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The Effect Of Irrigation Water Salinity On Potato Crop Productivity Based On Irrigation Technique In Sandy Soil In El Oued Region/Algeria

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ABSTRACT

El Oued region in Algeria experiences significant variation in potato crop yield from one farmer to another, despite being exposed to similar factors such as water salinity level, irrigation duration, and water quantity applied to the potato plants, albeit with variations in the irrigation method, either through center-pivot irrigation or drip irrigation. This study aimed to determine the extent of the impact of irrigation water salinity on potato crop production in the irrigated areas using both spray and drip irrigation methods in El Oued, Algeria during the autumn season of 2020. A sample of 97 potato producers was utilized, and in order to test the homogeneity of the salinity effect between the spray-irrigated and drip-irrigated areas, a regression analysis was conducted using a logarithmic-linear function model to estimate the salinity effect parameters between the two irrigation methods, followed by a significance test to evaluate the difference in their effects. The study revealed that water salinity had a negative effect on potato yield per hectare in both spray-irrigated and drip-irrigated areas. The relationship was found to be non-linear, with an increasing decline in yield as water salinity increased. Based on these results, it can be concluded that there is a difference in the salinity effect depending on the irrigation method, whether through spray irrigation or drip irrigation. According to the study, it was observed that the salinity effect on plants was more pronounced in the case of spray irrigation compared to drip irrigation, as spray irrigation covers the entire plant, including the leaves and stems.

Keywords: *Center-pivot irrigation, drip irrigation, water salinity, potato productivity, sandy soil, Algerian Sahara region..*

Introduction

The region of El Oued has received significant attention from the Algerian government, as it has proven its worth in cultivating many agricultural crops, particularly potato production, which has achieved remarkable results in recent years despite numerous obstacles and difficulties related to the region's desert nature and hot climate. However, among the important variables that have considerably contributed to the development of this sector are the availability of agricultural land, groundwater resources, and the usage of natural fertilizers. As a result, El Oued has risen to the top of the national potato farming rankings in terms of both number and quality. Furthermore, its competitive advantage has created prospects for exporting its products internationally

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Statement of the Problem

Despite being exposed to nearly the same conditions, such as irrigation length and water quantity delivered to the potato plants, we found a substantial difference in potato output in the region of El Oued. Farmers maintain that the water salinity is the same, but there is still a perceptible variation, particularly in irrigation methods, whether center-pivot or drip.
Based on the foregoing, the research problem is as follows:
How and to what extent does water salinity effect potato output in irrigated regions utilizing center-pivot irrigation versus drip irrigation in the region of El Oued, Algeria?

Methods and Tools

1- Variables Employed in the Study

There are several factors that can influence potato production and its value. Below, we will present the factors that we have chosen for this study, as there were difficulties in measuring or determining the remaining factors in our study community. The selected factors are as follows:

1.1 Independent Variables

A. Area: A continuous quantitative variable representing the cultivated land area and its impact through increases. It is measured in square meters and denoted as **(IN1)** in the model.
B. Water Quantity: A continuous quantitative variable representing the amount of irrigation water for the crop. It is measured in cubic meters and denoted as **(IN5)** in the model.
C. Soil Age: A discrete quantitative variable measured by the number of times it has been cultivated and plowed. It is denoted as (IN4) in the model.
D. Salinity by Irrigation Method: A continuous quantitative variable measured in milligrams per liter. It represents the degree of salinity in irrigation water based on the drip irrigation method, denoted as (ING) in the model, as well as the degree of salinity in irrigation water based on the sprinkler irrigation method, denoted as (INO) in the model (David L. Debertin2012 ,PP189-190)

1.2 Dependent Variable

Potato Yield: A continuous quantitative variable measured in quintals. It represents the quantity of potato production **OUT** **(** Bezabih Emana،2015،PP160-162)

2- Data Collection Methodology

The data and information for this study were collected through various sources, which are outlined as follows:
- Field Visits (Interviews): A field visit involving interviews was conducted with 97 farmers who were randomly selected from different potato-producing regions within the state of El Oued during the autumn season of 2019/2020. The face-to-face interviews served as a primary means of data acquisition, enabling direct interaction with the farmers and facilitating the collection of relevant and context-specific data.
- Water Analysis Laboratory: To assess the salinity level of the study samples, water analysis was carried out in the laboratory of the Algerian Water Company (Algérienne des Eaux) located in the state of El Oued. The laboratory's expertise and specialized equipment ensured precise measurements of salinity levels in the water samples obtained during the study.
- Data from the Directorate of Agriculture: Historical data regarding potato crop production from the years 1999 to 2018 were obtained from the Directorate of Agriculture in the state of El Oued.

3- Standard Model for the Study

The process of modeling potato production involves estimating the yield function model of potatoes in El Oued, where we have relied on the logarithmic-linear function, which takes the following form:

$$\log OUT = C + B_1 IN1 + B_4 IN4 + B_5 IN5 + B_O INO + B_G ING$$

To estimate the parameters of this model, we used the ordinary least squares method, which attempts to find the best linear fit by minimizing the sum of squared differences between the actual and estimated observations. To linearize the function, we introduced the logarithm (Walter Nicholson,2008 , PP305-309).

4- Form validity test

4.1 Linear Independence Test

In our study, we relied on two tests; a test for a strong bivariate correlation between the dependent variables, and a test for the variance inflation factor (David R. Anderson,2015 , PP 305-309).

4-2 Test for Autocorrelation of Error Bounds

In our study, we relied on the Durbin's h test, which is a multiple Lagrange multiplier test to examine the presence of autocorrelation in the error terms of the model. (Paola Causin, 2005, pp. 1-22)

4.3 Heteroscedasticity Test of Error Bounds

In our study, we relied on the Breusch-Pagan-Godfrey test to test for the homoscedasticity assumption of the error terms in the model. This test helps us assess whether the variance of the error terms is constant across all levels of the independent variables. (Andreea Halunga, 2017, pp. 209-230)

4.4 Normality Test of Error Bounds

In our study, we relied on the Bera and Jarque test to assess the normality assumption of the error terms in the model. This test helps us determine whether the error terms follow a normal distribution. (Yulia R. Gel, 2008, pp. 30-32)

Results and Discussion

1. Model Estimation Results

Before estimating the model, we first specify the model equation as follows:

$$\log OUT = 5.205 + 0.600\, IN1 - 0.052\, IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING$$

It became evident to us that the coefficient of determination is highly acceptable at 0.82, and furthermore, the model is statistically significant based on the overall significance of the model as indicated by the F-statistic. Additionally, t-tests demonstrate that all estimated parameters are statistically significant at a 5% significance level.

2. Model Validity Test

2.1 Linearity Test

It is evident that there is a moderate to strong correlation between the independent variables in the model. However, these linear relationships are not complete, which allows us to include them together in the model without compromising the good estimation properties of this model.

2.2 Autocorrelation Test

Both the Fisher statistics and the Chi-Square statistics are statistically significant. Hence, the null hypothesis is accepted, indicating that the model does not suffer from autocorrelation issues.

2.3 Heteroscedasticity Test

Both the Fisher statistics and the Chi-Square statistics are statistically insignificant. Therefore, the null hypothesis is rejected, indicating that the model suffers from heteroscedasticity.

2.4 Normality Test

The Jarque-Bera statistic is statistically significant at 1% and 2% levels. Consequently, the null hypothesis is accepted, suggesting that the model residuals follow a normal distribution.

3.Correcting the model for the issue of heteroscedasticity

To correct the model, we will employ the Newey-West method for correcting the standard errors of the estimated parameters without altering the parameter values as follows:

Table 01: Newey-West Correction

Dependent Variable: LOUT
Method: Least Squares
Date: 08/23/20 Time: 20:04
Sample (adjusted): 1 97
Included observations: 97 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.205374	0.126523	41.14168	0.0000
IN1	0.593337	0.070741	8.387465	0.0000
IN4	-0.052054	0.007320	-7.111261	0.0000
INO	-0.061306	0.007872	-7.788199	0.0000
ING	-0.022738	0.011317	-2.009241	0.0475
IN5	0.000148	5.38E-05	2.748036	0.0072

R-squared	0.826692	Mean dependent var	5.535458
Adjusted R-squared	0.817170	S.D. dependent var	0.294917
S.E. of regression	0.126103	Akaike info criterion	-1.243579
Sum squared resid	1.447074	Schwarz criterion	-1.084318
Log likelihood	66.31358	Hannan-Quinn criter.	-1.179182
F-statistic	86.81537	Durbin-Watson stat	1.951301
Prob(F-statistic)	0.000000	Wald F-statistic	91.68238
Prob(Wald F-statistic)	0.000000		

Source: Based on the Outputs from Eviews 9 software

With Newey-West correction, we observe that the parameter values remain unchanged even with slight changes in their standard errors. However, these parameters still maintain statistical significance at the 5% level.

4. Technical Interpretation of Model Estimation Result

To analyze the model estimation results technically, we will start by summarizing the corrected regression function as follows:

Model Function	$\log OUT = 5.205 + 0.600\, IN1 - 0.052\ \ IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING$
Standard errors	$(0.1265)\quad (0.0707)\quad (0.0073)\quad (0.0078)\ (0.0113)\quad (5.38E-05)$
Coefficient of Determination	R-squared = 0.8266

Through the above growth regression model, it is observed that the potato production quantity in the region of El Oued depends on a sample of 97 producers for the same agricultural season. This production quantity is a function of the cultivated area (IN1), soil fertility (IN4), water quantity (IN5), and water salinity based on the irrigation method adopted, either through distillation or sprinkler irrigation (ING and INO, respectively). The technical relationship between each factor and the potato production quantity can be analyzed by studying how the production quantity changes when a production factor changes by one unit. This is achieved by taking partial derivatives of the production function with respect to each production factor while holding other production factors constant.

To facilitate mathematical comprehension of the function, we can reformulate it by introducing the exponential function on both sides of the estimated equation as follows:

$$e^{\log OUT} = e^{5.205 + 0.600\, IN1 - 0.052\ IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING} \Rightarrow$$

$$OUT = e^{5.205 + 0.600\, IN1 - 0.052\ IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING}$$

By relying on the aforementioned adapted function, we can examine the individual relationships between production factors and the quantity of output as follows:

4.1 The relationship between potato production quantity and the cultivated area

We derive the production quantity function, denoted as OUT, with respect to the cultivated area (IN1) as follows:

$$\frac{\partial OUT}{\partial\, \mathrm{IN1}} = 0.6e^{5.205 + 0.600\, IN1 - 0.052\ IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING} \Rightarrow$$

$$\frac{\partial \boldsymbol{OUT}}{\partial\, \mathbf{IN1}} = \mathbf{0.6}\, \boldsymbol{OUT}$$

This means that for each one-unit (hectare) change in the cultivated area (IN1), while holding other production factors constant, the production quantity (OUT) changes by 0.6 units in the same direction. In other words, the relationship between the cultivated area and the production quantity is positive and nonlinear. Increasing the cultivated area leads to an increase in the quantity of production, but the rate of increase is not constant and varies nonlinearly. The production output exhibits an accelerating response to changes in the cultivated area, indicating that the production function is not strictly linear, but rather exhibits positive and nonlinear economies of scale.

4.2 The relationship between potato production quantity and soil age

We derive the production quantity function (OUT) with respect to soil age (IN4) as follows:

$$\frac{\partial OUT}{\partial\, \mathrm{IN4}} = -0.052\ e^{5.205 + 0.600\, IN1 - 0.052\ IN4 + 0.0001\, IN5 - 0.061\, INO - 0.0227\, ING} \Rightarrow$$

$$\frac{\partial \boldsymbol{OUT}}{\partial\, \mathbf{IN1}} = -\mathbf{0.052}\, \boldsymbol{OUT}$$

This indicates that as the age of cultivated soil in agriculture increases by one unit (agricultural season), holding all other production factors constant, the produced quantity decreases by (-0.052 OUT). Hence, the relationship is non-linear and inversely proportional, as an increase in the age of the soil leads to a reduction in the production quantity, albeit at an increasing rate.

4.3 The Relationship between Potato Production Quantity and Daily Water Quantity

We derive the production quantity function (OUT) with respect to the consumed water quantity (IN5) as follows:

$$\frac{\partial OUT}{\partial \,\mathrm{IN5}} = 0.0001\ \mathrm{e}^{5.205+0.600\,IN1-0.052\ IN4+0.0001\,IN5-0.061\,INO-0.0227\,ING} \Rightarrow$$

$$\frac{\partial \boldsymbol{OUT}}{\partial \,\mathbf{IN5}} = \mathbf{0.0001}\,\boldsymbol{OUT}$$

This means that whenever the daily consumed water quantity changes by one unit (liter), while keeping all other production factors constant, the production quantity changes by (0.0001 OUT) in the same direction. Thus, the relationship is non-linear and positively correlated, indicating that an increase in the daily consumed water quantity leads to a higher production quantity, with an increasing rate.

4.4 The relationship between potato production quantity and water salinity in sprinkler irrigation

To derive the production quantity function (OUT) with respect to water salinity in sprinkler-irrigated areas (INO), we proceed as follows:

$$\frac{\partial OUT}{\partial \,\mathrm{IN}O} = -0.061\ \mathrm{e}^{5.205+0.600\,IN1-0.052\ IN4+0.0001\,IN5-0.061\,INO-0.0227\,ING} \Rightarrow$$

$$\frac{\partial \boldsymbol{OUT}}{\partial \,\mathbf{INO}} = -\mathbf{0.061}\,\boldsymbol{OUT}$$

This means that whenever water salinity changes by one unit (insert unit of measurement), while keeping all other production factors constant, the production quantity changes by (0.061 OUT) in the opposite direction. Thus, the relationship is non-linear and inversely correlated, indicating that an increase in water salinity in sprinkler-irrigated areas leads to a reduction in the production quantity, with an increasing rate.

4.5 The relationship between potato production quantity and water salinity in drip irrigation

To derive the production quantity function (OUT) with respect to water salinity in drip-irrigated areas (ING), we proceed as follows:

$$\frac{\partial OUT}{\partial \,\mathrm{IN}G} = -0.0227\ \mathrm{e}^{5.205+0.600\,IN1-0.052\ IN4+0.0001\,IN5-0.061\,INO-0.0227\,ING} \Rightarrow$$

$$\frac{\partial \boldsymbol{OUT}}{\partial \,\mathbf{ING}} = -\mathbf{0.0227}\,\boldsymbol{OUT}$$

This indicates that whenever water salinity changes by one unit (insert unit of measurement), while keeping all other production factors constant, the production quantity changes by (0.0227 OUT) in the opposite direction. Thus, the relationship is non-linear and inversely correlated, implying that an increase in water salinity in drip-irrigated areas leads to a reduction in the production quantity, with an increasing rate.

5. The Statistical Test of Significance of the Difference in the Effect of Water Salinity on Potato Production Quantity Based on Irrigation Methods

Based on the capabilities of the model above, we generally observe that the salinity of water has a statistically significant impact in both methods. However, the degree of salinity's effect varies depending on the irrigation method. In the sprinkler irrigation method, the coefficient was (-0.061), while in the drip irrigation method, the coefficient was (-0.022). Is this difference statistically significant, or is it merely a random variation due to factors other than the irrigation method?

To answer this question, and based on the data and model of this study, we can rely on what is called the WALD-TEST to test the significance of the difference between two parameters in the same function as follows:

- Null hypothesis - No difference in the effect of salinity $\mathrm{B_O} = \mathrm{B_G}\big(\mathrm{C}(4) = \mathrm{C}(5)\big)$
- Alternative hypothesis - Difference in the effect of salinity $\mathrm{B_O} \neq \mathrm{B_G}\big(\mathrm{C}(4) \neq \mathrm{C}(5)\big)$

Table (02): The effect of salinity on drip irrigation

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-7.795542	91	0.0000
F-statistic	60.77048	(1, 91)	0.0000
Chi-square	60.77048	1	0.0000

Null Hypothesis: C(4)=C(5)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4) - C(5)	-0.038568	0.004947

Restrictions are linear in coefficients.

Based on the results of this test, we observe that the probability of the null hypothesis being true is 0%, which means we reject the null hypothesis and accept the alternative hypothesis. This directly indicates that there is a significant difference in the effect of salinity on the irrigated areas between the drip irrigation method and the sprinkler irrigation method.
Furthermore, considering the effect size values, it appears that the impact of salinity is more pronounced in the drip irrigation method compared to the sprinkler irrigation method

Conclusion

We obtained very satisfactory results that are fundamental to our research, and the most important findings are as follows:
- Soil age has an inverse effect on production, meaning that as soil age increases, the quantity of production decreases. Therefore, we recommend all farmers, especially those in the region of El Oued where the soil is sandy, to practice crop rotation every season to avoid exhausting the cultivated soil.
- The quantity of irrigation water has a positive effect, indicating a non-linear positive relationship. As the daily amount of water used for irrigation increases, the quantity of production also increases, but at an increasing rate.
- Salinity of water used in drip irrigation has a negative effect, showing a non-linear inverse relationship. As the salinity of water used in drip irrigation increases, the quantity of production decreases, but at an increasing rate.
- Salinity of water used in sprinkler irrigation also has a negative effect, indicating a non-linear inverse relationship. As the salinity of water used in sprinkler irrigation increases, the quantity of production decreases, but at an increasing rate.
- There is a difference in the impact of salinity depending on the irrigation method, either drip or sprinkler. The study shows that the salinity's effect on plants is more significant in sprinkler irrigation, as it reaches all parts of the plant, including leaves and stems.
- The increase in potato production is non-linear and positive when the cultivated area increases by one unit (hectare). In other words, as the cultivated area expands the quantity of potato production increases, but at an increasing rate.

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