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ECONOMIC STUDY TO MEASURE THE EFFICIENCY OF IRRIGATION SYSTEMS (WHEAT CROP IN ANBAR GOVERNORATE AS A MODEL)

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Abstract
Aim of research measuring the economic, technical and allocative efficiency by applying the Data Envelopment Analysis method (DEA), Recognizing the importance of modern irrigation technologies in optimizing available water resources, addressing the water problem in agriculture, and increasing agricultural production at the lowest cost. The sample was collected randomly from 80 farmers from Anbar Governorate / Iraq, who are irrigated by the center pivot sprinkler irrigation system, with four holdings (15, 20, and 30) hectares. Through the results of the research, it was found that the average technical efficiency of irrigation farms with center pivot sprinkler irrigation system the constant return to scale, variable return to scale, and scale (0.97, 0.86, 0.86) respectively, the economic and allocative efficiency of the same system are (0.87, 0.74). Farms with a center pivot sprinkler irrigation system achieved revenue of 2405540 Dollars and profits of 1410414 Dollars, and net revenue of 1871971 Dollars, The researcher recommends relying on the modern irrigation system, the center pivot sprinkler irrigation system, which would increase and stabilize the production rates of agricultural crops as well as its role in rationalizing water consumption and reducing waste.
Keywords: Economic Efficiency, Technical Efficiency, Irrigation system, Wheat yields, Water.

1. Introduction

Iraq Rainfed regions can be classified to two kinds, arid regions and semi-arid regions. Farmers frequently waste irrigation water due to their inaccurate perceptions of how much water crops require, their unrealistic expectations for the amount of rainfall, the absence of the necessary legislation and laws to manage water, as well as the use of ineffective irrigation techniques [1]. Particularly in rainfed agriculture, modern technology has significantly improved the productivity of the available and restricted yield elements through its many instruments in a way that permits more production from the same resources or the same product with less resources[2-3]. When rainfall does not provide enough moisture for plants to grow naturally, supplemental irrigation is a technique used to supply water to rainfed crops to increase crop yields and stability. [4]. Many Arab countries have tended to use supplementary irrigation technology to secure the water needs of crops, reduce reliance on precipitation, and reduce risk because rainfed agriculture, which is the primary source of grain production (wheat and barley), suffers from unstable productive conditions and the degradation of productivity in many agricultural systems caused by fluctuating precipitation rates. In general, yearly precipitation rates are much below what water crops require to provide an economically viable crop, and root zone soil water storage is insufficient to meet water crop demands throughout the growing season [5]. Improving irrigation use efficiency is an essential factor in improving wheat production in Iraq, which suffers from a large food gap [6-7]. The average production of wheat in Iraq is 2.1 million tons and the need to this crop for the country is 3.5 million tons and this means that the self-sufficiency is 42.85% [8-9].

The current study aims to work on the application of modern quantitative methods in the field of efficiency measurement, which have become known in developed countries identifying the efficiency of modern irrigation systems in increasing the productivity of wheat farms, measuring the economic efficiency and technical efficiency and allocative efficiency by applying the Data Envelopment Analysis method (DEA), recognizing the importance of modern irrigation technologies in optimizing available water resources, addressing the water problem in agriculture, and increasing agricultural production at the lowest cost.

2. Materials and Methods

This study was depended on primary data collected from wheat crop growers in Anbar Governorate/Iraq who adopted the supplementary irrigation methods (center pivot sprinkler irrigation system) during the growing seasons of 2021 and 2022. Anbar Governorate has an area of 138,501 square kilometers with an estimated population is 1796557 and it is located in the western of Iraq, the province is located at a longitude of 43.3 wests and latitude of 33.41. The governorate has high temperatures, high evaporation, high humidity, strong wind speeds, and erratic precipitation rates due to its semi-arid environment. Farmers' information was gathered using a direct questionnaire form that was created for the study and a personal interview format with each farmer to get the required data. Data were collected randomly from each agricultural division compared to the community's size in the farming division. The questionnaire has conducted on 80 farmers who used a center pivot sprinkler irrigation system with three categories of possession: 15, 20, and 30 Hectares. Data Envelopment Analysis (DEA) method was used to estimate the technical and economic production efficiency of wheat farms in the research sample. The input aspect was used to extract the efficiency, as it included the use of efficiency for center pivot sprinkler system farms. And the comparison between those efficiencies based on the size of the farm on the one hand, and the comparison between farms that use center pivot sprinkler irrigation system farms. The method of analyzing this type of data is represented by using the (DEA) method according to variable return to scale. And according to the Constant Return to Scale (CRS), this allows estimating Technical Efficiency (TE) and Scale Efficiency (SE), from the input side under the output function variables. Also, through the application of this method of analysis (DEA), the Allocative Efficiency (AE) and Economic Efficiency (EE) were estimated.

3. Results and Discussion

Technical Efficiency (TE) Result for Center Pivot Sprinkler Irrigation System farms

- **Constant Return to Scale (CRSTE)**

The technical efficiency of the farms that used the pivot sprinkler irrigation ranged between a minimum of 0.831, and a maximum of one for 15 farms, which constituted 17% of the pivot sprinkler irrigation farms. While the average technical efficiency ratio was 0.976, therefore, these farms can increase their production by 0.24%.

- **Variable Return to Scale (VRSTE)**

The technical efficiency of the farms in which the pivot sprinkler irrigation was used ranged between a minimum of 0.609 and a maximum of 1 to 18 farms, which constituted 22% of the irrigation farms of the moving pivot sprinkler. The average technical efficiency about 0.868, this indicates that there may be a way to raise production by 13% without using any more resources. When comparing the technical efficiency in variable return to scale and constant return to scale, it is noted that the farms that achieved full technical efficiency in variable return to scale 18 farms exceeded their counterparts in constant return to scale by 17 farms. While we find that the farms that have achieved a full technical efficiency of 100% reached 11 farms, which constituted 14% of the total irrigation farms with axial pivot sprinkler irrigation. Those farms that were working on the production possibilities curve in different proportions. The increase in the number of farms operating with increasing returns over the number of those farms operating within decreasing returns indicates that the rate of increase in the volume of production is greater than the rate of increase in the volume of production factors. This implies that technically inefficient farms may either use less input to get the same level of production or use the same input to achieve a greater level of output.

- **Scale**

The technical efficiency of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.585 and a maximum of one for 11 farms, which constituted 14% of the total irrigation farms of the center pivot sprinkler irrigation system. When the technical efficiency ratio was on average 0.849, this means that these farms can either increase production by 15% or lose some of their production-related financial resources. Regarding the quantity of irrigation farms using a center pivot sprinkler irrigation system, 45 farms, or 56% of the total, were running with rising returns. While the number of farms operating with decreasing returns reached 19 farms, representing a percentage of 23% of the total number of with center pivot sprinkler irrigation system farms. Returns to decreasing scale mean that the change in the production ratios is less than the change in the ratios of the factors of production used. Also, the production is less than the rate of increase in the productive factor. These indicators explain that the rate of increase in the production volume is less than the rate of increase in the productive elements actually used in the production process.

Table1. Minimum And Maximum values and Averages of Irrigation Technical Efficiency for Center Pivot Sprinkler Irrigation System Farms.

Details	Constant Return to Scale (CRSTE)	Variable Return to Scale (VRSTE)	Scale
Maximum	1	1	1
Minimum	0.831	0.609	0.585
Average	0.976	0.868	0.849

Source: Prepared by the researcher based on the questionnaire and data envelopment analysis (DEA).

In order to determine the extent of the impact of area size on technical efficiency and scale efficiency, the study sample was divided into three categories for the size of the area.

The first category: It consisted of farms that used the irrigation system in a category of 15 hectares, and their number 34 farms, which constituted 42% of the irrigation farms with a center pivot sprinkler irrigation system.

1. Constant Return to Scale (CRSTE)

The technical efficiency of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.618 for one farm and a maximum of one for 6 farms, which constituted 17%, while the average technical efficiency was 0.868. These farms can increase their production by 13%.

2. Variable Return to Scale (VRSTE)

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.698 and a maximum of one for 7 farms, which constituted 20% of the category farms. While the average technical efficiency ratio is 0.888, these farms can increase their production by 12%.

3. Scale

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.886 and a maximum is one for 7 farms, which constituted 20%, while the average technical efficiency (TE) was 0.975, meaning that these farms could increase their production by 2% or lose some amount of their economic resources used in production, As a result, the cost will increase by 2%. The number of farms operating with increasing scale returns is two farms. As for the number of farms operating with diminishing returns, there are 25 farms, representing 73% of the first category. As a result, the cost will increase by 2%. The number of farms operating with increasing scale returns is two farms. As for the number of farms operating with diminishing returns, there are 25 farms, representing 73% of the first category.

- **The second category:** It consisted of farms that used the irrigation system category of 20 hectares and numbered 33 farms, which constituted 41% of the irrigation farms with a center pivot sprinkler system.

1. Constant Return to Scale (CRSTE)

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.592 and a maximum of 1 for 5 farms, which constituted 15%, while the average technical efficiency (TE) was 0.872. Therefore, these farms can increase their production by 13% or achieve the level same from the current production, reducing costs by 13%.

2. Variable Return to Scale (VRSTE)

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.750 and a maximum of 1 for 7 farms, which constituted 21%, while the average technical efficiency (TE) was 0.902. Therefore, these farms can increase their production by 8% or achieve the same level, of the current production by reducing the cost of inputs by 8%.

3. Scale

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.960 and a maximum of 1 for 7 farms, which constituted 21%, while the average technical efficiency (TE) was 0.991, meaning that these farms can increase their production by 0.009 or they lose a certain amount of its economic resources used in production, which results in an increase in cost by 0.009. As for the number of farms that were operating with increasing return to scale, 17 farms accounted for 51% at the level of the second category, while there are 8 farms operating with diminishing return to scale. This indicates that the increase in the volume of production is greater than the rate of increase in the factors of production actually used in the production process, within the second category of area.

- The third category: consisted of farms with an area of 30 hectares and numbered 13 farms, which constituted 16% of the sample farms.

1. Constant Return to Scale (CRSTE)

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.585 and a maximum of 0.932, while the average technical efficiency is 0.741, and therefore, these farms can increase their production by 25%.

2. Variable Return to Scale (VRSTE)

The technical efficiency of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.619 and a maximum of 1 for 3 farms, which constituted 23%, while the average technical efficiency (TE) was 0.794, these farms can increase their production by 20%.

3. Scale

The technical efficiency (TE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.831 and a maximum of 1 for one farm, which constituted 7% of the sample farms, while the average technical efficiency (TE) was 0.941, meaning that these farms can increase their production by 5% or they are It loses some of its economic resources used in production, which results in an increase in costs by 5%. As for the number of farms that were operating with increasing returns, they were two farms, which accounted for 15% at the level of the third category. As for the number of farms that were operating with diminishing returns to scale, 9 farms made up 85% of the third category and this indicates that the rate of increase in the volume of production is greater than the rate of increase in the factors of production actually used in the production process within the first category.

Table2. Minimum and Maximum Values and Averages for Technical Efficiency for Center Pivot Sprinkler irrigation System farms According to the Categories of Farms Size

Details		**Area Size / hectare**		
		15 ha	20 ha	30 ha
Constant Return to Scale (CRSTE)	Maximum	1	1	0.932
	Minimum	0.618	0.592	0.585
	Average	0.872	0.873	0.741
Variable Return to Scale (VRSTE)	Maximum	1	1	1
	Minimum	0.698	0.609	0.619
	Average	0.891	0.878	0.794
Scale	Maximum	1	1	1
	Minimum	0.886	0.960	0.831
	Average	0.977	0.991	0.941

Source: Prepared by the researcher based on the questionnaire and data envelopment analysis (DEA).

The Results of the Economic Efficiency (EE) for Center Pivot Sprinkler Irrigation System Farms

The economic efficiency (EE) was estimated according to the cost function variables using resource quantities and prices. The results of the levels of estimating the economic efficiency (EE), with its components, the allocative efficiency (AE) and the technical efficiency (TE) have been presented. Through these results, it is noted that the levels of technical efficiency (TE) are according to the analysis of economic efficiency (EE) of the cost function variables. As the results were completely identical for all farms and the minimum and maximum values and their averages, this confirms the validity of the work estimate within the method used for Data Envelopment Analysis (DEA).

- **Allocative Efficiency (AE):**

The allocative efficiency (AE) of the farms in which irrigation by center pivot sprinkler irrigation system was used ranged between a minimum of 0.527 for one farm and a maximum of 0.997, while the average allocative efficiency (AE) is 0.747, which indicates that the redistribution of economic resources used in wheat cultivation will provide 25.3% Of the total production costs of the wheat crop in the irrigation farms by center pivot sprinkler irrigation system, which means that there is a waste of 25.3%, meaning that these farms can obtain the same amount of production using 74% of the total costs used, or produce a higher amount of the current product at the current costs used.

- **Economic Efficiency (EE(:**

The economic efficiency (EE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.585 for one farm and a maximum of one for 10 farms, which constituted 12.5%, while the average economic efficiency (EE) was 0.749, which means that farmers can reduce costs by 25% achieving the same level of production, meaning that farmers are able to produce the same amount of production using 74.9% to become economically efficient, and the number of farms that managed to reach the best output with a specific number of inputs is the same that achieved technical efficiency (TE) and allocative efficiency (AE) at the same time. It operates within the equal production curve, so it must continue to produce according to the same method.

Table3. Minimum and Maximum Values and Averages of the Economic Efficiency for Center Pivot Sprinkler irrigation System farms

Details	Technical Efficiency (TE)	Allocative Efficiency (AE)	Economic Efficiency (EE)
Maximum	0.997	0.997	1
Minimum	0.485	0.527	0.585
Average	0.747	0.879	0.749

Source: Prepared by the researcher based on the questionnaire and data envelopment analysis (DEA).

In order to determine the impact of the harvested area (hectares) on economic efficiency (EE), the farms were divided into three categories:

- The first category: It consisted of farms that used the irrigation system a category of 15 hectares, and their number was 34 farms, which constituted 42% of the sample farms.

1. **Allocative Efficiency (AE(:**

The allocative efficiency (AE) of the farms in which irrigation by center pivot sprinkler irrigation system was used ranged between a minimum of 0.712 and a maximum of 0.997, while the average rate of allocative efficiency (AE) was 0.909. This indicates that the redistribution of economic resources used in wheat cultivation will save 9.1% of the total costs of production of the wheat crop in irrigation farms by center pivot sprinkler irrigation system, which means that there is a waste of 9.1%, meaning that these farms can obtain the same amount of production using 0.909 of the total costs used, or produce a higher amount of the current product at the current costs used.

2. **Economic Efficiency (EE):**

The economic efficiency (EE) of the center pivot sprinkler irrigation system farms ranged between a minimum of 0.618 and a maximum of one for 6 farms, which constituted 17%, while the average economic efficiency (EE) was 0.868.

- Second Category:

It consisted of farms that used the irrigation system class of 20 hectares and numbered 33 farms, which constituted 41% of the sample farms.

1. Allocative Efficiency (AE):

The allocative efficiency (AE) of the farms in which irrigation by center pivot sprinkler irrigation system was used ranged between a minimum of 0.651 and a maximum of 0.996, while the average of allocative efficiency (AE) amounted to 0.880. This indicates that the redistribution of economic resources used in wheat cultivation will save 12% of the total costs of producing a crop Wheat in irrigation farms by center pivot sprinkler irrigation system, which means that there is a waste of 12%, meaning that these farms can obtain the same amount of production using 0.880 of the total costs used, or produce a higher amount of the current product at the current costs used.

2. Economic Efficiency (EE):

The economic efficiency (EE) of the farms in which the center pivot sprinkler irrigation system was used ranged between a minimum of 0.592 and a maximum of one for 5 farms, which constituted 15% of the total farms of the category, while the average economic efficiency (EE) was 0.871.

- Third Category: It consisted of farms that used the irrigation system category of 30 hectares, numbering 13 farms, and they constituted 16% of the sample farms.

1. Allocative Efficiency (AE):

The allocative efficiency (AE) of the farms in which irrigation by center pivot sprinkler irrigation system was used ranged between a minimum of 0.527 and a maximum of 0.894, while the average allocative efficiency (AE) is 0.797. This indicates that the redistribution of economic resources used in wheat cultivation will save 20.3% of the total costs of production of the wheat crop in irrigation farms by a center pivot sprinkler system, which means that there is a waste of 20.3%, meaning that these farms can obtain the same amount of production using 0.797 of the total costs used, or produce a higher amount of the current product at the current costs used.

2. Economic Efficiency (EE):

The economic efficiency (EE) of the farms that used the center pivot sprinkler irrigation system ranged between a minimum of 0.585 and a maximum of 0.932, while the average economic efficiency is 0.741.

Table4. Minimum and Maximum Values and Averages of The Economic Efficiency for Center Pivot Sprinkler irrigation System farms According to the Categories of Farms Size

Details		**Area Size / hectare**		
		15	20	30
Technical Efficiency (TE)	Maximum	0.997	0.996	0.741
	Minimum	0.534	0.522	0.485
	Average	0.789	0.767	0.586
	Maximum	0.997	0.996	0.894

Allocative Efficiency (AE)	Minimum	0.712	0.651	0.527
	Average	0.909	0.880	0.797
Economic Efficiency (EE)	Maximum	1	1	0.931
	Minimum	0.618	0.592	0.585
	Average	0.868	0.871	0.741

Source: Prepared by the researcher based on the questionnaire and data envelopment analysis (DEA).

- **Wheat Crop Revenue**

The revenue generated from the wheat crop in the irrigation farms with the center pivot sprinkler irrigation system for the study sample amounted to 2405540 dollars. At the level of the categories, the second category acquired the highest revenue, 1086844 dollars, and this value constituted an importance ratio of 45% of the total revenues of the center pivot sprinkler irrigation system farms, followed by the first category with an amount of 796700 dollars. With relative importance of 33%, and finally, the third category came with an amount of 521996 dollars and relative importance of 22%, and these percentages are expected because the area of land taken by the second category is the largest in the study sample.

Table5. Wheat Crop Revenue for Center Pivot Sprinkler Irrigation System Farms

The Irrigation Method	Area / hectare	Revenue	Relative Importance
Center Pivot Sprinkler Irrigation System	15	796700	33%
	20	1086844	45%
	30	521996	22%
	Total	2405540	100%

Source: Prepared by researcher based on questionnaire.

- **Profits**

It was shown from the table (Fig) that the profits for the wheat crop in the irrigation farms by the center pivot sprinkler system for the study sample amounted to 1410419 dollars as a total value. At the level of categories for the cultivated area, the second category of irrigation farms with a center pivot sprinkler irrigation system showed the highest value, reaching 633,927 dollars, and this value constituted 45% of the total value, followed by the first category with a value of 507,219 dollars and a contribution rate of 36%, and the third category with a value of 507,219 dollars. It amounted to 269,273 dollars, with a relative importance of 19% of the total contribution.

Table6. Profits for Center Pivot Sprinkler Irrigation System Farms

Irrigation Method Area / hectare Total Cost Revenue Profit Relative Importance

Irrigation Method	Area / hectare	Total Cost	Revenue	Profit	Relative Importance
Center Pivot Sprinkler Irrigation System	15	289481	796700	507219	36%
	20	422917	1086844	633927	45%
	30	252723	521996	269273	19%
	Total	965121	2405540	1410419	100%

Source: Prepared by researcher based on questionnaire.

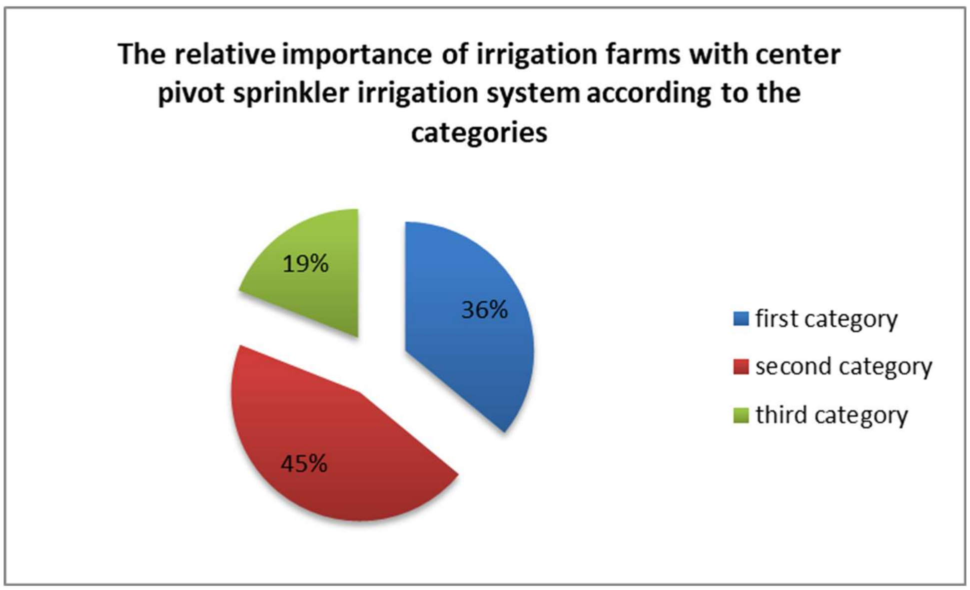

Figure1. The relative importance of profits of center pivot sprinkler irrigation system farms according to categories.

- **Net Revenue**

The net revenue of the wheat crop in the irrigation farms with the center pivot sprinkler system for the study sample amounted to 1871971 dollars as a total value. At the level of categories for the cultivated area, the second category of irrigation farms with a center pivot sprinkler irrigation system farms showed the highest value, reaching 833749 dollars, and this value constituted 46% of the total value, followed by the first category with a value of 629566 dollars and a contribution rate of 34%, and the third category with a value of 408656 dollars. It amounted to 318,656 dollars, with a relative importance of 20% of the total contribution.

Table6. Net Revenue for Center Pivot Sprinkler Irrigation System Farms

Irrigation Method	Area / hectare	Variable Cost	Revenue	Net Revenue	Relative Importance
Center Pivot Sprinkler Irrigation System	15	140134	769700	629566	34%
	20	253095	1086844	833749	46%
	30	113340	521996	408656	20%
	Total	776569	2405540	1871971	100%

Source: Prepared by researcher based on questionnaire.

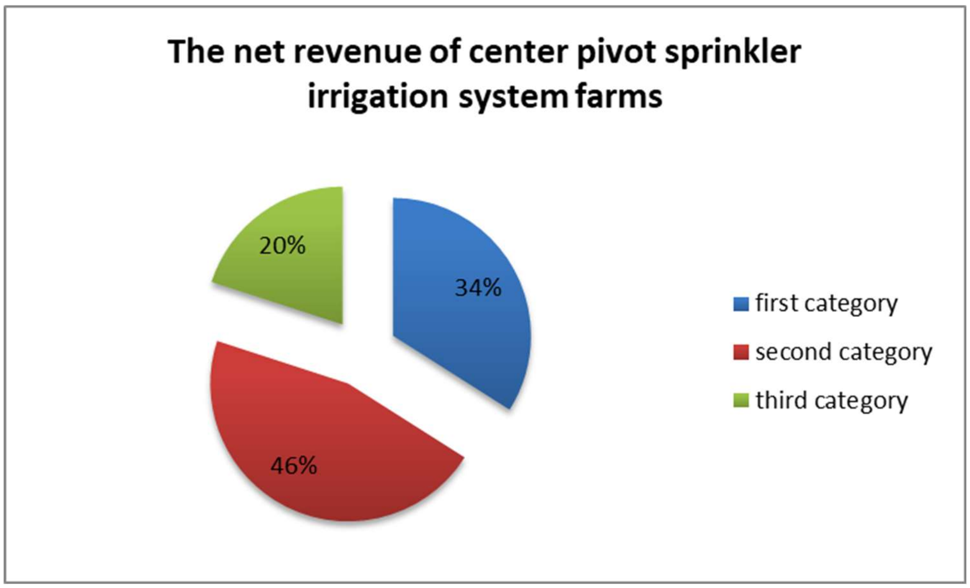

Figure2. The relative importance of net revenue of center pivot sprinkler irrigation system farms according to categories.

4. Conclusion

In this study the economic, technical and allocative efficiency has been measured by adopting the Data Envelopment Analysis method (DEA) of modern irrigation technologies in optimizing available water resources, addressing the water problem in agriculture, and increasing agricultural production at the lowest cost. From the analyzing the collected data it can be deriving the following **conclusions:**

- With the increase in the efficiency of water use and with the expansion of the size of the farm, the technical efficiency increased, and this indicates the importance of water management and good use on the one hand, and the importance of center pivot sprinkler irrigation system.
- By reviewing the areas of Anbar province and some of its resources, the province can have a major role in increasing wheat production at the level of Iraq.

- By estimating the technical efficiency according to the method of data envelope analysis (DEA) and depending on the variables of the production function, it is clear that the redistribution of economic resources will save a proportion of the quantities of resources used , which amounted to an average of about 25% in the irrigation system by center pivot sprinkler. Profits amounted to wheat farms is 1410419 Dollars, the wheat farms of the center pivot sprinkler irrigation system farms achieved net revenue of $ 1,871,971 Dollars, and the first category is the highest net income by 833749 Dollars.
- The need to pay attention to the issue of irrigation by the directorate of agriculture of Anbar and to provide data related to irrigation quantities in each region after conducting surveys and studies related to the subject, or at least to provide data on irrigation rates.

The study recommends conducting more research that diagnoses the determinants of the level of technical competence and ways to improve them, taking into account the economic and social factors surrounding production conditions. Also, a study of the reasons that led to the achievement of full (optimal) efficiency in some farms and try to take them as applied models for inefficient farms to follow in order to reach full efficiency. Reliance on modern irrigation methods that will increase and stabilize production rates for agricultural crops, as well as its role in rationalizing water consumption and reducing waste.

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