Technical Efficiency in Fig Orchards: The Role of Residual Soil Nitrogen and Nitrogen Volatilization in Babylon Governorate during the 2024 Production Season

Diaa Abbas Abu Duaila [1*], Usraa Traiq Bakr2 [2]
[1']Ministry of Education.
[2] College of Agriculture, University of Tikrit, Iraq.
*Corresponding author's 1E-mail: da230129pag@st.tu.edu.iq
2E-mail: Usraa_Tariq@tu.edu.iq

Abstract

The present study was aimed to study the effect of the nitrogen resources (volatile and residual) on a sample of fig trees in 2024 with 100 orchards as well as studying the technical efficiency of the fig orchard in Babylon Governorate in 2024. The volatile nitrogen (-0.254) and family labour (0.66) were significant at 1% and 5% level respectively in the SFA while others were not significant. The difference between the results was attributed to technical inefficiency in the case of the gamma valuewhich was close to unity (0.99). The overall average efficiency was 0.66 and the productivity gap was 34% and only 27% of orchards had efficiency over 81%. The value of technical efficiency was observed to be inversely related with the volatilisation in the range of 11.7 kg/dunum to 2.1 kg/dunum. The study concluded the benefits of the increased input were not as large as the benefits from increased technical efficiency and reduced N loss, The Stochastic Frontier Analysis (SFA) approach was employed to estimate the production frontier and farm-level technical efficiency scores using Frontier 4.1. The production function included family labor, hired labor, pesticides, applied nitrogen, volatilized nitrogen, and residual soil nitrogen, whereas the inefficiency model included orchard size, educational level, and farming experience.

keywords : Random boundary analysis, technical efficiency, biological control, volatile nitrogen and residual nitrogen, organic fertilizers.

Introduction

Agriculture is one of the economic activities most closely linked to the direct use of natural resources and productivity. The efficiency of the production process depends on the agricultural producer's ability to achieve maximum output given the available quantities of land, labor, capital, water, and fertilizers. Therefore, evaluating agricultural performance is no longer limited to the volume of production or the economic return achieved, but is now linked to the efficiency of resource use and the reduction of waste, especially of resources with dual economic and environmental impact. Technical efficiency is defined as the ability of a production unit to achieve maximum output using a given level of inputs, or to achieve a given level of output using the minimum available resources [1]. The fruit orchard is one of the most important agricultural activities because of its long production time, high of fixed investment and requirement of large number of agricultural services for the fruit orchard including: irrigation, fertilization, pest management, fruit orchard pruning, labour services, Ficus carica L. (fig tree) is one of the oldest fruits plants cultivated by man. The trees of figs are highly tolerant of adverse environmental conditions

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especially in the dry and semi dry areas. It is also nutritionally and economically important, and is highly adaptable to production of fresh fruit, along with drying and other processing operations, making it an important way to diversify an agricultural production system towards sustainable horticulture production. This will lead to increased costs, but not increased production, and therefore a decrease in the technical efficiency of the orchard, however, the imbalance of inputs (especially nitrogenous fertilizers) may lead to increased costs. An important contribution of this study is the addition of indicators of nitrogen losses to the economic efficiency analysis, and not just only on the total amount of fertilizers applied. This way, you'll be able to get a good assessment. In extensive studies on N use efficiency around the world, volatilisation of ammonia has been identified as one of the major causes for N use inefficiency, which can be affected by the: type of N source, rate and timing of N application, soil properties, soil pH and soil temperature [2] and the production performance and opportunities for reduction of losses of N to the environment, increase in production and decrease in cost of production and environmental impacts. Therefore, this research aimed to: Improve nitrogen management efficiency as one of the practical measures that help improving the sustainability of the fig production in Babylon Governorate.

The importance of research:

This research is of importance because it adopted a methodology that investigates fig orchards' TE with a view which transcends only productivity measurements. Furthermore, it analyzes the technical efficiency, in the management of one of the most critical productive and environment resources – Nitrogen. The existing rating systems only factor in use of the fertiliser, and no thought is given to how much can be absorbed by the tree and/or how much can evaporate from the tree. Hence the following variables can be used in the optimum production function – the more realistic indicator of the performance of the production. Furthermore it distinguishes the input of the resources, their efficiency in it and it looks into if there is any correlation between the loss of N and the reduction of production and the impact of deviation from the optimal production threshold. The production function estimation is the only one that has been attempted in the same model and the concepts of technical efficiency measurement and analysis of determinants of technical inefficiency have only been realised through the production function estimation.

Research Problem:

The difference between the resources that the owners have been provided and use to get the actual production is the problem of economic and production in fig orchards in Babylon Governorate. Not only input utilization, but also input utilization efficiency and the approximation of the actual production to the maximum production theoretically possible by productive and technological equipment of orchards are the factors that determine orchards' efficiency in their work. This is only half correct, in that more production can be achieved if more of these – labour, pesticides or even fertilizers – could be used, provided that they are used in combination with poor management and/or losses prior to entering the production process. The research problem is the lack of available information about the degree of technical efficiency of fig orchards in

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the Babylon Governorate, the gap between actual and potential output of figs, the effect of the residual and volatile nitrogen in the soil on the production of figs is not clearly known and the role of the economic, social and environmental characteristics in explaining the absence of technical efficiency within the fig orchards. How much underutilization is the productive resources of the fig orchards in Babylon Governorate of Iraq suffering from? In addition, between orchards what happens to the N residue and N volatilised in the soil, in the production and in the level of the technical efficiency?

Research hypotheses:

The relative technical efficiency of the different fig orchards in Babylon Governorate is different. Some of these differences may be linked to the usage and management of the resources especially to limit volatiles nitrogen losses, as previously discussed. None of the economic and social features like the size of the orchard, education level and experience are correlated with technical efficiency of the fig orchard..

Research Objective

The objectives of the study were to estimate technical efficiency level in the fig orchards in the governorate of Babylon in the season of 2024, analyze the technical efficiency level of the orchards, estimate the effect of the various production factors on the technical efficiency of the orchards particularly the soil residual nitrogen factor, the soil volatile nitrogen, and to explain the causes of the low level of technical efficiency in the orchards.

Data Sources

All the research was done on two types of data sets;

1. Primary Data

This study used primary data obtained from 100 randomly selected fig orchard owners in Babylon Governorate during the 2024 production season, representing 5% of the study population of 2000 farmers, through a questionnaire specifically designed for this study and the needs of the analysis..

2. Secondary Data

The relevant data/information published from official source, studies, research papers/science articles and international reports were also used, which was published and unpublished collected data from the official source and relevant towards the technical efficiency and nitrogen management and perennial fruit production system.

Research Methodology

In this research the research method used was descriptive, analytical and econometric to test the hypotheses to be tested. This was made up of arithmetical mean, percentage and lower bound. The econometric part used stochastic frontier analysis (SFA) to estimate the fig production function and to evaluate the level of technical efficiency of individual orchard based on the individual level. This method was chosen because it would allow for the differences that can occur because of Random deviation and Technical incompetence to be separated. The transcendental logarithmic production function is one of the most popular production functions used in economic analysis, and is extremely elastic relative to other production functions traditionally used, particularly when there are multiple factors of production. The functions may be complicated because the relationship between the factors of the production is not necessarily linear and if there are interactions between the factors, then the functions are not necessarily linear, e.g. the

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Cobb-Douglas and constant elasticity of substitution. This led to the derivation of the production function known as the "transcendental logarithmic production function" and then the tests were carried out without the production function assumption to test the substitution hypothesis and economies of scale. As orchard data had a very high variance, it was decided to use this function for the stochastic frontier analysis (SFA), with the aim of gaining more knowledge about the efficiency of orchard production. Furthermore, it can be used to shed light on the differences in terms of the independent variables such as the “implicit linear” and “implicit quadratic” variables and an infinite number of variables that can be utilized in production [3] .

The SFA model has been developed based on the transcendental logarithmic (TL) production function. One was to take the MB at the same time as the ALS model with the error (or noise) being divided between the random effect component and the technical inefficiency component, where the former is a cross sectional model and the latter is a technical inefficiency model. The main advantage of the Stochastic Frontier Approach (SFA) is that it does not assume all deviations are random; rather, part of the error is attributed to technical inefficiency. Technical Efficiency (TE) of fig farms is estimated via a Translog (TL) production function within SFA, emphasizing critical production factors. Its dual error structure distinguishes random shocks from inefficiency, provides a best-practice frontier benchmark, and allows one-step modelling of inefficiency determinants. The main limitation is the necessity to assume a specific inefficiency distribution (exponential, gamma, half-normal, or truncated-normal), which requires appropriate frontier specification for assessing orchard efficiency. [4].

The first characterization of the cross sectional model was offered by the proposal for random frontier analysis by Meeusen, W. and Van Broeck (WB) and Aigner, D., Lovell, C. and Schmidt (ALS) at the same time; it is based on a splitting of the error term into two main components, one serving to measure the random effect and the other the technical inefficiency. The methodological issue is that it is not assumed that all errors are random and part of the error is due to technical inefficiency. It is implemented through SFA method with better logarithmic production function (TL) and estimate of the technical efficiency (TE) of the fig orchards. For estimation of the technical efficiency estimation and calculation was done with the aid of software ‘Frontier 4.1' used for the estimation of the stochastic frontier of production and maximum estimation of the parameters of the function. The method of estimation was three stages, technical efficiency estimation function was (Translog) and the following is the form of the function used[5]

$$Y_{it}=\exp=BLnX_{it}+V_{it}U_{it}$$

$$LnYi= \beta o+\beta_1 \ln x_{(1} + \beta_{(2} \ln x_2+ \beta_3 \ln x_{(3}+\beta_4 \ln x_{(4}+\beta_5 \ln X_5+\beta_6 \ln X_6+ \beta_7 〖(\ln X_1)〗^2 +\beta_8 〖(\ln X_2)〗^2 + \beta_9 〖(\ln X_3)〗^2+\beta_{10} 〖(\ln X_4)〗^2 + \beta_{11} (\ln X_5)^2+\beta_{12} 〖(\ln X_6)〗^2 + \beta_{(13} \ln x_{(1} \ln x_{(2} \ln x_{(3} \ln x_{(4} \ln x_{(5} \ln x_{(6}+ (Vi+Ui).$$

Where:

Y: the dependent variable, representing the quantity of figs produced in tonnes.

βo: the constant term.

βs: the parameters, where β represents the intercept.

Xm: the independent variables, which include:

ISSN 2072-3857

X1: the number of hours of family labour.

X2: Number of hours of hired labour.

X3: Quantity of pesticides (litres).

X4: Quantity of nitrogen added (hours).

X5: Amount of nitrogen volatilised (kg per day), calculated on the basis of residual nitrogen and the equations provided by the Soil and Water Resources Department.

X6: Amount of nitrogen remaining in the soil (kilograms per day), calculated at the Muradiyah Station laboratories following analysis of soil samples collected from orchard owners in the sample.

Vi: Represents the random error, which accounts for variables beyond the farmer's control, such as weather conditions, measurement errors, random errors and Others, where the variation in yield is because of the difference among the farms. The following assumptions are made: these errors are independent, normally distributed with a N(0, δ^2v), variance and that 'α' is independent of ui.

Ui: a non-negative random variable attributable to inefficiency variables, following an independent and identically distributed exponential or quasi-normal distribution, with a mean not equal to zero and variance n(>0, δzu).

The inefficiency model is defined as follows:

U_it=D_0+D_1 Z_1+D_2 Z_2+D_3 Z_3

These are:

D 1–D 5: Parameters of the inefficiency model

Z1–Z3: Management variables, namely:

Z1: Orchard area (in dunams).

Z2: Educational level, expressed as [1 (illiterate), 2 (primary), 3 (lower) (secondary), 4 (upper secondary), 5 (university), 6 (higher education)].

Z3: Orchard owners' experience (in years).

Estimates of the 'Translog' production function with the stochastic frontier analysis (SFA) are presented.

It was developed by the use of Stochastic Frontier Analysis (SFA) model with Fig production quantity as dependent variable and family labour, hired labour, quantity of insecticides, added N, volatilised N and residual N in the soil as independent variables. The inefficiency variables comprised managerial inefficiency variables which were orchard area, education level and orchard owner experience and social inefficiency variables.

The maximum likelihood (ML) method was used to estimate this model through the use of the 'Frontier 4.1' software. The analysis was done using the final MLE estimates because these are final result of the random effects model, whereas ordinary least squares (OLS) estimates would be considered as a preliminary step in the random effects model estimation process. It should be noted that estimated equation in the present results contains the linearized terms of the variables in logarithmic form,

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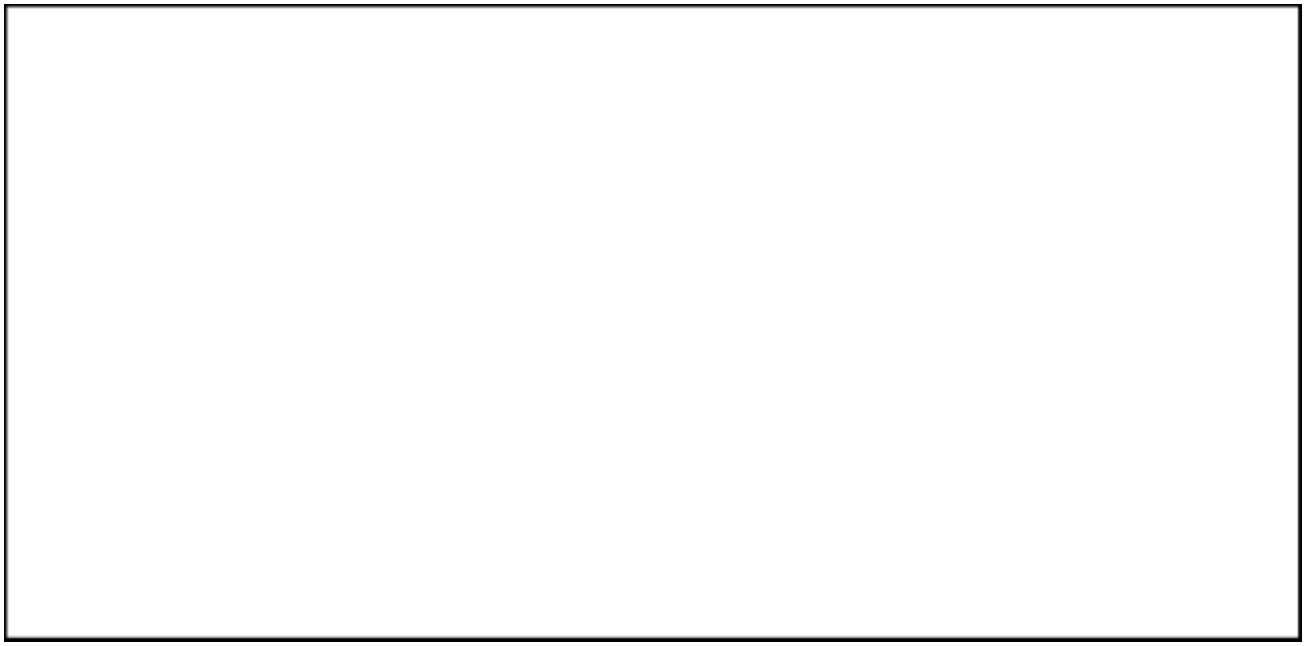
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Table (1): Results of the estimation of the Translog production function using stochastic frontier analysis (SFA)

t-ratio	Standard Error	ML Coefficient	Parameter	Variable
-1.126	0.513128	-0.577830	β0	Constant
2.220	0.299976	0.665959	β1	Family labour X1
0.575	0.333585	0.191751	β2	Paid labour X2
0.324	0.172972	0.056028	β3	Pesticides X3
1.082	0.616109	0.666718	β4	Added nitrogen X4
-3.443	0.073662	-0.253646	β5	Volatilised nitrogen X5
-1.509	0.459444	-0.693078	β6	Residual nitrogen X6
0.890	0.123037	0.109496	δ0	Constant representing technical inefficiency
1.935	0.039053	0.075586	δ1	Orchard area Z1
-0.064	0.028801	-0.001856	δ2	Level of education Z2
-0.397	0.006563	-0.002607	δ3	Orchard owners' experience Z3
6.351	0.028445	0.180642	σ^2	Sigma-squared
—	0.000002	0.999999	γ	Gamma
	0.195-	-0.974		log likelihood function

Source: Compiled by the researcher based on the output of the Frontier 4.1 programme.

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Source: From the researcher's work based on Table (1)

ISSN 2072-3857

Discussion and conclusions

The value of the likelihood ratio test (LR Test) was around (19.5322) with number of samples = 100 and chi-squared value = 0.1806 which was statistically significant, it means that the composite term of the model has heteroscedasticity. The value of gamma was close to 1 (around 0.99) indicating that the variations in yields of the various fig orchards were not just random but mainly due to the level of technical inefficiency in the various orchards. The variable effect of the productive resource/inputs and variable effect of the environmental resource/inputs on the output of the fig tree is reflected in the estimated stochastic marginal production function of the fig tree (Table (1)) following the principle of statistical analysis. The coefficient value of family labour (X1) was 0.666, t value 2.220 and it was resulted as a statistically significant level (5%) and found that family labour has positive effect on cotton production. The production would increase by about 0.666% with an increase in family labor hours.The results demonstrate the vital importance of family labour in fig orchards, particularly in relation to the sovereignty of the small-holder and the need to have labour available to perform various tasks on the farm, such as lopping trees, irrigating, pest control and multiple harvesting and sorting. The other two variables, pesticides (X3) and N application (X4) on the other hand had positive coefficients of 0.056 and 0.667 respectively but small when compared to wage labour (X2) which was 0.192. This effect was not statistically significant however. The bad news, however, is that there is a positive impact on production of these resources, which may have been because they were complementary to wage labour. The efficacy of pesticide is related to type, timing and application whilst nitrogen benefits from application is related to efficiency of application as well as timings and adaptations to the needs of trees. The coefficient value of 'volatile nitrogen' (X5) was found to be (-) 0.254 and coefficient value of t was found as (-) 3.443 and the effect was found to be significant at 1 % level. For all 4 of the variables, a change in percentage (with the other variables held constant) results in a change of production of the fig of 0.254%.There are 4 variables, each of which can either increase or decrease by +1 and -1 (all other variables kept constant) and these 4 variables change the production of the fig by 0.254% for each change. .If the percentage of the variable Volatile nitrogen increases by 1%, then the percentage of production of the fig decreases by 0.254%, if the percentage of the variable Volatile nitrogen decreases by 1%, then the production of the fig decreases by 0.254%, all the other variables are held constant. Loss is one of the largest outputs from the model since it represents not only an environmental impact of the crop, but also a production effect since it reduces the amount of nitrogen available for plant production. To reduce losses and optimise the use of elements it is important to fertilise the correct time and in the correct way. The residual nitrogen in soil (X6) showed negative coefficient and the coefficient is the highest of −0.693. However this effect was not statistically significant (t value: −1.509). This should not therefore be seen as an expression of the negative production impact of the residues of N. Instead, it is a trend seen in the sample data and could be due to quantities not used in some orchards. It does not get absorbed by trees during the season due to either a mismatch in the amount of material added and the trees' supply requirements in the season, or a mismatch between when the material is added and the time trees can absorb it. Overall, the results indicate that increasing the inputs does not necessarily lead to

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increased fig production, but rather to more effective use of inputs, less time spent on the individual inputs and less losses.

Analysis of the Determinants of Technical Inefficiency

The meaning of the coefficients in the inefficiency model are not the same as the meaning of the coefficients of the production function. The sign "+" is interpreted as the result of increasing the variable in the inefficiency model will be an increase in technical inefficiency, while the sign "-" is expected to be the result of increasing the variable in the inefficiency model in terms of decreasing technical inefficiency. The stochastic boundary model has been useful to differentiate the effect of random conditions beyond the control of the producer, from that of technical inefficiency, and has been appropriate for agriculture, where climatic conditions, pests and other environmental factors impact the industry [6].

The results of estimating the technical inefficiency function

There were differences in the effectiveness of fig orchards due to structural and human factors. The area coefficient of orchards was positive (0.0756), the (t) value was (1.935) which is significant at the (10%) level. The technical efficiency function was positive and showed that the more area the orchard had the less was the technical efficiency in the study sample. This may be due to the large scale of orchards (in terms of size of management/supervision, labour requirements and financial requirements). Where an increase in the size of the area is not accompanied by some improvement in administrative and technical ability. It does not mean that in every instance a bigger area will result in a lower efficiency, but that the one with the highest area in this sample tested in this study has not yielded a higher benefit of greater area. Educational level and experience, however, had two negative signs (-0.0019) and (-0.0026) respectively, which shows that when it comes to direction, an increase in educational level and experience is correlated with an increase in technical inefficiency. This is an indication that education is important in learning technical information; experience is important in the problem solving aspect as they use resources and when they encounter production problems to make decisions on when to operate. Both of these (t) values are (−0.064) and (−0.397) and both are sample trends with the two pointing to these two effects not being statistically significant.

Technical Efficiency (TE) according to Random Frontier Analysis (SFA)

The individual TE scores of the study sample's fig orchards were then estimated, using the production function estimated by the application of the Random Frontier Analysis model. The concept of technical efficiency is the efficiency of the orchard in using the inputs and production technology to produce the maximum output. The value will be between 0 and 1. The closer the orchard is to the efficient production threshold, the closer the efficiency value is to one - the farther away the lower efficiency value, the farther away the orchard is from the efficient production threshold. The minimum (0.28), maximum (0.99) and average (0.66) technical efficiency of the sample were found to be approximately the minimum, average and maximum technical efficiency respectively from the above result.

ISSN 2072-3857

Table (2): Technical proficiency (TE) according to random frontier analysis (SFA) for the study sample

TE	Firm	TE	Firm	TE	Firm	TE	Firm	TE	Firm
0.71	**81**	**0.67**	**61**	**0.48**	**41**	**0.75**	**21**	**0.56**	1
0.93	**82**	**0.65**	**62**	**0.98**	**42**	**0.80**	**22**	**0.78**	2
0.57	**83**	**0.95**	**63**	**0.74**	**43**	**0.92**	**23**	**0.56**	3
0.74	**84**	**0.70**	**64**	**0.69**	**44**	**0.96**	**24**	**0.59**	4
0.99	**85**	**0.37**	**65**	**0.74**	**45**	**0.53**	**25**	**0.78**	5
0.61	**86**	**0.43**	**66**	**0.50**	**46**	**0.91**	**26**	**0.46**	6
0.35	**87**	**0.83**	**67**	**0.54**	**47**	**0.52**	**27**	**0.81**	7
0.31	**88**	**0.97**	**68**	**0.54**	**48**	**0.62**	**28**	**0.74**	8
0.71	**89**	**0.94**	**69**	**0.89**	**49**	**0.35**	**29**	**0.57**	9
0.53	**90**	**0.69**	**70**	**0.61**	**50**	**0.66**	**30**	**0.99**	10
0.84	**91**	**0.57**	**71**	**0.39**	**51**	**0.98**	**31**	**0.60**	11
0.28	**92**	**0.39**	**72**	**0.38**	**52**	**0.86**	**32**	**0.72**	12
0.55	**93**	**0.82**	**73**	**0.32**	**53**	**0.78**	**33**	**0.74**	13
0.92	**94**	**0.34**	**74**	**0.99**	**54**	**0.52**	**34**	**0.85**	14
0.30	**95**	**0.65**	**75**	**0.83**	**55**	**0.47**	**35**	**0.99**	15
0.90	**96**	**0.89**	**76**	**0.85**	**56**	**0.49**	**36**	**0.74**	16
0.58	**97**	**0.63**	**77**	**0.75**	**57**	**0.61**	**37**	**0.63**	17
0.45	**98**	**0.48**	**78**	**0.63**	**58**	**0.63**	**38**	**0.37**	18
0.84	**99**	**0.62**	**79**	**0.67**	**59**	**0.45**	**39**	**0.67**	19
0.78	**100**	**0.68**	**80**	**0.40**	**60**	**0.99**	**40**	**0.72**	20
MAX					**0.99**	**Men**			0.66
MIN					**0.28**				

Source: From the researcher's work based on the results of assessing technical proficiency using Frontier 4.1 software.

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The technical efficiency of the different fig orchards included in the present study is shown in the results presented in Table (2) and indicates that there is a significant difference between the different ones with an average value of about 33% between the average attained and the estimated optimum. This is the room for improvement where greater use of available production resources, better orchard management and more efficient working practice and optimum fertilization regime (as well as optimum quantity of all the inputs) can help.

Measuring technical efficiency in light of added, residual, and volatile nitrogen levels

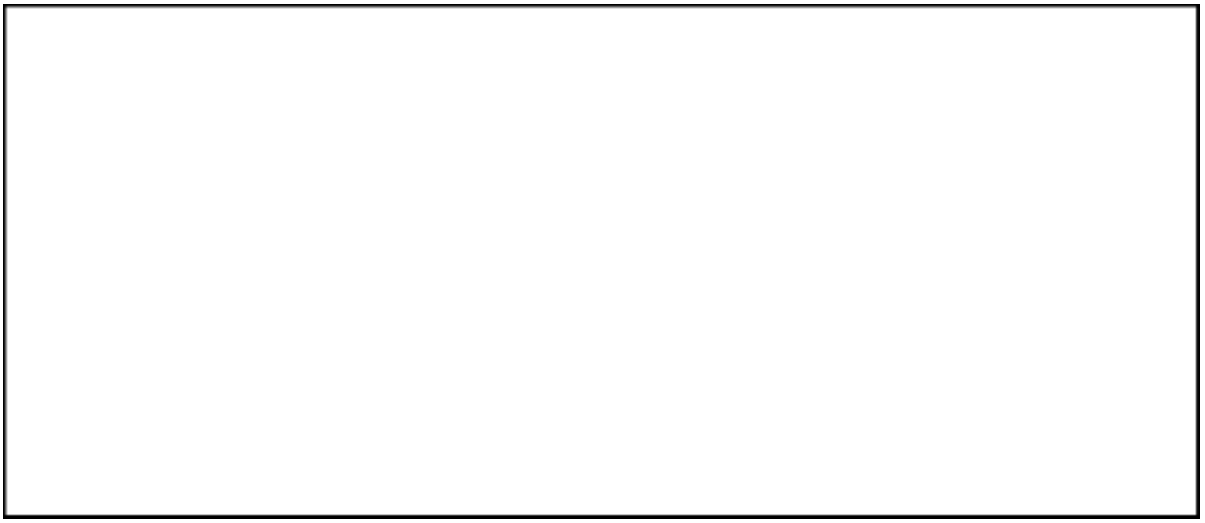
One of the most crucial macro-nutrients, vegetative and fruiting growth and vegetative and fruiting systems. The efficiency in production gained can be coupled to the efficiency in nutrient management, the efficiency in the production system (the trees) and the efficiency with which the nutrient is lost from the system due to different processes (e.g., volatilization). Based on the data presented in the table (3), therefore, a study on the efficiency-correspondence of the use of this resource on the production side and the environment side can be conducted taking into consideration the efficiency of added N, residual N and volatile (V) N. It was revealed that technical efficiency of production process was increased gradually as nitrogen level was increased from lowest level of added nitrogen (4.2 kg/dunum) to highest level of added nitrogen (22.6 kg/dunum) with values of (0.40) and (0.90) respectively. The average nitrogen residue was also higher - (2.8) to (19.7 kg/dunum) - with the various levels of efficiency, whilst the average volatility loss of nitrogen was lower - (11.7) to (2.1 kg/dunum) - at the various efficiencies.

Table (3): Averages added, residual, and volatile nitrogen according to technical efficiency levels.

average volatile nitrogen (kg/dunum(	average residual nitrogen (kg/dunum(	average nitrogen added (kg/dunum)	Average technical efficiency
11.7	2.8	4.2	0.40
9.8	6.1	9.6	0.50
7.5	11.4	15.7	0.60
4.3	14.9	18.2	0.70
2.1	19.7	22.6	0.90

Source: Researcher's work based on the results of the estimated technical proficiency using Frontier 4.1 software, soil analysis results, and questionnaire data.

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Source: From the researcher's work based on Table (3)

The efficiency of the average machine was then slowly lowered at 90 % efficiency from 11.7 kg/dunum to 2.1 kg/dunum in both approaches to the analysis (descriptive versus normative) at the same efficiency (40 %). This means that when nitrogen loss from the system occurs due to volatilisation then technical efficiency is inversely proportional. This is in line with the result of the random bounds analysis (SFA) model which had an approximate coefficient of -0.254 with p value<-0.1 (negative coefficient and significant at 1% level). This is because, as N volatilises more, less will be produced and therefore the difference from the maximum production will be larger. Hence, the results for volatile N were the most consistent and reliable and the negative trend was found both for volatile N - descriptive and volatile N – normatively. More critical technical challenges to be addressed to expand the capacity of the fig orchards are nitrogen fertilization management and minimising N losses from the orchards through evaporation.

Conclusion

Based on the research results, it can be concluded that the differences in the production of figs in the Babylon Governorate are not only random factors of the orchard owners' lives but also due to the differences in the level of technical efficiency of the owners. An additional 34% production would be possible if the resources and technologies are used optimally as it is seen from the mean efficiency of 66% in case of the fig orchards. The greater the inputs, the more production there will be but this does not always exist. Hired labour, pesticides and the additional nitrogen were found to be significant, but not statistically significant, indicating the need for increased management efficiency, rather than increased amount of the resource. The results and conclusions suggest that the extension programmes to be promoted should be directed towards increasing the technical efficiency of the resources available in the fig orchards rather than only directed towards increasing the number of resources. This also includes the introduction of nitrogen fertilization management programmes that calculate the exact demand for nitrogen of trees according to their age, tree density, production level and soil properties and minimise nitrogen losses by optimising the timing and way of nitrogen fertiliser application and avoiding practices that increase the potential for nitrogen losses.

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