GRAPEFRUIT WATER FOOTPRINT IN SPAIN

METHODOLOGY: The Water Footprint Assessment Manual. Water Footprint Network (WFN)

The water footprint of grapefruits produced in Spain is 203 m^3/tonne.

By producing provinces, the grapefruits produced in Almería has the highest water footprint (WF) with 321 m^3/t while in Cordoba it is the lowest (177 m^3/t). In Alicante it is 237 m^3/t; in Málaga it is 233 m^3/t; in Cádiz it is 224 m^3/t; in Murcia it is 207 m^3/t; in Valencia it is 202 m^3/t; in Huelva it is 186 m^3/t; and in Sevilla it is 181 m^3/t.

In the last 30 years, the water footprint of grapefruits in Spain has fallen by 36.9%, meaning that producing 1 tonne of grapefruits in 2020 requires 119 m^3 less water than in 1990.

This reduced water footprint is a product of the major efforts being made to optimise irrigation water and increase production yields, which has led to **Spanish grapefruits having a water footprint 59.9% lower than the world average.**

Despite all this progress, **our sector continues to make strides to further improve its water footprint** by implementing technologies and practices to further reduce water consumption and make more sustainable use of inputs in grapefruit production.

1. INTRODUCTION

Grapefruit tree cultivation in Spain occupied an area of 2,628 hectares (ha) in 2020. According to the Spanish Ministry of Agriculture, Fishing and Food (MAPA), grapefruit production in the same year reached 81,556 tonnes, with an average yield of 31,03 t/ha.

Table 1. Grapefruit cultivation area, production and yield in Spain – 2020

	Cultivation area (ha)	Production (t)	Yield (t/ha)
GRAPEFRUIT	**2,628**	**81,556**	**31.03**

Source. MAPA

Freshwater is a scarce and limited resource. Human activities consume and pollute a huge volume of water, with agricultural production being the largest consumer of water resources.
Today, consumers, producers, retailers, food industries and traders of water-intensive products are all necessary agents of change when it comes to water management, in their role as both direct and indirect users.

Following the introduction of the water footprint concept in 2002, the notion of considering water use within supply chain management has been gaining momentum. This concept looks not only at direct water use of a consumer or producer, but also at the indirect water use. It is a comprehensive indicator of water resource appropriation.

We at the Spanish Lemon and Grapefruit Interprofessional Association (known as AILIMPO), as part of our commitment to innovation, technology and knowledge, operate with close regard to the three axes of sustainability; environmental, social and economic. Our central role is to get all the agents involved in the lemon and grapefruit sector (producers, cooperatives, exporters and industries) ready to face the various challenges that lie ahead.

In 2015, the United Nations adopted the 2030 Agenda, which includes a commitment to achieve all the Sustainable Development Goals (SDGs). To help achieve this, **AILIMPO measures the water footprint of grapefruits produced in Spain, thus contributing to the following SDGs:**

- **SDG 6 – Clean Water and Sanitation.** The goal is to ensure the availability and sustainable management of water and sanitation for all.
- **SDG 12 – Responsible consumption and production.** The aim is to optimise water use and water reuse in food extraction and production.

2. OBJECTIVES AND SCOPE OF THIS REPORT

This report seeks to assess the water footprint of grapefruits in Spain.

In doing so, we analyse the water footprint at national level and for each producing regions.

To find the trend of water footprint in grapefruits, we compared the figures for 2020 with those for 1990.

We then benchmark the data contained in the report against global data and average data for other countries, as well as against water footprint data for other agricultural products obtained from available bibliographic sources.

We then provide explanations for the sector's water footprint figures as obtained during the assessment phase and lastly we offer a number of recommendations on how producers can further reduce their water footprint.

3. WHAT IS THE WATER FOOTPRINT?

The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal. **The**

water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain.

Freshwater is used for the purposes of the water footprint in three ways, as follows:

- **Blue water footprint (WFblue). It is an indicator of consumptive use of so-called blue water, in other words, fresh surface or groundwater.** The term 'consumptive water use' refers to one of the following four cases:
  1. Water evaporates.
  2. Water is incorporated into the product.
  3. Water does not return to the same catchment area, for example, it is returned to another catchment area or the sea.
  4. Water does not return in the same period, for example, it is withdrawn in a scarce period and returned in a wet period.

- **Green water footprint (WFgreen).** The green water footprint is an indicator of the human use precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (but not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth).
  The green water footprint is the volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood.

- **Grey water footprint (WFgrey).** It indicates the degree of freshwater pollution that can be associated with the process step. It is defined as the **volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards**. The grey water footprint concept has grown out of the recognition that the size of water pollution can be expressed in terms of the volume of water that is required to dilute pollutants such that they become harmless.

Therefore, the total water footprint of growing crops (WFcrop) is the sum of the blue, green and grey footprints.

$$WFcrop = WFblue + WFgreen + WFgrey$$

We must also consider the indirect water footprint, which is defined as follows:

- **Indirect water footprint (WFindir).** The indirect water footprint of a product **refers to the consumption and pollution produced by the inputs consumed in the activity being carried out, in this case, on farms,** excluding water as this would be the WFcrop.

Lastly, the **total water footprint of the grapefruit production process (WFtotal)** is the sum of the crop water footprint and the indirect water footprint.

$$WFtotal = WFcrop + WFindir$$

4. METHODOLOGY EMPLOYED TO CALCULATE THE GRAPEFRUIT WATER FOOTPRINT IN SPAIN

The methodology used in this report is as set out in The Water Footprint Assessment Manual published by the Water Footprint Network (WFN), which is the worldwide reference guide for calculating the water footprint.

Below we describe the calculation process used for each aspect of the water footprint.

4.1 Blue water footprint (WFblue)

Following the methodology of the WFN, we calculate it as follows:

$$WFblue = (ETc + WT - Peff)/Yield$$

$$ETc = ETo \ x \ Kc$$

ETc = Evapotranspiration of the crop
ETo = Reference evapotranspiration
Kc = Crop coefficient
WT = Water used in plant protection treatments
Peff = Effective precipitation
P = Precipitation
Yield = Grapefruit production per unit of land. It is based on the average yield over the last five years in each province and for Spain as a whole.

The following sections describe how the data for ETc, ETo, Precipitation (P), Effective Precipitation (Peff) and Water used in plant protection treatments (WT) have been obtained.

4.1.1. Calculating Crop Evapotranspiration (ETc)

ETc represents the water needs of the crop.

In this report, it has been obtained on the basis of the ETc values for the grapefruit crop in each of the main producing regions.

The crop coefficient (Kc) we used was obtained from the Murcia Agricultural Information System (known as SIAM), based on the following annual average values for each variety:

Grapefruit…………..Kc=0.372

4.1.2. Reference evapotranspiration data (ETo) and Precipitation (P)

For the ETo and precipitation values we have considered climate data from stations located in the different regions over the last 19 years (from 2002 to 2020). Although the WFN recommends a longer historical series, we have been limited by the lack, in some cases, of climate data prior to 2002.

All weather stations calculate ETo according to the Penman-Monteith equation.

The following system and sources of climate data were used:

- **Murcia**. Murcia Agricultural Information System (SIAM). Data from 21 stations located in the grapefruit producing areas. The ETo and P (mm) data for each station are calculated to subsequently obtain the calculation of the average data for the 21 stations, which we use for the entire grapefruit area of the province.
- **Alicante and Valencia**. Valencian Institute of Agricultural Research – Instituto Valenciano de Investigaciones Agrarias (IVIA). The reference stations we used are the 10 stations located in the province of Alicante and 25 in the province of Valencia. We then obtain the average of this data, which we use for the entire area of every province.
- **Andalusia**. Andalusian Agroclimatic Information Network (known as RIA). Due to the way in which climate data is provided, it is not possible to run the calculation using the same methodology as for Murcia and Alicante. Therefore, a reference station is selected for each province (Cuevas de Almanzora, for Almería, Cártama for Málaga, Palma del Condado for Huelva, Lora del Río for Sevilla, Palma del Río for Córdoba and Veger de la Frontera for Cádiz) and the ETo and precipitation data are transferred to the wider province.

4.1.3. Effective precipitation (Peff)

Effective precipitation is the fraction of total precipitation that is taken up by the crops. It depends on multiple factors such as precipitation intensity, climate aridity, slope of the terrain, soil moisture content and infiltration rate. We have applied the formula proposed by Brouwer and Heibloem in 1986 for application in areas with slopes of less than 5%. Thus, depending on the precipitation during the month, we use:

$$Peff = 0.8 * P - 25 \qquad If\ P > 75\ mm/month$$

$$Peff = 0.6 * P - 10 \qquad If\ P < 75\ mm/month$$

If, when applying them, the result of Peff is negative, Peff = 0.

Where:

P = monthly precipitation (mm/month)

Peff = effective precipitation (mm/month)

For Murcia Alicante and Valencia, effective precipitation has been obtained on the basis of monthly precipitation data (as indicated in the above formula) for a single representative weather station, calculating the % that effective precipitation represents of the resulting total precipitation, as indicated in section 4.1.2.

In each of the provinces of Andalusia, given that Precipitation and ETo data for the reference weather station have been taken as being representative of the province as a whole, effective precipitation is calculated using the above formulae.

4.1.4. Water used in plant protection treatments (WT)

The amount of water used for plant protection treatments (AT) does not have a significant impact on the total Blue Footprint of the crop, although we do take it into account when making the calculation.
García, J. (2018) estimates the average number of plant protection treatments at five per year for both Fino and Verna varieties. We will consider that eight treatments take place in both cases.

Eight treatments/year with an average spray volume of 1000 l/ha reveals a **WT value of 8 m³/ha**.

4.2 Green water footprint (WFgreen)

The calculation is carried out according to the WFN methodology and using the following expression:

$$WFgreen = Peff/Yield$$

Peff = Effective precipitation
Yield = Grapefruit production per unit of land

4.3 Grey water footprint (WFgrey)

To calculate the grey water footprint, we have taken into account the nitrogen supplied for fertilisation as the most representative pollutant.

The maximum nitrogen input for grapefruit growing, according to the Code of Good Farming Practices for the Region of Murcia, is 7 kg N/tonne produced and the content above which a watercourse (surface or groundwater) is considered to be polluted by nitrates according to Directive 91/676/EEC is 10 mg N/litre. It is based on a leaching factor of 10%.

Thus, the WFgrey is a product of the following expression:

$$WFgrey = \frac{(Kg\ chemical\ product\ applied) * \frac{(leaching\ factor)}{(aquifer\ max\ permitted\ concentration)}}{Yield}$$

4.4 Crop Water Footprint (WFcrop)

The total water footprint of the crop is the sum of the blue, green and grey water footprints.

$$WFcrop = WFblue + WFgreen + WFgrey$$

4.5 Indirect water footprint (WFindir)

The inputs we consider in the WFindir calculation are fertilisers and plant protection product packaging.

The calculation for grapefruit growing presents certain difficulties as there are no sources of information on the water footprint in the manufacture of fertilisers and plant protection product containers. Therefore, we will rely on estimates already used in other water footprint studies such as Tolón A., et al (2013).

4.5.1. Fertilisers

To analyse the indirect water footprint represented by the use of fertilisers, we rely on the amounts used for growing as indicated in the Murcia Agricultural Information System (SIAM).

We have considered a water footprint per kilo of commercial fertiliser used of 180 litres/tonne of fertiliser.

For grapefruits, the total amount of fertiliser used is 886 kg/ha.

Thus, the indirect water footprint of the fertilisers used in grapefruit growing is 159.48 l/ha.

4.5.2. Plant protection product containers

We have considered all plant protection product containers to be plastic, with a capacity of 1 litre. The water footprint for this type of container is 3 litres of water/pack. We estimate that 30 containers/ha/year are consumed.

Therefore, the total water footprint of plant protection containers used for grapefruit growing is 90 litres/ha.

4.6 Total water footprint (WFtotal)

Lastly, we obtain the total water footprint of the grapefruit production process, which is calculated as the sum of the crop water footprint and the indirect water footprint.

$$WFtotal = WFcrop + WFindir$$

4.7 Total water footprint in 1990

To find out the trend in the water footprint of grapefruits over the last 30 years, we calculated the total water footprint in 1990.

For this purpose, we took the average grapefruit production yields over the 1986-1990 period (5 years).

As for not having ETo and precipitation climate data available for the weather stations used to calculate the WFtotal 2020 between 1970 and 1990, we would make the following remarks:

- We used the ETo values used for the WFtotal 2020, knowing that, due to the increase in average temperatures as a consequence of climate change, the values for 1990 were lower. Therefore, the data employed will result in a WFtotal 1990 that is somewhat higher than what would have been obtained had the ETo values for the years 1970 to 1990 been available.
- We estimated that, for the calculation of WFtotal in 1990, average precipitation in the period before 1990 was 10% higher than in the period considered for WFtotal 2020 (also due to lower levels of precipitation as a consequence of climate change).
- A total of 12 plant protection treatments/year are carried out, as per the current crop growing trend of reducing the number of treatments (in 2020 we estimate 8 treatments/year).
- The WFgrey in 1990 is the same as in 2020.

5. ACCOUNTING OF THE WATER FOOTPRINT OF GRAPEFRUIT PRODUCTION IN SPAIN

The total water footprint of the grapefruit sector is 16.6 Hm^3, revealing an average volume of 6,306 m^3/ha. The following table shows the data by footprint type.

WFindir accounts for only 0.007 m^3/t, and therefore has a very small impact on WFtotal. Therefore, while it is included in WFtotal, we will not be showing it in the tables and graphs from this point forwards.

Table 2. Total water footprint in Spain of grapefruit growing, using various metrics

WF UNIT	WFblue	WFgreen	WFgrey	WFtotal
m^3/tonne	79	54	70	203
m^3/ha	2,466	1,668	2,172	6,306
Hm^3	6.5	4.4	5.7	16.6

Source. Prepared in-house

The total water footprint of grapefruit production in Spain is 203 m^3/tonne, where the WFblue, WFgreen and WFgrey are 79 m^3/t, 54 m^3/t and 70 m^3/tonne, respectively.

If we consider the total water footprint for crop growing by province (Table 3), we can observe that the province with the greatest total water footprint of grapefruit growing is Murcia with 6.40 Hm^3, following by Valencia with 3.10 Hm^3, Sevilla with 2.29 Hm^3 and Alicante with 1.32 Hm^3. The rest of the provinces are below 1 Hm^3.

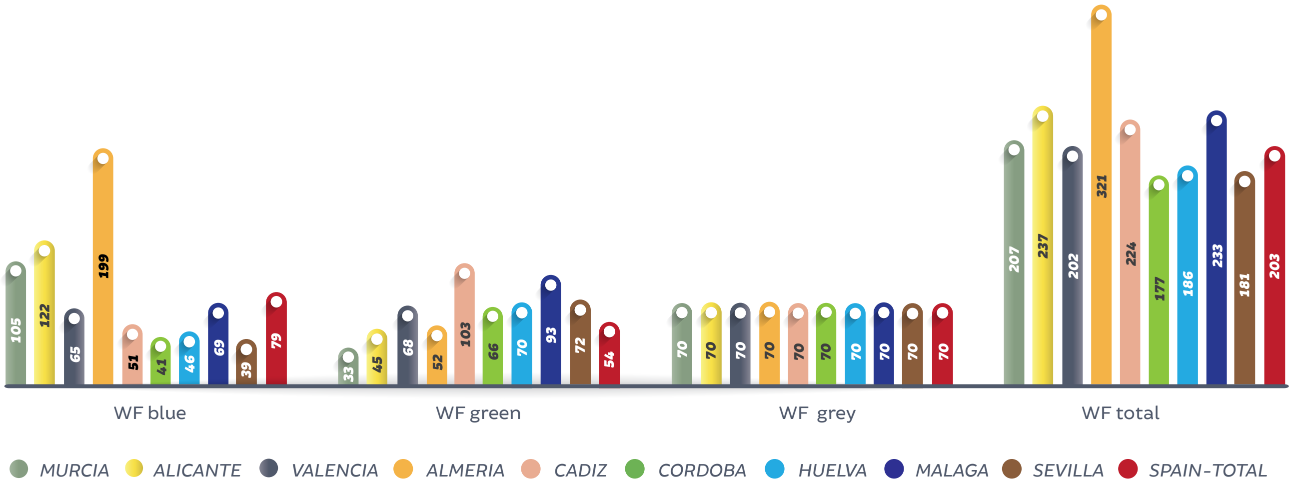
Table 3. Total water footprint of grapefruit production by province (Hm^3)

Murcia	6.40
Alicante	1.32
Valencia	3.10
Almería	0.82
Cádiz	0.73
Córdoba	0.82
Huelva	0.60
Málaga	0.27
Sevilla	2.29
Other provinces	0.25
Total Spain	**16.60**

Source. Prepared in-house

By producing provinces, figure 1 shows the water footprint of grapefruit is higher in regions with lower yields. A case in point is the province of Almería (WFtotal of 321 m³/t).

Figure 1. Water footprint, grapefruit growing in Spain (m³/tonne)



Source. Prepared in-house

The producing region with the lowest water footprint is Cordoba, with 177 m³/t. In Alicante it is 237 m³/t; in Málaga it is 233 m³/t; in Cádiz it is 224 m³/t; in Murcia it is 207 m³/t; in Valencia it is 202 m³/t; in Huelva it is 186 m³/t; and in Sevilla it is 181 m³/t.

6. TREND IN THE WATER FOOTPRINT OF GRAPEFRUIT GROWING IN SPAIN. COMPARISON, 1990 VS 2020

As can be seen in table 4, to produce 1 tonne of grapefruits today, the water footprint is 119 m^3 less than in 1990, meaning that **the water footprint has fallen by 36.9% over the last 30 years**.

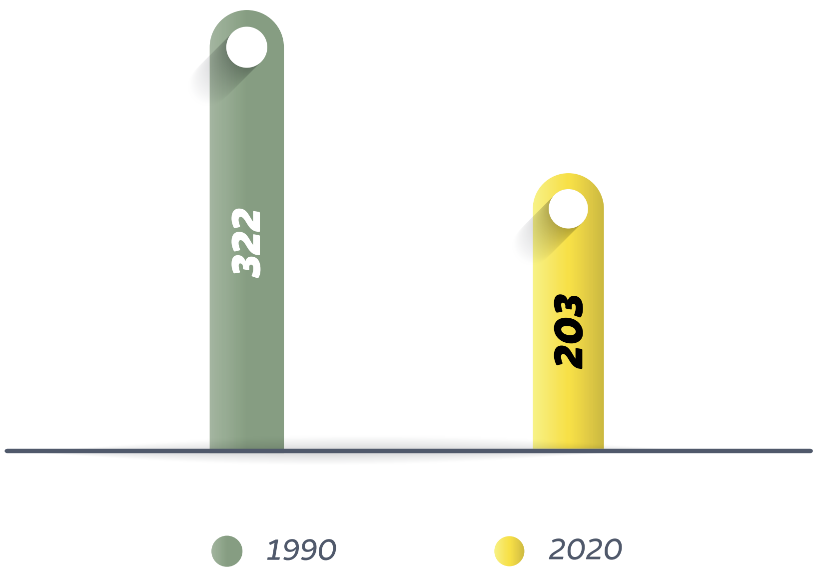
This significant decline is down to more streamlined and efficient use of water resources and also an increase in crop yields.

Table 4. Trend in total water footprint for grapefruit in Spain, 2020 vs 1990

	WFtotal (m^3/t)		2020 vs 1990	
	1990	2020	(m^3/t)	dif (%)
GRAPEFRUIT	**322**	**203**	**-119**	**-36.9%**

Source. Prepared in-house

Figure 2. Trend in WFtotal in Spain, 2020 vs 1990 (m^3/t)



Source. Prepared in-house

7. INTERNATIONAL COMPARISON OF THE GRAPEFRUIT WATER FOOTPRINT

As we can see in table 5, the average worldwide water footprint (WF according to UNESCO-IHE) for grapefruit is 506 m^3/t while the WF in Spain is 59.9% lower than the world average.

In short, **the water footprint for grapefruit production in Spain is well below the worldwide average** because local producers are more efficient in their use of water. In addition, we have strong potential to further improve our water footprint over the coming years, as there are many young plantations that are not yet producing or have not yet reached their maximum productive potential, which in the near future will have the effect of increasing average yields.

Table 5. Water footprint for grapefruit across different countries (m^3/t)

	WATER FOOTPRINT		Spain vs UNESCO-IHE	
	UNESCO-IHE	SPAIN	m^3/t	%
WFblue	85	79	-6	-7.1%
WFgreen	367	54	-313	-85.3%
Hgris	54	70	16	29.6%
HH total	**506**	**203**	**-371**	**-59.9%**

Source. Prepared in-house

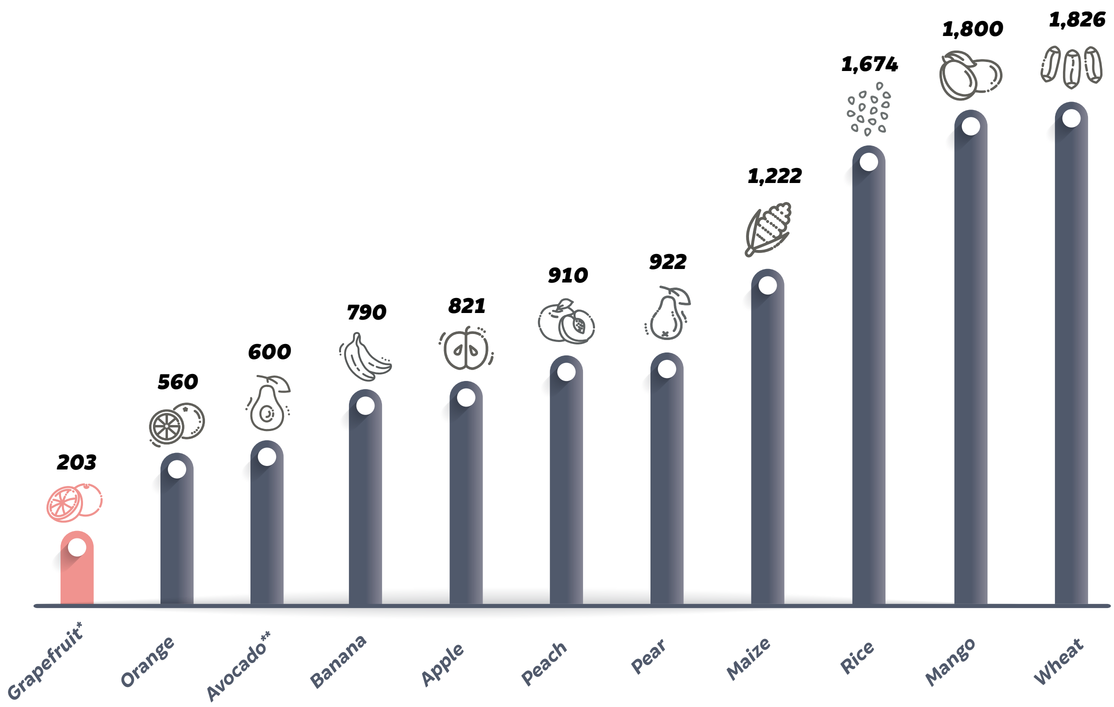
8. COMPARISON BETWEEN THE WF FOR GRAPEFRUITS IN SPAIN AND OTHER AGRICULTURAL PRODUCTS

Agricultural production accounts for most of the world's water use. It is estimated that 86% of the human water footprint is related to this activity.

Therefore, given that the water footprint of an agricultural product can cause quite a stir when analysed individually (in the case of grapefruits, producing 1 kilo in Spain means a water footprint of 203 litres), it is important to know how our WF compares to that of other products.

Therefore, in figure 3 we show a comparison between the water footprint for grapefruits obtained from this study and that of other agricultural products, revealing that the water footprint for grapefruits is lower than for other products such as oranges (560 m^3/t). For non-citrus fruits, the figures range from 600 m^3/t for avocados, 790 m^3/t for bananas, 821 m^3/t for apples, 910 m^3/t for peaches and 922 m^3/t for pears. For mangos, the figure comes to 1,800 m^3/t .

Figure 3. Graph comparing the water footprint (WF) of different products (m³/t)



Source. Prepared in-house. UNESCO-IHE data. (*) AILIMPO. (**) World Avocado Organization (WAO)

If we compare the water footprint for grapefruits with the WF for the most consumed cereal crops (maize, rice or wheat), we can observe that the water footprint for grapefruits is much lower, as for these particular cereal products it is 1,222, 1,674 and 1,826 m^3/tonne, compared with 203 m^3/t for grapefruit.

In short, the water footprint for grapefruits produced in Spain is rather positive when compared with other agricultural produce.

9. ACTIONS TAKEN BY GRAPEFRUIT GROWERS IN SPAIN TO REDUCE THEIR WATER FOOTPRINT

In general, average water consumption per hectare in Spain fell from 8,250 m^3/ha to 6,500 m^3/ha between 1950 and 2007.

Grapefruit production in Spain is a model in the optimal use and management of irrigation water. Major investments in storage infrastructure and improvement of distribution facilities are leading to a significant reduction in water losses during transport to farms.

For citrus farming, ESYRCE claims that 84% of the area irrigated relies on localised irrigation systems. This enables optimal adaptation of the dosage and distribution of water and nutrients during all phases of the vegetative and production process, thus optimising the productivity of the water used, due to:

- The uniform distribution of water and fertilisers in the place where the roots of the tree are located.
- Availability of water and fertilisers "on demand", that is, being able to locate, depending on the point of the vegetative cycle, the water and fertilisers that the crop demands.
- Correction of deficiencies in any nutritional element in a short period of time.
- A more rational use of water and fertilisers, in order to increase productivity and quality with the least environmental impact.

Over the last 30 years, there has been a 268% increase in the size of growing areas with localised irrigation for lemons and grapefruits. **These advances in irrigation and fertilisation have succeeded in increasing productivity**.

In addition, the practice of **shredding and mulching pruning waste has become widespread within the sector, which reduces the evaporation of water from the soil and increases organic matter**. This improves water retention capacity and the use of both irrigation water and rainwater, thus reducing the WFblue and WFgreen.

The sector is therefore using water efficiently and embracing practices to further reduce its water footprint.

10. RECOMMENDATIONS ON HOW TO FURTHER IMPROVE THE WATER FOOTPRINT OF GRAPEFRUIT GROWING IN SPAIN

The grapefruit industry must continue to reduce its water footprint over the coming years. To succeed, farmers must continue to invest in **precision farming technologies** that maximise productivity and minimise **water use. Training in water management efficiency techniques is also very important**. Below we offer a series of recommendations that are already being introduced in some plantations, although we believe that more widespread acceptance would lead to further improvements in the water footprint.

- **Regulated deficit irrigation (RDI).** Where water doses below those required by the crop are sporadically used. This deliberate stressing should be as small as possible during the most critical phases of the crop (in citrus fruits these are the flowering and setting, growth and ripening phases). FAO refers to this system as an agronomic practice with a positive influence on water use efficiency, indicating that any reduction in yield will be insignificant compared to the benefits of saving water. This technique is useful as an emergency measure for the subsistence of the crop in cases of having less water resources as a result of a drought. However, its application over many harvests can cause significant losses in productivity, so it cannot be sustained for many years in a row. **For grapefruits, RDI saves up to 40% in water consumption, although production is also slightly lower.**

- **Reducing water consumption through information obtained with soil moisture monitoring tools**. By monitoring the water status of the soil with sensors, it is possible to monitor soil moisture and gauge actual water consumption by the plant and the water that is lost below the area where its roots are. In this way, irrigation times and the intervals between watering can be adjusted to meet the demands of the plants without losing water or nutrients below their root level. **Irrigation management based on the information obtained from these probes allows us to reduce the amount of water we use by 20-30% in citrus trees, while also avoiding nutrient leaching and therefore reducing both WFblue and WFgrey.**

- **Installing plastic mulch on the soil.** Using plastics mulch on the soil along crop rows generates a reduction in water loss due to evaporation. In addition, since the plastic used is black, the growth of weeds that stop competing with the tree for water and nutrients is prevented. It is estimated that it is possible to save up to 25% in water use.

- **Covering irrigation ponds.** Most farms have one or more irrigation ponds where water is stored and then used for watering the crops. There are different systems for covering irrigation ponds to reduce the amount of evaporated water. Various studies estimate that between 20 and 30% of the water stored annually evaporates, so covering the ponds helps prevent these losses.

- **Using less fertiliser and pesticide.** It is important to optimise the use of fertilisers to avoid leaching. Meanwhile, the incorporation of biological and technological pest control techniques has led to a reduction in the use of pesticides. All these practices help reduce the WFgrey.

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