Sizing and Evaluation of Basin Irrigation Solar Water Pump for Rice Farm in Abakiliki, Ebonyi State, Nigeria

Iniobong Edifon Abasi-Obot [1], Enyenihi Henry Johnson [2], Anyanime Tim Umoette [3]
[1,2,3]Department of Electrical/Electronic Engineering, Akwa Ibom State University Mkpat Enin, Akwa Ibom State, Nigeria.
([2]gentlejayy@yahoo.com)

***Abstract*— In this paper, the sizing and evaluation of basin irrigation solar water pump for rice farm in Abakiliki, Ebonyi State, Nigeria is presented. The rice farm located at a latitude of 6.312238 and a longitude of 8.110437 spans an area of 1 hectare and it is irrigated using the basin irrigation method. Requisite meteorological data were obtained from the NASA portal. Also, relevant mathematical expressions for the determination of the daily water demand for the basin irrigation system are presented. The water source is a borehole and the water is drawn from the well by a submersible water pump which stores hat water in a tank with 4 days storage capacity of the farm daily water demand. The results showed that the system had very negligible annual missing water value of 0.4 %. The annual volume of water pumped is 51635 m^3 while the annual water demand is 51830 m^3. Also, the result showed that the missing water occurred only in the months of August and September, with September having the higher value of 10.77 m^3 which is about 7.6% of the daily water demand. As such, further analyses were carried out to assess the rainwater capture for the two months. The rainwater capture analysis showed that rainwater alone can provide over 565 of the daily water demand for the two months. In all, when rainwater capture is accounted for, the water pump system will supply more water in every month than the daily water demand; without any missing water in any single day.**

***Keywords*— Basin Irrigation, Solar Energy, Rainwater Capture, Missing Water, Solar Water Pump, Renewable Energy**

I. INTRODUCTION

In recent years Nigeria is making effort to reduce the capital flight it incurs due to excessive rice importation [1,2,3,4,5,6]. Accordingly, the Nigerian government has placed some restrictions on rice importation [7,8,9,10,11,12]. Meanwhile, Ebonyi state is popularly known across the federation for their high rice production records [13,14,15,16,17,18]. In particular, Ebonyi state has a unique brand of rice which is in high demand across Nigeria. However, the much-needed water for effective rice yield is had to provide in Ebonyi State. Furthermore, the poor electricity power supply across Nigeria makes it more difficult to rely on the national grid supply for effective irrigation water supply to the farms [19,20,21,22,23]. Besides, the rice farms are always in remote areas , far away from the national grid. As such, the only option for powering the irrigation water supply for the rice farms in Ebony state is an alternative energy source, which solar photovoltaic power is the most favoured in the case study area.

In this paper, the focus is to determine the volume of water that will be required daily for basin irrigation of a rice farm in Ebonyi State. Furthermore, the PVSyst software [24,25] was used to select appropriate submersible water pump and PV modules that will be used to supply the water from a borehole. Further analysis is conducted to ensure that the solar-powered water pump can meet the water need of the farm. Importantly, the rainwater capture is also considered as the option for meeting whatever missing water volume may occur from the solar-powered water pumping system.

II. DESCRIPTION OF THE RICE FARM

The rice farm considered in this paper is a 1 hectare (1 ha) farm located in Abakiliki in Ebonyi state, Nigeria with a latitude of 6.312238 and a longitude of 8.110437. The rainfall (or precipitation) data, the peak sun hours data and the ambient temperature data for the rice farm location are given in Table 1.

Table 1 The rainfall (or precipitation) , Peak Sun Hours and Ambient Temperature for the Rice Farm Location (*source: [26]*)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual Average
Precipitation (mm/day)	0.33	0.82	2.65	5.18	6.89	8.11	7.66	7.97	9.13	8.67	2.32	0.26	5.02
PSH (hr/day)	5.8	5.3	5.7	5.2	5.1	4.5	4.3	4.1	4.2	4.7	5.1	5.5	4.9
Amb. Temp. (°C)	25.8	26.2	25.7	25.5	25.4	24.4	23.6	23.6	23.8	24.1	24.1	24.8	24.8

III. DETERMINATION OF THE WATER VOLUME REQUIRED FOR THE IRRIGATION PROCESS

The rice farm is irrigated using the basin irrigation approach. The volume of water required for the basin irrigation is given as [27,28];

$$V_{bs} = h_w(A_{bs}) \quad (1)$$

Where V_{bs} is the required water volume, h_w is the required water height or depth of the irrigation water and A_{bs} is the total watered area. The entire irrigation water can be supplied in a given number (n) of days called the irrigation cycle. In that case, the daily water demand (V_{bspd}) for the basin irrigation and the area (A_{bspd}) that are irrigated per day is given as follows [27,28];

$$V_{bspd} = \frac{V_{bs}}{n} = h_w\left(\frac{A_{bs}}{n}\right) \quad (2)$$

$$V_{bspd} = 10\,(A_{bspd})(h_w) \quad (3)$$

$$A_{bspd} = \frac{A_{bs}}{n} \quad (4)$$

$$Q = \frac{V_{bspd}}{T} \quad (5)$$

Where V_{bspd} is in m^3, A_{bspd} is in ha, A_{bs} is in ha, h_w is in mm, n is in days, Q is the water discharge rate in m^3/hr or litre/sec) and T is the irrigation duration per day in hour or second . According to [27];rice requires irrigation water depth or water height (h_w) of 8.5cm (or 85mm or 0.085m). Then, for 1 ha (10000 m^2) of rice farm the volume of water required is ;

$$V_{bs} = h_w(A_{bs}) = 0.085\,(10000) = 850\ m^2$$

For a 6 days irrigation cycle (n = 6) , the daily water demand (V_{bspd}) is given as;

$$V_{bspd} = \frac{V_{bs}}{n} = \left(\frac{850}{6}\right) = 141.7\ m^3/day \approx 142\ m^3/day$$

So, the daily water demand is 142 m^3. Again, for the 6 days irrigation cycle (n = 6), the area irrigated per day (A_{bspd}) is ;

$$A_{bspd} = \frac{A_{bs}}{n} = \frac{10000}{6} = 1666.7\ m^2/day$$

Therefore, for the basin irrigation approach with six days irrigation cycle, in every six days, the entire 1 ha of rice farm will be irrigated with a total water volume of 850 m^2.

IV THE PVSYST SOLAR PUMP SIMULATION PARAMETERS

The water for the irrigation is drawn from a borehole and the pump stores the water in a storage tank from where the basin irrigation mechanisms obtain the water to irrigate the rice farm. Essentially, the deep well-to-storage water pumping framework is used and this requires a submersible water pump. The daily water demand is 142 m^3which with four (4) days autonomy requires a storage tank size of 568 m^2. In order to use PVSyst software to determine the pump and PV modules that can be used to meet the water demand for the rice farm, the parameters in Table 2 are needed. The simulation input parameters in PVSyst software are shown in Figure 1 and Figure 2 while Figure 3 shows the selected pump and PV module.

Table 2: The required parameters for the tank, the well and the hydraulic circuit

Storage Tank Parameters		The Well Parameters		The Hydraulic Circuit Parameters	
Volume	568 m^3	Static level depth	32 m	Pipes Type and diameter	PE25(1")
Diameter	16 m	Max. pumping depth	51m	Piping length	290 m
Height (full level)	2.83 m	Pump depth	55 m	Number of elbows	9
Feeding altitude	14m	Well diameter	41cm	Other friction losses	0.5
				Water needs (yearly constant)	142 m^3/day

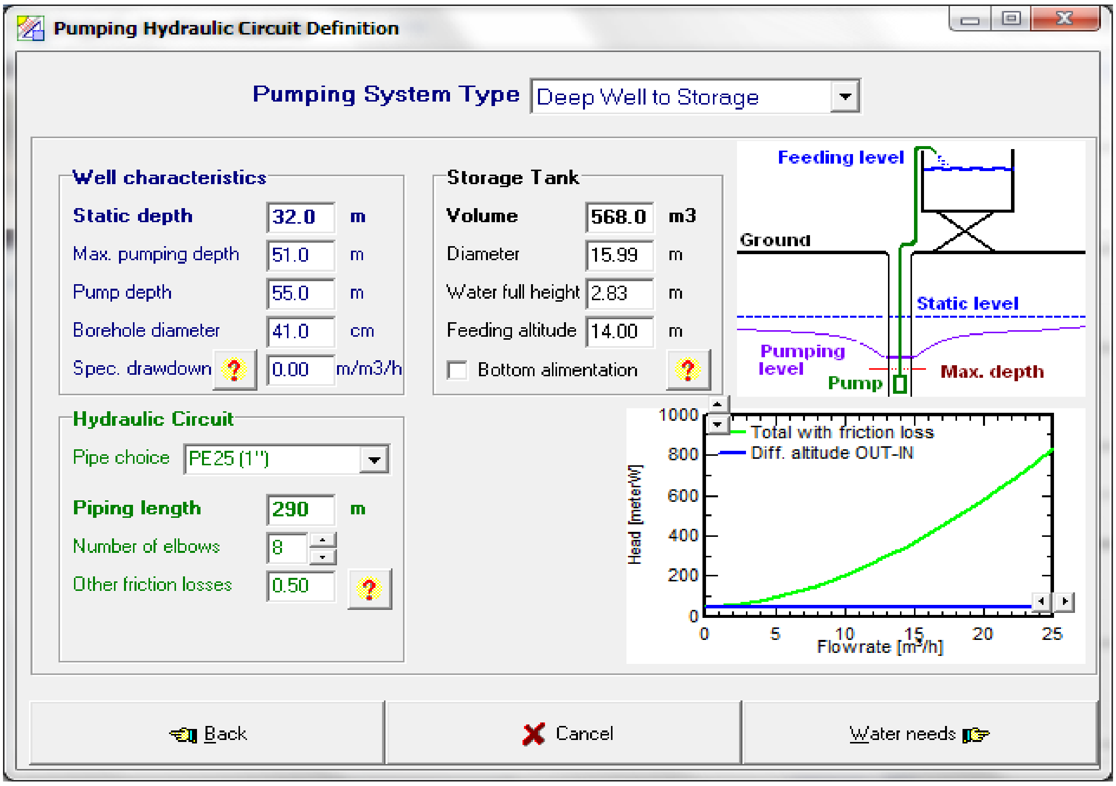

Figure 1 The Hydraulic Circuit and well parameters in PVSyst Software

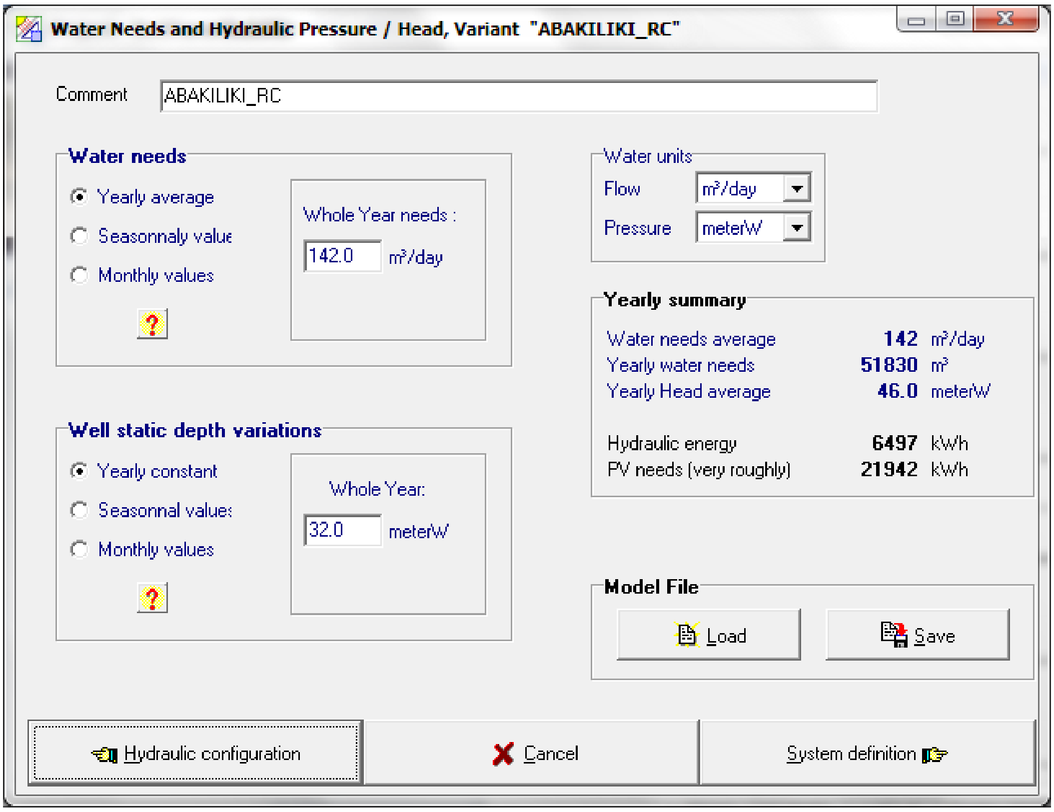

Figure 2 The storage tank parameters in PVSyst Software

Figure 2 shows that the total yearly water demand is 51830 m^3, the required hydraulic energy is 6497 kWh and the required PV energy is 21942 kWh. The selected pump and PV module are shown in Figure 3.

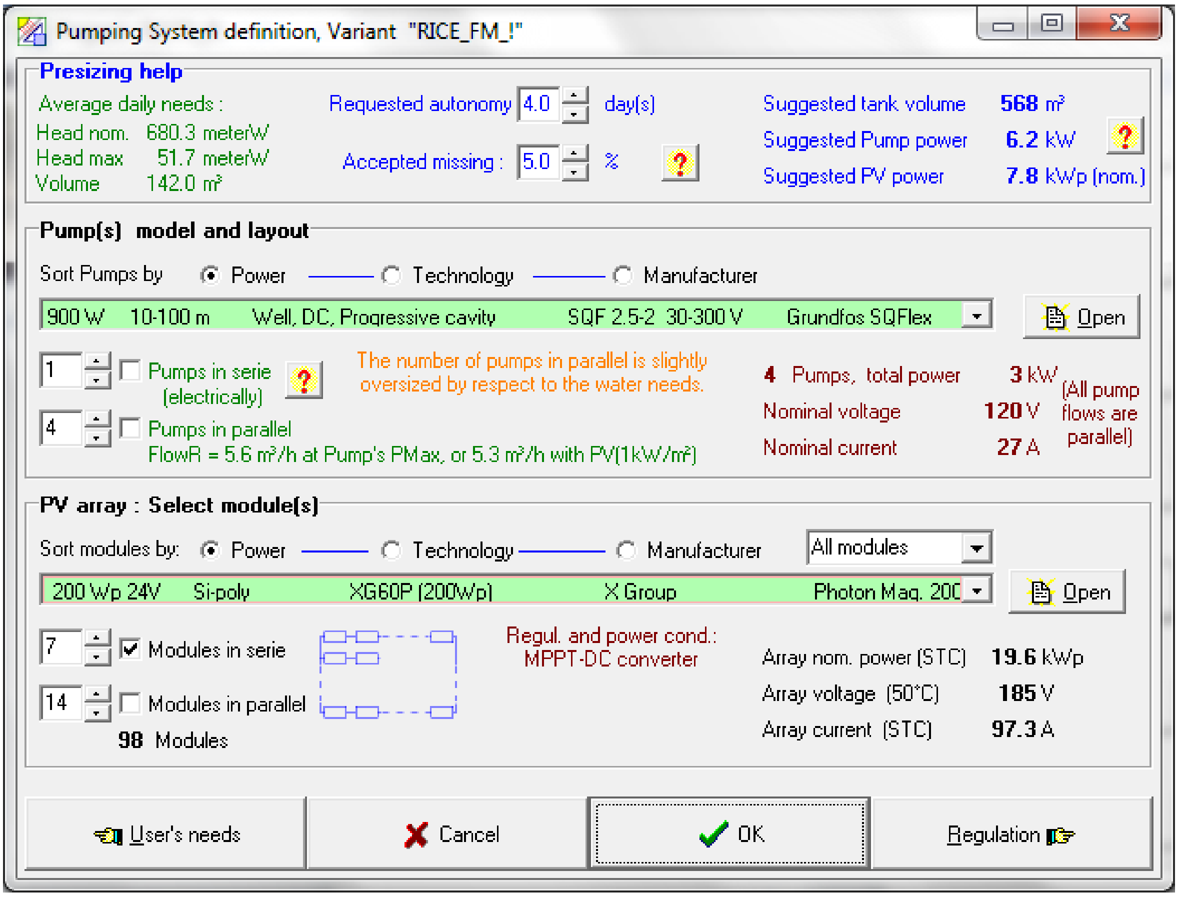

Figure 3 The selected pump and PV module

V. RESULTS AND DISCUSSION

The main results from the PVSyst software are shown in Figure 4 and it shows that the system satisfied the annual water demand with a negligible missing water value of 0.4 %. The annual volume of water pumped is 51635 m^3 while the annual water demand is 51830 m^3. This means that a total of 195 m^3 which is actually a missing water of 0.37%. The system performance is 50.1% with the specific energy yield of 0.97 kWh/m^2.

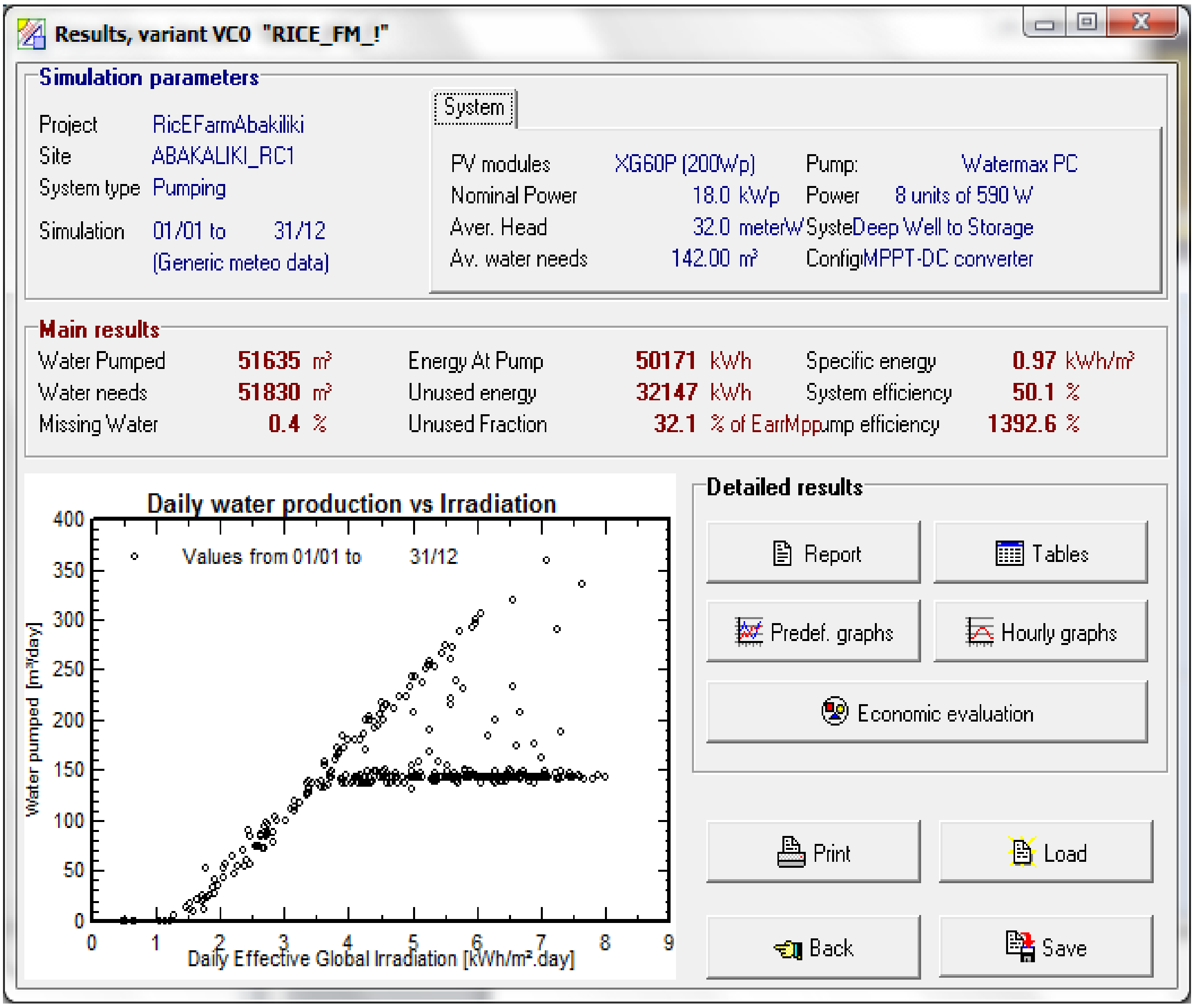

Figure 4 The main results from the PVSyst software

The PVSyst balances and main result table shown in Table 3 shows that the missing water occurred only in the months of August and September, with September having the higher value of 10.77 m^3 which is about 7.6% of the daily water demand. Fortunately, based on rainfall data in Table 1, the month of September has the highest rainfall in the case study site, with rainfall value of 9.13 mm per day. Since the 1 hectare(10000 m^2) rice farm is an open field, the whole farm area of 10000 m^2 is used to capture the rainwater. Hence, the daily water captured from the rainwater on the farm in the month of September with $9.13\ \mathrm{mm}$ daily rainfall data is $\left(10000\ \mathrm{m}^2\right)\frac{9.13\ \mathrm{mm}}{1000} = 91.3\ \mathrm{m}^3$ per day.

This daily rainwater capture in the month of September is about 64% of the daily water demand for the farm.

Similarly, the month of August has average daily rainfall data of 7.97 mm and this gives a daily rainwater capture of 79.791.3 m^3 per day which is about 56 % of the daily water demand. In essence, the month of August and September will have over 40% excess water supply when the rainwater capture is considered along with the pumped water. In all, considering the rainfall data for the case study site, the solar powered pump water system is capable of providing the daily water demand of the farm without any missing water.

Table 3 The PVSyst balances and main result table for the rice farm water pump

Simulation variant : RICE_FM_!

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RICE_FM_!

Balances and main results

	GlobEff	EArrMPP	E PmpOp	ETkFull	H Pump	WPumped	W Used	W Miss
	kWh/m²	kWh	kWh	kWh	meterW	m³/day	m³/day	m³/day
January	188.6	2877	1248	1237	1311	149.9	142.0	0.00
February	167.8	2538	1070	1103	1142	141.9	142.0	0.00
March	172.2	2644	1188	1055	1046	142.0	142.0	0.00
April	151.6	2336	1146	802	1060	141.8	142.0	0.00
May	143.5	2210	1189	616	1018	142.2	142.0	0.00
June	126.5	1958	1154	347	833	142.0	142.0	0.00
July	121.8	1891	1196	224	742	141.9	142.0	0.00
August	117.8	1822	1140	218	823	135.7	138.3	3.69
September	127.5	1970	1084	452	997	133.8	131.2	10.77
October	146.6	2269	1190	657	960	142.0	142.0	0.00
November	162.6	2495	1149	970	1118	142.2	142.0	0.00
December	183.0	2808	1184	1247	1179	142.0	142.0	0.00
Year	1809.6	27819	13936	8930	1004	141.5	140.8	1.20

VI CONCLUSION

An assessment of a submersible pump powered by solar photovoltaic power is studied. The water pump is designed to meet the water demand for a basin irrigation system used on a 1-hectare rice farm in a remote location in Abakiliki, Ebonyi State, Nigeria. The focus is to ensure that the solar pump will adequately supply the needed water even in the face of fluctuations in the solar radiations, sunshine hours and rainfall at the site. The meteorological data were obtained from NASA portal and the water demand was computed from the rice farm coverage area along with published data on rice daily water demand , basin irrigation water volume and irrigation cycle for rice. The results showed that the system had very negligible annual missing water value whereas the missing water for the months of August and September were above the acceptable value. As such, further analyses were carried out to assess the rainwater capture for the two months. The rainwater capture analysis showed that rainwater alone can provide over 565 of the daily water demand for the two months. In all, when rainwater capture is accounted for, the water pump system will supply more water in every month than the daily water demand; without any missing water in any single day.

REFERENCES

1. Merem, E. C., Twumasi, Y., Wesley, J., Isokpehi, P., Shenge, M., Fageir, S., ... & Ochai, S. (2017). Analyzing Rice Production Issues in the Niger State Area of Nigeria's Middle Belt. *Food and Public Health*, *7*(1), 7-22.
2. Obi-Egbedi, O., Okoruwa, V. O., Aminu, A., & Yusuf, S. (2012). Effect of rice trade policy on household welfare in Nigeria. *European Journal of Business and Management*, *4*(8), 160-170.
3. Emodi, I. A., & Madukwe, M. C. (2008). A review of policies, acts and initiatives in rice innovation system in Nigeria. *Journal of Agricultural extension*, *12*(2).
4. RAHJI, M. Y., & Adewumi, M. O. (2008). Market supply response and demand for local rice in Nigeria: Implications for self-sufficiency policy. *Journal of central European agriculture*, *9*(3), 567-573.
5. Tiamiyu, S. A., Akintola, J. O., & Rahji, M. A. Y. (2009). Technology adoption and productivity difference among growers of new rice for Africa in Savanna Zone of Nigeria. *Tropicultura*, *27*(4), 193-197.

6. Ogundele, F. (2007). Trade liberalization and import demand for rice in Nigeria: A dynamic modelling. *J. Econ. Rural Dev*, *16*(1), 34-45.
7. Daramola, B. (2005). Government policies and competitiveness of Nigerian rice economy. *A Paper presented at the workshop on Rice Policy & Food Security in Sub-Saharan Africa'organized by WARDA, Cotonou, Republic of Benin, November*, 07-09.
8. Arigor, A. J., Nyambi, N. I., & Obuo, P. O. (2015). Analysis of effect of governments trade policy on rice supply in three local government areas of Cross River State, Nigeria. *African Journal of Agricultural Research*, *10*(8), 829-834.
9. Akpokodje, G., Lançon, F., & Olaf, E. (2003). Nigeria's rice policy and development: A review. *Final Draft submitted to WARDA, Abidjan, Cote d'Ivoire*.
10. Ajala, A. S., & Gana, A. (2015). Analysis of Challenges Facing Rice Processing in Nigeria. *Journal of Food Processing*, *2015*.
11. Ajala, A. S., & Gana, A. (2015). Analysis of Challenges Facing Rice Processing in Nigeria. *Journal of Food Processing*, *2015*.
12. Ogundele, F. (2007). Trade liberalization and import demand for rice in Nigeria: A dynamic modelling. *J. Econ. Rural Dev*, *16*(1), 34-45.
13. Osabuohien, E. S., Okorie, U. E., & Osabohien, R. A. (2018). Rice Production and Processing in Ogun State, Nigeria: Qualitative Insights From Farmers' Association. In *Food Systems Sustainability and Environmental Policies in Modern Economies* (pp. 188-215). IGI Global.
14. Ohen, S. B., & Ajah, E. A. (2015). Cost and return analysis in small-scale rice production in Cross River State, Nigeria. *International Research Journal of Agricultural Science and Soil Science*, *5*(1), 22-27.
15. Olomola, A., Mogues, T., Olofinbiyi, T., Nwoko, C., Udoh, E., Alabi, R., ... & Woldeyohannes, S. (2014). Agriculture Public Expenditure Review at the Federal and Subnational Levels in Nigeria (2008-12).
16. Hartwich, F., Devlin, J., Kormawa, P., Bisallah, I. D., Odufote, B. O., & Polycarp, I. M. (2010). Unleashing agricultural development in Nigeria through value chain financing. *A draft report prepared for Federal Government of Nigeria by Central Bank of Nigeria in collaboration with UNIDO and BOI*.
17. Akpa, E. C. (2014). *Gender and environmental degradation in agrarian communities of Ebonyi State, Nigeria* (Doctoral dissertation).
18. Oluwaseyi, A. B., Nehemmiah, D., & Zuluqurineen, S. B. (2016). Genetic Improvement of Rice in Nigeria for Enhanced Yield and Grain Quality-A Review. *Asian Research Journal of Agriculture*, *1*(3), 1-18.
19. Charles, A. (2014). How is 100% renewable energy possible for Nigeria. *Global Energy Network Institute (GENI), California*.
20. Mshelia, I. H. (2012). Energy Access for All: The role of clean energy in alleviating energy poverty. *Energy Access for All, 33*, *43*.
21. Obideyi, O. O. (2017). *Integrating renewable energy into Nigeria's energy mix: implications for Nigeria's energy security* (Master's thesis, Norwegian University of Life Sciences, Ås).
22. Oladeji, A. S., & Sule, B. F. (2015). Electrical Load Survey and Forecast for a Decentralized Hybrid Power System at Elebu, Kwara State, Nigeria. *Nigerian Journal of Technology*, *34*(3), 591-598.
23. Ohajianya, A. C., Abumere, O. E., Owate, I. O., & Osarolube, E. (2014). Erratic Power Supply in Nigeria: Causes and Solutions. *International Journal of Engineering Science Invention*, *3*(7), 51-55.
24. Mermoud, A. (2012). Pvsyst: Software for the study and simulation of photovoltaic systems. *ISE, University of Geneva, www. pvsyst. com*.
25. Hansen, C. (2015). Estimating Parameters for the PVsyst Version 6 Photovoltaic Module Performance Model. *Albuquerque, NM, Sandia National Laboratories. SAND2015-8598*.
26. NASA Power Data Access Viewer online free tool. Available at https://power.larc.nasa.gov/data-access-viewer/ . Accessed on December 3, 2018
27. Khan, M. T. U. I., & Pathik, B. B. (2014). A comprehensive study on photovoltaic irrigation system for different crop cultivation: financial evaluation perspective. *Journal of Electrical Engineering*, *2*, 228-237.
28. MLSU (2018) Surface Irrigation Systems – Design Principles . Midlands State University eLearning content . Available at: http://web.msu.ac.zw/elearning/material/1319044006SURFACE%20IRRIGATION%20DESIGN.ppt Accessed on 3rd December 2018
29. https://www.revisor.mn.gov/rules/pdf/4715.3600/2014-01-18%2005:50:52+00:00 Accessed on December 3, 2018.