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Research

Performance Evaluation of Flywheel Solar Water Pump for Semiarid Climate Zone in Nigeria Using ANOVA

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Abstract: A flywheel solar water pump is a pump used to deliver water for irrigation, farming, and domestic used for house hold. A flywheel was incorporated on the rotating shaft to increase the shaft power and minimize power waste during operation. Mounting or installing a solar water pump in the wrong location leads to the solar water pump's short life and low discharge capacity when in use. To evaluate the performance matrix (flow rate) of the flywheel solar water pump in the semi-arid climate zone in Nigeria, and to examine a suitable location with reasonable discharge capacity of this pump, was the aim of this study. Standard test conditions and four (4) locations were chosen, with the average temperature of the location and solar irradiance of the dry and wet seasons. Analysis of variance was used to analyze the performance of the flywheel solar water pump in terms of flow rate capacity. STC (250C), Kano (270C), Abuja (280C), Niger (290C), and Kebbi (300C) with irradiance of 1000W/m2, 5800W/m2 and 7000W/m2 respectively. The findings show that the location with temperatures such are 250C, 270C, 280C, 290C, and 300C indicate that the flow rate in m3/s also differs, such as 0.0025m3/s, 0.00275m3/s, 0.0005m3/s, 0.0030m3/s and 0.0010m3/s respectively. Also, the irradiance (W/m2) for standard test conditions, dry season and wet season, such as 1000W/m2, 5800W/m2, 7000W/m2 has a different effect on the defendant or response factor (flow rate m3/s) as 0.00275m3/s, 0.0001m3/s and 0.00175m3/s, respectively, with 53% (0.53) pump efficiency.

Keywords: Performance, Pump, Temperature, Flow rate and ANOVA

1.0 INTRODUCTION

It is obvious that, nowadays, the installation of solar systems in Nigerian cities is becoming competitive among households to provide the energy for domestic use.

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Researchers, manufacturers, and students are busy in the development and execution of solar system projects to bridge the gap of electricity and water supply deficit in Nigeria.

Solar water pump is among the alternative systems for the provision of water for daily needs found in Nigeria today for domestic use or irrigation farming. The pump works with the sun energy which facilitates the pumping of water from underground via the suction pipe. The main components of the solar water pump include DC motor, rotating shaft, battery, charge controller, pump, solar panel and the flywheel. Flywheel was incorporated between the DC motor and the pump which is mounted on the rotating shaft to increase the output energy of the pump shaft. This journal aimed to analyze the performance of Flywheel solar water pump when placed or install in semi-arid climate zone in Nigeria (Northern Nigeria) in four (4) location namely; Abuja, Kano, Kebbi and Niger.

The analysis will be based on independent variables such as temperature, irradiance and head, and relate with the dependent variable (flow rate) using ANOVA. Are the independent variables significant or not for the performance of the pump in terms of discharge or flow rate (Q)? This is the research question mind.

2.0 SEMI-ARID CLIMATE ZONE IN NIGERIA

Nigeria has three distinct climatic zones [1] . According to the Nigerian Meteorological Agency, it is mainly tropical. It can be categorized into three including the tropical monsoon climate in the southern part, the tropical savannah climate, and Sahelian hot and semi-arid climate in the northern parts of the country [1]. While temperature and rainfall plays key roles in the determination of the country's climate, rainfall has been opined to be the key element based on its relevance and implications for agriculture [2].

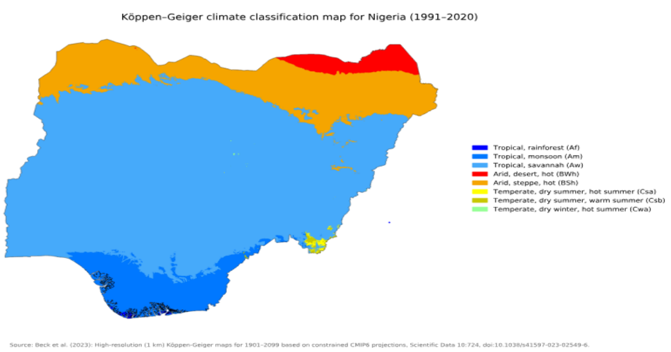


***Figure 1**. climate classification map for Nigeria [3].*

2.1 SAHELIAN HOT (BWH) AND SEMI-ARID CLIMATE (BSH)

The Sahelian hot and semiarid climates have average daytime temperatures of 35 °C (95 °F) and 21 °C (70 °F) at nighttime [1]. Regions experiencing this climate are majorly part of the Northern part of Nigeria and they experience very low annual mean rainfall below 700mm. Northern states like Kaduna, Kano, Niger and Sokoto are examples. Nigeria has two seasons in a year: dry and wet.

1. Dry season

The dry season is accompanied by the dusty northeast winds where midday temperatures can sometimes reach 100°F (38°C). During the dry season, there are lesser rainfalls, more sun and lower humidity. This period falls between October and April every year. It is normal to experience harmattan and dry spells during this period. The harmattan usually appears from December to January [4]. 1983 holds the record as the driest year Nigeria has ever seen since 1981 [5].

2. Wet season

The wet season is also referred to as rainy season. It falls between April and September every year. The wet season is particularly noticeable on the southeastern coast, where annual rainfall reaches about 130 inches (330 cm), where temperatures rarely exceed 90°F (32°C). 2019 holds the record as the wettest year Nigeria has ever seen since 1981 [5].

3. Temperature

Nigeria experiences high temperatures throughout the year, influenced by its location near the equator. The average annual temperature ranges from 25 °C to 32 °C, with regional variations based on factors such as elevation and proximity to water bodies [6].

The average monthly temperature in Nigeria is between 24°C and 30°C [7].

The highest temperatures are usually seen between February and April during the dry season and are called the hot season. It falls between February and March ranging from 39.5 to 39.9 °C (103.1 to 103.8 °F) in the south, and March to May ranging from 42.9 °C to 44.5 °C in the north. In 2021, this period lasted until May.

In 2020, Nigeria saw a slight increase with southern states recording a mean average temperature of 30 °C - 32 °C while northern states had a record of 34 °C to 37 °C. Nigeria recorded 2021 as the year with the highest temperature in 40 years [4].

2.2 SOLAR ENERGY IN NIGERIA

In 2018, Nigeria's primary energy consumption was about 155 Mtoe [8]. Most of the energy comes from traditional biomass and waste, which accounted for 73.5% of total primary consumption in 2018. The rest is from fossil fuels (26.4%) and hydropower [8].

Solar thermal energy has been utilized for decades in processes for cooking, food preservation, and agriculture. In 2016, President Buhari inaugurated the country's first solar power plant in Ibadan [9]. As of December 2017, Nigeria's federal government has invested $20 million on solar projects throughout the country [10].

Nigeria's climate, resources, and economic and societal conditions made solar energy a suitable alternative energy source. The Northern part of Nigeria has the highest potential for solar. The North has an average solar insolation of 2200 kWh/m^2, [11] while the southern part has 1800 kWh/m^2. In addition to adequate power outputs, solar energy would aid the country in reducing carbon emissions from fossil-fueled energy generation. Furthermore, solar power would provide a reliable and stable source of energy in both urban and other locations and could alleviate the resources-conflict associated with oil [12].

3.0 METHODS

ANOVA is considered to be a special case of linear regression which in turn is a special case of the general linear model [13]. All consider the observations to be the sum of a model (fit) and a residual (error) to be minimized . This (ANOVA) is going to be used to analyze the pump performance in term of flow rate in meter cube per second with respect to the temperature, head, and irradiance.

In first place, surface response design will be created in design of experiment (DOE) with three (3) factors dependents variables such are temperature with five (5) levels (25^{0}C, 27^{0}C, 28^{0}C, 29^{0}C and 30^{0}C), Head with six (6) levels (2m, 3m, 4m, 5m, 6m and 7m) and irradiance with three (3) levels (1000Watts, 5800Watts and 7000Watts).

Probability of accepting the null hypothesis is when the P-Value is high (>0.05) and will be rejected if is low (≤0.05). A very small *p*-value means that such an extreme observed outcome would be very unlikely under the null hypothesis [14]. The linear model will observe the performance of the flywheel solar water pump based on the effects of temperature, head and irradiance and see how the discharge capacity (flow rate in m^3/s) of the pump varies.

Standard test condition (STC) will be represented with 25^{0}C, Abuja represent 28^{0}C, Kano represent 27^{0}C, Kebbi represent 30^{0}C and Niger represent 29^{0}C. solar irradiance were choosing as 1000Wm^2, 5800W/m^2, 7000W/m^2 for standard test condition, dry season and wet season respectively.

3.1 Materials to be used are as follows:

1. Metrological data (Temperature ^{0}C) for standard test condition and four (4) locations.

Table 1. *Metrological data Standard Test Condition and 4 Locations*

S/N	LOCATION	LATITUDE (^{0} N)	METEONORM 8. Data (^{0}C)	PVSyst7.4 Data (^{0}C)	ANOVA Data (^{0}C)
1	Standard	STC	25.0	25.0	25.0
2	Abuja	9.85760	27.1	28.1	28.0
3	Kano	11.5000	27.3	27.0	27.0
4	Kebbi	12.5244	30.3	29.7	30.0
5	Niger	10.2500	28.5	28.0	29.0

2.Designed Pump Parameters

Table 2. *Pump parameters*

S/N	Pump Parameter	Value
1	Hydraulic power	697.5Watts
2	System Efficiency	0.069 (6.9%)
3	Shaft power	776.4 Watts
4	Power in	1492Watts (2hp)

3.2 PUMP

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action, typically converted from electrical energy into hydraulic or pneumatic energy [15]. Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration etc.

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. For centrifugal pumps, the efficiency tends to increase with flow rate up to a point midway through the operating range (peak efficiency or Best Efficiency Point (BEP)) and then declines as flow rates rise further [15].

Flow Rate: Flow rate refers to the volume of fluid a centrifugal pump delivers per unit of time, it is measured in m^3/s, m^3/h or GPM (gallon per minute). Mathematically, actual flow rate is influenced by system efficiency (η_{Syt}) and hydraulic power (H_P)

$$Q = \frac{Hp * \eta Syt}{\rho * g * H} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad (1)$$

Where Q = Flow rate in m^3/s

H_P = Hydraulic power in Watts

η_{Syt} = System efficiency in %

ρ = density of water 1000kg/m^3

g = 9.81m/s^2

H = Head in meters (m)

Pump Efficiency (η) : Is the ratio of hydraulic power delivered to the fluid(P_{out}) to the mechanical power supplied to the shaft (P_{in}) [15]. Mathematically the pump efficiency is determined using the following formula:

$$\frac{Pshf}{Pin} \quad - \quad - \quad - \quad - \quad - \quad - \quad (2)$$

Where η = efficiency of the pump in percentage (%)

P_{shf}=shaft power in Watts

P_{in} = Input power in Watts

PV Power Output: Photovoltaic power output is the electrical power generated by solar panel using the photovoltaic effects, commonly measured in Watts Peak (W_p). Mathematically determined by the following formula:

$$P_{PV} = A \cdot \eta_{mod} \cdot I \quad - \quad - \quad - \quad - \quad - \quad - \quad (3)$$

Where P_{PV} = Power output of the panel in Watts peak

A = array area in meters (m)

η_{mod} = Module efficiency in percentage

I = is the Solar irradiance in W/m^2

3.3 Minitab (DOE and ANOVA) Linear Model

Table 4. *Factor Information*

FACTOR	TYPE	LEVEL	VALUES
Temperature (^{0}C)	Fixed	5	25, 27, 28, 29, 30

Head (m)	Fixed	6	2, 3, 4, 5, 6, 7
Irradiance (Wm^2)	Fixed	3	1000, 5800, 7000

Table 5. *Effectiveness Coefficients of ANOVA for Temperature, Head and Irradiance*

Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	0.002449	0.000783	3.13	0.014	
Temperature (^0C)					
25	0.00052	0.00122	0.43	0.678	1.88
27	0.00108	0.00195	0.55	0.596	2.95
28	0.00234	0.00151	1.55	0.161	3.79
29	0.00092	0.00176	0.52	0.614	2.40
30	0.00019	0.00175	0.11	0.918	-
Head (m)					
2	0.00024	0.00120	0.20	0.845	2.48
3	0.00083	0.00236	0.35	0.734	6.26
4	0.00142	0.00140	1.02	0.339	3.37
5	0.00097	0.00144	0.67	0.521	2.80
6	0.00188	0.00214	0.88	0.405	4.02
7	0.00174	0.00130	1.34	0.216	-
Irradiance (W/m^2)					
1000	0.00003	0.00109	0.02	0.981	2.53
5800	0.000761	0.000944	0.81	0.443	2.51
7000	0.000734	0.000949	0.77	0.461	-

Table 6. *Model Summary*

S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**
0.0022738	53.51%	0.00%	-

Regression Equation

Flow rate = 0.002449 + 0.00052 Tempeature_25 + 0.00108 Temperature_27 + 0.00234 Temperature_28 + 0.00092 Temperature_29 + 0.00019 Temperature_30 + 0.00024 Head_2 + 0.00083 Head_3 + 0.00142 Head_4 + 0.0097 Head_5 +0.00188 Head_6 +0.00174 Head_7 +0.00003 Irrdiance_1000+0.000761 Irradiance_5800+0.000734 Irradiance_7000

Table 7. *Total 20 runs for flow rate response parameter*

Obs	**Flow rate (m^3/s)**	**Fit**	**Residual**	**Std Residual**
1	0.00491	0.00395	0.00096	0.61
2	0.00123	0.00077	0.00046	0.23
3	0.00491	0.00324	0.00166	01.07
4	0,00491	0.00379	0.00111	0.81
5	0.00123	0.00077	0.00046	0.23
6	0.00070	0.00203	0.00133	0.87
7	0.00469	0.00041	0.00428	-2.82R
8	0.00070	0.00126	0.00056	0.52
9	0.00123	0.00125	0.00002	0.01
10	0.00123	0.00077	0.00046	0.23
11	0.0123	0.00156	0.00033	0.22
12	0.00070	0.00181	0.00111	0.81
13	0.00070	0.00197	0..00127	0.88
14	0.00054	0.00239	0.00293	2.06R
15	0.00123	0.00178	0.00056	0.52
16	0.00123	0.0067	0.00056	0.52
17	0.00123	0.00227	0.00104	0.61
18	0.00491	0.00435	0.00056	0.52
19	0.00123	0.00123	0.00000	*X
20	0.00123	0.00012	0.00135	1.30

4.0 RESULT

	Gh kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta °C	Td °C	FF m/s
January	165	76	134	26.8	5.8	2.7
February	152	86	86	29.1	7.9	2.4
March	186	100	108	31	13.2	2.1
April	187	90	124	30.5	19.4	2.2
May	184	87	130	28.4	21.8	2.1
June	168	81	119	26.2	21.9	2
July	173	73	139	24.9	21.6	1.9
August	155	84	96	24.1	21.3	1.7
September	168	80	123	24.6	21.6	1.6
October	180	77	147	25.7	21.8	1.5
November	175	61	174	27.2	15.7	1.9
December	160	72	137	26.9	7.7	2.7
Year	2052	967	1516	27.1	16.7	2.1

Result informations

Uncertainty of yearly values: Gh = 4%, Bn = 8%, Ta = 1.5 °C
Trend of Gh / decade: - Variability of Gh / year: 5.0%

(a)

	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	168.3	78.3	28.1	2.60	9.047	27.7
February	155.3	96.4	30.4	2.39	11.367	29.2
March	177.9	104.8	32.0	2.20	12.513	37.0
April	190.3	97.8	31.1	2.30	9.909	55.2
May	180.6	94.5	29.5	2.21	8.029	69.7
June	164.0	88.2	26.8	1.99	6.405	80.5
July	168.5	82.5	26.3	1.99	5.254	82.6
August	150.6	88.8	25.4	1.81	4.997	86.2
September	162.7	88.3	25.6	1.59	5.246	86.7
October	179.6	86.8	26.9	1.61	6.358	80.6
November	184.5	57.0	27.9	1.90	6.530	52.8
December	167.4	72.2	28.0	2.61	7.400	31.7
Year	2049.5	1035.7	28.2	2.1	7.755	60.0

Global horizontal irradiation year-to-year variability 5%

(b)

Figure 2. *(a) meteonorm data for Abuja and (b) PVsyst Value for Abuja (9.8576⁰N)*

	Gh kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta °C	Td °C	FF m/s
January	152	76	114	27	2	3.4
February	141	84	74	30.1	3.9	3.2
March	177	102	95	33.6	7.3	2.9
April	185	95	112	35.1	16.5	2.5
May	195	93	132	33.4	22.2	2.5
June	187	88	129	31.1	23.5	2.2
July	198	85	156	28.9	24	1.9
August	178	93	115	27.5	24.1	1.7
September	184	79	144	28.7	24.4	1.7
October	175	83	130	30.6	22.5	1.6
November	155	69	133	30.3	12.7	1.9
December	147	72	119	27.7	5.7	3
Year	2074	1017	1453	30.3	15.7	2.4

Result informations

Uncertainty of yearly values: Gh = 6%, Bn = 12%, Ta = 1.5 °C
Trend of Gh / decade: - Variability of Gh / year: 5.5%

	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	154.3	75.0	26.6	3.40	8.601	22.3
February	152.6	87.4	29.9	3.20	10.071	20.3
March	188.4	104.7	33.5	2.89	11.999	20.7
April	198.3	98.5	34.4	2.50	10.434	35.3
May	197.3	97.6	32.9	2.50	8.868	54.0
June	189.3	91.2	29.9	2.19	7.983	67.7
July	193.9	88.1	28.5	1.89	6.418	76.3
August	173.1	93.3	27.0	1.70	5.861	83.4
September	179.1	84.1	27.6	1.69	6.168	81.6
October	177.5	85.0	29.9	1.61	8.056	65.1
November	166.4	64.9	29.2	1.90	7.417	37.4
December	147.6	73.1	27.0	3.01	7.216	26.9
Year	2117.9	1043.0	29.7	2.4	8.258	49.2

Global horizontal irradiation year-to-year variability 5.5%

(a) (b)

Figure 3. *(a) meteonorm data for Kebbi and (b) PVsyst data for Kebbi (12.5344⁰N)*

	Gh kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta °C	Td °C	FF m/s
January	157	72	133	21.8	1.1	2.9
February	147	83	88	24.9	0.9	2.8
March	185	97	113	29.1	3	2.7
April	190	95	120	32.2	10	2.5
May	199	91	139	32.1	18.7	2.7
June	190	86	136	30	22.2	2.8
July	198	81	155	27.4	22.6	2.7
August	180	89	123	26.3	22.5	2.3
September	186	78	149	27.5	23	2.1
October	180	82	136	28.3	17.7	2.1
November	160	69	136	25.9	7.6	2.5
December	149	71	123	22.4	3.1	2.8
Year	2122	992	1550	27.3	12.7	2.6

Result informations

Uncertainty of yearly values: Gh = 6%, Bn = 11%, Ta = 0.5 °C
Trend of Gh / decade: -   Variability of Gh / year: 5.1%

	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	154.1	78.2	21.5	2.60	8.610	28.6
February	156.6	90.1	24.8	2.60	9.859	23.7
March	195.9	105.9	29.0	2.49	11.201	20.1
April	201.6	103.1	31.5	2.30	10.892	27.7
May	197.5	97.3	32.0	2.50	9.249	45.9
June	188.9	91.5	29.3	2.70	8.316	66.4
July	196.9	89.4	27.5	2.50	7.077	76.4
August	176.2	99.0	26.4	2.10	6.310	81.9
September	181.9	84.3	27.0	1.90	6.729	80.2
October	177.6	86.7	28.1	1.90	8.317	54.3
November	168.5	64.9	25.1	2.19	7.617	34.1
December	153.5	72.0	21.8	2.49	7.809	32.3
Year	2149.1	1062.3	27.0	2.4	8.499	47.6

Global horizontal irradiation year-to-year variability 5.1%

(a) (b)

Figure 4. *(a) meteonorm data for Kano and (b) PVsyst data for Kano (11.5000⁰N)*

	Gh kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta °C	Td °C	FF m/s
January	154	84	100	28.1	7.9	2.6
February	137	90	60	30.4	10.2	2.4
March	177	104	89	32.3	15.6	2.2
April	183	96	110	31.7	21.2	2.3
May	184	94	119	29.7	23.4	2.2
June	172	83	120	27.6	23.5	2.1
July	177	79	134	26.3	23.2	2
August	162	91	97	25.5	22.8	1.8
September	170	83	122	26	23.2	1.6
October	178	83	131	27.1	23.4	1.5
November	162	76	129	28.5	17.6	1.9
December	148	82	100	28.3	9.6	2.6
Year	2004	1045	1309	28.5	18.5	2.1

Result informations

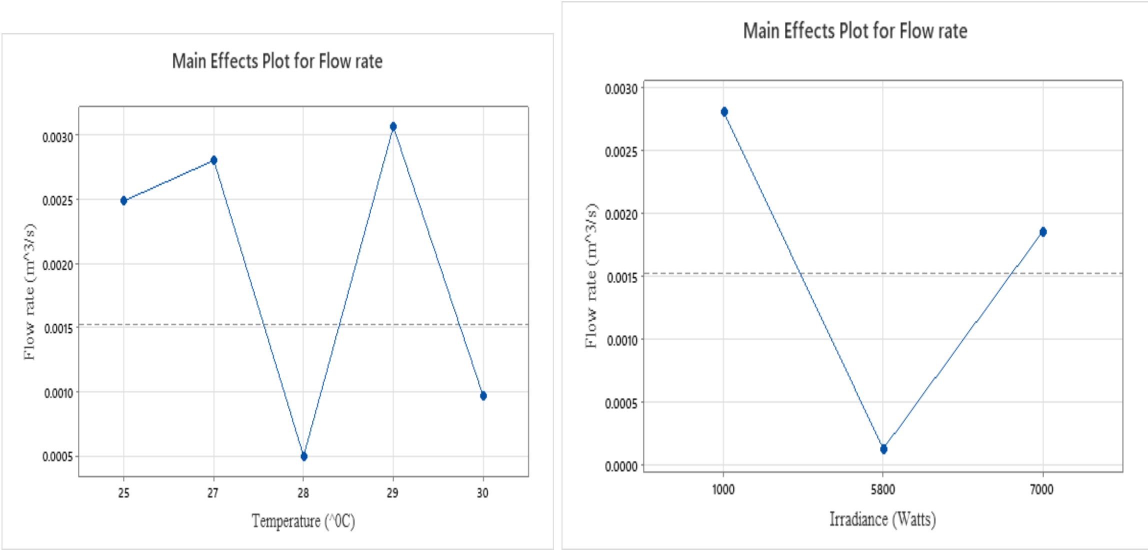
Uncertainty of yearly values: Gh = 4%, Bn = 8%, Ta = 1.1 °C
Trend of Gh / decade: -   Variability of Gh / year: 5.0%
Radiation interpolation locations: Satellite data (Share of satellite
Temperature interpolation locations: Minna (82 km), Ilorin (171 km

	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	157.7	84.8	27.9	2.60	9.618	29.5
February	142.7	94.2	30.3	2.39	11.798	32.0
March	183.9	109.3	31.8	2.19	12.782	39.3
April	188.0	97.0	30.7	2.30	10.012	57.7
May	181.7	93.0	29.2	2.20	8.041	70.9
June	168.1	87.7	26.6	2.11	6.252	81.2
July	173.6	79.7	26.2	2.00	5.081	82.5
August	159.2	92.7	25.3	1.80	4.845	86.1
September	164.1	81.4	25.5	1.70	5.146	87.1
October	176.0	84.8	26.7	1.60	6.642	81.5
November	174.5	68.4	27.7	1.90	7.224	55.0
December	157.2	79.1	27.8	2.61	8.194	33.2
Year	2026.6	1052.1	28.0	2.1	7.970	61.3

Global horizontal irradiation year-to-year variability 5%

(a) (b)

Figure 5. *(a) meteonorm data for Niger and (b) PVsyst data for Niger (10.2500⁰N)*



(a) (b)

Figure 7. *(a) effect of flow rate versus temperature and (b) the effect of flow rate versus irradiance*

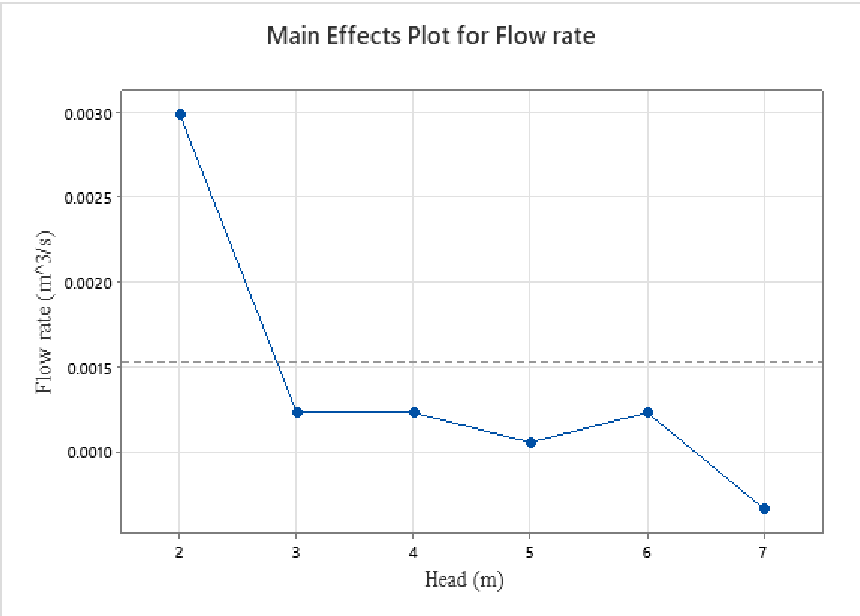
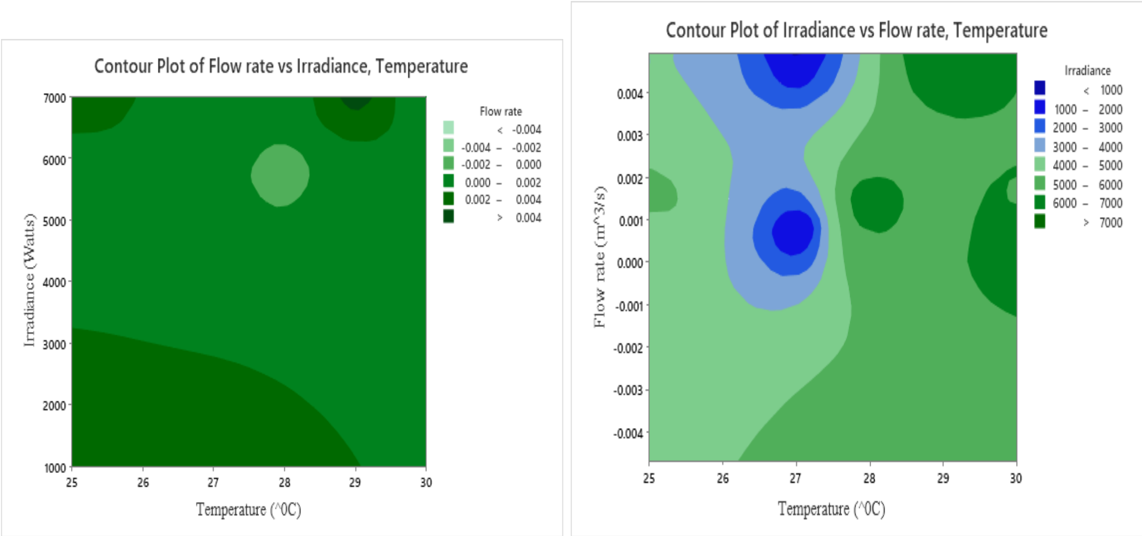
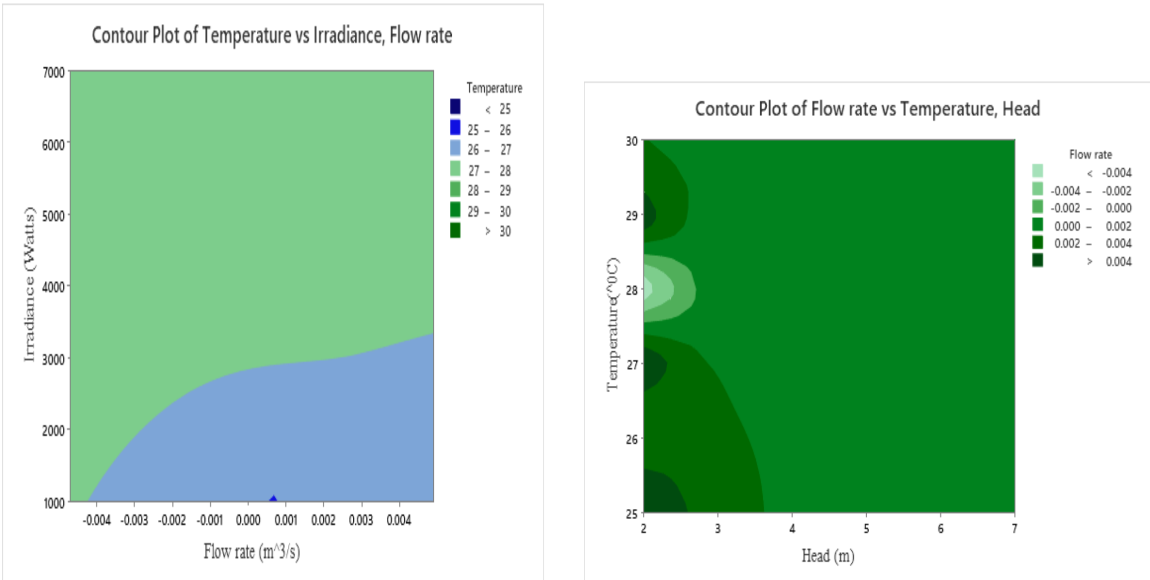


Figure 8*. The effect of flow rate versus Head*



(a) (b)

Figure 9. *(a) contour plot of flow rate versus irradiance and (b) temperature and contour plot of Irradiance versus Flow rate and Temperature*



(a) (b)

Figure 10. *(a) contour plot of temperature versus irradiance and (b) flow rate and contour plot of flow rate versus temperature and head.*

The variation in temperature such are 25^{0}C, 27^{0}C, 28^{0}C, 29^{0}C, and 30^{0}C indicate that, the performance index (flow rate in m^3/s) also differ such as 0.0025m^3/s, 0.00275m^3/s, 0.0005m^3/s, 0.0030m^3/s and 0.0010m^3/s respectively. Also the irradiance (W/m^2) for standard test condition, dry season and wet season such are 1000W/m^2, 5800W/m^2, 7000W/m^2 has difference effect on the defendant or response factor (flow rate m^3/s) as

0.00275m^3/s, 0.0001m^3/s and 0.00175m^3/s respectively. Another independent factor such as head in meter has effect on the performance matrix (flow rate m^3/s) on the varying heads such are 2m, 3m, 4m, 5m, 6m, and 7m suction heads. The discharge capacity on this varying heads are 0.0030m^3/s, 0.00123m^3/s, 0.00123m^3/s, 0.00120m^3/s, 0.00123m^3/s and 0.0001m^3/s respectively.

On the contour plot, the pump indicate the highest flow rate would be achieved during wet season at 29^{0}C location (Niger) temperature between 0.0040m^3/s and above. Also the pump will pump between 0.0020m^3/s to 0.0040m^3/s on 3.5m head at the location with 27^{0}C (Kano). Finally, when the solar irradiance is between 1000W/m^2 to 3200W/m^2 and temperature range between 25^{0}C to 29^{0}C (i.e STC, Kano, Abuja and Niger) the pump discharge capacity would be between 0.0020m^3/s to 0.0040m^3/s with 53% (0.53) pump efficiency.

5.0 CONCLUSION

In conclusion, the analysis of variance (ANOVA) indicates a low value of P-Value (0.014), which means the model is very good and has significance. And also the means of independent variables (temperature, irradiance and head) are not equal, we therefore reject the null hypothesis since the probability of having equal effect on the flow rate is less than 0.05, that is 1.4% (0.014).

In the final note, 25^{0}C, 27^{0}C, 28^{0}C, 29^{0}C, and 30^{0}C represent standard test conditions, Kano, Abuja, Niger, and Kebbi, respectively. Solar irradiance of 1000W/m^2, 5800W/m^2 and 7000W/m^2 represent standard test conditions, dry season and wet season, respectively. The locations used in semi-arid climate change are Abuja, Kano, Kebbi, and Niger with latitudes of 9.8576^{0}N, 11.5000^{0}N, 12.5344^{0}N, and 10.2500^{0}N, respectively.

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