THE IMPLICATION OF THE AVOCADO TRADE FOR GLOBAL WATER SCARCITY

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science

ABSTRACT

The popularity of avocado consumption has been soaring across Europe and the United Stated, but the implications of this for global freshwater resources are not well understand. The aim of the project was to explore the impacts of the avocado trade on water scarcity. A Blue Water Scarcity Footprint (WSF) approach has been used to indicate the potential impacts on national water resources over the period 1990–2015. Over this period, the demand for avocado exports has increased from 230 to 1300 million kg. The annual global production of avocados increased from 1700 to 4025 million kg. The BW required in the production of avocado has increased from 523 to 1058 million m^3. The annual global WSF of avocado production rose from 20675 to 46967 million m^3 H_2O_e. Over 25-year period increasing demand for avocado is promoting exchanges in virtual water from water-scarce countries such as Mexico, Chile, Israel, USA, Australia and South Africa to water-abundant countries such as the USA, the Netherlands, the United Kingdom, Sweden and Japan. Given the projected impacts of population growth and potential impacts of climate change on the availability of global freshwater resources, the long-term sustainability of this trend has been evaluated in the present study.

Keywords:

Avocado; Blue water; Blue water scarcity footprint; Chile; Climate change; Export; Food production; Import; Mexico; Peru; Scarcity; South Africa; Spain; Sustainable agriculture; USA; Virtual water.

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BW	Blue Water
GW	Green Water
UAE	United Arab Emirates
USA	United State of America
UK	United Kingdom
WSF	Blue Water Scarcity Footprint

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1 INTRODUCTION

1.1 Water crisis

Global economic forum (2014) has established water crisis as a major global risk threatening the future sustainability, where water resource availability is one of the major challenges (Musolino, Massarutto and de Carli, 2018). The World Water Assessment Programme (2012) estimated that around 700 million people suffer from water scarcity and if no measures were taken, it is anticipated that the figure will at least double by 2025. Therefore, it is important to consider the current practices and drivers affecting water usage and tackle any identified problems.

Water scarcity is getting worse in shorter time by many different activities, including population growth, climate change and economic development, which adds further pressure on the global water availability (Dalin *et al.,* 2012). Population growth is expected to exceed 9 billion in 2050 (FAO, 2012) and food demand is expecting a 60% growth as a result of this. To catch up with the rising food demand, pressure has been placed on the irrigation system, which many countries employ for food production (Sauer *et al.,* 2008). This is shown where irrigated land has risen from 47.3 million hectares in 1930 to 254 million hectares in 1995 (Önder, Ceyhan and Kahraman, 2011). In fact, some of the river basins in several of the world´s top crop-producing countries (Figure 1-1) are experiencing water scarcity (FAO 2017). This demonstrates the demand for irrigation adds to the water scarcity in many regions (Food and Agriculture Organization of the United Nations, 2017), as decrease the water available for domestic and other industrial purposes.

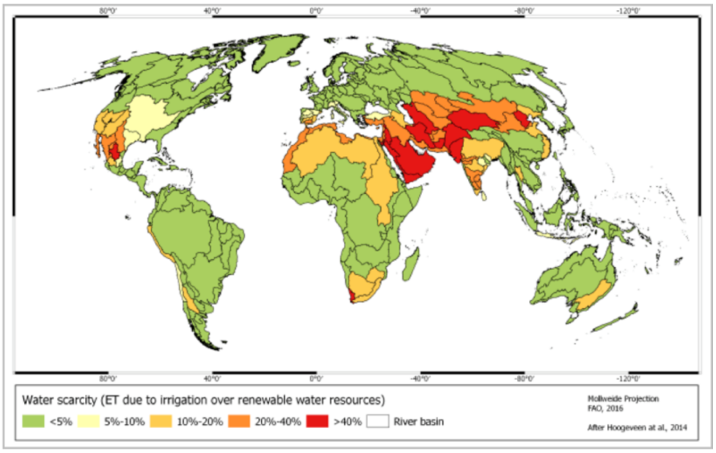

Figure 1-1. Global water scarcity by major river basin (FAO, 2017)

Climate change is having an important implication on agriculture through increasing global temperature, affecting rainfall patterns and reducing water availability and therefore limiting crop productivity (Kang, Khan and Ma, 2009). It has special impact on fruits and vegetables as they are most sensitive to these environmental changes (Abewoy, 2017). This will lead to an increase water demand through irrigation (FAO, 2016), particularly in countries which are already known to be water scarce, such as South Africa and Chile (Kreft *et al.,* 2014).The reduction in food production, not only impact the country´s economy, it may also induce an inflation in fruits and vegetables crop prices (Malhotra 2017), because of the reduction in supply and the potential need to import. Data consultancy Mintec affirmed that last year there was an increase of more than 50 % in prices of vegetables in the UK. Some reasons might have been courgette and lettuce shortages in Spain due to snow and rain, the delayed harvest in Mexico, drought in California and floods in Peru (Butler and Jones, 2017).

Not only are fruits and vegetables sensitive to abiotic factors, they also have the highest average water footprint per calories compared with other types of crops (excluding spices and nuts) (Mekonnen and Hoekstra, 2011). The consumption of these high water footprint value products are increasing popular (FAO, 2016) due to increasing global multi-cultural exposure and changes in diet patterns, as shown where the production of fruits and vegetables are increasing at a rate of 3.2 and 1.6 percent per year respectively (Barbosa-Cánovas et al., 2003). This means water scarcity would have an impact on the production of fruits and vegetables, causing a shortage in supply.

1.2 Water footprint and virtual water

Mekonnen and Hoekstra (2011) developed the concept of water footprint, which provides a quantifiable indicator in expressing the amount of water consumed in crop production. This may vary depending on the production location due to the difference in the rates of evapotranspiration.

Water footprint is composed of green water (GW) and blue water (BW) (Mekonnen and Hoekstra, 2011). These components refer to the source of the water use. GW refers to water coming from rainfall, of which the contribution to crop production is limited to the area where precipitation is experienced. Thus, GW cannot be controlled and is only beneficial for forestry, agriculture or environmental applications. In contrary, BW refers to water obtained through surface or groundwater abstraction, where the water can be used but may not be consumed (Rockstrom and Falkenmark, 2006). This is particularly useful during water shortage periods (Rost *et al.,* 2008), because BW can be recycled to the drainage basin and therefore available as a reserve. It is estimated that BW for irrigation purpose reaches 2,500 km^3 /year, which constitute up to 70% of the total BW consumed worldwide (Rost *et al.*, 2008). However, this water footprint does not always retain in the country in which the food was produced (Falkenmark, 2003). This created the need to understand the movement of water between producing countries and those that import them.

This was then investigated through the concept of virtual water, which was introduced to understand the virtual movement of water associated with the international trade of agricultural goods (Tamea, Laio and Ridolfi, 2016). Virtual water is the water included in the product, that was used in the production of the commodities (Allan, 1998). Nearly 80% of global virtual water is related to international agricultural trades (World Water Assessment Programme (WWAP), 2017). The concept was developed as a way to sustain food production and save water, with the intension to move food from water-rich countries to water-scarce countries (Dalin *et al.,* 2012), making food supply more affordable and sustainable (Hanjra and Qureshi, 2010). For instance, Kenneth and Major, (2002) forecasted that with appropriate application of virtual water, the cereal exports from water-abundant region to water-deficit region will increase by 15% between 1995 to 2025. Nonetheless, the vision has not been successful, where about 25% of the global cereal trade was living up with the vision (Yang and Zehnder, 2007) similar to that in 1995 (Kenneth and Major, 2002). Therefore, it is necessary to understand the movement of virtual water, which may provide an explanation as to why the vision has not be realised.

1.3 Aims and objectives

The study aims to estimate the BW consumption through investigation a fruit which uses BW in its production and explore the virtual water movement of this fruit through studying the impacts of its trade and how that relate to the global water scarcity problem. To set the scope of the study, avocado was chosen.

Avocado is a tropical fruit which requires enormous amount of water in its production. In many cases, they are grown using BW (Bower and Cutting, 1988). Its production per kilogram requires four times more water than the production of a kilo of oranges and ten times of that of a kilo of tomato (Water Civilization International Centre, 2018). Avocado production thrives in subtropical, tropical climate with high humidity (Stan, 2013), where optimum growth temperature is between 20º to 25º C and outside this range, the production and quality of the avocado is compromised (Agriculture Republic of South Africa, 2003). Not only does it require a substantial amount of water, avocado is also becoming increasingly popular. Since its introduction to the commercial market in the 90s, avocado has become one of the fruits with the greatest demand (Carman, Li and Sexton, 2009). This is shown in the United States, where a rapid increase in the annual consumption of avocado reached 2.7 kg per capita, doubling the 1.2 kg registered a decade ago (Butler and Jones, 2017). This is also demonstrated in avocado imports to European counties, such as France, Germany and the United Kingdom, where the import has doubled from 2002 to 2016 (Ministry of foreign affairs, 2016). The popularity of avocado is related to its versatility and its countless health benefits (Dw documentary, 2018). It also receives media attention as found where avocado is one of the most Instagrammed food (Fresh Plaza, 2018).

As avocado uses BW and is a popular import for many countries, it is an ideal fruit for the illustration of the study. This will be achieved through calculating the changes in demand for avocado export between 1990-2015 and thereby identifying the nations which have the highest demand, expressed in the change in supply per capita between this period. Secondly, to understand the production trend and quantify the BW required for avocado production, to estimate the BW footprint of avocado trade within the same timeframe and, finally evaluate whether this practice is sustainable.

2 METHODOLOGY

To set the scope of the study, the data between 1990 to 2015 was employed, where the average of 1990 to 1995 was set as the baseline value of all the calculations, which was then compared against the average between 2010 to 2015.

2.1 Change in global avocado demand

To calculate the changes in global demand for avocado and to identify which nations have the highest demand, a statistical analysis has been conducted during the period under reviewed. This was achieved through identifying the top 8 countries with the greatest demand, followed by comparing the changes in demand per year in each of the country. To standardize this data, the change in supply per capita of the main import countries was also calculated for comparison purposes. To identify the volumes of avocado supplied globally over this period, the annual total net mass of avocado production was adapted from FAOSTAT (2017). Also, the import and export data of annual total net mass was adapted from UN Comtrade (UN Comtrade, 2017).

2.1.1 Supply per capita

It is not possible to know the exact volume of avocado consumption per capita since it would require information about the volume of avocado that was thrown away, hence supply per capita has been calculated instead.

USA, Spain and France produce some of their own avocados domestically, so the supply was defined according to equation (2-1).

$$Domestic\ supply = A_i + D_p - A_e \qquad \textbf{(2-1)}$$

Where A_i is the volume of imported avocado, D_p is the domestic avocado production and A_e is the volume of exported avocado. For the case of the Netherlands, the United Kingdom, Germany and Sweden, as they do not produce avocado, $D_p = 0$.

To normalize the growth in supply due to rising population, the totals annual kilograms were divided by the population of each country (Worldometers, 2017).

2.2 The WSF of avocado trade

To explore the implication of avocado production for the global water scarcity and to evaluate its changes over time, the global WSF of avocado production during the period over reviewed has been calculated.

2.2.1 Production

2.2.1.1 WSF

The WSF of avocado is the product of the kilograms of avocado, the volume of BW consumed in its production and the local water scarcity factor (International Organization for Standardization [ISO], 2014). It provides an indication of the potential impact that the production of the avocado can have on the BW scarcity.

The absolute number is in water equivalent m^3 H_2O_e where 1 m^3 H_2O_e is thought to have an equal impact on water scarcity as 1 m^3 of water removed from a catchment area at the global average level of water stress. Although the WSF does not have a physical meaning, it is an indicator to compare the location and the hazards of products to water scarcity.

2.2.1.2 BW

To calculate the quantity of BW spent in the production of a product, it is necessary to determine the total water needs and the irrigation requirements according to the environmental conditions of the producing country (Mekonnen and Hoekstra, 2011). The BW of each avocado producing country was extracted from Mekonnen & Hoekstra (2011) (Table A-1), and the analysis included only those that use BW as supplemental irrigation.

2.2.1.3 The water scarcity factor

These factors were calculated through AWARE, a modeled average runoff between 1996 - 2010 introduced by Boulay et al. (2018) for assessing water scarcity. The resulting factor ranges between 0.1 and 100 at the national scale for agriculture water use. The global average water scarcity is represented by the factor 1 whereas a factor >1 means an increase in water scarcity. The water scarcity factors for each country were taken from WULCA, (2014) (Table A-1).

2.2.1.4 Avocado

To identify the volume of global avocado production and exports over the 25-year period, data on the annual total net mass production was extracted from FAOSTAT (2017). Whilst data on the annual total net mass of export from one country to another was taken from UN Comtrade (2017). In this study, the tariff code of 6 digits HS 080440 was used to access UN Comtrade data (which identifies fruit, edible; avocado fresh or dried). The Harmonized System, used by the majority of the trading nations, is an international nomenclature developed by The World Customs Organization to classify traded goods on a common basis (European Comission, 2017).

The data was sub-divided to assess water scarcity values attributable to domestic supplies consumed in-country, of which was produced for the purposes of export for international trade. To assess the changes in domestic supplies, the water scarcity values attributable to domestic supplies and export were assessed in the WSF main avocado producing countries. As these countries both produce and import avocado, the domestic production was obtained according the equation(2-1).

2.2.2 Export

Exports of a country can be differentiated as exports of domestic goods and exports of foreign goods. The second group is referred to as re-export (Mogilevskii, 2017). The study contains both the exports of foreign and domestic avocado. To calculate the WSF of the main avocado exporting countries, the countries re-exporting were not taken into account as there was not any direct water scarcity implication.

3 RESULTS

3.1 Changes in global avocado demand

Between the study period (1990-2015), the demand of exported avocado has increased from 230 to 1300 million kg (Figure B-1). The USA had by far the world's largest demand for avocados with nearly 50% of global annual imported avocado. Following the USA, there were France (15%), The Netherlands (8%), the United Kingdom (5%), Japan (4%), Germany (3%), Spain (3%) and Sweden (1%) (Table B-2).

There is a significant growth between 2010 and 2015, increasing by 100% of the annual global volume of imported avocado (Figure B-1). The growth in the Netherlands was noticeable, which increased from 83 million kg of avocado in 2010 to 144 million kg of avocado in 2015. The USA was another country that experienced a fast increase in demand, rising by 85%, followed by Sweden (79%), Japan (78%), Germany (66%) and Spain (48%). In the last positions are the UK (12%) and France (9%) (Table B-3).

3.1.1 Supply per capita

As a result of the increase in the popularity of avocado, the per capita avocado supply has risen over the 25-year period.

The supply per capita of avocado in Japan increased from 0.03 kg/year/person in 1990 to 0,41 kg/year/person in 2015. This high increase in the supply per capita reflects Japan's intention to develop in the fruit and vegetable import market at a fast pace, as Honma(1993) pointed out previously. The USA has experienced very strong growth of avocado supply from 0.66 kg/year /person in 1990 to 2.24 kg/year/person in 2015. Sweden was another country that experienced a fast increase in supply per capita, rising from 0.49 kg/year/person in 1990 to 1.91 kg/year/person in 2015.

Netherlands re-export the majority of avocado imported, over the period 1990-95 the volume of re-exported avocado was 20 times higher than over the period 2010-15. Even so, during this period the supply per capita in Netherlands went up from 0.23 to 1.66 kg/year/person. In the case of Spain, even suffering a decrease in population growth it doubled the supply per capita of avocado during the period under review. France and UK experienced an increase in supply per capita in the period of 25 - years but it was little compared to Japan, Sweden and USA (Table B-3).

3.2 The WSF of avocado trade

To explore the implication of avocado production in the water scarcity and to evaluate its changes over time, the global WSF over the 25-year period.

3.2.1 Production

With a constantly rising demand for the avocado by the consumer, tropical and subtropical countries where the avocado grows, are seeing the opportunity to produce and export the fruit all over the world. Between the study period (1990-2015), the annual global production of avocados had an upward trend, increasing from 1700 to 4025 million kg (Figure C-1). Over this period the majority of avocado production has been concentrated in Mexico with 38 % of annual global production, followed by the USA with 7%, the Dominican Republic and Colombia with 6% and Peru, Brazil and Chile with 5%.

3.2.1.1 BW consumption

The BW required in the production of avocado has increased noticeably in the 25-years period from 523 million m^3 1990 to 1058 million m^3 in 2010 (Figure C-2). The BW required in the production of avocado is different according to the country (Table 3-1). For instance, Australia requires to remove 1046 litres of BW from a catchment area to produce 1 kilogram of avocado whereas Jamaica requires to remove 3 litres and Dominican Republic only 1 litre.

Table 3-1. BW consumption by country taken from Mekonnen & Hoekstra

Country	BW (l/kg)	Country	BW (l/kg)
Australia	1046	**Zimbabwe**	114
Chile	808	**Costa Rica**	107
South Africa	759	**Ecuador**	103
Israel	698	**Honduras**	94
USA	599	**Tunisia**	58
Rwanda	472	**Panama**	57
Sri Lanka	472	**Brazil**	51
Bolivia	472	**China**	31
Venezuela	472	**Ethiopia**	14
Portugal	421	**Cameroon**	12
New Zealand	352	**Kenya**	8
Peru	341	**Colombia**	8
Argentina	321	**Guatemala**	7
Greece	278	**Barbados**	6
Mexico	266	**Jamaica**	3
Turkey	243	**Dominican Republic**	1
Morocco	224	**Haiti**	1
Lebanon	210		
Spain	204		

3.2.1.2 WSF

The potential water scarcity impact of avocado production depends on water resources availability and the water scarcity of the avocado producing countries. As Figure 3-1 illustrates, avocado production has a greater potential impact on the freshwater scarcity in Australia with 77 m^3 H_2O_e/ kg and Chile with 66 m^3 H_2O_e /kg than in France with 1 m^3 H_2O_e/kg or Zimbabwe 0.5 m^3 H_2O_e/kg (Table A-1).

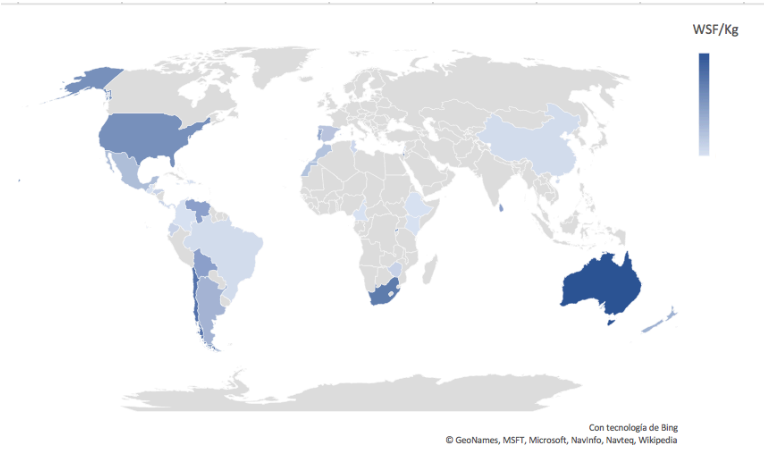

Figure 3-1. WSF/kg of avocado production per country

The top countries of WSF avocado production during the period under reviewed were Mexico with 27% of the global WSF avocado production, Chile with 22%, Israel with 12%, USA with 11%, followed by Australia (7%), South Africa (5,6%), Rwanda (5%), Peru (3,6%), Spain (3%) and Morocco (1%) (Table C-1).

The steady increase in the avocado production has led to constant increase in WSF, raising by 127% (Figure 3-2). Morocco, Peru, Chile or Australia recorded an increase of more than 100% of the annual global avocado production between 1990 and 2015, rising by about 519%, 257%, 255% and 240% respectively. South Africa, Spain and Mexico went up by about 90% whereas Israel and USA only grew by 50% (Table C-2).

The Figure 3-2 illustrates the annual global WSF of avocado production and the relation of annual global WSF/kg over the period 1990-2015. The WSF/kg was greater than the annual global WSF of annual avocado production between 1990 and 2011. It means that BW used in avocado production were primarily from countries with high water-stress. However, from 2011, WSF/kg decreases and it was found to be lower than the annual global WSF of avocado production, highlighting an increase in avocado production in countries such as the Dominican Republic, Colombia and Brazil, which have lower water-stress compared to high water-stress countries, such as Mexico and Peru. This is clearly shown where the production in Dominican Republic increased by 220% between the studied period. This is further evident where Dominican Republic moved from the 16th to the 2nd position regarding the top avocado producer ranking.

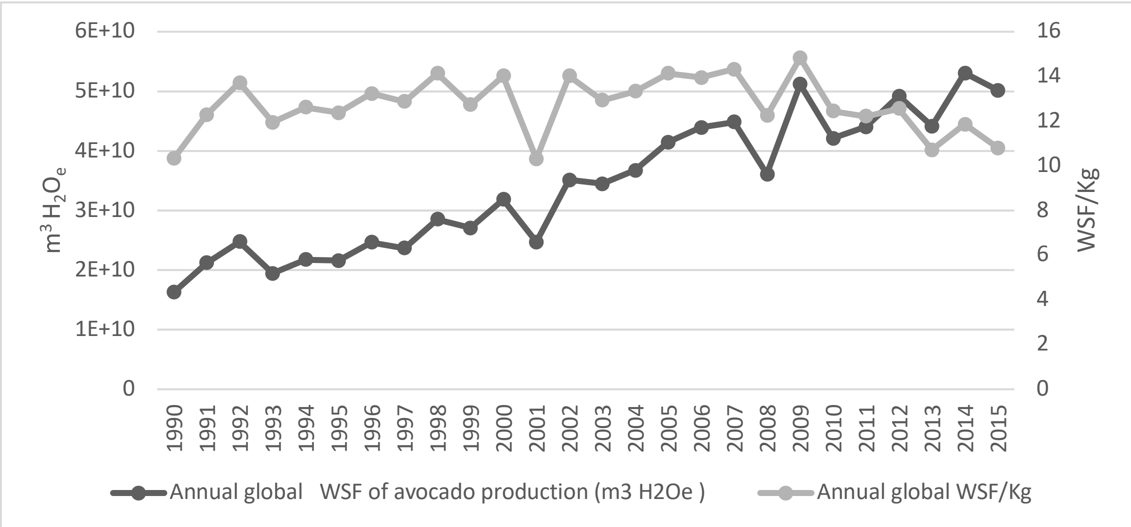

Figure 3-2 Annual global WSF and annual global WSF/kg of avocado production between 1990 and 2015

3.2.1.3 Domestic supplies and export for international trade

The increasing demand of avocado all over the world has led to an increase in the volume of avocado produced for the purposes of export. In 1990-95 Mexico exported about 2% of the avocado produced, and the rest was for domestic supplies whereas 2015 the volume of the exported avocado grew up by to about 70% of avocado produced. In Peru, in 1990 nearly 90% of the avocado produced was consumed locally, whereas in 2015 it was only 60%. In the case of Chile, the volume of exported avocado was 7 times higher in 2015 than in 1990 (Figure C-3). It has resulted in increases in the WSF associated with exports to countries such as The Netherlands, United Kingdom, France, Swaziland and Japan (Table C-3).

Australia and Morocco account also for a high percentage of BW footprint of avocado production, however the majority of that BW has been consumed locally. In Israel, Spain and South Africa, the relation between avocado consumed locally and exported has been steady, the amount of avocado produced for the purposes of export have been 10-20% higher than domestic supplies between 1990-2015. In USA, the volume of avocado produced for the purposes of export increased from about 5% in 1990 to 16 % in 2015 (Figure C-3).

3.2.2 Export

Over the 25-year period, the volume of re-exported avocados makes up 10% of the annual global exported avocado. The Netherlands was responsible for about 8% of the re-export, followed by Belgium, Germany and Italy with 0.6% (Table C-4).

Mexico was by far the world's largest exporter of avocados with nearly 23 million kg in 1990 and 628 million kg in 2015. This was followed by Chile, as the second greatest exporter with approximately 12 million kg and 97 million kg, followed by Spain, South Africa, Israel, Peru and the USA. Therefore, it demonstrated that the countries with high BW requirement per unit of production and the water scarce location are the main avocado exporting countries during the period under review (Table C-5).

While these countries dominated world avocado export, it is interesting to note that countries, such as China experienced substantial annual growth rate 23% in terms of export from 2010-2015, while other countries, such as Dominican Republic expressed a growth rate of 3.7%. China was followed by Tanzania and Sri Lanka. It is also important to note an increase of over 100% in countries under less water-stress regarding the volume of exported avocado, including Colombia, Barbados and Brazil (Table C-6).

3.2.2.1 WSF of exported avocado

With the steady increase of avocado exports, the WSF of exported avocado increased from 77 million m^3 H_2O_e (1990-1995) to 795 million m^3 H_2O_e (2010-2015).

During the period under review the largest WSF of exported avocado was associated with Chile (40%), whose annual global WSF increased from 791 million m^3 H_2O_e (1990-1995) to 6500 million m^3 H_2O_e (2010-2015). It was followed by Israel (19%) Mexico (17%) South Africa (10%), Spain (6%), USA (3%), Peru (3%) (Table C-7).

4 DISCUSSION

This study aims was to estimate the BW required for avocado production to explore the impacts of the avocado trade on global water scarcity, how it has changed over time and whether this practice is sustainable. This was calculated through the BW and WSF use for avocado production to explore the impacts of the avocado trade on water scarcity. This provides useful evidence in the water for food debate, illustrating the growth of the WSF associated with imports to countries such as The Netherlands, United Kingdom, France, Sweden and Japan from countries under higher water stress such as Mexico, Israel, Chile and Peru.

4.1 Contribution to the academic debate around "water for food"

Postel, Daily and R.Enrich (1996) pointed out the necessity to double the rate of food production and access to fresh drinking water by 2050 to support rapid population growth with more consumptive lifestyles and climate change. However, FAO (2011) suggested that water resources and land are constrained to the point where their capacity to meet current and future demand required is seriously threatened. This was supported by (Koehler, 2008), where the desiccation of rivers has been largely due to a spreading of the irrigation system with the help of water from aquifer, lakes and rivers with the aim to increase agricultural production, especially food. Here the study showed a sharp growth of water resources used to meet the rising demand for avocado. It has also shown that global demand for avocados has more than doubled the quantity of BW required to meet production needs between 1990-2015.

With globalization comes the opportunity for trading virtual water. The notion of virtual water suggests that a well-functioning global trade system could encourage countries to export goods based on their natural resource availability (FAO, 2011). Yang et al. (2003) strongly suggested, based on rigorous statistical analysis, a direct linkage between food imports and water availability per capita when water becomes scarce. Zimmer and Renault (2003) also showed the importance of virtual water trade in balancing global water scarcity. Ziervogel et al. (2014) pointed out the importance of the trade as a significant tool to sustain global food security in the context of climate change and water scarcity.

However, this study pointed out the increase of exported water through the avocado from high water stress countries such as Chile, Mexico or Peru to low water stress such as The Netherlands, United Kingdom, France, Swaziland and Japan. The Netherlands illustrates the point that virtual water is moving from more water stressed to less water stressed areas. It has been identified as one of the nation's creating more demand for avocado in the last years. Our findings are close to what Oel, Mekonnen and Hoekstra (2008) found in another recent global water scarcity study. They pointed out that the Netherlands consumption was impacting the use of water resources through the world, with important negative impacts on foreign water resources. Hoekstra and Chapagain (2007) have also shown the Netherlands import more virtual water in form of water-intensive agricultural commodities than they export. The water footprint calculations illustrate that the Netherlands depends on water resources elsewhere in the world for 95% (Hoekstra and Chapagain 2007).

This movement of water from high to low water stress countries suggests the unlikely sustainability of this trade in the long term. However, the study revealed the increase of avocado produced by countries with less water-stress such as the Dominican Republic or Colombia over the period 2010-2015, which suggests the possibility of expanding production of avocado with less BW requirement in order to meet the future demand while reducing impacts on other ecosystem values.

4.2 Environmental and socio-economic impacts that are occurring in main avocado exporting countries.

4.2.1 Environmental impacts

Agriculture production have more than tripled between 1960 and 2015, due in part to productivity-enhancing Green Revolution technologies and a noticeable expansion in the use of water and other natural resources for agricultural purposes (Evenson, 2003). However according to FAO (2013), the intensification of production has been associated with important negative environmental effects, such as intensifying water scarcity, loss in biodiversity, groundwater pollution and soil erosion. Moreover, climate change is likely to exacerbate the problem of water scarcity in many regions (Ziervogel et al., 2014). The implication of climate change for global food production are geographically very irregularly distributed, with major losses in sub-humid and arid tropics and mainly in poor countries with high level of water stress and low capability of adaptation (Hanjra and Qureshi, 2010). This means that more than 80% of the water for domestic, agricultural and industrial users is withdrawn annually, leaving communities vulnerable to shortage of water (Vörösmarty *et al.*, 2000). According to Chambers and Conway (1991) the today's agriculture and food systems are unlikely to meet the needs of a global population that is projected to increase. A similar conclusion was reached by (FAO, 2009), which adds the high challenge of achieving the required production, even as the pressures on already scarce land and water resources and the negative impacts of climate change intensify. Önder, Ceyhan and Kahraman (2011) pointed out the needs of developing countries to take more serious action related to agriculture and environment. Policies to improve agriculture infrastructure and regulations are required to carry out agriculture practices which are environment-friendly. The results demonstrate that the main avocado exporting countries are Chile, Peru, Israel, Mexico and South Africa. They are characterized by their naturally arid weather (Martinko, 2018) that suffer from long dry periods, so in the majority of the cases supplementary irrigation is required to meet avocado production (Stan, 2013). As can be seen in Figure 4-1, these countries face "high and extremely high" levels of baseline water stress. In the case of South Africa for instance, which is naturally prone to suffer droughts, there have been combined impacts of a serious drought that has decreased the water resources available leading to the need of setting up water restrictions still implemented (Agrisa, 2016). The most suitable areas for avocado production in South Africa (KwaZulu – Natal, Mpumalanga and Limpopo) were declared as the most drought disaster regions (Napier and Rubin, 2001). However, the country has continued producing avocados, in fact between 1990-2015, the avocado production has more than doubled the quantity of BW required to meet production need.

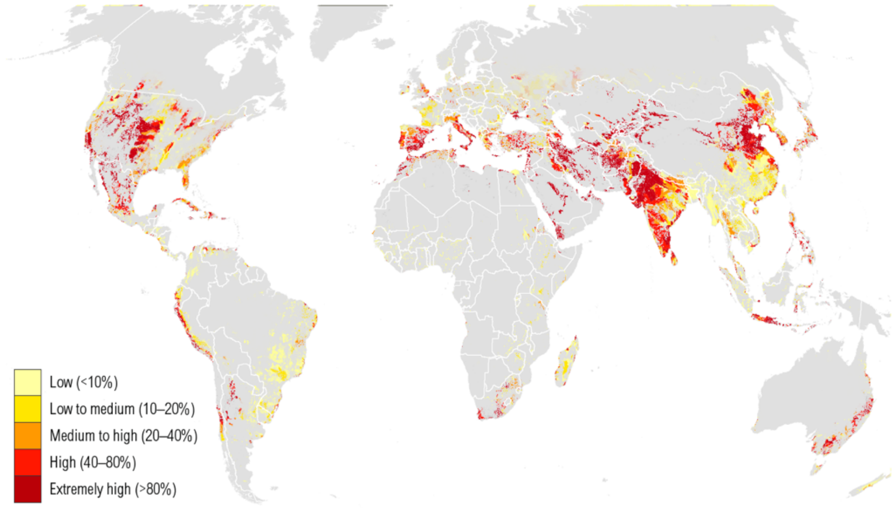

Figure 4-1. Exposure to Water Stress in Areas of Agricultural Production Worldwide. Source: Gassert *et al.* (2013)

The insufficient presence of water in these countries is resulting in illegal and unsustainable activities. The installation of illegal pipes and wells in Child to divert water from rivers in order to irrigate the avocado plantations has dried up rivers and groundwater in avocado producing areas such as La Lingua or Petorca Valley (Budds, 2004). Gabriel and Hort (2015) suggested that the environmental impact of avocados is generating concern in producer associations, government agencies and the general public. According to the UN`s Food and Agricultural Organization, Mexico controls about half of the global avocado trade causing an intensive avocado production in the country. As a result, it is causing an important impact on the environment. Forests are being destroyed to create more avocado plantations. Moreover, the expansion of avocado orchards requires nearly twice as much water as dense forest (Dorantes, Parada and Ortiz, 2004) .While in Mexico, fruit is more sensitive to insect infestation (Peña, Mohyuddin and Wysoki, 1998), so it is necessary to use pesticides to maintain a properly biological control. Nevertheless, they are finding their way into the natural water resources causing severe health problems for people and local ecosystems (Isman, 2006).

However, more European companies are becoming aware of the environmental conditions in the producing areas and international actions have been conducted to increase sustainability in avocado production(Önder, Ceyhan and Kahraman, 2011). For instance, the Sustainability Initiative Fruit and vegetable (SIFAV) association, which aim is to make imports of fruit and vegetables from Africa, Asia and South America more sustainable by 2020 (Colley, 2015). In order to promote a more sustainable practice, decreasing damage caused by pesticides, the EU has set maximum residue levels (MRLs). Which main aim is to ensure that products coming from countries such as Mexico do not contain more pesticides than allowed. On the contrary, it will be pulled out from the EU market (Ministry of Foreign Affairs, 2016). Ministry of Foreign CBI (2018), in charge of importing from developing countries (Africa, Asia and Latin America) and contributing to inclusive economic development in developing countries through the expansion of exports to Europe countries, affirms that avocados are so popular all over the world and consumers are prepared to pay superior prices for high-quality. Therefore, effects can be positive if profits are fairly distributed and utilized to support equitable development.

4.2.2 Socio-economic impacts

The rapid increase in the international markets of fruits and vegetables has attracted many countries´ attention, as the increasing export trade are expected to contribute to employment opportunities and agricultural diversification (Honma, 1993).This was supported by Nieuwoudt, Backeberg and Du Plessis´ study (2004) who affirmed that, although the agriculture sector is generating less output per unit of water, it is the leader generating jobs per value of output among the other sectors. The expansion of the avocado industry has boosted the regional economy during the periods of production, creating jobs where avocado is produced. In the case of Mexico, for instance by 2003 the avocado production generated 187,000 indirect jobs, 47,000 direct jobs and 70,000 seasonal jobs (APROAM, 2003). Moreover, during the 90´s Mexico´s government established changes in labour laws and tax, which drove the farmer to pay taxes and pay the workers higher salaries, hence benefiting the local population in the long-term (Committee on commodity problems, 2009). For South Africa, avocado industry plays an important role in the context of employment creation during the periods of production (Republic of South Africa-Department of Agriculture Forestry and

Fishery, 2012). Although there are many beneficial effects from the production of avocado, the avocado trade is the lack of collaboration of the domestic organizations as well as the international differences caused by the economic, political and social interests (Ceja-Torres, Daniel Téliz-Ortiz and Morales-García, 2000). An example could be Chile, which conducted in 1981 their Water Code to support the liberalization of the economy. This objective was pretended to be achieved, to a large extent, through natural resource-based exports and economic development by the private sector in a free market framework. However, the application of the code has led to an increase in the unequal distribution of water and land between large and peasant farmers (Budds, 2004).

According to the Intergovernmental Panel on Climate Change (2004), the climate change effects on water resources are going to be more intensive in the close future than previously foreseen. Giving place both indirect and direct impacts on the socio-economic environments, climate change has been contributing factor to food price crises, and its implications on agriculture in developing countries is expected to get worse (Farauta *et al.,* 2011). Hass avocado board (2016) affirms the fact that The Netherlands, United Kingdom, New Zealand and France are increasing on the European the total value of imported avocados markets, indicating low prices for suppliers. The consumption of avocados is increasing globally by about three percent yearly. However, the production slows due to climate change and modifications in production planning, leading to an increase in 2015 and 2016 (Ministry of Foreign CBI, 2018), due to the poor or postponed crops caused by flooding in Peru and droughts in Chile (Kreft *et al.*, 2014). According to the ONS(2018) the price of avocado in the UK has doubled over the last years and is expected to increase steadily in the near future. Moreover, it is expected increase steadily in the near future (Hass avocado board, 2016). Although the UK imports the majority of avocados from Chile, Spain, South Africa, and Peru, the intensive droughts in California and Mexico could have also repercussions in UK, as the supply gaps have to be filled by these countries (Butler and Jones, 2017).

4.3 Further research

Naamani (2011) affirmed that avocado supply is comparatively low compared to older products such as citrus, bananas, and apples. In historical terms, it is just taking its first commercial steps. Hass avocado board (2016) adds that there is a shortage of world avocado supplies as the limiting factor is the supply while the demand is far from being saturated. Committee on Commodity Problems(2009) affirmed that avocado markets have expanded rapidly over the last decades and these trends are expected to continue in the future. With new market emerging such as China, the expectancy is that the global demand will still be increasing for a number of years (Ministry of Foreign Affairs, 2016). Here the study has showed the noticeable increase of demand for exported avocado over 1990-2015. In countries such as Japan and The USA the avocado supply per capita increased by more than 100%. However, basing on the other popular fruits´ development, future consumption scenario could change. Citrus fruits rank first in terms of international trade value. These fruits, as well as avocado, are characterized by their high nutritional value. Nevertheless, over the last decades, there has been a decrease in trade of bigger citrus fruits such as grapefruit. The evaluation of consumer preference has been more oriented to easy-peeler, small-sized and seedless fruits (Lacirignola C. and D’onghia, 2009).

Therefore, it remains unclear the future of the avocado trade and further study to evaluate the possibility to expand production of avocado with less BW would be required, in order to meet the future demand while reducing impacts on other ecosystem values.

5 CONCLUSION

Using a WSF analysis has allowed the volumes of BW removed from water resources to be put into the context of the degrees of water scarcity in the avocado producing countries.

Avocado has become one of the tropical fruits with the greatest demand which increased from 230 in 1990 to 1300 million kg in 2015. Over this period growing demand for imported avocados from the USA, the Netherlands, the United Kingdom, Sweden and Japan has increased production in countries such as Mexico, Chile, Israel, USA, Australia and South Africa leading to increasing BW scarcity in these locations. This movement of virtual water from more water stressed to less water stressed areas is leading to an increase of the litres of BW required to meet the annual global avocado demand, which increased from 523 million m^3 in 1990 to 1058 million in 2015.Therefore, although a number of studies have shown a significant reduction in the virtual water requirement of vegetarian or healthy diets (Gerbens-Leenes, Mekonnen and Hoekstra, 2013) this study has shown the rising WSF generated by avocado consumption. Moreover, given the projected impacts of population growth and potential impacts of climate change on the availability of global freshwater resources carried out in the avocado producing countries, this trend is unlikely to be sustainable in the longer term. On the other hand, the environmental and socioeconomic impact of avocado trade on avocado producing countries have been discussed and it has pointed out the possibility of getting positive effects if profits are fairly distributed and utilized to support equitable development.

6 REFERENCES

Agrisa (2016) *A Raindrop in the Drought : Agri SA's Status Report on the Current Drought Crisis*.

Allan, J. A. (1998) 'Virtual water: A strategic resource global solutions to regional deficits', *Ground Water*, 36(4), pp. 545–546. doi: 10.1111/j.1745-6584.1998.tb02825.x.

APROAM (2003) *APHIS*, *Recetario del Aguacate.3rd.Ed.Mexico*. Available at: www.aphis.usda.gov/ppq/avocados (Accessed: 20 August 2018).

Barbosa-Cánovas, G. *et al.* (2003) *Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas*, *Food and Agriculture Organization of the United Nations*. doi: ISBN 92-5-104861-4.

Boulay, A. M. *et al.* (2018) 'The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE)', *International Journal of Life Cycle Assessment*. The International Journal of Life Cycle Assessment, 23(2), pp. 368–378. doi: 10.1007/s11367-017-1333-8.

Bower, J. and Cutting, J. (1988) 'Avocado fruit development and ripening physiology', *Horticultural Reviews*, 10(1982), pp. 229–271. doi: 10.1002/9781118060834.

Budds, J. (2004) 'Power, nature and neoliberalism: The political ecology of water in Chile', *Singapore Journal of Tropical Geography*, 25(3), pp. 322–342. doi: 10.1111/j.0129-7619.2004.00189.x.

Carman, H. F., Li, L. and Sexton, R. J. (2009) 'An Economic Evaluation of the Hass Avocado Promotion Order ' s First Five Years', (December).

Ceja-Torres, L. F., Daniel Téliz-Ortiz, S. O.-K. and Morales-García, J. L. (2000) *Etiología, Distribución e Incidencia del Cancro del AguacatePersea americanaMill. en Cuatro Municipios del Estado deMichoacán, México*.

Chambers, R. and Conway, G. (1991) ‘Sustainable rural livelihoods: practical concepts for the 21st century’, *Ids Discussion Paper*, 296(Brighton: Institute of Development Studies, University of Sussex), p. 29. doi: ISBN 0 903715 58 9.

Colley, K. (2015) ‘Sustainability Initiative Fruit & Vegetables (SIFAV)’.

Committee on commodity problems (2009) *Product segmentation and market perspectives in the european community and the united states avocado markets*.

Da, F. (2017) ‘Review on Impacts of Climate Change on Vegetable Production and its Management Practices’, *Advances in Crop Science and Technology*, 5(5), pp. 1–7. doi: 10.4172/2329-8863.1000306.

Dalin, C. *et al.* (2012) *Correction for Dalin et al., Evolution of the global virtual water trade network*, *Proceedings of the National Academy of Sciences*. doi: 10.1073/pnas.1206123109.

Department: Agriculture Republic of South Africa (2003) *Cultivating subtropical crops*.

Dorantes, L., Parada, L. and Ortiz, A. (2004) ‘Avocado Post-harvest Operations’, *Food and agriculture Organization of the United Nations*, p. 67.

Dw documentary (2018) *Avocado - a positive superfood trend?* Available at: https://www.youtube.com/watch?v=05oMsK0-jjA, (Accessed: 30 May 2018).

European Comission (2017) *EU product classification system*. Available at: http://trade.ec.europa.eu/tradehelp/eu-product-classification-system (Accessed: 18 July 2018).

Evenson, R. E. (2003) ‘Assessing the Impact of the Green Revolution, 1960 to 2000’, *Science*, 300(5620), pp. 758–762. doi: 10.1126/science.1078710.

Falkenmark, M. (2003) ‘Freshwater as shared between society and ecosystems: From divided approaches to integrated challenges’, *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358(1440), pp. 2037–2049. doi: 10.1098/rstb.2003.1386.

FAO (2009) ‘How to Feed the World in 2050’, *Insights from an expert meeting at*

FAO, 2050(1), pp. 1–35. doi: 10.1111/j.1728-4457.2009.00312.x.

FAO (2011) *The State of the World's land and water resources for Food and Agriculture. Managing systems at risk*, *Food and Agriculture Organization*. doi: 978-1-84971-326-9.

FAO (2012) 'Coping with water scarcity An action framework for agriculture and food security', *Food and Agriculture Organization of the United Nations*, p. 79. doi: http://www.fao. org/docrep/016/i3015e/i3015e.pdf.

FAO (2016) 'Coping with Water Scarcity in Agriculture', *Food and Agriculture Organization of the United Nations*, pp. 1–12.

FAOSTAT (2017) *FAOSTAT*. Available at: http://www.fao.org/faostat/en/#home (Accessed: 10 July 2018).

Farauta, B. K. *et al.* (2011) *Farmers' perceptions of climate change and adaptation strategies in Northern Nigeria: an empirical assessment*, *African Technology Policy Studies Network*.

Food and Agriculture Organization of the United Nations (2017) *Water for Sustainable Food and Agriculture*. Rome.

Fresh plaza (2018) *OVERVIEW GLOBAL AVOCADO MARKET*. Available at: http://www.freshplaza.com/article/190075/OVERVIEW-GLOBAL-AVOCADO-MARKET (Accessed: 28 July 2018).

Gabriel, O. and Hort, H. (2015) 'Energy consumption in the management of acovado orchards in Michoacan, Mexico', (April), pp. 4–20. doi: 10.5154/r.rchsh.

Gassert, F. *et al.* (2013) 'Aqueduct country and river basin rankings: a weighted aggregation of spatially distinct hydrological indicators', (December), p. 28. Available at: wri.org/publication/ aqueduct-country-river-basin-rankings.

Gerbens-Leenes, P. W., Mekonnen, M. M. and Hoekstra, A. Y. (2013) 'The water footprint of poultry, pork and beef: A comparative study in different countries and production systems', *Water Resources and Industry*, 1–2, pp. 25–36. doi: 10.1016/j.wri.2013.03.001.

Hanjra, M. A. and Qureshi, M. E. (2010a) 'Global water crisis and future food security in an era of climate change', *Food Policy*. Elsevier Ltd, 35(5), pp. 365–377. doi: 10.1016/j.foodpol.2010.05.006.

Hanjra, M. A. and Qureshi, M. E. (2010b) 'Global water crisis and future food security in an era of climate change', *Food Policy*. Elsevier Ltd, 35(5), pp. 365–377. doi: 10.1016/j.foodpol.2010.05.006.

Hass avocado board (2016) *TOP 10 TRENDS Changes and Challenges to Build Hass Avocado Retail Sales*.

Hoekstra, A. Y. and Chapagain, A. K. (2007) 'The water footprints of Morocco and the Netherlands: Global water use as a result of domestic consumption of agricultural commodities', *Ecological Economics*, 64(1), pp. 143–151. doi: 10.1016/j.ecolecon.2007.02.023.

Honma, M. (1993) 'Growth in horticultural trade: Japan's market for developing countries', *Agricultural Economics*, 9(1), pp. 37–51. doi: 10.1016/0169-5150(93)90035-B.

International Organization for Standarization [ISO] (2014) 'ISO 14046 Water footprint - Briefing note: Measuring the impact of water use and promoting efficiency in water management', p. 2. Available at: http://www.iso.org/iso/iso14046_briefing_note.pdf.

Isman, M. B. (2006) 'Botanical Insecticides, Deterrents, and Repellents in Modern Agriculture and an Increasingly Regulated World', *Annual Review of Entomology*, 51(1), pp. 45–66. doi: 10.1146/annurev.ento.51.110104.151146.

Kang, Y., Khan, S. and Ma, X. (2009) 'Climate change impacts on crop yield, crop water productivity and food security - A review', *Progress in Natural Science*. National Natural Science Foundation of China and Chinese Academy of Sciences, 19(12), pp. 1665–1674. doi: 10.1016/j.pnsc.2009.08.001.

Kenneth, F. D. and Major, D. C. (2002) ‘Climate Change and Water Resources’, *The Management of Water Resource, volume 2*.

Koehler, A. (2008) ‘Water use in LCA: Managing the planet’s freshwater resources’, *International Journal of Life Cycle Assessment*, 13(6), pp. 451–455. doi: 10.1007/s11367-008-0028-6.

Kreft, S. *et al.* (2014) *Global climate risk index 2013: Who suffers most from Extreme weather events? Weather-related loss events in 2013 and 1994 to 2013*, *Think Tank & Research*. doi: 978-3-943704-04-4.

Lacirignola C. and D’onghia, A. M. (2009) ‘The Mediterranean citriculture: productions and perspectives’, *Citrus tristeza virus and Toxoptera citricidus: a serious threat to the Mediterranean citrus industry*, 17, pp. 13–17. Available at: http://om.ciheam.org/article.php?IDPDF=801383http://www.ciheam.org/.

Malhotra, S. K. (2017) ‘Horticultural crops and climate change’, *Indian Journal of Experimental Agriculture*, 87(1), pp. 12–22.

Martinko, K. (2018) *Avocado mania continues to suck Chile dry*, *treehugger*. Available at: Avocado mania continues to suck Chile dry (Accessed: 4 July 2018).

Mekonnen, M. M. and Hoekstra, A. Y. (2011) ‘The green, blue and grey water footprint of crops and derived crop products’, *Hydrology and Earth System Sciences*, 15(5), pp. 1577–1600. doi: 10.5194/hess-15-1577-2011.

Ministery of Foreign CBI (2018) *Exporting fresh avocados to Europe*. Available at: https://www.cbi.eu/market-information/fresh-fruit-vegetables/avocados/europe/ (Accessed: 3 June 2018).

Ministry of foreign affairs (2016) ‘Exporting fresh avocados to Europe Contents of this page’, (804).

Ministry of Foreign Affairs (2016) ‘Exporting fresh avocados to Europe Contents of this page’, (804).

Mogilevskii, R. (2017) ‘Re-Export Activities in Kyrgyzstan: Issues and Prospects’, *Ssrn*, (9). doi: 10.2139/ssrn.3023226.

Musolino, D. A., Massarutto, A. and de Carli, A. (2018) ‘Does drought always cause economic losses in agriculture? An empirical investigation on the distributive effects of drought events in some areas of Southern Europe’, *Science of The Total Environment*. Elsevier B.V., 633, pp. 1560–1570. doi: 10.1016/j.scitotenv.2018.02.308.

Naamani, G. (2011) ‘Global Trends in main avocado markets’, *Proceedings VII World Avocado Congress*, 2011(September).

Napier, M. and Rubin, M. (2001) ‘Managing Environmental and Disaster Risks Affecting Informal Settlements : Lessons From Southern Africa’, pp. 92–104.

Nieuwoudt, W. L., Backeberg, G. R. and Du Plessis, H. M. (2004) ‘The value of water in the South African economy: Some implications’, *Agrekon*, 43(2), pp. 162–183. doi: 10.1080/03031853.2004.9523643.

Oel, P. R. Van, Mekonnen, M. M. and Hoekstra, A. Y. (2008) ‘water footprint of the Netherlands : quantification and impact assessment’, (33). doi: 10.1016/j.ecolecon.2009.07.014.

Office for National Statistics (2018) *https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/doht/mm23*

Önder, M., Ceyhan, E. and Kahraman, A. (2011) ‘Effects of Agricultural Practices on Environment’, 24(March), pp. 28–32.

Peña, J. E., Mohyuddin, A. I. and Wysoki, M. (1998) ‘A review of the pest management situation in mango agroecosystems’, *Phytoparasitica*, 26(2), pp. 129–148. doi: 10.1007/BF02980680.

Postel, S. L., Daily, G. C. and R.Enrich, P. (1996) *Human appopriation of renewable fresh water*.

Republic of South Africa-Department of Agriculture Forestry and Fishery (2012) ‘A Profile of the South African Avocado Market Value Chain’. Available at: http://www.nda.agric.za/docs/AMCP/Avocado2012.pdf.

Rockstrom, J. and Falkenmark, M. (2006) 'The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management', *Journal of Wafile:///Volumes/Sin título/thesis new/Discussion/water food/1-s2.0-S0306919214001559-main.pdf file:///Volumes/Sin título/thesis new/Discussion/water food/1994_rijsbermanf.pdf file:///Volumes/Sin título/thesis new/Discussion/water food/Falkena*, 132(3), pp. 129–132. doi: 10.1061/(ASCE)0733-9496(2006)132:3(129).

Rost, S. *et al.* (2008) 'Agricultural green and blue water consumption and its influence on the global water system', *Water Resources Research*, 44(9), pp. 1–17. doi: 10.1029/2007WR006331.

Sarah, B. and Sam, J. (2017) *Holy guacamole! Avocado fans in UK face further price rises*, *The Guardian*.

Sauer, T. *et al.* (2008) 'Agriculture, population, land and water scarcity in a changing world – The role of irrigation', *12th Congress of the European Association of Agricultural Economists – EAAE 2008*, (August), pp. 1–9.

Schwab, K. *et al.* (2014) *The Global Competitiveness Report*, *World Economic Forum Reports 2014*. doi: ISBN-13: 978-92-95044-73-9.

Stan, C. (2013) *Avocado*.

Tamea, S., Laio, F. and Ridolfi, L. (2016) 'Global effects of local food-production crises: A virtual water perspective', *Scientific Reports*. Nature Publishing Group, 6(November 2015), pp. 1–15. doi: 10.1038/srep18803.

The Intergovernmental Panel on Climate Change (2004) 'Introduction The Intergovernmental Panel on Climate Change (IPCC) Why the IPCC was created How the IPCC is organized IPCC products', *Water*, (December).

UN Comtrade (2017) *UN Comtrade Database*. Available at: https://comtrade.un.org/ (Accessed: 28 May 2018).

Vörösmarty, C. J. *et al.* (2000) 'Global water resources: Vulnerability from climate change and population growth', *Science*, 289(5477), pp. 284–288. doi:

10.1126/science.289.5477.284.

World Water Assessment Programme (WWAP) (2017) *Facts and figures, UNESCO*.

Worldometers (2017) *worldometers*.

WULCA (2014) *AWARE*. Available at: http://www.wulca-waterlca.org/aware.html (Accessed: 29 June 2018).

Yang, H. *et al.* (2003) 'A water resources threshold and its implications for food security', *Environmental Science and Technology*, 37(14), pp. 3048–3054. doi: 10.1021/es0263689.

Yang, H. and Zehnder, A. (2007) '"Virtual water": An unfolding concept in integrated water resources management', *Water Resources Research*, 43(12), pp. 1–10. doi: 10.1029/2007WR006048.

Ziervogel, G. *et al.* (2014) 'Climate change impacts and adaptation in South Africa', *Wiley Interdisciplinary Reviews: Climate Change*, 5(5), pp. 605–620. doi: 10.1002/wcc.295.

Zimmer, D. and Renault, D. (2003) 'FAO: Virtual water in food production and global trade: Review of methodological issues and preliminary results', *Fao*, (1), pp. 1–19.

APPENDICES

Appendix A

A.1 WSF/kg per country

Table A-1 The BW, the water scarcity indicator and the WSF/kg of avocado production per country

COUNTRY	BW (l/kg)	SI	WSF/kg ($m^3 H_2 0_e/kg$)
Australia	1046	73.66	77.048
Chile	808	81.85	66.135
Israel	698	83.68	58.409
Rwanda	472	72.15	34.055
South Africa	759	38.11	28.925
USA	599	36.49	21.858
Portugal	421	51.03	21.484
Greece	278	70.11	19.491
Morocco	224	86.79	19.441
Lebanon	210	86.81	18.230
Argentina	321	54.15	17.382
Spain	204	79.13	16.143
Turkey	243	57.39	13.946
Sri Lanka	472	22.36	10.554
Mexico	266	34.25	9.111
Peru	341	25.53	8.706
New Zealand	352	12.16	4.280
Tunisia	58	68.33	3.963
Bolivia	472	8.21	3.875
Venezuela	472	4.90	2.313
China	31	45.53	1.411

Zimbabwe	114	4.25	0.485
Ecuador	103	4.62	0.476
Ethiopia	14	25.01	0.350
Costa Rica	107	1.35	0.144
Brazil	51	2.45	0.125
Cameroon	12	9.82	0.118
Honduras	94	1.00	0.094
Barbados	6	14.35	0.086
Kenya	8	9.67	0.077
Panama	57	1.29	0.074
Jamaica	3	10.87	0.033
Dominican Republic	1	8.79	0.009
Guatemala	7	1.17	0.008
Colombia	8	0.55	0.004
Haiti	1	2.09	0.002

Appendix B

B.1 Annual global demand for exported avocado

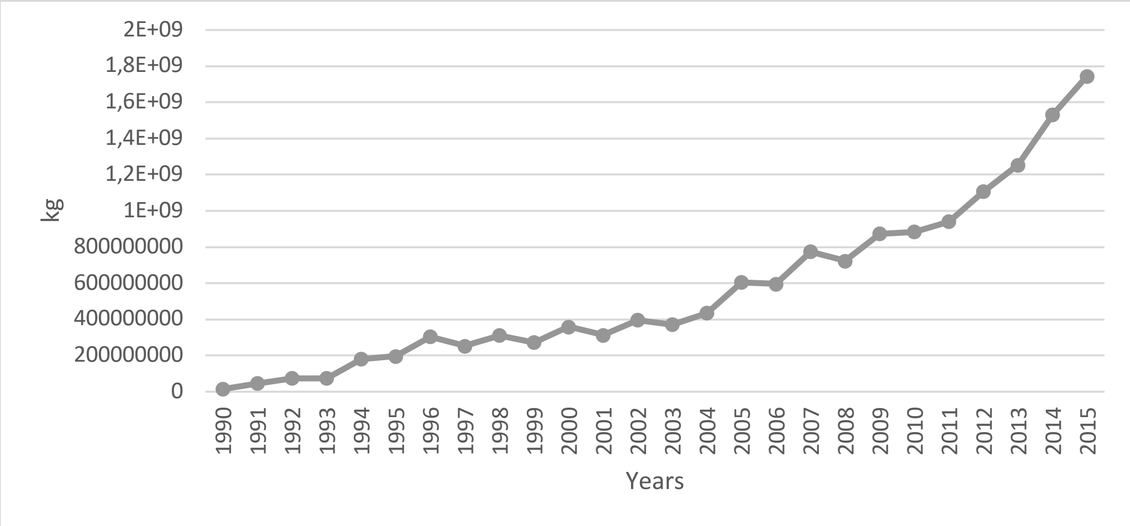

Figure B-1 Annual global demand for exported avocado over 1990-2015

B.2 The main avocado demanding countries

Table B-1 Global demand for exported avocado over 1990-2015 by the main avocado demanding countries

Countries	Million kg
USA	5660
France	2143
Netherlands	1122
UK	772
Japan	595
Germany	490
Spain	432
Sweden	225
Others	3198

B.3 Change in global avocado demand

Table B-2 Change in global avocado demand between 2010-2015 by the main avocado demanding countries

Countries	Demanand in 2010 (million Kg)	Demand in 2015 (million Kg)
Netherland	55	115
USA	370	684
Sweden	10	18
Japan	30	53
Germany	21	34
Spain	28	42
UK	42	47
France	95	103

B.4 Supply per capita

Table B-3 The supply per capita of avocado between 1990-2015 by the main avocado demanding countries

COUNTRIES	YEARS	Domestic production (kg)	Imported avocado (kg)	Exported avocado (kg)	Avocado supplied (kg/year)	Population	kg/year/person
USA	1990	167901842.50	16493669.76	11696125.44	172699386.80	263424231	0.61
	2015	189867122.20	544420031.20	31184389.01	703102764.40	314234596	2.24
France	1990	96736.59	82328351.58	8623441.63	73801646.55	57597752	1.28
	2015	1136434.32	101407074.40	15006679.24	87536829.45	63737957	1.37
The Netherlands	1990		8734047.92	5294405.17	3439642.74	15214575	0.23
	2015		134738599.50	106839214.55	27899384.91	16810222	1.66
UK	1990		13890283.30	337810.80	13552472.49	58462562	0.23
	2015		44718869.35	1453492.11	43265377.23	65592534	0.66
Spain	1990	42792839.01	672088.87	24740880.38	18724047.51	39597221	0.47
	2015	81292466.21	40431746.02	68839573.88	52884638.35	65592534	0.81
Japan	1990		3440429.26		3440429.26	124515561	0.03
	2015		51857216.00		51857216.00	127974958	0.42
Germany	1990		9972917.90	175943.55	9796974.34	80172442	0.12
	2015		33043388.46	5990610.05	27052778.40	80894785	0.33
Sweden	1995		4293293.40	10935.94	4282357.45	8700862	0.49
	2015		17633459.13	71488.26	17561970.87	9212719	1.91

Appendix C

C.1 Annual global avocado production

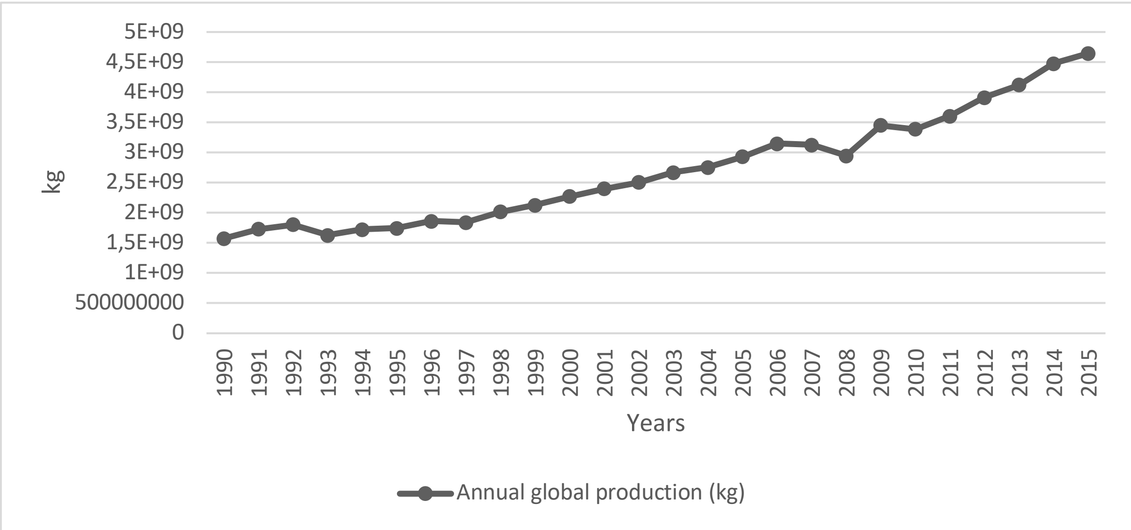

Figure C-1 Annual global avocado production over the period 1990-2015

C.2 The total annual global BW used for avocado production

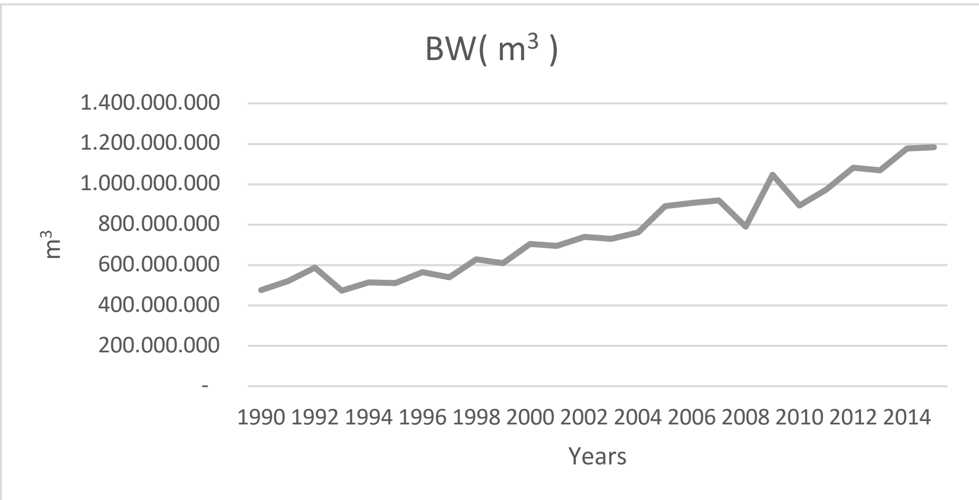

Figure C-2 The total annual quantity of BW used globally to meet the avocado demand over the period 1990-2015

C.3 The WSF main avocado producing countries

Table C-1 The countries with the highest global WSF of avocado production over the period 1990-2015

WSF	Million m^3 H_2O_e
Mexico	258155
Chile	214220
Israel	115385
United State of America	110943
Australia	66282
South Africa	53945
Rwanda	47038
Peru	34734
Spain	29630
Morocco	9879
Others	19130

C.4 The change in WSF main avocado producing countries

Table C-2 Changing production between 1990-2015 by the WSF main avocado producing countries

Countries	Production (1990) (million kg)	Production (2015) (million kg)
Morocco	6	36
Peru	76	270
Chile	44	157
Australia	13	45
South Africa	45	87
Spain	43	81
Mexico	739	1375
Israel	54	83
United State of America	6	36

C.5 The exported avocado

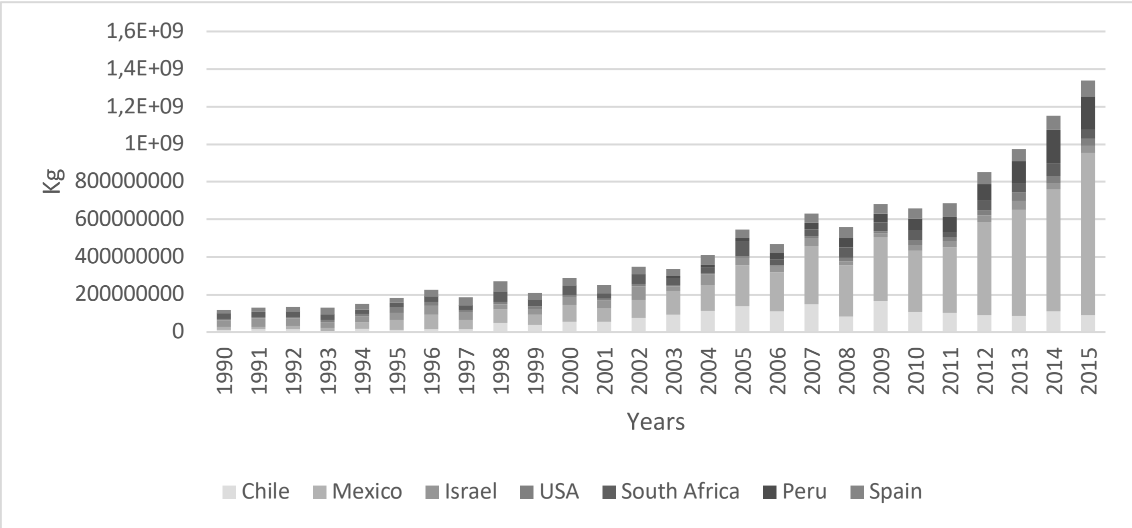

Figure C-3 The exported avocado over the period 1990-2015 by the WSF main avocado producing countries

C.6 The nations have created more demand

Table C-3 The nations have created more demand in the WSF main avocado exporting countries over the period 1990-2015

Exporting countries						
Chile	**Mexico**	**Israel**	**Peru**	**USA**	**South Africa**	**Spain**
Importing countries						
Netherlands	USA	France	Netherlands	Canada	Netherlands	France
USA	Japan	UK	Spain	Rep. of Korea	UK	Germany
UK	UK	Netherlands	USA	UAE	Spain	Netherlands
Argentina	Spain	Russian Federation	China	Turks and Caicos Isds	Zambia	Belgium
China	China	Slovenia	Chile	Singapore	USA	Finland
Spain	Canada	Sweden	UK	Japan	Turkey	Denmark
France	Singapore	Spain	Costa Rica	Saudi Arabia	Swaziland	Austria
Costa Rica	Netherlands	Ukraine	Japan	Kuwait	UAE	Morocco

C.7 Global exported avocado by importing countries over the period 1990-2015

Table C-4 The annual global re-exported avocado over the period 1990-2015

Countries	Global re-exported avocado (million kg)
Netherlands	10945
Belgium	88
Germany	78
Italy	73
Lithuania	26
United Kingdom	25
Nicaragua	21

C.8 Global exported avocado from producing countries over the period 1990-2015

Table C-5 The total annual quantity of BW used globally for avocado production over the period 1990-2015

Countries	Global exported avocado (million kg)
Mexico	5514
Chile	1836
Spain	1197
South Africa	1050
Israel	973
Peru	919
USA	430
France	374
Dominican Republic	306
New Zealands	197

C.9 The increase of exported avocado

Table C-6 The top countries have experienced the highest increase in exported avocado between 2010-2015

Countries	% Increase (2010-2015)
China	11753
Tanzania	4802
Sri Lanka	3766
Colombia	2231
Portugal	333
Peru	172
Barbados	161
Lebanon	146
Morocco	1423
USA	135
Brazil	132
Costa Rica	116
Turkey	114
Mexico	103

C.10 The main countries associated with the largest WSF of exported avocado

Table C-7 The annual global WSF of the main avocado exporting countries over the period 1990-2015

WSF (million m^3 H_2O_e)		
Countries	**1990**	**2015**
Chile	791	6500
Israel	2014	2120
Mexico	206	4641
USA	450	2857
South Africa	814	1413
Spain	395	735
Peru	2	927