THEMATIC AREA: RENEWABLE ENERGY AND SUSTAINABILITY

TITLE: WIND POWERED AUTOMATIC IRRIGATION SYSTEM WITH PUMP HYDRO SCHEME IN JOS PLATEAU STATE.

Executive Summary

It is a known fact that farmers depend on rain-fed agriculture in Nigeria, with sources indicate that about 94% to over 95% of Nigeria's farmland is rain-fed. Consequently, only a small fraction, around 5% to 6%, of Nigeria's farmland is equipped for irrigation. This heavy reliance on rainfall makes Nigerian agriculture highly vulnerable to weather variability and poses a significant challenge to food security. This over reliance on rainfall affect and contribute to lack of job opportunity in Nigeria because agriculture can contribute immensely to jobs opportunity. Although rainfall is the primary and mostly the method of water application to farmland for many years, it has undermined the potential of agricultural output in the country, this keeps the country far from achieving national food security, economic growth (in term of exportation), availability of jobs and more. In the future, food will control economy not oil. This realization intends to physically implement the installation and construction of a wind-powered automatic pump hydro storage scheme irrigation system to pump water from earth reservoir or dams for irrigation purposes. The proposed implementation will generate electrical power from the wind by the use of (S3-1000-B8) wind turbine farm when sufficient wind is available for generation of power to pump water from a lower reservoir or dams to a higher reservoir storage for the purpose of irrigation. The Arduino microcontroller with the aid of a soil moisture sensors monitors the farm parameters like soil moisture, so as to irrigate the form automatically when needed by opening series of valve located at the farm. The micro controller will also monitor and control the reservoir water level to avoid overflow. The pump is a (DC or AC) induction motor which rating will depend on the scale or annual amount of water need for a particular farm.

The two major rivers in Nigeria, the river Benue and river Niger are major insurance for irrigation farming in the country as source for abundant supply of water. It is unfortunate that the abundant water from the river is allowed to pass through the country to the ocean without making any significant use of it in agriculture. The two rivers can also serve as a major water source for irrigation agriculture in Nigeria especially the northern part of the country.

The implementation of this work, will help farmers not to depends only on rainfall but also promote all year-round farming which will increase agricultural output and boost

economy of the country by promoting food security. This implementation will also help aquatic farming across the country even where there is water scarcity. It can also be used to stop desertification by pumping or supplying farmers with sufficient water to the desert encroaching communities.

Background of the Project

Agriculture plays a pivotal role in the global economy by providing food, raw materials, and livelihoods for millions of people. In many third-world nations, agriculture is essential to sustainable development and the reduction of poverty. For a nation to modernize and progress, the issue of sustainable agricultural development must be resolved, Ahmed et al., (2023). The greening program was proposed in the Common Agricultural Policy (CAP) 2014–2020 adopted by the European Commission which among other things intends to improve energy efficiency in agricultural production. Using innovative wind energy technology like renewables in farms can help reach energy efficiency.[1]. Globally, 70% of water use is applied in irrigation of crops, making irrigation the largest consumptive user of fresh water. Over 80% of freshwater withdrawals in developing countries is applied in irrigation. Irrigated agriculture provides 40% of the world's food from less than 20% of the cultivated area highlighting the importance of irrigation in global food security.[2]. It is observed that the monthly mean wind speed in seven meteorological stations within region of the North-West (NW) geo-political region of Nigeria ranges from 2.64 m/s to 9.83 m/s using 36-year (1971–2007) wind speed data measured at 10 m height subjected to 2-parameter Weibull analysis. The annual wind speeds range from 3.61 m/s in Yelwa to 7.77 m/s in Kano. It is further shown that Sokoto, Katsina and Kano are suitable locations for wind turbine installations with annual mean wind speeds of 7.61, 7.45 and 7.77 m/s, respectively. The results also suggest that Gusau and Zaria should be applicable for wind energy development using taller wind turbine towers due to their respective annual mean speeds and mean power density while Kaduna is considered as marginal. In addition, higher wind speeds were recorded in the morning hours than afternoon periods for this region. A technical electricity generation assessment using four commercial wind turbines were carried out. The results indicate that, while the highest annual power is obtained with Nordex N80–2.5 MW as 14233.53 kW/year in Kano, the lowest is in Yelwa having 618.06 kW/year for Suzlon S52. It is further shown that the highest capacity factor is 64.95% for Suzlon S52–600 kW in Kano while the lowest is 3.82% for Vestas V80–2 MW in Yelwa.[3]. Jos, Plateau state, with wind speed potential of $3ms^{-1}$ to $9.37ms^{-1}$ all year round, making it viable to generate power for pumping irrigation water. Also, the nature of the terrain which will enable or support the pump hydro storage technology. From the wind potential, a single wind turbine would be able to generate an average energy of 16kWh/month and pump $234.864m^3$ of water. Therefore, in total, the wind farm would generate 336kWh/month and pump equivalent of $4{,}932m^3$. In conclusion, it is feasible to generate sufficient wind power for the purpose of irrigation agriculture in Shen, Jos, Plateau State.[4]. Utilizing Wireless Sensor Networks (WSN) for data collection and transmission in the agricultural environment was part of the methodology, which allowed for the real-time monitoring of a number of characteristics, including temperature, humidity, and soil moisture. Through the use of Wireless Sensor Networks (WSN), data analytics, and node sensors, the study was able to accomplish effective irrigation control for crop cultivation while guaranteeing economical water use.[5]. Two modules for the automated watering system will be designed and implemented as part of the methodology; the first module measures the moisture content of the soil, and the second module detects the water level in the lower and upper reservoir. In order to guarantee the designed system's efficiency and usefulness in managing irrigation facilities according to soil moisture and water levels.[6].

Aim and Objectives

The specific aim of this project is implementing physical realization and construction of wind powered automatic irrigation system with pump hydro scheme in Jos plateau state to offers a sustainable and efficient solution for local farmers with the following objectives:

1. To develop a wind-powered automatic irrigation system to support farming activities on Jos plateau state.
2. To reduce reliance on rainfall and improve crop yield through efficient water management.
3. To promote sustainable agriculture practice and enhance food security in the region.
4. To provide a reliable and cost-effective irrigation solution for local farmers.

Material and method

The installation and construction of a wind powered automatic irrigation system with pump hydro scheme for irrigation purposes is a process that comprises hardware and software development. Below is the step-by-step procedure for the realization.

Step 1: Defining our Objectives and Requirement:

The project will begin by identifying the weekly farm requirement of the farm, that is the amount of water required for irrigation per week for different crop that is cultivated at the location farmland. And availability of abundant water source that will support the projects.

Step 2: Project Implementation

Site Clearance: Preparing the approved site by removing all obstruction and leveling the field to create a safe workable environment.
Setting Out: This is the transferring of the design plan to the physical site of the of the wind turbine installation matrix and that of the reservoir. The wind turbine needs to be located and aline to be able to convert wind power effectively. The reservoir most be located so as to effectively store and release water under gravity to the farmland.

Excavation and Casting: The digging of the reservoir to the designed dimension, followed by the casting of concrete if required. However, reservoir can be constructed by just digging the earth to hold water without concrete casting. Also, the foundation of the wind turbine base will be duged and concrete will be cast according to the designed plan.

Step 3: Installations
Wind Turbine: The strategic installation of the wind turbine evenly around the choosing site to effectively capture the wind for optimal generation. The foundation of the wind turbine is laid according to the size of the wind turbine selected. The wind turbine farm is effective in capturing wind power than a single wind turbine. The number of wind turbines use in the wind farm will depend on the power requirement of the farm.
Piping Installation: At this level in the laying of pipes from the upper reservoir to the pumping unit, and then from the pumping unit to the upper reservoir. Piping network will also be installed from the upper reservoir to the farm or farms.
Pumping Unit: This comprises of induction motor ranging between 5kWh to 15kWh according on the water requirement or power requirement of the farm.
Step 4: Control Unit
This system comprises of microcontroller and sensors. Soil sensors are installed in the farms and positioned to effectively monitors the soil moisture. The water level sensor monitors the reservoir water level to avoid over flow. The actuators valve will be installed on the pipes outlet at the farm for controlling irrigation of the farm.

Step 5: Control Box
This houses the control unit, contactor, voltage monitoring relay, surge protector, and energy meter. The microcontroller uses the contactors to turn-on and turn-off the induction motor/pumps. The energy meter in use to monitor the energy generated every week by the wind turbine.

Step 6: Backup Energy Storage Installation
Battery Bank: The battery bank will store energy to support the control system and also when scaled up will serves as backups for pumping water when wind speed remains below cut-in or generating speed for a long time.
Inverter: The installed power of this device will be twice the equivalent of the required power to be able to power and withstand the inductive load start-up togue.

Step 7: Security Lighting
This is to illuminate the installation site like the wind farm and the reservoirs.

System Design

- **Wind Turbine:** installation of S3-1000-B8 or Sun-1000 wind turbines, capable of generating enough energy to pump a minimum of 8.7m^3 and a maximum of 176m^3 of water per week
- **Irrigation Control:** automatic irrigation system with soil moisture and water level

sensors to optimize water usage

- **Water Storage:** construction of water reservoir to store pumped water for safe irrigation

Expected Outcome

- **Increased Crop Yields:** improved water management and reduced reliance on rainfall
- **Water Saving:** efficient irrigation system reduces water waste and conserves resources
- **Energy Efficiency:** wind-powered system reduces energy consumption and greenhouse gas emissions
- **Economic Benefits:** increased crop yields and reduces water waste led to improved economic outcomes for local farmers

Innovativeness and Novelty

The Wind-Powered Automatic Irrigation System represents an innovative solution for agriculture on Jos Plateau State, Nigeria, leveraging local wind resources for sustainable water management:

- **Renewable Wind Energy utilization:** harnessing local wind energy for sustainable irrigation, reducing fossil fuel dependency and lowering cost and emissions.
- **Automated Efficiency:** Optimizes water use via automatic controls, improving crop management and water conservation.
- **Contextual Suitability:** The Plateau's wind patterns can support wind-power systems, offering off-grid irrigation potential and agricultural support.
- **Eco-Friendly Agriculture:** Promotes sustainable farming, aligning with environmental goals.
- **Climate Resilience:** Support agriculture in region with variable rainfall, enhancing food security.
- **Potential for Hybrid Systems:** the system could integrate with solar power for enhance reliability.

This systems innovativeness lies in applying wind power for automated and efficient irrigation, potentially benefiting agriculture in Jos Plateau State through sustainable practice.

Market Studies

Demand: The demand for Wind-Powered Irrigation systems is driven by increasing needs for sustainable agriculture, water scarcity, and rising energy costs. Africa, with its significant agricultural sector and wind resources, presents a growing market. Key drivers include:

- **Water Scarcity:** Efficient irrigation solutions are crucial in water-stressed regions.
- **Renewable Energy Push:** Governments promote renewables to reduce carbon footprints.

- **Agricultural Productivity:** Efficient irrigation boosts crop yields.

Investment: Investments in wind energy, including Wind-Powered Irrigation, are substantial and growing.

- **Global Wind Energy Market:** Valued at $100 billion, with $175 billion invested in new wind projects in 2022.
- **Africa's Growth:** Wind power installations in Africa grew 30% in 2022.
- **Funding Sources:** Green bonds, government grants, and partnerships support projects.

Potential for the Product: Wind-Powered Irrigation systems offer significant potential, especially in regions like Jos Plateau State, Nigeria:

- **Renewable Energy Utilization**: Harnessing wind reduces fossil fuel dependency.
- **Sustainable Agriculture:** Supports eco-friendly farming practices.
- **Off-Grid Solutions:** Suitable for remote areas with wind resources.

Competition: The market features competition from various renewable energy and irrigation technology providers:

- **Solar-Powered Irrigation:** A competing renewable solution, with a market projected to reach $15 billion by 2028.
- **Key Players:** Companies like Lorentz, SunCulture innovate in solar irrigation.
- **Technological Advancements:** Innovations in turbines and automation enhance competitiveness.

Expansion Opportunities: Expansion potential exists in developing regions with agricultural needs and wind resources:

- **Hybrid Systems:** Combining wind with solar for reliability. Further analysis on implementation costs, local infrastructure, and hybrid systems (wind-solar) could enhance project viability.
- **Smart Irrigation:** Integration with IoT and automation for efficiency.

Preliminary Results

Feasibility studies was conducted on the viability of harnessing wind power for the purpose of irrigation in Shen, Jos, plateau State and the following paper was published.

- Feasibility Assessment of Wind Energy-Driven Automatic Irrigation System for Jos Plateau [4].

The feasibility study of a wind energy-driven automatic irrigation system for Jos Plateau shows promising results, leveraging the region's wind resources for sustainable agriculture.

Key Findings:

- **Wind Speed Potential:** Jos Plateau experiences year-round wind speeds of 3 to 9.37 m/s, making it suitable for wind-powered irrigation.
- **Water Pumping Capacity:** A single wind turbine (S3-1000-B8) can pump 8.7 m^3 to 176 m^3 of water weekly.

- **Irrigation Needs:** 21 wind turbines can meet the 180 m^3 weekly irrigation requirement for 10,000 m^2 of farmland.
- **Energy Generation:** A wind turbine can generate an average of 16 kWh/month and pump 234.864 m^3 of water monthly.
- **Storage Requirement:** 720 m^3 of stored water is needed for a month of safe irrigation.

System Components:

- **Wind Turbines:** Horizontal Axis Wind Turbines (HAWTs) are commonly used.
- **Pump Hydro Storage:** Utilizes water reservoirs for energy storage, reducing reliance on batteries.
- **Automation:** Microcontroller-based systems monitor soil moisture and water levels.

Benefits:

- **Sustainable Agriculture:** Reduces dependence on rainfall and fossil fuels.
- **Climate Resilience:** Supports irrigation farming, enhancing food security.
- **Eco-Friendly:** Aligns with environmental conservation goals.

Scalability

Scaling up the wind energy-driven automatic irrigation system involves technical, economic, and stakeholder engagement aspects.

1. Technical Expansion

- **Pilot Project:** Implement a pilot system on a small farm (e.g., 1-5 hectares) to test performance and gather data.
- **Turbine Selection and Optimization:** Evaluate multiple wind turbine models for efficiency and cost-effectiveness in Jos Plateau's wind conditions.
- **Hybrid Systems:** Explore wind-solar hybrid irrigation systems for enhanced reliability.
- **Automation and IoT:** Integrate sensors and IoT for real-time monitoring of soil moisture, wind speed, and water usage.

2. Economic and Financial Aspects

- **Cost Analysis:** Conduct detailed cost-benefit analysis including capital expenditure (CAPEX), operating expenses (OPEX), and payback periods.
- **Funding and Grants:** Seek government grants, green bonds, or international climate funds supporting renewable energy in agriculture.
- **Business Models:** Explore leasing models for farmers or cooperative ownership structures.

3. Stakeholder Engagement

- **Farmer Engagement:** Involve local farmers in design and testing phases for buy-in and feedback.
- **Government and Policy:** Engage with Nigerian agricultural and energy ministries for policy support and incentives.

- **Partnerships:** Collaborate with NGOs, research institutions, and private sector players in renewable energy.

4. Expansion Strategy
- **Regional Pilots:** Test systems in different agro-climatic zones of Nigeria for broader applicability.
- **Capacity Building:** Train local technicians on installation, operation, and maintenance.
- **Scalability Metrics:** Define key performance indicators (KPIs) for water savings, energy efficiency, and crop yield improvements.

5. Research and Development
- **Performance Monitoring:** Long-term data collection on system performance, wind patterns, and water usage.
- **Adaptation to Local Conditions:** Tailor systems to Jos Plateau's specific soil, crop, and climate conditions.
- **Innovation Integration:** Explore innovations like advanced blade designs or AI for predictive irrigation management.

6. Impact Assessment
- **Environmental Impact:** Assess benefits like reduced carbon footprint and water conservation.
- **Socio-Economic Impact:** This project will be in line with the Renewed Hope Agenda and NASENI's vision of fostering sustainable development in Nigeria.

Technology Readiness

The technology readiness of wind energy-driven automatic irrigation systems appears promising, particularly for regions like Jos Plateau in Nigeria with suitable wind speeds ranging from 3 to 9.37 m/s.
- **Wind Turbine Performance:** The S3-1000-B8 wind turbine can pump 8.7 m^3 to 176 m^3 of water weekly, meeting irrigation needs for 10,000 m^2 of farmland with 20 turbines.
- **Automation and Sensors:** Systems integrate microcontrollers, soil moisture, and water level sensors for efficient irrigation management.
- **Hybrid Systems Potential:** Combining wind with solar power can enhance reliability and energy availability.
- **Pump Hydro Storage:** Utilizes water reservoirs, reducing reliance on batteries for energy storage.

Challenges and Considerations:
- **Initial Costs:** Deployment costs and technological adoption barriers exist.
- **Maintenance:** Local capacity building for operation and maintenance is crucial.
- **Adaptation to Local Conditions:** Tailoring systems to specific soil, crop, and climate conditions is necessary.

Research and Applications: Studies indicate wind-powered irrigation can boost agricultural productivity sustainably, with potential for AI and IoT integration to optimize water use.

CIRCUIT DIAGRAM IMPLEMENTATION

The circuit diagram that implements the proposed wind powered automatic irrigation system with pump hydro scheme is shown in Figure 1. The main circuit drivers for the irrigation and pumping are done by the microcontroller. The soil moisture sensor's reading is fed both to the microcontroller and the Raspberry board. The moisture condition of the soil is monitored on the computer via a USB serial communication of the raspberry Pi.

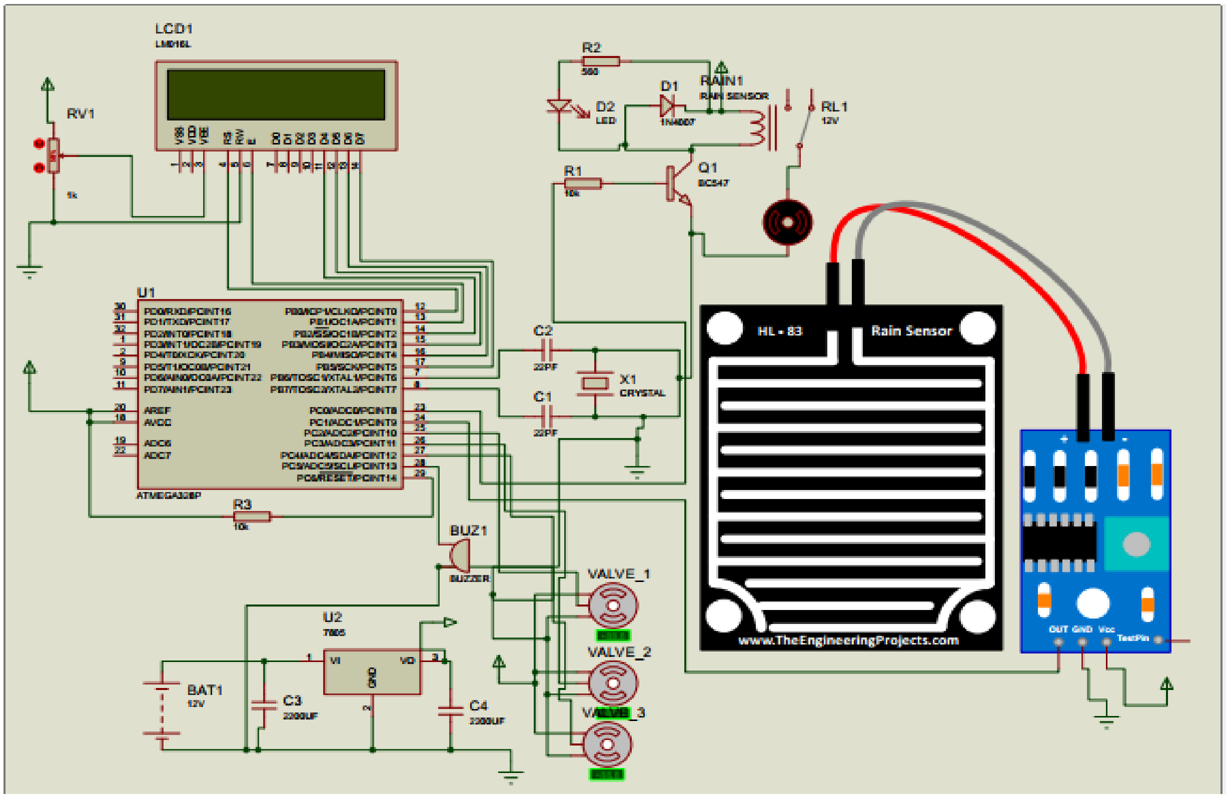
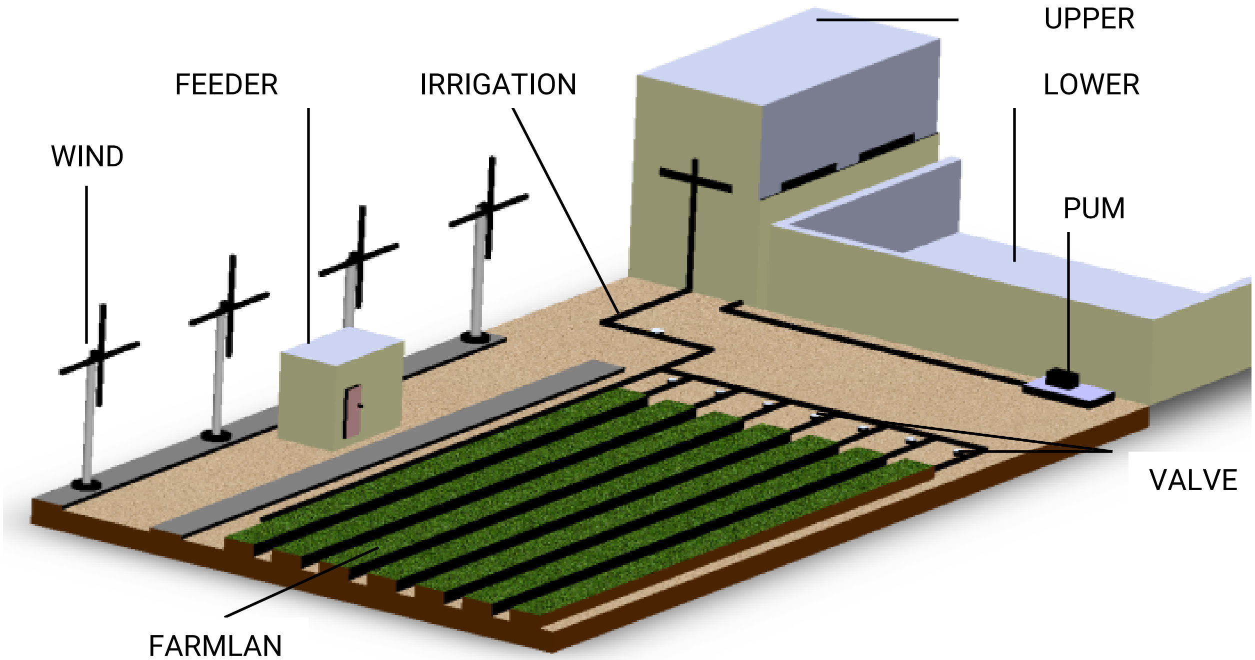


Figure 1: The Circuit diagram of an automatic irrigation system with raspberry Pi and microcontroller

ORTHOGONAL DRAWINGS



PROJECT BUDGET BREAKDOWN

S/No	DESCRIPTION OF ITEIM	JUSTIFICATION	UNIT PRICE (₦)	QUANTITY (₦)	TOTAL (₦)
1.	1kW, wind turbine generator (Sun -1000)	The wind turbine generator is the power source of the system use to pump water and also store energy in the power bank for back-up.	600,000	21	12,600,000
2.	3HP water pump (ATPUMP: WQ Sewage submersible pump series)	The pump will be use to pump water from the upper reservoir to the lower reservoir	1,375,000	2	2,750,000
3.	Arduino uno microcontroller	This will be responsible for the control of the pumping and irrigation	75,000	2	150,000
4.	15kWh Lithium battery	Back-up for control system and lighting the facility	2,500,000	1	2,500,000
5.	Wireless soil moisture sensor	It's monitors soil moisture at wide range	10,000	20±	200,000
6.	contactors	Is use to switch on and off the pumps and the valves	35,000	6	210,000
7.	Relay timer	This is used to delay switching of the contactor	20,000	3	60,000
8.	Voltage monitor	It cuts out under voltage and over voltage to protect the contactor and the load	25,000	3	75,000
9.	Digital energy	It will record the	50,000	1	50,000

	meter with memory	useful energy generated by the wind turbine in real time			
10.	3 inches DC solenoid valves	The microcontroller will use the device to control irrigation	350,000	5±	1,750,000
11.	DC 35A Star plug	Serves as current breakers to protect the wind turbine	5,000	21	105,000
12.	Panel box	It will house the, contactors, meters, relay, star plugs switches and the microcontrollers	50,000	1	50,000
13.	Electronics work station and digital meters	Will be used to build the microcontroller circuits	345,000	1	345,000
14.	Tool box	This is needed for the installation	150,000	1	150,000
15.	2.5mm, 2 core cable	This carries power from the wind turbine charge controller to the panel box	1000	780m	780,000
16.	2.5mm, 3 core cable	Connect the wind turbine with the charge controller	1500	50m	75,000
17.	Combiner box	To connect the output of all the wind turbine charge controllers to one bus.	25,000	1	25,000

18.	Cement (bags)	For concrete foundation of the wind turbine and to build reservoir were necessary	11,000	100 bags	1,100,000
19.	16mm re-enforcement frame	For concrete re-enforcement	5000	21	105,000
20.	Gravel	For concrete making	167,000	10	1,670,000
21.	Sand	For concrete making	120,000	1	120,000
22.	Fencing barb wire	For fencing the perimeter	50,000	20	1,000,000
23.	Pipe (2 inches)	For pumping water to the reservoir and for conveying water for irrigation to various farm	10,000	50	500,000
24.	2 inches tap	To turn off and on the water flow	8,000	20 ±	160,000
25.	**TOTAL**				**26,605,000**

PROJECT TIMELINE BREAKDOWN

Projected Implementation Time Line							
Duration: 12 Months							
S/N	Activities	Duration (Months)	Year	Quarterly			
				1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Approval Guideline for the study, feasibility study, site selection, system design and sourcing of project components.	3	2026				
2.	Development implementation of circuit schematic and switching system, installation of wind turbine and irrigation infrastructure and testing of all connected units.	3	2026				
3.	System testing, training, and evaluation	3	2026				
4.	Documentations, presentations, workshops, conferences and publications.	3	2026				

COMCLUSION

The wind-powered automatic irrigation system offers a sustainable and efficient solution for farmers on Jos Plateau State and most of the northern state of Nigeria. With careful planning, implementation and monitoring, this project can improve crop yields, reduce water wastages, and promote sustainable agricultural practices in the region.

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