International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

ASSESSMENT OF WATER BALANCE IN FOOD TRADE IN THE WATER-SCARCE REGIONS OF NIGERIA

Gozen Elkiran [a*], Jazuli Abdullahi [a]

[a] *Civil and Environmental Engineering Faculty, Near East University, Near East Boulevard, 99138, Nicosia, NORTH CYPRUS*

ARTICLEINFO

Article history:
Received 04 January 2019
Received in revised form 07 February 2019
Accepted 21 February 2019
Available online
25 February 2019

Keywords:
Food trade; crop productions; water footprint; water balance; virtual water; CROPWAT; imports and exports.

ABSTRACT

Rapid growth in the world population leads to increase demand for water and hence water scarcity rises. Water is said to be virtually transported when the produced food are transferred from the point of its production to the point of consumption. Hence, this research was aimed at determining the volume of virtual water required to produce 25 different crops in the most water-scarce region of Nigeria for the year 2013. In the meantime, the virtual water imports and exports, the volume of virtual water produced, water balance, and water footprint, contributions of green, blue, and grey water for crop productions, imports costs, exports income and productions value of the selected crops were distinguished. CROPWAT 8.0 software was used in conducting this research. The result showed that in the selected six states of the water-scarce region, the sum of the volumes of virtual water produced of the crops selected was approximately 34.7 Gm^3/yr., virtual water imports volume was 8.3 Gm^3/yr, virtual water exports volume was 26.5 Mm^3/yr., water balance was 8.3 Gm^3/yr. and water footprint was 43 Gm^3/yr. Total production value was \$2.5 billion, import cost \$763.5 million and export income \$1.1 million. The most suitable state to grow crops in the water-scarce region of Nigeria is Zamfara as it has more percentage of green water used than others, which can, therefore, reduce cost of production and scarcity of water.

1. INTRODUCTION

With persistent increase in world population, water resources are tremendously regarded as an economic good due to its scarcity in numerous countries and areas of the globe (Yang et al., 2006, Hoekstra and Hung, 2005). So many countries due to their scarcity of water resources depend on food importation in order to acquire the desired domestic demand of food. However, for those water-scarce countries, the food imported was virtually equal to the importation of water which can be used under other circumstances to produce food within the nation domestically. According to Allan (1993), water which is conveyed within imported food is regarded as 'Virtual Water'. Moreover, Hoekstra (2003) expanded the idea of virtual water as water needed to produce agricultural goods and also goods by industries. Deliberations on issues of virtual water are until now based mainly on food items because of their major ratio in aggregate water use (Yang et al., 2006). Yang et al (2003) meanwhile, explained that, with a prolonged increase in scarcity of water in numerous countries of the globe, the function of virtual water trade (VWT) in equating domestic water budget is anticipated to rise.

This research was aimed at determining the volume of virtual water required to produce 25 different crops in the water-scarce region of Nigeria in 2013, virtual water imports and exports, volume of virtual water produced, water balance, and water footprint, contributions of green, blue, and grey water for crop productions, imports costs, exports income and productions value of the selected crops. The result showed that in the selected 6 states of the water-scarce region, the sum of the volumes of virtual water produced of the crops selected was approximately 34.7 Gm^3/yr, virtual water imports volume was 8.3 Gm^3/yr, virtual water exports volume was 26.5 Mm^3/yr, water balance was 8.3 Gm^3/y and water footprint was 43 Gm^3/yr. Total production value was $2.5 billion, import cost $763.5 million and export income $1.1 million. The most suitable region to grow crops in the water-scarce region of Nigeria is Zamfara as it has more percentage of green water used than others, which can, therefore, reduce cost of production and scarcity of water.

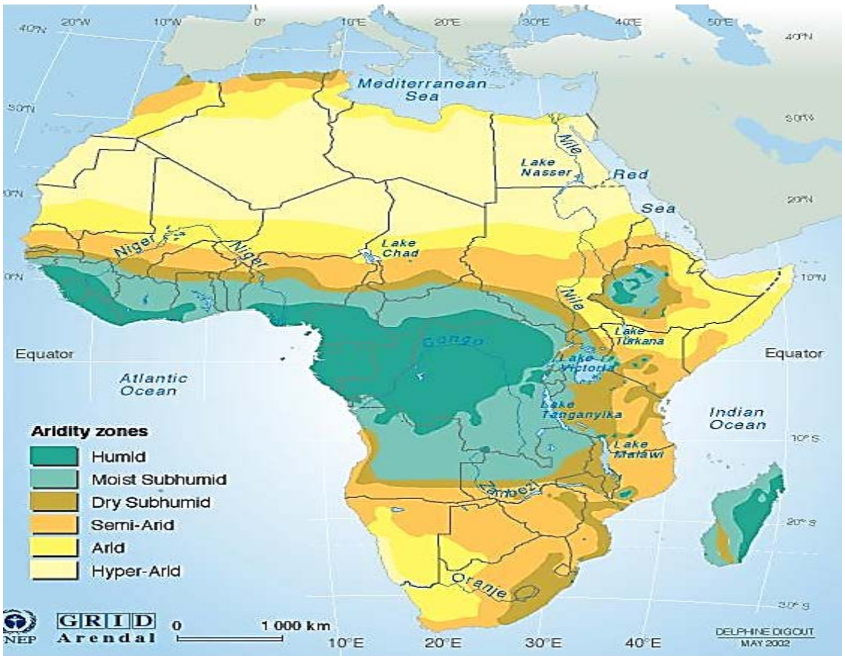

Figure 1: Aridity zones in Africa
[Source: World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), climate change 2001. Accessed February 2016]

2. MATERIALS AND METHOD

2.1 STUDY COUNTRY

Nigeria is situated in West African region of the tropical zone, it has latitude between 40N to 140N and longitudes of 202'E to 14030'E with an area of 923,770 km^2. The distance from North to South of Nigeria is 1,050 km while the optimum distance from east to west is 1,150 km. Nigeria is surrounded by Benin to the west, to the North and Northwest by Niger, to the Northeast by Chad, and to the east by Cameroon, while bordered by the Atlantic Ocean in Southern Nigeria. Nigeria's Land constitutes of dense rain forests and thick mangrove forests at south, and the close-to-desert situation at the northeastern part of the country (FAO AQUASTAT, 2005). The Nigeria's federal capital territory (F.C.T) is Abuja and is surrounded by 36 states that form up the country. Six states representing the water-scarce region were selected for this study including Zamfara, Kano, Katsina, Borno, Yobe and Sokoto.

The aridity zones in Nigeria are categorized into four (as in Figure 1) they are;

- Humid
- Moist sub-humid
- Dry sub-humid and
- Semi-arid

Among the four zones, the semi-arid zone has the highest rate of water scarcity. Therefore, this research was conducted in the most scarce water region of the northern part of Nigeria.

2.2 STUDY REGION

The water-scarce (semi-arid) region covered a huge part of Northern Nigeria and it includes Sahel savanna and Sudan bioclimatic regions. Rain-bearing dominated the climate, the dry, tropical continental North-easterly, and tropical maritime South Westerly air masses (Tarhule and Woo, 1998). Humidity discontinuity called Inter-tropical Discontinuity of a quasi-frontal zone formed by the air masses meeting which traveled over West Africa in reaction to the relative intenseness of the St. Helena and the Azores-Libyan system for tropical pressure (Anyadike, 1993). The rainy season begins at any moment, whenever the Inter-tropical Discontinuity migrates beyond Northward bound while retreating at the end Southward. Within June to September, the Inter-tropical discontinuity invade the North and the Northern Nigeria subsequently influenced by tropical maritime. Figure 2 shows the study region.

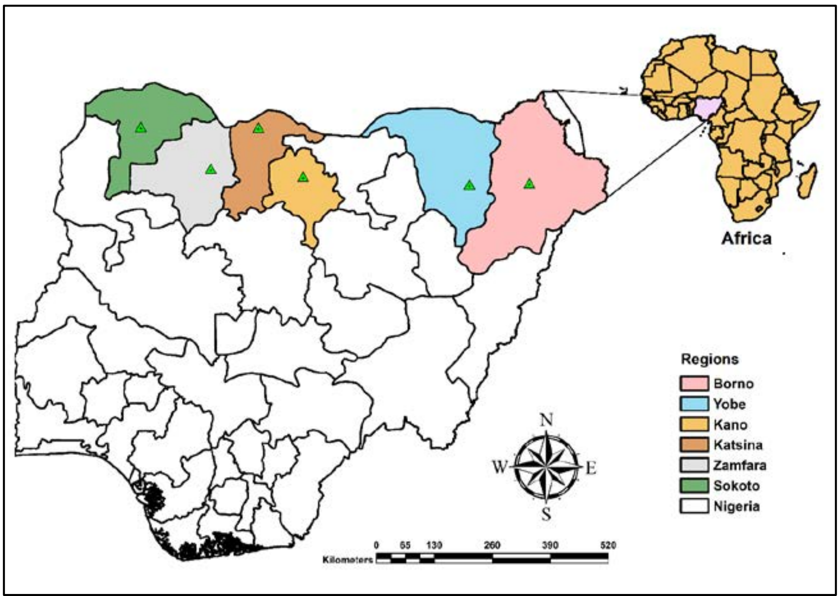

Figure 2: Map of Nigeria showing the study region
[Source: FAO AQUASTAT, 2005/Nigeria. Accessed February 2016]

In each of the states, 25 crops were selected. The crops are: Banana 1, Banana 2, Barley, Beans dry, Beans green, Cabbage, Citrus, Date palm, Groundnut, Maize, Mango, Millet, Pepper, Potato, Pulses, Rice, Sorghum, Soybean, Sugarcane, Sugarbeet, Tobacco, Tomato, Vegetables fresh nes, Wheat (spring) and Winter wheat. They were grouped into Cereals, Vegetables, Fruit and Nuts, Oilseed crops and other crops.

2.3 VIRTUAL WATER TRADE

The virtual water flows for the water-scarce region of Nigeria were calculated using the equations in Table 1:

Table 1: Virtual water trade calculations procedure.

Equation Name	Equation	
Virtual Water Content (VWC)	$ETc = Kc\ x\ ETo$	(1)
Reference evapotranspiration (ET_0)	$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34U_2)}$	(2)
Virtual Water Content (VWC)	$VWC[n,c] = \frac{CWR[n,c]}{CY[n,c]}$	(3)
Virtual Water Import (VWI)	$VWI\ [ni, c, t] = CT\ [ni, c, t]\ x\ VWC\ [n, c, \mathrm{t}]$	(4)
Virtual Water Export (VWE)	$VWE\ [ne, c, t] = CT\ [ne, c, t]\ x\ VWC\ [n, c, \mathrm{t}]$	(5)
Net Virtual Water Import (NVWI)	$NVWI = GVWI - GVWE$	(6)
Gross Virtual Water Import (GVWI)	$GVWI\ [ni, c, t] = \sum VWT\ [ni, c, t],$	(7)
Gross Virtual Water Export (NVWI)	$GVWE\ [ne, c, t] = \sum VWT\ [ne, c, t]$	(8)
Virtual Water Demand (VWD)	$VWD\ [c, t] = QP\ [c, t]\ x\ VWC\ [c, t]$	(9)
Water Footprint (WP)	$WP = VWD + NVWI$	(10)

where Kc is crop coefficient Rn = net radiation at the crop surface (MJ/m^2/day), G = soil heat flux density (MJ/m^2/day), T = mean daily air temperature at 2 m height (°C), U_2 = wind speed at 2 m height (m/s), e_s= saturation vapour pressure (kPa), e_a = actual vapour pressure (kPa), $(e_s - e_a)$ = saturation vapour pressure deficit (kPa), γ = slope vapour pressure curve (kPa/°C), Δ = psychrometric constant (kPa/°C), CWR represents crop water requirements in (m^3/ha), CY represent crop yield in (ton/ha), CT implies crop trade (ton/y), ne, ni, t implies, Nigeria export, Nigeria import, at time t, QP = Quantity produced (ton/yr), VWC = Virtual water content (m^3/ton).

2.4 CLIMATE DATA

CLIMWAT 2.0 for CROPWAT is a database software developed by FAO to provide a climate data that can be used as an input to CROPWAT (FAO, 2015). It provided data on temperatures, relative humidity, solar radiation, sunshine hours and wind speed. The software is available and can be downloaded from FAO's website. There are data for over 100 countries in the CLIMWAT database, and the data for Nigeria (as a case study) is inclusive.

2.5 CROP PARAMETERS

The crop parameters for which includes crop coefficient in the initial stage, middle stage, and late stage, and also root depth were adopted from CROPWAT/CLIMWAT database, planting date from FAO crop calendar. Crop yield data was taken from FAOSTAT database and is accessible via FAO's website (FAOSTAT, 2015).

The regional cultivated lands owing to the lack of the data is obtained by generating an equation considering the population distributions in the country.

2.6 PROPOSED METHODOLOGY

The step by step procedure applied for the virtual water trade in the water-scarce region of Nigeria were summarized in Figure 3.

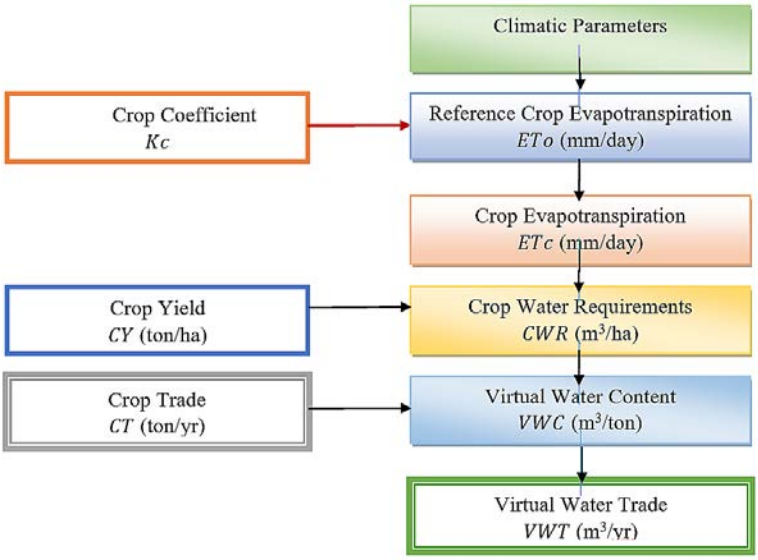

Figure 3: Flow chart showing the overall procedure for virtual water trade calculations

3. RESULTS AND DISCUSSION

Owing to the methodology and procedure explained, the results were obtained and presented. According to the results obtained in Table 2, crops grew in Kano have the highest virtual water content, consequently, consumed/required more water than any production area of the region. The next in terms of water consumption by crops is Borno then followed by Sokoto, Yobe, Zamfara, and lastly Katsina. The volume of Virtual water import in the water-scarce region of Nigeria in 2013 was far larger than that of virtual water export with 363 million m^3/yr import and 1 million m^3/yr export, from Yobe which was the least region in terms of virtual water. Being the highest crop virtual water content region, Kano also had the largest volume of virtual water for both imports and exports with 3.1 billion m^3/yr and 9.3 million m^3/yr, respectively (Table 2).

Even though Borno was the second highest virtual water content region, but it was the third with regards to crops' virtual water volume for both imports with 1.4 billion m^3/yr and exports with 4.4 million (Table 2). The average volume of gross virtual water imports between the 6 states in the region can be calculated from Table 2 as approximately 1.4 Gm^3/yr for 2013 while for export as 4.4 Mm^3/yr.

Table 2: Gross virtual water content, import, and export for water-scarce region of Nigeria.

State Name	GVWC (m^3/ton)	GVWI (m^3/yr)	GVWE (m^3/yr)
Zamfara	104,668	674,802,864	2,724,064
Kano	127,859	3,078,763,708	9,345,039
Katsina	102,012	1,601,627,723	5,473,175
Borno	127,205	1,443,513,905	4,400,463
Yobe	105,082	363,234,270	1,078,763
Sokoto	118,895	1,159,193,397	3,513,415
Total	685,721	8,321,135,867	26,534,919

Based on the result obtained and shown in Figure 4, the volume of virtual water produced was incomparably larger than both volumes of imports and exports in each region by providing more than two-thirds of the total virtual water volume of productions, imports, and exports.

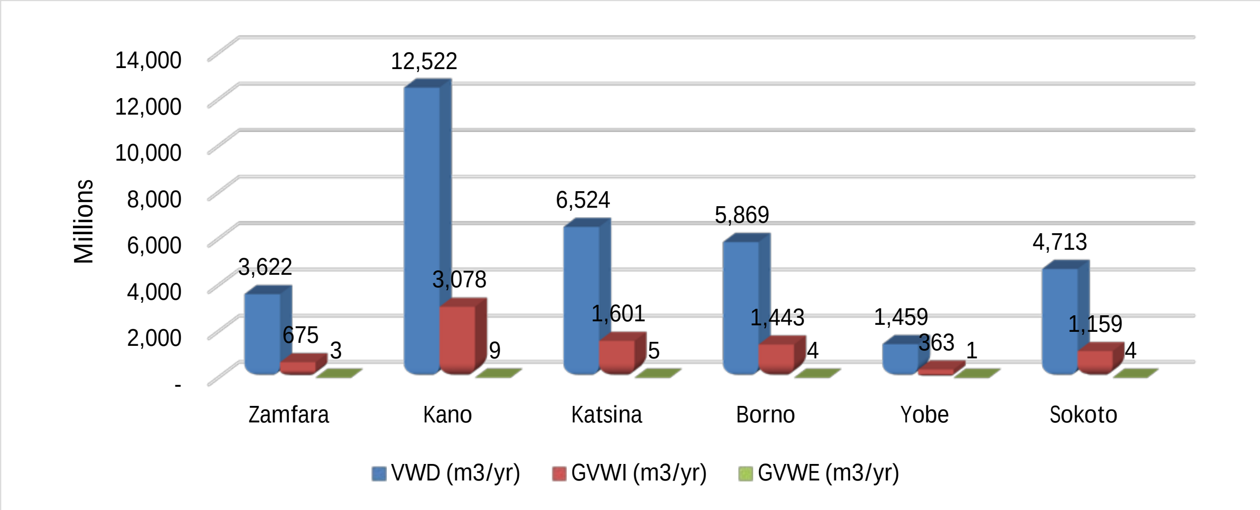

Figure 4: Variations in production, imports, and exports of virtual water.

Kano was by far the largest Green water region between the 6 states of the water-scarce region with 3.6 Gm^3/yr (Table 3). Zamafara came second with regards to Green water availability with a difference of over 2 billion cubic meters of water when compared to Kano. The third was Katsina, then Borno, Sokoto, and the highest Green water scarce region was Potiskum, with 459 Mm^3/yr (As seen in Table 3 and Figure5).

The region which consumed the largest Bluewater was Kano which happens to be the biggest consumer of crops virtual water with approximately 9 Gm^3/yr. The next in Bluewater consumption was Katsina, followed by Borno, Sokoto, Zamfara, and Yobe the lowest Green water region had the lowest Bluewater demand with 999 Mm^3/yr (As seen in Table 3 and Figure 5).

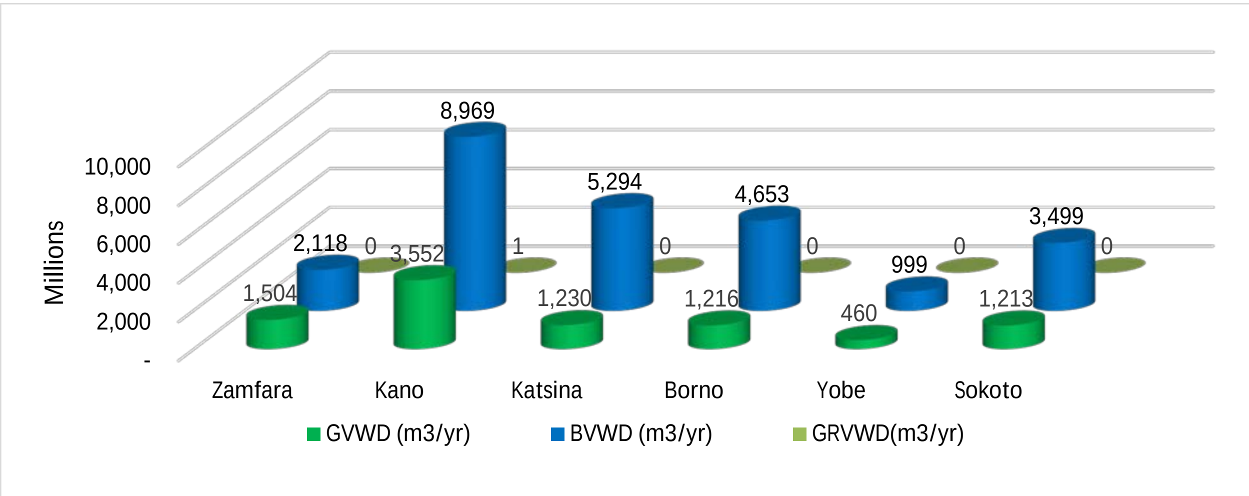

Figure 5: chart showing the contributions of Green, Blue and Greywater of water-scarce region of Nigeria in the year 2013.

Table 3: Summary of Green, Blue, and Greywater of each state of water-scarce region

State Name	GVWD (m^3/yr)	BVWD (m^3/yr)	GRVWD(m^3/yr)
Zamfara	1,504,465,401	2,117,760,631	159,620
Kano	3,551,547,344	8,969,386,987	609,755
Katsina	1,229,568,020	5,294,143,902	42,085
Borno	1,216,349,109	4,652,553,446	110,831
Yobe	459,737,955	999,386,669	9,856
Sokoto	1,213,002,117	3,499,408,156	218,988
Total	9,174,669,946	25,532,639,791	1,151,136

Grey water was less significant in crop productions. As a result, less than 0.01% of Greywater was used for the entire produced selected crops. Kano region has the highest virtual water volume of Greywater with 609.8 thousand m^3/yr, followed by Zamfara, Sokoto, Borno, Katsina, and the fewest Potiskum with 9.7 thousand m^3/yr (as shown in Table 3).

Considering the result obtained, Bluewater had the highest virtual water contributions to crops production in the region of Nigeria in 2013 (Figure 6). The overall Blue, Green and Greywater contributions are given in Figure 6. The Bluewater contributions for each region were Zamfara 58%, Kano 72%, Katsina 81%, Borno 79%, Yobe 68% and Sokoto 74%. However, Green water contributions were 42%, 28%, 19%, 21%, 32% and 26%, respectively. Greywater remained 0% throughout the region (as seen in Figure 6).

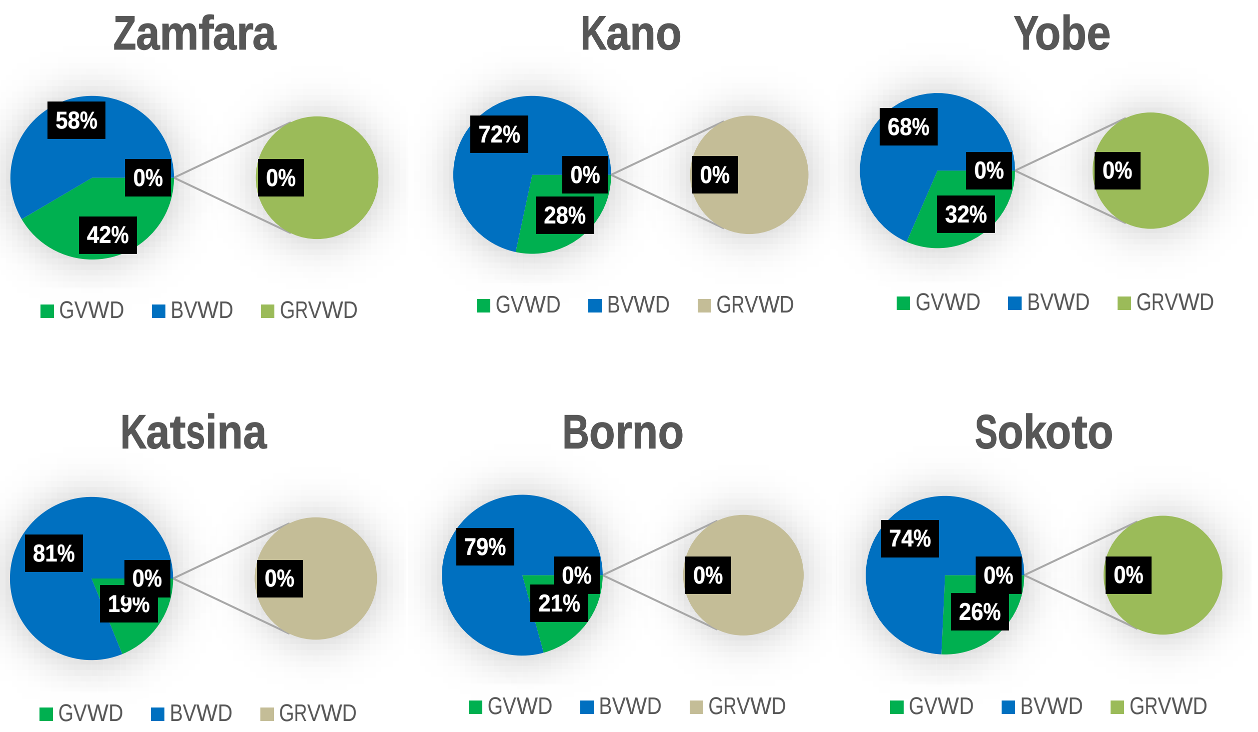

Figure 6: Regional percentage contributions of Green, Blue, and Greywater.

The water balance for all the region were positives (NVWI), implying that there were more imports than exports (Table 4). It can be calculated from Table 4 that the total volume of virtual water demand (virtual water produced) in the region is 81% of total water used (water footprint) while the water balance to be 19%. The region with a maximum volume of virtual water used was Kano with 15.6 Gm^3/yr and the minimum was Yobe with 1.8 Gm^3/yr (Table 4).

By vividly looking at table 4, it can be distinguished that production value is higher than import cost which in turn greater than export income. As may be predicted owing to its superiority production quantity, Kano region had the highest production value which stood at $842 million. Katsina reclaimed the next position with $511.9 million, Borno $375.5 million, Sokoto $326.7 million, Zamfara $292.2 million, and Yobe $109.9 million. Furthermore, Kano led in import cost with $261.5 million, joined behind by Katsina, Borno, Sokoto, Zamfara, and Yobe $34 million. The export income goes in a similar manner with $364.33 thousand, $221.4 thousand, $162.4 thousand, $141.3 thousand,

$126.4 thousand, and $47.5 thousand, respectively. The total production value was $2.5 billion, import cost $763.5 million, and export income $1.1 million (Table 4).

Table 4: Virtual water demand, water balance, water footprint, production value, import cost and export income of the water-scarce region of Nigeria for the year 2013

State Name	VWD (m^3/yr)	NVWI (m^3/yr)	WP (m^3/yr)	Production Value ($)	Import Cost ($)	Export Income ($)
Zamfara	3,622,385,651	672,078,800	4,294,464,451	292,209,166	90,761,786	126,448
Kano	12,521,544,086	3,069,418,670	15,590,962,756	842,028,048	261,539,746	364,333
Katsina	6,523,754,007	1,596,154,548	8,119,908,555	511,886,141	158,995,364	221,399
Borno	5,869,013,385	1,439,113,442	7,308,126,827	375,456,645	116,619,529	162,381
Yobe	1,459,134,481	362,155,507	1,821,289,989	109,901,608	34,135,493	47,483
Sokoto	4,712,629,262	1,155,679,982	5,868,309,244	326,694,329	101,473,382	141,259
Total	34,708,460,872	8,294,600,949	43,003,061,822	2,458,175,937	763,525,300	1,063,303

4. CONCLUSION

The virtual water content of crops varied in each of six water-scarce region of Nigeria due to the difference in climatological parameters. It was observed that some crops have high water requirements but due to their large crop yield, they possessed less virtual water content.

Based on the results obtained, it was deduced that the circumstances surrounding the virtual water trade volume could be classified into regulated and unregulated circumstances. The regulated circumstances include the types of crops and the quantities of their imports and exports. While, the unregulated circumstances are Temperatures (Max. and Min.), humidity, wind speed, sunshine hours and solar radiation.

With the advancement in technology and improved awareness in the agricultural production techniques, Nigeria may soon be self-sufficient in food production, as of 2013, production was averagely 81% of virtual water consumed with only 19% imported through virtual water trade. By immense contributions in food productions, the country within the semi-arid zone was able to domestically produced food crops which was consumed that amount to approximately $2.5 billion and also received internal income of $1.1 million but spent $763.5 million for food importation. As production capacity increases, there will be a rise in income generation and drought in food expenditure through import, and consequently, result in developmental growth.

As the world population continues to increase, and the global warming continues to be experienced, the scarcity of water tends to be ascending due to increasing water demand and drying of surface water. Hence, a care should be given to the regions necessitating the minimum blue water for cultivation of the crops in order not to depleting the water resources. Consequently, among the seven (6) states of the water-scarce region of Nigeria, Zamfara is the preferable state to grow crops due to it higher percentage of green water and minimum blue water used and therefore, reduced cost of blue water provision.

4.1 RECOMMENDATIONS

Upon completion of this research and the results obtained, the recommendations were drawn:

This research was limited to most water-scarce region of Nigeria, similar researches should be conducted in other regions to determine how the degree of aridity influence productions, imports, and exports of virtual water in Nigeria.

The research was specifically conducted for 2013, more researches should be done earlier and later than 2013, to figure out how a change in population (and possibly weather) affects the virtual water trade in Nigeria.

The study was based on 25 most populous crop products in Nigeria, more crops should be added for future researches.

The research was focused on crop products, same research should be conducted on livestock products to know the virtual water trade of livestock products in Nigeria.

In consideration of the obtained result in this research, where it is revealed that the majority of water used was blue water and continues crop productions will eventually exhaust the available blue water in the region, and thereby exposing people living in the areas to unnecessary hardship due to scarce water supply for daily use. Crop productions in the region should be stopped or reduce to the barest minimum. For the vulnerable people that cannot afford it or whose, their survival is dependent on farming, government should devise a means of supporting and empowering by enrolling them into skills acquisition programs, give them loans to start trade, and a lot of other initiatives that can provide for their daily needs. By so doing, the region will continue to be comfortable area for its dwellers by utilizing the little available water in the regions for consumptions and other day-to-day activities.

As the nation continue to experience a tremendous growth in population, the demand for food is also on the rise. Therefore, modern sophisticated means through advanced farming machines and equipments should be employed to enhance the current production capacity, so that the country could be self-reliable in crop productions and the money that could have been used for food imports will then be channeled into other infrastructural works for the benefits of the citizens.

5. REFERENCES

Allan, J. A. (1993). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. *Priorities for water resources allocation and management, 13, 26.*

Anyadike, R. N. C. (1993). Seasonal and annual rainfall variations over Nigeria. *International journal of climatology*, *13*(5), 567-580.

FAO (Food and Agricultural Organization of the United Nations) AQUASTAT (2005). Geography, Climate, and Population. FAO's Information System on Water and Agriculture [online]. Available at http://www.fao.org/nr/water/aquastat/countries_regions/nga/index.stm [accessed February 2016].

FAO (Food and Agricultural Organization of the United Nations) 2015. CLIMWAT 2.0 for CROPWAT: A Climatic database for Irrigation Planning and Management [online]. Available at http://www.fao.org/nr/water/infores_databases_climwat.html [accessed September 2015].

FAOSTAT (Food and Agricultural Organization of United Nations Statistical Division) 2015. Crop Yield Data [online]. Available at http://faostat3.fao.org/browse/Q/QC/E [accessed November 2015]

Hoekstra, A. Y. (2003). Virtual water: An introduction. *Virtual water trade*. Proceedings of the International Expert Meeting on Virtual Water Trade. Value of Water Research Report Series N0.12, 13. IHE Delft, The Netherlands.

Hoekstra, A. Y., & Hung, P. Q. (2005). Globalization of water resources: international virtual water flows in relation to crop trade. *Global environmental change*, *15*(1), 45-56.

Tarhule, A., & Woo, M. K. (1998). Changes in rainfall characteristics in northern Nigeria. *International Journal of Climatology*, *18*(11), 1261-1271.

World Meteorological Organization (WMO), United Nations Environmental Programme (UNEP), Climate Change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). http://www.grida.no/graphicslib/detail/aridity-zones_a6d3

Yang, H., Reichert, P., Abbaspour, K. C., & Zehnder, A. J. (2003). A water resources threshold and its implications for food security. *Environmental science & technology*, *37*(14), 3048-3054.

Yang, H., Wang, L., Abbaspour, K. C., & Zehnder, A. J. (2006). Virtual water trade: an assessment of water use efficiency in the international food trade. *Hydrology and Earth System Sciences Discussions*, *10*(3), 443-454.

Dr. Gozen Elkiran is an Associate Professor at Civil and Environmental Engineering Faculty, Near East University, Near East Boulevard, Nicosia, North Cyprus. He earned his bachelor and master's degree from Dokuz Eylul University. He received his PhD degree from Eastern Mediterranean University. His researches encompass hydraulics, hydrology and water resources engineering and applications.

Jazuli Abdullahi is a Research Assistant at Civil and Environmental Engineering Faculty, Near East University, Near East Boulevard, Nicosia, North Cyprus. His researches include water modeling and analysis.