1990-2000).

The treated water is allocated by 53% indirect or ecological use (wetlands, groundwater recharge, etc.), 33% in irrigated area, 12% for golf courses and 2% green spaces. 20,3 Mm^3 of treated wastewater is reused for irrigation which only meets 1% of the needs of irrigated agriculture (ONAS, 2017). The Irrigated area has continuously increased since 1965 (ONAS, 2017) and during the 2015-2016 campaign the irrigable area using treated wastewater was 8,474 of which 32% was irrigated. The most significant areas are: Borj Touil and Mornag in the North and Dhraa Tamar in Kairouan, in the Center and El Hajeb in Sfax in the South. The crops grown are mainly fruit trees (45% of the total area), especially olive trees, and fodder (51%), field crops represent only 4% of the surface (ONAS, 2017). Water reuse in the irrigation of green spaces and golf courses remains very limited. In the tourism sector, there are a few cases of TWWR to water the green spaces of hotels in the touristic area of Sousse and Djerba. The reuse of treated wastewater in the industry is minimal.

The governance of the TWWR involves state institutions, with a central role in the decision-making process, regardless of its use i.e. agricultural, green space (tourist and municipal), golf, and groundwater recharge, research, donors, industrialists, user groups as well as civil society associations established at the regional level complete the panorama (ONAS, 2017). The Ministry of Public Health and the National Agency for Sanitary and Environmental Control of Products (ANCSEP) are responsible for the sanitary control of water (drinking water, mineral water, raw and treated wastewater and bathing water). The Ministry of Agriculture, Water Resources and Fisheries, – the institution responsible for administering the hydraulic public domain and plans the mobilization and allocation of water resources – through several directorates-general and supervisory structures have specific attributions to the TWWR (ONAS, 2017): in particular, the Regional Commissariats for Agricultural Development (CRDA), are responsible for the implementation of the agricultural policy adopted by the government. They carry out water and soil conservation missions, distribution of agricultural water, management of hydraulic equipment. In the irrigated perimeters, the CRDA is responsible for the distribution of the wastewater to irrigated agricultural areas, the monitoring and maintenance of all hydraulic equipment, the application of the water code, the collection of fees, operation of public irrigated areas and the quality control of TWWs. Finally, the National Sanitation Office (ONAS), an industrial and commercial public establishment endowed with legal personality and financial autonomy created in 1974 to ensure the management of the sanitation sector in Tunisia. In 1993, ONAS's mission has shifted from a sanitation network manager to that of the leading player in water environment protection and the fight against all sources of pollution. ONAS carries out self-monitoring of its water's microbiological and chemical quality throughout the purification process. This regular monitoring targets both environmental discharge standards and TWWR standards. ONAS can rely on regional sanitation offices to carry out these missions in the governorates. In 1975 the use of treated wastewater was regulated with the publication of the Water Code (Law No. 75-16 of March 31, 1975) that reaffirms the hydraulic public domain, provides measures regarding the pollution of surface and underground waters, prescribes general provisions for the treatment of wastewater and the regulation of discharges into the environment and prohibits the use of raw wastewater and the irrigation of market garden crops with treated wastewater (ONAS, 2017). In 1985, wastewater discharges into the receiving environment were regulated and in 1989, a decree (No. 89-1047 of July 28, 1989) set the conditions for the use of treated wastewater for agricultural purposes and the decision-making process between the various ministries in charge of hydraulic production, health control, and environmental. The use of treated wastewater for agricultural purposes must be authorized by the Minister of Agriculture, issued after approval by the Minister of Public Health, and advice from the National Environmental Protection Agency. Two standards developed based on FAO and WHO recommendations were also published that same year on environmental protection and effluent discharges into the water environment and the quality of TWWs reused for agricultural purposes with physicochemical and biological specifications (ONAS, 2017). From 1991, irrigation projects using treated wastewater must comply with decree no. 91-362 of March 1, 1991, regulating the procedures for drawing up an impact study which must be approved by ANPE. In 1993, ONAS passed from the role of manager of the sanitation network to that of the leading player in protecting the water environment and the fight against all sources of pollution. To this end, it is responsible for promoting the distribution and sale of treated water, sludge from treatment plants, and all other by-products. Decree No. 93 R 2447 of December 13, 1993**,** extends the powers of distributing organizations that are now responsible for part of the analyses (ONAS, 2017). In 1994, a decree of the Minister of Agriculture fixed the list of crops that can be irrigated by treated wastewater, including industrial crops (cotton, tobacco, flax, jojoba, castor oil), cereals (wheat, barley, oats), fodder (maize, sorghum), fruit trees (date, lemon, vine), fodder trees, forest trees, floral and aromatic crops. In 1995**,** the terms and conditions for using treated wastewater were set providing a series of prevention and control measures for farmers, with analyses to be carried out by public or private laboratories. In 2002, a new standard (NT 106.20) was drawn up to regulate the use of sewage sludge from urban wastewater treatment works as fertilizer. There is currently no legal framework for other benefits of TWW (aquifer recharge, golf courses, green spaces, industry, etc.). Tunisia is in the process of revising its reuse standards to reflect the broader applications of treated wastewater.

3. Materials and methods

3.1. *The study case of OUARDANINE TWWR system*

Ouardanine WWTP is one of the Tunisian WWTP dedicated to irrigation systems. The city of Ouardanine belongs to the governorate of Monastir located about 160 km south of the capital and lim-

Figure 1 - Location of Tunisia, Monastir governorate, district of Ouardanine.

ited to the northeast by the Mediterranean, to the northwest by the governorate of Sousse, to the west by the governorate of Kairouan, and to the south by the governorate of Mahdia (Figure 1). Currently, the population of Ouardanine totals 21,814 people, divided into 6,312 homes. Because the region has a semi-arid environment, it has a water deficit of 1,000 mm per year. The salty (4.3 g/L) and overexploited (110 percent) Sahline-Ouardadine aquifer underneath the area is no longer usable for irrigation (Mahjoub *et al.*, 2016) and, although agricultural activity is centred on dry farming, wastewater reuse is the best alternative water supply for supporting the development of a more intensive and productive irrigated agriculture (Vally Puddu, 2003).

Ouardanine has long experienced the negative impacts of discharging untreated sewage into the Oued Guelta stream, resulting in the rural area's degradation (CRDA, 2014). The lack of economic possibility combined with the environmental deterioration encouraged many locals to leave the area. Based on the farmers' request, the ONAS and the Ministry of Agriculture and Water Resources subcontracted a study to treat the used water and then use it in an irrigation scheme as part of the national water reuse program. The CRDA of Ouardanine developed the irrigation scheme with the farmers regrouping in a formal water user organization the *Groupement de Développement Agricole* (GDA) responsible for site selection, land rights decisions, and plant culture selection, while ONAS built the treatment system. This has made it possible to lower farmers's resistance to use recycled water.

The WWTP was completed in 1993 and gathered 17,000 people's effluents with a treatment capacity of 1000 m^3/d and 600kg of Biological oxygen demand (BOD) per day (ONAS, 2022). It uses an oxidation pond treatment technology to function. Currently, the plant treats 17500m^3/year (GDA, 2022).

The WWTP is composed of (ONAS, 2022) a lifting station at the head of the treatment plant, a pre-treatment structure consists of two non-aerated static grit channels followed by two automatic fine screening channels, a static de-oiling, a contact well, a "carousel" design oxidation channel equipped with a surface aerator, a circular clarifier, a lifting station, with an Archimedean screw, returns the sludge to the contact well, a station for removing excess sludge to the thickening stage, an harrowed static thickener, a set of natural drying beds for thickened sludge. In addition, the existing wastewater treatment plant in the city of Ouardanine is equipped with

Table 1 - Evolution of treated wastewater and irrigated land.

Year	*2002*	*2006*	*2014*	*2022*
Treated water (m^3/day)	200	500	500-1,500	1,000-1,500
Irrigated area (ha)	23	48	74	72.99
Total treated water (m^3)	6,968,000			

Source: CRDA, 2014 and GDA, 2022.

a gauging channel for measuring flow rates, a drainage network for internal water, a closing service building of transformer station, offices, store, workshop, room for workers, changing rooms, showers, and toilets. The irrigated area of Ouardanine, established in 1994, is currently of 74 ha of which 72.99 ha are used and the number of beneficiaries increased to 42. Table 1 provides an overview of the time evolution of the treated wastewater and the irrigated land.

The irrigation scheme is composed of one pumping station, one reservoir with a capacity of 1000 m^3, the water distribution network, 21 hydrants and the control and monitoring system. In 2007, a 500 m^3 storage basin was built upstream the perimeter, about 5 m high, to ensure gravity distribution of TWW to the irrigated land. The quality of TWW transferred into the basin caused sediment to settle and irrigation systems to block and difficulties in cleaning up the basin have produced environmental problems (CRDA, 2014).

In 2007, the CRDA built a 1,000 m^3 storage basin to control the quantity of TWW released to the irrigated area, to adjust the daily irrigation demand to the 16-18 hours functioning of the WWTP and to improve the TWW's quality by enabling suspended material to settle and microbes to die off. CRDA of Monastir manages the irrigated perimeter IP where they are responsible for the distribution of wastewater to irrigated land, maintenance and monitoring of hydraulic equipment, operation of irrigation channels and their rehabilitation, care of the pumping station and filtration station; quality control of TWW, collection of water fees from the GDA, training to the farmers.

The GDA of Ouardanine, is composed of 42 farmers, and charged with the collection of water fees, small maintenance of water facilities, coordination between the farmers and the authorities.

The Ouardanine WWTP is managed by the Regional Direction of Monastir of the ONAS. The main missions of the office are the collection of waste water, monitoring the quality of the TWW, the management, operation, maintenance, renewal and construction of any for urban sanitation work, the collection of water disposal fees from the inhabitants of the region, the treatment of waste water, the management, operation, maintenance, rehabilitation and construction of any work intended for the WWTP, the free distribution of purified water to the CRDA, the free supply of sludge to farmers.

Planted crops consist mainly of fruit trees covering about 70 ha, 34 ha of peaches, 10 ha of pomegranates, figs, apples, and medlars, 11 ha of olive trees, 15 ha for supplementary irrigation for olive seedlings, forage crops like alfalfa and barley are grown as well only 2 ha (GDA, 2022).

A 2.3-kilometer irrigation network has been installed to irrigate cereal and fodder crops with furrow irrigation while for permanent crops farmers adopted drip irrigation techniques more than 15 years ago with a discharge of 4L/h to ensure optimum quality and output of peaches (Mahjoub *et al.*, 2008). Irrigation systems are seen as an effective approach to protect soil, crops, and end-users from chemical and biological pollution, as well as a health precaution. Notwithstanding these efforts to use irrigation water efficiently, most of the crops suffer from a moderate water stress since available resources are not sufficient to fully meet crop water requirements.

The government provides incentives to farmers who adopt water-saving practices. When transitioning from classic irrigation techniques like furrow irrigation to more water-saving technologies (sprinklers or drip), up to 60% of the irrigation system's investment cost are subsidized (GDA, 2022).

Together with incentives several constraints also act over the development and appropriate functioning of the project. They are economic, such as the high expense of wastewater treatment and the limited availability of funding for the maintenance; technical, such as droplet blockage due to high suspended matter, poor utilization of available water resources, poor storage capacity; deteriorating water quality from the purification station, need to expand the irrigated area, failure to respond to the water needs of crops when there are damages in the disinfection station; social, such as the reluctancy to buy fruits and vegetables irrigated by treated wastewater (Saliba *et al.*, 2018). Also, the inhabitants of the region demand those products to be less expensive than those irrigated with conventional water. Another important factor is the lack of coordination between the CRDA and ONAS resulting in the water not being provided according to the need of the farmers.

3.2. *The Cost-Benefit Analysis*

Wastewater treatment projects are implemented to both increase water availability and to improve and protect the environment. For this reason, both an economic analysis and a financial analysis will be performed to evaluate both the national budget and that of the different stakeholders.

A comparison between a reference scenario – without the project – and the project alternative is performed using the CBA approach. The study covers the entire duration of the project considering that the WWTP was built in 1993 while the IS was constructed in 1997 and assuming that the construction of the WWTP and the IS has been completed in one year and that Operation and Maintenance costs (O&M) begin in the second year.

Therefore, this economic analysis is an "ex-post evaluation" to assess the economic results of the operation of the WWTP after 29 years of service. This type of analysis has the advantage that uses real data and therefore the results are more reliable than when assessing the current value of future developments. "In principle ex-post CBA shall be performed exactly as an ex-ante but using historical rather than forecasted data. However, far from being as straightforward as apparently it would look like, performing an ex-post CBA raises several interesting methodological issues" like, for example, the choice of an appropriate reference scenario (Florio and Vignetti, 2013) which have been taken into account in this paper. All the benefits and costs have been converted from the Tunisian Dinars (TDN) into USD using the average conversion rate of each year of the project life.

Economic analysis and financial evaluation of the projects both involve identifying project benefits and costs in the years in which they occur and converting all future cash flows to their present value using the technique of discounting. However, the perspectives and objectives of the two analyses differ.

The financial evaluation is carried out from the perspective of the project investor and considers incremental cash flows (both revenues and costs) generated by the project. The purpose of financial evaluation is to assess the ability of the project to generate adequate cash flows to recover its financial costs (capital and recurrent costs) without external support. On the other hand, economic analysis is carried out from the perspective of the entire country's economy, and it assesses overall impact of a project on the welfare of all the citizens of the country concerned. Indirect effects and externalities – both positive and negative - should be identified, evaluated, and included in the analysis since the purpose of project economic analysis is to assess whether a project is economically viable for the country.

3.2.1. *Determination of costs and benefits*

Relevant data were collected throughout multiple meetings with CRDA, ONAS, and GDA and local farmers in the region of Ouardanine, Monastir, Tunisia during a field data collection campaign which lasted one month (from 26 February 2022 to 26 Mars 2022) aimed at describing all the events that happened during the lifespan of the project and the costs and benefits associated to them (Table 2). These data were used to calculate the costs and benefits of the main physical structures or organizations involved in the process.

3.2.1.1. Environmental benefits

Environmental benefits are calculated using the shadow price approach developed "to assess internal (which is easy to monetize) but also external economic impacts" (Ćetković *et al.*, 2022; Molinos-Senante *et al.*, 2011 and 2012). The shadow price is the monetary value assigned to an abstract or intangible commodity which, not traded in the market, must be included in an economic evaluation (Sartori *et al.*, 2014). They are mainly used to take into account the numerous market distortions while their use for determining the environmental benefits is a relatively new approach that still has been used little.

Shadow prices can be used to quantify the environmental benefits and costs of wastewater treatment (Molinos-Senante *et al.*, 2011 and

Table 2 - Costs and benefits associated to the main components of the project.

Main components	*Costs*	
	Investments costs	*Annual recurrent costs*
WWTP	Investments in physical works, land, and administrative Major improvements	Fix and variable annual costs
Irrigation system	Investment in irrigation network. Pumping station, reservoir, hydrants	O&M costs of the irrigation system
On-farm Cost	All investments considered depreciated since farm investments are older than 10 years	The total cost of production are calculated according to standard practices based on local information
Main components	*Benefits*	
WWTP	Subscription fee paid by the inhabitants of the Ouardanine region. Environmental Benefits	
CRDA	Annual subscription + Fee collection (The CRDA collects water for free from the WWTP and sells it to the GDA)	
CDA	Annual subscription + Fee collection resulting from selling the water to farmers	
On farm benefits	The benefits are calculated based on the production quantity and crop prices	

2012), thus reflecting actual values of inputs and products that may differ from market values. In some studies (Molinos-Senante *et al.*, 2011), calculated as the costs of not removing basic wastewater pollutants such as nitrogen (N), phosphorus (P), suspended particles (SP), Biological oxygen demand (BOD) and chemical oxygen demand (COD) – shadow prices "actually represent the avoided damages/costs, i.e. the benefit/income realized for the environment as a result of the removal of pollutants during treatment in the sewage treatment plant. The difference between pollution costs for wastewater and pollution costs for treated water represents the savings achieved in the cost of pollution, i.e., the environmental benefits" (Ćetković *et al.*, 2022).

To our knowledge there is no studies that investigate the monetary value of water treatment environmental benefits in Tunisia, but also in many of more developed countries. For the computation of the environmental benefits this paper takes the recommendations from relevant studies (Ćetković *et al.*, 2022) using shadow prices developed by (Hernández-Sancho *et al.*, 2015) and those based on previous studies (Molinos-Senante *et al.*, 2011). The shadow prices used in this study are reflected in Table 3.

The original values in EURO were converted to USD on 7/18/2022.

To compute the environmental benefits, the quantity of removed pollutants will be first calculated and then, using the value of shadow prices of the main pollutants in water presented in the Table 3, we will attribute a monetary value to them.

3.2.2. *Choice of the discount rate*

In CBA, future cash flows are discounted at the chosen discount rate to obtain the present value (PV) of a future sum of money or stream of cash flows: the higher the discount rate,

Table 3 - Shadow prices of the main pollutants in water.

	Phosphorus	*Nitrogen*	*COD*	*Suspended Particles*	*BOD*
Shadow prices USD/kg	83.75	35.73	0.21	0.01	0.03

Source: Ćetković et al., 2022.

the lower the present value of the future cash flows. Determining the appropriate discount rate is the key to properly valuing future cash flows. The discount rate can refer to both the interest rate that national and international financial institution's set for short-term loans or to most complex evaluation that tries to reflect the social view on how future benefits and costs should be valued against present ones (Sartori *et al.*, 2014). For example, in the context of climate change policymaking, the choice of the discount rate is considered very important for working out how much today's society should invest in trying to limit the impacts of climate change in the future; it is usually considered between 2% and 3%. To discount a monetary flow, the following formula is used.

$$V_i = \sum_{j=0}^{n} \left(F_j * \left(\frac{1}{(1+r)_j}\right)\right)$$

where: Vi = current value of the project; Fj = monetary flows at the nth year; r = discount rate; n = time frame of the project.

In this paper, we will use actualization which mean that we will use the present value of payment that have been made in the past to help us understand the importance of the costs and benefits and for that we will use the following formula:

$$V_i = \sum_{j=0}^{n} \left(F_j * (1+r)^j\right)$$

where r, is given by the annual discount rate selected.

Given the difficulties in finding the trend of official discount rates in Tunisia, we decided to consider the inflation rate of the currency adopted as a proxy for the discount rate (Table 4).

3.2.3. *CBA indicators*

Two indicators are evaluated: the NPV and the BCR. The first one determines the potential profitability of projects It is the difference between the present value of cash inflows and the present value of cash outflows over a period.

$$NPV = B_i - C_i$$

where: $C_i = IC_i + AOM_i$; $B_i = R_i + E_i$; B_i = initial accumulation of benefits (benefit present value); C_i = initial accumulation of costs (cost present value); IC_i = Investment cost; AOM_i = accumulation of annual O&M costs; R_i = accumulation of annual revenue; E_i = accumulation of environmental benefits expressed in monetary terms.

The investment is cost-effective when:

$$NPV > 0$$

The second one, the benefit cost ratio (BCR), is a dimensionless number that reflects the importance of the benefits compared to the costs.

$$BCR = B_0/C_0$$

where: B_0 = initial accumulation of benefits (benefit present value); C_0 = initial accumulation of costs (cost present value).

The investment is cost-effective when:

$$BCR > 1$$

All the items considered have been discounted to be expressed as present monetary values.

3.2.4. *The simulated scenarios*

To better highlight the different benefits and costs generated by the project, the economic feasibility has been assessed in four different scenarios.

- Scenario 1: no-action situation. Without any

Table 4 - Inflation rate, 1994-2020.

Year	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
(%)	4.73	6.24	3.72	3.65	3.12	2.69	2.96	1.98	2.72	2.71	3.63	2.01	3.22	2.96
Year	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
(%)	4.34	3.66	3.33	3.24	4.61	5.31	4.62	4.43	3.62	5.30	7.30	6.72	5.63	5.73

Source: International Monetary Fund, International Financial Statistics and data files.

Table 5 – Benefits and costs for each scenario.

Scenario	*Cost*	*Benefits*
Scenario 1	Environmental	Opportunity cost
Scenario 2	Investment, O&M of the WWTP	Environmental; Subscriptions fees
Scenario 3	Investment, O&M of the WWTP Investment, O&M of the IS Farm-level costs	Environmental; Subscription fees; Farm benefits; Irrigation system benefits
Scenario 4	Investment, O&M of the WWTP Investment, O&M of the IS Farm-level costs	Subscription fees; Farm benefits; Irrigation system benefits

project the used water would be released directly to Wed El Gelta without any treatment.

- Scenario 2: only water treatment situation. In this case, we assume that the used water would be treated and then released to Wed El Gelta without any direct uses.
- Scenario 3: water treatment plus reuse in irrigation. In this case, after the wastewater treatment, a part of it is be used in irrigation of a nearby irrigation scheme.
- Scenario 4: the environmental benefits will not be considered.

Table 5 reflects the main benefits and costs considered for each of the above scenarios.

3.2.4.1. Water pricing alternatives

Several scenarios have been considered to evaluate impact of different water tariffs on the net benefit of the different stakeholders. The water pricing policy depends on several factors, some of which are purely political, and therefore it goes beyond the scope of the present paper, but we intend to analyze the possible financial effect of the different scenarios proposed on farmers' budget to provide a first assessment of their possible application.

We will analyze the following water pricing scenarios:

WP1. Present tariff (used as the reference): 0.025 USD/m^3

WP2. Present tariff with the addition of electricity costs: 0.038 USD/ m^3

WP3. A tariff covering the full O&M costs of the CRDA: 0.036 USD/ m^3

WP4. A tariff covering 20% of the total costs (O&M + Recovery of investments): 0.449 USD/m^3

WP5. A tariff covering the cost of water used by farmers (44% of the treated wastewater):0.749 USD/m^3

WP6. A tariff covering the full costs (O&M + Recovery of investments), as the EU recommends in the Water Directive (2000/60/EC): 1.675 USD/m^3.

The present tariff – WP1 – is set to encourage farmers to use the treated water from the WWTPs and is lower that the tariff applied for conventional water resources. The rest of the scenarios reflect a progressive increase in the recovery of costs starting by the O&M cost of electricity and up to the last scenario where all investments and O&M costs are recovered. Even though the full recovery of cost is far to be applied in practice, we try to understand if the system would be capable of paying for it.

3.2.5. *Sensitivity analysis*

In an ex-post CBA, sensitivity analysis can serve two different purposes: i) assessing the impact of unlikely but possible omissions or inaccuracies in the collected data and ii) performing a risk analysis of the projects to get useful indications for the cost and benefits evaluation of similar future projects. The sensitivity analysis will be conducted for an increase in costs of 10%, 20%, and 30% and a decrease in benefits of 10%, 20%, and 30%.

Table 6 - Investment costs.

	Investments cost in USD (year)	Actualization to year 2021 (USD)
WWTP	1,200,000 (1993)	3,665,874
IS	337,000 (1997)	860,667
Improvement of IS	130,407 (2007)	252,711
Improvements of WWTP	778,627 (2019)	869,591
	4,306,049 (2021)	4,306,049
Actualised Total Investments		9,954,892

Source: CRDA, 2014; Drechsel and Hanjra, 2018.

Table 7 - Production costs for the year 2021.

Production Costs	Olive (new)	Olive (old)	Peach
Materials (USD/ha)	106.18	68.07	1,494.91
Labour (USD/ha)	308.70	197.88	4,346
Total Costs=M+L (USD/ha)	414.88	265.95	5,840.91
Planted area (ha)	15	11	34
Total crop production costs (USD)	6,233.17	2,925.42	198,590.87

4. Results

4.1. *Costs calculation*

The costs of different components of the project – investment, O&M, and major improvement – have been calculated.

4.1.1. Investment costs

The investment costs for the WWTP and the IS have been made respectively in 1993 and 1997. Also, improvements were made in 2007 for the IS and in years 2019 and 2021 for the WWTP. All the costs incurred in Tunisian dinars have been converted in USD and actualised according to the methodology illustrated. Table 6 illustrates the cost of investments made and their actualized value.

The total actualized investment costs are 9,954,892 USD and the investment of the WWTP represents the biggest share (80%) of the total investment costs while the IS only account for 20% of the total.

4.1.2. *O&M costs*

O&M costs vary from year to year based on the level of operation of the system: for the irrigation system, they depend on the irrigated area and for the WWTP they depend on the treatment capacity. Based on the available data for 2013, we estimate the costs for the other years, calculating the O&M costs per cubic meter for WWTP and the O&M costs per hectare for IS. From the presented data we can calculate the O&M/ha and the O&M/m^3.

$$O\&M(TND/ha) = Total\ IS_{O\&M}\ cost / Area = 19{,}434/75 = 259.12\ TND/ha$$

Considering that the WWTP works five days a week and fifty-two weeks a year, the average O&M costs of the irrigated area in the different periods, and the exchange rate of TND/USD the actualized value of the total IS O&M cost is: 382,485 USD.

$$O\&M(TND/m^3) = Total\ WWTP_{O\&M}\ cost/ Treated\ water\ year = 50{,}660.5/1500*(5*52) = 0.13\ TND/m^3.$$

Considering the volume of the water treated in the different period, the average O&M cost value of the m^3 and the exchange rate of TND/USD the total actualized WWTP O&M cost is 908,124 USD. Like with the WWTP investment costs, the WWTP O&M costs are much higher than those of the IS.

4.1.3. *Farm costs*

Following the procedure indicated in section 3.2.1, the farm costs of the major crops have been calculated and reported in Table 7.

Water price is not included in the production costs, but it is considered in a separate way as it's a cost for the farmer but a benefit for the managers of the irrigation scheme, in particular for the CRDA and GDA.

4.2. *Benefits calculation*

4.2.1. *Wastewater treatment plant benefits*

Benefits for WWTP are generated from two pillars: subscription fees and environmental benefits. The subscription fees are paid by households of Ouardanine village: they are fixed at 5 USD per household per year (Drechsel and Hanjra, 2018) regardless of the collected or treated water. The total collection of the subscription fee for the year 2013 was17,000 USD/year which is 53% of what potentially should have been collected. Then, using the yearly exchange rate from TDN to USD, we determine the yearly paid fee in USD. After the actualisation process of this benefit, we found that the present value of the subscription fees paid was:

SB = 1,092,244.89 USD

4.2.2. *Environmental benefits*

The environmental benefits come from removing the pollutants from the used water and will be calculated using the next three steps:

I. Quantity of treated water per year

The WWTP works 5 days a week, 52 weeks a year for a total of 260 days per year. The amount of treated water per day has been changing throw out the years. Mainly, the treatment capacity remained the same, but the actual treated water changed according to the demand of the farmers as shown in the Table 1.

II. Amount of removed pollutants and benefits per m^3 treated

Table 8 shows the total quantity of removed pollutants considering the amounts of water treated for the different periods mentioned above and the benefits per m^3 treated.

Table 8 - Quantity of removed pollutants.

Parameter	*Removed*	*Benefit (USD/m^3)*
TSS (Kg/m^3)	358 10^{-3}	0.004
COD (Kg/m^3)	1051 10^{-3}	0.221
BOD (Kg/m^3)	441 10^{-3}	0.013
Global nitrogen NGL (Kg/m^3)	80 10^{-3}	2.858
Phosphorus Pt (Kg/m^3)	2 10^{-3}	0.168

III. Environmental benefits

After calculating the removed pollutants per cubic meter of water, we can estimate the benefit of the treatment per cubic meter using the total volume of treated water. Total benefit per treated m^3 = 3.26 USD and therefore the total environmental benefits are:

B_E = 6,968,000 ∗ 3.26 =22,739,510.56 USD

4.2.3. *Irrigation scheme benefits*

Farmers use the irrigation system that it is managed by the GDA which is responsible for the small maintenance and the collection of water fees. At the same time, the GDA pays CRDA for the water provision. The beneficiaries of the irrigation scheme are both the CRDA and the GDA.

4.2.4. *CRDA benefits*

The CRDA's only benefit comes from providing water to the GDA. The water sales, varying from year to year, were calculated as an average per hectare for those years in which it was available and used to interpolate the missing data. Once the yearly benefit was calculated we change the values to USD and then actualized them to 2021 (Table 9).

4.2.5. *GDA level benefits*

The GDA sells the treated wastewater to farmers against payment of a fee composed of two parts: a fixed fee per hectare and a variable one depending on the water consumption. The same steps that were used to calculate the CRDA benefits are used in this section for year with missing data.

Table 9. CRDA benefits.

Start year	1998	2003	2007
End year	2002	2006	2021
Distributed water (m^3)	23,333	58,333	175,000
Price (TDN/m^3)	0.02	0.02	0.02
Subscription fees (TDN/farmer)	50	50	50
CRDA benefits (USD)	*99,242*		

Table 10 - GDA benefits.

Start year	1998	2003	2007
End year	2002	2006	2021
Used water (m^3)	23,333	58,333	175,000
Water price (TDN/m^3)	0.035	0.035	0.035
Subscription fees (TDN/farmer)	50	140	275
GDA benefits (USD)	*275,633*		

4.2.6. *Farm benefits*

The revenue of the farmers comes from the value of crop production obtained. In this part, we will treat the entire irrigated area as a big farm and compute the total production for the year 2021.

The main components of the total crop production costs are reflected in Table 11 and the total revenue for the year 2021 is 732,843 USD and the average revenue per hectare is 10,470 USD.

The Table 12 represents the evolution of the farmer's revenues from the start of the project until 2021: data from 1996 to 2001 were provided by the CRDA and those for the years 2013 and 2021 were taken from the literature. It should be noted that the farmers' revenue is largely influenced by the variable market prices.

Before the project, most of the land was planted with olive trees and was not irrigated which explains the low income in the year 1996. After the installation of the irrigation scheme, the farmer's income starts to increase from year to year and reaches a maximum in 2001. For the other years, we used interpolation to estimate the revenue. The calculated total revenue since the start of the project is 26,149,647 USD.

Table 11 - Crop production.

	Production (kg/tree)	*Planted area(ha)*	*Trees per ha*	*Total production (kg)*	*Price (USD/Kg)*	*Total income (USD)*
Olive (new)	25	15	156	58,500	0.414	24,219
Olive (old)	25	11	100	27,500	0.414	11,358
Peach	40	34	494	671,840	0.889	597,266
Others	40	10	500	200,000	0.5	100,000

Table 12 - Farmer's revenue per year.

Year	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2013*	*2021*
Revenue (TND)	1,000	0	2,500	6,000	10,000	30,000	17,000	17000
Revenue (USD)	947	0	2,199	5,474	7,974	21,023	10,900	10,470

Table 13 - Financial CBA results.

	WWTP	*CRDA*	*GDA*	*FARMERS*
Costs (USD)	8,841,513	1,495,862	246,008	8,874,418
Benefits (USD)	1,092,245	99,242	275,633	26,149,647
NPV (USD)	-7,749,269	-1,396,620	29,626	17,275,229
BCR	0.12	0.07	1.12	2.95

Table 14 - Economic CBA results.

	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Costs	22,739,511	9,749,638	19,844,285	19,844,285
Benefits	0	23,831,755	50,257,035	27,517,525
NPV	-22,739,511	14,082,117	30,412,750	7,673,239
BCR	0.00	2.44	2.53	1.39

4.3. *CBA results*

After the calculation of the different costs and benefits, we performed the financial CBA for every stakeholder of the project and then the economic analysis under each scenario.

4.3.1. *Financial Cost Benefits Analysis*

The evaluation of the financial costs and benefits for each stakeholder of the project leads to a negative NPV for both WWTP and CRDA and positive for the GDA and the farmers (Table 13). WWTP only recovers 12% of its expenditure and the rest is subsidized. The current pricing policies need to be changed to increase the financial benefits, especially since wastewater treatment proved to be the most expensive part of the project.

As for the CRDA, despite receiving the treated water for free, the result is highly negative. The benefit of the CRDA represents only 7% of the costs. Again, this evidences that the water pricing applied is unsustainable from a financial point of view and the need for upgrading it. On the other side, despite being a non-profitable organization, the GDA shows a positive NPV and a BCR of more than 1, but this is compatible with their non-profit nature since the small benefit of every year is used to reduce the planned costs for the following year. Finally, for the farmer's the results are highly positive with almost three times the return on their investment. Nevertheless, the project shows a large benefit when considered as a unit but when the different types of farms are taken into account there are large differences between the peach growers and the rest of the farms as it will be demonstrated later.

4.3.2. *Economic Cost Benefits Analysis*

The results of the economic analysis are summarized in table 14 for the four scenarios considered. In Scenario 1, the Economic CBA's results reflect the cost of the effect of placing the untreated sewage water of Ouardanine on the environment. In other words, if the project was not implemented the environmental damages will cost the society 22,139,510.56 USD and no significant benefits. Strictly speaking, the old existing olives under rainfed conditions would have generated some small benefits but they are negligeable compared to the large environmental costs. The results of Scenario 2 are the opposite: the wastewater treatment feasibility is proven by the high BCR obtained where benefits are nearly 2,5 times higher than the costs. The results of Scenario 3 after the introduction of water reuse in irrigation are slightly better than the Scenario 2 but still highly positive. The NPV is double but, with the increase in costs, the BCR increased a little compared with Scenario 2. On the other hand, this scenario has improved greatly the wellbeing of the benefiting farmers and contributed to the development of subsidiary activities in the agriculture sector like transport, markets, agriculture machinery and

Table 15 - Sensitivity analysis of the economic CBA.

Scenario 1				
Decrease benefit		*10%*	*20%*	*30%*
NPV	-22,739,511	-22,739,511	-22,739,511	-22,739,511
BCR	0	0	0	0
Increase Cost		*10%*	*20%*	*30%*
NPV	-22,739,511	-25,013,462	-27,287,413	-29,561,364
BCR	0	0	0	0
Scenario 2				
Decrease benefit		*10%*	*20%*	*30%*
NPV	14,082,117	11,698,942	9,315,766	6,932,591
BCR	2.44	2.20	1.96	1.71
Increase Cost		*10%*	*20%*	*30%*
NPV	14,082,117	13,107,153	12,132,190	11,157,226
BCR	2.44	2.22	2.04	1.88
Scenario 3				
Decrease benefit		*10%*	*20%*	*30%*
NPV	30,412,750	25,387,046	20,361,343	15,335,639
BCR	2.53	2.28	2.03	1.77
Increase Cost		*10%*	*20%*	*30%*
NPV	30,412,749.77	28,428,321	26,443,893	24,459,464
BCR	2.53	2.30	2.11	1.95
Scenario 4				
Decrease benefit		*10%*	*20%*	*30%*
NPV	7,673,239.21	4,921,486.75	2,169,734.30	-582,018.15
BCR	1.39	1.25	1.11	0.97
Increase cost		*10%*	*20%*	*30%*
NPV	7,673,239.21	5,688,810.67	3,704,382.14	1,719,953.61
BCR	1.39	1.26	1.16	1.07

others. Even without considering the environmental benefits, the project is profitable in Scenario 4: the results show that the irrigation reuse of treated wastewater can cover the expensive cost of wastewater treatment plus those of the irrigation system which is quite remarkable.

4.4. *Sensitivity analysis*

The sensitivity analysis shows that the project is economically feasible even under extreme assumptions of increasing costs and decreasing benefits up to 30%.

Obtained results (Table 15) mainly reflect the importance of the environmental benefits: the NPV is positive for all the scenarios and the BCR is bigger than one for all of them and higher than those of Scenario 2. These results confirm the robustness of the results obtained for the economic evaluation and prove once again the feasibility of the project.

The fourth Scenario shows that only the scenario of a 30% decrease in the benefits gives a negative result. For the others the results were positive, and this shows that the project is sensitive to the reduction of benefits of more than 20%

The sensitivity analysis of the financial CBA for the farmers (Table 16), who are the main

Table 16 - Sensitivity analysis for the farmer's financial CBA.

	FARMERS			
Decrease benefit		*10%*	*20%*	*30%*
NPV	17,275,229	14,660,264	12,045,300	9,430,335
BCR	2.95	2.65	2.36	2.06
Increase cost		*10%*	*20%*	*30%*
NPV	17,275,229	16,387,787	15,500,346	14,612,904
BCR	2.95	2.68	2.46	2.27

Table 17 - CBA under water pricing scenarios for farm typology.

Olive Farmer	*WP1*	*WP2*	*WP3*	*WP4*	*WP5*	*WP6*
C	465.48	487.52	490.48	1,311.93	1,913.57	3,765.20
B	1,614.60	1,614.60	1,614.60	1,614.60	1,614.60	1,614.60
NPV	1,149.12	1,127.08	1,124.12	302.37	-298.97	-2,150.60
BCR	3.47	3.31	3.29	1.23	0.84	0.43
Peach farmer	*WP1*	*WP2*	*WP3*	*WP4*	*WP5*	*WP6*
C	5,942.12	5,986.19	5,992.12	7,635.01	8,838.30	12,541.55
B	17,566.64	17,566.64	17,566.64	17,566.64	17,566.64	17,566.64
NPV	11,624.52	11,580.45	11,574.52	9,931.63	8,728.34	5,025.09
BCR	2.96	2.93	2.93	2.30	1.99	1.40

beneficiaries of the project, shows for all scenarios that the CBA is positive even when we consider extreme cases with cost higher than 30%. For all the other stakeholders – GDA, GCDA and WWTP – any increase in costs will lead to increases in the water pricing (benefits) with negligible impact of their CBA financial results.

4.5. *Water pricing scenarios*

The financial effect on farmers' budget of the different water pricing scenarios have been estimated to provide a first assessment of the possible application of different water pricing policies. Scenarios have been evaluated separately for the two main type of farmers, i.e. peach and olive growers (Table 17).

The present tariff – WP1 – is set to encourage farmers to use the treated water from the WWTPs and is lower that the tariff applied for conventional water resources. The rest of the scenarios reflect a progressive increase in the recovery of costs starting by the O&M cost of electricity and up to the last scenario where all investments and O&M costs are recovered. Even though the full recovery of cost is far to be applied in practice, we try to understand if the system would be capable of paying for it.

We conclude that a higher price in scenarios WP2 and WP3 will have positive effects on the CRDA since they reduce their current financial deficits. On the other hand, the recovery of the investments (scenarios WP4, WP5 and WP6) that could affect the balance of the WWTP, only appears feasible for the peach growers but with significant losses in their benefits and for olive growers, only scenario WP4 would be marginally possible. For olive farmers, the WP5 and WP6 are not economically feasible while even the WP4 gives a positive but insignificant NPV. The WP2 and WP3 give better results furthermore they are not far away from the current scenario.

Peach farmers can pay the prices in each scenario and still have a positive NPV but the difference in the NPV between the WP1 and WP6 is quite high, and the farmer's benefit will be reduced by more than half. Scenarios WP5 and WP4 are economically feasible but involve a still high reduction in the benefit (25% and 15% respectively) and their practical application

Figure 3 - NPV for the two main types of farms.

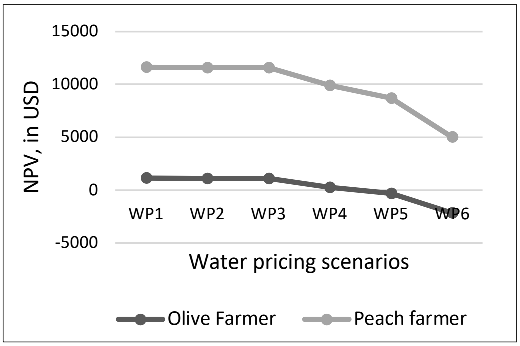
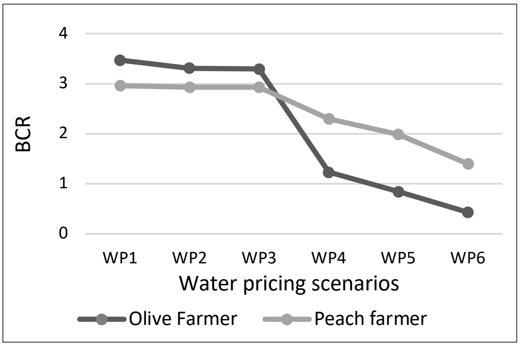


Figure 4 - BCR for the two main types of farms.



does not appear feasible because of the logical resistance of the farmers. On the other side, the olive growers could not afford their payment in scenarios WP5 and WP6 and only marginally for scenario WP4. In general, the recovery of the investments of the irrigation system appears highly questionable while the impact of water price changes on different type of farmers being olive farmers more vulnerable to water fees then peach farmers.

Figures 3 and 4 illustrate the difference between the current situation and other scenarios but also the large difference between the scenarios that only recover partly or totally the O&M costs (scenarios WP1, WP2 and WP3) and those that recover also partly or totally the investments (scenarios WP4, WP5 and WP6) made in the construction of the main works. Great differences also exist between the NPV of peach and olive growers being the later much more sensitive to reduction of the NPV when water pricing increases.

In conclusion, only scenarios WP2 and WP3 have a real potential for their implementation. A gradual approach whereby the scenario WP2 is applied for a short number of years followed by the scenario WP3 should deserve a more detailed consideration by the concerned stakeholders.

5. Conclusions and policy implications

This paper presents an ex-post CBA of Ouardanine wastewater treatment plant and of the irrigation project for the reuse of the TWW implemented in 1993 and 1997, respectively.

Firstly, the financial feasibility of the project for the different stakeholders – WWTP, CRDA, GDA and the farmers – was assessed. Given the current business model, for both the WWTP and the CRDA, the project is unfeasible: after 27 years of operating for the WWTP and 24 for the CRDA they were able to recover respectively 12% and 7% of their costs. Contrarily, the GDA despite being a non-profitable organization had a small positive financial analysis. For the farmers, the obtained results show that they are by far the bigger beneficiary of the project.

Secondly, we performed an extended CBA including both the economic and the environmental costs and benefits of treating and reusing wastewater. The benefits of removing the main pollutants - suspended particles, phosphorus, nitrogen, COD and BOD - from the water used were evaluated by applying the shadow process approach. The evaluation was carried out under four different scenarios followed by a sensitivity analysis and a study of the effect of different water pricing scenarios on the farmers' net benefit.

The results obtained indicate positive and significant benefits from water treatment, especially if we look at the costs on non-treatment for a country like Tunisia that, in recent decades, has been facing severe water shortage and water quality degradation. With only the treatment, the economic impact shifted from a loss of approximately 22 million USD for the non-treatment to a gain of more than 14 million USD. These results, although refer to our study case, confirm those of by Molinos Senante *et al.*, 2011 who demonstrated the economic feasibility of wastewater treatment when non-use option is considered.

The results of the third and fourth scenarios shows that the development of the treatment and reuse in irrigation is a highly profitable investment both economically and financially. The CBA indicators (NPV and BCR) were positive with and without considering environmental benefits while the NPV doubled when we considered both the environmental benefits and the benefit of wastewater reuse in irrigation, and this demonstrates the importance of the treated water reuse.

The sensitivity analysis, useful to understand the level of stability and sustainability of the analyzed project as well as to generalize the result to similar projects, showed that the project, even under extreme considerations of 30% drop in benefits and 30% increase in costs, still provides positive results.

This ex-post CBA evaluation shows fundamentally that the investments made in the WWTP of Ouardanine are economically advantageous for Tunisia independently of the construction or not of the irrigation system (Scenario 2). This important statement – based on the estimation of the environmental benefits which largely compensates all the investment and operational costs in economic terms – leads to conclude that Tunisia should develop similar WWTPs provided that technologies used are comparable and the level of removal of contaminants is about the same or greater than for the case of Ouardanine the unit costs are kept below those of Ouardanine.

The second important policy issue is the relevance of constructing irrigations systems to reuse the treated water. Hence the question is to be seeing from the perspective of the potential increments of social and economic benefits that the beneficiaries may obtain out of the new irrigation system. The results obtained confirmed that the opportunities to develop reuse projects exist and depend on the possibility of increasing overall social well-being since if social welfare is actually increased, then forms of compensation/incentives/subsidies to support the projects can be devised (Arena *et al.*, 2020).

In this case, the economic and financial analysis are not only strictly necessary but not sufficient since the capacity of the beneficiaries to use a new intensive agricultural production system under irrigated conditions needs to be evaluated and complemented with the learning and financial facilities that may render this objective achievable.

The third policy issue is related to the of water pricing for the beneficiaries of the WWTP and the irrigation system. In the case of Ouardanine, both farmers and house dwellers pay a very small fraction of the currents costs of the IS and the WWTP. The analysis undertaken here show that famers could pay much higher fees than those actually paid. This also applies to the dwellers of Ouardanine since only 50% of the dwellers pay the annual contribution to the O&M costs of sewage system and nothing for the O&M costs of the WWTP. Considering the predominantly positive economic returns of the beneficiaries in Scenarios 2, 3 and 4 the pertinence of revising present water prices policies appears fully justified. This does not necessarily mean that strong increases in water tariffs should be promoted compared to the current situation, but a progressive adaptation to a more realistic recovery of recurring costs could be studied and discussed with stakeholders.

6. Method caveats and future research and development pathways

The main limitation of this analysis concerns the availability and adequacy of data, in particular relating to costs and revenues at the farm level and the actual quantity of water treated in the treatment plant. If we consider the sensitivity analysis where the results do not change much, we believe that this limitation does not fundamentally question the results obtained. However, to increase the reliability of the evaluation, it would be advisable to replicate the ex-post feasibility analysis of this project and other similar ones in the wastewater treatment and reuse sector in order to extrapolate simple and scalable indicators, to establish fully reliable benchmarks and to inform the decision-makers in the allocation of public and private budget funds. Considering that Tunisia is a leading country in the use of the reuse of treated water the development of such indicators could be of relevance to other countries of the Mediterranean Region.

It should be noted that the economic evaluation is not the only criteria to evaluate the feasibility of a project and that multicriteria approaches should be used to have a more complete assessment. However, in this case the analysis focuses on the economic analysis since is the one that is more commonly absent. Furthermore, the social acceptance of the system is largely proved by the fact that the present number of farmers has been increasing since 2002 until reaching the maximum possible in 2014 and at present the cultivated area exceeds the technical capacity of the irrigation system and farmers suffer from critical water shortages.

The Ouardanine system is generally considered as one of the most successful experiences in Tunisia in the development of treatment of reused water and has a consolidated experience of more than 30 years making out of it an excellent laboratory for further learning in these complex undertakings. Future research lines mainly could include:

- Improving a more traditional approach to CBA in WWTP, complementing the environmental benefits with social benefits and costs.
- The determination of the environmental benefits in this paper has been done based on shadow prices determined outside Tunisia and therefore the definition of more accurate shadow prices for Tunisia and the rural area of the Mediterranean is necessary.
- The environmental impact of the treated water placed in the riverbed during the winter season, when water is not used by the irrigation system, is unknown but could have significant effect in improving the quality of deteriorated underlying aquifers.
- The evolution of the present cropping pattern needs to be understood clearly.
- The environmental effects of the solid waste as a fertilizing practice needs to be evaluated.
- The existing governance systems is shared among several organizations with limited communication among them and economic consequences that affect their functioning. For instance, the financial benefit of the CRDA depends on the level of fees imposed to the GDA but they are low and insufficient to undertake a proper maintenance of the irrigation system. Similarly, the WWTP often interrupts the service due to maintenance problems which may deserve review of the fees paid by all beneficiaries of the treatment plant (for instance, by using part the land use tax for this purpose).
- The present WWTP meets only a part of the crop water requirements of the present cropping area and surrounding farmers are anxious to have access to the irrigation water. Furthermore, the WWTP was constructed in 1993 for an estimated population of 17,000 inhabitants while the present population exceeds 23,000 inhabitants and it is obvious that it is under designed for the present needs of the population. Therefore, the need for a substantial enlargement is urgent and the design of a new plant is under consideration by ONAS. In this later case, a significant improvement of the irrigation system should go in parallel.

References

Acampa G., Giustra M.G., Parisi C.M., 2019. Water Treatment Emergency: Cost Evaluation Tools. *Sustainability*. 11(9): 2609. https://doi.org/10.3390/su11092609.

Alobaidy A.H.M.J., Al-Sameraiy M.A., Kadhem A.J., Majeed A.A., 2010. Evaluation of treated municipal wastewater quality for irrigation. *Journal of Environmental Protection*, 1(3): 216-225. https://doi.org/10.4236/jep.2010.1302.

Arena C., Genco M., Mazzola M., 2020. Environmental Benefits and Economical Sustainability of Urban Wastewater Reuse for Irrigation—A Cost-Benefit Analysis of an Existing Reuse Project in Puglia, Italy. *Water*, 12(10): 2926. https://doi.org/10.3390/w12102926.

Benabdallah S., 2007. The water resources and water management regimes in Tunisia. In: Holliday L. (ed.), *Agricultural Water Management: Proceedings of a Workshop in Tunisia* (Series: Strengthening Science-Based Decision Making in Developing Countries). Washington, DC: The National Academies Press.

Birol E., Koundouri P., Kountouris Y., 2010. Assessing the economic viability of alternative water resources in water-scarce regions: Combining economic valuation, cost-benefit analysis and discounting. *Ecological Economics*, 69(4): 839-847. https://doi.org/10.1016/j.ecolecon.2009.10.008.

Castellet L.; Molinos-Senante M., 2016. Efficiency assessment of wastewater treatment plants: A data envelopment analysis approach integrating technical, economic, and environmental issues. *Journal of Environmental Management*, 167: 160-166.

Ćetković J., Knežević M., Lakić S., Žarković M., Vujadinović R., Živković A., Cvijović J., 2022. Financial and Economic Investment Evaluation of Wastewater Treatment Plant. *Water*, 14(1): 122. https://doi.org/10.3390/w14010122.

Chen R., Wang X.C., 2009. Cost-benefit evaluation of a decentralized water system for wastewater reuse and environmental protection. *Water Science and Technology*, 59(8): 1515-1522. https://doi.org/10.2166/wst.2009.156.

CRDA - Commissariat Régional au Développement Agricole de Monastir, 2014. *The experience of the Ouerdanine 2 development complex in the use of treated water*.

Drechsel P., Hanjra M.A., 2018. Wastewater and biosolids from fruit trees Tunisia. In: Derchsel P., Otoo M. (eds.), *Resource recovery from waste business models for energy, nutrient and water reuse in low- and middle-income countries*. Oxon (UK): Taylor & Francis, pp. 569-583.

European Commission, Directorate-General for Regional and Urban Policy, 2015. *Guide to cost-benefit analysis of investment projects – Economic appraisal tool for cohesion policy 2014-2020*. Luxembourg: EU Publications Office. https://data.europa.eu/doi/10.2769/97516.

Fernandez D., Jouravlev A., Lentini E., Yurquina A., 2009. *Contabilidad regulatoria, sustentabilidad financiera y gestión mancomunada: temas relevantes en servicios de agua y saneamiento*. Santiago de Chile: Publicación de las Naciones Unidas.

Florio M., Vignetti S., 2013. *The use of ex post Cost-Benefit Analysis to assess the long-term effects of Major Infrastructure Projects*. CSIL Centre for Industrial Studies, Working paper No. 02/2013. https://www.csilmilano.com/docs/WP2013_02.pdf.

GDA (*Groupement de Développement Agricole)*, 2022. *Personal Communication from 26 February 2022 to 26 Mars 2022*.

Godfrey S., Labhasetwar P., Wate S., 2009. Greywater reuse in residential schools in Madhya Pradesh, India-A case study of cost-benefit analysis. *Resources, Conservation and Recycling*, 53(5): 287-293. https://doi.org/10.1016/j.resconrec.2009.01.001.

Hanjra M.A., Blackwell J., Carr G., Zhang F., Jackson T.M., 2012. Wastewater irrigation and environmental health: Implications for water governance and public policy. *International Journal of Hygiene and Environmental Health*, 215(3): 255-269. https://doi.org/10.1016/j.ijheh.2011.10.003.

Hernández F., Urkiaga A., de las Fuentes L., Bis B., Chiru E., Balazs B., Wintgens T., 2006. Feasibility studies for water reuse projects: An economical approach. *Desalination*, 187(1-3): 253-261. https://doi.org/10.1016/j.desal.2005.04.084.

Jeder H., Ben Hamza E., Belhouchette H., 2019. An optimal price for sustainable irrigated agriculture in central-eastern Tunisia. *New Medit*, 18(2): 3-14. http://dx.doi.org/10.30682/nm1902a.

Jeder H., Ben Khalifa A., Sghaier M., 2014. Economic analysis of water demand in public irrigation systems in Tunisia, using FSSIM model. *New Medit*, 13(4): 46-53.

Kihila J., Mtei K.M., Njau K.N., 2014. Development of a cost-benefit analysis approach for water reuse in irrigation. *International Journal of Environmental Protection and Policy*, 2(5): 179-184. https://doi.org/10.11648/j.ijepp.20140205.16.

Maesano G., Chinnici G., Falcone G., Bellia C., Raimondo M., D'Amico M., 2021. Economic and environmental sustainability of olive production: A case study. *Agronomy*, 11(9): 1-22. https://doi.org/10.3390/agronomy11091753.

Mahjoub O., Gomez E., Bahri A., 2008. Les polluants organiques dans les eaux usées traitées et les sols-Résultats préliminaires d'un cas d'étude dans la région de Oued Souhil (Nabeul). *Les Annales de l'INRGREF*, 11: 161-176.

Mahjoub O., Mekada M., Gharbi N., 2016. Good irrigation practices in the wastewater irrigated area of Ouardanine, Tunisia (Tunisia). In: Hettiarachchi H., Ardakanian R. (eds.), *Safe use of wastewater in agriculture: good practice examples*. Dresden: UNU-FLORES, pp. 101-120. https://collections.unu.edu/eserv/UNU:5764/SafeUseOfWastewaterInAgriculture.pdf.

Meneses M., Pasqualino J.C., Castells F., 2010. Environmental assessment of urban wastewater reuse: Treatment alternatives and applications. *Chemosphere*, 81(2): 266-272. https://doi.org/10.1016/j.chemosphere.2010.05.053.

Molinos-Senante M., Garrido-Baserba M., Reif R., Hernández-Sancho F., Poch M., 2012. Assessment of wastewater treatment plant design for small communities: Environmental and economic aspects. *Science of the Total Environment*, 427-428: 11-18. https://doi.org/10.1016/j.scitotenv.2012.04.023.

Molinos-Senante M., Hernández-Sancho F., Sala-Garrido R., 2010. Economic feasibility study for wastewater treatment: A cost-benefit analysis. *Sci-*

ence of the Total Environment, 408(20): 4396-4402. https://doi.org/10.1016/j.scitotenv.2010.07.014.

Molinos-Senante M., Hernández-Sancho F., Sala-Garrido R., 2011. Cost-benefit analysis of water-reuse projects for environmental purposes: A case study for Spanish wastewater treatment plants. *Journal of Environmental Management*, 92(12): 3091-3097.

Mujeriego R., Compte J., Cazurra T., Gullón M., 2008. The water reclamation and reuse project of El Prat de Llobregat, Barcelona, Spain. *Water Science & Technology*, 57(4): 567-574. doi: 10.2166/wst.2008.177. PMID: 18359997.

ONAS (Office National de l'Assainissement République Tunisienne), 2017. Etude préalable a un plan national *Réutilisation des eaux usées traitées. Diagnostic de l'existant*.

ONAS (Office National de l'Assainissement République Tunisienne), 2022. *Rapport Annuel 2022*. http://www.onas.nat.tn/Fr/telecharger.php?code=293.

Saliba R., Callieris R., D'Agostino D., Roma R., Scardigno A., 2018. Stakeholders' attitude towards the reuse of treated wastewater for irrigation in Mediterranean agriculture. *Agricultural Water Management*, 204(C): 60-68.

Sartori D., Catalano G., Genco M., Pancotti C., Sirtori E., Vignetti S., Bo C., 2014. *Guide to cost benefit analysis of investment projects economic appraisal tool for cohesion policy 2014-2020*. Bruxelles: Publications Office of the European Union.

Urkiaga A., de las Fuentes L., Bis B., Chiru E., Balasz B., Hernández F., 2008. Development of analysis tools for social, economic and ecological effects of water reuse. *Desalination*, 218(1-3): 81-91. https://doi.org/10.1016/j.desal.2006.08.023.

Vally Puddu M., 2003. *Diagnostic Technico-économique de la Réutilisation des eaux usées traitées dans le Périmètre de Ouardanine (Monastir-Tunisia)*. Monastir: INRGREF.

Verlicchi P., Al Aukidy M., Galletti A., Zambello E., Zanni G., Masotti L., 2012. A project of reuse of reclaimed wastewater in the Po Valley, Italy: Polishing sequence and cost-benefit analysis. *Journal of Hydrology*, 432-433: 127-136. https://doi.org/10.1016/j.jhydrol.2012.02.024.

Winpenny J., Heinz I., Koo-Oshima S., 2010. *The wealth of waste: The economics of wastewater use in agriculture*. FAO Water Reports, 35. Rome: FAO.

Explaining drivers of farmers' willingness for early adoption of enhanced irrigation technologies: Case of Tunisia

Ali Chebil*, Chokri Thabet**, Zouhair Rached***, Wafa Koussani****, Asma Souissi**, Marco Setti*****

DOI: 10.30682/nm2401f
JEL codes: O13, Q12, Q16

Abstract

The objective of this paper is to identify the influencing factors of farmers' willingness for early adoption of enhanced irrigation technologies in Tunisia. We estimate a multinomial logit model with data from 931 farmers in Central (Chebika) and Northern (Fernana) of Tunisia. Regression results reveal that early adoption is positively influenced by levels of extension service quality, trust in farmers' associations and extension agents, farmer's perception towards the innovation, credit access, and off-farm income. However, it is negatively affected by market access issues, risk aversion, and age. Risk, trust, and perception towards technology are important factors in driving early adoption decision. The findings imply that farmers training on water conservation technologies, financial support for innovation adoption, awareness of young farmers about the opportunities of agricultural innovation, incentives to farmers' associations in order to improve their market access, and inclusive participatory approaches during technology generation and transfer are all accelerators of early adoption of innovations by farmers.

Keywords: *Early adopters, Enhanced irrigation technologies, Multinomial ordered model, Drivers of early adoption, Tunisia.*

1. Introduction

Agricultural innovation is crucial for increasing agricultural productivity, food security, conservation of natural resources, and alleviating poverty. Adoption rate and speed to adopt determine the ultimate impact of agricultural innovation on these indicators. Speed of adoption is the time from the date of innovation introduction to adoption. Innovation spread within temporal involves different states and types of adopters (innovators, early adopters, early majority, late majority, and laggards). Innovation adoption decision is a process which includes: knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). In fact, farmers do not accept innovation immediately, they need time to think things over before making decision.

* University of Carthage, National Research Institute for Rural Engineering, Water and Forestry (INRGREF), Tunis, Tunisia.
** University of Sousse, High Agronomic Institute of Chott Meriem (ISACM), Sousse, Tunisia.
*** University of Carthage, National Institute of Agronomic Research of Tunis (INRAT), Tunis, Tunisia.
**** University of Carthage, National Agronomic Institute of Tunisia (INAT), Tunis, Tunisia.
***** University of Bologna, Department of Agricultural and Food Sciences, Bologna, Italy.
Corresponding author: chebila@yahoo.es

In Tunisia, some studies were carried out to analyze the adoption decisions of agricultural innovation (Aziza *et al.*, 2009; Fouzai *et al.*, 2018; Dhehibi *et al.*, 2018; Dhraief *et al.*, 2019; Dhehibi *et al.*, 2020; Dhehibi *et al.*, 2022). The majority of these studies showed that agricultural innovation promotion is characterized by low rate of adoption. However, to our knowledge, no studies tackled the early adoption of agricultural innovation in Tunisia. Early adoption of innovation adoption is usually required, since it can improve overall agricultural productivity and reveal the resilient farming systems (Batz *et al.*, 2003). Early adopters can lead to quickened diffusion of innovation because they take less time to adopt innovation than late adopters. The concept of 'early adopter' has become common in agricultural science since the Eightees (Lindner *et al.*, 1982; Bultena and Hoiberg, 1983; Korsching *et al.*, 1983; Byerlee and De Polanco, 1986). The identification of early adopters of enhanced irrigation technologies is especially important in current water scarcity, climate change and drought circumstances. Therefore, the main objective of this paper is to identify the major factors influencing farmers' willingness for early adoption of enhanced irrigation technologies in Northern and Central Tunisia.

2. Conceptual framework

The assumption of utility maximisation is generally used to explain farmers' adoption decisions of new technology (Adesina and Zinnah, 1993; Alcon *et al.*, 2011). Under this assumption, a farmer will adopt a given technology if the utility obtained from the new technology exceeds that of the old one. For example, farmers will adopt new irrigation system if their expected utility, subject to their preferences and constraints (e.g., time and climate), is maximized by doing so. Utility is a function of various factors including expected benefits and costs of adopting a practice versus not adopting. Several factors that condition farmers' adoption decisions have been discussed and can be divided into five categories as indicated in Figure 1: (1) Farmers' characteristics, (2) Farm characteristics, (3) Farmers' behavior and perception, (4) Technology characteristics, and (5) Institutional and communication factors. These categories and explanatory variables are based on the literature related to early adoption studies of agricultural technologies (Alcon *et al.*, 2011; Beyene and Kassie, 2015; Kassie *et al.*, 2015; Manda *et al.*, 2020; Ngango and Hong, 2021; Kumar *et al.*, 2021; Ayisi *et al.*, 2022; Tey and Brindal, 2023).

The most studied factors in the first category are age, education, gender and experience of the farmer. The second category is factors relating to the farm characteristics which include variables such as location, farm size, land tenure, off-farm income, etc. A third category of factors is the farmers' behavior and perception including variables such as the trust in extension agents and farmers' associations, risk attitude, time preferences, etc. The fourth category is the innovation characteristics (relative advantage). More specifically, the degree to which the new tech-

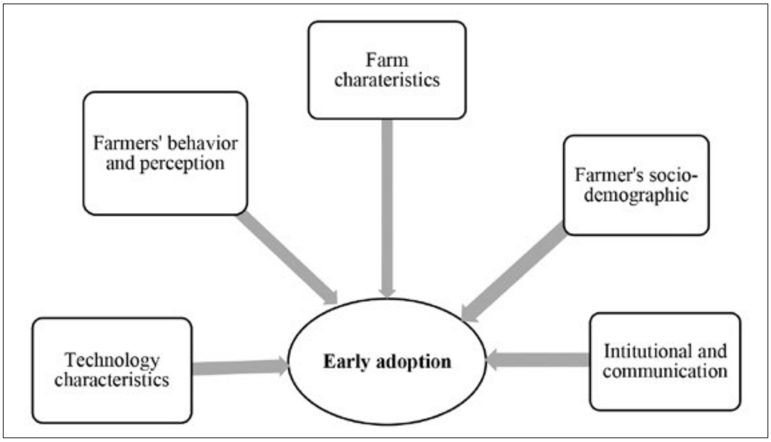
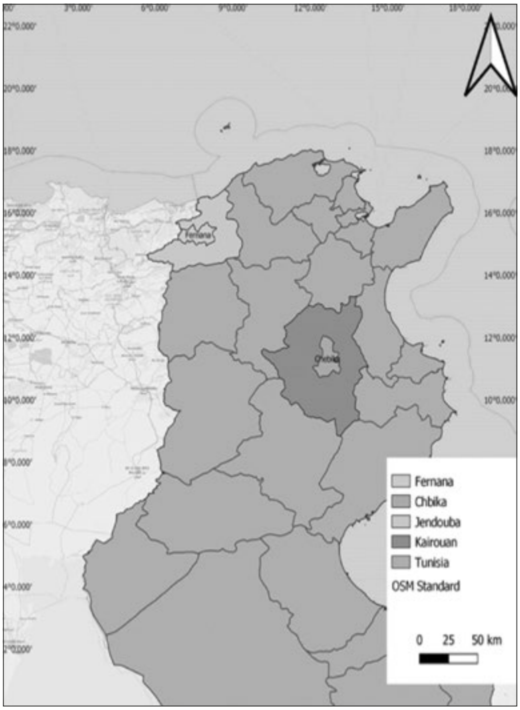


Figure 1 - Factors affecting early adoption of agricultural innovation among farmers.

Source: Own elaboration.

Figure 2 - Geographical locations of study areas.



nology is believed by farmers to perceive better as the one it will replace (perception regarding innovation). Finally, the fifth category including institutional and communication factors such as assistance from extension services, credit access, and market access.

3. Methodology

3.1. *Study area and data collection*

The data used for the empirical analysis was obtained from a farm survey conducted in September-October 2021 by the FoodLAND project Team in collaboration with extentionists. The survey covered two study areas indicated in Figure 2 (Fernana in the North and Chebika in the Center of Tunisia). Chebika is located in the governorate of Kairouan. It is a semi-arid area with an annual average rainfall of about 290 mm. This average varies between 250 and 400 mm. The main crops cultivated in the area are: wheat, vegetables (especially tomato and chilli pepper), and olive trees. These crops are mostly grown under irrigated conditions. Both surface (Houareb dams) and groundwater resources (deep and shallow aquifers) are available for irrigation in Chebika. However, Fernana is a sub-humid area with mean rainfall of 700 mm. Cereals under rainfall conditions are the dominated crops in this area. The stratified sampling by farm size was used to select 713 and 218 farmers in Chebika and Fernana, respectively. The total number of farmers in Chebika and Fernana are around 5000 and 2000, respectively. The questionnaire used for data collection includes questions about the context of farm, resources and technology, farm production, farmers' perception, and farmers' characteristics.

3.2. *Empirical model, variables used and hypotheses*

We categorized adopters based on their responses to the question, "To what extent would you consider introducing enhanced irrigation technologies on your farm?" The Likert scale used had the following options:

1. Not interested;
2. Interested if more than half of the farmers adopt;
3. Interested if at least half of the farmers adopt;
4. Interested if at least some of the farmers adopt;
5. Willing to be one of the first in my village.

We classified respondents who chose options 4-5 as early adopters, options 2-3 as late adopters, and option 1 as non-adopters. The dependent variable defines the type of adopters according to the speed of innovation adoption (early, late and no adoption) with an ordinal categorical nature. That's why a multinomial ordered logit model will be used to identify the factors influencing farmers' willingness early to adopt new agricultural technologies.

The ordered logit model is based on the following specification. We suppose that unobservable variable $Z_i = x_i'\beta + \varepsilon_i$ exists, related with the explanatory variable and affects the result of observable variable Y_i as follows:

$$Y_i = j \ \ if \quad \mu_{j-1} < Z_i < \mu_j \qquad (1)$$

We define the multinomial ordered model in the following way:

$$P(Y_i = j) = F(\mu_j - x_i'\beta) - F(\mu_{j-1} - x_i'\beta) \qquad (2)$$

i=1 , 2,……n;   j=0,1,…..m

The functional form of F most frequently used in application is logistic:

$$Logit \quad F(Z) = \frac{e^Z}{1+e^Z} \qquad (3)$$

Where $Z = x'\beta \qquad -\infty < Z < +\infty$

The explanatory variables included in the model are farm location, farm size, age of farmer, education level of household head, risk attitudes and trust in other farmers and extension agents, access to extension services, land tenure, access to credit, market access, off-farm income and perception towards enhanced irrigation technologies. The definitions of the variables and hypotheses are presented in Table 1.

Since we have only three groups in our example, the model (1) is simplified and presented as follows:

$$\begin{aligned} Y_i &= 0 \quad if \quad Z_i \le \mu_0 \\ Y_i &= 1 \quad if \quad \mu_0 \le Z_i \le \mu_1 \\ Y_i &= 2 \quad if \quad Z_i \ge \mu_1 \end{aligned} \qquad (4)$$

Where: U_i unobserved thresholds defining the group;

$$Z_i = x_i'\beta + \varepsilon_i$$

Zi= B0+ B1 Age + B2 EL + B3 Gender + B4 Location + B5 Size + B6 Tenure + B7 Off-farm + B8 Pertec + B9 Risk + B10 Trust + B11 Extension + B12 Credit + B13 Market + εi

Table 1 - Variables used in the ordered logit model and hypohetized sign.

Variable	*Description*	*Nature of quantification*	*Hypothetised sign*
Dependent variable	Types of adopters	0 not interested in adopting, 1 interested to be late adopters, 2 interested to be early adopters	
Independent variable			
Demographic characteristics			
Age	Age of farmer	number of years	+/-
EL	Education level	1 higher than primary level, 0 otherwise	+
Gender	Sex of the household head	1 male, 0 female	+/-
Farm characteristics			
Location	Chebika/Fernana	1 chebika / 0 fernana	+/-
Size	Farm Size	number of ha	+
Tenure	Land tenure	1 property, 0 otherwise	+/-
Off-farm	Off-farm income	1 yes / 0 No	+
Technological factors			
Pertec	Perception towards enhanced irrigation benefits	1 positive perception, 0 otherwise	+
Perception and behavioral factors			
Risk*	Risk attitudes	1 aversion, 0 otherwse	-
Trust*	Trust in farmers and extension agents	1 trust, 0 otherwise	+
Institutional and communication factors			
Extension services*	Assistance from extension services	1satisfied, 0 no	+
Credit	Credit access	1 yes / 0 No	+
Market*	Market access issues	1 no problem, 0 otherwise	-

** Likert scale is used from 1 to5 for data collection of these variables. We combined 1-3 as a base of disagree and 4-5 as an agree variable.*

4. Results and discussion

The Variance Inflation Factor (VIF) between the independent variables does not exceed 4, rejecting the hypothesis of multicollinearity. The results of Durbin-Wu-Hausman test of endogeneity show that we can accept the null hypothesis of no endogeneity of risk and trust variables because the p-value is higher than 0.05, indicating that these variables are not correlated with the error term. Empirical results are reported in Table 2. The coefficients of the two thresholds (u0 and u1) are statistically significant at 5% level. The likelihood ratio (LR) is also statistically significant at 1% level, indicating a good fit of the model.

Regression results of multinomial logit model reveal that early adoption is significantly and positively influenced by extension services, trust, perception towards innovation, credit access and off-farm income. However, it is significantly and negatively affected by market access issues, risk aversion, and age. Gender, farm location, farm size and education level of household head have no significant influence on early adoption decision of enhanced irrigation technologies.

The positive and significant association between extension services and early adoption shows that farmers who are satisfied from the assistance of extension services are more likely to be early adopters of enhanced irrigation technologies. This result is in line with previous studies (Daberkow and Mcbride 1998; Diederen *et al.*, 2003; Dadi *et al.*, 2004; Llewellyn, 2007; Beyene and Kassie, 2015; Deepak *et al.*, 2019).

The results also reveal that trust is significantly and positively affecting the early adoption decision. This result indicates that farms who trust other farmers and extension agents are more likely to be early adopters. This finding is similar to findings of Beyene and Kassie (2015) and Ainembabazi *et al.* (2016), and Deepak *et al.* (2019).

Furthermore, the results in Table 2 show that the perception towards innovation is significantly and positively associated with early adoption decision. This result is in agreement with the findings of Adesina and Zinnah (1993), Batz *et al.* (1999), Llewellyn and Brown (2020), Zhllima *et al.* (2021) and Nyairo *et al.* (2022).

Additionally, the financial variables such as off-farm income and credit access have a posi-

Table 2 - Maximum likelihood estimates of the ordered logit model of farmers' willingness to early adopt agricultural innovation.

Variables	*Coefficient*	*t-statistic*	*Marginal effects for early adopters*
Age	-0.153**	-2.46	-0.003**
EL	-0.160	-0.10	-0.031
Gender	-0.017	-0.97	-0.003
Location	-0.078	-0.40	-0.015
Size	-0.002	-0.23	-0.001
Tenure	-0.029	-0.13	-0.006
Off-farm	0.435*	2.48	0.083*
Pertec	0.429**	2.68	0.082**
Risk	-0.909***	-5.42	-0.174***
Trust	0.562***	3.56	0.108***
Extension	0.715***	3.74	0.1370***
Credit	0.383*	1.68	0.073*
Market	-0.461***	-3.07	-0.0883***
U_1	-2.219**		
U_2	-0.687**		
Log-likelihood	-708.305***		

**** significant at 1%; ** significant at 5%, * significant at 10%.*

tive and significant effect on early adoption decision. This paper thus confirms that financial variables play significant roles in the decision to early adopt enhanced irrigation technologies. Our results are in keeping with the findings reported in the speed adoption literature that identifies early adopters (Daberkow and Mcbride, 1998; Ayisi *et al.*, 2022).

The age of household head has a negative and significant influence on early adoption decision. This implies that older farmers are less likely to be early adopters. This result is in line with findings reported by Daberkow and Mcbride (1998), Diederen *et al.* (2003) and Ayisi *et al.* (2022).

As expected, table 2 further indicates that market access issue has found to be important driver of early adoption. This result is in line with the findings of Dadi *et al.* (2004) and Matuschke and Qaim (2008) who demonstrated that lack of market access is one of the major constraints affecting the adoption of enhanced irrigation technologies.

Finally, the results also indicate that risk aversion affect negatively and significantly early adoption decision. The finding is consistent with the empirical literature that identifies early adopters (Yoo, 2014; Finger and Möhring, 2022). In fact, risk takers farmers are more likely to be early adopters of agricultural innovation compared to risk averse farmers.

Marginal analysis shows that risk, trust, market access, extension services, and perception towards technology are important factors in driving early adoption decision. Therefore, to accelerate the adoption speed of enhanced irrigation technologies by farmers in Tunisia, especial attention should be given to these factors. This could lead enhancement of agricultural productivity sector.

5. Conclusion and policy implications

This paper identified the major factors influencing farmers' willingness for early adoption of enhanced irrigation technologies in Northern (Fernana) and Central (Chebika) of Tunisia. The paper used a multinomial logit model for the empirical analysis of the collected data from a survey conducted to 931 farmers.

The identification of early adopters of enhanced irrigation technologies is especially important in current water scarcity, climate change and drought circumstances. The results highlight that farmers' perceptions and attitudes should be considered in the analysis of adoption studies.

Farmers with financial availability, those who trust extension agents and farmers' association, risk takers, young, satisfied from the assistance of extension services and without market access issues are more willing to be early adopters of innovation. The findings imply that following interventions can accelerate the adoption speed of farmers in Tunisia:

- Farmers and extension officers training on water conservation technologies is highly recommended;
- Farmers should be provided with mechanisms of financial support for innovation adoption such as subsidy for access to credit;
- Increase awareness of young farmers about the usefulness and opportunities of agricultural innovations;
- Participatory approach including all stakeholders during technology generation and transfer should be implemented;
- Provide incentives to farmers' associations in order to improve their market access;
- Inform farmers about the advantage of innovation through trials, field days, information and communications technology, etc.

Acknowledgements

This research is part of the FoodLAND project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement (GA No 862802). The views and opinions expressed in this document are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

The authors would like to thank Simone Piras and Laure Kuhfuss from James Hutton Institute Team, and Valentino Marini Govigli from University of Bologna for their suggestions and contributions, including administering the questionnaires and ensuring the quality of the dataset. Final thanks go to the local enumerators who supported the data collection in the field, and to all the farmers for taking their time to respond to the survey.

References

Adesina A.A., Zinnah M.,1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural Economics*, 9: 297-311.

Ainembabazi J.H., Van Asten P., Vanlauwe B., Ouma E.A., Blomme G., Birachi E.A., Dontsop Nguezet P.M., Mignouna D.B., Manyong Victor M., 2016. Improving the speed of adoption of agricultural technologies and farm performance through farmer groups: evidence from the Great Lakes region of Africa. *Agricultural Economics*, 48: 1-19.

Alcon F., De Miguel M.D., Burton M., 2011. Duration analysis of adoption of drip irrigation technology in southeastern Spain. *Technological Forecasting & Social Change*, 78: 991-1001.

Ayisi D.N., Kozári J., Krisztina T., 2022. Do smallholder farmers belong to the same adopter? An assessment of smallholder farmers innovation adopter categories in Ghana. *Heliyon*, 8(8): e10421.

Aziza M., Raoudha K., Gley K., 2009. The adoption of technical and organizational innovations and their impact on the dairy sheep breeding in Tunisia. *New Medit*, 8(3): 36-40.

Batz F.J., Janssen W., Peters K.J., 2003. Predicting technology adoption to improve research priority setting. *Agricultural Economics*, 28(2): 151-164.

Batz F.J., Petersa K.J., Janssen W., 1999. The influence of technology characteristics on the rate and speed of adoption. *Agricultural Economics*, 21: 121-130.

Beyene A.D., Kassie M., 2015. Speed of adoption of improved maize varieties in Tanzania: An application of duration analysis, *Technological Forecasting & Social Change*, 96: 298-307.

Bultena G.L., Hoiberg E.O., 1983. Factors affecting farmers' adoption of conservation tillage. *Journal of Soil and Water Conservation*, 38(3): 281-284.

Byerlee D., De Polanco E.H., 1986. Farmers' stepwise adoption of technological packages: evidence from the Mexican Altiplano. *American Journal of Agricultural Economics*, 68(3): 519-527.

Daberkow S.G., Mcbride W.D., 1998. Socio-economic profiles of early adopters of precision agriculture technologies. *Journal of Agribusiness*, 16: 151-168.

Dadi L., Burton M., Ozanne A., 2004. Duration analysis of technological adoption in Ethiopian agriculture. *Journal of Agricultural Economics*, 55(3): 613-631.

Deepak V., Pramod K.J., Devesh R., 2019. *Identifying Innovators and Early Adopters of Agricultural Technology. A Case of Wheat Varieties in Rajasthan, India*. IFPRI Discussion Paper 01808. Washington, DC: International Food Policy Research Institute.

Dhraief M.Z., Bedhiaf-Romdhania S., Dhehibi B., Oueslati Zitouna M., Jebali O., Ben Youssef S., 2019. Factors affecting the adoption of innovative technologies by livestock farmers in arid area of Tunisia. *New Medit*, 18(4): 3-18.

Dhehibi B., Dhraief M.Z., Ruediger U., Frija A., Werner J. M., Straussberger L., Rischkowsky B., 2022. Impact of improved agricultural extension approaches on technology adoption: Evidence from a randomised controlled trial in rural Tunisia. *Experimental Agriculture*, 58(e13): 1-16.

Dhehibi B., Ruediger U., Moyo P.H., Dhraief M.Z., 2020. Agricultural Technology Transfer Preferences of Smallholder Farmers in Tunisia's Arid Regions. *Sustainability*, 12(1): 1-18.

Dhehibi B., Zucca C., Frija A., Kassam S.N., 2018. Biophysical and econometric analysis of adoption of soil and water conservation techniques in the semiarid region of Sidi Bouzid (Central Tunisia). *New Medit*, 17(2): 15-28.

Diederen P., van Meijl H., Wolters A., Bijak K., 2003. Innovation adoption in agriculture: innovators, early adopters and laggards. *Cahiers d'Economie et de Sociologie Rurales*, 67: 29-50.

Finger R., Möhring N., 2022. The adoption of pesticide-free wheat production and farmers' perceptions of its environmental and health effects. *Ecological Economics*, 198: 107463.

Fouzai A., Smaoui M., Frija A., Dhehibi B., 2018. Adoption of Conservation Agriculture technologies by smallholders' farmers in the semiarid region of Tunisia: resources constraints and partial adoption. *Journal of New Sciences*, 6(1): 105-114.

Kassie M., Teklewold H., Jaleta M., Marenya P., Erenstein O., 2015. Understanding the adoption of a portfolio of sustainable intensification practices in Eastern and Southern Africa. *Land Use Policy*, 42: 400-411.

Korsching P.F., Stofferahn C.W., Nowak P.J., Wagener D.J., 1983. Adopter characteristics and adoption patterns of minimum tillage: Implications for soil conservation programs. *Journal of Soil and Water Conservation*, 38(5): 428-431.

Kumar G., Engle C., Avery J., Dorman L., Whitis G., Roy L.A., Xie L., 2021. Characteristics of early adoption and non-adoption of alternative catfish production technologies in the U.S. *Aquaculture Economics & Management*, 25(1): 70-88.

Lindner R.K., Pardey P.G., Jarrett F.G., 1982. Distance to information source and the time lag to early adoption of trace element fertilizers. *Australian Journal of Agricultural Economics*, 26(2): 98-113.

Llewellyn R.S., 2007. Information quality and effectiveness for more rapid adoption decisions by farmers. *Field Crops Research*, 104: 148-156.

Llewellyn R.S., Brown B., 2020. Predicting adoption of innovations by farmers: what is different in smallholder agriculture? *Applied Economic Perspectives and Policy*, 42(1): 100-112.

Manda J., Khonje M.G., Alene A.D., Tufa A.H., Abdoulaye T., Mutenje M., Setimela P., Manyong V., 2020. Does Cooperative Membership Increase and Accelerate Agricultural Technology Adoption? Empirical Evidence from Zambia. *Technological Forecasting and Social Change*, 158: 120160.

Matuschke I., Qaim M., 2008. Seed Market privatisation and farmers' access to crop technologies: The case of hybrid pearl millet adoption in India. *Journal of Agricultural Economics*, 59(3): 498-515.

Ngango J., Hong S., 2021. Speed of Adoption of Intensive Agricultural Practices in Rwanda: A Duration Analysis. *Agrekon*, 60(1): 43-56.

Nyairo N.M., Pfeiffr L., Spaulding A., Russell M., 2022. Farmers' attitudes and perceptions of adoption of agricultural innovations in Kenya: a mixed methods analysis. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 23(1): 147-160.

Rogers E.M., 2003. *Diffusion of Innovations*. New York: The Free Press.

Tey Y.S., Brindal M., 2023. A meta-analysis of factors speeding the adoption of agricultural intensification methods in Africa. *The Journal of Agricultural Education and Extension*. https://doi.org/10.1080/1389224X.2023.2240758.

Yoo D., 2014. *Farm Heterogeneity in Biotechnology Adoption with Risk and Learning: an Application to U.S. Corn*. Paper presented at the Annual Meeting of the Agricultural and Applied Economics Association, July 27-29, Minneapolis, MN.

Zhllima E., Shahu E., Xhoxhi O. *et al*., 2021. Understanding farmers' intentions to adopt organic farming in Albania. *New Medit*, 20(5): 97-110.

Impact of Young Farmers Supports on the young farmers' willingness to continue farm activities: A case of TR52 region in Türkiye

Metin Türker*

DOI: 10.30682/nm2401g
JEL codes: O13, O18, P25

Abstract

There has been an increase in the demand for agricultural products and different support programs are implemented by countries to keep a sufficient, economically active population in agriculture. The aim of this study was to examine the impacts of the Young Farmer Support Program (YFP) in Türkiye. The primary data for this study was obtained from face-to-face surveys conducted with 155 young farmers. The logit model was used to analyse the factors affecting the willingness of young farmers to continue agricultural activities. The results showed that about half of the young farmers were not satisfied with the provided support, and 23.7% of them considered exiting the agricultural sector. The results of the Logit model showed that the satisfaction from the Program, the presence of social facilities in the rural areas, crop diversity, agricultural insurance, and investments in the farms were statistically significant and had an impact on the willingness of young farmers to continue their farm activities. Diversifying and expanding the scope of support policies for young farmers could make significant contributions to keeping young farmers in the agricultural sector and rural areas.

Keywords: *Impact assessment, Logistic regression, Support program, Young farmers.*

1. Introduction

Nowadays, the effective and efficient use of natural resources for adequate and balanced nutrition comes to the fore for the growing population. Meanwhile, the socio-economic challenges and changes faced by farmers in rural areas for agricultural production constitute a priority area. In this context, the shrinkage faced in the field of agriculture, the reduction in the scale of the operation, the increase in ownership issues, the depletion of natural resources, water scarcity, global climate change problems, as well as the migration problems in rural areas, the migration of young people from agriculture, and the aging agricultural population are among the extremely important issues of food supply. On the other hand, while global crises, pandemics, natural disasters, and rising food prices have increased the importance of the agricultural sector in meeting food needs, it is becoming more and more important for young people to remain involved in agricultural activities. An aging agricultural population is one of the most important problems for the sector in Türkiye. According to the Farmers Registry System, 69% of the farmers were aged 50 and above (MoAF, 2021). According to TURK-

* General Directorate of Agricultural Research and Policies, Ministry of Agriculture and Forestry, Ankara, Türkiye.
Corresponding author: metin.turker@gmail.com

STAT, by the end of December in 2022, there were a total of 57,934,583 individuals living in the localities categorized as densely populated in Türkiye. These areas covered just 1.6% of Türkiye's entire land area. To put it differently, densely populated areas accommodated approximately 67.9% of Türkiye's population (TURKSTAT, 2023). This reduces the effectiveness of digitalization, agricultural mechanization, education-dissemination, organization, and agricultural policies. In 2021, the median age in Türkiye was recorded at 33.1 years. Presently, 9.5% of the population is aged 65 and above, indicating a growing concern over population ageing as highlighted in various official policy documents. The current size of this age group is approximately 8 million individuals and is projected to surpass 27 million by the year 2080 (Yıldız *et al.*, 2023).

Because young farmers play an important role in the sustainability of agriculture and food security for countries, various support policies or programs have been implemented by both developed and developing countries to encourage young farmers to stay in the agricultural sector and to establish their own businesses. Thus, to find solutions to the problems of young farmers, the European Union (EU) provided financial assistance of 3.7 billion euros to 126,000 young farmers who started their own businesses in the period between 2007 and 2013, and it was expected to pay 2.6 billion euros to 180,000 young farmers during the existing period of support program (AP, 2017) within the scope of the Common Agricultural Policy (CAP). The draft council regulation laying down the EU's multi-annual financial program framework for the years between 2020 and 2027 puts an emphasis on supporting young farmers, and the final declaration of the Agricultural Council held in 2019 includes the issues on supporting young and women entrepreneurs in rural areas.

Similarly, Young Farmer Support Program has been implemented in Türkiye. The aim of YFP is to prevent the migration of young farmers from rural areas by encouraging reverse migration from urban to rural areas, and to make young farmers choose agriculture as a profession and to implement a strong project prioritizing voluntary and disadvantaged groups aiming to develop entrepreneurship in the rural areas. Within the scope of the YFP, a grant of 30,000 Turkish Lira (TL) was paid to young entrepreneurs between the ages of 18 and 40 who live or commit to live in rural areas in the period of 2016-2018. Thanks to this support program, 47,750 entrepreneurs migrated from urban areas to rural areas and approximately 20,000 new businesses were established (MoAF, 2021).

The literature mentioned above examined YFP at the regional and provincial levels, but there has not been a study conducted in the TR52 Region (In the context of the Statistical Regional Units Classification (NUTS) of Türkiye, TR52 Region is one of the 2nd level regions, which includes Konya and Karaman provinces). In this study, the willingness of young farmers to continue their agricultural activities in TR 52 Region of Türkiye was examined based on the Young Farmer Support Program. After the implementation of the Young Farmer Project, the problems and expectations of young farmers about the program have been examined. In this context, Berk (2018) investigated the problems of young farmers and the factors affecting the departure of young farmers from agricultural activity in Niğde province. According to the findings of the study, young farmers left agriculture in search of better living conditions, especially for the education and health of their children. Moreover, Alkan and Özkan (2020) evaluated the realization potential and sustainability of the YFP implementation in Antalya province. The study showed that the vast majority of the farmers (85%) benefited from the project thought that the project was beneficial and 14.2% of farmers started agricultural production with YFP. On the other hand, Yalçın *et al.* (2020) conducted a study to determine the tendency of young farmers to stay in agriculture and migrate from rural to urban areas of young people between the ages of 18-40 who benefited from the Young Farmer Grant Support in Gaziantep and Şanliurfa provinces. The results of the study showed that 39%

Figure 1 - Research area.

Source: MoAF, 2021.

of the young farmers tended to migrate from the rural areas. Akkaya and Gülçubuk (2018) conducted a study about YFP in the Polatlı district of Ankara province, and the research results showed that 80% of the young farmers benefited from YFP see themselves as entrepreneurs and 36.7% of young farmers wanted to migrate from their farms. Çağlayan *et al.* (2020) evaluated YFP for animal breeders and developed new criteria to evaluate the success of the program. The research findings demonstrated that YFP was successful despite flaws such as insufficient grant funding. In a similar study, Aggelopoulos and Arabatzis (2010) determined that the outcomes reveal that following the initiation of the financing programme, the focus of the farms has shifted towards capitalizing on the comparative benefits of diverse regions through the cultivation of crops that are well-suited to the respective areas. On the other hand, Yılmaz and Keskin (2020) examined the YFP in Hatay province to identify the problems experienced in the implementation process of the project. The findings showed that the intended effectiveness level was not achieved, because the breeders did not receive the targeted efficiency or was not given the animal they wanted. Birol *et al.* (2020) determined a new criterion for the YFP support program and measured the willingness of the farmers to get paid with different scenarios and found that the biggest needs of entrepreneurs were marketing and that the support should be 51,000 TL for young entrepreneurs. And Can and Engindeniz (2020) indicated in their study that factors such as age, being a farmer within the family, and possessing family-owned farmland have a positive impact on the likelihood of students taking advantage of the YFP.

2. Materials and methods

The primary data for the study was obtained from young farmers in the TR52 Region (Konya and Karaman provinces) in 2021 through the face-to-face survey method. The research area was chosen purposefully, and the proportional sampling method (formula 1) was used to determine the sample size, since the research was aimed at a specific target group and audience. There is no significant difference between the two provinces selected as the research area in terms of crop pattern and infrastructure. The young farmer ratios in the provinces and regions were used in the sample size calculation. The sample size calculation was made by taking the 2020 FRS data into consideration. It has been determined that there was a total of 101,329 farmers in Konya and Karaman provinces, and the total number of young farmers (under 40 years old) was 13,274 and consists of 13.1% of the total population (Figure 1).

In this context, the p ratio was taken as 13.1% in the calculation. For the research, the number of samples was determined as 155, with a confidence interval of 99% and a deviation of 7% from the mean. Furthermore, to distribute the sample size to the relevant provinces, the proportion of young farmers in the provinces was taken into consideration. In this context, the face-to-face survey was conducted with 127 young farmers in Konya province and 28 young farmers in Karaman province.

$$n = \frac{N * p * q}{(N-1) * \sigma^2_{P_x} + p * q}$$

q=p-1

$$\sigma^2_{P_x} = \left(\frac{r}{Z_{\propto/2}}\right)^2$$

where:
N = Population size
n = Number of sample size
p = Proportion of young farmers in the population
q = Proportion of non-young farmers in the population
σ = Standard deviation
R = Mean deviation
Z = Z-score (Newbold, 1995)

As of 2018, the TR52 Region constitutes 3% of the total population of Türkiye (about 2.5 million). In addition, it was observed that there was a reduction in the population size of the region, which is one of the reasons for the study area selection. There was migration from the TR52 region, and the migration rates fluctuated between 2 and 5% (MEVKA, 2019).

In the research, the logit model was used to analyse the factors affecting the willingness of young farmers to continue agricultural activities. Various trials were conducted in the selection of variables to be included in the logit model, and the variables generating the most meaningful results have been incorporated into the model. Some variables, however, were not included as they did not make a significant contribution to explaining the model. The logit model is expressed as (Gujarati, 1995):

$$P_i = F(Z_i) = F\,(\alpha + \beta X_i) = \\ = \frac{1}{1 + exp^{-(z_i)}} = \frac{1}{1 + exp^{-(\alpha + \beta x_i)}} \quad (1)$$

P_i is the probability of i[th] household to select a specific choice, F is the probability function, is constant coefficient, Z_i equals *α plus* βX_i, β is the estimation of parameters for each explanatory variable and, x_i represents i[th] independent variable. By rearranging the equation 1 and finding the natural logarithm of both sides of the equation, the equation becomes.

$$L_i = Ln\left[\frac{P_i}{(1-P_i)}\right] = Z_i = \\ = \alpha + \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \varepsilon_i \quad (2)$$

Marginal probability shows the variation in the probability of poverty in accordance with the change in each explanatory variable (Greene, 2011). The estimated β-coefficients of equation (2) do not directly represent the marginal effects of the independent variables on the probability P_i. In the case of a continuous explanatory variable, the marginal effect of X_j on the probability P_i is given by:

$$\frac{\partial P_i}{x_{ij}} = \frac{|\beta_j \ \exp(-\beta X_i)|}{|1 + \exp(-\beta X_i)|^2} \quad (3)$$

If the explanatory variable is qualitative or discrete, however, $\partial P_i / \partial X_{ij}$ do not exist. In such a case, the marginal effect is obtained by evaluating P_i at alternative values of x_{ij}. For example, in the case of a binary explanatory variable x_{ij} that takes values of 1 and 0, the marginal effect is determined as:

$$\frac{\partial P_i}{x_{ij}} = P(X_{ij}) = 1 - P(X_{ij}) = 0 \quad (4)$$

Table 1 shows the descriptive statistics of the Logit model variables. The descriptive statistics were analysed in a split-file format to illustrate differences between the young farmers who were willing and not willing to continue in their farm activities. Based on below explanatory variables including the satisfaction from Young Farmer Support Program, the dependent variable of the model was taken as the willingness young farmers to continue agricultural activities (Y_i=1) and otherwise (Y_i=0). The descriptive results showed that 27% of the young farmers were willing to continue their farm activities, while 73% of the young farmers were willing to exit farm activities. About half of the young farmers were satisfied with the Young Farmer Support Program, while 63% the young farmer ensured

Table 1 - Descriptive statistics of the model variables.

Variables	*Definition*	*Mean*	*Std. Dev.*
Dependent variable			
WTCAGRACT	1 for willingness to continue agricultural activities, 0 otherwise	0.27	0.44
Independent variables			
SATYFARSUP	1 for farmer satisfied with the YFP, 0 otherwise	0.50	0.50
CROPDIVERS	1 for the young farmer that ensures crop and/or product diversity, 0 otherwise	0.63	0.49
AGINSURANCE	1 for the young farmer that has agricultural insurance, 0 otherwise	0.25	0.44
SUFSOCFAC	1 for the sufficient social facilities in rural areas, 0 otherwise	0.30	0.46
SUFINFRSER	1 for rural area that has sufficient infrastructure services, 0 otherwise	0.38	0.49
FARMINVEST	1 for the young farmer that has invested in the farm, 0 otherwise	0.61	0.49
INCOME	1 for the young farmer that has a monthly income higher than TL 1500, 0 otherwise	0.79	0.41
EDUCATION	1 for the young farmer that completed high school or higher education, 0 otherwise	0.64	0.48

crop and/or product diversity in their farms. About 25% of the young farmers insured their crops or animals. Moreover, 30% and 38% of the young farmers had sufficient infrastructure and social facilities in their rural areas, respectively. In addition, 61% of the young farmers made investments in their farms. About 78% of the young farmers had a monthly income higher than 1500 TL, and 64% of the young farmers had completed high school or higher education.

3. Results and discussions

The political, economic, and social developments have caused a substantial migration from rural to urban areas in recent years. It is also known that rapid and irregular migration leads to various problems in both the agricultural sector and urban areas. Investigating these problems is important in terms of troubleshooting the problems in the country. As it can be seen in Table 2, the average age of young farmers was 33.4 years. The young farmers have a household size of 4.6 with 2.3 children. The average agricultural experience of young farmers was 12 years. About ¾ of the young farmers have completed high school or below-grade education level. While the young farmers who were willing to continue farm activities had most commonly completed their high school education, the young farmers who were not willing to continue farm activities had most commonly completed their primary school education. About 60% of the young farmers have lived only in the villages, while the proportion of people living in the village was 35.4% for the young farmers who were willing to continue farm activities and 40% for the young farmers who were not willing to continue farm activities. The average land size of young farmers was 312.6 decares, and about half of the young farmers had 50 or fewer decares of land, and 27.7% of the young farmers' land had increased in the last 5 years. A high proportion of young farmers (81.6%) stated that they would be willing to continue their agricultural activities if the land was inherited from their families. In terms of education, residence place, land size, and income, there was a statistically significant difference at the level of 10% between the young farm groups. The lack of job opportunities and insufficient income levels in the rural areas are among the main reasons for young farmers to leave the rural areas. About two-third of young farmers had a household monthly income between 1501 and 5000 TL. There was a statistically significant difference between the young farmer groups in terms of income level. Furthermore, 69.7% of the respondents stated that they would prefer to live in the rural areas if their financial situation was good, and 22.6% of the

Table 2 - Descriptive statistics of the socio-demographic and economic variables.

	Willing to Continue		*Not Willing to Continue*		*All Young Farmers*	
	Mean/ Frequency	*Std. deviation/%*	*Mean/ Frequency*	*Std. deviation/%*	*Mean/ Frequency*	*Std. deviation/%*
Age (years)	32.10	5.65	33.84	4.845	33.37	5.12
Household size (person)	4.5	2.18	4.63	1.57	4.59	1.75
Children (person)	2.25	0.84	2.31	0.86	2.30	0.86
Experience (years)	11.07	7.20	12.64	7.67	12.21	7.55
Education (%)*						
Illiterate	0.0	0.0	1,8	1.2	1.4	0.9
Primary school	26.2	16.9	38,1	24.6	34.8	22.5
High school	52.4	33.8	35,4	22.8	40.0	25.8
University	21.4	13.8	24,7	15.9	23.8	15.4
Residence (%)*						
Village	54.8	35.4	62,8	40.5	60.6	39.1
District	21.4	13.8	18,6	12.0	19.4	12.5
Village & district	21.4	13.8	10,6	6.8	13.5	8.7
Urban center	2.4	1.5	8,0	5.2	6.5	4.2
Land size (decare)*						
<10	5	11.9	22	19.5	27	17.4
11-50	16	38.1	30	26.5	46	29.7
51-100	5	11.9	15	13.3	20	12.9
101-250	6	14.3	19	1.8	25	16.1
251-500	6	14.3	13	11.5	19	12.3
501 and above	4	9.5	14	12.4	18	11.6
Income (TL/Month) *						
0-1500	8	19.0	24	21.2	32	20.6
1501-3000	15	35.7	44	38.9	59	38.1
3001-5000	13	31.0	32	28.3	45	29.0
5001-9999	5	11.9	11	9.7	16	10.3
10000 ≥	1	2.4	2	1.8	3	1.9

** Means of the 2 subsets are statistically different at 10% levels.*

respondents were considering moving to the city within the next 5 years.

The results of agricultural activity granted skills and training needs of the young farmers are given in Table 3. About 32.6% of the young farmers benefited from bovine breeding activity, while others benefited from ovine breeding (26.1%), vegetable or fruit projects (15.2%), beekeeping, poultry, and sericulture (10.9%), greenhouse cultivation (10.3%), and medical aromatic plants and mushrooms (4.3%). About more than half of young farmers had the ability to drive tractor, use social media, do accounting, shop online and prune fruits, and less than one-third of young farmers had the ability to know about rural development programs, apply agricultural supports, prepare agricultural project, involve sport, operate the stock exchange and set up a business. The young farmers create an expectation that they will attend various courses and trainings on agricultural activities and become certified. About 40% of young farmers had a certificate of different agricultural field. Young farmers ranging from 21% to 55% need training

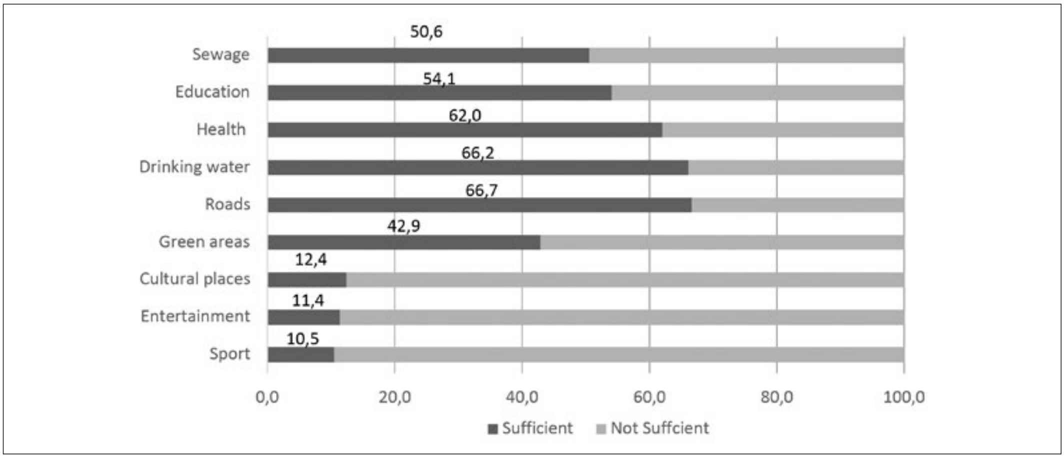
Table 3 - Agricultural activity granted, skills and training need of the young farmers.

	Frequency	*Percent (%)*
Agricultural activity granted by the young farmer		
Bovine animal breeding	51	32.6
Ovine animal breeding	40	26.1
Vegetable or fruit production	24	15.2
Beekeeping, poultry or sericulture	17	10.9
Subsoil or greenhouse cultivation	17	10.9
Herbal Production- Medicinal Aromatic-Mushroom, etc.	7	4.3
Skills of the young farmer		
Drive tractor	127	81.9
Use social media	103	66.5
Understand accounting	91	58.7
Shop online	87	56.1
Prune fruits	79	51.0
Knowledge on rural development programs	48	31.0
Apply agricultural supports	37	23.9
Prepare agricultural project	31	20.0
Involve a sport	24	15.5
Operate the stock exchange	12	7.7
Set up a business	10	6.5
Training or guidance needs of the young farmer		
Plant production maintenance works	86	55.4
Project preparation and finding financial support	81	52.3
Use of tools and equipment	68	43.9
Investing-starting a company	66	42.6
Information technologies	65	41.9
Accounting-sales	57	36.8
Sports activities	35	22.6
Fine arts	33	21.3

or guidance on plant production maintenance works, project preparation and finding financial support, using agricultural machinery and equipment, investing, and starting a company, information technologies, accounting and sales, and sports and fine arts.

The most important factor that encourages young farmers to continue their lives in rural areas is the adequacy and quality of public services brought to their place of residence. In this study, young farmers were asked to evaluate the services brought to their place of residence. The results show that the provincial directorates of district agriculture and forestry was ranked as the first institution among the others providing necessary services to young farmers. Half of the young farmers stated that they were satisfied with the services of this institution. About 52.9% of the young farmers could not protect themselves against the fluctuations in the price of the agricultural products, while 47.1% of the young farmers tried to protect themselves by following the market price of the products, storing their crops and selling crops or products in cash.

Figure 2 - Adequacy of infrastructure and facilities in the rural areas (%).



About 61.9% of the young farmers stated that a new employment area had not been created for young farmers in the rural areas during the YFP, while 60.4% of the respondents stated that various infrastructure investments were made by the state in their regions. Young farmers ranging from 50.1% to 66.7% stated that rural infrastructure such as sewage, education, health, drinking water, and roads was sufficient, while young farmers ranging from 57.1% to 89.5% stated that green areas, cultural places, entertainment, and sports facilities were not sufficient in their rural areas (Figure 2).

In the study, the expectations of young farmers were evaluated by the Likert scale statements in Table 4. The results showed that the young farmers agree with the statements such as "the problems of young farmers are not known sufficiently", "young farmers manage businesses better", "young farmers perform production more efficiently", "young farmers are sensitive to the disease and pest management", "young farmers are giving hope to the society for the future", "the young farmers grow higher quality crops", and "agricultural activities were adversely affected by the pandemic". However, some of the young farmers agree with the statements such as "young farmers are sufficiently interested in agricultural policies", "young farmers insured all crops and animals", "adequate support is provided to young farmers", "young farmers cooperate well with the universities" and "the state adequately meets the needs of young farmers."

The logit model results of the willingness of young farmers to continue agriculture are given in Table 5. The results of the Logit model showed that the satisfaction of young farmers from the YFP, the presence of social facilities in the rural areas, the attitudes toward crop/product diversity, agricultural insurance, and investments in the farms had statistically significant impacts on the willingness of young farmers to continue their farm activities.

Agricultural support is an important instrument in guiding and motivating young farmers in their agricultural activities, as well as making important contributions to the sustainability of the farms. The research results showed that the young farmers who were satisfied with the YFP were 23.4% more likely to continue their farm activities than their counterparts. Turkekul and Abay (2020) also found that agricultural support is one of the important factors on farmers' quitting decisions from the agricultural sector. In addition, Kan *et al.* (2018) stated that higher support should be given young farmers to improve their entrepreneurial spirits.

Moreover, physical infrastructure and social facilities in rural areas have also affected young farmers' willingness to continue farm activities. Social facilities such as adequate social opportunities in rural areas, access to education and health services as well as individual wishes

Table 4 - Expectations of the young farmers.

Statements	*Average**
The problems of young farmers are not known sufficiently.	3.74
Young farmers manage businesses better.	3.54
Young farmers perform production more efficiently.	3.54
Young farmers are sensitive to the disease and pest management.	3.50
Young farmers are giving hope to the society for the future.	3.42
The young farmers grow higher quality crops.	3.39
Agricultural activities were adversely affected by the pandemic.	3.39
The professional knowledge of young farmers is sufficient.	3.18
Young farmers have no marketing problems.	3.08
Young farmers have sufficient knowledge about the use of inputs.	3.07
Young farmers generally perform dry farming on their agricultural lands.	3.06
Young farmers have enough knowledge about soil reclamation, erosion control and drainage management.	3.06
Young farmers sell their crops/products faster with digital tools (social media).	3.01
The agricultural credit use of young farmers is low.	3.00
Young farmers are sufficiently interested in agricultural policies	2.95
Young farmers insured all crops or animals.	2.61
Adequate support is provided to young farmers.	2.59
Young farmers cooperate well with the universities.	2.55
The state adequately meets the needs of young farmers.	2.32

**1: I strongly disagree / 2: I disagree / 3: Indecisive / 4: I agree / 5: I strongly agree.*

Table 5 - Logit model results.

	Coef.	*Std.*	*P>|z|*	*Marginal effects*	*P>|z|*
CONSTANT	-0.265	0.660	0.689		
SATYFARSUP ***	1.577	0.472	0.001	0.234	0.000
SUFSOCFAC**	1.115	0.466	0.017	0.165	0.010
CROPDIVERS***	1.544	0.451	0.001	0.229	0.000
SUFINFRSER	0.680	0.550	0.216	0.101	0.207
AGINSURANCE *	1.052	0.610	0.085	0.156	0.077
FARMINVEST*	0.952	0.526	0.070	0.141	0.060
INCOME	0.990	0.635	0.119	0.144	0.093
EDUCATION	0.512	0.469	0.275	0.076	0.268
Number of obs	155				
LR $chi^2(11)$	40.15				
Prob > chi^2	0.0000				
Pseudo R^2	0.2217				

and desires keep young farmers in rural areas. The model results showed that the young farmers who consider social opportunities sufficient were 16.5% more likely to continue farm activities than their counterparts. Altintas *et al.* (2019) found also that the difficulties in rural areas caused the migration of farmers from agricultural sector.

The possibility and desire to increase crop/product diversity in the farm is an important factor keeping farmers in agricultural sector. Young farmers who want to increase their agricultural crop/product diversity were 22.9% more likely to remain in the farms than those who do not want to increase their crop diversity. Bragg and Dalton (2004) found also that greater diversification of farm income was more likely associated with a decision to leave dairy farming.

Insurance provides farmers with the opportunity to compensate for the crop and economic losses they experience when faced with risks. Young farmers who have agricultural insurance were 15.6% more likely to remain in agricultural sector than their counterparts.

Fixed capital investment in the farms is an important tool to increase their production and income. Young farmers who invest in their farms were 14.1% more likely to remain agriculture sector than their counterparts.

4. Conclusions

Aging of population in agricultural sector and migration from the sector are among the most important problems in Türkiye. To reduce exit from the sector and keep the young population in agriculture, the government should enable farmers to have access to basic physical infrastructure and social services in rural areas, as well as generate a sufficient income from their farms. Moreover, government programs for young farmers have to support the decision of the farmers to stay in the sector.

Many countries have implemented different programs aimed at assisting young farmers in embarking on careers in farming. Nevertheless, certain programs have faced criticism for their insufficient support, particularly due to a lack of consideration for the diverse profiles of young farmers. These criticisms arise from the realization that young farmers come from varied backgrounds, possess different skill sets, and face unique challenges. Therefore, it is crucial for farming programs to account for this diversity and offer comprehensive support that addresses the specific needs and circumstances of young farmers.

Türkiye needs additional measures to advance the implementation of the integrated administration and control system. The Farm Accountancy Data Network (FADN) currently encompasses all 81 provinces and is integrated into the agricultural production and registration system. However, the agricultural census is still ongoing, and there is a need to adopt a strategy for agricultural statistics.

In Türkiye, YFP was implemented from 2016 to 2018 to prevent rural migration, encourage reverse migration from urban areas to rural areas, and support young entrepreneurs. In this study, the impact of Young Farmer Support Program was evaluated. Young farmers believe that adequate services and supports have not been provided to them, and their expectations have not been fully met. In designing efficient policies, the government should focus on and meet the expectations of young farmers. The government should provide needed services and adequately supports to young farmers. To ensure the involvement of young farmers in the agricultural sector, the government should give satisfactory direct payments to professionally competent young farmers. In addition, new support schemes for young farmers such as setting up businesses and retirement program should be designed and applied. The majority of the young farmers (81.6%) were willing to stay on the farm activities if they inherited land from their parents and earned enough money from their farms. This situation emphasizes the necessity of solving multiple ownership problem in agriculture. Young farmers should be given the opportunity to acquire ownership of the land on which they have cultivated, with appropriate financing conditions. Young entrepreneurs should be privileged on renting public and/or private idle lands under appropriate conditions, mediate in their sales, lower interest rates and longer repayment period on investment and business loans, increasing the project limits of YFP and facilitating access to loans, giving more additional points for young farmers in Rural Development Investments Support Program and IPARD supports, higher premium subsidy for TARSIM in order to set up an export-oriented marketing mechanism for the product storage. There had been inadequacy of infrastructure and social facilities in the study area. Therefore, the government should invest on improving social facilities in the rural areas. Agricultural insurance is not common among young farmers. Therefore, young farmers should be encouraged on increasing crop / product diversity with higher premium subsidies. Türkiye has achieved a moderate level of preparedness in the realm of regional policy and the coordination of structural instruments. Furthermore, there has been ongoing progress in accelerating the absorption of funds allocated under the Instrument for Pre-Accession Assistance (IPA II). This indicates Türkiye's commitment to effectively utilizing these funds for the country's development and integration with the European Union.

References

Aggelopoulos S., Arabatzis G., 2010. European Union young farmers program: A Greek case study. *New Medit*, 9(2): 50-55.

Akkaya M.A., Gülçubuk B., 2018. *The Challenge of Rural Youth with Entrepreneurship: A Study on Young Farmer Support Application*. Paper presented at the 4th International EMI Entrepreneurship & Social Sciences Congress, 29-30 November, Istanbul.

Aksoy A., Yavuz F., 2012. Analysis on the reasons for quitting sheep and goat rearing of farmers: A case of East Anatolia Region. *Anadolu Journal of Agricultural Sciences*, 27(2): 76-79.

Alkan A., Özkan B., 2020. Research on the application and sustainability of young farmers project in the Antalya province. *Mediterranean Agricultural Sciences*, 33(1): 67-72.

Altıntas G., Altintaş A., Bektaş H., Çakmak E., Oruç E. Kızılaslan H., Birol D., 2019. Effects of young farmer project support on the tendency of young farmers to stay in agriculture: Case of TR83 Region, Turkey. *Turkish Journal of Agriculture - Food Science and Technology*, 7(10): 1682-1693.

AP, 2017. *Research for AGRI Committee - Young farmers - Policy implementation after the 2013 CAP reform. Study*. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies, Committee on Agriculture and Rural Development. https://www.europarl.europa.eu/RegData/etudes/STUD/2017/602006/IPOL_STU(2017)602006_EN.pdf.

Berk A., 2018. Factors affecting the exit from farming of young farmers in Turkey: the case of Niğde province. *Ciência Rural*, 48(8): e20180471.

Birol D., Yilmaz H.I, Akdemir H.A., Çobanoğlu F., 2020. Determination of parameters that can be criteria to young farmer supports in Turkey: Choice Experiment Method. *Turkish Journal of Agricultural Economics*, 26(2): 131-146.

Bragg L.A., Dalton T.J., 2004. Factors affecting the decision to exit dairy farming: A two-stage regression analysis. *Journal of Dairy Science*, 87(9): 3092-3098.

Çağlayan Z.C., Göktaş I., Örmeci Kart M.C., Gümüş S., 2020. Evaluation of the young farmer program in terms of animal breeders: Case of İzmir. *Journal of Agriculture Faculty of Ege University*, Special Issue: 107-117.

Can B.A., Engindeniz S., 2020. A research on the opinions and suggestions of the youth who study agriculture in Turkey on the Young Farmer Grant Project. *New Medit*, 19(4): 117-132. https://doi.org/10.30682/nm2004h.

Greene W.H., 2011. *Econometric Analysis*, 7th ed. London: Pearson Education Limited.

Gujarati D.N., 1995. *Basic Econometrics*, 4th ed. New York: United State Military Academy.

Kan A., Kan M., Dogan H.G., Tosun F., Uçum I., Solmaz C., 2018. Evaluation of young farmers project support program in terms of agri-entrepreneurship in Turkey. *Pakistan Journal of Agricultural Sciences*, 55(4): 1021-1031.

MEVKA, 2019. *Konya-Karaman Socioeconomic Outlook*. Konya: Mevlana Development Agency.

MoAF, 2021. Ministry of Agriculture and Forestry, General Directorate of Agricultural Reform, Ankara.

Newbold P., 1995. *Statistics for Business and Economics*. Upper Saddle River, NJ: Prentice-Hall International.

Turkekul B., Abay C., 2020. Factors affecting the Turkish farmers' decision to quit farming. *Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development"*, 20(3): 617-624.

TURKSTAT, 2023. *Urban-Rural Population Statistics*. https://data.tuik.gov.tr/.

Yalçın E.G., Munis T., İpekcioğlu Ş., Birol D., 2020. A tendency to maintain agriculture of farmers benefiting from the grant support of a young farmer in Gaziantep and Sanliurfa. *Turkish Journal of Agriculture - Food Science and Technology*, 8(3): 526-530.

Yıldız D., Adalı T., Özdemir Ö., 2023. An overview of Türkiye's population on the 100th anniversary of the Republic. *Population and Societies*, 608. https://www.ined.fr/fichier/s_rubrique/33461/608a_ined_v3.d.en.pdf.

Yılmaz A., Keskin M., 2020. Investigation of the productivity of young farmer livestock projects under rural development supports. *KSU Journal of Agriculture and Nature*, 23(6): 1598-1607.

Work and living conditions of Syrians in Turkey and their situation in the agricultural sector

Mediha Hammude*, Nermin Bahşi*

DOI: 10.30682/nm2401h
JEL codes: J43, J61, R23

Abstract

The purpose of this research is to find out how Syrians with temporary protection status in Turkey live and work, as well as how they are treated in the agriculture industry, from the point of view of Syrians. The study used a survey-based approach to collect primary data from 210 Syrian asylum seekers residing in Hatay province, which hosts a substantial population of Syrian refugees, accounting for 18% of the province's total population. The researchers employed the Simple Random Sampling Method to select the participants, ensuring a representative sample from the overall Syrian refugee population in the region. While a notable proportion of respondents (37%) reported having no major problems at their workplaces, a substantial portion (44%) faced significant challenges. These challenges encompassed issues such as low wages, heavy workloads, language barriers hindering communication, social exclusion, and a lack of access to social security benefits. The research brought attention to the vulnerable position of Syrian refugees in the labor market and the need for comprehensive measures to improve their working conditions and overall well-being.

Keywords: *Syrian asylum seekers, Migration, Temporary protection, Integration, Hatay, Turkey.*

1. Introduction

Many reasons such as wars, natural disasters, climatic conditions, earthquakes, the presence of factors threatening human life, inadequacy of economic conditions, unemployment lead to national and international collective or individual migration movements (Özkarslı, 2015). Gürel Üçer *et al.* (2018) define migration as the geographical displacement of individuals or communities from their current location or settlement to a new one for natural, political, social, or economic reasons. Particularly, individuals who are compelled to leave their homes and migrate to other countries due to war or other compulsion face unique difficulties in the countries they move to. These people, who are asylum seekers in the countries they move to, must first meet their economic needs in order to continue living. These asylum seekers are compelled to live in poor circumstances due to their incapacity to adjust to the society to which they migrated and their lack of revenue from their home countries.

The escalating intensity and scope of the clashes between opposition groups engaged in anti-government activities and the Syrian regime, which began in March 2011, have become

* Osmaniye Korkut Ata University, Osmaniye, Türkiye.
Corresponding author: nerminbahsi@osmaniye.edu.tr

an issue that has spread to Europe, particularly to neighboring countries (Açıkel, 2016). The political crisis that began in Syria on March 15, 2011 took on a worldwide dimension, prompting the majority of the region's inhabitants to flee their country, and a massive influx of immigrants to numerous nations, particularly Turkey (İşcan and Çakır, 2019). Since 2012, when the Syrian civil war escalated, Turkey has been one of the nations that has welcomed the greatest number of Syrian asylum seekers, along with Lebanon, Jordan, and Iraq (Erol *et al.*, 2017). Due to geographical proximity, historical, cultural, and social linkages, as well as kinship, language, and religious unity, Turkey is among the most popular destinations for Syrian migrants (Özkarslı, 2015). As of May 2021, there are 3.672.646 Syrians under temporary protection in Turkey. Currently, more than 98% of Syrians under temporary protection reside throughout Turkey's 81 provinces, urban centers, and rural areas, while less than 2% reside in the seven remaining Temporary Accommodation Centers (TACs) (3RP, 2021). The provinces where they are most prevalent are Istanbul, Gaziantep, Şanlıurfa, and Hatay, respectively. There are 368.715 registered Syrians in Hatay, which accounts for 18% of the province's total population (The Presidency of Migration Management, 2022). Syrians constitute 22,07% of the population of Hatay province. Considering their ratio to the province's population, Syrian asylum seekers have a considerable impact on the economic and sociocultural equilibrium in Hatay.

The key requirement for these people, who have fled the civil war and become asylum seekers in neighboring nations, to survive while they are abroad is to meet their economic requirements (Çetin, 2016). Despite the fact that the Work Permit Regulation provides access to employment in Turkey, it is difficult for Syrians to join the workforce due to obstacles such as a lack of information about the rights and responsibilities of foreigners and employers in obtaining work permits and a lack of Turkish language skills (3RP, 2019). Due to their dense population structure and size, Syrian immigrants are a source of inexpensive labour in a variety of commercial sectors, particularly in agricultural work regions (Bayramoğlu and Bozdemir, 2019). In Turkey, several legal and administrative arrangements have been made to promote the involvement of the Syrian people in the labour force and to expand their engagement in formal employment, for 2018, the work permit cost obtained from the employer in the case of employment of Syrians who are granted temporary protection has been reduced by 40%, and those who will work in seasonal agriculture or animal husbandry jobs within the scope of the law will not be required to pay a work permit price (3RP, 2019). According to sector officials, the Syrians have covered the gap in unskilled people on the labor markets, particularly in seasonal sectors that Turks do not choose, and these sectors may now operate at full capacity (Duruel, 2017). According to Çetin (2016), the most common challenges that Syrians encounter in their working lives are the usurpation of rights through the payment of lower wages, delays in payments, and sometimes non-payment at all compared to other employees. On the other hand, İlgazi (2019) claims that asylum seekers who find employment in the informal sectors are coerced into accepting whatever salary offer or working condition that is presented to them by their employers. In addition to seeking employment, Syrians under temporary protection also establish their own small businesses in the food and agriculture sector; however, they face a number of obstacles, including limited access to credit, a lack of productive assets, and a limited understanding of property rights and market dynamics (3RP, 2021).

In the studies conducted with refugees and migrants in the national and international literature, interviews were conducted with refugees and migrants, and their problems in their home countries and adaptation processes were explored. In his research of Mexican laborers in the American agricultural sector, Martin (2002) asserts that the agricultural sector is a significant entrance point for immigrants from rural and agricultural regions who work in U.S. fields and farm-related sectors such as meat and poultry processing. Franz (2003) notes that Bosnian refugee women are frequently compelled to take low-paying, low-skilled jobs in Vienna and New

York because they cannot afford to participate in acculturation programs such as language schools in their host countries, even if they have had a successful career in their home countries. According to Cannizzaro and Corinto (2012), their study has confirmed that local communities and governments rely heavily on immigrant labour to cut manufacturing costs, in effect using unlawful conditions to control the local market. Biner and Soykan (2016) explored how Syrians perceive the practices of constructing a new life in Turkey in the context of their relationships with economic, social, and legal frameworks, as well as the migration process. Sandal *et al.* (2016) investigated the migration movement from Syria to Turkey and its reflections in Gaziantep province. Kavak (2016) examined how the labor market for seasonal migrant labor in agriculture in Turkey has changed with the influx of refugees from Syria. According to Duruel (2017), Syrian asylum seekers labor in the agricultural, industrial, construction, and service sectors in the Hatay area, and it is undesirable for low-skilled locals to perform these occupations as they do in other provinces in the region. İçduygu and Diker (2017), examined the challenges Syrians face in the Turkish labor market in light of legal developments, arguing that policymakers should prioritize regulations that prevent refugees from entering the informal market without harming them, as well as incentives for employers who hire Syrians. In his paper, Dedeoğlu (2018) assessed the present condition of migrants working in agricultural production in Turkey and analyzed the employment of migrant labor in agricultural production in the context of social development in rural regions of Turkey. Mulazzani *et al.* (2020), first aimed to outline the link between food security and migration, and then to validate it using the empirical literature from the African continent. Cento and Bahşi (2022) evaluated the situation of Syrian agricultural workers under temporary protection in Turkey from the perspective of farmers.

The purpose of this research is to find out how Syrians with temporary protection status in Turkey live and work, as well as how they are treated in the agriculture industry, from the point of view of Syrians.

2. Material and method

The study's major source material consists of primary data collected via interviews with Syrian asylum seekers residing in Hatay province. In addition, national and international literature, information provided by public and private organizations are among the other materials used in the study. According to the data of the Hatay Provincial Directorate of Migration Management in February 2020, there were 438,936 Syrian asylum seekers in Hatay province and districts (Altınözü, Antakya, Arsuz, Belen, Defne, Dörtyol, Erzin, Hassa, Kumlu, Kırıkhan, Payas, Reyhanlı, Samandağ, Yayladağı, İskenderun).

The research questionnaire questions were developed with consideration of the study's objective, the topic's substance, and the characteristics of the primary audience to whom the questionnaire would be administered. A triple Likert scale was used to find out their views on agricultural activities, their satisfaction with living conditions, and their thoughts on living conditions.

In this research, the sample size was determined using the Simple Random Sampling Method. The formula used to calculate the sample size according to this method is (Yamane, 2001);

$$n = \frac{Nz^2s^2}{Nd^2 + z^2s^2}$$

n: Sample size
N: Population Size
z: The *z* value in the standard normal distribution table according to the error rate
d: Sensitivity (Accepted fault tolerance level)
s: Sample standard deviation.

The sample volume was calculated as 191 with the 95% confidence level (*z*: 1,96), the standard deviation calculated from the pilot sample (n: 14,83), and the accepted error tolerance level within the limits of ±5. Taking into account the shortcomings that may arise in the surveys to be conducted, the sample size was increased by about 10% and 210 surveys were conducted. The survey study started in December 2019. 210 surveys were done after the sample size was expanded by about 10% to allow for any flaws in the to-be-conducted surveys. The surveys were conducted by face-to-face interviews with Syrian asylum seekers on a voluntary basis. The research findings are presented in the form of frequency distributions and averages.

3. Research findings and discussion

3.1. *Description of respondents*

In Hatay, 50,5% of the Syrian asylum seekers who participated in the survey were women, 49,5% were men, 77,6% were married, 22,4% were single and the average age was 36,9. While 2,4% of the participants in the research are illiterate, 13,8% have completed elementary school, 32,9% have completed secondary school, 30,5% have completed high school, and 20,5% have completed higher education. The average household size was 4,56 individuals. Eight out of ten married couples do not have children. The average number of children in households was 3,5, while the average number of school-aged children was 2,4. Potocky-Tripodi (2004), in his study examining the effects on the economic adaptation of Latin American and Asian immigrants and refugees residing in Miami-Fort Lauderdale and San Diego, states that they tend to live in fairly large households (the average number of people living in households is 5, and the average number of children in households is 3.2). About 59,5% of the Syrians participating in the research in Hatay know Turkish, while 40.5% do not. As of the 2019-2020 period in which the research was conducted, the average length of stay of Syrian asylum seekers in Turkey is 6,6 years. While 34,8% of the Syrians participating in the survey received Turkish citizenship, 65,2% did not. While 87,1% of Syrian asylum seekers migrated with their families, 12,9% came only with other migrants. The family members of 51,4% of the Syrian asylum seekers participating in the survey are still living in Syria. While 91,9% do not travel to Syria, 8,1% do commute. While 61,4% stated that they came to Turkey because of trust, others stated that they chose Turkey to live in due to religious affinity, racial proximity, good conditions, ease of transportation, Turkey's opening of doors, being close to the border, having relatives, and necessity. It has been discovered that 85,2% of the Syrians who participated in the study entered Turkey illegally and 14,8% did so with a valid passport. While 49% of Syrians who participated in the survey got assistance throughout the adaptation process, 51% did not. 55,4% of those who received support from the state during the adaptation process, 25,2% received support from their family and close circle, and 19,4% received support from non-governmental organizations. 35,3% of the participants in the study received Turkish language education, while 64,7% did not. 32,4% of those who received Turkish education received their Turkish education from TÖMER, 44,6% from the public education center, while the rest received it in different places (school, special courses, etc.).

While 44,8% of the Syrian asylum seekers participating in the survey do not work in any job, 45,2% work full-time and 10% work part-time. The findings show similarities with the studies conducted in different regions of Turkey. It is seen that approximately half of the Syrian asylum seekers do not work in any job. About 55% of Syrians in Turkey, according to Erdoğan (2019), are employed, 30% are housewives, 8,5% are unemployed, and 2,3% are students. According to Potocky-Tripodi (2004), almost half of the respondents do not have a job in their country of origin (48%), over half of the remaining respondents have low-prestige employment in their country of origin (23,6%), and the remaining respondents have higher-prestige positions (28%). According to the research conducted in Gaziantep by Başarıcı (2019), 58,3% of Syrians are unemployed, 14,3% are employed in the service sector, 10,9% are employed in other sectors, and 10,2% are employed in the industrial sector. Arslan *et al.* (2017) found that in his research in Gaziantep province, 25,9% of Syrians are unemployed and that 36,3% of the participants were people in similar situations (sick, extremely elderly, unable to work, etc.). Gürel Üçer *et al.* (2018) state that 50% of the household heads interviewed are involved in the labor market. Erdoğan (2020) states that 37,9% of Syrians work in any job, 50,2% of Syrians working in regular wage jobs, 33,6% in daily (day-to-day) jobs, and 13,7% in their own account or as employers. İşcan and Çakır (2019) stated that 42,8% of Syrians have not yet had a job and do not work in Turkey, while 17,2% are full-time and 39,9% are working occasionally or part-time or on a daily basis. It was determined by İlgazi (2019) that 47,9% of the Syrian labor force is working and 52,1% is not working.

The average daily working time of the Syrians participating in the study in Hatay is 8,8 hours. When the causes for non-working people are considered, 37,4% do not want to work, 5,3% do not have a work permit, 9,6% are unwell, 2,1% are caring for children, 10,7% are ill and injured, 2,1% are housewives, 13,8% are unemployed, 18,1% are unable to find a job that matches their credentials, and 9,6% are students. It is seen that there are differences between the reasons why Syrian asylum seekers living in Hatay do not work with those living in other provinces. It is seen that Syrians in other provinces have more difficulty in finding jobs that match their qualifications. Başarıcı (2019) listed the reasons why Syrians in Gaziantep do not work as other reasons (31,1% – taking care of their children, health problems, being a student, not having an education, not having a work permit, not needing to work), not being able to find a suitable job (27,9%), low wages and difficult working conditions (16,7%), not being accepted to work (15,8%). İşcan and Çakır (2019) stated that 36,7% of Syrians who did not work could not find any job, 30,5% could not find a job suitable for their qualifications, 25,4% did not have a work permit and 7,5% did not need to look for a job. According to İlgazi (2019), the reasons for not working in the labour force are as follows: 11,9% are unable to find work, 70,8% are educated, 6,4% are ill, 6,4% are unwilling to work, and 4,7% are other. It was found that 54,8% of the Syrian asylum seekers in Hatay who took part in the study had workers in their families besides themselves, and 80% of them had at least one more worker besides themselves.

At the time of the research, the average monthly income of households in Turkey was 1186,6 Turkish Liras, but the average monthly income in Syria was 76662,5 Syrian Liras. The most important reason for income differences is thought to be due to the fact that they do not have the chance to do their professions in Turkey, which they have in their own countries.

Only 9,1% of the participants have a work permit and 16,7% have information about obtaining a work permit. It is seen that Syrian asylum seekers did not have work permits at the time of the research. These findings are supported by other studies in the literature. İşcan and Çakır (2019) determined that more than half of the participants did not have information about the work permit, and that much less than the 32,1% of the participants who had information (7,6%) had a work permit. Gürel Üçer *et al.* (2018) states that none of the participants have a work permit in Turkey and therefore knowing that they have to work to live condemns them to long working hours with low wages. It is seen that Syrian asylum seekers living in Hatay have to work in jobs other than their own professions in Turkey despite working in different professions in their own countries. In a number of specific occupations (welder, painter, doctor, nurse, etc.), there are also Syrians working in Turkey. Compared to Syria, the proportion of workers working as workers has increased (Syria 10%, Turkey 31%). While the rate of traders in Syria was 11,1%, this rate decreased to 5,2% in Turkey. Housewives in Syria are 21% and in Turkey they are 22,9%. While 29% are students in Syria, it is 10,5% in Turkey. 1% of students also work as workers. There is no change in the proportion of farmers (9,5%). While 70% of the Syrians who farm in Turkey are engaged in agriculture in Syria, 30% state that they do this job only in Turkey. Başarıcı (2019) found that while in Syria, 37,22% of the participants worked as housewives, 20,3% as civil servants and 13,0% as other professions. Arslan *et al.* (2017) determined that 20% of Syrians work as workers, while very few people (5,45%) work as traders. Gürel Üçer *et al.* (2018) states that when the work done by Syrians in their own countries and in Turkey is compared, 30% of them are doing the same job as they do in Syria; It was determined that 30% of them worked in qualified jobs as lawyers, teachers, interpreters and guides in Syria, while they worked in lower jobs in terms of status and wages in Turkey. Coşkun and Yılmaz (2018) state that male asylum seekers work as a daily wage earner in construction works that require more physical strength, animal farms, porter jobs in the transportation sector, car washing, and that among the irregular jobs, jobs such as workplace and house cleaning, labor in textile and dessert manufacturing workshops and hairdressing at home stand out. In Takeda (2000), in the study titled "Psychological and Economic Adaptation of Iraqi Adult Male Refugees", in addition to non-agricultural labor, participants worked in various occupations such as truck or taxi driver (14,7%), student (13,7%), welder (11,6%), soldier (10,5%), electrician (6,3%) and mechanic (5,3%) while in the United States, they did not do the same jobs except one electrician and a mechanic, most of them worked as non-agricultural workers after migrating to this country. Özkarslı (2015) states that 42% of Syrians work in construction, 13% in textile, 9% in agricultural sectors and the rest work in household services, food sector, transportation porter, carpenter, driver, etc. İşcan and Çakır (2019) state that 22,9% of the participants in Syria are workers, 12,7% are students, 19,9% are housewives, other prominent professions are craftsmanship, driver, civil servant, merchant and teacher, and that asylum seekers working as workers (56,5%) in Turkey also take part in working life as waiters, civil servants and merchants. İlgazi (2019) determined that 19,0% of the Syrian workforce is worker, 6,2% is tailor, 17,0% is a teacher, 4,2% is a health personnel, 41,3% is a student, 12,4% is other, and in Turkey, 25,6% is a worker, 6,2% is a tailor, 17,2% is a teacher, 4,9% is a health personnel, 40,0% is a student and 6,2% is other. Çetin (2016) states that those who work as daily temporary jobs (5,3% in Syria, 15,3% in Turkey) and wage workers (16,7% in Syria and 20% in Turkey) have increased in Turkey compared to Syria. The proportion of those who are artisans (Syria: 28,7%, Turkey: 5,3%), professional professions (Syria: 12,7%, Turkey: 0,7%), traders (Syria: 9,3%, Turkey: 6,7%), merchants (Syria: 1,3%, Turkey: 0,7%) and students (Syria: 11,3%, Turkey: 6%) decreased in Turkey, while the situation of those who were housewives (14%) did not change (Çetin, 2016).

It is observed that Syrians working as workers in Hatay work in the agricultural, construction and industrial sectors. Çetin (2016) states that 26% of the Syrian refugees included in the labor market are employed as wage workers, and almost all of them work informally in the manufacturing industry, mostly in the textile sector. Only 8,1% of the Syrians working in Hatay are insured. 33,8% of Syrians state that the job they work in is in accordance with their professional experience. While 39,6% of the Syrian asylum seekers participating in the study in Hatay have never worked, 40% of them have only worked in one job, and the rest have worked in multiple job fields. While 46,4% of Syrians found work themselves, 21,8% found work through relatives and neighbors, 11,8% with the help of intermediaries, 10,9% with the help of friends, 1,8% through the Internet and social media, 3,6% through labor Sundays and coffee shops, 3,6% through family. Gürel Üçer *et al.* (2018) state that all of the Syrians working on the sites found the jobs through their acquaintances. Coşkun and Yılmaz (2018), asylum seekers in order to cope with the injustices of friends, relatives through trusted channels such as looking for a job, even lower wages than the market cost of acquaintances, work and effort that you spend working in workplaces with the prospect of buying an assert. Özkarslı (2015) states that finding a job using social networks is a very widely used method for immigrants, and 53% of them find a job through relatives and acquaintances. Erol *et al.* (2017), horizontal social networks in the textile industry (an acquaintance, relative, etc. who works at work), and getting to know the employer are important factors, with 51% of Syrian workers stating that they found this job through a friend or acquaintance.

While 60,4% of the Syrians who participated in the survey stated that they could not earn a living with the income they received, 18,6% stated that their income was sufficient and 21% stated that it was partially sufficient. The largest expenditure items for Syrians are food, rent and other household expenses. Of Syrians living in Hatay 37% stated that they have not encountered any problems while they work in the workplace, 44% asserted that the problems are low wages, heavy work, language problems, social exclusion and lack of social protection. Gürel Üçer *et al.* (2018), stated that 58% of Syrians do not have any problems with work, while others express problems such as long working hours, working on weekends and working under severe conditions. Erol *et al.* (2017) stated that at least one of the situations such as being discriminated against and insulted while looking for a job of 39% of Syrian workers, not receiving their wages even though they work, receiving lower wages than they agreed, being discriminated against by an employer or co-workers in the workplace, and being subjected to psychological or physical violence in their workplace has happened to them in their working life. Erdoğan and Ünver (2015) state that due to the lack of a regulation on the working rights of Syrians under temporary protection in Turkey, the informal economy and informal employment are experienced intensively, and that there is intense activity in agriculture, construction, textile and manufacturing sectors, especially seasonal labor. Özkarslı (2015) stated that the most common problems experienced by the participants were not receiving low wages or wages, getting late, heavy working conditions, being made to do other work other than their own work, prejudices arising from being foreigners and negative consequences of their perspective, being despised, not liking their work. In Hatay, only 8,1% of the respondents attended vocational training courses. The courses they attend are listed as emergency and disaster management, shoemaking, ice cream, handicrafts, first aid, occupational health and safety, mushrooming, beekeeping, strawberry growing, culinary arts, and pastry making. İlgazi (2019) stated that 19,2% of the Syrian workforce received vocational training and 80,8% did not receive vocational training.

3.2. *Reasons for dealing in agriculture*

The reasons for the Syrian refugees engaged in agricultural activities to engage in agriculture are shown in Table 1. It is said that the most important reason to work in agriculture is that it is hard to find another job. Other reasons include having a profession, loving this job, and not needing permission to start a business.

While 60,0% of those engaged in farming carry out their agricultural activities on the lands they rent, 40,0% are partners. 90% of the farmers are engaged in agricultural production on lands smaller than 10 decares. The average land width with agricultural activity is 4,675 decares. The average number of workers employed in agricultural activities is 2,5. Family members of 35% of Syrians engaged in agricultural activities also help in agricultural activities. Predominantly (57,1%) children are seen to help with agricultural activities, while family members such as spouses and mothers also provide support. While 90% of Syrians make plant production, 5% only produce animal production, and 5% produce both plant and animal. While 70% of the farmers grow strawberries, 10% grow vegetables such as tomatoes, peppers, etc. along with strawberries. A group of 5% is engaged in pomegranate cultivation. 60% of those engaged in agricultural activity have attended a course on agriculture. While 63,7% of the participants received mushroom cultivation training, 91,1% received beekeeping and strawberry cultivation training along with mushroom cultivation, and 9,1% received beekeeping and strawberry cultivation training along with mushroom cultivation. 36,4% received beekeeping training along with strawberry cultivation and 9,1% strawberry cultivation. 15% of those engaged in agricultural activities are also workers, grocers and traders. While 55% of Syrians engaged in farming have information about organic agriculture, 45% do not have information. None of them do organic farming. While the most important problems experienced by farmers related to agricultural activities are not receiving sufficient support (40%), not being able to provide fertilizers (10%), inadequate irrigation systems (5%), not having enough experience (5%), high land rents (5%), 35% state that they do not have any problems.

Table 1 - Reasons for dealing in agriculture.

The reason for dealing with agriculture	*f*	*%*
Little need to speak Turkish	1	5,0
Does not require a business permit	2	10,0
Difficulty finding another job	8	40,0
Own profession	5	25,0
For what I love	3	15,0
Livelihood	1	5,0
Total	20	100,0

3.3. *Thoughts on agricultural activities*

The opinions of farmers about agricultural activities are given in Figure 1. It is seen that farmers are engaged in agriculture as a source of livelihood, they are very happy to engage in agriculture, they have sufficient experience and knowledge in the field of agriculture, they think that it is difficult to work in the field of agriculture, and they would not want to engage in agriculture if they had a sufficient income. It is seen that they are undecided about the idea that there is a future in agriculture for their children. On the other hand, they state that there is not enough support in the field of agriculture and that they are not engaged in agriculture as a hobby.

3.4. *Satisfaction levels related to living conditions*

While 76,2% of Syrians stay in rented houses, 21,9% stay in camps and 1,9% stay in different shelters such as dormitories. The average number of people living in the same household is 5,5. It is also common for more than one family to live in the same household. Başarıcı (2019) states that 75,5% of the Syrians surveyed in Gaziantep live in a house, apartment, 11,2% in temporary shelter and 10,9% in a camp. Arslan *et al.* (2017) state that 73,2% of the respondents live in rent, 16,6% in temporary accommodation centers and 10,1% live with their relatives. While 53,4% of the Syrian asylum seekers who participated in the survey in Hatay met their nutritional needs by working, 11,4% met them with state support and aid, and 35,2% stated that they met them through other means. 9,5% of the respondents stated that they had some kind of handicap or disability. While 95,3% of them receive health services from state hospitals, the rest receive them from private hospitals.

It is observed that Syrians are content with their education, health, nutritional circumstances, and employment, whereas they are only partially content with their housing, living conditions, and income (Figure 2). While 59% do not have problems with nutrition, the rest state that they cannot eat regularly and healthily. Başarıcı (2019) found that 66,4% of the Syrian migrants surveyed did not have nutritional problems, 13,8% could not eat regularly, and 9,9% could not find fruits and vegetables. While 49% of the Syrians who participated in the survey in Hatay stated that they did not have any problems with education, 25,3% stated that they could not meet their stationery needs, 13,9% did not know the language, 6,7% could not go

Figure 1 - Thoughts on agricultural activities.

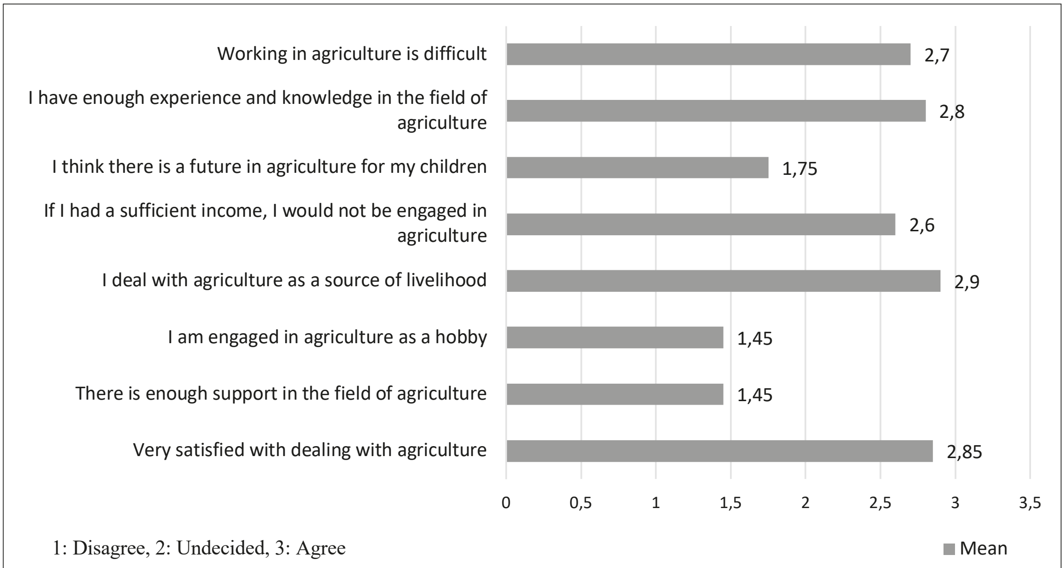
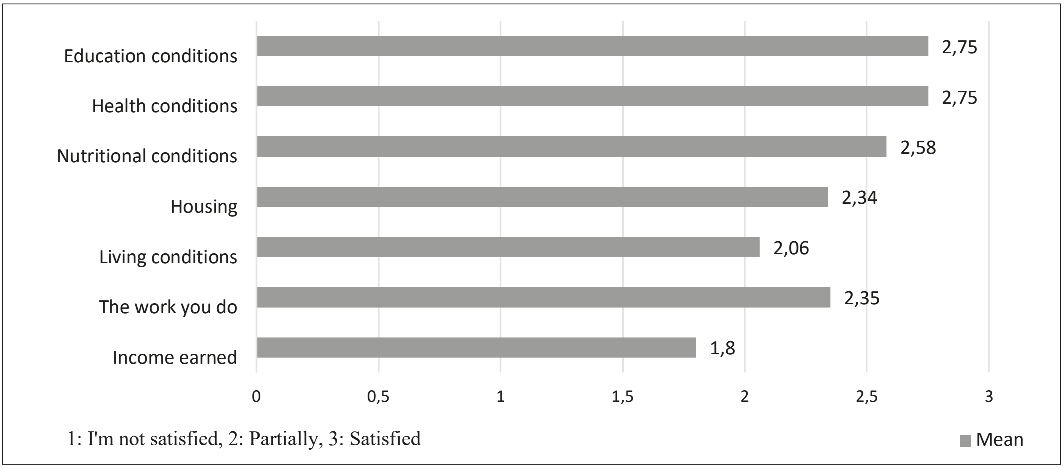


Figure 2 - Satisfaction levels related to living conditions.

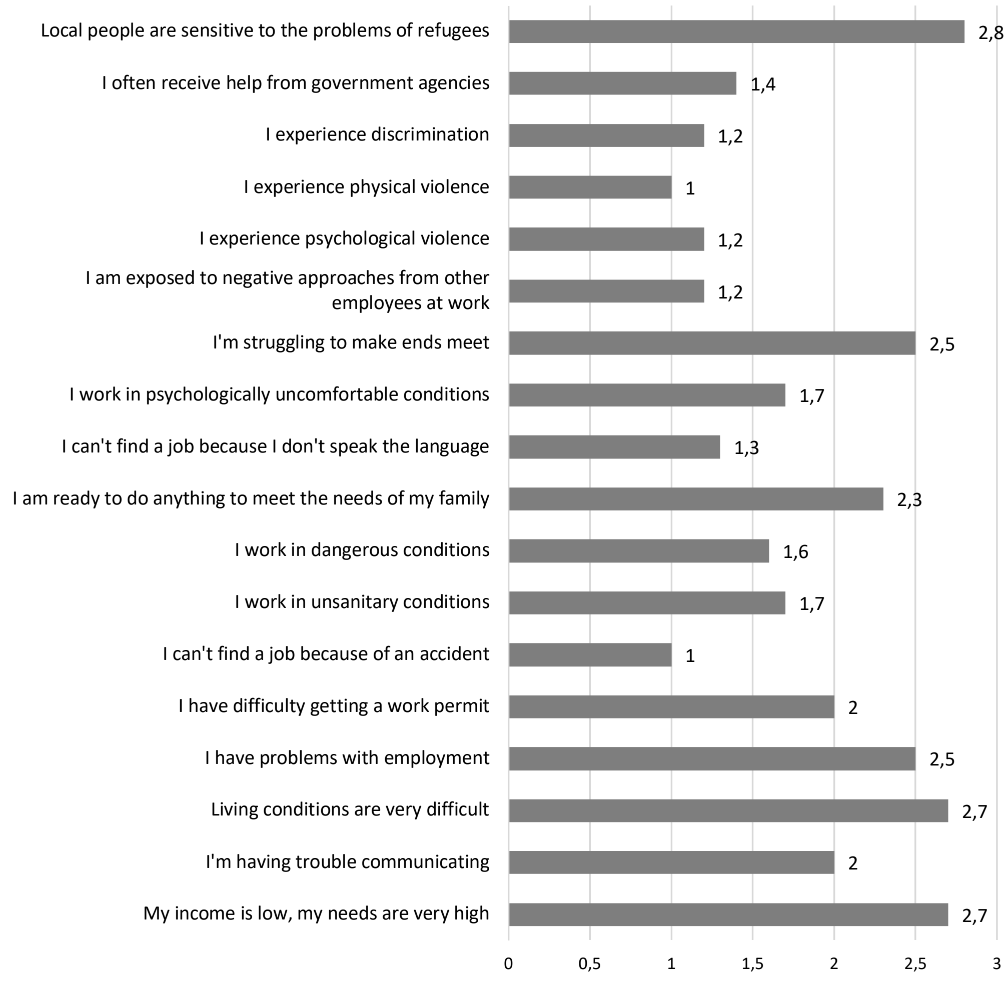


to school because of work, 2,4% had registration difficulties, and 2,7% of the children did not want to go to school. Especially in schools, language education should be given before starting normal education in order to solve language problems. Erdoğan and Ünver (2015) state that education is one of the most serious problems experienced by Syrians in Turkey. Yıldırımalp *et al.* (2017) state that even if they experience some problems in the education service, they are willing to experience these difficulties rather than stay out of the system and that they have full faith that the problems will be eliminated in time. Başarıcı (2019) listed the problems experienced by the Syrians participating in the survey in the education of their children as 63,7% language problems, 20,4% economic difficulties and 8,2% social cohesion. While 39% of Syrian asylum seekers living in Hatay state that they have no problem with accommodation, 17,6% say that they have problems due to the small size of the place they are staying. Apart from these, the problems related to the shelter are listed as: heating system, lack of water, high rent, lack of sun, several families staying together, dampness. Başarıcı (2019) found that 34,1% of the Syrians surveyed could not pay their rent, 18,8% did not fit where they stayed, 18% had other problems (they lived in a house with mice, a house without glass, no one wanted to rent their house because they were Syrian, they lived on the ground floor, basement, they lived in places far from the city where no one went, in houses that did not see the sun), 16,9% had heating problems. Gürel Üçer *et al.* (2018), 83% of Syrians are dissatisfied with their housing for various reasons, the main reasons for their dissatisfaction are; it is expressed as the fact that the size of the houses is not enough for crowded families, they do not heat up due to the fact that they are uninsulated and old. Yıldırımalp *et al.* (2017) state that Syrians usually live in basements and small houses, divide rent, and that these narrow, dark houses where they live in crowded ways are not suitable for human health. Coşkun and Yılmaz (2018) state that asylum seekers living in poor and unhealthy conditions also experience problems in terms of not being able to find housing, high rents, the risk of not being able to pay bills, security problems and relations with neighbors due to social discrimination.

3.5. *Thoughts about living conditions*

Figure 3 depicts the opinions of Syrians with temporary protection status residing in Hatay on their living conditions. Syrian asylum-seekers living in Hatay province report that the local people are sensitive to the problems of asylum-seekers, that living conditions are very difficult for them, that their income is low, and their needs are high, that they have problems in employment and that they experience livelihood difficulties. Syrians under temporary protection status; I am

Figure 3 - Thoughts about living conditions.



1: Disagree, 2: Undecided, 3: Agree

ready to do everything to meet the needs of my family, I have difficulties in communicating, I have difficulty getting a work permit, I work in unsanitary conditions, I work in psychologically disturbing conditions, partially agree with these thoughts. I work in dangerous conditions, I often get help from government agencies, I can't find a job because I don't speak the language, I am exposed to negative approaches of other employees at work, I face psychological violence, I experience discrimination, I cannot find a job because of an accident, I face physical violence, they do not seem to agree with their thoughts. Arslan *et al.* (2017), 78% of them stated that they were not subjected to any serious discrimination and 22% of them faced discrimination from time to time.

About 54,8% of Syrians polled in Hatay, Turkey, say their most significant problems are financial difficulties, 16,7% language difficulties, 10% a lack of social communication, 3,8% social exclusion, and 1,0% a lack of employment opportunities, while 12,9% of them say that they do not have a problem, and 0,8% of them did not express an opinion on this issue.

According to Başarıcı (2019), the Syrians who participated in the survey in Gaziantep reported difficulty in communicating (52,1%), social-cultural adaptation problems (20,1%), other problems (18,7%), and not being accepted by locals (9,1%). Those who selected the other problems option generally complained about high rents and the inability to find a job. Arslan *et al.* (2017) state that the most important problems experienced by Syrian asylum seekers in Gaziantep province are unemployment with 27%, high housing rents with 22%, livelihood problems with 16,6%, education problems with 9,3%, health problems with 8%, and that there are no serious problems in terms of social exclusion/pressure (4,6%) in the city. Güneş Aslan and Güngör (2019) stated that one of the most common problems expressed by Syrians living in Istanbul is language problems, 68% have financial problems, 58% cannot access financial assistance, 33% have housing problems, 14% have education problems, 21% have health problems, 20% have expressed house rent as an important problem, 13% have difficulty meeting their basic needs, and 12% have expressed the cost of living in Istanbul. Gürel Üçer *et al.* (2018) stated that Syrians can benefit from health and aid services due to their temporary protection status, but they cannot agree with hospital staff because they do not speak Turkish. Coşkun and Yılmaz (2018) state that one of the important problems for most asylum seekers in Düzce is the lack of a livelihood and that they have to work informally in the informal labor market in order to maintain their lives. Erdoğan (2020) lists the areas where Syrians have the most problems as working conditions (36,2%), communication-language (33,2%), food (26,7%), housing (26,7%), discrimination (21,1%), health (17%) and education (7,4%), and states that the area where Syrians are most satisfied in Turkey is "health services".

When the desire to return to Syria following the conclusion of the civil conflict is assessed among the Syrian asylum seekers participating in the study, 77,6% want to return, 13,8% are unsure, and 8,6% do not want to return. Başarıcı (2019) indicates that 52,9% of Syrians want to return to their country if situations return to normal, while 47,1% do not. Gürel Üçer *et al.* (2018) state that 58% of Syrian respondents plan to return to Syria at the end of the war, 38% never intend to return to Syria, and 4% are undecided. Erdoğan (2020) stated in the SB-2019 study that 54% of Syrians in Turkey want to stay in Turkey, 8% do not want to stay, and 26,9% neither want to stay nor do they want to stay. İlgazi (2019) stated that 48,6% of the Syrian workforce wants to return to their countries after the war, 25,4% do not want to return, 23,2% are undecided, and 2,9% want to go to European countries. According to Başarıcı (2019), 44,8% of those who do not want to return cite factors such as the lack of security in Syria, 30,9% believe they may build a new and happy life by remaining here, and 13,3% have built their order here.

3.6. *Expectations from the local population*

When evaluating the expectations of Syrians towards the local populace, it is discovered that 70% of them have no expectations and are satisfied. The most significant reason why Syrian refugees who participated in the survey responded that they do not want anything from the local government in the future and that they are satisfied is that they believe the locals are doing their responsibilities in the most effective manner. Other expectations of Syrians from the local population are 6,7% better behavior, 4,3% non-discrimination and sensitivity, 4,8% acceptance, not hated, not prejudiced, 5,7% job opportunities, and 3,8% financial assistance.

4. Conclusions and recommendations

Syrians who had to leave their countries due to the civil war in Syria had to take refuge in neighboring countries such as Turkey, Lebanon, Jordan and Iraq. With its humanitarian attitude and open-door policy, Turkey is the nation that admits the largest number of asylum seekers. Particularly, persons who are compelled to leave their homes and move to other countries for causes such as war confront unique challenges in their new homes. These asylum seekers are compelled to live in poor circumstances due to their inability to adjust to the society to which they move and their lack of revenue from their home countries. Citizens who are compelled to migrate must engage in business activities in order to continue their lives in the countries where they have sought asylum.

In this research evaluating the working and living situations of Syrians with temporary protection status in Turkey as well as their position in the agriculture sector, it was concluded that around half of the Syrians residing in Hatay were unemployed. While some of them choose not to work, others are unable to work for a variety of reasons, including inability to find a job that matches their skills, lack of employment possibilities, sickness and accidents, etc. It is observed that Syrian asylum seekers residing in Hatay are required to work in occupations other than their own in Turkey, despite having worked in professions other than their own in Syria. In a few specific occupational groups (welder, painter, doctor, nurse, etc.), there are also Syrians who do their own profession in Turkey. It is observed that Syrians employed in Hatay work in the agricultural, industrial, and construction sectors. It was determined that those who farmed engaged in agricultural activities on small plots of land without owning property, in the form of tenancy and partnership. It is seen that Syrians are satisfied with education, health, nutritional conditions and the work they do, while they are partially satisfied with housing, living conditions and income.

It was determined that the Syrians participating in the research had difficulty making a living with the income they earned to a large extent. The biggest expenses for Syrians are food, rent and other household expenses. While some of the Syrians living in Hatay province claim that they do not encounter any problems in the workplace where they work, a significant number of them state that they have problems such as low wages, working in heavy jobs, language problems, social exclusion, and lack of social security. The most important problems experienced by the Syrians participating in the research in Hatay, Turkey are listed as financial problems, language problems, lack of social communication, social exclusion and lack of job opportunities.

To alleviate the difficulties faced by Syrians, it is vital to increase language training for asylum seekers and to ensure that they are placed in positions commensurate with their abilities. Although legal arrangements for the work of asylum seekers have been made in Turkey, it is evident that unregistered employment cannot be eliminated. Therefore, establishing the required arrangements respecting the social rights of asylum seekers and refugee workers employed in our country would be a significant benefit for both local employees and Syrian asylum seekers. In addition, the pay regulation will improve the living circumstances of refugee employees, thus raising their incentive to work and subsequently their productivity. Without neglecting the employment contribution of Syrian refugees in many sectors of our society, the government should take the necessary steps to create the environment for them to be more productive by understanding that they reside and will continue to live in our country. In addition, in order to facilitate the social adaptation of asylum seekers, necessary studies should be carried out to eliminate information pollution about asylum seekers and to provide accurate information to society.

References

Açıkel A., 2016. *Employment of Syrians in Turkey, Basic Employment Policies*. ORSAM Specialization Workshop: Compilation of Student Articles. Ankara: The Center for Middle Eastern Studies (ORSAM).

Arslan İ., Bozgeyik Y., Alancıoğlu E., 2017. Socio-Economic Reflections of Migration: The Example of Syrian Immigrants in Gaziantep. *İlahiyat Akademi*, 4: 129-148.

Başarıcı M., 2019. *Economical and Social Problems of Syrian Refugees in Urban Adaptation Period between 2011-2017 years: Gaziantep case*. Doctoral dissertation.

Bayramoğlu Z., Bozdemir M., 2019. Evaluatıon of External Immigration's Effects on Seasonal Agricultural Labour. *Journal of the Institute of Science and Technology*, 9(2): 1164-1176.

Biner Ö., Soykan C., 2016. *Suriyeli Mültecilerin Perspektifinden Türkiye'de Yaşam*. Çeşitlilik ve Stratejik Davalama Ağı Projesi.

Cannizzaro S., Corinto G.L., 2012. Can the Horticultural District in South-East Sicily benefit from migrant workers to achieve an efficient internationalization pattern? *New Medit*, 11(3): 59-65.

Cento H., Bahşi N., 2022. Farmers' opinion about Syrian workers in agricultural sector in Turkey: Case study of Gaziantep. *New Medit*, 21(4): 85-95. https://doi.org/10.30682/nm2204g.

Coşkun E., Yılmaz Ç., 2018. Sığınmacıların Toplumsal

Uyum Sorunları ve Sosyal Hizmetlere Erişimi: Düzce Uydu Kent Örneği. *Sosyal Siyaset Konferansları Dergisi*, 75: 269-305.

Çetin I., 2016. Labor Force Participation of Syrian Refugees and Integration: Case of Adana and Mersin Cities. *Gaziantep University Journal of Social Sciences*, 15(4): 1001-1016. DOI: 10.21547/jss.265320.

Dedeoğlu S., 2018. Migrant Workers in Turkish Agriculture: Rivalry of the Poor and Antagonism. *Calisma ve Toplum*, 56(1): 37-68.

Duruel M., 2017. The Effects Syrian Refuges on the Turkish Labor Market: Opportunities and Threats. *International Journal of Economic Studies*, 3(2): 207-222.

Erdoğan M.M., 2019. *Türkiye'deki Suriyeli Mülteciler*. Ankara: Konrad Adenauer Stiftung, 25 pp.

Erdoğan M.M., 2020. *Suriyeliler Barometresi 2019, Suriyelilerle Uyum* İçinde Yaş*amın Çerçevesi*. Ankara: Orion Kitabevi.

Erdoğan M.M., Ünver C., 2015. *Türk Iş Dünyasının Türkiye'deki Suriyeliler Konusundaki Görüş, Beklenti ve Önerileri*. Türkiye İşveren Sendikaları Konfederasyonu.

Erol E., Akyol A.E., Salman C., Pınar E., Gümüşcan İ., Mısırlı K.Y., Kahveci M., Mutlu P., 2017. *The Processes and Effects of Syrian Refugees' Involvement in The Labor Market in Turkey: The Case of Istanbul Textile Industry*. **İ**stanbul: Birle**ş**ik Metal-i**ş** Publications.

Franz B., 2003. Bosnian Refugee Women in (Re) Settlement: Gender Relations and Social Mobility. *Feminist Review*, 73(1): 86-103.

Güneş Aslan G., Güngör F., 2019. The Problems of Syrian Refugees Faced After Migration to Turkey: Case of Istanbul. *OPUS International Journal of Society Researches*, 11(18): 1602-1632.

Gürel Üçer Z.A., Özkazanç S., Atılgan Z., 2018. Local Integration of Syrian Refugees: Employment in Ankara Siteler. *Journal of International Scientific Researches*, 3(2): 610-624.

Hatay İl Göç İdaresi Müdürlüğü, 2020. *Hatay İlinde Yaşayan Geçici Koruma Kapsamındaki Yabancı Sayısı, ilçelere göre dağılım*. 31963903-000-E.6885 sayılı yazı.

İçduygu A., Diker E., 2017. Labor Market Integration of Syrians Refugees in Turkey: From Refugees to Settlers. *Göç Araştırmaları Dergisi*, 3(1): 12-35.

İlgazi A., 2019. The Effects of Syrian Refugees on Labour Market: Gaziantep and **Ş**anlIurfa Sample. *Econharran Harran University Journal of FEAS*, 3(4): 93-123.

İşcan İ.H., Çakır M., 2019. The Turkish Labor Market Impact of Refugees and Asylum Seekers in Turkey: A Field Study. *Journal of Social Policy Studies*, 19(43): 177-236.

Kavak S., 2016. Syrian Refugees in Seasonal Agricultural Work: A Case of Adverse Incorporation in Turkey. *New Perspectives on Turkey*, 54: 33-53.

Martin P., 2002. Mexican Workers and US Agriculture: The Revolving Door. *International Migration Review*, 36(4): 1124-1142.

Mulazzani L., Manrique R., Stancu C., Malorgio G., 2020. Food security and migration in Africa: a validation of theoretical links using case studies from literature. *New Medit*, 19(2): 19-36. https://doi.org/10.30682/nm2002b.

Özkarslı F., 2015. Syrian Immigrants Working in Informal Employment in Mardin. *Individual and Society Journal of Social Science*, 5(1): 175-192.

Potocky-Tripodi M., 2004. The Role of Social Capital in Immigrant and Refugee Economic Adaptation. *Journal of Social Service Research*, 31(1): 59-91.

The Presidency of Migration Management, 2022. *Geçici Koruma, İstatistikler*, T.C.İçişleri Bakanlığı Göç İdaresi Genel Müdürlüğü. https://www.goc.gov.tr/gecici-koruma5638#. Accessed on July 18, 2022.

Sandal E.K., Hançerkıran M., Tıraş M., 2016. Syrian Refugees in Turkey and Their Reflections in Gaziantep Province. *Gaziantep University Journal of Social Sciences*, 15(2): 461-483.

Şahin I., Düzgün O., 2015. Türkiye'ye Gerçekleştirilen Ortadoğu Kaynakli Zorunlu Göçlerin Sosyo-Ekonomik Etkileri: 1979-2014 Arasi. *Tesam Akademi*, 2(2): 167-195.

Takeda J., 2000. Psychological and Economic Adaptation of Iraqi Adult Male Refugees. *Journal of Social Service Research*, 26(3): 1-21. DOI: 10.1300/J079v26n03_01.

3RP, 2019. *Regional Refugee and Resilience Plan, 2019-2020 Turkey Country Chapter*. https://reliefweb.int/sites/reliefweb.int/files/resources/68618.pdf. Accessed on May 07, 2021.

3RP, 2021. *Regional Refugee and Resilience Plan, 2021-2022 Turkey Country Chapter*. http://www.3rpsyriacrisis.org/wp-content/uploads/2021/02/3RP-Turkey-Country-Chapter-2021-2022_TR-opt.pdf. Accessed on June 02, 2021.

Yamane T., 2001. *Temel Örnekleme Yöntemleri* (translated by Esin A., Akif Bakır M., Aydın C., Gürbüzsel E.). İstanbul: Literatür Yayınları, Birinci Basım.

Yıldırımalp S., İslamoğlu E., İyem C., 2017. Suriyeli Sığınmacıların Toplumsal Kabul ve Uyum Sürecine İlişkin Bir Araştırma. *Bilgi Sosyal Bilimler Dergisi*, 2: 107-126.

Assessing technical efficiency and its determinants for dairy cattle farms in northern Algeria: The two-step DEA-Tobit approach

Fatah Ameur*, Amine Oulmane*, Karima Boudedja*, Amel Bouzid*, Mohamed Amine Benmehaia**

DOI: 10.30682/nm2401i
JEL codes: O13, Q12

Abstract

The purpose of this paper is to analyze the technical efficiency of dairy cattle farms in Tizi Ouzou region as one of the main dairy basins in Algeria. To do so, a two-step analysis was applied. First, Data Envelopment Analysis (DEA) was used to quantify the technical efficiency of dairy cattle farms. In the second step, a Tobit model to examine factors affecting farms' technical efficiency is used. The analysis used cross-sectional data collected from 146 dairy cattle farmers. The study found that the average technical efficiency under VRS assumption is relatively high, suggesting that farms can reduce their inputs by an average of 17% while maintaining the same level of output. The study also highlights the crucial role that agricultural advisory system and traditional insemination play in enhancing technical efficiency. In this region, where cattle breeding is traditionally practiced on a small scale, increasing herd size can result in reduced performance. The study also recommended that agricultural policies should be adapted to local specificities and that a more supportive strategy should be adopted for small-scale family dairy farms instead of promoting the large farm model.

Keywords: *Technical efficiency, Data Envelopment Analysis, Efficiency determinants, Dairy farm, Algeria.*

1. Introduction

The dairy sector constitutes a significant aspect of the food landscape in Algeria, where the per capita consumption of milk products is substantial, averaging at 154 liters per year (MADR, 2019). To satisfy the growing domestic demand for milk, partly due to population growth since independence, Algeria has continued to spend massive sums to import dairy products including 90% of powdered milk to reach 1,5 billions $ in 2020 (Knips, 2005; Sraïri *et al.*, 2013; Ministry of Finance, 2020). This orientation was favored by the financial ease experienced by the country owing to hydrocarbon revenues, on the one hand, and to the international context characterized by the low prices of dairy products on the

* Research Center in Applied Economics for Development – CREAD, Algiers, Algeria.
** Department of Agricultural Sciences, University of Biskra, Algeria.
Corresponding author: ameur_fatah@hotmail.com

international market (Bellil and Boukrif, 2021). However, the collapse of oil prices during the late 1980s triggered adjustment plans to support national production for this traditional product. Indeed, in this perspective of reducing import bills, the Algerian authorities have invested considerable financial resources over the past decades reflected on a series of upgrade policies to restructure the dairy sector with an objective of reducing the country's dependency on milk imports (Bellil and Boukrif, 2021; Meklati *et al.*, 2020; Oulmane et *al.*, 2022).

Efforts to redress the situation in this sector have most often resulted in massive imports of highly productive and exotic dairy cows (Kalli *et al.*, 2018). Although the local dairy production has registered a positive increase – following these measures induced by the government – the growing national consumption is only based on 60% of the national production (Bessaoud *et al.*, 2019). This growth observed in local production over the past two decades is not the result of an improvement in milk production and productivity per cow, but is rather due to an increase in the number of dairy cattle spurred by import policies (Bellil and Boukrif, 2021). Indeed, these dairy support policies, have not improved the situation of milk production (Djermoun and Chehat, 2012; Kheffache and Bedrani, 2012).

The lack of adaptation of imported exotic breeds to local breeding conditions and management practices is generally put forward as the main justification for the low productivity recorded despite the genetic potential of these imported breeds (Kheffache and Bedrani, 2012). As in other Maghreb countries, crosses with local strains have multiplied, through artificial insemination, but often in an unplanned manner, reducing therefore zootechnical performances (Djemali and Berger, 1992), and the choice of suitable breeds is still an open question (Sraïri *et al.*, 2007). Moreover, the persisting policies applied to milk powder imports to fill the gap is also represented as a major constraint to the development of local production (Bousbia *et al.*, 2013; Sraïri *et al.*, 2013; Yerou *et al.*, 2019). While numerous studies have shared the observation that these various policies have not been able to achieve the expected results (Belhadia *et al.*, 2014; Bellil and Boukrif, 2021; Kheffache and Bedrani, 2012; Mamine *et al.*, 2011), very few studies have focused on the technical efficiency of dairy cattle, especially in terms of the use of already scarce resources.

In terms of the methodological approach, a series of approaches have been developed to assess farm efficiency (Ahmed *et al.*, 2020). One of the most widely used efficiency measurement methods is the nonparametric method, due to its advantage of not imposing functional forms on the data (AlFraj and Hamo, 2022; Oulmane *et al.*, 2019; Speelman *et al.*, 2011; Tesema and Gebissa, 2022). Based on the work of Farrell (1957), this method, namely the Data Envelopment Analysis (DEA) was originally developed by Charnes *et al.* (1978). It is defined as a linear programming methodology that empirically quantifies the relative efficiency of several similar entities or DMUs (Decision Making Units) (Cooper *et al.*, 2006). By considering farms as DMUs and coupled with regression analysis, many works have been interested in determining but especially in explaining the technical efficiency of these units (Battese and Coelli, 1988; Chavas *et al.*, 2005; Clemente *et al.*, 2015; Morantes *et al.*, 2022; Oulmane *et al.*, 2019). This analysis can better inform agricultural decision makers about the potentialities to promote the agricultural sector by enhancing farm performances.

In response to the growing demand for dairy products in Algeria, livestock productivity needs to be improved and is becoming an interesting research topic. Hence, this paper aims at analyzing and interpreting the technical efficiency of dairy cattle farms in a Northern region of Algeria, namely the Wilaya of Tizi Ouzou, and to address the determining factors that influence farm inefficiencies. To do this, a two-step analysis was implemented. In the first step, Data Envelopment Analysis (DEA) was used to measure the technical efficiency of dairy cattle farms. The second step, by using the Tobit model, the study aims to explore the relationship between these estimated scores of technical efficiency and other relevant variables, namely herd size, farming experience, use of agricultural advisory services, the surface intended to fodder production.

The paper is organized as follows: section 2 presents research methodology, namely the study area and the empirical strategy used in this study, section 3 presents results and discussion in terms of efficiency analysis, section 4 concludes.

2. Research methodology

2.1. *The study area*

For this study, the Wilaya of Tizi Ouzou is selected because of its vocation for bovine dairy production. Although it is a mountainous region with little fodder, this region is considered among the leading regions in the production of cow's milk, ranking the second place at national level in terms of milk production and collection (MADR, 2019). According to data provided by the Regional Directorate of Agricultural Services (DSA, 2019), the region has 40,700 cattle heads, more than 3,650 dairy cattle farmers and 22 dairies that collect more than 63% of the locally produced milk. Dairy cow production in this region has been increased since 2000. It has an average of 57.1 million liters during the period 2000-2007 (MADR, 2009) and reached an average of 113.6 million liters during 2009-2017 (DSA, 2019). The UAA is 98,000 ha of which only 5-6% (i.e. 7050 ha) is irrigated according to the Directorate of Agricultural Services (DSA, 2019). Due to the scarcity of water resources, the fragmentation of cultivated lands and the problem of fodder availability, livestock systems are characterized by the practice of soilless breeding, the use of subsidized corn silage produced in Saharan areas and the use of feed concentrate as a supplement.

For the present study, a total of 146 dairy cattle farms randomly generated were surveyed to collect both qualitative and quantitative data (i.e. 4% of the population). The surveys were conducted during 2021. Firstly, structural parameters of dairy cattle farms were inventoried, this essentially concerns the profiles of farmers, the size of farms, the herd size, access to productive resources, and access to agricultural advice. Secondly, functional parameters were investigated through the determination of livestock management practices, the determination of input consumption and costs, and the inventory of milk production. In parallel, semi-directive interviews were carried out with breeders to understand the dynamics of this sector and challenges facing its development.

2.2. *The empirical procedure: A two-stage DEA-TOBIT model*

The usually used two-stage approach follows a first stage estimation of efficiency scores using the DEA method, then, a second stage regression analysis using Tobit model seeking to reveal the determinants explaining the variation in terms of efficiency scores.

It is not question to survey the method here, but the main idea could be briefed as follows. Debreu (1951), Farrell (1957) and Koopmans (1951) were the pioneers of the efficiency concept. Koopmans define a firm as being efficient "if it is technologically impossible to increase output and/or reduce an input without simultaneously reducing at least one other output and/or increasing at least one other input". Farrell was the first to separate economic efficiency into two: technical efficiency – related to the use of optimal quantities of inputs – and allocative efficiency – related to cost, i.e. the use of a combination of inputs with the lowest cost. While the existence of several methods to calculate efficiency, namely, parametric and non-parametric methods – including the widely used DEA method (Bravo-Ureta and Pinheiro, 1993), this study focus in the later.

The DEA method is a pioneering non-parametric method of evaluating efficiency that uses mathematical programming rather than regression (Oluwatayo and Adedeji, 2019). It is also a method used to evaluate the efficiency of a set of decision-making units (DMUs: dairy cattle farms in our case) by comparing them to a set of best-practice DMUs. In recent years, this method has gained increasing attention in various fields of research. Within this field, agriculture is one of the most recent application areas for DEA (Angón *et al.*, 2015; Cecchini *et al.*, 2021; Emrouznejad and Yang, 2018; Ullah *et al.*, 2019).

One of the key strengths of DEA is its ability to handle multiple inputs and outputs, which makes it well suited for evaluating the efficiency of complex systems. From an efficiency frontier, the technical efficiency scores of different dairy cattle farms are calculated. Farms located on the frontier are considered technically efficient with a score of 1 (100%) and those located below the frontier are considered inefficient with a score ranging from 0 to 1 (Coelli *et al.*, 2005). Then the inefficiencies are estimated by measuring the distance between a given farm and the frontier – represented by those having the best inputs/outputs combination. The Constant Returns to Scale (CRS) suggested by Charnes *et al.* (1978) was the first DEA model for estimating technical efficiency. This model assumed that all DMUs are operating at their optimal scale, i.e. the variation in outputs is perfectly proportional to the variation of inputs. However, this is not the case particularly in agriculture.

The DEA model suppose that there are n DMUs, where each DMU i utilize N inputs and M output. For the i^{th} DMU, these are represented by the vectors x_i and q_i columns, respectively, X is the input matrix $N\times I$ and Q the output matrix $M\times I$; they represent the data of the DMU_I. The technical efficiency under CRS assumption can be estimated by solving the following program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ \text{s.t.} \quad & -q_i + Q\lambda \geq 0 \\ & \theta x_i - X\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \tag{1}$$

Where θ is a scalar and λ is a $I\times 1$ vector of constants. The model is solved once for each farm and therefore gets a θ value for each farm. The value of θ obtained corresponds to the score of the technical efficiency of the first i^{th} farm.

Banker *et al.* (1984) subsequently followed up this work to propose a DEA model by considering Variable Returns to Scale (VRS). The latter assumption is considered to be more appropriate in the case of agriculture. Two orientations can be used; these are the input-oriented (minimizing the use of inputs) and the output-oriented approach (maximizing outputs) (Coelli *et al.*, 2002; Fried *et al.*, 2008). As farmers have more control over inputs than outputs, the input-oriented model is preferred. Also, in the situation of increasing scarcity of natural resources, it is more relevant to consider potential decreases in inputs than increases in outputs (Rodríguez Díaz *et al.*, 2004).

The technical efficiency under VRS assumption can be estimated by solving the following program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ \text{s.t.} \quad & -q_i + Q\lambda \geq 0 \\ & \theta x_i - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{2}$$

In summary, the technical efficiency under CRS assumption (TE CRS) is a subset of technical efficiency that assumes a constant scale of production. It measures the efficiency of a farm in achieving the maximum output level when all inputs are increased proportionally. However, the technical efficiency under VRS assumptions (TE VRS) takes into account the possibility of varying production scales and measures the efficiency of a farm when there are diseconomies or economies of scale. It considers the potential to adjust the scale of production to achieve higher efficiency levels. It is more flexible than TE CRS as it allows for variations in the scale of operations. The Scale Efficiency (SE) is a related concept that evaluates the overall efficiency of a farm by considering both technical efficiency and the optimal scale of production. It combines the concepts of TE CRS and TE VRS to provide a comprehensive assessment of efficiency, taking into account both the efficient utilization of inputs and the appropriate scale of operations.

Furthermore, the Returns to Scale (RS) score is calculated for each farm to assess their operational efficiency based on the relationship between the proportion of inputs and the corresponding output. In economics, the RS is classified as constant, increasing, or decreasing. This determination is made by calculating the total elasticity of production ε shown in the formula below (Coelli *et al.*, 1998):

$$\varepsilon = \sum_{i=1}^{n} E_i$$
$$E_i = \frac{\partial y}{\partial x_i} * \frac{x_i}{y} \quad (3)$$

The RS score provides insights into how a farm's production output changes concerning the scale of its input utilization. In the second step and for identifying the determinants which affect efficiency scores, the literature recommends using the truncated regression Tobit model because efficiency is a bounded quantitative variable (bounded between zero and one) (Wooldridge, 2002; Greene and Zhang, 2019). This method involves estimating a linear regression that expresses efficiency according to a set of socioeconomic variables. The Tobit model can be expressed as:

$$Y_i^* = \beta X_i + \varepsilon_i \quad i = 1, 2, \ldots, N$$
$$Y_i = Y_i^* \quad \text{if} \quad Y_i^* > 0 \quad (4)$$
$$Y_i = 0 \quad \text{if} \quad Y_i^* \leq 0$$

Where Y_i is the dependent variable (speed above the posted limit) measured using a latent variable Y_i^* for positive values and censored otherwise, β is a vector of estimable parameters, X_i is a vector of explanatory variables, ε_i is a normally and independently distributed error terms with zero mean and constant variance σ^2, and N is the number of observations (Washington *et al.*, 2020).

3. Results and discussion

3.1. *Statistical description and frequency distribution of dairy cattle farms' characteristics*

The analysis of the survey data shows that there are mainly small cattle dairy cattle farms, as the 3rd quartile of the sampled dairy cattle farms holds fewer than 10 dairy cows (Table 1) and 18 is average herd size (Table 3), among it, there are only 9 milking cows per farm – 42% of farms has less than 5 milking cows – (Table 1). The breeds are represented to 70% by improved cows (Holstein and Montbéliarde), the remainder are local cows or resulting from crossings. According to the Table 1, the output of milk production ranged from 3,000 to 300,000 liters/year with a mean of approximately 47,000 liters/year among the sampled dairy cattle farms, where the milk production per cow is around 540 liters/year.

Regarding the profiles of the breeders, the majority (95%) were male-headed, which is representative of the patriarchal nature of the society. Their average age is 46 years ranging between 27 and 80 years. As the breeding activity in this mountainous region has a historical vocation, a certain experience is developed in the management of livestock, built on no less than 18 years in this activity on average. Most of breeders are educated but with a level that does not go beyond secondary school for the majority, only 9% are illiterate.

Being located in an area where agricultural lands are scarce, surfaces intended for fodder production are therefore very limited (less than 4 ha per farm on average (Table 3). The analysis shows the importance of green fodder to boost milk production. Farms that produce green fodder have higher milk yields compared to farms that do not produce (5,528 and 5,097 liter/cow/year, respectively). However, fodder surfaces are unequally distributed between farms, and only 9.5% of the sample totaling 54% the fodder surface, and 38% of farms produce no fodder resources. This explains the massive recourse to the purchased livestock feed and concentrates, which economically weighs heavily on small dairy cattle farms, and especially with the increasing trend in prices of these concentrates on the markets, whose access is sometimes difficult. Indeed, on average, 214,000 DZD/year is the amount dedicated to the purchase of food for a single cow in lactation, and this amount can increase to 264,000 DZD/year for farms that do not produce their own fodder resources.

Finally, and in order to enroll the new production techniques in their practices and to manage the animal health aspects, the recourse to different agricultural advisory services is almost a common practice, this is the case for 86% of breeders.

Table 1 - Descriptive statistics of the variables used in efficiency analysis.

Parameters	*Output*	*Inputs*			
	Milk production (liter/year)	*Number of milking cows*	*Cost of feeding in kDZD/year*	*Volume of work in hour/year*	*Sanitary costs in kDZD/year*
Min.	3,000	1	2,340	2,920	0
Q_1	18,000	4	11,838	3,376	0
Median	32,400	7	16,260	5,110	10,45
Mean	47,038	9	18,661	6,120	32,03
Q_3	59,850	10	21,405	7,300	43,63
Max.	300,000	43	150,060	24,820	450,00
S.D.	*47,819*	*8*	*14,064*	*3,823*	*55,41*

3.2. *Assessing the technical efficiency of dairy cattle farms*

The data in Table 1 represents the inputs and the output used for the calculation of the efficiency scores according to the DEA model. Milk production per farm was retained as the only output in this analysis. For the set of inputs, the analysis included 4 inputs: 1) number of cows in lactation; 2) the cost dedicated to the acquisition of the different types of feed and concentrate; 3) the hourly volume provided for the management of the farms; 4) the cost spent on animal health.

The Table 2 illustrates the summary statistics of the input-oriented technical efficiency scores under variable returns to scale (VRS) and constant returns to scale (CRS) assumptions. It also illustrates their frequency distribution and scale efficiency (SE) scores.[1]

Under the CRS assumption, it was found that 10 out of the 146 dairy cattle farms achieved a technical efficiency score of 0.9 or higher, representing approximately 7% of the sample. The average technical efficiency for all dairy cattle farms was estimated to be 0.54. This implies that, on average, dairy cattle farms operating below optimal efficiency could potentially reduce their input usage by 46% while maintaining the same level of production. The CRS assumption is valid when all dairy cattle farms are operating at their optimal scale. However, according to Coelli *et al.* (2005), factors such as unfair competition and financial constraints can deviate a farm from operating at optimal scale. When relaxing the assumption of constant returns to scale and considering variable returns to scale in the model, the number of dairy cattle farms with a technical efficiency ≥ 0.9 increase to 65 out of 146 dairy cattle farms. The average efficiency also rose to 0.83 (83%), ranging from 0.42 to 1 with a standard deviation of 0.175. Considering the VRS assumption, it is found that farmers can save an average of 17% of the inputs used while maintaining the same level of production. For the least efficient farms with a score lower than 0.5, the potential savings in inputs amount to 10 825 kDZD/year and 9 219 hours of labor work. These findings are particularly significant considering the cost of food management for livestock, which heavily relies on imported resources subject to price fluctuations. Additionally, the scarcity of skilled workforce further highlights the importance of efficiency gains in optimizing resource utilization.

The results further indicate that the VRS model exhibited a lower standard deviation of the mean, implying a greater concentration of farms in the higher efficiency levels. In terms of scale efficiency, approximately 20% of dairy cattle farms performed at or near the optimal scale (0.9 ≤ SE). On the other hand, for the lowest efficiency scores (below 0.5), approximately 40% and 3% of the studied dairy cattle farms fell under CRS and VRS, respectively. Moreover, the assessment of scale efficiency revealed that these farms were not op-

[1] We note that we used R software for our estimations using "dear" package.

Table 2 - Scores of technical efficiency assessment under different specifications.

Efficiency Score	*DEA-CRS*		*DEA -VRS*		*DEA - SE*		*Input saving potential*			
	Number of farms	*%*	*Number of farms*	*%*	*Number of farms*	*%*	*Number of milking cows*	*Cost of feeding in kDZD/year*	*Volume of work in hour/year*	*Sanitary costs in DZD/year*
E < 0,5	58	40	4	3	34	23	5	10 825	9 219	51 604
0,5 ≤ E < 0,6	37	25	17	12	20	14	5	9 722	3 448	23 193
0,6 ≤ E < 0,7	28	19	24	16	22	15	4	7 139	2 502	20 106
0,7 ≤ E < 0,8	10	7	16	11	21	14	2	3 993	1 856	6 548
0,8 ≤ E < 0,9	3	2	20	14	20	14	1	3 519	833	2 204
0,9 ≤ E < 1	4	3	8	6	18	12	0	584	294	934
E = 1	6	4	57	39	11	8	0	0	0	0
Total	*146*	*100*	*146*	*100*	*146*	*100*	*17*	*35 784*	*18 153*	*104 588*
Min.		0,14		0,42		0,14	0	0	0	0
Q_1		0,40		0,67		0,50	0	0	0	0
Median		0,52		0,85		0,68	0	918	358	0
Mean		0,54		0,83		0,67	1	2 754	1085	5 673
Q_3		0,66		1,00		0,87	2	4 321	1557	5 038
Max.		1,00		1,00		1,00	13	17 742	12850	97 522
S.D.		0,19		0,17		0,22	3	4 358	2052	21 105

erating at an optimal scale, as indicated by an average scale efficiency score of 0.67. These findings suggest that a significant number of farms operate at an inefficient scale and would benefit from adjustments to improve their overall efficiency. Out of the 146 farms that were surveyed, 10 operated at CRS. This means that the output these farms increased by the same proportional increase in the inputs used. Tow (2) farms operated at decreasing returns to scale, i.e., the increase in output is proportionately lower than the increase in inputs. Meanwhile, the remaining 134 farms operated at increasing returns to scale, indicating that they obtained an output that increased by more than the same proportional change in inputs.

3.3. *Factors affecting technical efficiency of dairy cattle farms*

To provide informed recommendations for the implementation of effective policies in the dairy sector, it is crucial to identify the sources of variation in the assessed technical efficiency. In this regard, various external factors (as presented in Table 3) were regressed against the efficiency scores under the VRS assumption. This analysis aimed to determine the significance of each factor in influencing efficiency outcomes. The results of these regressions are presented in Table 4, shedding light on the relevance and impact of each factor in determining efficiency levels.

The Tobit regression analysis revealed significant findings regarding the factors influencing technical efficiency. Among the factors examined, five demonstrated high statistical significance at a 1% level, four exhibited moderate significance at a 5% level, and one factor showed weak significance at a 10% level. On the other hand, five factors did not display any statistically significant association with technical efficiency. These results provide valuable insights into the determinants of technical efficiency in the studied context.

Table 3 - Summary statistics for variables included in the Tobit regression.

Variables	*Continuous variables*				*Dummy/Ordinal variables*	
	Mean	*Min.*	*Max.*	*S.D.*	*Categories*	*Number of dairy cattle farms (%)*
Household size	5	0	21	3		
Experience in breeding	18	1	64	10		
Herd size	18	2	95	17		
Calving interval	12	10	18	1		
Frequency of access to extension service	15	0	200	26		
Forage production	4	0	65	8		
Education level					0: Illiterate	14 (10)
					1: Primary school level	30 (20)
					2: Middle school level	71 (49)
					3: Secondary school level	27 (18)
					4: University level	4 (03)
Agricultural training					0: No	114 (78)
					1: Yes	32 (22)
Non-farm activities					0: No	100 (68)
					1: Yes	46 (32)
Access to modern cows					0: No	12 (8)
					1: Yes	134 (92)
Enclosed breeding					0: No	109 (75)
					1: Yes	37 (25)
Access to artificial insemination					0: No	43 (29)
					1: Yes	103 (71)
Access to credits					0: No	124 (85)
					1: Yes	22 (15)
Access to advisory service					0: No	20 (14)
					1: Yes	126 (86)
Access to private advisory service					0: No	117 (80)
					1: Yes	29 (20)

The results reveal the positive significance of five factors, with agricultural advisory services standing out as having a substantial impact on the performance of on dairy cattle farms. The effect of advisory services on improving the technical performance of farms cannot be underestimated, especially in terms of improving farm management skills and fostering knowledge on new technologies and practices (Awunyo-Vitor *et al.*, 2013). In this regression analysis, it is pertinent to highlight that it is not the access to agricultural advisory services that accounts for observed performance (Table 4), instead, it is the frequency of such access that exhibits a positive and highly significant relationship. Furthermore, the quality of advisories provided by private services exerts a more substantial influence when compared to the perceived inefficiency of public advisory services. While private advisory services provide enhanced flexibility, personalized attention and specialized expertise, it is essential to recognize that they are typically associ-

Table 4 - Results of Tobit regression estimation for the efficiency determinants.

Variables	*Coefficients*	*z*	*p-value*	
Const.	0.414	2.679	0.007	***
Household size	−0.007	−1.384	0.166	
Experience in breeding	0.003	2.178	0.029	**
Herd size	−0.003	−2.964	0.003	***
Calving interval	0.034	3.371	0.001	***
Frequency of access to extension service	0.001	2.725	0.006	***
Forage production	0.003	1.394	0.163	
Education level	−0.026	−1.717	0.086	*
Agricultural training	0.080	2.420	0.016	**
Non-farm activities	−0.016	−0.555	0.579	
Access to modern cows	0.170	3.246	0.001	***
Enclosed breeding	−0.003	−0.108	0.914	
Access to artificial insemination	−0.103	−3.477	0.001	***
Access to credits	−0.085	−2.105	0.035	**
Access to advisory service	−0.028	−0.669	0.503	
Access to private advisory service	0.067	2.014	0.044	**
N	*146*	*p-value: 3.75e-10*		
Chi-square (16)	*75.989*			
Log likelihood	*70.763*			

*Note: asterisks are for the statistical significance level: *** for 1%, ** for 5%, * for 10%. No asterisk for no significance level.*

ated with a higher cost. Similarly, the variable "interval calving" exhibited a strong positive significance, suggesting that dairy cattle farms with longer calving intervals tend to be more efficient. This result may seem contradictory to the literature, which suggests that the longer the calving interval, the lower the efficiency. However, our study only focuses on data (inputs and outputs) from a single reference year, which may not fully reflect the long-term effects of increasing this interval. Therefore, the obtained result can be attributed to the fact that a longer calving interval contributes to extended lactation periods and improved animal health, ultimately resulting in enhanced technical efficiency (Bertilsson *et al.*, 1997). The positive effect of cow type on technical efficiency implies that utilizing modern cows, as opposed to local cows, leads to greater efficiency in dairy cattle farms. Modern cows, also known as high-yielding cows, have been selectively bred to produce more milk compared to local cows. Incorporating modern cows into dairy cattle farms can result in higher milk yields and improved efficiency in terms of production and cost-effectiveness (Gelan and Muriithi, 2012).

As expected in the scientific literature (Dhakal, 2022; Gonçalves *et al.*, 2008; Maina *et al.*, 2020; Parlakay *et al.*, 2015), agricultural training and experience in breeding have a positive influence on the technical efficiency of dairy cattle farms with statistical significance at the 5% level. These factors contribute to the facilitation of adopting new innovations, particularly those of a technical nature. Firstly, agricultural training equips farmers with the essential knowledge and skills required to improve their management practices. This includes areas such as feed management, disease prevention, and reproductive management. By implementing improved management techniques, farmers can enhance the productivity of their cows and reduce production costs, thereby increasing technical efficiency. Secondly, experience in breeding enables farmers to make informed decisions in selecting the best genetic traits for their cows. This aspect of expertise plays a crucial role in improving milk production, fertility, and other desirable traits. By carefully selecting breeding stock, farmers can optimize the genetic potential of their cows, leading to enhanced productivity and overall efficiency.

The results of the analysis reveal four factors that have a detrimental effect on the technical efficiency of dairy cattle farms. Among these factors, herd size and access to artificial insemination demonstrate a significant negative regression relationship at the 1% level. The decrease in technical efficiency of dairy cattle farms associated with smaller herd sizes can be attributed to the failure to achieve economies of scale. When herd size decreases, it indicates that the benefits of scale are not realized. Moreover, an increase in the number of dairy cows does not necessarily coincide with additional investments in infrastructure. Breeders often adopt a “reduce to better manage” approach, which can negatively impact efficiency. Larger herds tend to rely more on externally purchased feed, resulting in higher input usage and increased feed costs. Additionally, managing the nutritional needs of individual cows becomes more challenging in larger herds, leading to lower milk yields and higher feed expenses. Larger herds also face challenges related to disease transmission, which can result in higher veterinary costs and decreased productivity. The impact of herd size on dairy cattle farm efficiency remains a subject of debate in the existing literature. While some studies suggest a positive relationship between farm size and technical efficiency (Bravo-Ureta and Rieger, 1991; Hadley, 2006; Parlakay *et al.*, 2015), other studies confirm our findings of a negative relationship between herd size and technical efficiency in dairy cattle farms (Bardhan and Sharma, 2013).

The model reveals a strong negative influence of the mode of reproduction on technical efficiency, indicating that natural reproduction outperforms artificial insemination in terms of efficiency. This finding is not surprising considering the region’s adherence to traditional breeding methods. By practicing natural insemination, dairy cattle farmers have the advantage of selectively choosing the best genitors, often from neighboring farmers. This approach allows for result-based selection, in contrast to the lack of control over offspring in artificial insemination. Additionally, the preference for natural breeding may be influenced by cultural and social factors, such as attitudes towards technology, the traditional role of bulls in breeding practices, and the desire to preserve the genetic composition of the local herd. It is worth noting that the observed preference for natural reproduction and its positive impact on technical efficiency should be understood in the context of the region’s specific circumstances and traditional breeding customs.

The study findings indicate that access to financial resources, specifically through credits, exerts a significant negative impact on the technical efficiency of dairy cattle farms, with a significance level of 10%. This suggests that dairy farmers relying on credit to sustain their operations tend to have lower technical efficiency compared to their financially self-sufficient counterparts. The reliance on credits often leads to accumulating debt burdens, which can hinder farmers’ ability to invest in technologies aimed at improving technical efficiency. For example, financially self-sufficient dairy farms have the financial means to invest in advanced technologies like mechanical milking, which can enhance labor efficiency and reduce costs. In contrast, farmers dependent on credit may face limitations in adopting such innovations due to financial constraints. Therefore, it becomes crucial for dairy farmers to prioritize strategies that promote financial self-sufficiency, as it can contribute to the long-term sustainability of their operations. Furthermore, the model results also highlight a negative impact of education level on the technical efficiency of dairy cattle farms, significant at a 10% level. Surprisingly, farmers with higher levels of education do not necessarily demonstrate superior technical efficiency compared to those with lower educational backgrounds. This finding may be attributed to the fact that farmers with lower education levels often possess practical knowledge and hands-on experience in effectively managing dairy cattle, resulting in higher technical efficiency. Farmers with lower education levels also have a stronger inclination towards adopting traditional and proven methods of managing dairy cattle. While this may limit their exposure to certain modern technologies, their familiarity and expertise in traditional practices might contribute to their higher technical efficiency.

4. Conclusion

In order to improve the performance of dairy cattle farms, it is crucial to address the major constraints identified in this study. One key aspect that requires attention is the enhancement of farm advisory services. Both public and private advisory services should focus on developing localized initiatives, such as on-farm visits and practical demonstrations, to provide farmers with tailored guidance and support. Increasing the accessibility and frequency of advisory services can empower farmers with the necessary knowledge and skills to optimize their farm practices. Moreover, policies should aim to strengthen the linkages between advisory services and farmers, facilitating knowledge transfer and fostering a continuous learning environment. By investing in farm advisory services, the sector can leverage expert guidance and best practices to enhance overall farm performance. Another area for potential improvement lies in the promotion of modern cow breeds. Encouraging the adoption of high-yielding cows, such as Holstein and Montbéliarde, can significantly enhance milk production and efficiency on dairy cattle farms. This can be achieved through targeted programs that provide incentives for farmers to acquire and maintain these improved breeds. Additionally, efforts should be made to ensure the availability of quality breeding stock and the preservation of traditional insemination practices. Supporting breeding networks, cooperative structures, and training programs can facilitate access to quality genetics and contribute to improved technical efficiency in the sector. While the current programs offered by the agricultural sector have shown effectiveness, their reach needs to be expanded to ensure more widespread participation. Currently, only 22% of farmers benefited from these training programs. By adopting a strategy to make these programs more accessible to a larger number of dairy cattle farmers, there is great potential for improvement in farm efficiency. This could involve initiatives such as increasing the availability of training sessions, utilizing digital platforms for remote learning, or establishing partnerships with local farmer organizations to facilitate knowledge dissemination. These measures, coupled with collaborative initiatives and support at the local scale, will contribute to the long-term sustainability of dairy cattle farms in the region.

One other notable finding of this study is the negative impact of the number of dairy cows on technical efficiency, which challenges the conventional understanding of economies of scale. In the specific context of the mountainous region of Tizi Ouzou, where cattle breeding is deeply rooted in tradition and characterized by small herds, increasing the number of cattle actually leads to a decrease in farm performance. This suggests that policies need to be tailored to the unique characteristics of localities. Rather than pushing for consolidation into larger farms, it would be more beneficial to support and strengthen small family farms in this region. Recognizing the limited availability of fodder resources, policies should focus on promoting sustainable and efficient feeding practices that are suitable for small-scale farms. This could involve providing technical support and resources for on-farm fodder production, improving access to high-quality feed, and promoting grazing management strategies.

Furthermore, it is crucial to acknowledge the significant economic and social role that dairy farming plays in this mountainous region. For many small dairy farmers, it represents a vital source of income and employment opportunities. Therefore, agricultural policies should prioritize initiatives that enhance the viability and sustainability of these small family farms. This could include measures such as providing financial support for farm diversification, facilitating access to credit and financial services, and fostering market linkages for local dairy products. By empowering and supporting small dairy farmers, these policies can contribute to the economic development of the region and help alleviate rural poverty.

Funding

This work was supported by the research project *Exploring the impact of governance modes and institutional arrangements in agricultural advisory services on farm competitiveness and sustainability*. Project financed and managed by the Research Center in Applied Economics for Development – CREAD.

References

Ahmed O., Abdel-Salam S., Rungsuriyawiboon S., 2020. Measuring the economic performance of mixed crop-livestock farming systems in Egypt: A non-parametric DEA approach. *New Medit*, 19(2): 133-145.

Bousbia A., Ghozlane F., Benedir M., Belkheir B., 2013. Quantitative and qualitative response of dairy production of cattle herds to husbandry practices. *African Journal of Agricultural Research*, 8(45): 5622-5629.

AlFraj N., Hamo A., 2022. Evaluation of technical efficiency of some rain-fed cereal and legume crops production in Syria: does crisis matter? *Agriculture & Food Security*, 11: 49.

Angón E., Perea J., Toro-Mújica P., Rivas J., de-Pablos C., García A., 2015. Pathways towards to improve the feasibility of dairy pastoral system in La Pampa (Argentine). *Italian Journal of Animal Science*, 14(4): 3624.

Awunyo-Vitor D., Bakang J., Cofie S., 2013. Estimation of farm level technical efficiency of small-scale cowpea production in Ghana. *American-Eurasian Journal of Agricultural and Environmental Sciences*, 13(8): 1080-1087.

Banker R.D., Charnes A., Cooper W.W., 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. *Management Science*, 30(9): 1031-1142. https://doi.org/10.1287/mnsc.30.9.1078.

Bardhan D., Sharma M.L., 2013. Technical efficiency in milk production in underdeveloped production environment of India. *SpringerPlus*, 2: 65.

Battese G.E., Coelli T.J., 1988. Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics*, 38(3): 387-399.

Belhadia M., Yakhlef H., Bourbouze A., Djermoun A., 2014. Production et mise sur le marché du lait en Algérie, entre formel et informel : stratégies des éleveurs du périmètre irrigué du Haut-Cheliff. *New Medit*, 13(1): 41-50.

Bellil K., Boukrif M., 2021. Les réformes de la filière lait en Algérie : Bilan et perspectives. *Les Cahiers du CREAD*, 37(2): 129-157.

Bertilsson J., Berglund B., Ratnayake G., Svennersten-Sjaunja K., Wiktorsson H., 1997. Optimising lactation cycles for the high-yielding dairy cow. A European perspective. *Livestock Production Science*, 50(1-2): 5-13.

Bessaoud O., Pellissier J.-P., Rolland J.-P., Khechimi W., 2019. *Rapport de synthèse sur l'agriculture en Algérie*. Rapport de recherche. Montpellier: CIHEAM-IAMM, 82 pp.

Bravo-Ureta B.E., Pinheiro A.E., 1993. Efficiency analysis of developing country agriculture: a review of the frontier function literature. *Agricultural and Resource Economics Review*, 22(1): 88-101.

Bravo-Ureta B.E., Rieger L., 1991. Dairy farm efficiency measurement using stochastic frontiers and neoclassical duality. *American Journal of Agricultural Economics*, 73(2): 421-428.

Cecchini L., Vieceli L., D'Urso A., Magistrali C.F., Forte C., Mignacca S.A., Trabalza-Marinucci M., Chiorri M., 2021. Farm efficiency related to animal welfare performance and management of sheep farms in marginal areas of Central Italy: a two-stage DEA model. *Italian Journsl of Animal Science*, 20(1): 955-969.

Charnes A., Cooper W.W., Rhodes E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6): 429-444.

Chavas J., Petrie R., Roth M., 2005. Farm household production efficiency: evidence from the Gambia. *American Journal of Agricultural Economics*, 87(1): 160-179.

Clemente F., Lírio V., Gomes M., 2015. Technical efficiency in Brazilian citrus production. *Bio-based and Applied Economics*, 4(2): 165-178.

Coelli T., Rao D.S.P., Battese G., 1998. *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Coelli T., Rahman S., Thirtle C., 2002. Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: a non-parametric approach. *Journal of Agricultural Economics*, 53(3): 607-626.

Coelli T.J., Prasada Rao D.S., O'Donnell C.J., Battese G.E., 2005. *An introduction to efficiency and productivity analysis*. New York, NY: Springer.

Cooper W.W., Seiford L.M., Tone K., 2006. *Introduction to data envelopment analysis and its uses: with DEA-solver software and references*. New York, NY: Springer.

Debreu G., 1951. The coefficient of resource utilization. *Econometrica*, 19(3): 273-292.

Dhakal S.C., 2022. Determinants of technical efficiency among dairy farms in Chitwan, Nepal. *Journal of Agriculture and Forestry University*, 5(1): 149-156. https://doi.org/10.3126/jafu.v5i1.48459.

Djemali M., Berger P.J., 1992. Yield and reproduction characteristics of Friesian cattle under North African conditions. *Journal of Dairy Science*, 75(12): 3568-3575.

Djermoun A., Chehat F., 2012. Le développement de la filière lait en Algérie: de l'autosuffisance à la dépendance. *Livestock Research for Rural Development*, 24: 22.

DSA, 2019. Regional Directorate of Agricultural Services in Tizi Ouzou. Statistical service.

Emrouznejad A., Yang G., 2018. A survey and analysis of the first 40 years of scholarly literature in DEA: 1978-2016. *Socio-Economic Planning Sciences*, 61: 4-8.

Farrell M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A*, 120(3): 253-281.

Fried H.O., Lovell C.A.K., Schmidt S.S., 2008. *The measurement of productive efficiency and productivity growth*. Oxford: Oxford University Press.

Gelan A., Muriithi B.W., 2012. Measuring and explaining technical efficiency of dairy farms: a case study of smallholder farms in East Africa. *Agrekon*, 51(2): 53-74.

Gonçalves R.M.L., Vieira W.C., Lima J.E.L., Gomes S.T., 2008. Analysis of technical efficiency of milk-producing farms in Minas Gerais. *Economia Aplicada*, 12(2): 321-335. https://doi.org/10.1590/S1413-80502008000200007.

Greene W., Zhang Q., 2019. Nonlinear and related panel data models. In: Tsionas M. (ed.), *Panel Data Econometrics*. *Theory.* Amsterdam: Elsevier, pp. 45-96. https://doi.org/10.1016/B978-0-12-814367-4.00003-4.

Hadley D., 2006. Patterns in technical efficiency and technical change at the farm-level in England and Wales, 1982-2002. *Journal of Agricultural Economics*, 57(1): 81-100.

Kalli S., Saadaoui M., Ait Amokhtar S., Belkheir B., Benidir M., Bitam A., Benmebarek A.M., 2018. Éléments d'enquête générale sur la filière lait en Algérie. *International Journal of Business & Economic Strategy*, 8: 12-19.

Kheffache H., Bedrani S., 2012. Les importations subventionnées de génisses a haut potentiel laitier: un échec du a l'absence de politique laitière globale. *Les Cahiers du CREAD*, 101.

Knips V., 2005. *Developing countries and the global dairy sector. Part I global overview*. PPLPI (Pro-Poor Livestock Policy Initiative) Working Paper no. 30. Rome: FAO. https://www.fao.org/3/bp204e/bp204e.pdf.

Koopmans T.C., 1951. An analysis of production as an efficient combination of activities. In: Koopmans T.C. (ed.), *Activity Analysis of Production and Allocation. Cowles Commission for Research in Economics*. Monograph n. 13. New York: Wiley, pp. 33-97.

MADR, 2009. *Statistics on agricultural products*.

MADR, 2019. *Statistics on agricultural products*.

Maina F., Mburu J., Gitau G. *et al*., 2020. Factors influencing economic efficiency of milk production among small-scale dairy farms in Mukurweini, Nyeri County, Kenya. *Tropical Animal Health and Production*, 52: 533-539. https://doi.org/10.1007/s11250-019-02039-1.

Mamine F., Bourbouze A., Arbouche F., 2011. La production laitière locale dans les politiques de la filière lait en Algérie. Cas de la wilaya de Souk Ahras. *Livestock Research for Rural Development*, 23: 8.

Meklati F.R., Meribai A., Yezli N., Ben-Mahdi M.H., 2020. State of play of the dairy sector in Algeria: between objectives and dependencies: an overview. *CABI Reviews*, 15(027).

Ministry of Finance, 2020. *Statistiques du commerce exterieur de l'Algérie*.

Morantes M., Palomares R.D., de Pablo D.A.L., Rivas J., 2022. Efficiency and technology of dairy sheep production systems in Castilla-La Mancha, Spain. A metafrontier approach. *New Medit*, 21(1): 33-52.

Oluwatayo I.B., Adedeji T.A., 2019. Comparative analysis of technical efficiency of catfish farms using different technologies in Lagos State, Nigeria: a Data Envelopment Analysis (DEA) approach. *Agriculture & Food Security*, 8: 8.

Oulmane A., Ali C., Frija A., 2019. The water use efficiency and its determinants in small horticultural farms in Algeria. *SN Applied Sciences*, 1: 1236.

Oulmane A., Ameur F., Bouzid A., Boudedja K., 2022. A functional-structural approach to analyzing agricultural innovation systems in the dairy milk sector of the region of Ghardaïa (Algerian Northern Sahara). *New Medit*, 21(5): 102-116.

Parlakay O., Semerci A., Çelik A.D., 2015. Estimating technical efficiency of dairy farms in Turkey: a case study of Hatay Province. *Custos e Agronegócio Online*, 11(3): 106-115.

Rodríguez Díaz J.A., Camacho Poyato E., López Luque R., 2004. Applying benchmarking and data envelopment analysis (DEA) techniques to irrigation districts in Spain. *Irrigation and Drainage*, 53(2): 135-143.

Speelman S., D'Haese M., D'Haese L., 2011. Simulation of efficiency impact of drainage water re-use: Case of small-scale vegetable growers in North West Province, South Africa. *Agrekon*, 50(1): 89-101.

Sraïri M.T., Ben Salem M., Bourbouze A., Elloumi M., Faye B., Madani T., Yakhlef H., 2007. Analyse comparée de la dynamique de la production laitière dans les pays du Maghreb. *Cahiers Agricultures*, 16(4): 251-257.

Sraïri M.T., Benyoucef M.T., Kraiem K., 2013. The dairy chains in North Africa (Algeria, Morocco and Tunisia): from self sufficiency options to food dependency? *SpringerPlus*, 2: 162.

Tesema T., Gebissa B., 2022. Multiple Agricultural Production Efficiency in Horro District of Horro Guduru Wollega Zone, Western Ethiopia, Using Hierarchical-Based Cluster Data Envelopment Analysis. *The Scientific World Journal*, 4436262.

Ullah A., Silalertruksa T., Pongpat P., Gheewala S.H., 2019. Efficiency analysis of sugarcane production systems in Thailand using data envelopment analysis. *Journal of Cleaner Production*, 238: 117877.

Washington S., Karlaftis M., Mannering F., Anastasopoulos P., 2020. *Statistical and econometric methods for transportation data analysis*. New York, NY: CRC Press.

Wooldridge J.M., 2002. *Econometric analysis of cross section and panel data*. Cambridge (MA): The MIT Press, pp. 108, 245-254.

Yerou H., Homrani A., Benhanassali A., Boussedra D., 2019. Typological assessment of dairy farms systems in semi-arid Mediterranean region of western Algeria. *Biotechnology in Animal Husbandry*, 35(4): 335-346.

NEW MEDIT

Scope

New Medit is an international open access journal published quarterly on behalf of the Italian Institute of CIHEAM of Bari.

The Journal seeks to act as a bridge between the relevant regional studies to enhance regional cooperation and sustainable development, by providing a platform for theoretical and empirical debate in the fields of social and economic sciences, regional development and environmental studies in the Mediterranean Region.

The main subjects of interest include the economic and social transformations in Mediterranean Countries in particular agro-food economics, rural development, environmental economics and sustainability issues around all Mediterranean region.

New Medit welcomes studies tackling the various problems characterising the economy and agribusiness of Mediterranean countries with a multi-disciplinary approach and from diverse theoretical perspectives.

Types of article

New Medit publishes *Research/Themes* papers and *Notes/Reports*. *Research/Themes papers* include original essays and cutting-edge research closely related to the aims and scope of the Journal. *Notes/Reports* include comments or studies on singles experiences which aim to facilitate the debate and dissemination of the real questions among the different territorial areas of the Mediterranean.

The journal operates with a double-blind peer review policy.

Papers are published in English or in French, with an abstract in English.

Guidelines

http://www.newmedit.iamb.it.

Printed in Italy
March 2024