ISSN: 2321-8819 (Online) 2348-7186 (Print) Impact Factor: 1.498 Vol. 7, Issue 5, May, 2019

Mismanagement of the available irrigation potentials of rice farming in Kano State, Nigeria

Yusuf Tanko*[a], Cheah Yong Kang[b], Rabiul Islam[c]
*[a]OYA Graduate School Business, School of Economics, Finance and Banking, Universiti Utara Malaysia 06010 UUM Sintok, Kedah, Malaysia
[b]School of Economics, Finance and Banking, COB, Universiti Utara Malaysia 06010 UUM Sintok, Kedah, Malaysia
[c]School of International Studies, COLGIS, Universiti Utara Malaysia 06010 UUM Sintok, Kedah, Malaysia
*Corresponding author Email: *[a]ytanko64@gmail.com; yong@uum.edu.my: rabiul@uum.edu.my

Abstract

The objective of this paper is to examine the available irrigation facility in Kano state, its potential expectation, and utilization. Data available shows that, the state has 17 rice producing-centres and 17 dams that can irrigate 1,438,000 hectares of farm-land. Unfortunately, only 15.65% of the irrigated farm-land were utilized, living 84.35% of the irrigable farm-land un-utilized, which contribute to low rice productivity in the state. Some of the reasons for the under-utilization of the irrigated farm-land is the absence of drainages that link the dams with the farm-land. Also, the current practiced of continues flooding system which easily exhausts the available water for irrigation contributed in making a vast area of farm-land ideal. Rice production can be increased in Kano by constructing more drainages to link more unconnected farm-land with the source of water to enable supply of irrigation water to the farms. Rice production can also be increased by adopting some of the water-saving management such as the alternate wetting and drying, the alternate moderate wetting and drying, and the delaying flooding to reduce irrigation water input. The choice of water saving system will depend on each rice producing centre in the state.

Keywords: Irrigation facility; Water Saving Management; Utilization; Productivity; Rice

1 Introduction

The estimated global land used in rice production is over 100 million hectares (Xue et al., 2017). Rice (Oryza sativa) is presently among the food crop considered as the most important and it is consumed by more than 3 billion people (Yang, Zhou, & Zhang, 2017), more than half of the world population (Zhang et al., 2018). In West Africa, rice is the third most important food, a vital source of dietary, and a means to achieving food security, its consumption in the African continent is increasing at a faster rate more than any essential food (Macauley, 2015). Estimates show that the current world level of rice production must be increased by 60% to meet 2025 world population demand (Zhang et al., 2018).

Rice is a key staple food in Nigeria, a vital source of nutrients, a source of energy, and a strategic crop in the economy (Ben-Chendo and Joseph 2014; Maji et al., 2015; Onu et al. 2015; Ayinde, Bessler, and Oni 2014). Also, Maji et al. (2015) reports a fast growth in rice per capita consumption, Uduma, Samson, and Mure (2016) by 26.14% annually between 1960 and 2014, Tanaka et al. (2017) due to population growth, urbanization, changes in dietary needs and job structures, and as a staple food, and Uduma, Samson, and Mure (2016) partly due to rise in income owing to discovery of crude oil in Nigeria, hence, the need to increase rice production in the country.

The productivity of rice is the ratio of total outputs produced to the total inputs used in the production (Ben-Chendo & Joseph, 2014). Productivity is said to have increased when the growth rate of total output is faster than the growth rate of total inputs. The ideal increase in productivity is an increase in productivity without increasing the inputs used in production, due to the fact that the inputs are subject to diminishing marginal returns (Nin-pratt & Yu, 2009). Rice production can be increased by reducing the irrigated water input due to the current rise in the consumption of water by the cities and industries which decreases the supply of water for irrigated rice farming (Zhang *et al.*, 2017). Thus, irrigated rice productivity and sustainability are at stake (Ashouri, 2014). Irrigation is the use of skilful volumes of water to plants at an interval to facilitate the growth of crops, revegetate upset soil during rain shortfall or in the dry season, and routs weed growth in crop fields for better and increase in output (Bell *et al.*, 2015).

The objective of the paper is to examine; a) the available irrigation facility in Kano state, b) the potential expectations of the irrigation facility, and b) the level of utilization of the irrigation facility.

2 Literature review

Irrigated rice requires a large volume of water as it consumes 80% of the total fresh irrigated water when compared to all other irrigated crops (Tuong *et al.*, 2005). Whilst, there is a continuous decline in the available water which is posing a threat to the sustainability of irrigated rice production. This led to the development of some techniques to increase rice production through water-saving management to attain food security, self-sufficiency, and protect the environment (Zhang *et al.*, 2018).

Some of the water saving management developed to reduce the input of irrigation water includes, the ground cover rice production system (GCRPS) (Zhang *et al.*, 2017), the aerobic rice system (Jana et al., 2018), the delaying flooding (Cesari de Maria *et al.*, 2017), the non-flooded mulching cultivation (Zhang *et al.*, 2009), the alternate moderate wetting and drying (Yang *et al.*, 2017; Zhang *et al.*, 2009), and the alternate wetting and drying (AWD) (Belder *et al.*, 2007; Zhang *et al.*, 2012), the dry seeding-intermittent irrigation, the dry seeding delayed flooding, and the water seeding-continuous flooding (Cesari de Maria *et al.*, 2017). Even though some of the enhancement techniques compromise rice yield (Yang *et al.*, 2017), the most often employed technique is AWD especially in Bangladesh, China, India, and Vietnam (Bouman, 2007; Kukal *et al.*, 2005; Tuong *et al.*, 2005). Thus, the need for a study to estimate the water consumption of crops in Kano state with a view to selecting the appropriate water saving management (Chu *et al.*, 2017).

Irrigated rice can be increased through cropping system such as; the rice-wheat, rice-potato-onion, rice-garlic, and rice-radish-potato (Sharma *et al.*, 2015), the T.boro-T.aman, CTwheat-CTmungbean-T.aman, CTwheat-CTmungbean-CTDsaman, and STwheat-STmungbean-STDaman (Alam, *et al.*, 2017), and the wheat-maize and wheat-rice (Zhang *et al.*, 2015), and. Available good drainages facilitate flow of water for irrigation farming and led to an increase in rice production (Ahmed *et al.*, 2017). Similarly, irrigation facilities contribute immensely to expansion of land for irrigation activities (Binswanger et al., 1993; Ragasa & Chapoto, 2017). [(Soman *et al.*, 2018) (Sarkar *et al.*, 2018) (Basha & Sarma, 2017) (Sibayan et al., 2018)]

3 Methodology

The data presented in the paper on the irrigation facility was collected from Kano state Agricultural and Rural Development Authority (KNARDA). KNARDA is the government establishment charged with the responsibility of conducting and executing agricultural activities and training of farmers in the state with the aim of improving agriculture.

4 Discussion

4.1 Irrigation facility in Kano state

Kano is a state in the Northern Nigeria with a population of 13,076,892, a daily mean temperature of highest 33^0 C, lowest 10^0 C, and an average rainfall of 600 mm (National Bureau of Statistics [NBS], 2016). The state has 13 irrigation rice clusters, 17 dams designed to irrigate 1,438,000 hectares (Kano state Agricultural and Rural Development Authority [KNARDA], 2017). Data available shows that in the 2016 rice cropping season in Nigeria, the largest number of rice farmers for both rainfed (214,332) and irrigated (143, 768) were in Kano state, with 499,736.8 hectares for rainfed rice and 224,765.6 hectares for irrigation rice (KNARDA, 2017). Table 1 below presents the local governments where irrigation rice is cultivated and their corresponding rice producing centres in Kano state.

Table 1: Rice clusters in Kano state

S/No.	Local Government	Rice Cluster
1	Garun Malam	a) Chiromawa
		b) Garun Babba
		c) Kadawa
		d) D/ Sallau
2	Bunkure	a) Zangon Buhari
		b) Dabai
		c) Lautaye
3	Kura	a) Kura
		b) Karfi
		c) Butalawa
		d) Bugau
4	Garko	a) Garin Ali
5	Warawa	a) Larabar G/ Sarki

Source: KNARDA (2017)

Table 2 below presents the location of dams, local government area, and the number of hectares each dam can irrigate in Kano state. There are 17 dams that can irrigate 1,438,000 hectares of land in the state. Though out of the 17 dams, there is no data on two dams (Rimin Gado and Ruwan Kanyi) on the number of hectares that can be irrigated. Taking into consideration the number hectares that the dams can irrigate, gives Kano state a potential opportunity in irrigation rice production.

Table 2: Dams in Kano state and their catchment area

S/N	Dams	Local Government Area	Catchment areas (hactares)
1	Bagauda	Bebeji	20,700
2	Chalawa	Karaye	385,900
3	Gari	Kunchi	115,500
4	Guzuz guzu	Kabo	10,600
5	Jakara	Minjibir	55,900
6	Kafin chiri	Garko	22,500
7	Kusala	Karaye	8,000
8	Lake S/Sabo		100
9	Magaga	Kabo	11,900
10	Marashi	Gwarzo	4,300
11	Pada	Gwarzo	6,200
12	Rimin gado	Rimin Gado	Na
13	Ruwan kanyi	Rano	Na
14	Tiga	Kiru	664,100
15	Tomas	Danbatta	58,500
16	Tudun wada	Tudun Wada	8,500
17	Watari	Bagwai	65,300
			Total 1,438,000 hectares

Source: KNARDA (2017)

4.2 Potential rice output

Rice yield in the state's rice clusters range between 3.2 to 4.7 tons per hectare with a potential irrigation farmland of 1,438,000 hectares (KNARDA, 2017). Taking the average rice yield of 3.2 and 4.7 tons per hectare will be 3.95 tons per hectare in the state. Then, the expected potential irrigation rice output will be 5,680,100 tons annually in the state. The potential output of irrigation rice in Kano is equivalent to 81% of Nigeria's demand for rice which is 7 million tons (Suleiman, 2016).

4.3 Level of utilization

Unfortunately, only Tiga and Kafin Chiri dams were utilized in irrigation rice production leaving 15 dams (88.24%) un-utilized in the production of rice. Similarly, only 224,765.6 hectares (15.63%) of the irrigation hectares were utilized in irrigated rice production, showing under-utilization of 84.37%. While, the potential irrigated rice output expected is 5,680,100 tons, the observed rainfed and irrigated rice production was 1.6 million tons in 2016 crop season (Ajakaiye, 2017). This shows a gap of 4,080,100 tons of un-explored rice output that could be produced in the state. The low irrigated rice production can be linked to the poor management of irrigation facilities and poor support to irrigation rice farmers in Kano (Kim *et al.*, 2017). Thus, the irrigation potentials are yet to be tapped (Uduma *et al.*, 2016) hence, the need to explore the irrigation potentials in Kano to increase rice production.

From the 13 rice clusters in Kano, 11 clusters are in Garun Malam, Bunkure, and Kura local government areas and their source of irrigation water is from Tiga dam. The dam when efficiently utilized will irrigate 664,100 hectares of land. This is 295.46% more than the entire irrigated rice land currently used in irrigated rice farming in the state. In another word, it is 33.85% utilization of the dam compared to all the irrigated land used in the state, indicating under-utilization of the dam and the farmland, because Tiga dam alone can irrigate more than the present land used for irrigated rice production in all the clusters. In terms of output produced, in Tiga dam alone it could have been at least 2,025,120 tons of irrigated rice taking the least output 3.2 tons per hectare in the state. Therefore, under-utilization of both dam and land led to poor performance in the irrigated rice farming in the state.

4.4 Increasing irrigated rice production through water saving management in Kano state

The production of rice can be increased in Kano by adopting some water-saving management as reported by studies conducted in some countries. For instance, in south China, the technique of water management saves irrigation water by 24-71%, cuts irrigation inputs by 4.5% without losing rice yield, using different levels of nitrogen under mid-season drainage alternate wetting and drying (Pan *et al.*, 2017). Another experimental study in China shows the moderate alternate wetting and drying affect rice yield (Yang *et al.*, 2017), the alternate wetting and drying reduces water inputs without losing rice yield (Carrijo *et al.*, 2017), and reduces greenhouse gas emissions without losing rice yield or increasing nitrogen inputs in Biggs, California (LaHue *et al.*, 2016) also, in Iran an 8-day interval of watering rice farms reduces water intake by paddy rice without upsetting the yield (Ashouri, 2014).

Similarly, an experimental study in Italy by Cesari de Maria *et al.* (2017) report that the dry seeding-intermittent irrigation is more effective than the dry seeding delayed flooding and the least is water seeding-continuous flooding. The choice of water-saving management depends on the peculiarity of each rice-producing centre in the state. This is evident from an experimental study in Bangladesh, Cambodia, India, Nepal, and the Philippines reports a large disparity in the crop harvest by adopting the AWD water-saving management in these countries which permit the selection of high-yielding and steady genotypes for all the areas, and seasons and saves water by 5.7-23.4% without significantly forfeiting yield (Sandhu et al., 2017). Thus, the need for similar study in the rice-producing centres of Kano state.

Similarly, the nature of the soil determines the quantity of irrigation water required, therefore water saving management when adapted to the soil features and the dynamics of the rainfall will significantly reduce irrigation water input (Belder *et al.*, 2007). Compatibility of a crop in terms of water requirement, planting, and harvesting date is important in cropping system (Assefa et al., 2014). This implies that different rice clusters in Kano may requires a different water-saving management, because the soil features might be different. Thus, the need to identify the soil features in the clusters of Kano with a view to select the appropriate water saving management that suits each dam.

4.5 Increasing irrigated rice production through cropping system in Kano state

Irrigation rice production can be increased by adopting some rice cropping systems. Even though the under-utilized dams were utilized in the production of other crops and vegetables, still it could be utilized for combined production of rice with other crops and/or vegetables as it is done in other countries. For instance, in Bangladesh the triple cropping technique reduced water inputs in irrigated rice even-though with a slight effect on the harvested rice (Alam *et al.*, 2017) nonetheless, it will be an added advantage in the irrigated rice production in Kano state.

Similarly, an experimental study in Kangra district of Himachal Pradesh by (Sharma *et al.*, 2015), reports that there is a significant increase in rice yield and a higher return by adopting the rice-potato-onion, rice-garlic, and rice-radish-potato cropping system. Thus, the cropping system is superior to the conventional cropping rice-wheat. Therefore, farmers in the study area were advised to adopt the system as an alternative to conventional rice-wheat, but not as a complete replacement because the conventional rice-wheat is superior in terms of physical energy intensity and economical compared to the cropping system. In another study Sharma *et al.*, (2007) recommends irrigation farmers in the low hill of Himachal Pradesh to adopt rice-toria-potato cropping for higher returns.

Similarly, the study in China by (Zhang *et al.*, 2015) reported that cropping system in China led to a significant increase in grain production, though there are worries on the negative impacts of intensive cropping on the available water and the farmland soil. This necessitates further research study on the alternative cropping techniques that can increase productivity for food security as well as protect the environment by adapting some climate change measures. Also, an experimental study in Spain by Sanchez-Llerena *et al.* (2016), exploring the short and long-term effects of different irrigation and tillage techniques on soil and rice productivity, reports that the sprayer irrigation in the mid and long-term with no tillage is potentially productive and sustainable cropping system in rice farming. Hence, the need to explore the potentials of the 15 dams to increase their productivity in rice farming and adopt irrigated rice cropping system to increase the production of rice for self-sufficiency and food security in Kano state.

Providing suitable irrigation facilities to rice farmers in Kano will facilitate an increase in rice production (Ahmed *et al.*, 2017). For instance, availability of drainages and water source led to an increase in irrigated land area from 58 to 75 by public and 54 to 114 hectares by private per 1000 hectares each in India (Binswanger *et al.*, 1993) thus, increasing rice production by expanding the irrigated land area (Ragasa & Chapoto, 2017). Another study by Chun *et al.* (2016) assessing the impact of climate change on the future rice production in Southeast Asia shows that better irrigation facility increases rice yield from 8.2% to 42.7%. Hence, the vast un-utilized farm-land 84.37% in Kano can now be put to rice production to increase its production in the state.

Conclusion: Water saving management reduces water input in irrigated rice production. Also, provision of irrigation facilities such as dams, drainages linking dams with farm-land will facilitate an expansion of land area for irrigated rice production. The choice of water-saving management depends on an area. Thus, there is a need to conduct an empirical study to identify the water saving management that suits each rice cluster in the state. Similarly, there is a need for study to estimate the water consumption of crops cultivated in the state to enable effective selection of water saving management.

Reference

Ahmed, A., Xu, S., Yu, W., & Wang, Y. (2017). Comparative Study on Factors Influencing Rice Yield in Niger State of Nigeria and Hainan of China. *International Journal of Agricultural and Food Research [IJAFR]*, *6*(1), 15–25.

Ajakaiye, A. (2017, January 19). Kano increases rice production to 1.6 metric tons-Ganduje. *Businee Day Online News Paper*. Nigeria. Retrieved from www.busineedayonline.com/kano-increase-rice-production-1.6m-tonnes-ganduje/

Alam, M. J., Humphreys, E., Sarkar, M. A. R., & Yadav, S. (2017). Intensification and diversification increase land and water productivity and profitability of rice-based cropping systems on the High Ganges River Floodplain of Bangladesh. *Field Crops Research*, *209*(April), 10–26. http://doi.org/10.1016/j.fcr.2017.04.008

Ashouri, M. (2014). Water use efficiency, irrigation management and nitrogen utilization in rice production in the North of Iran. *APCBEE Procedia*, *8*(Caas 2013), 70–74. http://doi.org/10.1016/j.apcbee.2014.03.003

Assefa, Y., Roozeboom, K., Thompson, C., Schlegel, A., Stone, L., & Lingenfelser, J. E. (2014). Rotation Effects of Corn and Sorghum in Cropping Systems. In *Corn and Grain Sorghum Comparison* (pp. 87–101). http://doi.org/http://dx.doi.org/10.1016/B978-0-12-800112-7.00007-8

Ayinde, O. E., Bessler, D. A., & Oni, F. E. (2014). Analysis of supply response and price risk on rice production in Nigeria. In *The agricultural and applied economics association Mnneapolis MN, July 27-29, 2014* (pp. 1–20). Texas: The Agricultural & Applied Economics Association"s 2014 AAEA Annual meeting, Minneapolis MN, July 27- 29, 2014. Copyright.

Basha, S. J., & Sarma, R. S. (2017). Yield and water use efficiency of rice (Oryza sativa L.) relative to scheduling of irrigations. *Annals of Plant Sciences*, 1559–1565. http://doi.org/10.21746/aps.2017.02.005

Belder, P., Bouman, B. A. M., & Spiertz, J. H. J. (2007). Exploring options for water savings in lowland rice using a modelling approach. *Agricultural Systems*, *92*(1–3), 91–114. http://doi.org/10.1016/j.agsy.2006.03.001

Bell, A. R., Bryan, E., Ringler, C., & Ahmed, A. (2015). Rice productivity in Bangladesh: What are the benefits of irrigation? *Land Use Policy*, *48*, 1–12. http://doi.org/10.1016/j.landusepol.2015.05.019

Ben-Chendo, G. N., & Joseph, V. N. (2014). Comparative analysis of rice productivity of farmers on different land tenure systems in Imo State. *International Journal of Small Business and Entrepreneurship Research*, *2*(3), 24–32.

Binswanger, H. P., Khandker, R. S., & Rosenzweig, R. M. (1993). How infrastructure and financial institutions affect agricultural output and investment in India. *Journal of Development Economics*, *41*, 337–366.

Bouman, B. A. M. (2007). A conceptual framework for the improvement of crop water productivity at different spatial scales. *Agricultural Systems*, *93*(1–3), 43–60. http://doi.org/10.1016/j.agsy.2006.04.004

Carrijo, D. R., Lundy, M. E., & Linquist, B. A. (2017). Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. *Field Crops Research*, *203*, 173–180. http://doi.org/10.1016/j.fcr.2016.12.002

Cesari de Maria, S., Bischetti, B. G., Chiaradia, A. E., Facchi, A., Miniotti, F. E., Rienzner, M., … Gandolfi, C. (2017). The role of water management and environmental factors on field irrigation requirements and water productivity of rice. *Journal Irrigation Science*, *35*(1), 11–26. http://doi.org/10.1007/s00271-016-0519-3

Chu, Y., Shen, Y., & Yuan, Z. (2017). Water footprint of crop production for different crop structures in the Hebei southern plain, North China. *Hydrology and Earth System Sciences*, *21*(6), 3061–3069. http://doi.org/10.5194/hess-21-3061-2017

Chun, J. A., Li, S., Wang, Q., Lee, W. S., Lee, E. J., Horstmann, N., … Vang, S. (2016). Assessing rice productivity and adaptation strategies for Southeast Asia under climate change through multi-scale crop modeling. *Agricultural Systems, 143,* 14–21. http://doi.org/10.1016/j.agsy.2015.12.001

Jana, K., Karmakar, R., Banerjee, S., Sana, M., Goswami, S., & Am, P. (2018). Aerobic rice cultivation system: Eco-friendly and water saving technology under changed climate. *Agricultural Research and Technology*, *13*(2), 1–5. http://doi.org/10.19080/ARTOAJ.2018.13.555878

Kim, I., Elisha, I., Lawrence, E., & Moses, M. (2017). Farmers adaptation strategies to the effect of climate variation on rice production: A case study in Ekiti State, Nigeria. *Environmental and Ecology Research*, *5*(4), 289–301. http://doi.org/10.13189/eer.2017.050406

KNARDA. (2017). National Estimated Outputs, Area Cultivated, Yield, Output, and Specific Outputs from the FGD for 2016 Season. Kano State, Nigeria: Kano Agricultural and Rural Development Authority, Hadejia Road, Kawo adjacent to Yankaba Motor Park, Nigeria.

Kukal, S. S., Hira, G. S., & Sidhu, A. S. (2005). Soil matric potential-based irrigation scheduling to rice (Oryza sativa). *Irrigation Science*, *23*(4), 153–159. http://doi.org/10.1007/s00271-005-0103-8

LaHue, G. T., Chaney, R. L., Adviento-Borbe, M. A., & Linquist, B. A. (2016). Alternate wetting and drying in high yielding direct-seeded rice systems accomplishes multiple environmental and agronomic objectives. *Agriculture, Ecosystems and Environment*, *229*, 30–39. http://doi.org/10.1016/j.agee.2016.05.020

Macauley, H. (2015). *Cereal crops: Rice, Maize, Millet, Sorghum, Wheat*. *Feeding Africa: An action plan for African Agricultural transformation*.

Maji, A. T., Bashir, M., Oduba, A., Gbanguba, A. U., & Audu, S. D. (2015). Genotype X environment interaction and stability estimate forgGrain yield of upland rice genotypes in Nigeria. *Journal of Rice Research*, *03*(02), 1–5. http://doi.org/10.4172/2375-4338.1000136

National Bureau of Statistics [NBS]. (2016). The population of Nigeria. Abuja, Nigeria: National Bereau of Statistics Abuja, Nigeria. Retrieved from www.nigeriastat.gov.ng

Nin-pratt, A., & Yu, B. (2009). An updated look at the recovery of agricultural productivity in Sub-Saharan Africa. *Contributed Paper Prepared for Presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009*, (202).

Onu, D. O., Obike, K. C., Ebe, F. E., & Okpara, B. O. (2015). Empirical assessment of the trend in rice production and imports in Nigeria (1980 – 2013). *International Research Journal of Agricultural Science and Soil Sciences*, *5*(6), 150–158.

Pan, J., Liu, Y., Zhong, X., Lampayan, R. M., Singleton, G. R., Huang, N., … Tian, K. (2017). Grain yield, water productivity and nitrogen use efficiency of rice under different water management and fertilizer-N inputs in South China. *Agricultural Water Management*, *184*, 191–200. http://doi.org/10.1016/j.agwat.2017.01.013

Ragasa, C., & Chapoto, A. (2017). Limits to green revolution in rice in Africa: The case of Ghana. *Land Use Policy*, *66*(April), 304–321. http://doi.org/10.1016/j.landusepol.2017.04.052

Sanchez-Llerena, J., Lopez-Pineiro, A., Albarran, A., Pena, D., Becerra, D., & Rato-Nunes, J. M. (2016). Short and long-term effects of different irrigation and tillage systems on soil properties and rice productivity under Mediterranean conditions. *European Journal of Agronomy*, *77*, 101–110. http://doi.org/10.1016/j.eja.2016.04.005

Sandhu, N., Subedi, S. R., Yadaw, R. B., Chaudhary, B., Prasai, H., Iftekharuddaula, K., … Kumar, A. (2017). Root traits enhancing rice grain yield under alternate wetting and drying condition. *Frontiers in Plant Science*, *8*(October), 1–13. http://doi.org/10.3389/fpls.2017.01879

Sarkar, N., Ghosh, U., & Biswas, K. R. (2018). Effect of drip irrigation on yield and water use efficiency of summer rice cultivation in pots. *Journal of Pharmacognosy and Phytochemistry*, *7*(1), 37–40.

Sharma, S. K., Rana, S. S., Sharma, K. S., Bhargava, M., Sharma, J. J., & Sharma, H. L. (2007). Production potential and economic feasibility of irrigated rice based cropping sequences on cultivators' fields under sub-montane low hill conditions of Himachal Pradesh. *Himachal Journal of Agricultural Research*, *33*(1), 110–112.

Sharma, S. K., Rana, S. S., Subehia, S. K., & Negi, S. C. (2015). Production potential of rice-based cropping sequences on farmers' fields in low hills of Kangra district of Himachal Pradesh. *Himachal Journal of Agricultural Research*, *41*(1), 20–24.

Sibayan, E. B., Samoy-Pascual, K., Grospe, F. S., Casil, M. E. D., Tokida, T., Padre, A. T., & Minamikawa, K. (2018). Effects of alternate wetting and drying technique on greenhouse gas emissions from irrigated rice paddy in Central Luzon, Philippines. *Soil Science and Plant Nutrition*, *64*(1), 39–46. http://doi.org/10.1080/00380768.2017.1401906

Soman, P., Singh, S., Bhardwaj, A. K., Pandiaraj, T., & Bhardwaj, R. K. (2018). On-farm drip irrigation in rice for higher productivity and profitability in Haryana, India. *International Journal of Current Microbiology and Applied Sciences*, *7*(02), 506–512.

Suleiman, I. (2016). Nigeria produces 3.5m tonnes of rice and needs 7m tonnes. *Vangurad Online News*. Nigeria. Retrieved from https://www.vanguardngr.com/2016/11/nigeria-produces-3.5m-tonnes-rice-needs-7m-tonnes-ogbe

Tanaka, A., Johnson, J. M., Senthilkumar, K., Akakpo, C., Segda, Z., Yameogo, L. P., … Saito, K. (2017). On-farm rice yield and its association with biophysical factors in sub-Saharan Africa. *European Journal of Agronomy*, *85*, 1–11. http://doi.org/10.1016/j.eja.2016.12.010

Tuong, P., Bouman, B. A. M., & Mortimer, M. (2005). More rice, less Water-integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. *Plant Production Science*, *8*(3), 231–241. http://doi.org/10.1626/pps.8.231

Uduma, B. U., Samson, O. A., & Mure, U. A. (2016). Irrigation potentials and rice self-sufficiency in Nigeria: A review. *African Journal of Agricultural Research*, *11*(5), 298–309. http://doi.org/10.5897/AJAR2015.10284

Xue, W., Lindner, S., Dubbert, M., Otieno, D., Ko, J., Muraoka, H., … Tenhunen, J. (2017). Supplement understanding of the relative importance of biophysical factors in determination of photosynthetic capacity and photosynthetic productivity in rice ecosystems. *Agricultural and Forest Meteorology*, *232*, 550–565. http://doi.org/10.1016/j.agrformet.2016.10.009

Yang, J., Zhou, Q., & Zhang, J. (2017). Moderate wetting and drying increases rice yield and reduces water use, grain arsenic level, and methane emission. *The Crop Journal*, *5*(2), 151–158. http://doi.org/10.1016/j.cj.2016.06.002

Zhang, H., Li, H., Yuan, L., Wang, Z., Yang, J., & Zhang, J. (2012). Post-anthesis alternate wetting and moderate soil drying enhances activities of key enzymes in sucrose-to-starch conversion in inferior spikelets of rice. *Journal of Experimental Botany*, *63*(1), 215–227. http://doi.org/10.1093/jxb/err263

Zhang, H., Xue, Y., Wang, Z., Yang, J., & Zhang, J. (2009). An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. *Crop Science*, *49*(6), 2246–2260. http://doi.org/10.2135/cropsci2009.02.0099

Zhang, H., Yu, C., Kong, X., Hou, D., Gu, J., Liu, L., … Yang, J. (2018). Progressive integrative crop managements increase grain yield, nitrogen use efficiency and irrigation water productivity in rice. *Field Crops Research*, *215*, 1–11. http://doi.org/10.1016/j.fcr.2017.09.034

Zhang, L., Wang, G., Zheng, Q., Liu, Y., Yu, D., Shi, X., … Fan, X. (2017). Quantifying the impacts of agricultural management and climate change on soil organic carbon changes in the uplands of eastern China. *Soil and Tillage Research*, *174*(January), 81–91. http://doi.org/10.1016/j.still.2017.06.005

Zhang, W., Zheng, C., & Song, Z. (2015). *Farming systems in China: Innovations*. *Crop Physiology* (Second Edi). Elsevier Inc. http://doi.org/10.1016/B978-0-12-417104-6/00003-0

Zhang, Y., Liu, M., Dannenmann, M., Tao, Y., Yao, Z., Jing, R., … Lin, S. (2017). Benefit of using biodegradable film on rice grain yield and N use efficiency in ground cover rice production system. *Field Crops Research*, *201*, 52–59. http://doi.org/10.1016/j.fcr.2016.10.022

Zhang, Z. C., Xue, Y. G., Wang, Z. Q., Yang, J. C., & Zhang, J. H. (2009). The relationship of grain filling with abscisic acid and ethylene under non-flooded mulching cultivation. *Journal of Agricultural Science*, *147*(4), 423–436. http://doi.org/10.1017/S0021859609008557

Ahmed, A., Xu, S., Yu, W., & Wang, Y. (2017). Comparative Study on Factors Influencing Rice Yield in Niger State of Nigeria and Hainan of China. *International Journal of Agricultural and Food Research [IJAFR]*, *6*(1), 15–25.

Ajakaiye, A. (2017, January 19). Kano increases rice production to 1.6 metric tons-Ganduje. *Businee Day Online News Paper*. Nigeria. Retrieved from www.busineedayonline.com/kano-increase-rice-production-

1.6m-tonnes-ganduje/

Alam, M. J., Humphreys, E., Sarkar, M. A. R., & Yadav, S. (2017). Intensification and diversification increase land and water productivity and profitability of rice-based cropping systems on the High Ganges River Floodplain of Bangladesh. *Field Crops Research*, *209*(April), 10–26. http://doi.org/10.1016/j.fcr.2017.04.008

Ashouri, M. (2014). Water use efficiency, irrigation management and nitrogen utilization in rice production in the North of Iran. *APCBEE Procedia*, *8*(Caas 2013), 70–74. http://doi.org/10.1016/j.apcbee.2014.03.003

Assefa, Y., Roozeboom, K., Thompson, C., Schlegel, A., Stone, L., & Lingenfelser, J. E. (2014). Rotation Effects of Corn and Sorghum in Cropping Systems. In *Corn and Grain Sorghum Comparison* (pp. 87–101). http://doi.org/http://dx.doi.org/10.1016/B978-0-12-800112-7.00007-8

Ayinde, O. E., Bessler, D. A., & Oni, F. E. (2014). Analysis of supply response and price risk on rice production in Nigeria. In *The agricultural and applied economics association Mnneapolis MN, July 27-29, 2014* (pp. 1–20). Texas: The Agricultural & Applied Economics Association"s 2014 AAEA Annual meeting, Minneapolis MN, July 27- 29, 2014. Copyright.

Basha, S. J., & Sarma, R. S. (2017). Yield and water use efficiency of rice (Oryza sativa L.) relative to scheduling of irrigations. *Annals of Plant Sciences*, 1559–1565. http://doi.org/10.21746/aps.2017.02.005

Belder, P., Bouman, B. A. M., & Spiertz, J. H. J. (2007). Exploring options for water savings in lowland rice using a modelling approach. *Agricultural Systems*, *92*(1–3), 91–114. http://doi.org/10.1016/j.agsy.2006.03.001

Bell, A. R., Bryan, E., Ringler, C., & Ahmed, A. (2015). Rice productivity in Bangladesh: What are the benefits of irrigation? *Land Use Policy*, *48*, 1–12. http://doi.org/10.1016/j.landusepol.2015.05.019

Ben-Chendo, G. N., & Joseph, V. N. (2014). Comparative analysis of rice productivity of farmers on different land tenure systems in Imo State. *International Journal of Small Business and Entrepreneurship Research*, *2*(3), 24–32.

Binswanger, H. P., Khandker, R. S., & Rosenzweig, R. M. (1993). How infrastructure and financial institutions affect agricultural output and investment in India. *Journal of Development Economics*, *41*, 337–366.

Bouman, B. A. M. (2007). A conceptual framework for the improvement of crop water productivity at different spatial scales. *Agricultural Systems*, *93*(1–3), 43–60. http://doi.org/10.1016/j.agsy.2006.04.004

Carrijo, D. R., Lundy, M. E., & Linquist, B. A. (2017). Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. *Field Crops Research*, *203*, 173–180. http://doi.org/10.1016/j.fcr.2016.12.002

Cesari de Maria, S., Bischetti, B. G., Chiaradia, A. E., Facchi, A., Miniotti, F. E., Rienzner, M., … Gandolfi, C. (2017). The role of water management and environmental factors on field irrigation requirements and water productivity of rice. *Journal Irrigation Science*, *35*(1), 11–26. http://doi.org/10.1007/s00271-016-0519-3

Chu, Y., Shen, Y., & Yuan, Z. (2017). Water footprint of crop production for different crop structures in the Hebei southern plain, North China. *Hydrology and Earth System Sciences*, *21*(6), 3061–3069. http://doi.org/10.5194/hess-21-3061-2017

Chun, J. A., Li, S., Wang, Q., Lee, W. S., Lee, E. J., Horstmann, N., … Vang, S. (2016). Assessing rice productivity and adaptation strategies for Southeast Asia under climate change through multi-scale crop modeling. *Agricultural Systems*, *143*, 14–21. http://doi.org/10.1016/j.agsy.2015.12.001

Jana, K., Karmakar, R., Banerjee, S., Sana, M., Goswami, S., & Am, P. (2018). Aerobic rice cultivation system: Eco-friendly and water saving technology under changed climate. *Agricultural Research and Technology*, *13*(2), 1–5. http://doi.org/10.19080/ARTOAJ.2018.13.555878

Kim, I., Elisha, I., Lawrence, E., & Moses, M. (2017). Farmers adaptation strategies to the effect of climate variation on rice production: A case study in Ekiti State, Nigeria. *Environmental and Ecology Research*, *5*(4), 289–301. http://doi.org/10.13189/eer.2017.050406

KNARDA. (2017). National Estimated Outputs, Area Cultivated, Yield, Output, and Specific Outputs from the FGD for 2016 Season. Kano State, Nigeria: Kano Agricultural and Rural Development Authority, Hadejia Road, Kawo adjacent to Yankaba Motor Park, Nigeria.

Kukal, S. S., Hira, G. S., & Sidhu, A. S. (2005). Soil matric potential-based irrigation scheduling to rice (Oryza sativa). *Irrigation Science*, *23*(4), 153–159. http://doi.org/10.1007/s00271-005-0103-8

LaHue, G. T., Chaney, R. L., Adviento-Borbe, M. A., & Linquist, B. A. (2016). Alternate wetting and drying in high yielding direct-seeded rice systems accomplishes multiple environmental and agronomic objectives.

Agriculture, Ecosystems and Environment, *229*, 30–39. http://doi.org/10.1016/j.agee.2016.05.020

Macauley, H. (2015). *Cereal crops: Rice, Maize, Millet, Sorghum, Wheat*. *Feeding Africa: An action plan for African Agricultural transformation*.

Maji, A. T., Bashir, M., Oduba, A., Gbanguba, A. U., & Audu, S. D. (2015). Genotype X environment interaction and stability estimate forgGrain yield of upland rice genotypes in Nigeria. *Journal of Rice Research*, *03*(02), 1–5. http://doi.org/10.4172/2375-4338.1000136

National Bureau of Statistics [NBS]. (2016). The population of Nigeria. Abuja, Nigeria: National Bereau of Statistics Abuja, Nigeria. Retrieved from www.nigeriastat.gov.ng

Nin-pratt, A., & Yu, B. (2009). An updated look at the recovery of agricultural productivity in Sub-Saharan Africa. *Contributed Paper Prepared for Presentation at the International Association of Agricultural Economists Conference*, *Beijing, China, August 16-22, 2009*, (202).

Onu, D. O., Obike, K. C., Ebe, F. E., & Okpara, B. O. (2015). Empirical assessment of the trend in rice production and imports in Nigeria (1980 – 2013). *International Research Journal of Agricultural Science and Soil Sciences*, *5*(6), 150–158.

Pan, J., Liu, Y., Zhong, X., Lampayan, R. M., Singleton, G. R., Huang, N., … Tian, K. (2017). Grain yield, water productivity and nitrogen use efficiency of rice under different water management and fertilizer-N inputs in South China. *Agricultural Water Management*, *184*, 191–200. http://doi.org/10.1016/j.agwat.2017.01.013

Ragasa, C., & Chapoto, A. (2017). Limits to green revolution in rice in Africa: The case of Ghana. *Land Use Policy*, *66*(April), 304–321. http://doi.org/10.1016/j.landusepol.2017.04.052

Sanchez-Llerena, J., Lopez-Pineiro, A., Albarran, A., Pena, D., Becerra, D., & Rato-Nunes, J. M. (2016). Short and long-term effects of different irrigation and tillage systems on soil properties and rice productivity under Mediterranean conditions. *European Journal of Agronomy*, *77*, 101–110. http://doi.org/10.1016/j.eja.2016.04.005

Sandhu, N., Subedi, S. R., Yadaw, R. B., Chaudhary, B., Prasai, H., Iftekharuddaula, K., … Kumar, A. (2017). Root traits enhancing rice grain yield under alternate wetting and drying condition. *Frontiers in Plant Science*, *8*(October), 1–13. http://doi.org/10.3389/fpls.2017.01879

Sarkar, N., Ghosh, U., & Biswas, K. R. (2018). Effect of drip irrigation on yield and water use efficiency of summer rice cultivation in pots. *Journal of Pharmacognosy and Phytochemistry*, *7*(1), 37–40.

Sharma, S. K., Rana, S. S., Sharma, K. S., Bhargava, M., Sharma, J. J., & Sharma, H. L. (2007). Production potential and economic feasibility of irrigated rice based cropping sequences on cultivators' fields under sub-montane low hill conditions of Himachal Pradesh. *Himachal Journal of Agricultural Research*, *33*(1), 110–112.

Sharma, S. K., Rana, S. S., Subehia, S. K., & Negi, S. C. (2015). Production potential of rice-based cropping sequences on farmers' fields in low hills of Kangra district of Himachal Pradesh. *Himachal Journal of Agricultural Research*, *41*(1), 20–24.

Sibayan, E. B., Samoy-Pascual, K., Grospe, F. S., Casil, M. E. D., Tokida, T., Padre, A. T., & Minamikawa, K. (2018). Effects of alternate wetting and drying technique on greenhouse gas emissions from irrigated rice paddy in Central Luzon, Philippines. *Soil Science and Plant Nutrition*, *64*(1), 39–46. http://doi.org/10.1080/00380768.2017.1401906

Soman, P., Singh, S., Bhardwaj, A. K., Pandiaraj, T., & Bhardwaj, R. K. (2018). On-farm drip irrigation in rice for higher productivity and profitability in Haryana, India. *International Journal of Current Microbiology and Applied Sciences*, *7*(02), 506–512.

Suleiman, I. (2016). Nigeria produces 3.5m tonnes of rice and needs 7m tonnes. *Vangurad Online News*. Nigeria. Retrieved from https://www.vanguardngr.com/2016/11/nigeria-produces-3.5m-tonnes-rice-needs-7m-tonnes-ogbe

Tanaka, A., Johnson, J. M., Senthilkumar, K., Akakpo, C., Segda, Z., Yameogo, L. P., … Saito, K. (2017). On-farm rice yield and its association with biophysical factors in sub-Saharan Africa. *European Journal of Agronomy*, *85*, 1–11. http://doi.org/10.1016/j.eja.2016.12.010

Tuong, P., Bouman, B. A. M., & Mortimer, M. (2005). More rice, less Water-integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. *Plant Production Science*, *8*(3), 231–241. http://doi.org/10.1626/pps.8.231

Uduma, B. U., Samson, O. A., & Mure, U. A. (2016). Irrigation potentials and rice self-sufficiency in Nigeria: A review. *African Journal of Agricultural Research*, *11*(5), 298–309.

http://doi.org/10.5897/AJAR2015.10284

Xue, W., Lindner, S., Dubbert, M., Otieno, D., Ko, J., Muraoka, H., … Tenhunen, J. (2017). Supplement understanding of the relative importance of biophysical factors in determination of photosynthetic capacity and photosynthetic productivity in rice ecosystems. *Agricultural and Forest Meteorology*, *232*, 550–565. http://doi.org/10.1016/j.agrformet.2016.10.009

Yang, J., Zhou, Q., & Zhang, J. (2017). Moderate wetting and drying increases rice yield and reduces water use, grain arsenic level, and methane emission. *The Crop Journal*, *5*(2), 151–158. http://doi.org/10.1016/j.cj.2016.06.002

Zhang, H., Li, H., Yuan, L., Wang, Z., Yang, J., & Zhang, J. (2012). Post-anthesis alternate wetting and moderate soil drying enhances activities of key enzymes in sucrose-to-starch conversion in inferior spikelets of rice. *Journal of Experimental Botany*, *63*(1), 215–227. http://doi.org/10.1093/jxb/err263

Zhang, H., Xue, Y., Wang, Z., Yang, J., & Zhang, J. (2009). An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. *Crop Science*, *49*(6), 2246–2260. http://doi.org/10.2135/cropsci2009.02.0099

Zhang, H., Yu, C., Kong, X., Hou, D., Gu, J., Liu, L., … Yang, J. (2018). Progressive integrative crop managements increase grain yield, nitrogen use efficiency and irrigation water productivity in rice. *Field Crops Research*, *215*, 1–11. http://doi.org/10.1016/j.fcr.2017.09.034

Zhang, L., Wang, G., Zheng, Q., Liu, Y., Yu, D., Shi, X., … Fan, X. (2017). Quantifying the impacts of agricultural management and climate change on soil organic carbon changes in the uplands of eastern China. *Soil and Tillage Research*, *174*(January), 81–91. http://doi.org/10.1016/j.still.2017.06.005

Zhang, W., Zheng, C., & Song, Z. (2015). *Farming systems in China: Innovations*. *Crop Physiology* (Second Edi). Elsevier Inc. http://doi.org/10.1016/B978-0-12-417104-6/00003-0

Zhang, Y., Liu, M., Dannenmann, M., Tao, Y., Yao, Z., Jing, R., … Lin, S. (2017). Benefit of using biodegradable film on rice grain yield and N use efficiency in ground cover rice production system. *Field Crops Research*, *201*, 52–59. http://doi.org/10.1016/j.fcr.2016.10.022

Zhang, Z. C., Xue, Y. G., Wang, Z. Q., Yang, J. C., & Zhang, J. H. (2009). The relationship of grain filling with abscisic acid and ethylene under non-flooded mulching cultivation. *Journal of Agricultural Science*, *147*(4), 423–436. http://doi.org/10.1017/S0021859609008557