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Assessment of Virtual Water of Irrigated Agriculture, Imports, Exports and Water Footprint for Sri Lanka.

W.C.S. Wanasinghe[1]*, E.R.N. Gunawardena[2] and M.I.M. Mowjood[2]

[1]*Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka*
[2]*Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka*

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Wanasinghe, W.C.S
https://orcid.org/0009-0006-2007-8448

ABSTRACT

Irrigated agriculture is the highest water user in Sri Lanka. Therefore, when there is an increasing demand of other sectors such as drinking, industries, environment etc., it is required to reallocate water from the irrigated agriculture sector to meet this increased demand. However, this needs to be done while ensuring the food security of the nation using the virtual water concept, which is defined as the embedded water in a product. Therefore, this study is conducted with the objective of assessing the, i) virtual water of agricultural production, ii) virtual water of food imports and exports, iii) virtual water trade and iv) water footprint of the nation. The data on crop water requirements, extent cultivated, imported, and exported agricultural products were collected from secondary sources and the analysis was made according to the globally accepted methodology. The annual virtual water value of domestic production is found to be 8.13 Gm^3 of which paddy contributes 54.7%. The average virtual water value of paddy in *Maha* season is less than that in the *Yala* season whilst the virtual water value of paddy in minor schemes are higher than that in the major schemes in both seasons implying that more water is required to produce 1kg of paddy in minor schemes. The net import of Virtual water is 3.8 Gm^3 per year. The water footprint of Sri Lanka is 12.0 Gm^3 per year with a per capita water footprint of 535.22 m^3 per year. The water required for domestic production is about 15.8% of the surface runoff of the country indicating the possibility of meeting the food demand with the available water resources.

* Corresponding author- chaminiewanasinghe90@gmail.com

INTRODUCTION

Annually, Sri Lanka receives about 112.3 Gm^3 of rainfall which contributes to surface and ground water resources of approximately 51.3 Gm^3 and 7.8 Gm^3 respectively (Gunatilaka, 2008). In terms of per capita water availability, Sri Lanka is classified as a country with adequate water resources of 2,500 m^3, well above the 1,700 m^3 considered the threshold for defining water stress. However, the spatial and temporal variability of rainfall has created an overall scarcity of water in the dry zone, where per capita water availability is only about 1,200 m^3 (ADB, 2014).

Irrigated agriculture consumes 85% of water from total abstraction and the remaining 15% is shared by drinking, domestic, and industrial uses (Chandrasekara et al., 2021). However, the demand is predicted to increase further with population growth, change of lifestyles and the growth of industry. The growth in the domestic water supply sector is driven by the government's policy, in alignment with the Sustainable Development Goal No 6, to provide safe drinking water to all by 2025. This is to be achieved by increasing pipe water coverage from 51% to 79% and the balance 21% by the community water supply schemes (NWSDB, 2020).

Most of this additional water is to be obtained by the water resources currently allocated for irrigated agriculture which may also require more water in the future. For example, the area under cultivation of other food crops needs to be increased by threefold between 2009 and 2030. Therefore, the water allocation among the sectors is crucial for sustainable water resources management in Sri Lanka.

The concept of "Virtual water" has been put forward as a tool to address this issue of reallocation of water from agriculture to other sectors in 1993 by Tony Allan (Allan & King, 2003) while guaranteeing the food security. He defined the term virtual water as the water embodied in an agricultural product or else the water needed to produce agricultural commodities. Agricultural products are mainly responsible for the movement of water as virtual water around the world as far as the trade volumes are concerned. For example, the total water use by crop production in the world is 5400 Gm^3/yr (Falkenmark, 2011) whilst the total gross virtual water related to trade of crops is 695 Gm^3/yr (Chapagain & Hoekstra, 2003). If the quantity of virtual water for certain products are extraordinarily high, it would be disadvantageous for a country facing water scarcity to export such products and vice versa.

The 'water footprint' (WFP) concept has been developed by Hoekstra and Hung (2005) as an indicator of water use in relation to consumption by people. The water footprint of a nation for agriculture production can be assessed by taking the use of domestic water resources for local production, subtracting the virtual water flow that leaves the country as exports and adding the virtual water flow that enters the country as imports.

At present domestic production of many agricultural products, including the staple food of rice have failed to meet the current demand in Sri Lanka. Hence, the country has to import large varieties of food items implying that the country must rely on other countries to fulfil the food demand (Mayadunne & Romeshun, 2013). Since there is a growing request to allocate water from irrigated agriculture to meet the increasing demand for drinking, industries *etc*, policy makers must make informed decision as to how this allocation is made. Before making decision of reallocation of water from agriculture to other sectors, it is important to assess the amount of water required to meet the local production as well as how much water to be imported as embedded water to assure food security of the nation. According to a study undertaken by Hoekstra and Hung (2005), Sri Lanka is identified as a top 12 net importers exceeding the countries such as Japan, Indonesia, China, Saudi Arabia etc. However, lack of detail information and analysis, especially the disaggregated information for agricultural produce, does not help to verify such higher values. Therefore, this study is conducted with the objective of assessing the, i) virtual water of agricultural production, ii) virtual water of food imports and exports, iii) virtual water trade and iv) water footprint of Sri Lanka.

METHODOLOGY

The methodology of this study comprised of four parts; the first was to assess the virtual water values (VWV) to produce paddy and other selected irrigated crop products within Sri Lanka, and the second was to assess the virtual water value of imported crop products to the country. Third was to determine the virtual water of agriculture products exported from the country. The fourth was to estimate, the net virtual water balance and the water footprint of the country for agriculture produce. For the estimations, the period of recent decade from 2009 to 2018 was considered.

Based on the rainfall, there are two cropping seasons, namely *Yala* season (May to September) and *Maha* season (November to February). For Paddy, *Yala* and *Maha* seasons yield data were considered separately under both major and minor irrigation schemes to identify any temporal and spatial variability of virtual water for domestic paddy production. For every other crops only annual yield data were considered.

Estimation of virtual water value of crops produced within the country

The crop water requirement of a given crop is considered as one of the most important information required to estimate the virtual water embedded in a crop. The information on reference evapotranspiration, the crop coefficient of a given crop during its growing season and the length of the cropping season are the required data for this purpose. The Natural Resources Management Centre (NRMC) of the Department of Agriculture has estimated the average evapotranspiration (ET) of all major crops using FAO Penman Monteith model (CROPWAT) (NRMC, Undated). For the Paddy, crop, ET was estimated based on the variety, age classes, drainage classes and the season. All the ET values applied for this study were given in the Table 1.

Table 1-ET values of selected crops

Crop Category	Crop Product	ET (mm)
Paddy	Paddy in *Maha* season	470.37
	Paddy in *Yala* season	677.28
Vegetables	Beans	275
	Beetroot	295
	Cabbage	350
	Carrot	350
	Raddish	150
	Okra	300
	Bittergourd	475
	Brinjal	430
	Capsicum	400
	Cucumber	340
Fruits	Banana	1700
	Mango	1500
	Orange	750
	Papaya	1215
	Passionfruit	900
	Pineapple	1112.5
OFC	Millet	350
	Maize	600
	Greengram	360
	Cowpea	300
	Soyabean	380
	Blackgram	360
	Gingelly	325
	Groundnut	390
	Red onion	385
	Big onion	420

Source- NRMC, Undated

According to the Ag-stat data the main paddy varieties grown within Sri Lanka are the Bg varieties of 3 months 3 ½ months, and 4-4 ½ months (Thilmany & Garner, 2004). These varieties cover nearly 98% of the total extent under paddy production. Therefore, average ET values for the Paddy grown in Sri Lanka in both *Yala* and *Maha* seasons were taken by assuming that Bg varieties are prominent and represents all the paddy varieties grown in the entire country. Also, the average ET value was considered for crops with *ratoon*, such as Pineapple. These average ET values were used for the entire study period.

The Equation 1 was used to calculate the VWV (Liu et al., 2007). Water use efficiency and additional water requirements (i.e., leaching) are neglected and only the crop water consumption or evapotranspiration (ET) is considered.

— Eq. 1

Where,

VWV – Virtual water value (m^3/kg)

ET - Evapotranspiration of a crop in the growing season in mm,

Y - Crop yield in kg ha^{-1}

Once the VWV is determined for each crop, the total virtual water to produce given crop product is estimated by multiplying the VWV by the total yield.

Crop selection

The main crops grown within Sri Lanka based on the data availability are identified for this study as shown in Table 2.

The data on yields of the above crops was obtained from the annual paddy statistics reports published by the Department of Census and Statistics (available at, http://www.statistics.gov.lk/Agriculture/StaticalInformation/PaddyStatistics), and the annual agricultural statistics reports, published by the Socio-Economic and Planning Centre of the Department of Agriculture (available at, https://doa.gov.lk/naicc-books/#1628491951058-49ca7ba3-ac39).

Quantification of virtual water trade of imported crop products to Sri Lanka

Same data sources were referred to identify the imports for the said period. A database was prepared with the imported quantity of products in each year. However, there were some limitations with data availability. Any of the referred data sources did not provide the necessary information to find the origin of the imported product. Selected imported crop products for the calculation of virtual water trade (VWT) are given in Table 3.

Table 2 Selected major crop products

Crop category	Crop products
Paddy	Both Maha and Yala season
Other Field Crops	Millet, Maize, Green gram, Cowpea, Soya bean, Black gram, Gingelly, Ground nut, Red onion, Big onion
Vegetables	Up country- Cabbage, Beans, Carrot, Raddish, Beetroot Low Country- Brinjal, Okra, Capsicum, Cucumber, Bitter gourd
Fruits	Banana , Mango, Orange, Papaw, Pineapple, Passion fruit

Table 3 Selected major import crop products to Sri Lanka

Crop category	Crop products
Grains	Rice and Wheat
Cereals and legumes	Soybean, Lentil, Onion, Maize, Potatoes, Ground nut, Chickpea, Millet, Cowpea
Vegetable	Carrot, Peas, Lettuce, Tomato, Cucumber
Fruits	Grapes, Apple, Dates, Orange

The Equation 2 was used to calculate virtual water trade (VWT) of imports. 'Specific water demand' (SWD) is another term used for 'virtual water value' or 'virtual water content' (Bamji, 2008). Different authors have introduced different terms referring to the same VWV. For example, (Oki & Kanae, 2004) used 'unit water requirement' whilst (Renault, 2002) defined the 'virtual water value'. Using the Equation 2 (Bamji, 2008) the SWD is used without any alteration.

(ne c) (ne t) (ne c) Eq. 2

Where,
VWT = Virtual Water Trade (m^3yr^{-1}) from exporting country (n_e) to importing country (n_i) in year t as a result of trade in crop c
CT = Crop Trade ($t\ yr^{-1}$) from exporting country ne to importing country n_i in year t for crop c
SWD = Specific Water Demand ($m^3\ t^{-1}$) of crop c in the exporting country

As both crop water requirements and crop yields vary between countries, specific water demand is also going to be changed accordingly. Crop water requirements differ over countries mainly due to the differences in climatic conditions. Therefore it is assumed that SWD or VWV for each crop products varies spatially though not temporarily (Hoekstra & Hung, 2005)(Bamji, 2008).

Since there is no information from the quantity of the crop imported from each country, the average VWV s calculated by getting the arithmetic mean of VWV of a given crop from those countries. For example, Sri Lanka imports rice mainly from India, Pakistan, Vietnam, Thailand, and China and the VWV of rice in each country are 3350, 3677, 2163, 4047, 1072 m^3/t respectively. Thus, the average VWV of imported rice is 2862 m^3/t. (Journal and Education, 2003; FAO, 2012; Fereres, 2012). After calculating VWT of imports in each crop product, the gross virtual water import to the country was derived by using Equation 3 (Bamji, 2008). The gross virtual water import to a country is the sum of all imports to the country. Finally gross value was calculated to understand how much water it carries through VWT to Sri Lanka.

$\sum$ V Eq. 3

Where,
GVWI = Gross Virtual Water Import (m^3yr^{-1})
VWT = Virtual Water Trade (m^3yr^{-1})

Virtual water export from the country

The virtual water exported from the country (VWE) of a given crop is calculated by multiplying the VWV of the crop by the quantity exported. The sum of all these is are equal to the gross virtual water exports ($m^3\ yr^{-1}$).

Virtual water trade balance

The net virtual water import of a country is equal to the gross virtual water of imports minus the gross virtual water of exports and is defined as the 'VW trade balance'. The VW trade balance of any country is given by Equation 4. It is the difference between the gross virtual water flow that enters in to the country and the gross virtual water flow that that leaves the country (Bamji, 2008).

Eq. 4

Where,
NVWI= Net Virtual Water Imports ($m^3\ yr^{-1}$)
GVWI=Gross Virtual Water Imports (m^3yr^{-1})
GVWE=Gross Virtual Water Exports(m^3yr^{-1})

Water footprint of Sri Lanka

The volume of water needed to produce the goods and services consumed by the inhabitants of the country is defined as the water footprint. This is assessed by taking the use of domestic water resources, , and adding the net virtual water flow imports that enters in to the country, as shown in Equation 5 (Bamji, 2008).

Eq. 5

Where,
WFP= Water Footprint
WU= Water Use for domestic production ($m^3\ yr^{-1}$)
NVWI= Net Virtual Water Imports ($m^3\ yr^{-1}$)

The per capita water footprint of a nation is another parameter that provides information about how much water is used by an individual and is calculated by dividing the national water foot print by the population of the country.

RESULTS AND DISCUSSION

Virtual water value of crops

Since, long term ET for a given crop is used, the VWV of crops for the years 2009 - 2018 varies according to the crop yield of each year. The following sections describe the VWV of each selected crop products.

Paddy

VWV of paddy grown under Sri Lankan conditions was calculated for both the *Yala* and *Maha* seasons by using average ET values for the selected ten years period from 2009 to 2018. The contribution from rainfed paddy cultivation is comparatively the lowest and hence is omitted from this study. Therefore, VWV calculated for the *Maha* and *Yala* seasons for both major and minor irrigation schemes in Sri Lanka are given in Table 4 and graphically illustrated in Figure 1 and 2 respectively.

According to Figures 1 and 2, the calculated average VWV of paddy in major irrigation schemes for both the *Maha* and *Yala* seasons is found to be 0.96 $m^3kg^{-1}$and 1.37 m^3kg^{-1} respectively. The same pattern is noted in minor irrigation schemes as well where VWV during *Maha* and *Yala* seasons are 1.14 m^3kg^{-1} and 1.76 m^3kg^{-1} respectively. For both major and minor schemes, the average VWV of paddy in *Maha* season is less than the *Yala* season. Since the slight difference observed between average crop yield during *Yala* and *Maha* seasons is not adequate to explain this variation of VWV, it could be due to the less water use during *Maha* season during which much of the crop water requirement is supplemented by the rainfall. The sum of average total VW is 4455.3 MCM.

It is also found that the VWV of paddy in minor schemes is higher than that in the major schemes in both seasons implying that more water is required to produce 1kg of paddy in minor schemes. This could be explained by the higher average yield of major irrigation schemes compared to minor irrigation schemes.

Non paddy crops

The variation of VWV of Other Field Crops (OFCs), vegetables and fruits for years 2009 to 2018 is shown in Figures 3, 4 and 5 respectively. Within the OFC group, crops such as black gram (WVW of 4.00 m^3/kg), gingerly (VWV of 3.92 m^3/kg) have higher VWV of whilst big onion (0.31 m^3/kg and red onion (0.26m^3/kg) has lower VWV. This is because of the higher yields of red and big onion compared to black gram and gingerly as shown in Table 4. Vegetables tend to have a very low VWV compared to the OFC group because of the higher yields obtained by the former per unit of water used.

Unlike vegetables and other field crops most fruit crops are perennial crops. Also, there are *ratoon* for crops like pineapple. The highest VWV recorded is in orange which is 8.76 m^3/kg. When compared to all the other crops selected for this study, fruits recorded comparatively high values of VW. This is due to the high ET value as shown in Table 1, primarily because of the longer duration of the crops. The virtual water of all locally produced crops is given in Table 5. Paddy consumes the highest quantity of water compared to all the other crops combined.

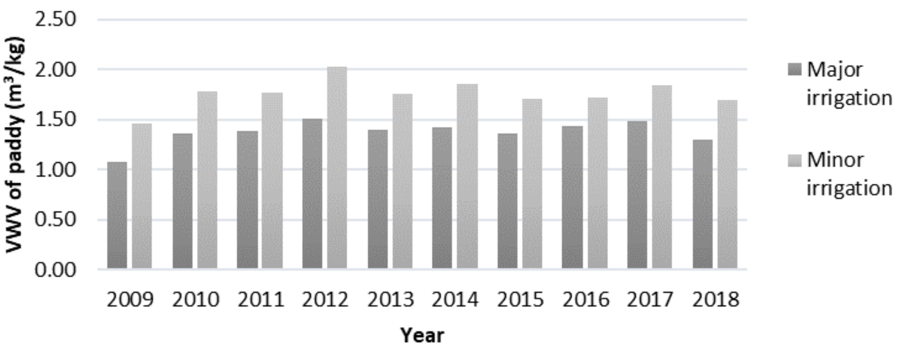

Figure 1: VWV of irrigated paddy in Maha season 2009-2018

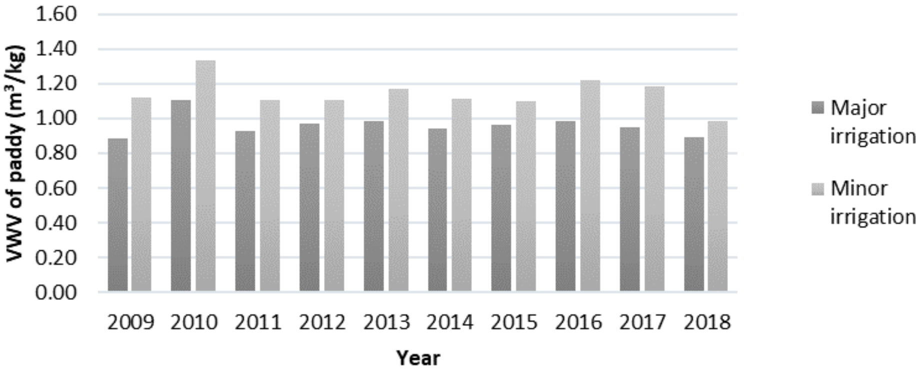

Figure 2: VWV of irrigated paddy in Yala season 2009-2018

Table 4 Total VW to produce irrigated paddy in Sri Lanka 2009-2018

Year	Average yield (mt/ha)				Harvested extent (000'ha)				Total virtual water (million cubic meters)			
	Yala season		*Maha* season		*Yala* season		*Maha* season		*Yala* season		*Maha* season	
	Major	Minor	Major	Minor	Major	Minor	Major	Minor	Major	Minor	Major	Minor
2009	6.28	4.65	5.33	4.21	188.5	73.8	304.5	159.2	1,276.76	499.81	1,432.29	748.64
2010	4.98	3.82	4.24	3.52	256.1	85.7	277.0	175.3	1,734.41	580.63	1,302.82	824.50
2011	4.90	3.82	5.08	4.25	296.6	119.2	331.7	169.2	2,008.68	807.37	1,560.01	795.90
2012	4.50	3.35	4.85	4.26	222.2	51.7	330.6	204.3	1,504.96	350.40	1,555.05	960.84
2013	4.84	3.86	4.78	4.02	288.8	110.5	300.2	127.3	1,956.26	748.06	1,412.15	598.71
2014	4.77	3.66	5.00	4.24	186.0	74.0	336.3	195.8	1,259.52	501.07	1,581.80	920.83
2015	4.98	3.97	4.88	4.28	301.6	121.8	340.1	201.7	2,042.59	824.94	1,599.54	948.92
2016	4.72	3.95	4.77	3.86	263.1	88.0	240.9	71.5	1,781.68	596.11	1,132.93	336.48
2017	4.58	3.68	4.96	3.98	174.4	38.4	318.6	133.3	1,181.05	259.93	1,498.72	627.12
2018	5.28	4.77	5.28	4.77	237.6	80.6	343.8	190.8	1,636.18	652.91	1,617.32	897.41
Average	4.98	3.95	4.92	4.14	241.5	84.37	312.36	162.84	1,638.21	582.12	1,469.26	765.94

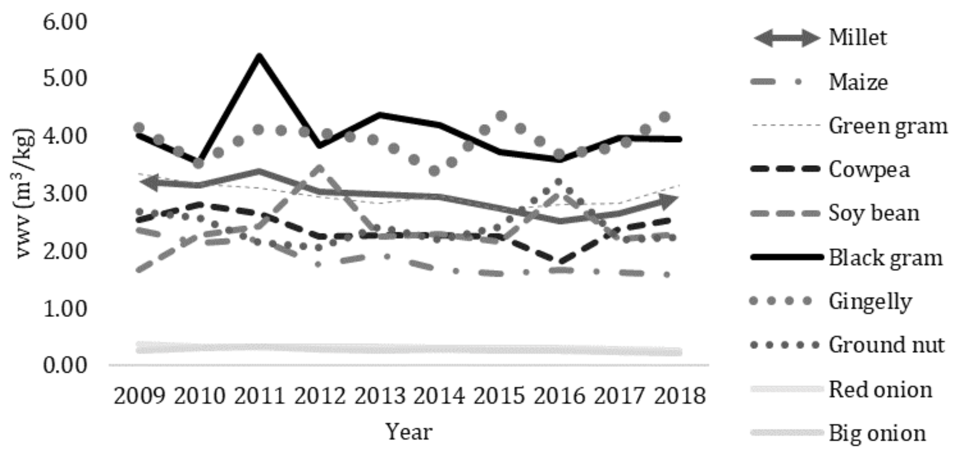

Figure 3: VWV of selected domestically produced OFC crop products

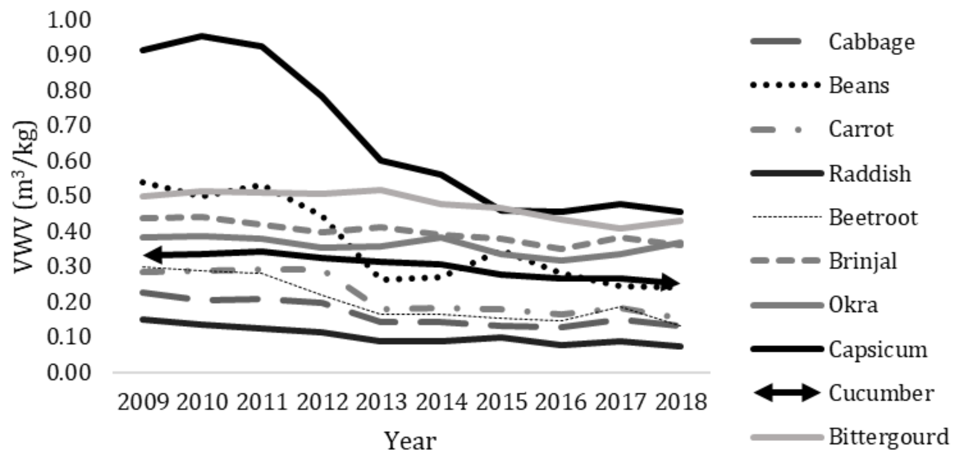

Figure 4: VWV of selected domestically produced vegetables

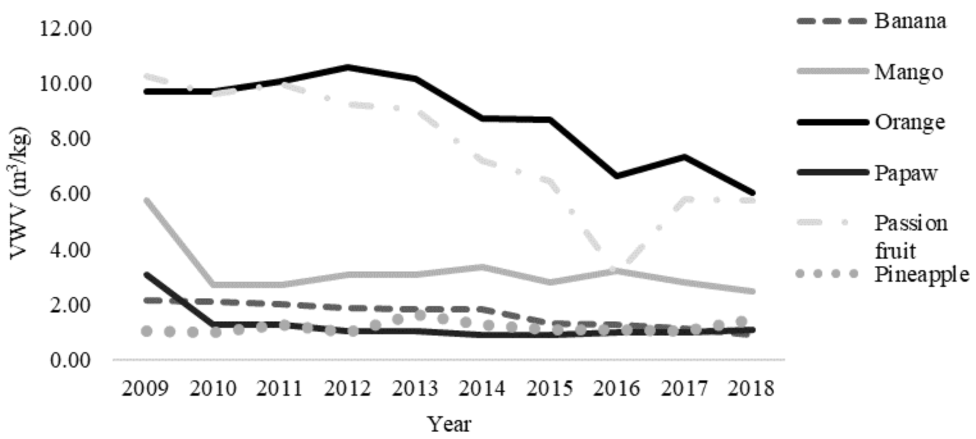

Figure 5: VWV of selected domestically produced fruits

Virtual water value of imported crop products to Sri Lanka

Sri Lanka imports large varieties of agricultural products such as rice, wheat flour, sugar, fruits, dried chilli, red onions, potatoes, red lentils, green grams, soybeans, *etc*. (Mayadunne & Romeshun, 2013). The VWV of wheat and rice, OFCs and fruits are given in the following figures. According to Figure 6", wheat is identified as the top ranked one of VW import compared to rice. Since Sri Lanka is not domestically producing wheat, the full domestic demand must be met by imports.

Figure 6 also shows that the VWV of wheat does not fluctuate very much whereas the virtual water imports of rice have increased in 2014 and 2017. This is due to the reduction of local rice production as shown in Figure 7. The years 2013-2014 and 2016-2017 were identified as drought years in Sri Lanka (Abeysingha & Rajapaksha, 2020). This has contributed to the lower production of rice. To meet the national demand, the country has, therefore, imported higher quantities of rice as virtual water.

As shown in Figure 8, soybean is ranked as the number one OFC. It is due to the expansion of the soy based product manufacturing industries in Sri Lanka (Dissanayake, 2017). According to Ag-stat data, the import of soybean is a combination of soybeans and soybean meals and tends to fluctuate of on annual basis. For example, in 2010 the imported quantity of soybean was 1611 metric tons and the soybean meal was 168,188 metric tons, whilst in 2011, the imported quantities of soybean and soybean meal were 0.038 metric tons and 145,656 metric tons respectively. The imports of fruits have gradually increased over the years since 2014 as shown in Figure 9 though the total VWV is comparatively negligible to that of wheat, rice and OFCs.

The summary of the virtual water imported crop products is given in Table 6.

Virtual water value of exported crop products from Sri Lanka

The VWV exported crops out of Sri Lanka is given in Table 7. Among the three groups of OFCs, vegetables and fruits, the latter contributes to more than half of the export VW

The net virtual water imports and the water footprint of Sri Lanka.

As given in Table 5, and 6, the total average annual VW of imports is 3916.77 MCM per year whereas the gross VW export of food crop products is 457.86 MCM per year. Therefore, the net virtual water import to Sri Lanka is calculated as 3458.91 MCM per year. The water footprint (WFP) of Sri Lanka is estimated at 11598.22 MCM using the following Equation 5,

$$WFP=WU+NVWI \qquad \text{Eq. 5}$$

where,
Total average annual VW of domestic production (WU) = 8139.31 MCM per year
Net virtual water imports (NVWI) = 3458.91 MCM per year.

Based on this water footprint of 11598.22 MCM and the population of Sri Lanka as of 2018, 12.67 million (in 2018), the per capita water footprint is calculated as 535.22 m^3. This is slightly higher than the per capita water footprint of Israel which is 821 m^3 (Wichelns, 2010).

Sri Lanka primarily uses surface runoff for irrigated agriculture. The annual total volume of surface runoff is estimated as 51.3 Gm^3 (Gunatilaka, 2008). The VWV of irrigated agricultural crops according to this study is about 8.13 Gm^3 or 15.8% of surface runoff. Though all surface runoff is not available for abstraction since part of is discharged to sea especially during rainy season, there is sufficient water available to locally produce adequate quantities of food.

Table 5 Summary of VW of domestically produced crop products

Crop product	ET (mm)	Average Yield (kg/ha)	VWV (m^3/kg)	Average Annual yield (million kg)	Average Extent Cultivated (ha)	Total VW of domestic production (MCM per year)
Paddy*						4455.3 (54.7%)
Other Field Crops						
Millet	350	1190	2.94	72.05	6,033	212.75
Maize	600	3300	1.82	2051.30	61,418	3,801.03
Green gram	360	1210	2.98	121.09	9,951	360.98
Black gram	360	900	4.00	126.67	10,408	301.18
Cowpea	300	1280	2.34	73.01	9,952	175.31
Soy bean	380	1640	2.32	94.13	4,462	381.71
Gingelly	325	830	3.92	119.55	14,363	471.82
Ground nut	390	1660	2.35	218.91	13,497	528.66
Red onion	385	12520	0.31	616.70	4,956	191.42
Big onion	420	15970	0.26	676.88	4,320	179.93
					Sub Total	6, 60.48 (8.1%)
Vegetables						
Beans	275	8340	0.33	657	7,878	239.54
Beetroot	295	15880	0.19	393	2,511	79.45
Cabbage	350	22190	0.16	932	4,170	153.73
Carrot	350	17270	0.20	438	3,150	95.75
Radish	150	15360	0.10	496	3,252	51.03
Okra	300	8390	0.36	639	7,634	229.50
Bitter gourd	475	10060	0.47	433	4,339	205.93
Brinjal	430	10920	0.39	1,204	11,043	476.53
Capsicum	400	6660	0.60	235	3,490	154.44
Cucumber	340	11460	0.30	368	3,220	110.48
					Sub Total	179.64 (2.2%)
Fruits						
Banana	1700	11320	1.50	5,724.36	51,198	8586.54
Mango	1500	4950	3.03	1,403.76	28,316	4253.40
Orange	750	890	8.43	57.55	6,445	485.15
Papaya	1215	11070	1.10	772.75	6,970	850.02
Passion fruit	900	1340	6.72	6.60	485	44.35
Pineapple	1112.5	9780	1.17	50.84	5,240	8586.54
					Sub Total	2843.89 (34.9%)
			Total average annual VW of domestic production (WU)			8139.31 (100%)

* *The details are given in table 4*

Figure 6: VWV of Wheat and Rice imports

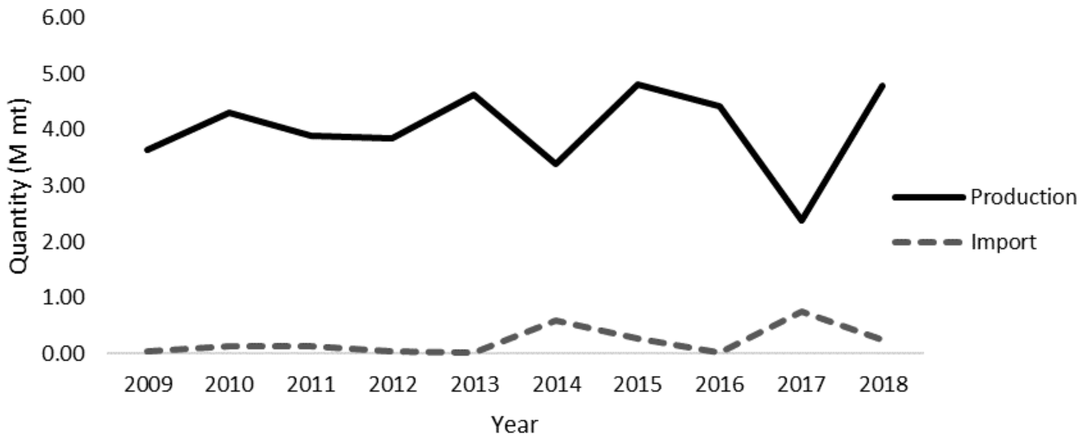

Figure 6: Domestic production *vs* imported quantity of Rice

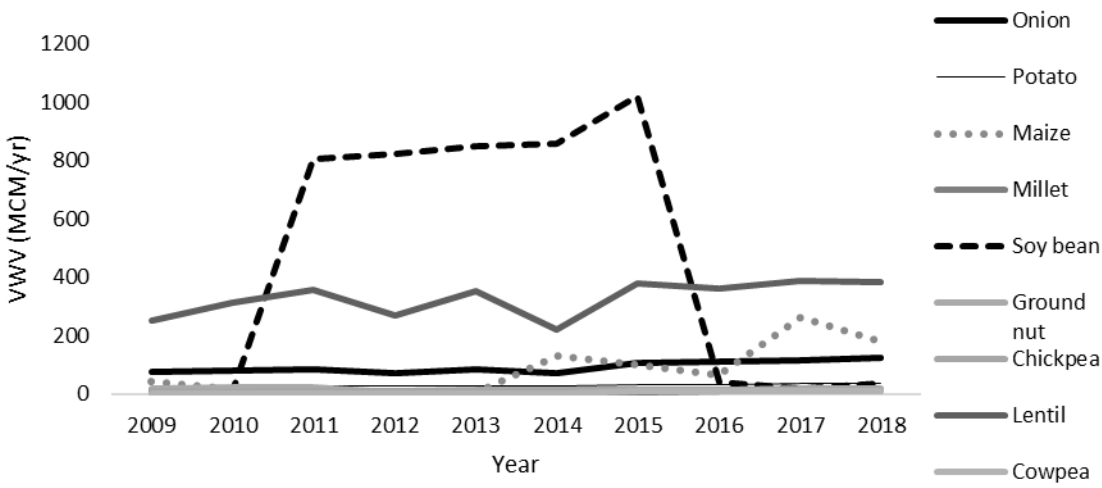

Figure 7: VWV of imported OFC crop products

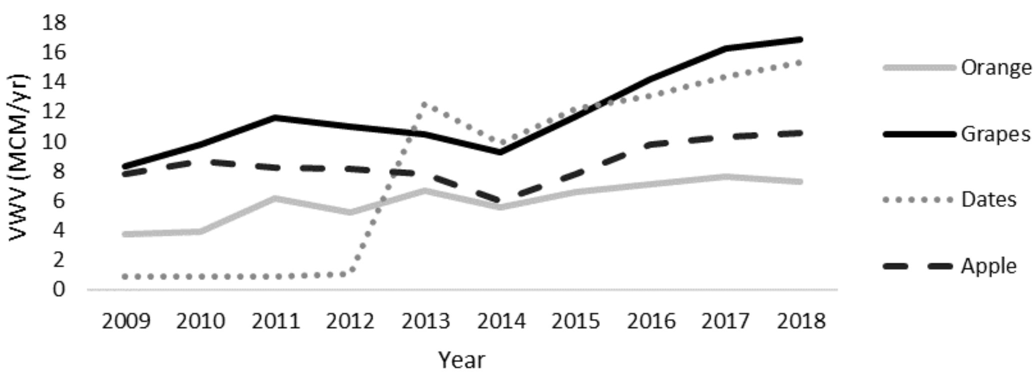

Figure 8: VWV of imported fruits

Table 5 Summary of VW of imported crop products

Crop product	Average virtual water value (m³/ton)	Average annual crop trade of imports (mt/yr)	Average annual VWV of imports (MCM per year)
Wheat	1,973.80	1,121,221.20	2213.07 (56.5%)
Rice	2,861.80	227,542.30	651.18 (16.6%)
Soybean	5,532.33	80,697.98	446.45
Lentil	2,344.69	139,556.70	327.22
Onion	468.00	196,080.30	91.77
Maize	1,482.20	54,969.00	81.48
Potatoes	222.60	132,203.10	29.43
Ground nut	4,598.33	3,208.30	14.75
Chickpea	567.60	22,578.30	12.82
Grapes	1,681.50	7,108.50	11.95
Millet	4,425.00	2,173.70	9.62
Apple	387.00	21,979.70	8.51
Dates	1,660.00	4,886.40	8.11
Orange	875.50	6,844.50	5.99
Cowpea	1,423.73	3,114.50	4.43
		Total average annual VW of imports	**3916.77 (100%)**

Table 6 Summary of VW of exported crop products

Crop	VWV (m^3/kg) (calculated for Sri Lanka)	Average annual crop trade of exports (mt/yr)	Average annual VWV of exports (MCM per year)
OFC			
Chillie	1.74	244.89	4.25
Maize	1.85	212.15	3.93
Millet	2.95	3.19	0.00
Ground nut	2.42	0.47	0.01
Soy bean	2.40	266.82	6.41
Cowpea	2.38	18.43	0.44
Green gram	2.98	280.26	8.35
Gingelly	3.95	3097.22	122.25
Potato	0.39	28.49	0.11
Red onion	0.31	4.94	0.02
Big onion	0.27	44.70	0.12
Manioc	1.01	3381.83	20.44
Sweet potato	0.37	15.92	0.04
Black gram	4.06	236.47	8.63
		Sub total	175
VEGETABLE			
Tomato	0.38	24.32	0.08
Leeks	0.17	2.84	0.00
Carrot	0.22	11.74	0.02
Cucumber	0.30	7.04	0.01
Beans	0.36	29.30	0.06
Capsicum	0.66	15.04	0.09
		Sub total	0.27
FRUITS			
Banana	1.63	14161.50	230.55
Pineapple	1.17	1174.60	13.71
Mango	3.19	109.31	3.49
Orange	8.76	62.12	3.81
Papaw	1.24	2500.00	31.05
		Sub total	282.60
		Gross VW exported food crop products	457.86

CONCLUSION

The study has shown that the virtual water value of domestic production is 8.13 Gm^3 of which irrigated paddy contributes about 54.7%. For both major and minor schemes, the average VWV of paddy in the *Maha* season is less than the *Yala* season. It is also found that the VWV of paddy in minor schemes is higher than that in the major schemes in both seasons implying that more water is required to produce 1kg of paddy in minor schemes.

The net imports of virtual water are about 3.45 Gm^3 since Sri Lanka exports negligible quantities of agriculture produce as virtual water exports. The imported products as virtual water is dominated by wheat (2.21 Gm^3) followed by rice (0.67 Gm^3). The water footprint of Sri Lanka is estimated as 12.0 Gm^3 with a per capita water footprint as 535.22 m^3. The results indicate that the water required for domestic production is about only 15.8% of the surface runoff of the country indicating the possibility to meet the food demand with the available water resources.

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