UNIVERSITAT DE BARCELONA

MASTER FINAL PROJECT

MASTER OF ENVIRONMENTAL ENGINEERING

Water Footprint for People

Author

Agustina María Garino

July 2020

Director/s

Dr. Jaume Giménez Farreras

Departament of Chemical Engineering and Analytical Chemistry. University of Barcelona

Content

Abstract

The water footprint (WF) is an indicator that measures the amount of water used and polluted to produce each of the goods and services we use (volume/ time). It can be calculated for a process, a product's entire value chain, a business, a river basin, a nation, an individual person or community of consumers. It has three components: green water footprint (rain water stored in the root zone of the soil and evaporated, transpired or incorporated by plants), blue water footprint (water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product, changed from one water body to another or returned at a different time) and grey water footprint (amount of fresh water required to assimilate the load of pollutants to meet specific water quality standards).

For this project, the footprint of an average consumer in Spain was calculated. The type of diet, habits, activities, consumption of products, and country of origin have an impact in the accounting of an individual's footprint. The footprint is composed of both direct and indirect water use.

The direct water footprint is the water that a person uses and pollutes directly in activities such as taking a shower, washing the dishes, watering a garden, flushing the toilet, etc. To calculate it, the minimum flow of different appliances and an assumed frequency and duration of every activity was considered. The direct water footprint calculated was 226 m^3/year.

The indirect water footprint is the water use associated to the production of the goods and services used by the consumer. The indirect footprint was calculated for an average Spanish diet and other consumptions like clothing, footwear, tobacco and books. The footprints for many of the products consumed by a Spanish person have already had their footprint accounted through numerous studies, but for some of the consumptions the footprint had to be calculated using different methodologies obtained from the Water Footprint Assessment Manual.

For the diet component of the footprint there were three food products that had theirs calculated. The first methodology used was for the green, blue and grey footprint of growing a crop. This calculating methodology was previously tested comparing the footprint for bananas grown in Morocco, given in a previous study, with the calculated footprint of bananas grown in Islas Canarias. The testing showed the variablility of the outcome, given different climatological and crop parameters. The crop chosen to calculate its footprint as part of the Spanish diet was the melon. The second calculating methodology was used to calculate the footprint of producing fish through acquaculture, which considered the feed-related footprint and the water evaporation and infiltration from the ponds. The third product considered was pastries, which considered all the possible pastry compositions varying the ingredient proportions and the type of fat used. The footprint associated to a Spanish diet amounted to 1,839 m^3/year.

For the other consumptions an average Spanish person has on a yearly basis, the calculation was made adding the individual footprint for each material, taken from various studies, in adequate proportions for each product. The total footprint for the assumed yearly purchases of clothing, footwear, tobacco and books was 123.13 m^3/year.

Considering the direct and indirect water footprint for an average Spanish consumer the total calculated was 2.188 m^3/year. The indirect footprint had the biggest impact on the total, contributing with 1,962.13 m^3/year. The food group with the largest footprint was farm animal meats, which includes pig, bovine, poultry and goat meat and offals, with 515.65 m^3/year, and the single product with the largest contribution to an average Spanish person's annual footprint was pigmeat with 303 m^3/year.

Making changes in habits, diet and other consumptions can have a significant impact on reducing one's water footprint. However, it has to be taken into account that when reducing the consumption of a product there is an associated increase in the consumption of a substitute, which changes the location of the footprint but does not necessarily reduce it. Hence, when the aim is to reduce our footprint, it is important to compare the alternatives to see if it entails an actual significant reduction.

1. Introduction

The water footprint (WF) is an indicator that measures the amount of water used and polluted to produce each of the goods and services we use. In other words, it is a measure of humanity's appropriation of fresh water in volumes of water consumed and polluted, it is analogue to the ecological footprint. The impact depends on where the water is taken from and when. Thus, if water comes from a place where it is already scarce or highly polluted, the consequences can be significant and require action.

The water footprint has three components [1]:

- Green water footprint: is rain water stored in the root zone of the soil and evaporated, transpired or incorporated by plants.
- Blue water footprint: is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product, changed from one water body to another or returned at a different time.
- Grey water footprint: is the amount of fresh water required to assimilate the load of pollutants to meet specific water quality standards.

The concept of water footprint was defined by Arjen Hoekstra in 2002. In 2008, the Water Footprint Network was founded by the University of Twente, WWF, UNESCO- IHE, World Business Council for Sustainable Development, International Finance Corporation, Netherlands Water Partnership, and Water Neutral Foundation. It is a platform where companies, organizations and individuals collaborate to overcome unsustainable water use. In 2011 the standard for an accepted methodology for conducting a water footprint assessment was published in *The Water Footprint Assessment Manual: Setting the Global Standard* [1], which consists of a complete and comprehensive guide to calculate blue, green and grey water footprints, to assess the sustainability of these footprints and to define and prioritize the actions to take.

WF can be calculated for a process (expressed as water volume/unit of time or water volume/product unit), a product's entire value chain (water volume/product unit), a business (water volume/unit of time or water volume/monetary unit considering its turnover), a river basin (water volume/unit of time), a nation (water volume/unit of time), an individual person (water volume/unit of time or water volume/monetary unit considering their income) or community of consumers (water volume/unit of time/capita).

The blue water footprint of a process or a process step includes: water evaporated (which is usually the most significant), water incorporated into the product, water withdrawn from a water resource but returned to a different catchment area or returned to the same one but at a different period. The green footprint is most significant in agricultural and forestation processes and includes the water evapotranspirated from the plantations and the water incorporated into the crops. The grey footprint considers the amount of water needed to assimilate the load of pollutants.

Since making a product consists of various process steps, the water footprint of a product is the sum of the water consumption (blue and green footprint) and pollution (grey footprint) in all the steps.

When calculating the footprint of a business both direct and indirect water used have to be considered. The direct use includes the water consumed and polluted in the business' own operations (for example, water used for cleaning, office bathrooms and kitchen, etc.). The indirect water use refers to the supply chain, and is the water consumed and polluted to produce the goods and services of that particular business.

The water footprint accounting for a river basin and a nation is similar, since in both cases it accounts within a geographically delineated area. The most crucial part of the calculation is to correctly define the boundaries of the area studied. The water footprint within the area defined is calculated as the sum of the footprints of all the processes in the area.

The water footprint of a consumer is defined as the total volume of freshwater consumed and polluted for the production of the goods and services used by the consumer. Thus, the type of diet, habits, activities, consumption of products, and country of origin have an impact in the accounting of an individual's footprint. To calculate the water footprint, it is necessary to look at both direct (water used directly by the individuals) and indirect water use (the summation of the water used for all the products consumed). The footprint of a group of consumers is the sum of the footprints of all the consumers included in that group.

The goal of water footprint accounting and assessing its sustainability is to see the impact of certain activities or products on water scarcity and pollution, and to formulate responses to these impacts, preventing them and avoiding an unsustainable use of water.

2. Objectives

The aim of this work is to define a calculating methodology, using the Water Footprint Assessment Manual, for the estimation of the water footprint of an average consumer in Spain and to establish comparisons looking for the most important parameters, in order to determine where footprint reductions can be made.

3. Water footprint of a person

The water footprint of a person is the volume of freshwater consumed and polluted to produce the goods and services he or she uses.

The person chosen to study his or her water footprint is an average Spanish consumer. It is important to specify the location to determine his or her consumption patterns, which define the activities and habits that have an impact on the overall footprint. The different calculating methodologies were obtained from the Water Footprint Assessment Manual and adapted for each individual product, using data from various resources to make the footprint accounting as exact as possible.

The calculation will be centered around the most significant consumptions that can be determined using reliable information since it would be impossible to encompass the entirety of a person's water use, especially regarding the indirect component.

3.1 Calculation and discussion

The water footprint of a person can be calculated by adding their direct and indirect water use (volume/ time):

$$WF_{person} = WF_{person,direct} + WF_{person,indirect} \quad (1)$$

The direct water footprint is the water that a person uses and pollutes directly in activities such as taking a shower, washing the dishes, watering a garden, flushing the toilet, etc. The water consumption for these activities can be calculated from the minimum flow of the different appliances. This information is summarized in Table I and was obtained from the Technical Building Code [2]. Knowing these flows, the estimation of water consumption, requires to assume frequency and duration of these activities, based on a personal experience (how many showers a person takes in a day or year and for how long, how many times one washes their hands or brushes their teeth, etc.) and appliances manuals (how much water does a washing machine or a dishwasher use, how much water is flushed down the toilet, etc.). In addition to the footprint associated to the estimated water consumption (blue water footprint) there is a grey water footprint due to flushing soap, shampoo, oil, medicine, or any kind of pollutants down the drain. Although it is not possible to quantify this component of the footprint on account of insufficient information.

Table I - Direct water use of a person

Activities	Type	Duration min/act	Frequency act/day	Frequency act/year	Impact min/year	Flow l/min	Impact l/year
Shower	Continuous	12	1	365	4,380	12	52,560
Washing hands	Continuous	0.5	8	2,920	1,460	6	8,760
Brush teeth	Continuous	1	3	1,095	1,095	6	6,570
Wash dishes by hand	Continuous	10	3	1,095	10,950	12	131,400
Dish washing machine	Continuous	30	1	183	5,475	0	1,825
Wash clothes	Continuous	105	0.1	37	3,833	0	1,679
Cooking	Continuous	1	2	730	730	12	8,760
Activities	**Type**	**Discharge l/act**	**Frequency act/day**	**Frequency act/year**			**Impact l/year**
Toilet flush	Intermittent	6	6	2,190			13,140
Cleaning indoor spaces	Intermittent	2	0.3	104			209
Watering indoor plants	Intermittent	1	0.1	52			52
Cleaning outdoor spaces	Intermittent	1	0.1	52			52
Drinking water	Intermittent	2[1]	1	365			730
						Total	**225,737**

The indirect water footprint is the water use associated to the production of the goods and services used by the consumer, such as the water used to produce the food he or she eats, the clothes he or she buys, the books he or she reads, etc. For the calculation of the water footprint of a person, it is necessary to determine where he or she lives and what he or she consumes. In our case, it was decided that the consumer was located in Spain, which helped to establish certain consumer patterns using local information.

To determine what type of diet this consumer has, the Food Balance Sheets of the FAO were consulted [3]. This contains information on food supply (kg/cap/yr), which represents the quantity of food purchased by the consumer. To complement this information, a study by the

[1] It was considered that drinking 2 L is the total amount drank in a day, so this is an activity done once a day

National Institute of Statistics was used [4]. This will be considered the starting point to establish the most important parameters in the water footprint of a person. The spanish diet mostly corresponds to a Mediterranean diet, and the types of food and beverages most present are shown in Table II. It is important to know the quantities of each product consumed in a specific period for accounting its total water footprint.

The water footprint for most of these foods can be found in two studies that calculate the green, blue and grey water footprint of crops [5] and animal products [6]. In these cases, it was analized where these foods were produced (local production or imported) to select the footprint most suited to a Spanish consumer since the magnitude of the footprint and its WF_{green}/WF_{blue} ratio is completly dependent on location. For example, most fruits and vegetables were produced locally. Thus, the Ministry of Agriculture, Fisheries and Food of Spain was consulted to determine which region or regions were the biggest producers for the purpose of choosing the footprint corresponding to that area, or average the values of different areas. In the case of foreign products such as coffee, tea, sugar, or dates, it was determined which country exported most to Spain and the footprint chosen as most relevant was the country average. In the case of products that are made from various components, a global average footprint was used instead of a location specific one, which is not as precise but it can still be useful. In few cases, it was not possible to pinpoint a single origin, and the global average footprint was also used.

The water footprint of the products not included in any of these two studies will be calculated later, following the methodology described in The Water Footprint Assessment Manual [1].

Table II - Most consumed foods in Spain and their water footprint per inhabitant

Product	Food Supply Quantity	Water footprint			
		Green	Blue	Grey	Total
	kg/capita/yr	l/kg	l/kg	l/kg	l/kg
Wheat and products	99.83				
Pastries	13.73				
Bread	81.10	1,124	301	183	1,608
Pasta	4.99	1,292	347	210	1,849
Rice (Milled Equivalent)	11.98	497	1,867		2,364
Barley and products	0.48	2,205	52	54	2,311
Maize and products	1.99	1,061	87	122	1,270
Rye and products	0.78	2,000	-	357	2,357

Oats	0.51	1,295	1,282	336	2,913
Potatoes and products	58.07	79	16	47	142
Sweet potatoes	0.13	191	207	-	398
Sugar (Raw Equivalent)	31.35	1,035	46	86	1,167
Honey	0.70				
Beans	1.11	1,107	29	431	1,567
Peas	0.82	488	26	-	514
Pulses, Other and products	3.16	3,180	141	734	4,055
Nuts and products	6.78	7,016	1,367	680	9,063
Soyabeans	0.05	1,560	92	10	1,662
Groundnuts (Shelled Eq)	1.35	1,975	122	369	2,466
Sunflower seed	1.15	3,142	114	384	3,640
Coconuts - Incl Copra	0.09	2,669	2	16	2,687
Sesame seed	0.07	8,460	509	403	9,371
Olives (including preserved)	2.07	2,361	529	6	2,897
Oilcrops, Other	0.06	2,023	220	121	2,364
Sunflowerseed Oil	11.34	6,161	47	145	6,353
Olive Oil	10.74	11,010	2,569	27	13,606
Tomatoes and products	59.69	36	27	25	88
Onions	18.40	82	119	102	304
Vegetables, Other	57.01				
Lettuce	39.86	35	89	56	181
Carrots	17.14	56	91	35	181
Oranges	31.84	213	192	55	460

Lemons, Limes and products	3.38	201	198	54	454
Grapefruit and products	0.51	163	116	40	319
Citrus, Other	1.04				
Tangerine	1.04	479	118	152	748
Bananas	7.63	110	197	17	324
Apples and products	11.02	304	102	56	462
Pineapples and products	4.00	215	9	31	255
Dates	0.20	1,032	3,271	84	4,387
Grapes and products (excl wine)	3.38	855	148	245	1,248
Fruits, Other	26.10				
Melons	7.11				
Pear	7.05	304	131	57	492
Watermelon	5.97	72	67	32	170
Peach	5.97	359	177	74	610
Coffee and products	3.89	6,568	-	292	6,860
Tea (including mate)	0.10	4,778	1,332	360	6,470
Pepper	0.04	240	42	97	379
Spices, Other	0.11	5,872	744	432	7,048
Wine	21.04	994	173	285	1,452
Beer	75.17	210	18	50	278
Bovine Meat	12.54	7,545	411	489	8,445
Mutton & Goat Meat	2.10	3,328	304	-	3,632
Pigmeat	51.39	4,598	630	670	5,898
Poultry Meat	29.65	1,660	201	274	2,135

Offals, Edible	2.84	11,241	627	729	12,597
Butter, Ghee	0.99	7,185	1,052	1,266	9,503
Cheese	5.91	4,264	439	357	5,060
Yogurt	7.48	1,535	225	270	2,030
Cream	1.56	2,042	299	360	2,701
Fats, Animals, Raw	2.01	2,128	271	351	2,750
Eggs	12.58	1,568	204	266	2,038
Milk - Excluding Butter	167.06	1,320	193	233	1,746
Freshwater Fish	3.58				
Demersal Fish	13.51				
Pelagic Fish	10.18				
Marine Fish, Other	1.20				
Crustaceans	3.51				
Cephalopods	2.40				
Molluscs, Other	8.77				

3.1.1 Water footprint of a crop or a tree

According to The Water Footprint Assessment Manual, the water footprint of the process of growing a crop is the sum of its green, blue and grey components (WF, volume/mass):

$$WF_{proc} = WF_{proc,green} + WF_{proc,blue} + WF_{proc,grey} \quad (2)$$

Both the green and blue components are calculated as the crop water use (CWU, m^3/ha) divided by the crop yield (Y, ton/ha):

$$WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (3)$$

$$WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (4)$$

The green crop water use represents the total rainwater evaporated from the field during the growing period, while the blue crop water use represents the total irrigation water evaporated from the field. Hence, both components are calculated as the accumulation of daily evapotranspiration (ET, mm/day):

$$CWU_{green} = 10 \times \sum_{d=1}^{lgp} ET_{green} \quad (5)$$

$$CWU_{blue} = 10 \times \sum_{d=1}^{lgp} ET_{blue} \quad (6)$$

Where *lgp* represents length of growing period (days), from the day of planting to the day of harvest.

Evapotranspiration is the combination of two processes that occur simultaneously, evaporation and transpiration. Evaporation is the process where liquid water is removed from the soil surface and converted to vapour. This process needs energy from solar radiation and ambient temperature to change the state of the molecules, a vapour pressure gradient between the soil surface and atmosphere to remove the water and wind speed to replace saturated air with dry air (so the climatological parameters are the ones regulating this process). Transpiration is the transformation of water contained in plant tissues into vapour and its removal into the atmosphere. It depends on the same climatological parameters as evaporation, as well as the crop type. The field measuring of evapotranspiration is a very difficult and expensive process, so the FAO recommends using the Penman-Monteith equation [7] to compute evapotranspiration from weather data, and it is the method used by The Water Footprint Assessment Manual through FAO's CROPWAT 8.0 model [8]:

Penman-Monteith equation : $\lambda \mathrm{ET} = \frac{\Delta(R_n - G) + \rho_a C_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$ (7)

Where:

- R_n is the net radiation
- G is the soil heat flux
- ρ_a is the mean air density at constant pressure
- C_p is the specific heat of the air
- (e_s - e_a) represents the vapour pressure deficit of the air
- Δ represents the slope of the saturation vapour pressure temperature relationship
- γ is the psychrometric constant
- r_s and r_a are the (bulk) surface and aerodynamic resistances

CROPWAT calculates crop evapotranspiration from climatological and crop data using this equation.

Green water evapotranspiration (ET_{green}, length/time) can be equated with the minimum of total crop evapotranspiration (ET_C, length/time) and effective rainfall (P_{eff}, length/time, part of the total amount of precipitation that is retained by the soil). To determine effective rainfall, The Water Footprint Assessment Manual, recommends using the United States Department of Agriculture's Soil Conservation Service method [9] out of the four alternatives the CROPWAT 8.0 model has available. This method was developed by registering 50 years of precipitation at 22 experimental stations with different climates and soils. It takes monthly mean rainfall and mean monthly consumptive use to give a value of mean monthly effective rainfall from a chart. Blue water evapotranspiration (ET_{blue}, length/time) is equal to the total crop evapotranspiration (ET_C) minus effective rainfall (P_{eff}) or zero when effective rainfall exceeds crop evapotranspiration:

$$ET_{green} = min(ET_c, P_{eff}) \quad (8)$$

$$ET_{blue} = max(0, ET_c - P_{eff}) \quad (9)$$

The grey component is defined as the load of pollutants that enters the water system (L, mass/ time) divided by the difference between the maximum acceptable concentration of a certain pollutant (Cmax, mass/ volume) and its natural concentration in the receiving water body (Cnat, mass/ volume) [1].

$$WF_{proc,grey} = \frac{L}{C_{max} - C_{nat}} \quad (10)$$

3.1.2 Water footprint of a crop or tree: method test

Since the values on Table II were taken from two studies that calculate the green, blue and grey water footprint of crops [5] and animal products [6], the same methodology (3.1.1) was used to calculate the footprint of bananas produced in a particular place to see how these results can vary. Banana was the crop chosen since it has different crop coefficients and length of development depending on the year of harvest, this not only allows a comparison to be established between the given footprint and the calculated one but also between two calculated footprints with different crop data.

To determine green and blue evapotranspiration the CROPWAT 8.0 model was used [8]. This was developed by the FAO to determine a crop's evapotranspiration, water requirements and irrigation requirements, using the Penman-Monteith equation for evapotranspiration and the choice of four different methods (the USDA SCS was chosen) for the effective rainfall. The "crop water requirement option" was used to estimate green and blue evapotranspiration under optimal conditions (disease free, well- fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production under the given climatic conditions) [7]. To run this option, only climate and crop data are required. To specify this information, it was necessary to determine where the bananas were produced.

Since the diet information was taken from FAO's Food Balance Sheets for consumers in Spain, the production of bananas in Islas Canarias was chosen to do the comparison (which represents Spain's entire banana production and its main supply). The production in Santa Cruz de Tenerife amounts to 78,8 % and in Las Palmas 21,2 % [10], so the former was the weather station chosen to obtain climate data, through the State Meteorological Agency (AEMET) [11], since this is the most representative station. However, since the study previously mentioned does not account for any crops in Islas Canarias (it is the only Spanish autonomous community that has not been included in this study), the footprint selected to generate a comparison was the one associated to bananas cultivated in Morocco (which provides a more accurate footprint than any other region in Spain, given its proximity to the islands).

For the CROPWAT 8.0 model running, the climate data required are:

- Minimum temperature (°C)
- Maximum temperature (°C)
- Humidity (%)
- Wind (km/day)
- Sun (hours)
- Rain (mm)

These inputs are based on monthly averages. The CROPWAT 8.0 model uses this information to determine the particular climatic circumstances under which this crop is being grown: radiation ($MJ/m^2/day$), reference crop evapotranspiration (ET_o, $_{mm}$/day) and effective rainfall (mm).

In addition to this, the crop data required are:

- Planting date
- Crop coefficients (K_c, ratio of potential evapotranspiration for a given crop in relation to that of a reference crop, it represents the crop type and development)
- Lengths of crop development stages (days)
- Rooting depth (m)
- Critical depletion fraction (p, represents the critical soil moisture level where first drought stress occurs affecting crop evapotranspiration and crop production)
- Maximum crop height (m)
- Yield response factor (Ky, represents the effect of a reduction in evapotranspiration on yield losses)

All these factors were obtained from the Food and Agriculture Organization [7]. To compare the different water footprints, the crop data considered correspond to the first and second year of harvesting. This makes the planting date, crop coefficients and length of development stages different for each scenario.

The model calculates the crop's water requirements, which is assumed is fully met using both effective precipitation and irrigation, so the crop water requirements are equal to the crop's evapotranspiration ($CWR=ET_c$). Using the model's output and the equations (3) to (9) it is possible to determine the green and blue water footprint, while using equation (10) gives us the grey water footprint:

Table III- calculated WF comparison for bananas

Crop	**$WF_{proc,green}$**	**$WF_{proc,blue}$**	**$WF_{proc,grey}$**	**$WF_{bananas}$**
Bananas	**m3/ton**			
1^{st} year	60	260	19	339
2^{nd} year	55	345	19	419

As it can be seen clearly in Table III, different values of crop data makes the water footprint accounting differ by 80 m^3/ton for the total process footprint. In addition, the WF_{green}/WF_{blue} ratio is 0.23 for the 1^{st} year and 0,16 for the 2^{nd} year. These differences show the importance of crop data and how it can affect the outcome.

The water footprint for bananas given in Table II (110 m^3/ton WF_{green}, 197 m^3/ton WF_{blue}, 17 m^3/ton WF_{grey}, 324 m^3/ton WF_{total}) represents Morocco's average footprint. The total footprint for a 1^{st} year (339 m^3/ton WF_{total}) is similar in total but differs mostly in the WF_{green}/WF_{blue} ratio, whilst the total for a 2^{nd} year (419 m^3/ton WF_{total}) is 29 % larger. These differences can be attributed to variations in the climatic parameters chosen to run the model. Since the grey component does not depend on climate or crop data (it depends on the fertilizer application rate, the fraction of fertilizer that reaches water bodies and the concentration of different pollutants contained in them) its accounting deviated only 11 % from Morocco's.

This testing of the method using bananas shows the importance the chosen parameters have on water footprint accounting, how the input of different crop and climatological data can provide various outcomes.

The following sections of this work will be dedicated to demonstrating different calculating methodologies for the water footprint depending on the product considered: a crop (melons), an animal (fish) and a derived wheat product (pastries). These three foods were chosen for the analysis because they are needed to have a complete accounting for the average Spanish diet, and because the methodologies for calculating each of their water footprints show very different approaches, which demonstrates the importance of using the correct methodology and parameters when calculating a water footprint.

3.1.3 Water footprint of melons

The melon is one of the present foods in the Spanish diet which water footprint was not calculated in the studies mentioned before. Therefore, in this section the water footprint for the melon will be evaluated also as an example of application of the method tested in the previous section with bananas

According to the Ministry of Agriculture, Fisheries and Food of Spain (MAPA), the region with the largest production of melons is Castilla- La Mancha (approximately 34% of the total production) and the province of Ciudad Real produces 87% of it in 4,949 hectares of irrigated fields [10]. Therefore, this was the place considered to estimate the green, blue and grey water footprint of melons.

Table IV - Cultivated area, yield and annual production of melons in Castilla- La Mancha

Provinces and autonomous regions	**Dry Land Area**	**Yield**	**Irrigated Area**	**Yield**	**Production**
	ha	**kg/ha**	**ha**	**kg/ha**	**t**
Albacete	20	1,600	287	42,000	12,086
Ciudad Real	**-**	**-**	**4,949**	**40,000**	**197,960**
Cuenca	31	3,600	80	40,000	3,312
Guadalajara	28	8,000	14	20,000	504
Toledo	412	7,000	244	47,500	14,474
CASTILLA-LA MANCHA	491	6,622	5,574	40,381	228,336

Another important information needed to calculate the melon's water footprint is the estimated dates for sowing and harvesting in each autonomous region, in this case, Castilla-La Mancha. This information can also be found in the Ministry of Agriculture, Fisheries and Food of Spain [12]. The sowing date selected was May 1^{st} and the harvesting date determined by the CROPWAT 8.0 model was August 28^{th}. The crop coefficients, lengths of crop development stages, rooting depth, critical depletion fraction and yield response factor were obtained from the Food and Agriculture

Organization [7]. This constitutes the crop data needed to run the CROPWAT 8.0 model to calculate a crop's evapotranspiration.

Regarding the climate data needed, the meteorological station of Ciudad Real [13] was consulted through the State Meteorological Agency (AEMET), since this is the nearest station to the melon-producing region considered. The information was entered in the model as the following monthly averages: minimum temperature (between 1.1 and 18.9 °C), maximum temperature (10.9-34.5 °C), humidity (40-81 %), wind speed (292-411 km/day), hours of sun (9.3-15.0 h) and precipitation (5.0-59.0 mm).

Given all this crop and climate data, the model calculates evapotranspiration using a time step of ten days as shown in Table V:

Table V - Green and blue evapotranspiration based on CWR option output on CROPWAT 8.0

Month	Period	Stage	K_C	ET_C	ET_C	P_{eff}	Irrigation Req.	ET_{green}	ET_{blue}
				mm/day	mm/period				
May	1	Initial	0.50	2.8	28.0	13.7	14.3	13.7	14.3
May	2	Initial	0.50	3.03	30.3	13.1	17.2	13.1	17.2
May	3	Development	0.53	3.59	39.5	11.4	28.1	11.4	28.1
Jun	1	Development	0.70	5.19	51.9	9.7	42.3	9.7	42.2
Jun	2	Development	0.87	7.08	70.8	8.2	62.7	8.2	62.6
Jun	3	Mid- season	1.05	8.88	88.8	6.1	82.7	6.1	82.7
Jul	1	Mid- season	1.11	9.99	99.9	3.5	96.4	3.5	96.4
Jul	2	Mid- season	1.11	10.49	104.9	1.2	103.7	1.2	103.7
Jul	3	Mid- season	1.11	10.09	111.0	1.4	109.6	1.4	109.6
Aug	1	Late- season	1.11	9.65	96.5	1.1	95.3	1.1	95.4
Aug	2	Late- season	1.00	8.43	84.3	0.7	83.6	0.7	83.6
Aug	3	Late- season	0.86	6.54	52.3	2.4	49.1	2.4	49.9
Total growing period					858.2	72.5	785	72.5	785.7

Using the equations (3) to (9), it is possible to calculate the green and blue water footprint of the process of growing melons. The results are shown in Table VI.

Table VI - Calculation of green and blue process water footprint

Crop	ET_{green}	ET_{blue}	ET_a	CWU_{green}	CWU_{blue}	CWU_{tot}	Y	$WF_{proc,green}$	$WF_{proc,blue}$	WF_{proc}
-	mm/period			m^3/ha			ton/ha	m^3/ton		
Melons	72.5	785.7	858.2	725	7,857	8,582	40	18	196	215

In agricultural products one should also consider the water incorporated into the product (in addition to the water evapotranspirated in the process of growing). However, in the case of melons the water fraction is around 90 %, which means that the footprint of the water incorporated into melons is 0.9 m^3/ton. This is less than 0.5 % of the evapotranspiration water footprint and will not be considered.

The grey component of the water footprint is calculated according to:

$$WF_{proc,grey} = \frac{(\alpha \times AR) / (C_{max} - C_{nat})}{Y} \quad (11)$$

Where:

- AR (kg/ha) is the chemical application rate per hectare.
- α (leaching-run-off fraction) is the fraction of applied chemicals reaching freshwater bodies).
- C_{max} (kg/m^3) is the maximum acceptable concentration.
- C_{nat} (kg/m^3) is the natural concentration for the pollutant considered.
- Y (ton/ha) is the crop yield.

For the estimation of the grey component of the water footprint only the run-off of nitrogen in fertilizers was considered. The leaching-run-off fraction is assumed to be 10 % of the fertilizer application rate according to The Water Footprint Assessment Manual. The closest approximation to the fertilizer application rate for melons, was of 85 kg/ha of nitrogen [14] (world's average use of this fertilizer on fruits). For the maximum acceptable concentration and natural concentration of nitrogen 25 mg/l (Directive 91/676/EEC) [15] and 1.77 mg/l [16] were respectively used. Finally, the crop yield is the same that was used for the green and blue footprints.

Table VII - Calculation of the grey water footprint

Average fertilizer application rate	**Nitrogen leaching-run-off factor (α)**	**Maximum concentration**	**Natural concentration**	**Yield**	**$WF_{proc,grey}$**
kg/ha	**%**	**mg/l**	**mg/l**	**ton/ha**	**m^3/ton**
85	10	25	1.77	40	9

Having calculated the green, blue and grey components, the total water footprint for melons harvested in Castilla- La Mancha is the following:

Table VIII - Water footprint of melons

$WF_{proc,green}$	$WF_{proc,blue}$	$WF_{proc,grey}$	WF_{melon}
m³/ton			
18	196	9	224

3.1.4 Water footprint of fish

Fish and other edible sea products are also part of the foods present in the spanish diet which water footprint was not calculated in the studies mentioned before. In fact, no data appears in Table II. For this reason, the calculation of the water footprint of fish has also been selected as an example of application of the proposed methodologies.

Spain is a country that has many kilometers of coastline and therefore a long fishing tradition. However, given its high demand, it is also necessary to import fish from countries such as China, Argentina, Portugal, the Netherlands or France [17].

In order to determine the footprint of the aquatic organisms consumed in Spain, only the ones produced through acquaculture will be considered, since wild catches don't require to be fed with man-made products or to extract water from a location to fill in the ponds where they are bred and raised.

According to Pahlow et al. (2015) [18], the footprint associated to the production of fish, crustaceans, molluscs and plants is composed of a large share of feed-related footprint and a smaller share related to the water evaporated from the ponds and the pollution of freshwater resources. This study estimates the feed-related water consumption and pollution for 39 fish and crustacean species. In Verdegem and Bosma (2009) [19], an average value of pond evaporation of 5.2 m^3/kg is estimated (it does not offer a species-specific distinction). The value of the footprint related to the pollution of freshwater resources was not included in the study of Verdegem and Bosma and will be later calculated following the methodology described in the Water Footprint Assessment Manual Appendix IV for any water-using process [1].

According to this publication, the amount of water withdrawn from streams, rivers or pumped from aquifers is 15.2 m^3/kg of production of which 5.2 m^3/kg are mostly evaporated from the system, 6.9 m^3/kg are infiltration losses (from vertical percolation and lateral seepage) and 3.1 m^3/kg are for draining and recharging the ponds. Water from fishponds contains various substances that can pollute freshwater resources such as nutrients, metals, etc. For the purpose of calculating the grey water footprint associated to these systems, the content of nitrogen in pond water will be used. Tucker and Hargreaves (2004) [20] estimated the concentration of total nitrogen in catfish ponds between 5 and 7 mg/L (C_{effl}), and there is no other information available that distinguishes nitrogen concentration by fish species. This will be the range considered for all the species in Table II. The European Environment Agency places the average concentration of nitrate in European rivers, between 2000 and 2017, at 1.77 mg/L (C_{act}) [16] and the maximum allowed nitrogen concentration (C_{max}) in superficial water destined to produce drinking water is 25 mg/L (Directive 91/676/EEC) [15]. Therefore, the grey water footprint associated to the additional load of pollutants to a freshwater body is calculated in the following range:

$$6.9 \times 7 - 15.2 \times 1.77 = \frac{21.4}{25-1.77} = 0.92\,\frac{m^3}{kg}$$

and

$$6.9 \times 5 - 15.2 \times 1.77 = \frac{7.6}{25-1.77} = 0.33\,\frac{m^3}{kg}$$

Since there is no indication in Tucker and Hargreaves (2004) of which of these total nitrogen concentrations in catfish ponds is seen more frequently, an average between these two values will be the one selected as the grey water footprint: 0.63 m^3/kg.

Considering the feed-related water footprint (green, blue and grey), the evaporation from the ponds-related footprint (blue) and the pollution of freshwater resources-related footprint (grey), the footprint of fish by species is:

Table IX- Water footprint of fish by species

Type	**Species**	**Water footprint**			
		Green	**Blue**	**Grey**	**Total**
		l/kg	**l/kg**	**l/kg**	**l/kg**
Freshwater fishes	**Grass Carp**	1,688	5,481	890	8,059
	Common carp	1,938	5,387	869	8,194
	Crucian carp	1,906	5,388	849	8,143
	Wuchang bream	1,719	5,450	880	8,049
	Black carp	2,177	5,407	802	8,385
	Silver barb	2,498	5,412	782	8,691
	Indial major carps	1,313	5,481	786	7,580
	Nile tilapia	2,024	5,325	744	8,092
	Pangasiid catfish	1,655	5,355	731	7,740

	Channel catfish	1,708	5,336	786	7,830
	Hybrid catfish	1,781	5,357	755	7,893
	North african catfish	1,813	5,325	692	7,830
	Amur catfish	1,625	5,388	755	7,768
	Yellow catfish	1,063	5,263	693	7,018
	Snakehead	750	5,346	713	6,809
	Mandarin fish	68	5,206	644	5,918
	Asian swamp eel	1,354	5,315	755	7,424
	Characidae	2,469	5,356	755	8,580
Diadromous fishes	River eel	625	5,216	646	6,487
	Atlantic salmon	1,542	5,346	880	7,768
	Rainbow trout	1,188	5,325	796	7,309
	Milkfish	2,175	5,391	736	8,302
	Barramundi	938	5,293	682	6,913
Marine fishes	Flounder and Turbot	1,223	5,339	729	7,290
	Atlantic cod	458	5,325	693	6,476
	European seabass	917	5,325	713	6,955
	Gilthead seabream	349	5,294	687	6,330
	Grouper	1,188	5,325	755	7,268
	Red drum	1,930	5,352	750	8,032
	Mullet	1,563	5,263	724	7,549
	Japanese amberjack	656	5,263	676	6,595
Crustaceans	Chinese mitten crab	1,625	5,408	797	7,830

	Red claw crayfish	2,000	5,481	849	8,330
	Giant river prawn	1,792	5,387	776	7,955
	Oriental river prawn	1,688	5,450	770	7,908
	Whiteleg shrimp	1,333	5,430	755	7,518
	Giant tiger prawn	1,375	5,388	770	7,533
	Fleshy prawn	2,000	5,388	713	8,101

Since the study by Pahlow et al. calculates the feed-related fooptrints organized in the categories shown in Table IX which don't coincide with the ones from Table II, the species above were rearranged to fit the latter, resulting in the following footprints:

- Freshwater fish: 1,641 m^3/ton WF_{green}, 5,365 m^3/ton WF_{blue}, 771 m^3/ton WF_{grey}, 7,778 m^3/ton WF_{total}
- Demersal fish: 1,071 m^3/ton WF_{green}, 5,314 m^3/ton WF_{blue}, 717 m^3/ton WF_{grey}, 7,102 m^3/ton WF_{total}
- Pelagic fish: 1,099 m^3/ton WF_{green}, 5,305 m^3/ton WF_{blue}, 778 m^3/ton WF_{grey}, 7,182 m^3/ton WF_{total}
- Marine fish, other: 1,329 m^3/ton WF_{green}, 5,311 m^3/ton WF_{blue}, 726 m^3/ton WF_{grey}, 7,366 m^3/ton WF_{total}
- Crustaceans: 1,688 m^3/ton WF_{green}, 5,419 m^3/ton WF_{blue}, 776 m^3/ton WF_{grey}, 7,882 m^3/ton WF_{total}

The footprint of the two remaining categories Cephalopods and Molluscs was not possible to determine due to insufficient data.

3.1.5 Water footprint of pastries

The last item in Table II that will have its footprint calculated is pastries. This will be calculated by a different method than the two described previously. The method corresponds to the calculation of a product water footprint and is described in The Water Footprint Assessment Manual as the *chain-summation approach*, which can be applied in the cases where a production system has a single product as its output.

This approach sums the water footprints of the different processes involved (volume/time) and divides it by the amount that was produced (mass/time). In this case, the production of each of the ingredients will be considered as a separate process. Since the footprint of each of the ingredients is a known value already given in terms of volume/mass, what has to be considered is the proportion each has in the outcome product, which in this case is a pastry.

The term pastry encompasses various products such as tarts, pasties, croissants, etc. that are all made from four ingredients: flour, fat, salt and water combined in different proportions depending on which variety of pastry is being prepared. The production of these four ingredients will be considered as the process steps mentioned above.

According to S.L Andrews and J.B. Harte (2003) [21], the following ingredient proportions (by weight) are present in all pastries: 100 parts flour/ 42-59 parts fat/ 2.5 parts salt/ 31 parts water. The type of fat can be butter, lard or oil, and the footprint of the final product evidently depends on which is being used. The footprint will be calculated for both a pastry containing 42 parts of fat and 59 parts of fat, using each of the three types of fat, for the purpose of getting a range of possible footprints.

To calculate the footprint, first the proportions had to be converted into a percentage to see how much each ingredient contributes to the final product's footprint. When considering 42 parts of fat, the percentages are: 57 % flour / 24 % fat / 1 % salt / 18 % water. When the fat amounts to 59 parts, the percentages are: 52 % flour / 31 % fat / 1 % salt / 16 % water. Secondly, it was necessary to determine the footprints of each of these four ingredients:

- Flour (wheat): 1,292 m^3/ton WF_{green}, 347 m^3/ton WF_{blue}, 210 m^3/ton WF_{grey}, 1,849 m^3/ton WF_{total} [5]
- Butter: 7,185 m^3/ton WF_{green}, 1,052 m^3/ton WF_{blue}, 1,266 m^3/ton WF_{grey}, 9,503 m^3/ton WF_{total} [6]
- Lard: 2,128 m^3/ton WF_{green}, 271 m^3/ton WF_{blue}, 351 m^3/ton WF_{grey}, 2,750 m^3/ton WF_{total} [6]
- Oil (sunflower): 6,161 m^3/ton WF_{green}, 47 m^3/ton WF_{blue}, 145 m^3/ton WF_{grey}, 6,353 m^3/ton WF_{total} [5]
- Salt: 2.27 m^3/ton WF_{blue}[2], 2.27 m^3/ton WF_{total} [23]
- Water: 1 m^3/ton WF_{blue}[3], 1 m^3/ton WF_{total}

The footprint for both flour and oil was taken from the same study, which calculates the footprint of crops and their derived products as flour derives from wheat and the oil from sunflowerseed. Similarly, the values from butter and lard were taken from a study that calculates the footprint for farm animal products as butter is obtained from milk and lard from pig's fat tissue. The values

[2] Tata Chemicals Ltd. manufactures salt among other products using mostly seawater for its water requirements and discharges effluents into the sea instead of freshwater bodies.
[3] Considering that $1m^3$ of drinking water is equal to $1m^3$ of freshwater

cited above correspond to global averages. The only footprint value available for the production of salt was included in a report by Tata Group partnered with the International Finance Corporation and the Water Fooprint Network [22] where they specify salt is manufactured by the Tata Chemicals company in Mithapur, India.

Using these footprints and the two percentages mentioned before, the footprint for six different kinds of pastries was calculated resulting in the following footprints differentiated by type of fat used:

Table X- 24 % fat content: footprint by type

Type of Fat	Green	Blue	Grey	Total
	l/kg	l/kg	l/kg	l/kg
Butter	2,456	450	423	3,328
Lard	1,245	263	204	1,712
Oil (sunflower)	2,211	209	154	2,574

Table XI- 31 % fat content: footprint by type

Type of Fat	Green	Blue	Grey	Total
	l/kg	l/kg	l/kg	l/kg
Butter	2,873	503	497	3,873
Lard	1,323	264	217	1,804
Oil (sunflower)	2,559	195	154	2,908

Evidently in both cases the largest fooptrints were the ones that contained butter and the smallest were the ones with lard, which is consistent with their individual footprints' sizes. For both compositions, the butter pastries had a total footprint of around double the size of lard's and around 30 % larger than oil's.

Since Table II does not offer a distinction of which types of pastries are most consumed, the footprint of pastries will be considered as an average value between the largest of them (for 31 % butter content) and the smallest of them (24 % lard content), resulting in a footprint of: 2,059 m^3/ton WF_{green}, 383 m^3/ton WF_{blue}, 350 m^3/ton WF_{grey}, 2,739 m^3/ton WF_{total}.

3.1.6 Water footprint of food

Having completed Table II for the most consumed foods by Spanish people (except for a few products such as honey, cephalopods and molluscs due to insuffient data), and considering the amount of each product that is consumed yearly, it is now possible to determine the total footprint for the average Spanish diet. Taking the food supply quantity from Table II (kg/capita/year) and the green, blue and grey water footprint (l/kg) for each food, we get the annual footprint for all individual items on a Spanish diet. Adding up the footprint of all the food we obtain the footprint for a Spanish person's annual consumption of food: 1,274 m^3/year WF_{green}, 382 m^3/year WF_{blue}, 183 m^3/year WF_{grey}, 1,839 m^3/year WF_{total}.

3.1.7 Water footprint of non-food consumptions

As it was mentioned before, the indirect water footprint is the water use associated to the production of all the goods and services a person consumes. To determine these, an article published in El País by AFI Analytics and the National Institute of Statistics [23] was consulted to get a rough idea on what an average Spanish consumer spends their money on (apart from food).

Even though certain expenses such as rent, transportation, entertainment, health services, education, traveling, insurance, esthetic services, etc. amount to a large percentage (around 50 % of annual income is dedicated to these categories), in order to calculate the footprint only tangible products will be considered. Since the footprint for food consumption has already been accounted for, to avoid double counting, the expense for eating out will also be discarded. The rest of the expenses that contribute to the water footprint are for example, clothing and footwear, furniture and home equipment, books and other stationary items, tobacco. From these categories, clothing and footwear represents the largest percentage (5.09 % of annual income). For the purpose of calculating the annual water footprint associated to a Spanish person's clothing and footwear consumptions, the type of purchases made will be assumed.

In order to reduce the range of fabrics to study, it was determined that an interesting comparison to make will be between a synthetic and a natural fibre. The most popular synthetic fibre, according to the Textile Exchange Preferred Fiber and Materials Market Report 2019 [24], is polyester, which represents 52 % of the global fibre production whilst the most popular natural fabric is cotton, with 22 % of the production. The footprint for man-made fibres like polyester was taken from C&A's assessment in collaboration with the Water Footprint Network [25]. The footprint for natural fabrics like cotton was taken from M.M. Mekonnen and A.Y. Hoekstra's (2011) study on the footprint of crops and derived crop products [5].

Polyester is the most popular synthetic fabric in the world. It is obtained from crude oil and is mostly produced in China. Through the manufacturing process the polyester fibres obtained can take two different forms: filament and staple. Since staple fibres are easier to blend with other fabrics (and many clothing items are composed of blended fabrics), an average between the minimum and maximum footprint for these fibres will be the one considered: 31 m^3/ton WF_{blue}, 61,220 m^3/ton WF_{grey}, 61,251 m^3/ton WF_{total}[4]. This study explains that the vast difference between the blue and grey components is because the blue only occurs during the manufacturing of the fibres whilst the grey also includes the phases of oil exploration and refinery.

Cotton is a natural fibre, which takes many different production stages at various locations. Most of the world's seed cotton production comes from China, United States, India and Pakistan (62.5 % of global production) [26]. The average footprint for the cotton fabric and finished textiles in China is: 3,398 m^3/ton WF_{green}, 754 m^3/ton WF_{blue}, 1,846 m^3/ton WF_{grey}, 5,998 m^3/ton WF_{total}; for the United States: 4,987 m^3/ton WF_{green}, 2,303 m^3/ton WF_{blue}, 809 m^3/ton WF_{grey}, 8,099 m^3/ton WF_{total}; for India: 15,310 m^3/ton WF_{green}, 4,575 m^3/ton WF_{blue}, 2,583 m^3/ton WF_{grey}, 22,468 m^3/ton WF_{total}; for Pakistan: 2,317 m^3/ton WF_{green}, 5,258 m^3/ton WF_{blue}, 1,982 m^3/ton WF_{grey}, 9,557 m^3/ton WF_{total}. It can be seen clearly that the size of the water footprint is heavily dependent on location (16,470 m^3/ton difference between the largest and the smallest of the total footprints). The proportion between the green and blue components also has major variations depending on location and the different climatological parameters associated. The grey variations between countries are mostly due to the different water quality standards that allow disparate maximum pollutant concentrations and the various natural concentrations on the receiving freshwater bodies. Since these countries represent most of the world's production, the most representative values will be reflected in the global average footprint for the cotton fabric and finished textiles: 5,384 m^3/ton WF_{green}, 3,253 m^3/ton WF_{blue}, 1,344 m^3/ton WF_{grey}, 9,981 m^3/ton WF_{total}.

Assuming a cotton shirt weighs around 250 grams, the footprint of this product is 1.35 m^3 WF_{green}, 0.81 m^3 WF_{blue}, 0.34 m^3 WF_{grey}, 2.50 m^3 WF_{total}. A polyester shirt of the same weight would have a footprint of 0.008 m^3 WF_{blue}, 15.3 m^3 WF_{grey}, 15.3 m^3 WF_{total}, although polyester can be blended with different fabrics so its footprint would be an average considering the various possible compositions. A pair of jeans (which are made from cotton) weigh around 800 grams, meaning a footprint of 4.31 m^3 WF_{green}, 2.60 m^3 WF_{blue}, 1.01 m^3 WF_{grey}, 7.92 m^3 WF_{total}.

Evidently the number of shirts purchased yearly is an estimate, but considering that polyester is the most widely used fabric worldwide [24], especially among fast fashion brands that use it in most of their garments due to its versatility and low price, it is possible to assume that some of the clothes purchased are completely made or contain a significant percentage of this fabric. Even though polyester has the largest water footprint per ton of product, cotton's is still significant due to its extensive water use to meet irrigation requirements and pesticide and fertilizer application, and trying to lower our footprint by simply buying exclusively cotton clothes instead of polyester, will not be enough. As it was previously mentioned, crops' footprints are

[4] It is explained in this study that polyester does not have a green footprint since it is a synthetic fibre and it does not require the growing of crops to be produced.

highly dependent on location, so one would have to select a garment made from cotton produced in an area without water scarcity or contaminated freshwater resources (hotspots) in order to reduce their footprint and most of the times tracing the fabric's origin is just not possible. An alternative would be to buy exclusively organic cotton (which would have a significantly lower grey water footprint since it is cultivated without the use of toxic pesticides and fertilizers), but since it only makes up for 0,7 % of global cotton production [27], obviously, it is not enough to satisfy the entire world's demand. Since information about the water footprint of different textiles is still very scarce, and we don't have a detailed footprint accounting for all the different types of fabrics, it is not possible to determine which material is the best, most sustainable alternative. Instead of focusing on the materials, the most attainable approach would be to either purchase second-hand items or garments made from recycled fabrics, which would lower significantly the water footprint related to producing the fabrics.

Another item to be considered to complement this category is footwear. In this case, we have to know the proportions of the different materials from which the shoes are made. We will take as an example a pair of leather shoes, which can weigh around 1.4 kg, of which 0.5 kg are from the rubber sole and 0.9 kg are from the leather upper. Adding up each of their individual global average footprint values for leather [6] and rubber [5], the footprint for a pair of leather shoes will be around: 20.8 m^3 WF_{green}, 0.79 m^3 WF_{blue}, 0.66 m^3 WF_{grey}, 22.25 m^3 WF_{total}. Another type of shoe to consider is a leather sandal with a jute sole, weighing around 1 kg, of which 0.6 kg are from the sole and 0.4 kg from the leather straps (once again, this estimations are specified in order to calculate the footprint). The sum of the individual global average footprints for leather and jute [5], in the proportions mentioned before, amounts to a footprint for a pair of sandals of 7.78 m^3 WF_{green}, 0.29 m^3 WF_{blue}, 0.33 m^3 WF_{grey}, 8.4 m^3 WF_{total}.

According to the El País article [23], the average Spanish person has a budget of 10,950.55 €/year (this number may have varied by a small percentage from 2016 to this year). Considering that 5.09 % is spent on clothing and footwear, 560 €/year are dedicated on average to these purchases. This means that with this budget, a consumer could purchase per year a pair of leather boots, a pair of sandals, a couple of pairs of jeans and around 10 shirts. To simplify, it is assumed that 7 of the shirts are pure cotton and 3 are polyester. Then the footprint representing yearly purchases of clothing and footwear items would amount to:

Table XII- Water footprint for clothing and footwear per year

Item	Quantity	Green	Blue	Grey	Total
		m^3/year			
Leather boots	1	20.8	0.79	0.66	22.25
Sandals	1	7.78	0.29	0.33	8.4
Jeans	2	8.62	5.2	2.02	15.84
Cotton shirt	7	9.45	5.67	2.38	17.5

Polyester shirt	3	-	0.02	45.9	45.92
Total		**46.65**	**11.97**	**51.29**	**109.91**

The second largest percentage is the one associated to the consumption of tobacco for 137 €/year. Considering the global average footprint of tobacco [5], and assuming an average daily consumption of 10.7 cigarrettes [28] that weigh around 1 gram each, the footprint for a year will amount to 7.89 m^3 WF_{green}, 0.80 m^3 WF_{blue}, 2.73 m^3 WF_{grey}, 11.42 m^3 WF_{total}.

However, the footprint for smoking is even bigger since it also includes the footprint for the paper, filter and packaging. To get an even more detailed footprint accounting, one should also differentiate between tobacco variety and curing. This kind of detailed accounting was not possible due to insufficient information. However, like it was mentioned previously that it would be possible to lower the water footprint related to cotton by using organic production, the same could be applied to tobacco or any other kind of crop. By reducing the grey water footprint by not applying certain fertilizers and pesticides, the total water footprint will also be reduced.

The final category to be considered and the third largest percentage with 0.75 % is the one associated to the purchase of books, magazines and other stationery items, an expense that takes 82 €/year (44 €/year for books, 19 €/year for magazines and 18 €/year for other stationery items). Usually the price for a 16 x 24 cm and 500 pages book with a soft cover is set at around 20 €. This would represent the purchase of two books per year. Considering the individual footprints for printing paper and paperboard [29][5], an estimated footprint for the purchase of two books a year would be 1.8 m^3 WF_{total}.

This represents a rough estimate since the footprint is directly related to the amount and type of paper used (in this case the paper chosen for the analysis was printing paper, but the footprint for a coated paper, for example, is 5 % larger per ton of paper). Even though this is a small footprint compared to the rest of the purchases included, it could still be lowered by buying second-hand books. The acquisition of an electronic device to read e-books instead of paper books, could have a smaller water footprint in the long term, however, this is just a supposition since there are no studies comparing the two of them.

Finally the total water footprint for the most significant goods and services consumed, apart from food, is 123.13 m^3 WF_{total}.

[5] This study does not offer a distinction between green, blue and grey water footprint.

3.2 Final considerations

Considering the direct and indirect water footprint calculated prevously, the total footprint for a consumer in Spain is 2.188 m^3 WF_{total}. The total footprints divided by categories are shown in Table XIII:

Table XIII- Water footprint by category

Type	Category	Subcategory	WF_{Total} (m^3/yr)
Direct	**Personal use**	Personal hygiene	81.03
		Cleaning	135.22
		Self-consumption	9.49
Indirect	**Food**	Fruits	40.87
		Vegetables	35.62
		Pulses	14.94
		Fish	233.34
		Meat	515.65
		Animal by-products	381.59
		Alcoholic drinks	51.45
		Hot drinks	27.35
		Oils	218.09
		Nuts and seeds	69.70
		Grains	212.54
		Other	37.37
	Other	Clothing	79.26
		Footwear	30.65
		Tobacco	11.42
		Books	1.80

As a group, the footprint for farm animals, including pig, bovine, poultry and goat meat and offals is the largest, which leads to the assumption that in order to reduce our food-related footprint, reducing the consumption of farm animal products and eating more vegetables, fruits and pulses should be the focus. However, to reduce the consumption of a food group it is necessary to substitute it with something that contains similar macronutrients. For example, lean red meat has around 20 % protein content, which is the same as many pulses, but the water footprint per kilogram of meat is twice as big. Since the footprints for animal products are within the largest, the reduction of its consumption on some meals would have a large impact in the overall footprint.

Other example related to the change in the water footprint, by changing one product for another, can be the olive oil. The yearly consumption of just olive and sunflowerseed oil has a footprint of

218 m^3/year. Olive oil's footprint is twice as big as the one for sunflowerseed, so if one were to replace all use of the former for the latter, the footprint would be reduced by almost 78 m^3. However, the use of these products is not as easy to replace considering one is healthier than the other (considering vitamin, mineral and fatty acid contents).

Like it has been mentioned previously, making certain changes both in diet and other consumptions can have a significant impact on reducing one's footprint. Although, reducing the consumption of a specific product usually will mean increasing the consumption of a substitute, changing the location of the footprint but not necessarily reducing it. For this reason, when aiming to reduce one's water footprint, it is important to compare the alternatives to see if there was a significant footprint reduction or if the weight simply shifted from one product to another.

However, the obtained results show a first estimation of the water footprint of Spanish people. In addition, the proposed methodologies have proven useful for estimating the water footprint.

4. Conclusion

The total water footprint for a consumer in Spain amounts to 2,188 m^3/year WF_{total}, with food being the most important contributor with 1,839 m^3/year, secondly the direct water use with 226 m^3/year and finally other consumptions with 123.13 m^3/year. These results represent only a part of the total water footprint because, as indicated in the text, the means necessary to estimate all the items were not available. The results obtained, however, show a first approximation to the estimation of the Spanish water footprint, both in terms of its value and the methodology for its estimation.

The indirect water footprint related to food consumption was by far the largest with 1,839 m^3/year. The product that had the biggest contribution was pigmeat with 303 m^3/year, second was milk with 292 m^3/year and third was olive oil with 146 m^3/year. The products with the lowest contributions were the pepper with 13 m^3/year, sweet potatoes with 52 m^3/year and soyabeans with 83 m^3/year. Neither the pigmeat nor the milk are between the 10 products with the highest footprint per kilogram, but they are consumed in such large quantities that their yearly footprints amount to the most significant values. On the other hand, olive oil has the largest footprint per kilogram of product and is also consumed in large quantities throughout Spain, so it is not surprising that it has one of the largest yearly footprints.

The direct water footprint of 226 m^3 a year was calculated assuming daily activities that have a direct use of water. The way to lower the footprint is a very direct approach, involving practices that are already well known and widely practiced throughout Spain such as installing water-saving appliances and machines, dual toilet flushes, stopping the water from running when its not being directly used or avoiding flushing harmful substances down the drain.

Among other consumptions, apart from the consumptoin of water and food, clothing and shoes have turned out to be a significant part (109.91 m^3/year), being polyester the component with the highest weight with more than 40 % of the water footprint. In second place for other consumptions, tobacco contributes to 11.42 m^3 a year per person. The smallest footprint in this category was the one associated with books, with approximately 0.9 m^3 for one 500 pages book.

Reducing the water footprint for an average Spanish diet has a large impact on a person's habits and nutrition. So if somebody wanted to reduce theirs, they would have to look at each component and determine which can be avoided, reduced or replaced. But some small adjustments like eating less meat, replacing coffe for tea, wine for beer, or simply drinking water, reading labels to determine where a crop was grown, etc. can have an impact on the total water footprint.

5. List of symbols

Symbol	Description
WF	Water footprint
WF_{green}	Green water footprint
WF_{blue}	Blue water footprint
WF_{grey}	Grey water footprint
WF_{total}	Total water footprint
WF_{person}	Water footprint of a person
$WF_{person,direct}$	Direct water footprint of a person
$WF_{person,indirect}$	Indirect water footprint of a person
WF_{proc}	Water footprint of a process
$WF_{proc,green}$	Green water footprint of a process
$WF_{proc,blue}$	Blue water footprint of a process
$WF_{proc,grey}$	Grey water footprint of a process
CWU_{green}	Green crop water use
CWU_{blue}	Blue crop water use
CWU_{total}	Total crop water use
Y	Crop yield
ET	Evapotranspiration
ET_{green}	Green water evapotranspiration
ET_{blue}	Blue water evapotranspiration
lgp	Length of growing period
λ	Latent heat of vaporization
R_n	Net radiation
G	Soil heat flux
ρ_a	Mean air density at constant pressure
C_p	Specific heat of the air
e_s	Saturation vapour pressure
e_a	Actual vapour pressure
Δ	Slope of the saturation vapour pressure temperature relationship
γ	Psychrometric constant
r_s	Surface resistance
r_a	Aerodynamic resistance
ET_c	Total crop evapotranspiration
P_{eff}	Effective rainfall

L	Load of pollutants that enters the water system
C_{max}	Maximum acceptable concentration of a certain pollutant in the receiving water body
C_{nat}	Natural concentration of a certain pollutant in the receiving water body
ET_o	Reference crop evapotranspiration
K_c	Ratio of potential evapotranspiration
p	Critical depletion fraction
K_y	Yield response factor
CWR	Crop water requirement
α	Leaching-run-off fraction
AR	Chemical application rate
C_{effl}	Concentration of a chemical in an effluent
C_{act}	Actual concentration of a chemical in a water body

6. References

[1] Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M., The water footprint assessment manual: Setting the global standard, Earthscan, London. (2011)

[2] Ministerio de Fomento. Código Técnico de Edificación, Documento Básico de Salubridad, HS4 Suministro de agua (2019). https://www.codigotecnico.org/images/stories/pdf/salubridad/DBHS.pdf [25/03/2020]

[3] Food and Agriculture Organization. Food Balance Sheets. Rome, http://www.fao.org/faostat/en/#data/FBS [28/04/2020]

[4] Instituto Nacional de Estadística. Estudio nacional de nutrición y alimentación. Madrid (1995). https://www.ucm.es/data/cont/docs/458-2013-09-15-Moreiras-col-1995-ENNA-1-2-3.pdf [25/03/2020]

[5] Mekonnen, M.M. and Hoekstra, A.Y., The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15: 1577-1600 (2011)

[6] Mekonnen, M.M. and Hoekstra, A.Y., A global assessment of the water footprint of farm animal products, Ecosystems, 15: 401-415 (2012)

[7] Allen, R. G., Pereira, L. S., Raes, D. and Smith, M., Crop evapotranspiration: Guidelines for computing crop water requirements, FAO Irrigation and Drainage Paper 56, Food and Agriculture Organization, Rome (1998)

[8] Food and Agriculture Organization. CROPWAT 8.0 model. Rome, www.fao.org/nr/water/infores_databases_cropwat.html. [11/04/2020]

[9] N.G. Dastane. Effective rainfall in irrigated agriculture, Food and Agriculture Organization, Rome (1978)

[10] MAPA, Ministerio de Agricultura, Pesca y Alimentación. Superficies y producciones anuales de cultivo de acuerdo con el Reglamento (CE) 543/2009, datos avances de hortalizas. Madrid (2019) https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/superficies-producciones-anuales-cultivos/ [09/04/2020]

[11] AEMET, Agencia Estatal de Meteorología. Valores climatológicos reales. Santa Cruz de Tenerife. Período 1981- 2010. http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/valoresclimatologicos?l=C449C&k=undefined [18/05/2020]

[12] MAPA, Ministerio de Agricultura, Pesca y Alimentación. Calendarios Siembra, Recolección y Comercialización 2014- 2016 para hortalizas. Madrid (2019) https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/hortalizas_tcm30-514220.pdf [09/04/2020]

[13] AEMET, Agencia Estatal de Meteorología. Valores climatológicos reales. Ciudad Real. Período 1981- 2010.
http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/valoresclimatologicos?l=4121&k=undefined [09/04/2020]

[14] Food and Agriculture Organization. Fertilizer use by crop, FAO Fertilizer and Plant Nutrition Bulletin 17, Food and Agriculture Organization, Rome (2006)

[15] Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC)

[16] EEA, European Environment Agency. Nutrients in freshwater in Europe. Copenhagen (2019) https://www.eea.europa.eu/data-and-maps/indicators/nutrients-in-freshwater/nutrients-in-freshwater-assessment-published-9 [03/05/2020]

[17] La Vanguardia. Del mar a la mesa: ¿de dónde viene el pescado que comemos? Barcelona (2018) https://www.lavanguardia.com/vida/junior-report/20180125/44272761360/mar-mesa-origen-pescado-comemos-espana.html [22/06/2020]

[18] Pahlow M., van Oel P.R., Mekonnen M.M., Hoekstra A.Y., Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production, Science of the Total Environment, 536: 847- 857 (2015)

[19] Verdegem M.C.J., Bosma R.H., Water withdrawal for brackish and inland aquaculture, and options to produce more fish in ponds with present water use, Water Policy, 11: 52- 68 (2009)

[20] Tucker C.S., Hargreaves J.A., Biology and culture of channel catfish, Developments in aquaculture and fisheries science, 34: 215- 278 (2004)

[21] Andrews S.L., Harte J.B., Ingredient functionality and dough characteristics, Encyclopedia of food sciences and nutrition, Academic Press, San Diego (2003)

[22] Unger K., Zhang G., Mathews R., Water Footprint Assessment Results and Learning: Tata Chemicals, Tata Motors, Tata Power, Tata Steel, Tata Quality Management Services, International Finance Corporation, and Water Footprint Network (2013)
https://waterfootprint.org/media/downloads/WFN_2013.Tata_Industrial_Water_Footprint_Assessment.pdf [26/06/2020]

[23] AFI, Analistas Financieros Internacionales. ¿Cómo gastan el dinero los españoles? ¿Cuánto destinan a pan? ¿Y a zapatos? El País (2016)
https://elpais.com/economia/2016/06/20/actualidad/1466421723_914789.html [26/03/2020]

[24] Textile Exchange. The Preferred Fiber and Materials Market Report (2019)
https://textileexchange.org/wp-content/uploads/2019/11/News-Release-Textile-Exchange-Preferred-Fiber-and-Materials-Market-Report-2019.pdf [29/06/2020]

[25] Freitas A., Zhang G., Mathews R., Water Footprint Assessment of Polyester and Viscose (2017) https://waterfootprint.org/media/downloads/WFA_Polyester_and__Viscose_2017.pdf [28/06/2020]

[26] Chapagain A.K., Hoekstra A.Y., Savenije H.H.G., Gautam R., The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries, Ecological Economics, 60: 186- 203 (2006)

[27] Organic Trade Association. Get the facts about organic cotton (2019) https://ota.com/advocacy/fiber-and-textiles/get-facts-about-organic-cotton [03/07/2020]

[28] RTVE, Corporación de Radio y Televisión Española S.A. Los fumadores aumentan en España hasta alcanzar casi la cuarta parte de la población (2019). https://www.rtve.es/noticias/20190528/fumadores-aumentan-espana-hasta-alcanzar-casi-cuarta-parte-poblacion/1947143.shtml [02/07/2020]

[29] Schyns J.F., Booij M.J., Hoekstra A.Y., The water footprint of wood for lumber, pulp, paper, fuel and firewood, *Advances in Water Resources*, 107: 490-501 (2017)