Jordan Journal of Agricultural Sciences, Volume **20**, No.**4** **2024**
DOI: https://doi.org/10.35516/jjas.v20i4.1967

The Economic Viability of the Renewable Energy Systems in Agricultural Activities in Jordan

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Received on 8/11/2023 and Accepted for Publication on 11/6/2024.

ABSTRACT

This study aimes to study the economic viability of using renewable energy sources in different agricultural farms and activities. The economic viability was investigated according to the farm activities, size, and type of renewable energy source. A cross-sectional study was used by questionnaire for data collection. The questionnaire included two parts; the first part covered farm characteristics, while the second one covered the economic viability of renewable energy systems in the agricultural business. The questionnaire was distributed to a random sample of 100 farmers in different areas. The collected questionnaires were isolated and analyzed using the R software. Descriptive and inferential analyses were used to obtain the final results of the study. The results showed that the use of renewable energy system is viable in the agricultural sector. The economic viability increases as the size of the farm increases. The results showed that the cost-benefit ratio, the net present value, and the internal rate of return were the highest for the farms of 500 dunums and more. Solar radiation was found as the viable source that is widely distributed among farmers, followed by wind energy, and the least was recorded for biomass energy. The results showed that renewable energy sources are not sufficient to cover farm energy needs. In addition, the use of renewable energy systems was more viable in animal production farms and farms practicing both animal and plant production processes. The use of renewable energy was economically viable with different levels in all farms in the agricultural business. The economic viability increases in farms with mixed animal and plant activities. The study recommended that the government encourage the use of renewable energy systems to increase the farms' energy independence and protect the environment.

Keywords: Renewable Energy Systems, Economic viability, Agricultural Business, Farm Size, Farm Activities.

INTRODUCTION

The significance of renewable energy sources (RES) increased nowadays and the satisfaction of their use in different agricultural activities increased as a new source that provides an opportunity to diversify the agricultural activities and maximize the economic viability through savings and maximizing the production (Morris and Bowen 2020). On the other side, the RES contributed widely to protecting the environment and maximizing energy independence in agricultural businesses (Bolyssov et al. 2019). The impact of RES is increasing in remote rural areas through its positive impact on the agricultural economy and job opportunities created in this field (Chen et al. 2018). Furthermore, growing renewable energy plants on agricultural land can contribute to the long-term strategy of acquiring and using renewable energy sources, as well as diversifying energy resources (Weingart and Giovannucci 2004). The agricultural sector through using RES acts as both an energy user and supplier through the use of bioenergy and advanced technologies to improve

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efficiency and minimize energy consumption (Sutisna et al. 2022). Access to reliable and affordable RES is crucial for adding value to agricultural activities and moving beyond subsistence farming.

Palniladevi et al. (2023) reported four energy systems that can be used in agricultural activities including solar energy (SE), wind energy (WE), biomass energy (BE), and geothermal energy (GE). Also, they reported that the SE is a promising RES for agricultural activities. The studies found that the integration of energy sources from different RES will increase the sustainability and increase the cost-effectiveness of these systems. The use of RES such as the SE and WE will increase the farms' independence in providing the energy requirements for their farms (Bekir 2018). Different studies showed that the RESs are very suitable for some agricultural activities such as irrigation systems and fertilization (Gupta et al. 2023). \In some RES, technology plays a vital role in its economic viability. For example, the studies showed that the use of a dual-axis solar tracker will produce about 20-30% more energy compared to the use of fixed panel systems (Gupta et al. 2023). This incorporated the technology issue with the economic viability of using RES.

Moreover, the economic viability of using RESs is connected to other factors such as the readiness of the infrastructure, the governmental support and regulations, the awareness of the RESs by farmers, and the distribution of the technology in the targeted areas (Pestisha and Bai 2023; Wang et al. 2023)(Wu et al. 2023). In Jordan, the government's encouragement for the adoption of RESs increased in the last years which encouraged the farmers of different levels to adopt these systems. This study will investigate the economic viability of the adoption of RESs and the factors that affect the economic viability.

Literature review

Zeyad et al. (2022) reported that the RES has shown economic viability in the farming process. The SE and BE have been used to develop smart microgrids for poultry farms, resulting in cost-effective solutions and reduced emissions. Dinakar and Deepika (2019) have shown that in India, renewable technologies are being used to supply or supplement on-farm energy requirements, contributing to energy security and reducing environmental impact. Le et al. (2016) found that a hybrid power system using solar PV and wind turbines has been found to save costs for farms and provide flexibility in operating non-critical farm loads. Ibeawuchi et al. (2015) found that the application of organic manure, and organic mulches side by side with renewable energy sources has been recommended for sustainable farming, increased crop production, and improved soil quality. (Nnadi and Nwakwasi (2010) reported that SE has various applications in agriculture, including especially in reducing electricity and heating bills, providing hot water, and drying crops.

Alexy and Haidegger (2022) reported that the factors that affect the economic viability of use in farming systems include farmers' feelings of computer technology alienation, poor economic benefit perceptions, and incompatible information management skills. Diogo et al. (2017) have shown that the personal characteristics including life processes and education of farmers influence the learning and problem-solving styles which contribute to farmers' unwillingness to use computerized systems. Also, Schaffer and Düvelmeyer (2016) found that the farm size and the economies of scale of software use can influence economic benefit perceptions. Jaber et al. (2015) emphasized that the delay in software adoption resulted from the lack of operational skills, but training can help overcome this barrier. In terms of cropping systems, Sutisna et al. (2022) have shown that intercrops and rotations offer advantages including better resource use and improved nutrient cycling. As small farms form a considerable percentage in desert regions form a very important source of food production. The adoption of these farms for RES is influenced by many factors including membership of farmers' groups, proportion of female family members working on the farm, location, financial sources, and ownership of freehold land.

(Alexy and Haidegger 2022) discussed the environmental impact, the negative impact of the COVID-19 pandemic, and rising input costs considered other factors that affect the economic viability of use in farming systems. Additionally, Diogo et al. (2017) found that the complexity of technology applications and the need for scalable Internet of Things (IoT) based implementations pose challenges. (Kaushik and Chel 2011) found that communication protocols protection against weather conditions and the adoption of IT solutions are considered further barriers to RES use. Mascarello et al. (2017) discussed the crop sensitivity to climate conditions, the economic factors, and future climate change scenarios on the potential impacts on agricultural production systems. Rashid et al. (2021) discussed the adoption of RES in different attitudes by considering the impact on farm intensification and diversification that should be considered when using RES to avoid crop damage and improve economic viability. Furthermore, the relative importance of household strategies, such as farm intensification and off-farm income varies across farming systems. The use of Remotely Piloted Aircraft Systems (RPAS) and automated farming technologies can also contribute to the economic viability of farming systems.

Dupas et al. (2022) found that the size of the farm impacts the economic viability of using RES in farming. Small farms were found to achieve non-negligible shares of RES with a reduced loss of productivity resulting in small storage capacity. In underdeveloped regions, Vogt et al. (2018) found that small family farms can benefit from RES such as solar radiation, to improve farming returns. Le et al. (2016) discussed the benefits of hybrid power systems using wind turbines and solar PV in saving farm costs and providing flexibility in operating non-critical loads. Gholami et al. (2019) found that greenhouse emissions and daily farm energy can be met through the use of biomass power plants and PV plants as RES. Vogt et al. (2018) found that electric tractors provide an advantage over conventional tractors through the use of RES to save energy.

Ifeoma et al. (2022; Tymińska et al. (2023); and Babatunde et al. (2020) discussed the effect of farm activity having a significant impact on the economic viability of using renewable energy. In Nigeria, Pestisha et al. (2023) reported that farmers who use RES experienced a 39% increase in agricultural productivity. Additionally in Nigeria, Lotfi et al. (2023) reported that 75% of farmers surveyed are willing to use RES. Also, they found that agricultural biogas plants such as RES do not introduce significant disturbances to the power quality of the grid. Higher economic viability was found for the photovoltaic (PV)-battery systems compared to diesel power systems in livestock farmhouses resulting in a 48% savings in total net present cost (TNPC) and zero emissions. The importance of RES in the agricultural sector has been recognized globally which contributed to the agricultural development in different regions.

The economic viability of using different types of renewable energy depends on various factors. Jalil and Mohammed (2022) found that the SES economic simulation had higher capital costs compared to diesel generators and investment stations, but on the other hand, it had the lowest operational costs. Ogunwole and Krishnamurthy (2023) used an optimizer function to demonstrate the cost-effectiveness of different configurations of renewable energy sources, such as solar PV and wind turbines, in reducing net present and operating costs. Bhuiyan et al. (2023) found that WE is the most feasible type of marine renewable energy for many countries, while offshore wave energy is still in the pre-commercialization stage. Berishvili and Gejadze (2020) evaluated the profitability of using agricultural biomass residues and SE found that direct selling of biomass created the highest value while switching to biomass fuel was the most profitable option.

The type of RES used in farming systems had a significant impact on its viability. In the context of sustainable farming, Dash and Choudhury (2021) found that the adoption of RES and information communication technology (ICT) is considered the core to achieving sustainability in RES. In poultry farming, Zeyad et al. (2022), found that the smart microgrid using SE and BE was found to be the most cost-effective solution for meeting energy demand. (Le et al. 2016) A hybrid power system using wind turbines and solar PV was also found to be a viable option for supplying power to farms, resulting in significant cost savings over 20 years. (Berishvili and Gejadze 2020) Additionally, the use of agricultural biomass residues and SE was found to be beneficial and profitable in creating value in agribusiness In modern livestock facilities, Borek and Romaniuk (2020) found that the use of photovoltaic panels, heat recovery, and biogas production from manure fermentation contribute to energy savings and environmental protection.

Methodology

This study aimed to investigate the economic viability of RES in farming systems according to farmers' views from different regions in Jordan. A cross-sectional study was used to investigate the economic viability of using RES in farming systems. The study covered different parts of Jordan with different geographical characteristics. The study was executed in the period Feb 2023 to July 2023. The sample included 100 farmers who practiced different agricultural activities. The questionnaire was distributed to a random sample of farmers. The questionnaire was distributed in person to the sample. The questionnaire included two parts. The first part covered the characteristics of farms, while the second part covered the economic viability of using RES compared to traditional systems. The collected questionnaires were entered into an Excel database for data cleaning. R software (ver. 2023.12.1) was used for the analysis. The frequency and percentages were used to describe the farms' characteristics. The contingency tables and chi-square test were used to measure the statistical significance of distribution for the crosstabs of different RES and farm characteristics. To analyze the savings made by the farms resulting from using RES, eight farms of different sizes were selected to collect detailed financial data through personal interviews.

Results

Farms' characteristics

The farm sample included different farm sizes for comparison purposes. The results showed that the percentage of farms included in the sample ranged from less than 50 to more than 1000 dunums. The highest percentage was for farms ranging from 501 to 1000 dunums, which is considered the economic size for agricultural activities with 37.0%. The second size was for the area 201–500 dunums with 18.0%. The third level was for the area 101–200 and more than 1000 dunums with 15.0% for each of them. The least was recorded for the sizes 50-100 dunums and less than 50 dunums with 8.0% and 7.0%, respectively (Table 1).

The farms included in the study practiced three types of production: plant production alone of 100%, animal production of 14.5%, and mixed production including both animal and plant production of 4.1% (Table 1). Concerning the types of renewable energy sources used, the results showed that the highest source was solar radiation with 47.8%, followed by mixed sources including solar radiation and WE with 37.9%, followed by biofuel (methane) energy with 9.9%, and the lowest was recorded for the use of WE alone with 4.4% (Table1).

The coverage of RES for farm needs compared with traditional sources

The results showed that all the farms in the sample showed that the RES does not cover the farm's energy needs. The farms with an area of 501–100 dunums show the highest coverage of RES for their needs. followed by areas with more than 1000 dunums (Figure 1). One-third of the farms practicing plant production (34.0%) showed that the RES covered their needs, while one-fifth of the animal production farms showed that the RES covered their farm needs. In general, a considerable percentage of the sample shows that the RES is not enough to cover the farm needs. Energy self-sufficiency increased in the case of the use of solar radiation (31.0%) compared with other sources. The farms (20.0%) that use both SE and WE at the same time show that RES is sufficient to cover the farm needs. The lowest sufficiency was recorded for the biofuel source (7%) (Figure 1).

Table 1: Characteristics of farms

	Frequency	Percent
Area Category (Dun)		
Less than 50	8	8.0
50-100	7	7.0
101–200	15	15.0
201- 500	18	18.0
501–1000	37	37.0
> 1000	15	15.0
Agricultural Activity		
Plant production	100	81.3
Animal production	18	14.5
Both	5	4.1
RES used		
SE	97	47.8
WE	9	4.4
Both SE and WE	77	37.9
Biofuel (methane)	20	9.9

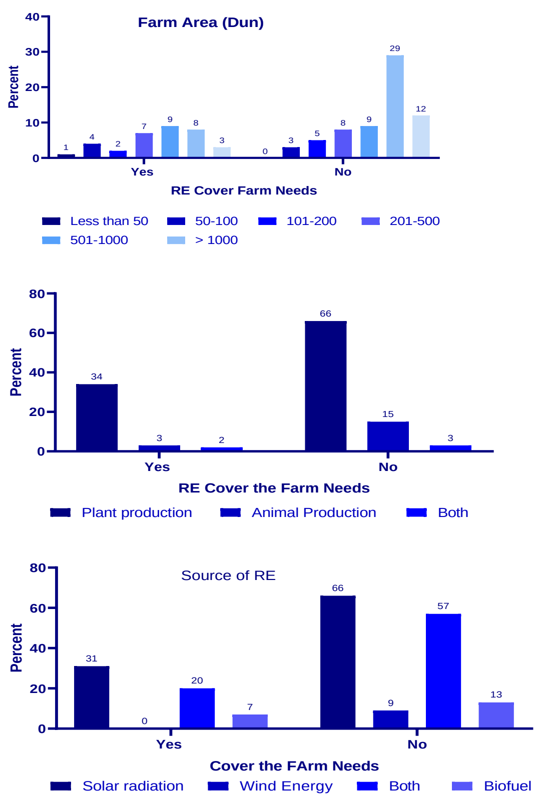


Figure 1: RES coverage for farm energy needs by area (Chi-sq = 10.666, p = 0.099), type of production (Chi-sq = 1.051, p = 0.305), and source of RE (Chi-sq = 6.004, p = 0.014)

Consumption of RES compared to traditional sources

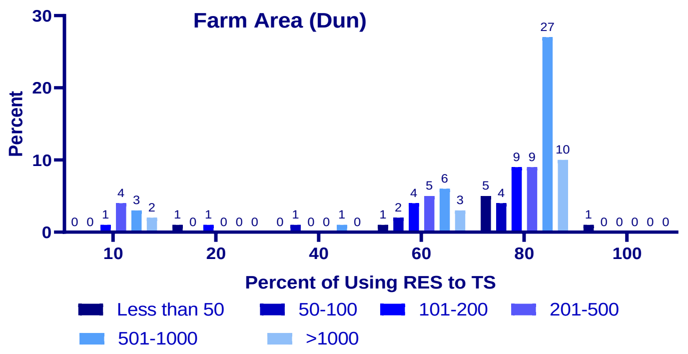
The maximum RES coverage for the needs reached 80%. The highest coverage for the RES needs was for the area 501–1000 dunums (27.0%). The cover of 80% of the needs for the other farm sizes did not exceed 10%. The second small coverage for the RES reached 60% for a small percentage of farms of different farm sizes. The highest proportion of RES contribution was recorded for the SE with a percentage reaching 63.4% for the coverage percent 80% of the needs. The use of both solar radiation and WE, which cover 80% of the needs, reached 52.0%. The second coverage for solar and mixed sources reached 60% of the farms. A small percentage of the farms showed coverage of the needs for a percentage less than 60 (Figure 2).

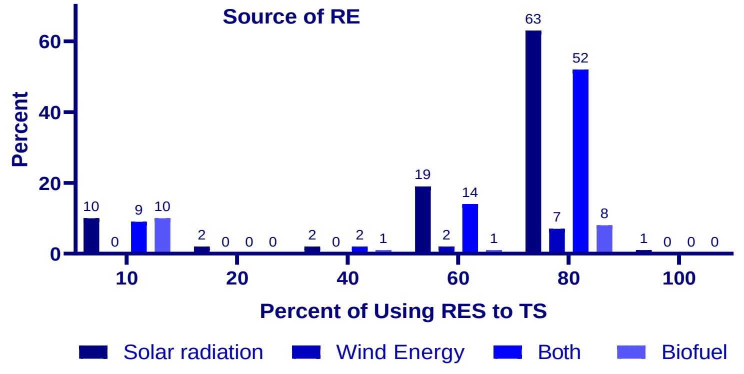
Uses of RE in Farm Activities

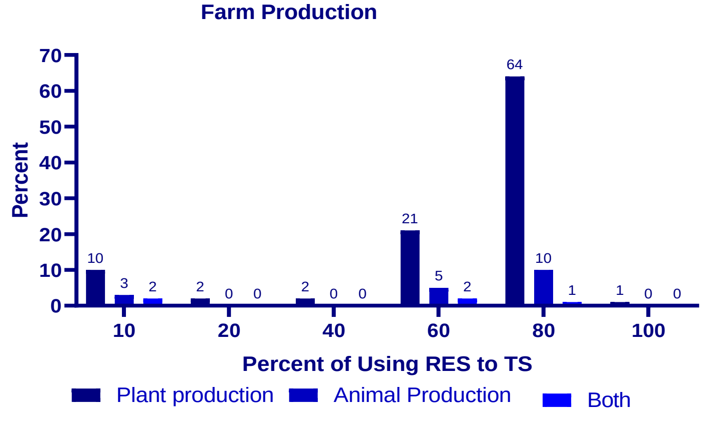
The SE was found to cover most of the farm needs in the case of its usage with different percentages distributed among the different farm activities. The highest use was reported for irrigation (97%). The lack of use of solar radiation was reported for the artesian wells because not all farms have such wells. The second coverage for farm energy needs was reported for the use of both solar radiation and WE with a percentage less than the use of solar radiation alone. (Figure 3)

Farm savings resulting from using RES

The use of RES was found to increase energy expense savings, which positively reflects farm production since the consumption of energy increased after the use of RES. The highest percentage of farms (11.0%) showed that the savings reached JD 1425 annually; moreover, about 7% of the farms showed that the savings reached about (JD2450) annually. About 43% of the farms showed that the savings were more than JD1100 annually. The rest of the sample showed savings ranging from JD0 to JD750. The third category of the sample showed that their expenses for energy did not change after the use of RES (Figure 4).


Farm Area (Dun)
Percent
Percent of Using RES to TS
Less than 50
50-100
101-200
201-500
501-1000
>1000


Source of RE
Percent
Percent of Using RES to TS
Solar radiation
Wind Energy
Both
Biofuel


Farm Production
Percent
Percent of Using RES to TS
Plant production
Animal Production
Both

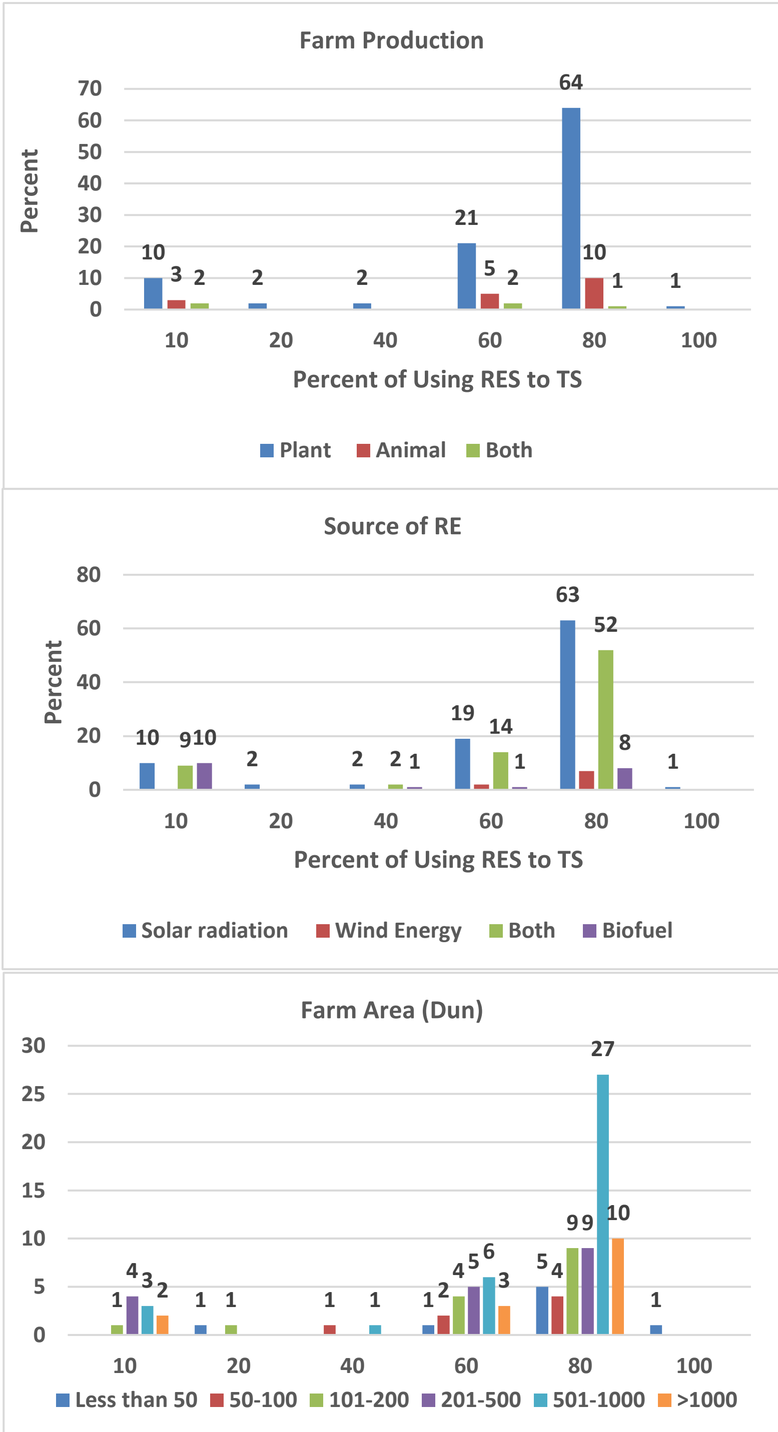


Figure 2: Percentage of RES to TS (Traditional sources) of the farm energy needs by area (Pearson Chi-sq = 79.175, p = 0.001), type of production (Chi-sq = 29.0, p = 0.0159), and type of RES (Chi-sq = 7.611, p = 0.6667).

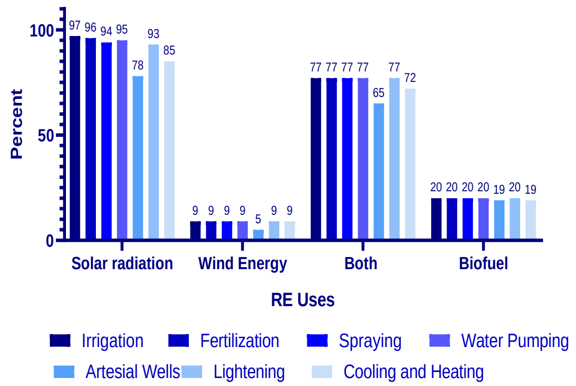


Figure 3: Uses of RES in farm activities

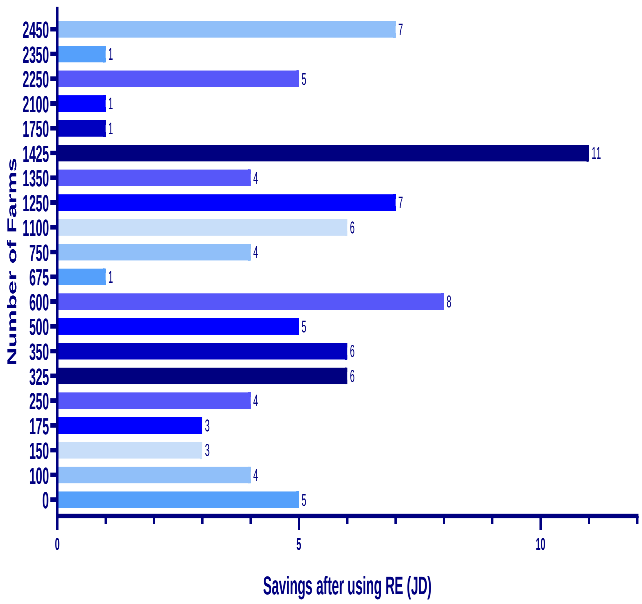


Figure 4: The amount of annual savings (JD) resulting from RES use.

Annual mean savings (JD) for the use of RES according to the area of the farm

According to the area, all the farms showed savings with different levels according to farm size. The highest the area (>1000 dunum), the highest the annual savings recorded (JD1621.7). The trend of savings showed that the increase in farm size makes it more feasible to use RES to cover farm energy needs (Table 2).

Table 2: Annual savings through RES use by farm size

Farm size	Mean	N
Less than 50	17.9	8
50-100	260.7	7
101–200	115.0	15
201- 500	981.9	18
501–1000	1042.6	37
> 1000	1621.7	15
Total	841.0	100
F*	10.178	
P**	0.001	

* F: Fisher test ** P: Probability

Annual mean savings (JD) for the use of RES according to farm production activity

The results showed that the highest savings (JD1350) were recorded in the farms that practiced plant and animal production activities. In addition, the results showed that the savings were higher for the animal production farms (JD1102.78) compared to the plant production farms (Table 3).

Table 3: Annual savings through the use of RES by farm activity

Farm activity	Mean	N
Plant production	841.00	100
Animal production	1102.78	18
Mixed production	1350	5
F	0.058	
P	0.810	

* F: Fisher test ** P: Probability

Annual mean savings (JD) for the use of RES according to the type of RE

The highest annual savings were recorded in the case of the use of biofuel energy (JD1181.25) followed by the use of a mixed system including solar radiation and WE (JD1009.42). The lowest savings were recorded in the case of WE (JD500.0) (Table 4).

Table 4: Annual savings through the use of RES by type RE

RE source	Mean	N
SE	855.67	97
WE	500.00	9
Mix	1009.42	77
Biofuel	1181.25	20

Increase in energy consumption percent and savings of using RES

The results showed an increase in the use of energy by 60% because the use of renewable energy sources recorded the highest savings which reached (JD1135.29) compared to other increase categories. The second highest savings were recorded when the increase in the use of renewable energy sources increased by 80%. The increases in savings were less in the case of the increase in the use of RE by 20 % and 40% (Table 5).

Table 5: Annual savings of the use of RES even after the increase in energy use

The percentage of energy use increase	Mean	N
20	15.0000	5
40	262.5000	6
60	1135.2941	34
80	797.2727	55
Total	841.0000	100

Table 6 shows the economic analysis of using the RES for five years. The table presents different farm sizes. The results showed that the cost-benefit ratio (CBR) was less than one for the farm areas of 450 dunums or less, while the CBR was more than for the farm areas ranging from 1200 to 17500 dunums. The CBR is one for the farm area of 30000 dunums. The CBR reflects that the RES is more feasible to be used in medium to large farms. Its use in very large farms was not economically feasible may be related to the high use of energy exceeding the capacity of RES. The net present value (NPV) showed that it was negative for the farms' areas 250, 450, 1500, and 30000 dunums. These results indicated that the NPV was positive for medium farms with areas of 9000 to 17500 dunums. Similar results were reflected using the international rate of return (IRR). The medium to large farm areas showed positive IRR values compared to other areas (Table 6).

Table 6: The economic analysis of using RES in different farm sizes

Farm area	**Cost-benefit ratio**	**NPV**	**IRR**
250	0.47	-1547.07	-28%
450	0.97	-1266.7	-16%
1200	1.92	1631.286	15%
1500	1.21	-503.359	-3%
2500	1.35	320.057	1%
9000	1.62	8214.969	8%
17500	1.38	2547.982	1%
30000	1.00	-21765.8	-9%

Discussion

The objective of this research is to investigate the viability of RES adoption on energy economic viability in agricultural farms. The sample included farms that use three types of RE: SE, WE, and BE. The sample included farms that practice plant, animal, and mixed production processes. The sizes of farms varied, which allowed the comparison process between the different sizes.

All the farms reported that the use of RES was not enough to cover all the farm needs, which reflects the continuity of use of traditional sources to supply the farms with the required energy. The results showed that RES covered 80% of the farms' total needs. The use of RES was viable in general for all farms and under different production activities. The results showed that different types of RES including SE, WE, and BE can be used to improve farming processes and the economic viability of the production process.

The size of the farm played a major role in determining the extent of the benefit of using the RES. The results showed that the farms with an area of more than 500 dunums accomplished more economic viability compared to the other sizes, resulting in the more efficient use of RES. The CBR, NPV, and IRR values showed that these farms accomplished savings that will be reflected positively on the farm economics. Farms of plant and animal production witnessed high viability of using RES. The farms with both types of production; plant and animal production, were able to use the RES for the improvement of production. These results were consistent with the results of Fallahinejad et al. (2022) and Choobchian et al. (2018) who found that farm size has a significant effect on the economic viability of renewable energy sources (RES). Ifeoma et al. (2022) found contradicting results where larger farms tend to have a higher share of traditional resources and a lower share of renewable natural resources, indicating a decrease in the use of RES as farm size increases. However, Ge et al. (2017) found that larger farms with RES also have a higher energy yield ratio and energy investment ratio, suggesting a higher yield per unit area.

Moreover, the result showed that the use of BE was the most viable among the farms, but it is uncommon among the farmers because of the need to produce RE. On the other side, the results showed farmers rely on SE and WE to produce RES. However, the use of SE and WE was feasible and served different farming activities. The SE is more adaptable and widely used as RES in farming systems compared to BE systems. The high distribution of SE was a result of the governmental support introduced for the adoption of this method and the operational cost connected to this system compared to the other systems. Gorjian et al. (2020) state that SE, specifically photovoltaic (PV) technology, has been employed in various agricultural applications such as water pumping, irrigation, crop drying, and greenhouse cultivation. Nnadi and Nwakwasi (2010) found that the SE can also be used to reduce fuel consumption and fulfill the electric demands of equipment and facilities in dairy farms.

The use of RES increased the consumption of energy inside the farms, which was positively reflected in both the production process and the savings made because of its use. The increase in energy use resulted in the availability of cheaper resources that can be used to improve the production processes. The increase in consumption was accompanied by higher savings of expenses on energy in the farms. The increase in the energy used by RES reflects the increase in the savings made and the higher the coverage of the processes in the farm.

Conclusions and recommendations

The objective of this research is to investigate the viability of using RES in agriculture farms. The variety of farms included in the study made it possible to make comparisons. The comparison included the farm size, the production sector, and the type of agricultural activity. The use of RES was found to increase farm savings. The intermediate farm, sizes ranged from 200 to 500 dunums showed more use of RES and more covering of the farm energy needs. The results showed that the use of RES improved the production process. Despite the increase in energy use because of RES, its use increases the farms' savings and increases the benefits and returns for farmers. The SE was the most popular among farmers, followed by the mixed systems of SE and WE production. The high uses of SE are related to the high sunny hours that can be utilized for energy production and the support of these systems by the government. The distribution of BE is limited due to their input needs for energy production. Most farmers showed that they made savings that increased with the increase in farm size. The study recommended an increase in the distribution of RES through increasing governmental support.

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الجدوى الاقتصادية لانظمة الطاقة المتجددة في الأنشطة الزراعية في الأردن

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تاريخ استلام البحث: 2023/11/8 وتاريخ قبوله: 2024/6/11.

ملخص

تهدف هذه الدراسة إلى التعرف إلى الجدوى الاقتصادية لاستخدام مصادر الطاقة المتجددة في المزارع. دُرست الجدوى الاقتصادية بناءاً على خصائص حجم المزرعة، والنشاطات الزراعية، ونوع مصدر الطاقة المتجددة المستخدم في هذه المَزارع. استخدمت الدراسة البيانات المقطعية العرضية باستخدام الاستبانات لجمع البيانات. وقد تألفت الاستبيانه من جزئين، الجزء الأول تعلق بجمع بيانات حول خصائص المزرعة، بينما تعلق الجزء الثاني بجمع بيانات حول جدوى أنظمة الطاقة البديلة في المزارع. وزعت الاستبيانه على عينة عشوائية تألفت من 100 مزارعاً في المناطق الزراعية المختلفة. تم عزل البيانات التي جمعت وتحميلها على برمجية (R) لأغراض التحليل. استخدم الإحصاء الوصفي والاستدلالي من أجل الوصول إلى نتائج الدراسة. أظهرت النتائج أن استخدام أنظمة الطاقة المتجددة كان مجدياً في القطاع الزراعي، وحجم المنفعة ازداد بزيادة حجم المزرعة، وأظهرت النتائج أن نسبه التكلفة الى المنفعة و صافي القيمة الحالية ومعول العائد الداخلي كانت الأعلى في المزارع ذات الحجم المتوسط أو أعلى (500 دونم أو أكثر)، وبينت النتائج أن أنظمة الطاقة الشمسية كانت الأكثر جدوى في العمل الزراعي، تلاها نظام طاقة الرياح وجاء في المرتبة الأخيرة استخدام الطاقة الحيوية. كما أظهرت النتائج أن كمية الطاقة المنتجة من مصادر الطاقة المتجددة لا تلبي حاجة المزرعة من الطاقة، وكذلك أن المنفعة الاقتصادية كانت أعلى في المزارع التي تحتوي على نشاطات نباتية وحيوانية معاً، وقد أوصت الدراسة بان تشجع الحكومة المزارعين على استخدام أنظمة الطاقة المتجددة من أجل زيادة الاستقلالية في طاقة المزارع ولحماية البيئة.

الكلمات الدالة: أنظمة الطاقة المتجددة، الجدوى الاقتصادية، العمل الزراعي، حجم المزرعة، النشاطات الزراعية

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