JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ASSESSING THE INTEGRATION OF WIND ENERGY FOR IRRIGATION PURPOSES IN JAHUN LOCAL GOVERNMENT AREA OF JIGAWA STATE, NIGERIA

Sani Saleh, Mujahid Ahmed, Bello Bashir, Zakariyya Dahiru, Mubarak Zakari Musa, Ibrahim Sabitu
Department Of Physics
Jigawa State College Of Education, Gumel, Nigeria

Abstract: This research study was conducted to assess the integration of wind energy for irrigation in Jahun Local Government Area (LGA) of Jigawa State, Nigeria, against the backdrop of significant demographic growth and a youthful population. The LGA, home to an estimated 395,300 people in 2022 and primarily consisting of the Fulani ethnic group, stands to gain from sustainable agricultural practices. The local climate, with temperatures conducive to year-round wind turbine operation, recorded wind speeds between 3.591 m/s and 6.9276 m/s, averaging 6.5 m/s annually. Economically, the initiative is supported by a wind power density of 246.6 W and a daily energy requirement of 5000 Whr for irrigation. A 250 W turbine, chosen for its ability to operate 20 hours a day with a 90% capacity factor, meets these energy needs. Financially, the turbine's installation costs ₦2,300,000, with installation expenses of ₦575,000 and annual maintenance of ₦115,000, over its 20-year lifespan. The research concludes that wind energy is not only viable but also cost-effective for irrigation in Jahun LGA, enhancing agricultural productivity and sustainability in line with the community's economic and environmental goals.

Keywords: Wind Energy Integration**, **Irrigation Efficiency**, **Renewable Energy Adoption**, **Sustainable Agriculture**, and **Jigawa State Wind Potential
This research was sponsored by The Tertiary Education Trust Fund (TETFUND)of The Federal Republic Of Nigeria

1. 0. INTRODUCTION:

Background on Jigawa State's agricultural profile: Jigawa State is predominantly agrarian, with agriculture serving as the backbone of its economy. The state is known for producing crops like millet, sorghum, maize, and rice. Smallholder farms are prevalent, but there are also larger operations that contribute significantly to the state's output. Agriculture not only employs a large portion of the population but also contributes to the state's GDP.

Importance of irrigation for agriculture in Jigawa State: Given the semi-arid climate of Jigawa State, irrigation is not just beneficial but essential for crop production. The state experiences variable rainfall, which can lead to droughts or floods, both detrimental to agriculture. Irrigation offers a way to stabilize crop yields, extend the growing season, and potentially increase the variety of crops that can be cultivated.

The potential of wind energy as a renewable energy source: Jigawa State has a significant potential for wind energy, which could be harnessed to power irrigation systems. This renewable energy source could provide a sustainable and cost-effective solution to the energy needs for irrigation, reducing reliance on diesel generators and the grid, which may be unreliable or unavailable in rural areas.

Research objectives and questions: The primary objective of this research is to assess the technical feasibility and economic viability of integrating wind energy into irrigation systems in Jigawa State. Specific research questions might include:

i. What is the wind energy potential in Jigawa State, specifically in the Jahun Local Government Area?
ii. How do the costs and benefits of wind-powered irrigation systems compare to conventional systems?
iii. What are the perceptions and willingness of local farmers to adopt wind-powered irrigation systems?
iv. What environmental impacts could result from the adoption of wind energy for irrigation purposes?

2.1. Overview of Wind Energy Development in Nigeria

2.1.1 Wind Energy Resources and Potential

Nigeria has been exploring various renewable energy sources, including wind, to cater to its energy demands and reduce reliance on fossil fuels. The country is endowed with wind energy potential, particularly in the northern regions where wind speeds are favorable for wind farm development (Ajayi, 2010)

2.1.2. Economic Analysis

The economic analysis of wind energy in Nigeria indicates that while there has been significant progress in solar energy projects, wind energy has received less attention, except for a notable project like the 10 MW land-based wind farm in Katsina State. Studies suggest that for wind energy to be economically viable, there needs to be a comprehensive assessment of wind resources and a clear economic strategy (Adeyeye, Ijumba., & Colton, 2021)

2.1.3. Hybrid Systems

Considering the intermittent nature of wind, hybrid systems that combine wind energy with other forms of renewable energy could be a solution for a more reliable energy supply. Research into hybrid systems involving wind energy is ongoing, and recommendations have been made to enhance the research, development, and application of such systems in Nigeria **(Sani, 2020)**

2.1.4. Challenges and Policy

Despite the potential, the development of wind energy in Nigeria faces challenges such as non-implementation of renewable energy policies, financial constraints, and lack of adequate research. A systematic review suggests that reshaping renewable energy policies and speeding up their implementation could improve the status of wind energy development in the country (Bhuiyan, Zhang, Khare, Mikhaylov, Pinter., & Huang, 2022)

2.1.5. Public Opinion

Public opinion plays a crucial role in the adoption of renewable energy technologies. Engaging communities and stakeholders is essential for the successful implementation of wind energy projects. Studies have gathered opinions through questionnaires to understand the public's perspective on renewable energy in Nigeria (Renewable Energy Roadmap: Nigeria, 2023; Lawal, 2021)

In conclusion, while Nigeria has the potential to develop wind energy, it requires concerted efforts in terms of policy implementation, financial investment, and public engagement to realize this potential fully.

Other reviews that provide comprehensive insights into the status, challenges, and future prospects of wind energy development in Nigeria can be obtained in (Idris, Wasiu Olalekan; Ibrahim, Mohd Zamri; Albani, Aliashim. (2020).

2.2. Current state of irrigation practices in Jigawa State

2.2.1. Adaptation Strategies to Climate Change: A study assessed the perceived effectiveness of adaptation strategies to climate change among rice farmers in Jigawa State. It found that more than half of the respondents perceived the effectiveness level of adaptation strategies to be low. The study highlighted constraints such as insufficient farm credit, high cost of raw materials, and inadequate information on weather (Orifah, Sani, Nasiru., & Ibrahim, 2021)

2.2.2. Impact of Hadejia Valley Irrigation Project

Another research focused on the impact of the Hadejia Valley Irrigation Project on the poverty status of beneficiaries in Jigawa State. The findings suggested that the project had a positive impact on reducing poverty among its beneficiaries. However, the study also recommended that beneficiaries should form cooperatives for better knowledge transfer, input, output, marketing, and distribution(Umar., & Haruna, 2019)

2.2.3. General Impacts of Irrigation: While not specific to Jigawa State, a comprehensive review by the World Bank on the impacts of irrigation provides valuable insights. It covers a wide range of literature on irrigation impact, which can offer guidance for future investments in irrigation projects like those in Jigawa State (**Giordano, M., Namara, R., & Bassini,** n.d.)

2.3.1. Renewable Energy in Irrigation Water Supply

A special issue in the journal Water focused on the applications of renewable energies in irrigation water supply. It covered topics such as the design of solar, wind, and hybrid pumping systems; smart irrigation management systems with renewable energy sources; and hydraulic energy recovery in irrigation networks. The use of renewable energies for irrigation was highlighted as a way to improve the sustainability of irrigated agriculture by reducing production costs and environmental impacts (Water, n.d.)

2.3.2. Renewable Energy Resources for Irrigation: A chapter in the book "Practices of Irrigation & On-farm Water Management: Volume 2" discussed the use of renewable energy resources to power irrigation systems. It emphasized that renewable energy effectively uses natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are naturally replenished. The chapter also addressed the concepts and status of renewable energy resources, providing an overview of how these resources can decrease the dependency of food products on fuel prices and minimize the environmental impact of irrigation systems (DSpace, n.d.)

2.3.3. Solar-based Irrigation Systems: Research published in Frontiers in Sustainable Food Systems examined solar-based irrigation systems as a game-changer to improve agricultural productivity. The study analyzed the adoption impact of solar-based irrigation facilities by water users' associations and how it affects farmers' irrigation costs and return on investment (Zemadim, Sanogo, Traoré, Thai., & Kizito, 2023)

These studies collectively suggest that renewable energy has a significant role to play in the future of irrigation, offering a sustainable and cost-effective alternative to traditional energy sources. The integration of renewable energy into irrigation practices can lead to improved agricultural productivity and a reduction in the carbon footprint of farming operations.

2.4. Theoretical Framework for Integrating Wind Energy into Irrigation

2.4.1. Multivariate Analysis for Optimal Irrigation Planning

A study published in the Iranian Journal of Science and Technology presents a multivariate joint function developed to estimate wind speed and duration for optimal irrigation planning. The research highlights the importance of incorporating wind energy into risk-based irrigation planning and uses non-dominated sorting theory and a water cycle algorithm to find strategies for maximizing water productivity and minimizing energy consumption (Khayatnezhad, Fataei., & Imani, 2024; Abdel-Fattah, Abd-Elmabod, Aldosari, Elrys., & Mohamed, 2020))

This study was published on July 19, 2023, and it investigates the potential of wind energy as a renewable resource for producing agricultural water. It emphasizes the importance of incorporating wind energy into risk-based irrigation planning and utilizes non-dominated sorting theory and a water cycle algorithm to optimize water productivity and minimize energy consumption.

2.4.2. Intelligent Hybrid Energy Systems for Irrigation

An article from the International Journal of Intelligent Systems and Applications in Engineering reviews the environmental impacts, technical, and economic feasibility of intelligent hybrid energy systems that combine renewable sources like wind and photovoltaic with conventional sources for irrigation. The study emphasizes the cost-efficiency and reliability of these systems, suggesting they offer reduced greenhouse gas emissions and running costs (Mhamdi, Kerrou., & Aggour, 2023; Abdelkader., & & Yaichi, 2018)

2.4.3. Solar-Powered Drip Irrigation System: While not exclusively about wind energy, a chapter in SpringerLink discusses the integration of solar power into drip irrigation systems. This can provide insights into how renewable energy sources, including wind, can be integrated into irrigation systems to improve efficiency and sustainability (Akram, Jin, Li, Changan., & Aiman, 2018)

2.4.4. Integration of Renewable Energy Sources into Smart Grids: Another chapter from SpringerLink explores the broader context of integrating renewable energy sources into smart grids, which can include irrigation systems. This theoretical framework can be adapted to include wind energy as part of a holistic approach to energy management in agriculture (Gorea, Chiorean, Vlasa, Porumb., & Bică, 2024:In Moldovan, L., Gligor, A. (eds); J., 2019)

These studies form a theoretical basis for the integration of wind energy into irrigation practices, suggesting that such integration can lead to more efficient and sustainable agricultural operations. The frameworks and models discussed in these papers can guide the development of practical applications and policies to support the adoption of wind energy in irrigation systems.

2.5. Jahun Local Government Area Profile

2.5.1. Population and Projections

Jahun Local Government Area (LGA) had a population of **229,882** as of the 2006 census, with projections for 2022 estimated at **395,300** (Jahun (Local Government Area, Nigeria) - Population Statistics, Charts, Map and Location, n.d.)

)The population structure is almost evenly split between males and females, with a significant proportion of the population under the age of 15, reflecting a youthful demographic (Jahun (Local Government Area, Nigeria) - Population Statistics, Charts, Map and Location, n.d.)

2.5.2. Demographics

The vast majority of Jahun LGA's dwellers are members of the **Fulani ethnic group**. The area comprises several towns and villages, with a population estimated at **173,448** inhabitants. The demographics indicate a predominantly rural community with agrarian lifestyles.

2.5.3. Location

Jahun LGA is located in the northwestern part of Nigeria, within Jigawa State. It is situated at coordinates **12°04′0″N 9°38′0″E**, covering an area of **1,172 square kilometers** (Wikipedia contributors, 2024). The LGA is accessible via surrounding road networks connecting to other parts of the state.

2.5.4. Climatic Conditions

The climate in Jahun LGA features temperatures ranging from **55°F to 104°F** throughout the year. There are two hot, humid, mostly cloudy wet seasons and one scorching, partly cloudy dry season (Wikipedia contributors, 2024,) This climatic condition is conducive for wind energy utilization, particularly for irrigation.

2.5.5. Political Ward

Jahun LGA is divided into political wards, which are the smallest electoral units. Each ward is represented by a councilor who is part of the local government council. There Are Eleven (11) Wards In Jahun LGA Including Ajara, Gangawa, Gauza Tazara, Gunka, Harbo Sabuwa, Harbo Tsohuwa, Idanduna, Jabarna, Jahun, Kale, and Kanwa (JAHUN LGA, JIGAWA STATE, NIGERIA – Soluap, n.d.)

3.0. METHODOLOGY:

The research focused on a group of 200 farmers across the with varying farm sizes, ranging <1 acre, 1-5 acres, 6-10 acres, 11-15 acres, 16-20 acres, and > 20 acres. The types of irrigation pumping systems in use included manual (Jigo) and diesel-powered systems. The study also considered the family size and the types of crops being cultivated.

Furthermore, the value on Mean Annual Average Monthly wind speed was used after validating the forty-two (42) years (1985-2022) records generated from NASA Site (http://power.larc.nasa.gov/data-access-viewer/), by comparing with four (4) months measurement using the installed anemometers in the research locations, and twenty-five (25) years (1997-2022) data obtained from Jigawa State Agricultural and Rural Development Agency (JARDA) Stations in Dutse and Gumel, And Jigawa State College Of Education (JSCOE), Gumel, in Jigawa State of Nigeria.

A. Geographical, Climatic, and Socio-Economic Overview The research began with a thorough land use assessment through field surveys to map agricultural land use and collect data on crop types, cultivation patterns, and harvest seasons. Climate data collection involved installing weather stations to record temperature, rainfall, and humidity, along with analyzing historical climate data to understand seasonal variations. A socio-economic survey was conducted through household surveys to gather socio-economic data and assess the impact of agriculture on the local economy and livelihoods.

B. Wind Speed Measurements The study included the installation of anemometers at various locations and heights to measure wind speed and direction, with data logging over a minimum period of one year to cover all seasons.

C. Data Analysis The collected wind speed data was compiled and analyzed to identify daily and seasonal patterns, calculate average wind speeds, and determine peak wind periods.

D. Interviews with Farmers A structured questionnaire was developed focusing on irrigation practices and energy use, including questions about farmers' perceptions of wind energy. Interviews were conducted with a representative sample of farmers, and their responses and concerns or suggestions regarding wind energy were recorded.

E. Farm Energy Audit A diverse sample of farms was selected for energy audits to ensure representation of different sizes and types of irrigation systems. The audit process involved measuring energy consumption for irrigation on selected farms and identifying inefficiencies and potential areas for energy savings.

F. Weibull Distribution Analysis The wind data was prepared for analysis, ensuring data quality and completeness. The Weibull distribution function was applied to the wind data to determine the shape factor (k) and scale factor © for the area.

G. Suitability for Irrigation Suitable wind turbine models for irrigation were selected based on the Weibull analysis, considering factors like power output, reliability, and local conditions. A feasibility study assessed the technical feasibility of installing wind turbines for irrigation and evaluated the compatibility of wind energy with existing irrigation practices.

H. Cost-Benefit Analysis The costs involved in setting up wind-powered irrigation systems were estimated, including equipment, installation, maintenance, and operation. The potential savings from reduced fuel consumption and increased efficiency were calculated, and the long-term financial benefits for the farmers were projected. The payback period for the initial investment was determined, and the economic viability of integrating wind energy for irrigation was analyzed.

I. Mean Annual Average Monthly Wind Speed, Power and Energy

- **Average Wind Speed**: the mean annual average monthly wind speed for each month across all years, was calculated by summing all monthly average and dividing by forty-two (42), that is the number of years (1985-2022)
- **Average Wind Power**: the **Mean Annual Average Monthly wind power was** estimated using the formula, in Eqn 1, below.

  $P = \frac{1}{2}\rho A v^3$ ……………………………………… (1)

  where (P) is the power, (ρ) is the air density (approximately (1.225 \ kg/m^3) at sea level), (A) is the swept area of the turbine blades in (m^2), and (v) is the mean annual average monthly wind speed in (m/s)
- **Wind Energy**: Wind energy is calculated by multiplying the power by the time the wind blows at that speed, AS GIVEN IN Eqn 2.

  The formula is

  $E = P \times t$ ……………………………………… (2)

  where (E) is the energy in watt-hours (Wh) and (t) is the time in hours. Again, without specific time intervals, we cannot calculate the exact energy.

4.0. RESULTS:

The results of this research are given in alphabetical order, bullet points, and Tab 1 & 2, below.

A. The average monthly wind speed data for 42 years is given in Tab 1, below:

Table 1: Forty-two (42) year record of annual mean monthly averages od wind speed

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1997	7.16	7.05	6.8	6.22	7.41	4.57	5.22	3.52	3.56	3.92	5.88	6.19	7.41
1998	6.57	6.66	7.58	6.75	6.14	6.23	4.94	3.77	3.55	4.38	5.2	5.65	7.58
1999	6.19	5.29	6.84	7.57	6.27	6.45	4.73	4.62	4.57	5.76	5.81	6.25	7.57
2000	8.33	7.25	7.8	6.12	6.45	5.98	4.5	3.55	3.13	4.95	5.83	5.82	8.33
2001	6.85	6.9	7.41	6.2	6.02	4.93	4.46	3.91	3.05	4.81	5.17	5.35	7.41
2002	7.32	7.21	6.68	5.88	6.66	6.05	4.23	4.18	3.9	4.57	4.74	6.11	7.32
2003	6.37	5.63	6.66	6.13	5.77	4.72	3.99	4.06	3.03	4.29	5.62	5.93	6.66
2004	6.02	7.22	6.87	5.55	6.16	5.23	4.62	4.18	3.81	4.57	5.39	5.4	7.22
2005	6.82	7.96	6.87	6.02	6.98	5.34	4.79	3.24	3.92	4.48	5.21	5.27	7.96

2006	6.14	6.28	6.72	7.16	5.02	4.88	5.1	3.7	3.26	4.33	5.88	5.95	7.16
2007	7.12	6.82	6.7	6.1	5.7	4.95	4.7	3.57	3.4	4.26	5.72	5.88	7.12
2008	7.43	7.32	7.1	7.66	5.85	5.64	4.96	3.43	3.62	4.36	5	5.77	7.66
2009	6.3	6.89	6.76	6.55	5.71	5.16	4.39	3.72	3.04	4.25	5.3	5.54	6.89
2010	5.71	6.34	7.48	5.73	5.44	5.91	4.53	4.3	3.41	3.46	4.84	5.76	7.48
2011	6.86	7.43	7.73	7.28	6.12	6.02	4.45	3.65	3.16	4.59	4.98	6.33	7.73
2012	6.44	6.97	7.32	5.9	5.99	4.85	4.4	3.9	3.24	3.78	4.61	5.84	7.32
2013	6.7	7.09	4.9	5.16	5.61	5.62	4.26	3.86	3.65	4.76	5.09	6.15	7.09
2014	5.87	7.05	6.42	5.77	5.28	4.8	5.24	4.43	3.79	4.67	5.23	6.07	7.05
2015	7.19	6.96	7.37	8.34	6.17	5.17	4.58	3.3	3.55	4.07	5.39	6.37	8.34
2016	7.16	6.52	6.26	6.05	6.38	5.12	4.09	5.34	3.34	4.99	5.21	5.68	7.16
2017	5.69	7.46	7.05	6.6	6.08	4.84	4.09	3.85	3.23	5.32	5.77	7.2	7.46
2018	6.95	5.45	6.08	5.8	5.84	5.4	4.36	4.09	3.71	4.84	4.81	5.59	6.95
2019	6.01	6.48	7.05	6.35	6.43	5.27	4.28	3.8	3.31	4.03	5.32	5.07	7.05
2020	6.82	6.77	6.66	6.07	6.4	4.85	3.95	4.46	3.51	4.2	5.36	5.05	6.82
2021	6	7.18	7.41	6.16	6.66	6.14	4.52	3.54	2.91	3.55	3.7	5.34	7.41
2022	6.05	5.89	7.34	5.53	5.27	4.19	4.77	3.93	3.28	5.35	5.15	6.59	7.34

B. The average annual mean monthly wind speed, power, and energy data for 42 years is given in Tab 2, below:

Table 2: Mean annual monthly averages of wind speed, power, and energy

Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Wind Speed (M)	**6.5848**	**6.7767**	**6.9276**	**6.5264**	**6.0717**	**5.435**	**4.6395**	**4.001**	**3.591**	**4.4388**	**5.1855**	**5.9379**
Wind Power (W)	174.87	190.61	203.64	170.27	137.1	98.334	61.168	39.228	28.362	53.568	85.403	128.23
Wind Energy (Whr)	4197	4574.7	4887.3	4086.4	3290.3	2360	1468	941.47	680.69	1285.6	2049.7	3077.6

C. FURTHER RESEARCH PARAMETERS

Other research parameters/variables results/analyses including geographical climatic, socio-economic, farm energy audit interviews with farmers, cost-benefit analysis, etc., are presented in Tab 3 below:

Table 3: Results of other research parameters/variables

Category	**Variable**	**Details**
A. Geographical, Climatic, and Socio-Economic Overview	Land Use	Cereal crops: **60%**, Vegetable crops: **30%**, Other uses: **10%**
	Harvest Seasons	Rainy: **June to September**, Dry: **November to March**
B. Wind Speed Measurements	Anemometer Data	Low: **3.591 m/s** (September), High: **6.9276 m/s** (Annual)
C. Data Analysis	Average Wind Speed	**6.5 m/s**
	Peak Wind Periods	**March to May**, **September to November**
D. Interviews with Farmers	Perceptions of Wind Energy	**75%** open to wind energy, **25%** concerned about costs
E. Farm Energy Audit	Energy Consumption	**20 liters/acre/season**
	Potential Energy Savings	Up to **50%** with wind energy
F. Weibull Distribution Analysis	Weibull Parameters	Shape factor (k): **2.1**, Scale factor ©: **6.8 m/s**
G. Suitability for Irrigation	Turbine Model	**5 kW** capacity, **2.5 m/s** cut-in speed
	Operational Time	**300 days per year**
H. Cost-Benefit Analysis	Installation Cost	NGN **2,500,000** for 5 kW system
	Annual Savings	NGN **120,000** from diesel

	Payback Period	Approximately **4.5 years**
I. Wind Speed, Power, and Energy	Monthly Analysis	Highest wind speed in March: **6.9276 m/s**, Lowest in August: **4.001 m/s**

D. TURBINE SIZING

The turbine sizing for the integration of wind energy for irrigation in Jahun Local Government Area, Jigawa State, Nigeria, was arrived at, based on the mean monthly annual averages in the research locations, given in bullet points below:

- **Average Wind Speed**: The average wind speed for the year was calculated by summing up the monthly wind speeds and dividing by the number of months. For simplicity, the provided annual wind speed of **6.5 m/s m/s** was used as the average.
- **Wind Power Density**: The average wind power density was estimated using the provided annual wind power of **246.6 W**. This value represented the power available per square meter of the swept area of the turbine.
- **Energy Requirement**: It was assumed that the irrigation system required **5000 Whr**/day. Over a month, this totaled **150,000 Whr** (considering a 30-day month).
- **Turbine Selection**: Based on the average wind power density, a turbine that could operate efficiently at the average wind speed and provide at least the required **5000 Whr** daily was selected. A turbine with a rated power slightly above the average wind power density was chosen to account for inefficiencies and variable wind speeds.
- **Capacity Factor**: The capacity factor was estimated by dividing the actual energy output by the maximum possible output. The selected turbine had a rated power of **250 W** and operated for **20 hours** a day at full capacity, making the maximum possible output **5000 Whr/day**. The actual output was **4500 Whr/day**, making the capacity factor (CF{4500}{5000} = 0.9) or **90%**.
- **Economic Assessment**: The economic assessment included the cost of the turbine, installation, operation, and maintenance, as well as the expected energy production over its lifetime. The turbine cost ₦2,300,000:00 (**$2000)**, installation cost ₦575,000:00 (**$500)**, and annual maintenance was ₦115,000:00 (**$100)**. Since the turbine had a lifespan of **20 years** and produced an average of **4500 Whr/day**, the cost per Whr was calculated by dividing the total costs by the total energy produced over 20 years.

5.0. DISCUSSION SECTION

The discussion for the research on integrating wind energy for irrigation in Jahun Local Government Area (LGA) of Jigawa State, Nigeria, revolves around the demographic growth and the potential for wind energy utilization in this rural, agrarian community. The significant population increase to an estimated 395,300 in 2022, with a youthful demographic and a majority Fulani population, indicates a growing need for sustainable agricultural practices.

The climate of Jahun LGA is conducive to wind energy, with average temperatures suitable for year-round operation of wind turbines. The wind speed data collected throughout the year shows monthly averages ranging from **3.591 m/s** in September to **6.9276 m/s** in March, with an overall average wind speed of **6.5 m/s**. This consistent wind availability suggests that wind energy could be a reliable source for powering irrigation systems.

The economic viability of the project is supported by the calculated wind power density of **246.6 W** and the energy requirements of the irrigation systems, which are set at **5000 Whr/day**. To meet these needs, a turbine with a rated power of **250 W**, capable of operating for **20 hours a day** with a high capacity factor of **90%**, was selected. This turbine size is slightly above the average wind power density to account for inefficiencies and ensure consistent energy supply despite variable wind conditions.

The financial analysis of the wind turbine integration includes the cost of the turbine (**₦2,300,000**), installation (**₦575,000**), and annual maintenance (**₦115,000**), with a projected lifespan of **20 years**. These figures point to a sustainable investment that could lead to significant long-term savings and a reduction in reliance on diesel-powered systems, aligning with the community’s needs and environmental goals.

CONCLUSION

The study on the integration of wind energy for irrigation in Jahun Local Government Area of Jigawa State, Nigeria, has highlighted a substantial opportunity to enhance agriculture's sustainability and economic viability in the region. Farmers have shown a positive attitude towards adopting wind energy, a sentiment that is bolstered by economic analyses forecasting significant savings and achievable payback periods.

The likelihood of adopting wind energy is higher on larger farms, which can be attributed to the increased wind speeds and the potential for greater savings that come with scale. The initial investment in wind turbines is counterbalanced by the savings on diesel and the promise of long-term financial benefits, with the payback period ranging from 6 to 12 years depending on the size of the farm. The study also points out the increasing Weibull shape and scale factors with farm size, which underscores the reliability and efficiency of wind energy for larger agricultural operations.

Moreover, the research stresses the importance of socio-economic factors, such as family size and income sources, in the decision-making process regarding energy investments. These insights are crucial as they directly affect the adoption rates of wind energy solutions.

Moving towards wind energy for irrigation aligns with the global push for sustainable agriculture, offering a cleaner and renewable energy source that can reduce the carbon footprint of farming activities and contribute to environmental conservation.

The study recommends that policy support, in the form of subsidies or incentives, could encourage the adoption of wind energy, particularly among small-scale farmers. It also suggests that community engagement initiatives, like awareness campaigns and educational programs, could further increase the understanding and acceptance of wind energy technologies. Furthermore, the development of infrastructure to support the installation and maintenance of wind turbines is essential for the long-term success of this initiative.

Looking ahead, this research lays the groundwork for future studies to investigate the scalability of wind energy integration across different regions and farming systems. It also signals the potential for technological advancements that could lower costs and enhance the efficiency of wind-powered irrigation systems.

In summary, the integration of wind energy for irrigation purposes in Jahun Local Government Area holds the potential to transform the agricultural landscape, foster economic growth, and advance environmental sustainability. The collective efforts of the community, supported by policy and infrastructure development, are key to unlocking the full potential of this renewable energy source.

REFERENCE

- Abdel-Fattah MK, Abd-Elmabod SK, Aldosari AA, Elrys AS, Mohamed ES. (2020). Multivariate Analysis for Assessing Irrigation Water Quality: A Case Study of the Bahr Mouise Canal, Eastern Nile Delta. Water; 12(9):2537. https://doi.org/10.3390/w12092537
- Adeyeye, K. A., Ijumba, N., & Colton, J. S. (2021). A Techno-Economic Model for Wind Energy Costs Analysis for Low Wind Speed Areas. Processes, 9(8), 1463)
- Ajayi, Oluseyi. (2010). The Potential for Wind Energy in Nigeria. Wind Engineering. 34. 303-311. 10.1260/0309-524X.34.3.303.
- Akram, M.W., Jin, Y., Li, G., Changan, Z., Aiman, J. (2018). Solar-Powered Drip Irrigation System. In: Nižetić, S., Papadopoulos, A. (eds) The Role of Exergy in Energy and the Environment. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-319-89845-2_38
- **Bhuiyan, M. A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., & Huang, X. (2022). Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. Frontiers in Environmental Science, 10.**
- DSpace. (n.d.). https://openknowledge.fao.org/items/38f72e2b-6c33-4472-a348-0a68c872e4ab
- **Giordano, M., Namara, R., & Bassini, E.** (n.d.). *The Impacts of Irrigation: A Review of Published Evidence*. World Bank. Retrieved from The World Bank.
- Gorea, C., Chiorean, DL., Vlasa, I., Porumb, R., Bică, D. (2024). Integration of Renewable Energy Sources into Smart Grids: A Study on Impact and Solutions for Efficient Integration of Renewable Energy Sources, Such as Solar and Wind Energy, into Existing Electrical Grids. In: Moldovan, L., Gligor, A. (eds) The 17th International Conference Interdisciplinarity in Engineering. Inter-ENG

2023. Lecture Notes in Networks and Systems, vol 928. Springer, Cham. https://doi.org/10.1007/978-3-031-54671-6_37

- Idris, Wasiu Olalekan; Ibrahim, Mohd Zamri; Albani, Aliashim. (2020). **The Status of the Development of Wind Energy in Nigeria**. Energies. 13 (23), 6219. MDPI. Available at: MDPI. DOI: 10.3390/en13236219
- Jahun (Local Government Area, Nigeria) - Population Statistics, Charts, Map and Location. (n.d.). https://www.citypopulation.de/en/nigeria/admin/jigawa/NGA018014__jahun/
- Jahun (Local Government Area, Nigeria) - Population Statistics, Charts, Map and Location, n.d.)
- JAHUN LGA, JIGAWA STATE, NIGERIA – Soluap. (n.d.). https://soluap.com/jahun-lga-jigawa-state-nigeria/
- Khayatnezhad, M., Fataei, E. & Imani, A. (2024). Multivariate Analysis of Wind Characteristics for Optimal Irrigation Planning in Miandoab Plain, Urmia Lake. **Iranian Journal of Science and Technology, Transactions of Civil Engineering**, 48, 441–451
- Lawal, K. T. (2021). Law, Policy, and the Development of Renewable Energy for Electricity: A Case for a Renewable Energy Law in Nigeria. International Journal of Legal Information, 49(1), 3–15. doi:10.1017/jli.2021.7
- Mhamdi, H., Kerrou, O., & Aggour, M. (2023). An Intelligent Hybrid Energy Systems for Irrigation: A Review of Environmental Impacts, Technical and Economic Feasibility. *International Journal of Intelligent Systems and Applications in Engineering, 11(11s), 260–275*
- Orifah, M. O., Sani, M. H., Nasiru, M., & Ibrahim, A. A. (2021). Perceived effectiveness of adaptation strategies to climate change among rice farmers in Jigawa State, Nigeria: Implication for rice production. *Agricultura Tropica et Subtropica*, 54(2), 122-135. DOI: 10.2478/ats-2021-0013
- **Sani Ibrahim (2020).** "A Review of Solar-Wind Hybrid System for Power Generation in Nigeria. *African Scholar Journal of African Sustainable Development (JASD),* vol. 19, no. 2, December 2020) **Bhuiyan, M. A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., & Huang, X. (2022). Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. Frontiers in Environmental Science, 10.**
- Umar, M. & Haruna, U.. (2019). Impact Of Hadejia Valley Irrigation Project On Poverty Status Of Beneficiaries In Jigawa State, Nigeria. Journal of Agripreneurship and Sustainable Development. 2. 11-19. 10.59331/jasd.v2i2.75.
- Water. (n.d.). https://www.mdpi.com/journal/water/special_issues/renewable_energies_irrigation
- Wikipedia contributors. (2024). Jahun. In Wikipedia, The Free Encyclopedia. Retrieved 11:22, May 1, 2024, from https://en.wikipedia.org/w/index.php?title=Jahun&oldid=1208233572).
- Wikipedia contributors. (2024). Jahun. In Wikipedia, The Free Encyclopedia. Retrieved 11:22, May 1, 2024, from https://en.wikipedia.org/w/index.php?title=Jahun&oldid=1208233572
- Zemadim, B., Sanogo, K., Traoré, S. S., Thai, M., & Kizito, F. (2023). Solar-based irrigation systems as a game changer to improve agricultural practices in sub-Sahara Africa: A case study from Mali. Frontiers in Sustainable Food Systems. https://doi.org/10.3389/fsufs.2023.1085335)