The 2017 tomato policy: assessing the impact of tomato paste production on Nigeria's freshwater

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Abstract: **The overall goal of the 2017 Nigeria tomato policy is to boost the local production of fresh tomatoes, stop importation, and enhance the domestic production of tomato paste. However, from the water perspective, the impact of tomato paste (double concentrate) production on Nigeria's freshwater resources remains unclear. Using the water footprint-resource sustainability calculation method, results showedthat the pressure exerted by tomato paste production amounted to 1518in the Lower Niger (LN) drainage basin and 1734 m^3/t in the Lake Chad (LC) drainage basin. Converting 60 per cent of the fresh tomatoes to tomato pastewill consume about 8per cent of the freshwater of the LN drainage basin per annum or 59per cent of that of LC. This is after accounting for the presumed minimum environmental flow requirement. With over 20 per cent usage, tomato paste production in the LC drainage basin in Nigeria is capable of contributing to freshwater scarcity. To reduce the impact of tomato paste production on Nigeria's freshwater, improvementson tomato yield are suggested.**

Keywords**: Fresh tomato; Water use; Tomato paste; Water footprinting; Water stress; Freshwater scarcity; Nigeria**

I. INTRODUCTION

Worldwide, tomato, *Lycopersicon esculentum* Mill., is the second most widely consumed vegetable after potato. To produce a fruit, the tomato plant requires between 90 and 150 days (Behzadian et al., 2015). Between 80 and 90 per cent of the fruit is water (Food and Agriculture of the United Nations (FAO), 2020a). Global tomato production was 182.26 million tonnes in 2018, with China accounting for the largest, 33.81 per cent (FAO, 2019). Statistics indicates that fresh tomato production is growing in Nigeria (Figure 1). In 2018, Nigeria was the 12th largest producer and the second largest producer in Africa after Egypt. Tomato, which can be consumed fresh, requires a well-drained, light loam soil with pH of 5 to 7 (FAO, 2020b). Crop yield in Nigeria varied from 9.8 t/hectare (ha) in 1961, highest at 10.4 t/ha in 1995, to its lowest of 3.7 t/ha in 2013 (FAO, 2019). Production in 2018 was 3.91 million t, highest at 4.23 million t in 2015 (Figure 1). On average, tomato consumption in Nigeria was 12 kg per capita in 2016 (PricewaterhouseCoopers (PwC) Nigeria, 2018). For the 193 million people in 2019, tomato demand amounted to 2.32 million tonnes (t) per annum. Notwithstanding this, national demand for fresh tomatoes has been estimated at 2 to 3 million t per annum (Ugonna et al., 2015). Because of production shortages and postharvest losses (estimated at over 45 per cent (PwC Nigeria, 2018)), Nigeria continues to depend on the importation of tomato paste to meet the demand-supply gap.

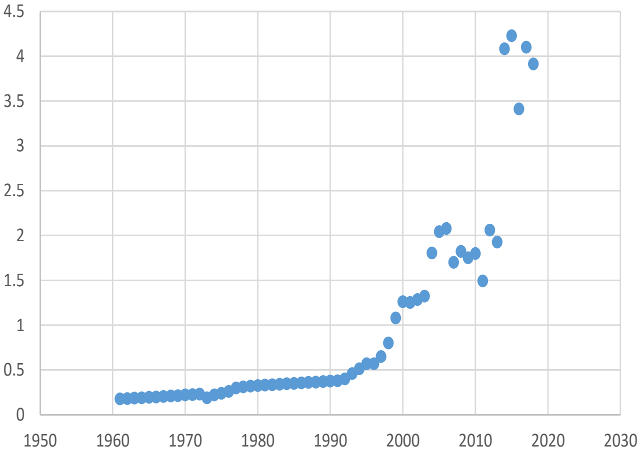

Fig. 1: Fresh tomato production in Nigeria between 1961 and 2018 (million t)(Data source: FAO, 2019)

Water is central to crop production and processing as well as to socio-economic development. Its subtractive property places an important emphasis on its availability for other uses and supply. While Nigeria's freshwater is limited, the per capita inland freshwater availability is decreasing. Statistics revealed that it decreased from 4,699 in 1962 (World Bank, 2020) to 1,800 cubic metres (m^3) per capita in 2010. It is expected to further decrease to 1,100 m^3 per capita in 2030 (FMWR, 2014). By 2044, per capita water use is expected to exceed per capita inland freshwater availability. Although Nigeria's agriculture is still largely rainfed, both the agriculture and the municipal (including domestic, industrial and commercial) water supplies are projected to account for 16.6 x 10^9 m^3 of the country's freshwater by 2030 (FMWR, 2014). Therefore, notable factors exercebating the pressures on Nigeria's freshwater include demographic, social and economic, technological, laws and policies, unsustainable use, changes in diet, pollution, climate change and climate variability. These pressures have among others contributed to the growing water scarcity and declining water quality being experienced in some river basins in Nigeria. However, amidst all this, there is still an urgent need to feed an increasing population projected to reach 389 million by 2050 (Federal Ministry of Water Resources (FMWR), 2014).

The economic diversification policy of the federal government introduced in 2016 has placed an important emphasis on the need for value addition to agricultural produce in Nigeria. In line with this policy, a new tomato policy was announced by the federal government in 2017. The policy, which became effective on 7 May 2017, aims among others to increase the local production of fresh tomatoes, tomato concentrates,and stop the importation of tomato paste, powder and concentrate. While the policy is silent on any specific production targets, it is expected that boosting fresh tomato production as well as diversifying the Nigerian economy from oil to non-oil will further impact freshwater availability and supply.At present little is known about the impact of tomato cultivation and processing on Nigeria's freshwater resources. This is the knowledge gap the study seeks to fill. The study aims to estimate the amount of freshwater needed for the production of tomato paste and assess the impact (defined as a measure of use relative to availability after accounting for minimum environmental flow) of this consumption on Nigeria's freshwater resources. Despite the importance of the tomato policy to the overall socio-economic development of Nigeria, it is envisaged that a failure to manage Nigeria's freshwater optimally may push the resource beyond its sustainable limits. Therefore, freeing water (especially the blue water resource) from agricultureand industrial sector will make water available for use in other sectors. To realise this and strike a balance between resource sustainability and development will therefore require a better understanding of the impacts of agricultural crop growth and processing on freshwater resource. This will help create a shift towards sustainable agriculture and food production systems and help inform policy formulation and practical application of integrated water resources management at the river basin level in Nigeria.

Various studies have looked at the impacts of crops and crop products on freshwater using the water footprint as an analytical tool. Examples of these include tomato (Evangelou et al., 2016; Ventrella et al., 2018), gazpacho - a chilled vegetable soup (Ibáñez et al., 2017), olive (Pellegrini et al., 2015), vegetables (Roux et al., 2016; Nyambo and Wakindiki, 2015), cereals and vegetables (Huang et al., 2013), and diets (Harris et al., 2019). However, in the case of Nigeria, that of tomato paste is less investigated. Scholars (for example, Ridoutt et al., 2009; Ridoutt and Pfister, 2010) point out that water footprint viewed alone does not reveal impact indepth, and argue that the concept comes alive when viewed relative to freshwater availability. Therefore, this study employs the water footprint to calculate the quantity of freshwater required to produce and process fresh tomato to tomato paste and the resource sustainability calculation method to examine the impact of this production on Nigeria's freshwater. The outcome of this study, which also contributes to the growing database of water footprint of arable crops, is beneficial to policy makers in Nigeria and elsewhere, tomato growers, intending tomato paste processors, and researchers as well. The information provided will help policy makers and planners formulate appropriate policies and plans needed to ensure a more efficient use of freshwater resources through improvements in water use efficiency, water productivity (defined as more crop per unit of water used), and reduction in the impacts of crop production and processing on freshwater resources.

II. DATA AND ANALYSIS

This study evaluates the impact of tomato paste production on Nigeria's freshwater using the water footprint-resource sustainability calculation method from the Nigerian perspective. The water footprint is the total volume of freshwater (in m^3) required to produce and/or consume a good or service (Chapagain et al., 2005). The concept assumes that an impact on freshwater resource is established when the water spent in the productionand/or consumption of a particular product or service is not available for use elsewhere.

Out of the 36 States in Nigeria, there are 9 major tomato growing areas (Table 1). As illustrated in Table 1, tomato is mostly grown in the northern part of Nigeria which largely falls within the Lower Niger (LN) drainage basin and the Lake Chad (LC) drainage basin. These major growing areas are responsible for almost 80 per cent of all the fresh tomatoes being produced in Nigeria. Tomato cultivation is done during the dry season (November–April) and as rainfed during the rainy season (July–October). Dry season cultivation is the main production period with higher yields and area under cultivation. This study focussed on the dry season farming. It is estimated that 60 per cent of the cultivated areas during the dry season are under irrigation within the large swampy (fadama) areas. Depending on location and cultivar, tomato is planted in these growing areas starting from August (before the commencement of the dry season)and harvested as from January. Between January and April, the supply of fresh tomatoes is high in Nigeria (Ugonna et al., 2015).

Table 1: The major tomato growing areas in Nigeria

Growing area	Average production(x 10^3 t/year)	% contribution to national production	Drainage basin
Sokoto	200-400	13.9	Lower Niger
Zamfara	100-200	8.5	
Katsina	100-200	6.4	
Kaduna	200-500	18.1	
Taraba	50-100	4.3	
Kano	200-500	17.1	Chad basin
Jigawa	100-200	5.3	
Gombe	25-50	2.1	
Bauchi	50-100	4.3	LC/LN*

*About 60 percent of Bauchi State contribute to the LC drainage basin (expecially the parts being drained by the Jama'are and Misau River systems, while the remaining 40 per cent contribute to the LNdrainage basin (expecially the parts being drained by the Gongola River system)

(Sources: van der Waal, 2015; FMWR, 2016; National Bureau of Statistics (NBS), 2012; Authors' contribution)

From field to final tomato paste, tomato passes through a sequence of production stages with different effects on the freshwater system. On the one hand are the impacts of crop growth and processing on freshwater depletion, and on the other hand are the impacts of crop growth and processing on freshwater quality. The amount of freshwater required to produce fresh tomato in Nigeria has three components: (a) the use of effective rainfall (or green water), (b) the use of irrigation water (or blue water) – water abstracted from surface and/or subsurface sources, and (c) the use of dilution water (or grey water) - resulting from the leaching of fertilizers, herbicides, and pesticides/insecticides into the freshwater environment (in-situ freshwater depletion through quality degradation). Generally speaking, there are two types of tomato under cultivation: determinates (which produce through one cycle like annual crops) and indeterminates (which produce over many cycles as in perennial crops). The types of tomatoes under cultivation in Nigeria are mostly the determinate cultivars.

Owing to a paucity of data on the field-level water requirements for tomato crop growth in Nigeria, the CROPWAT model (CropWat 8.0 for windows) developed by FAO Water was used to estimate the amount of freshwater required to crop tomato at the field level per growing area. The model utilisedthe FAO Penman–Monteith formula to calculate the reference crop evapotranspiration (ET_o) as described in Allen et al. (1998). Per ha of a single-cropped field, the model calculated the crop water requirement (CWR) by multiplying the crop coeffiecient (Kc, dimensionless) with the reference crop evapotranspiration (ET_o). The CWR was assumed to be fully met. The CROPWAT model has an inbuilt option to estimate the effective rain (defined as the fraction of rainwater available for crop use). The study selected the United States Department of Agriculture Soil Conservation (USDA S. C.) method, being one of the mostly used (Chapagain and Orr, 2008), in estimating effective rain. To calculate ET_oin the model, the climate and the rain data of the major tomato growing areas were taken from the CLIMWAT 2.0 database for CROPWAT. For a growing area without a meteorological station, weather parameters from the nearest station were used.

To estimate CWR, data on crop coefficients for tomato crop were obtained from Allen et al. (1998). The Kc values for tomato crop were taken as 0.60 (initial), 1.15 (mid-season), 0.80 (late), and 0.6 m (maximum crop height). The length of crop development stages (adjusted for local conditions) as 30 days (initial), 45 days (development), 45 days (mid-stage) and 30 days (late). Since certain fraction of the tomato produced in the fadama areas during the dry season in the growing areas is irrigated (about 60 per cent), the actual irrigation water used was taken as equal to this fraction times the net irrigation water requirements obtained from CROPWAT. Soil parameters are also an important input in estimating the CWR. However, because soil types in the major tomato growing areas were mixed, the medium soil data in the CROPWAT-FAO database were used. For all the growing areas (Table 1), the planting date was set at end of August. In the model, a 10-days time step was used to calculate the effective rain and the irrigation water requirements. If the entire CWR was met by effective rain, the irrigation water requirement (or blue water use) became zero. The model ultimately used the effective rain to determine the crop irrigation water requirement per time step. The green water use of fresh tomato was obtained as the ratio of the effective rainfall to the crop yield, while the blue water use of tomato crop was obtained as the ratio of the actual irrigation water used to the crop yield. Data on tomato production per unit area of land (t/ha) were obtained from the FAOSTAT database averaged for the period 2010 to 2018 (Table 2). Crop yield during the dry season for the major growing areas was estimated at 250 per cent of annual production. The study assumed that the average tomato yield in the various major growing areas did not vary much.

Table 2: Tomato yield and cropping area in Nigeria

Year	Yield (t/ha)	Cropping area (x 10^6 ha)
2010	6.60	0.27
2011	5.69	0.29
2012	4.39	0.47
2013	3.72	0.52
2014	7.54	0.54
2016	7.59	0.56
2016	6.67	0.83
2017	6.96	0.66
2018	6.44	0.61
Mean + SD	6.18 ± 1.34	0.53 ± 0.17

SD indicates standard deviation
(Source: FAO, 2019)

In the analysis of grey water use, the total amount of fertilizer applied (t/year) was calculated as:

average fertilizer application rate (t/ha) x average cropping area for the major tomato growing areas in Nigeria (ha/year)

The average fertilizer consumption in Nigeria was 5.5 kg/ha of NPK in 2016 (Indexmundi, 2020). Owing to a dearth of data, this consumption rate was roughly assumed for tomato cultivation in the major growing areas in Nigeria. The average cropping area was 0.53 x 10^6 ha/year between 2010 and 2018 (Table 2), with the major growing areas accounting for roughly 80 per cent of the total (75 per cent in the Lower Niger drainage basin and 25 per cent in the Lake Chad). The quantity of water required to bring the nitrate-polluted water to the permissible limit of 10 mg/l (nitrate, measured as nitrogen (N)) (United States Environmental Protection Agency (US EPA), 2020) was evaluated as (Chapagain et al., 2005):

total dilution water (m^3/year) = amount of nitrogen leached (t/year)/the permissible limit in freshwater bodies (t/m^3)

It was assumed that the tomato crop received the same quantity of nitrogen fertilizer per ha. On average, about 20 per cent of the applied nitrogen fertilizer were assumed lost to the environment through leaching and others. Following Chapagain et al. (2005), the quantity of nitrogen reaching the water bodies was assumed as 10 per cent of the average application rate. Per ha, the grey water use was obtained by dividing the total dilution water needed to dilute the nitrate-polluted freshwater (m^3/ha) to permissible limits with the crop yield (t/ha). In the analysis, the study did not consider multi-cropping practices, while the natural nitrate concentrations in the dilution water were assumed to be negligible. Also, the effect of pesticides/insecticides and herbicides in the cultivation of tomato on freshwater was ignored due to a paucity of data. To thin these pollutants to safe limits, this study acknowledges that the volume of freshwater required may be substantial. An implication of this is that the study has underestimated the grey water footprint.

Data on tomato processing were obtained from the laboratory analysis carried out in October 2019. The processing steps described in Adegbola et al. (2012) were followed. Tomato processing has two major impacts on freshwater. One, the amount of freshwater (blue water) required to process fruits to paste (freshwater depletion), and two, the amount of freshwater (blue water) required to dilute processing waste flows to safe limits (freshwater consumption through quality degradation). In the study, the latter was ignored because of the possibility of being reused in-situ. Following the methodology described in Chapagain and Hoekstra (2010) and used by others (for example, Adeoti (2010a)), the product fraction (pf), for each processing step, was calculated as the ratio of the resulting product to the original (or source) product. The water footprint of the resulting product (in m^3/t) was calculated by dividing the water footprint of the source product with the pf. This made the water footprint of the resulting product to be larger than that of the source product. Since tomato paste production requires process water (blue water) (a. water for tomato washing, and b. water for blanching), the amount of blue water required (in m^3/t of source product) was added to the water footprint value of the sourceproduct before evaluating the water footprint of the resulting product. In this study, the water footprint of tomato paste production in the growing areas in Nigeria was taken as the sum of the green, blue, grey footprints and processing water (blue water) use (Figure 2).

Since the water footprint metric measured alone provides insufficient indicator of impact on freshwater resource (Ridoutt and Pfister, 2010; Ridoutt et al., 2009), this was supplemented with the resource sustainability calculation method. Therefore, the concept comes to live when viewed in conjunction with the total annual internal renewable freshwater availability in each of the growing areas' drainage basins. In this study, the stress or pressure (refered to as the quantity of freshwater consumed relative to availability) imposed on the freshwater resource (%),β, due to tomato paste production, was calculated using:

$$\frac{c}{0.4R_{sw}} \text{x } 100\ (\%),$$

if 60 per cent of the average total internal renewable surface water flow per drainage area was reserved to maintain the environment[a](minimum environmental flow) as suggested by the Organisation for Economic Co-operation and Development (Policy Research Initiative (PRI) (2007). c is the amount of freshwater required to produce tomato paste in the drainage basin (m^3/yr), and R_{sw} is the average total annual internally generated renewable surface water flow per drainage basin (see Table 3). The environment is totally stressed if β = 100 % (available freshwater fully consumed), otherwise not, if β = 0 % (no consumption). Therefore, β = 100 %, if $c \geq 0.4R_{sw}$, and β = 0 %, if c = 0. As a proxy for freshwater stress, the resource sustainability indicator assumes that the greater the consumption, the more the pressure placed on the freshwater systems.

[a] The Nigeria National Water Resources Policy of 2016, though considered environmental flow as the first priority, the policy document did not allocate any percentage of internal renewable surface water flow to the environment. The National Water Resources Bill of 2018, though not yet binding, was also silent on the issue of allocating certain amount of internally generated surface water flow to the environment. As at the time of this paper, there was no official effort put in place to quantify the minimum stream flow requirement in Nigeria.

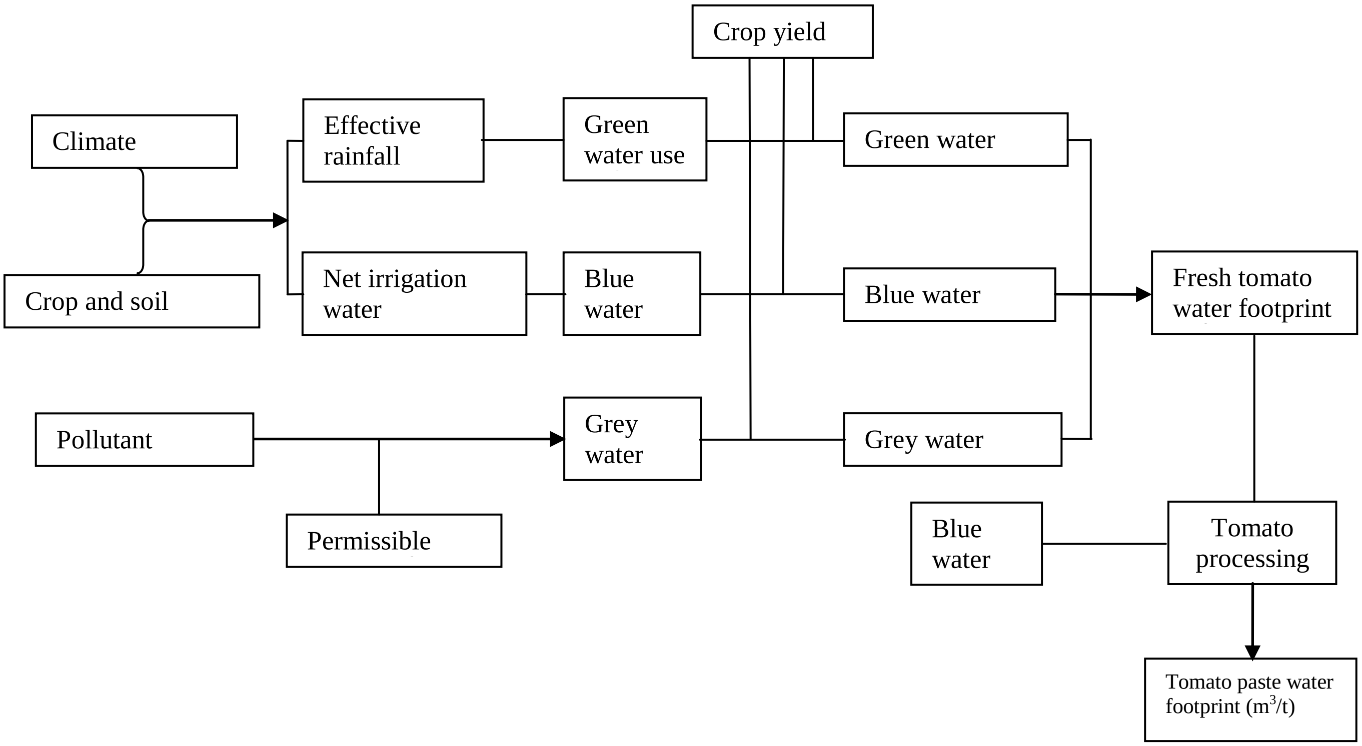

Fig. 2: Approach used for calculating the water footprint of tomato paste (Modified from Chapagain and Orr, 2008)

Table 3: The freshwater situations of the drainage basins in Nigeria

Drainage basin	Land area drained (%)	Mean annual rainfall (mm/year)	Internally generated renewable surface water flow (x 10^9 m^3/year)
Lower Niger	63	1,293	145.2
Lake Chad	20	610	7.2
Western littoral	11	1,541	35.6
Eastern littoral	6	2,106	56.2

(Sources: Adeoti, 2010b; FMWR, 2014)

Therefore, the resource sustainability analysis compared availability to withdrawals in each of the drainage basin where tomato is cropped and processed. This helped determine whether demand for freshwater for tomato paste production could be met in a sustainable manner by respecting a fair freshwater share to the environment. In calculating the stress value, the green, blue and grey water footprints are of concern to the ecosystem if measured at a basin scale. As also noted by Hoekstra (2016), this study holds that green water use contributes to water scarcity. To be meaningful, as suggested by Alcamo et al. (2003), the resource sustainability (a ratio of withdrawals to availability) indicator was evaluated at a river basin scale. This is because of the uneven spatial and temporal distribution of water at the country level. In the case of Nigeria, there are four natural drainage basin areas (Table 3). The total internal renewable surface water resources potential amounted to 244 x 10^9 m^3/year (FMWR, 2014). This study assumes consumption above 20 per cent of available freshwater resource as capable of contributing to freshwater scarcity, otherwise not. Freshwater availability was calculated as the volume of internally generated renewable surface water flow remaining after accounting for the presumed minimum environmental flow requirement. The major tomato growing areas are mostly located in the LN and in the LC drainage basins (see Table 1).

III. RESULTS AND DISCUSSION

Table 4 presents the results of the CROPWAT model and the grey water estimation. In the two drainage basins, the blue water footprint was the largest (Table 4). With one tomato fruit weighing averagely 57.4 g (data not shown), this translated to 20.6 litres per tomato in the LN drainage basin, or 23.5 litres per tomato in the LCdrainage basin. This revealed that it cost more water to produce a fresh tomato fruit in the LCdrainage basin than in the LNdrainage basin. The calculation of green and blue water footprints was mainly influenced by: (a) evaporative demand in the cropping areas, which varied from an average value of 4.30 to 6.18 mm/day (in the LN) and from 6.18 to 6.58 mm/day (in the LC), (b) the total amount of rain, which varied from 588.0 to 1192.0 mm (in the LN) and from 696.4 to 981.0 mm (in the LC), and (c) the dry season average crop yield of 15.5 t/ha, which was dependent on crop field management and variety. The green water footprint signifies the relative effect of the production of fresh tomato on soil moisture.

Table 4: Fresh tomato water footprint in Nigeria

Drainage basin	Green water (m^3/t)	Blue water (m^3/t)	Grey water (m^3/t)	Total (m^3/t)
Lower Niger	105.2	249.8	3.6	358.6
Lake Chad	83.6	322.8	3.6	410.0

Comparing the quantity of water required to produce fresh tomatoesin the LN drainage basin (358.6 m^3/t) or in the LC drainage basin (410.0 m^3/t) with that of Spain (81.3 m^3/t) as evaluated in Chapagain and Orr (2008), those of Nigeria were4.4and 5.0 times larger, respectively. In the central Greece Pinios river basin, Evangelou et al. (2016) found this value to be 61 m^3/t. In the case of Italy, Aldaya and Hoekstra (2010) evaluated the water footprint of fresh tomatoes to be 114 m^3/t. Between production in Nigeria and in these countries (cited above), two major factors accounted for the difference. They are: (a) the climatic conditions vis-à-vis evaporative demand, and (b) crop yield.In the case of yield for example, the average crop yield between year 2000 and 2004in Nigeria was 6.4 t/ha. This is roughly 89 per cent lower than that of Spain estimated at 60.0 t/ha (for open systems) over the same period (Chapagain and Orr, 2008). Therefore, because of low evaporative demand and high yield, it can be interpreted that the production of fresh tomato fruits consumed less water in Spain than in Nigeria. The fresh tomato water footprint values obtained in this study were higher than the global average value of 214 m^3/t reported in Mekonmen and Hoekstra (2011). Soils, local climatic conditions, yield, time of planting, pollutant parameters, embedded assumptions, as well as water management practices may be held responsible for the difference.

From fresh tomato of 9.3 ± 2.5 kg, the resulting tomato paste amounted to 2.2 ± 0.7 kg (Figure 3). This translated to a product yield of 23.6 per cent of fresh tomato. Aldaya and Hoekstra (2010) found this value to be 30 per cent in the case of tomato purée. Therefore, from source (fresh tomato) to end product (tomato paste), there was weight reduction. The pressure exerted by tomato paste production on freshwater in the LN translated to 1517.5 m^3/t (Figure 4) or 1734.4m^3/t in the LC (chart not shown). In the case of LN, about 69.8per cent of this impact was due to blue water consumption, while about 29.3per cent was due to the green water consumption. Inthe LC drainage basin, about 78.8per cent of this impact resulted from blue water consumption, while about 20.3per cent resulted from green water consumption (Table 5). The analysis revealed that the water footprint of tomato paste production was majorly governed by the water footprint of fresh tomato production. With the assumed same processing format for tomato in both drainage basins (Figure 3), to produce 1.0 kg of tomato paste (consisting of 30 per cent solids), about 4.23 kg of fresh tomato (at 87 ± 6.0 per cent moisture content (wet basis)) will be needed. The study of Behzadian et al. (2015)reported the global average water footprint for tomato paste to be 855 m^3/t. This value is lesser than the ones obtained in this study. Although the use of national average climate data for estimating products water footprint has been criticised (Chapagain and Orr, 2008), climate, soil, cultivar, and pollutant parameters as well as embedded assumptions have a direct impact on water footprint calculations, and may account for the difference. Besides this, the relatively high water footprint of tomato paste production in Nigeria was affected by the relatively low yield and high moisture content of fresh tomatoes (see, for example, the aspect of filtration in Figures 3 and 4).

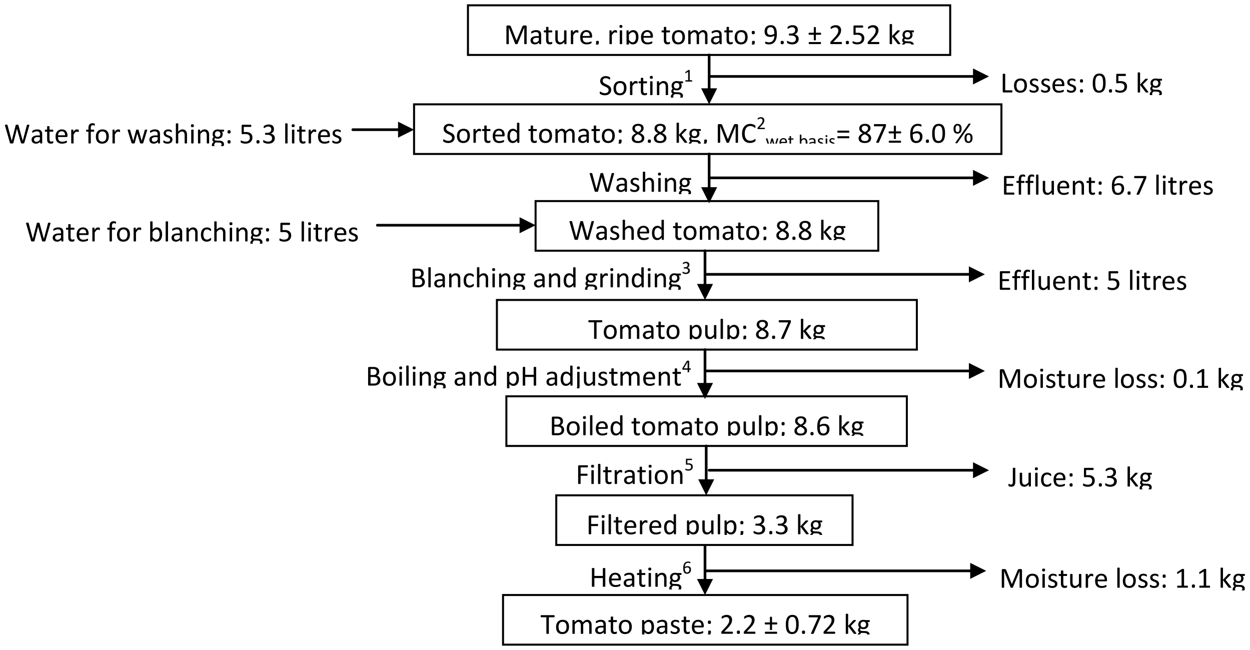

Fig. 3: Tomato paste processing step(mean value, n = 3)

[1] Removal of mouldy, damaged and rotten tomatoes

[2] The moisture content (in wet basis) of fresh tomatoes was measured as follows: to avoid moisture loss during size reduction, the fresh tomato samples were put in nylon bags and kept in a deep freezer for 36 hours. The frozen samples were removed from the freezer and some quantities were quickly grated manually. Samples weighing 5 g each were dried to constant weight in an oven at 60◦C.

[3] Boiled in water for 5 minutes and ground using an attrition grinding machine

[4] Boiled for 25 minutes. No pH correction was carried out because the mean pH value, 2.44, was below 4.0

[5] Juice was separated from the pulp using a cotton sack. The sack was left for one hour for the water to drain

[6] Heating was carried out slowly with constant stirring to prevent the pulp from burning until 30 per cent solids were obtained (classified as double concentratetomato paste . Also being referred to as tomato purée in the UK). The double concentrate is the most common form of tomato paste.

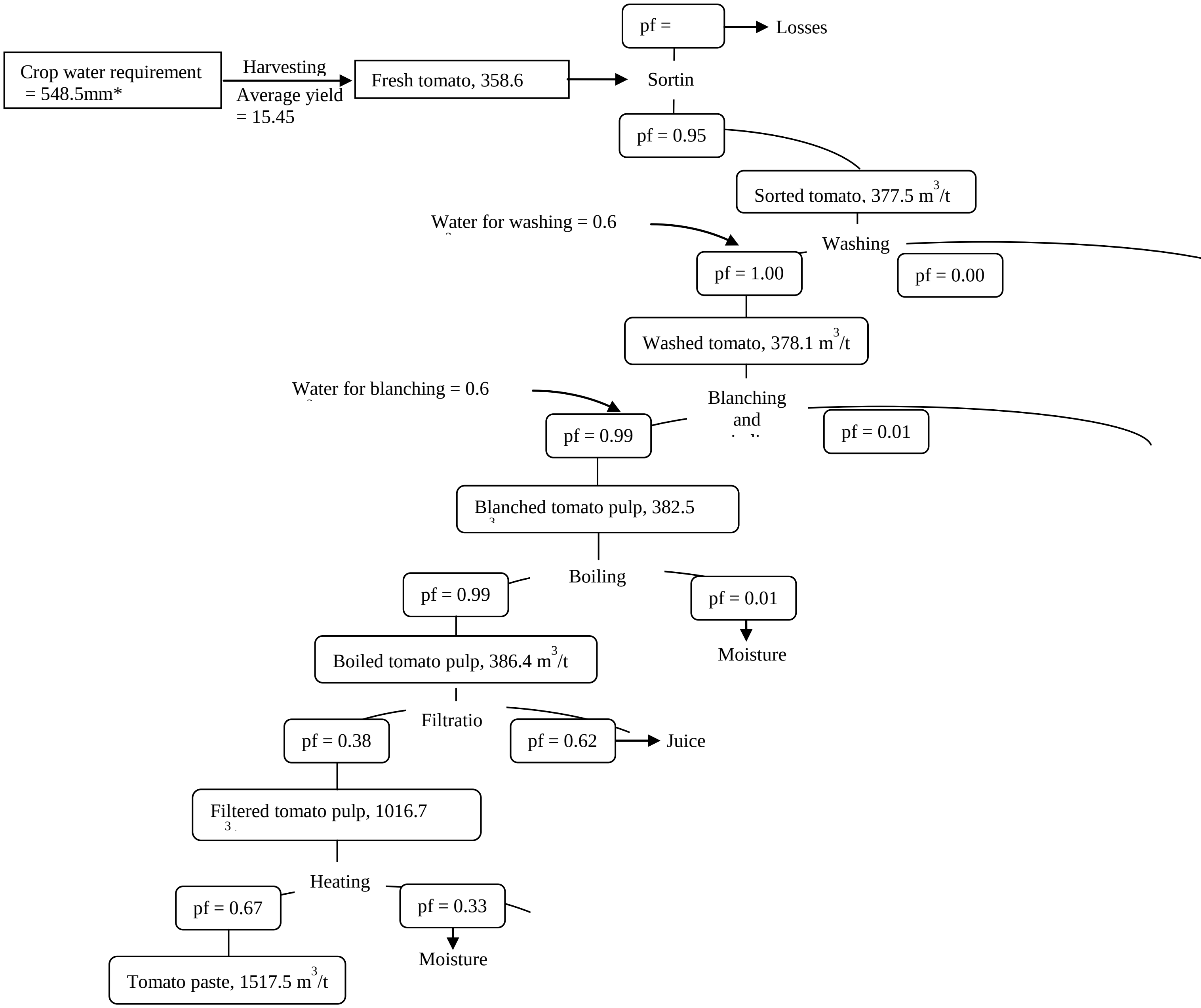

Fig. 4: The processing tree for tomato paste, showing the pf and the water footprint per processing step (mean value, n = 3). Estimating tomato paste water footprint in the LC drainage basin followed the same procedure.

*Averaged for the major tomato growing areas in the LN drainage basin (see Table 1)

**Average value2010 to 2018 (see Table 2), adjusted for the major growing areas

Table 5: Tomato paste water consumption in Nigeria

Drainage basin	Green water (m^3/t)	Blue water (m^3/t)	Grey water (m^3/t)*	Total (m^3/t)
Lower Niger	443.8	1058.5	15.2	1517.5
Lake Chad	352.7	1366.5	15.2	1734.4

*Did not include processing grey water footprint. The study assumed the process

water will be filtered and reused in-situ

As illustrated in Table 5, the blue and green pillars of water consumption will significantly affect the freshwater systems of the two drainage basins in different ways. For example, the consumption of green and blue water at a rate more than their immediate replacement ability will cause resource depletion and limit availability to other water users. As noted by Dabrowski et al. (2009), blue water has a greater alternatecost connected with its use and thus impacts more directly on scarcitythan green water. In this study, the alternate cost of the blue water used during crop growth is high, because the blue water resources has many important alternative uses in the drainage areas. The blue water can be held in wells and streams, pumped to meet domestic, commercial, and industrial water use. Unlike rainwater that falls by gravity, held in the soil pores for crop growth, blue water has supply cost associated with its use.

To provide a quantitative indicator of water stress, the resource sustainability analysis was used to serve as a relevant metric for calculating the pressure tomato paste production exertedon Nigeria’s freshwater resources. Owing to a paucity of data, for the drainage basins,the study assumed 60 per cent of the fresh tomatoes produced willbe processed to paste, translating to 2.95x 10^6t/year in the LN or 0.98 x 10^6 t/year in the LC. Considering the above and the data presented in Table5 together, the total freshwater use for tomato paste production, c, would amount to 4.5x 10^9 m^3/year (in the LN) or 1.7x 10^9 m^3/year (in the LC drainage basin). This usage amounted to 7.7 per cent of LN freshwater per annumor 59.2 per cent of LCfreshwater per annum. With over 20 per cent consumed, this indicates that tomato paste production in the LCdrainage basin has the possibility of contributing to freshwater scarcity. In both drainage basins, the pressure imposed on freshwater will rise with an increase in the proportion of fresh tomato being processed to paste and if water use due to transportation and energy inputs is considered.

In summary, (a) to produce 1 t of tomato paste (at 30 per cent solids), about 4.23 t of fresh tomato (at 87 per cent MC (wet basis) will be needed, (b) the pressure exerted by tomato paste on LN and LC freshwater resources amounted to 1518and 1734 m^3/t, respectively, and (c) under the assumptions made tomato paste production willexert 8 per cent stress on LN freshwater resource per annumor 59 per cent on LCfreshwater resource per annum. Therefore, a product that requires a larger amount of water to produce is of higher resource burden than when the same product requiresa smaller amount of water to produce. With over 20 per cent usagebased on the ratio of tomato paste water consumption to freshwater availability and the assumptions made in this study, tomato paste production in the LC drainage basin in Nigeria has the prospect of contributing to freshwater scarcity. As noted by Hoekstra et al. (2012), evaluating resource sustainability on an annual basis, instead of on a monthly time step, may provide an incomplete information about the month(s) when freshwater scarcitymay likely occur under the production and/or consumption scenarios in a drainage basin. This represents another important limitation of this study that warrants future research. Notwithstanding this, the study has established a first estimate of the impact of tomato paste production on Nigeria’s freshwater. The study will also serves as a pointer and guide to other countries in the west Africa sub-region growing fresh tomatoes in the sudan savanna and the northern guinea savanna agro-ecological zones.

IV. CONCLUSIONS AND POLICY RECOMMENDATIONS

The 2017 tomato policy, in line with the economic diversification policy of the federal government, has placed a serious emphasis on the need to boost fresh tomato production in Nigeria and stop the importation of tomato paste. However, the implication of this on Nigeria’s freshwater remains unknown. This study fills this knowledge gap by using the water footprint-resource sustainability calculation method. Results revealed that to produce one tonne of tomato paste in Nigeria, 1518m^3 of water will be needed in the LN drainage basin or 1734 m^3 in the LC drainage basin. Imprint of tomato paste water use intensity in the LC drainage basin, almost of high severity, is capable of contributing to freshwater scarcity than tomato paste production in the LN (which creates relatively low stress). This should be interpreted with caution, because the southern part of the LN drainage basin is richer in water and does not form part of the major areas contributing to fresh tomato production.

To reduce the impact of tomato paste production on Nigeria’s freshwater resources will entail implementing water saving measures at two stages: (a) cultivation, and (b) processing. At the cultivation stage, a combination of approaches can be followed: (i) planting hybrid seeds, (ii) improved soil, pests and diseases management, and (iii) time of planting (to benefit more from rainwater, thereby reducing irrigation water needs). Considerable investments in research will be required to develop tomato hybrids of low moisture content and high yield. To make it work, the whole process will alsorequire a field-level awareness generation. Using the LCdrainage basin as an example, doubling tomato yield (to 30.9 t/ha), holding cropping area constant, will amount to 206 $m^3$of water saved per tof fresh tomato. Considering the estimated mean total land area devoted to cropping tomato in the LC drainage basin (about 0,106 x 10^6ha), this will amount to 0.86 x 10^9 $m^3$of water saved. Therefore, increasing crop-water productivity in the LC drainage basin is crucial to ensuring increases in water flow to the shrinking downstream Lake Chad. At the processing stage, this will involve filtering and reusing the process water for applications such as tomato washing and tomato blanching. Besides this, the condensate from the evaporated filtered pulp can also be saved and used.

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REFERENCES

[1] Adegbola JA, Awagu F, Adu EA, Anugwom UD, Ishola DT and Bodunde AA (2012). Investment opportunities in tomato processing in Kano, northern Nigeria. Glo. Adv. Res. J. Agric. Sci. 1(10): 288-297

[2] Adeoti O (2010a). Water use impact of ethanol at a gasoline substitution ratio of 5% from cassava in Nigeria. Biomass and Bioenergy, 34(7): 985–992

[3] Adeoti, O. (2010b). Development of river basin organizations in Nigeria. Research Journal of Soil and Water Management 1 (3-4): 91-100

[4] Alcamo J, Doll P, Henrichs T, Kaspar F, Lehner B, Rosch T, and Siebert S (2003). Development and testing of the WaterGAP 2 global model of water use and availability. Hydrological Sciences Journal 28(3): 317-337

[5] Aldaya MM and Hoekstra AY (2010). The water needed for Italians to eat pasta and pizza. Agricultural Systems 103(6): 351-360.

[6] Allen RG, Pereira LS, Raes D and Smith M (1998). Crop evapotranspiration: Guidelines for computing crop water requirements, FAO Irrigation and Drainage Paper, vol. 56.FAO, Rome

[7] Behzadian K, Farmani R. and Butler D. (2015). Water in tomato paste (draft version). Exeter, UK

[8] Chapagain AK and Hoekstra AY (2010). The blue, green and grey water footprint of rice from production and consumption perspectives. Ecological Economics 70(4): 749–758

[9] Chapagain AK and Orr S. (2008).An improved water footprint methodology linking global consumption to local water resources: A case of Spanish tomatoes. Journal of Environmental Management 90, 1219-1228.

[10] Chapagain AK, Hoekstra AY, Savenije HHG and Gautam R (2005). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological Economics 60(1): 186-203

[11] Dabrowski JM, Masekoameng E and Ashton PJ (2009). Analysis of virtual water flows associated with the trade of maize in the SADC region: importance of scale. Hydrology and Earth System Sciences 13(10): 1967–1977

[12] Evangelou E, Tsadilas C, Tserlikakis N, Tsitouras A and Kyritsis A (2016). Water footprint of industrial tomato cultivations in the Pinios river basin: Soil properties interactions. Water 8, 515; doi:10.3390/w8110515

[13] FAO (2019). Crops. http://www.fao.org/faostat/en/#data/QC (last accessed 24 May 2020)

[14] FAO (2020a). Tomato – Yield. http://www.fao.org/land-water/databases-and-software/crop-information/tomato/en/ (accessed 12 June 2020)

[15] FAO (2020b). Tomato - Crop description and climate. http://www.fao.org/land-water/databases-and-software/crop-information/tomato/en/ (accessed 12 June 2020)

[16] FMWR (2014). The project for review and update of Nigeria national water resources master plan, volume 4 – National water resources master plan 2013. FMWR, Abuja

[17] FMWR (2016). National water resources policy. FMWR, Abuja

[18] Harris F, Moss C, Joy EJM, Quinn R, Scheelbeek PFD, Dangour AD and Green R (2019). The water footprint of diets: A global systematic review and meta-analysis. *Advances in Nutrition* 11 (2): 375–386, https://doi.org/10.1093/advances/nmz091

[19] Hoekstra AY (2016). A critique on the water-scarcity weighted water footprint in LCA. Ecological Indicators 66: 564–573

[20] Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE and Richter BD (2012). Global monthly water scarcity: Blue water footprints versus blue water availability. PLoS ONE 7(2): e32688. doi:10.1371/journal.pone.0032688

[21] Huang J, Ridoutt BG, Zhang H, Xu C and Chen F (2013). Water footprint of cereals and vegetables for the Beijing market: Comparison between local and imported supplies. Journal of Industrial Ecology, https://doi.org/10.1111/jiec.12037

[22] IbáñezGR, Ruíz JMM, Sánchez MIR and López JLC (2017). A corporate water footprint case study: The production of Gazpacho, a chilled vegetable soup. Water Resources and Industry 17: 34-42

[23] Indexmundi (2020). Nigeria - fertilizer consumption. https://www.indexmundi.com/facts/nigeria/fertilizer-consumption (accessed 30 May 2020)

[24] Mekonnen, MM and Hoekstra AY (2011). The green, blue and grey water footprint of crops and derived crop products. Hydrol. Earth Syst. Sci. 15: 577–600

[25] NBS (2012). National agriculture sample survey, 2010/2011. NBS, Abuja

[26] Nyambo P and Wakindiki IIC (2015). Water footprint of growing vegetables in selected smallholder irrigation schemes in South Africa. Water SA 41(4): 571-578, http://dx.doi.org/10.4314/wsa.v41i4.17

[27] Pellegrini G, Ingrao C, Camposeo S, Tricase C, Contò F and Huisingh D (2015). Application of water footprint to olive growing systems in the Apulia region: a comparative assessment. Journal of Cleaner Production 112 (part 4, 20): 2407-2418, https://doi.org/10.1016/j.jclepro.2015.10.088

[28] PRI (2007). Canadian Water Sustainability Index (CWSI) project report. PRI, Ottawa

[29] PwC Nigeria (2018). X-raying the Nigerian tomato industry: Focus on reducing tomato wastage. PwC Limited, Abuja

[30] Ridoutt BG and Pfister S (2010), A revised approach to Water Footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environmental Change, 20, p. 113-120

[31] Ridoutt BG, Eady SJ, Sellahewa J, Simons L and Bektash R (2009). Water footprinting at the product brand level: case study and future challenges. Journal of Cleaner Production 17(13): 1228-1235

[32] Roux Bl, van der Laan M, Vahrmeijer T, Annandale JG and Bristow KL (2016). Estimating water footprints of vegetable crops: Influence of growing season, solar radiation data and functional unit. Water 8, 473, doi:10.3390/w8100473

[33] Ugonna CU, Jolaoso MA and Onwualu AP (2015). Tomato value chain in Nigeria: Issues, challenges and strategies. Journal of Scientific Research and Reports 7(7): 501-515

[34] US EPA (2020). Ground water and drinking water: Inorganic chemicals. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Inorganic (31 May 2020)

[35] van der Waal J.W.H. (2015). Horticulture sector study for Nigeria. Taste, Barendrecht, Netherlands

[36] Ventrella D, Giglio L, Garofalo P. and Dalla Marta A (2018). Regional assessment of green and blue water consumption for tomato cultivated in Southern Italy. The Journal of Agricultural Science 156 (5): 689-701, doi: 10.1017/S0021859617000831

[37] World Bank (2020). Data – Nigeria. https://data.worldbank.org/country/NG (accessed 12 June 2020)