THE FUTURE OF THE AVAILABILITY OF WATER RESOURCES IN LEMON PRODUCTION AREAS IN SPAIN

Segura and Júcar drainage basins (Vinalopó-Alicantí demarcation), Andalusian Mediterranean Basin (Guadalhorce, Guadalmedina, Carboneras, Aguas and Almanzora Basins)

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"The availability of irrigation water in lemon producing areas could decrease by 17.57% by 2027 and 18.69% by 2039"

The availability of irrigation water in lemon-producing drainage basins could decrease by 17.57% by 2027 and 18.69% by 2039 as a result of there being less groundwater and water coming from the Tagus-Segura interbasin transfer.

In the Segura basin, which is the main basin where lemons are produced, on 41,100 hectares (81.5% of Spain's total production), the situation is similar, with water availability decreasing by 19.6% by 2027 and 21.49% by 2039, affecting production not only of lemons but also of other fruit and vegetables.

Faced with a scenario of reduced water resources, we can expect the first impact to most severely affect the production of seasonal crops (vegetables), especially perennial crops (fruit and citrus) since the effects of a lack of water may have an irreversible effect on trees, even leading to their death.

"Water resources reduction would not only affect lemon but all fruits and vegetables crops"

"On paper, there are political commitments to increase the volumes of desalinated water and lower its cost"

The basin plans contemplate an increase in the availability of desalinated water for future scenarios and, regardless of the planning schemes, on paper, there are political commitments to increase the volumes of desalinated water and lower its cost in order to reduce the water deficit in these basins.

Furthermore, even without knowing exactly what the real scope of the reduction in irrigation resources in these drainage basins will be, lemon producers are taking action to improve how water is used and reduce consumption to be prepared for the worst scenarios.

"A new Water Mix scenario will need to be analyzed in terms of its impact on crops"

1. GOALS

This study will analyse the current availability status for water resources for irrigation in lemon production areas in Spain. And we will look at the expected medium- and long-term scenarios to see how this availability will evolve over the coming years.

We will use information made available by different sources, while taking the hydrological plans for the basins where lemons are grown in Spain as a point of reference.

2. DEFINITIONS

In this section, we are going to define a series of terms that will make it easier to read the document.

- **Drainage basin.** According to the Water Framework Directive (2000/60/EC), it is the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta. The drainage basin as a resource management unit is considered indivisible.
- **Surface water.** These are inland waters (except groundwater), transitional waters and coastal waters. (Directive 2000/60/EC).
- **Groundwater.** All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. (Directive 2000/60/EC).
- **Reclaimed water.** According to Regulation (EU) 2020/741, it is defined as urban waste water that has been treated in a reclamation facility in accordance with Section 2 of Annex I to this regulation, allowing it to be subsequently used for agricultural purposes.
- **Desalinated water.** It is salt water that is processed to reduce its salinity, thus adapting it to be fit for a certain use.

3. METHOD

"98% of the lemon production area in Spain lies in these basins"

Lemon production in Spain is located mainly in **the Segura and Júcar drainage basins (Vinalopó-Alicantí demarcation) and in the Andalusian Mediterranean Basin, in the subsystems where there is lemon production (the Guadalhorce and Guadalmedina Basin, the Carboneras and Aguas Basin and the Almanzora Basin).** Table 1 shows that 98% of the lemon production area in Spain lies in these basins. The drainage basin containing the largest area of lemon crop is Segura.

Table 1. Lemon production area by drainage basin in 2021 (ha)

BASIN	Area (ha)	Basin % vs BASINS total	Basin % vs SPAIN total
Segura	41,100	83%	81%
Andalusian Mediterranean Basin	6,402	13%	13%
Júcar	1,919	4%	4%
3 BASINS TOTAL	**49,421**	**100%**	**98%**
SPAIN TOTAL	50,412		

Source. Prepared in-house

From the information available in each of the drainage basin hydrological plans drawn up by the Segura River, Júcar River and Andalusian Mediterranean Basin Authorities for 2022–2027, we have obtained data on volumes of water available for irrigation in 2021, as well as on what is expected to be usable in **2027** and in **2039**, according to water source.

All the information refers to all of the drainage basin crops, as the different plans do not include data to allow us to make estimates for citrus or lemon crops.

Regarding the data on water transferred from the Tagus-Segura aqueduct, we have considered that it will be lower due to the increase in ecological flows set out in the Tagus River Basin Plan, and the figures considered are as estimated by SCRATS, indicating a reduction in availability of 103.5 hm^3 by 2027 and by 2039 with respect to 2021.

In the case of the Vinalopó-Alicante demarcation, as we do not have data for 2027 and 2039, we have taken into account the same volumes as for 2021, reducing the volume of water expected to be transferred from the Tagus-Segura by the same proportion as for the other basins.

Given that the Segura Drainage Basin is the one with the largest lemon area (41,100 hectares, 83% of the 49,421 hectares of lemon production in all the basins analysed), we will focus in more detail on analysing the situation in this basin and its future projection.

“Tagus-Segura aqueduct, SCRATS indicates a reduction in availability of 103.5 hm^3 by 2027 and by 2039 with respect to 2021”

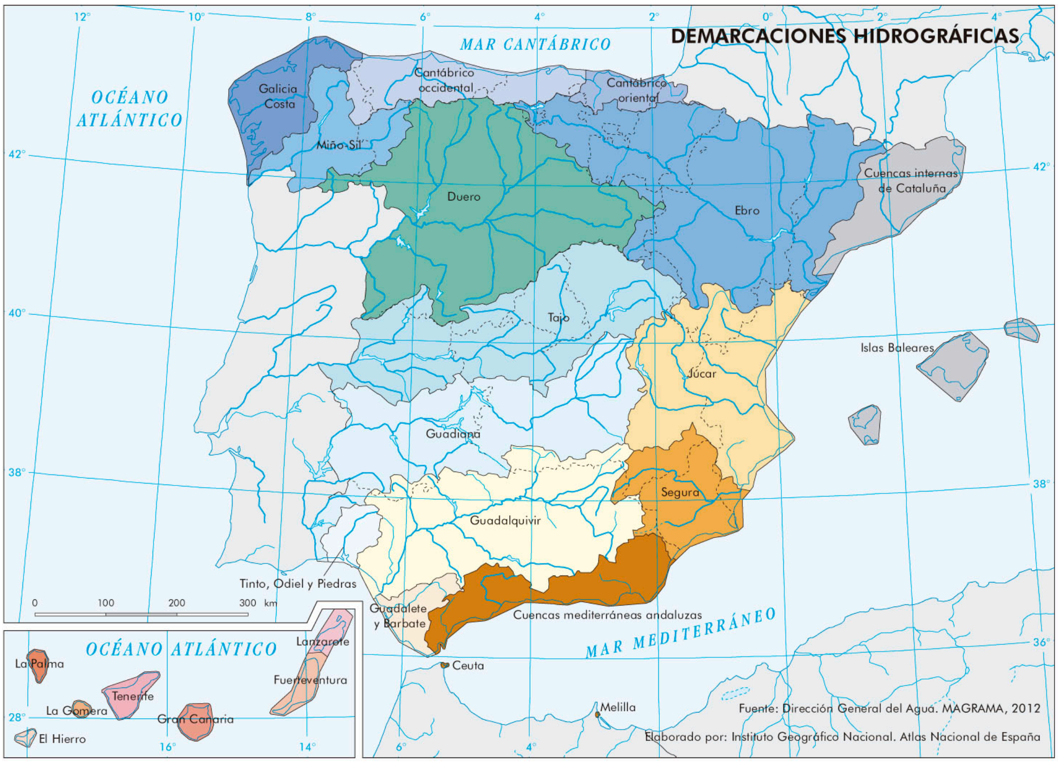
We will then analyse a series of factors that could change all the planning for the analysed drainage basins in relation to the future availability of water resources in the drainage basins where lemons are grown.

Lastly, we will indicate a series of actions that lemon producers will necessarily have to carry out on their farms to reduce their water consumption and thus adapt to the new conditions that they will have to implement in the medium and long term if there may be less availability of water in the future.

4. ANALYSIS OF THE AVAILABILITY OF WATER IN LEMON PRODUCTION AREAS IN SPAIN NOW (2021) AND IN 2027 AND 2039

As mentioned above, lemon production in Spain is located mainly in the Segura, Júcar and Andalusian Mediterranean basins, geographically located in the provinces of Alicante, Almería, Malaga and Murcia.

Figure 1. Drainage basins in Spain



According to the Ministry of Agriculture, Fisheries and Food, the area of lemon trees located in these provinces and, consequently, in the aforementioned drainage basins covered 49,421 hectares in 2021 (98% of the area of this crop in Spain).

AVAILABILITY OF WATER IN BASINS WITH LEMON PRODUCTION

The availability of water in the lemon-producing basins, shown in Table 2, is the sum of the volumes of the Segura Basin, the Júcar Basin (in the Vinalopó-Alicante demarcation) and the Andalusian Mediterranean Basin, in the subsystems in which there is lemon production (Guadalhorce and Guadalmedina Basin, Carboneras and Aguas River Basin and Almanzora Basin).

"It is estimated that crop area irrigated from the Tagus-Segura aqueduct could amount 26,600 lemon trees hectares"

In these drainage basins, there are transfers of water from other basins. All the drainage basins where lemon trees are grown receive resources from the Tagus River through the Tagus-Segura interbasin transfer. Furthermore, the Segura basin and the Andalusian Mediterranean Basin in the province of Almería also receive water from the Guadalquivir River basin through the interbasin transfer from the Negratín Reservoir.

In total, it is estimated that the citrus crop area irrigated with a greater or lesser proportion of water from the Tagus-Segura interbasin transfer could amount to 38,000 hectares, of which 26,600 hectares would be lemon trees, 70% of the total.

Table 2. Irrigation water in lemon production areas in Spain, according to source, in 2021 and in 2027 and 2039 (hm^3) . Three basins: Segura, Andalusian Mediterranean and Júcar basins.

SOURCE OF THE WATER	2021	2027	2039	2027 VS 2021		2039 VS 2021	
				diff (hm^3)	diff (%)	diff (hm^3)	Diff (%)
Surface water	537.67	507.16	501.06	-30.51	-5.67 %	-36.61	-6.81 %
Groundwater	630.74	378.19	350.88	-252.55	-40.04 %	-279.86	-44.37 %
Reclaimed water	160.82	179.34	179.24	18.52	11.52 %	18.42	11.45 %
Desalinited water (*)	224.01	277.40	290.59	53.39	23.83 %	66.58	29.72 %
Water from other basins (**)	264.61	156.34	156.38	-108.27	-40.92 %	-108.23	-40.90 %
Tagus-Segura Interbasin transfer	220.64	117.10	117.10	-103.54	-46.93 %	-103.54	-46.93 %
Negratín Interbasin transfer	43.97	39.24	39.28	-4.73	-10.76 %	-4.69	-10.67 %
TOTAL	**1,817.85**	**1,498.43**	**1,478.15**	**-319.42**	**-17.57 %**	**-339.70**	**-18.69 %**

(*) Volumes may increase due to political initiatives to increase desalinated water.
(**) Tagus-Segura and Negratín Inter-basin Transfer.
Source. Compiled based on data from the hydrological plans for the Segura, Andalusian Mediterranean and Júcar basins 2020–2027 and SCRATS.

The foreseeable reduction in volumes coming from other basins, by both 2027 and 2039, is a consequence of the current hydrological plan for the Tagus basin, which expects an increase in the ecological flows from the Tagus River, which will go from the current 6 m^3/s to 8.6 m^3/s, so that the average volume coming from this basin to the Tagus-Segura Interbasin Transfer will be reduced by 78 hm^3/year. Furthermore, this decrease will be greater due to the expected supply to the La Mancha plain from the Tagus-Segura aqueduct, which, according to the Central Union of Irrigators of the Tagus-Segura Water Transfer (SCRATS), will mean a total annual loss of irrigation resources transferred from the Tagus to receiving basins of 103.5 hm^3/year.

As for the foreseeable reduction of groundwater in the future, it is a consequence of the intensive use of this resource in recent years, which has caused a decrease in the volumes of water stored in the subsoil and, in many cases, the intrusion of saline water into coastal aquifers. Therefore, in order to reclaim these water masses both in quantity and to improve their quality, the hydrological plans contemplate a reduction in current irrigation usage by the two proposed future horizons.

"the foreseeable reduction of groundwater in the future, it is a consequence of the intensive use of this resource"

Next, we will analyse the availability of water for irrigation in 2021 and at the 2027 and 2039 horizons.

4.1 AVAILABILITY OF WATER FOR IRRIGATION IN 2021

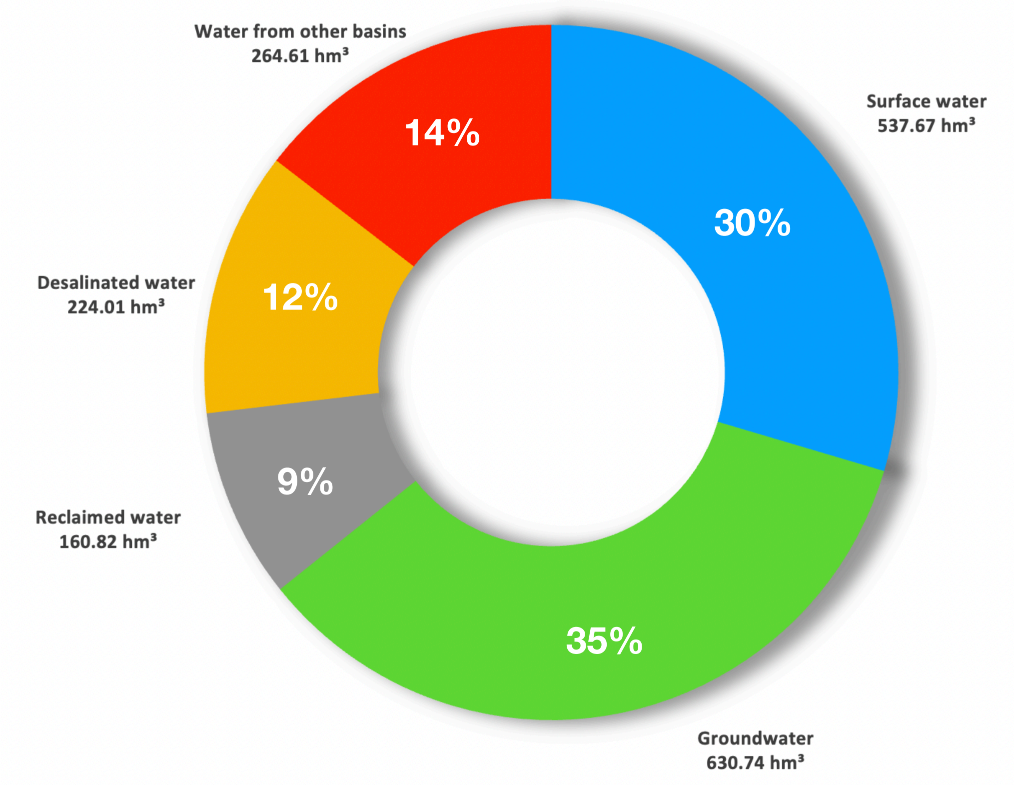
"the total consumption of the lemon area in the group of basins analysed would be 247.1 hm^3/year"

As can be seen in Table 2, 1,817.85 hm^3 of irrigation water were available in lemon production areas in Spain in 2021.

Estimating water consumption of 5,000 m^3/year per lemon hectare, the total consumption of the lemon area in the group of basins analysed would be 247.1 hm^3/year.

Regarding the source of the irrigation water, the following graph shows that 30% was surface water, 35% groundwater resources, 9% reclaimed water, 12% came from desalination and 14% was transferred from other basins.

Chart 1. Breakdown of water in lemon production areas 2021 (hm^3 and %)



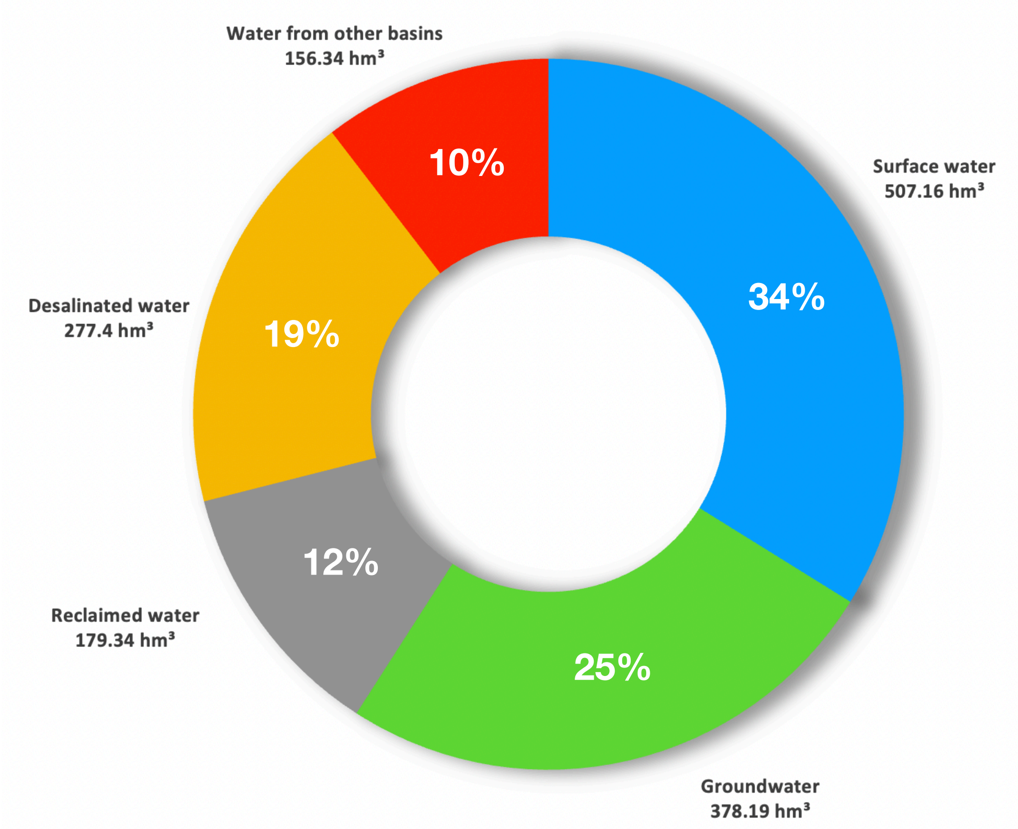
Source. Prepared in-house

4.2 AVAILABILITY OF WATER FOR IRRIGATION IN 2027

The total water resources for irrigation in 2027 are expected to be 1,498.43 hm^3. As shown in Table 2, a decrease of 17.57% is expected in 2027, with respect to current resources (-319.42 hm^3), mainly as a consequence of a reduction in groundwater volumes of 252.55 hm^3 (-40.04%) and a decrease of 40.92% in resources coming from other basins (-108.27 hm^3). On the other hand, greater quantities of reclaimed water (18.52 hm^3) and desalinated waters (53.39 hm^3) will help to offset, although slightly, the decrease in groundwater and resources from other basins.

Regarding the expected source of water available for irrigation in 2027, as can be seen in the following chart, it is estimated that 34% of the total will be surface water, 25% groundwater, 12% reclaimed, 19% desalinated and 10% will come from other basins.

Chart 2. Breakdown of water in lemon production areas 2027 (hm^3 y %)



Source. Prepared in-house

4.3 AVAILABILITY OF WATER FOR IRRIGATION IN 2039

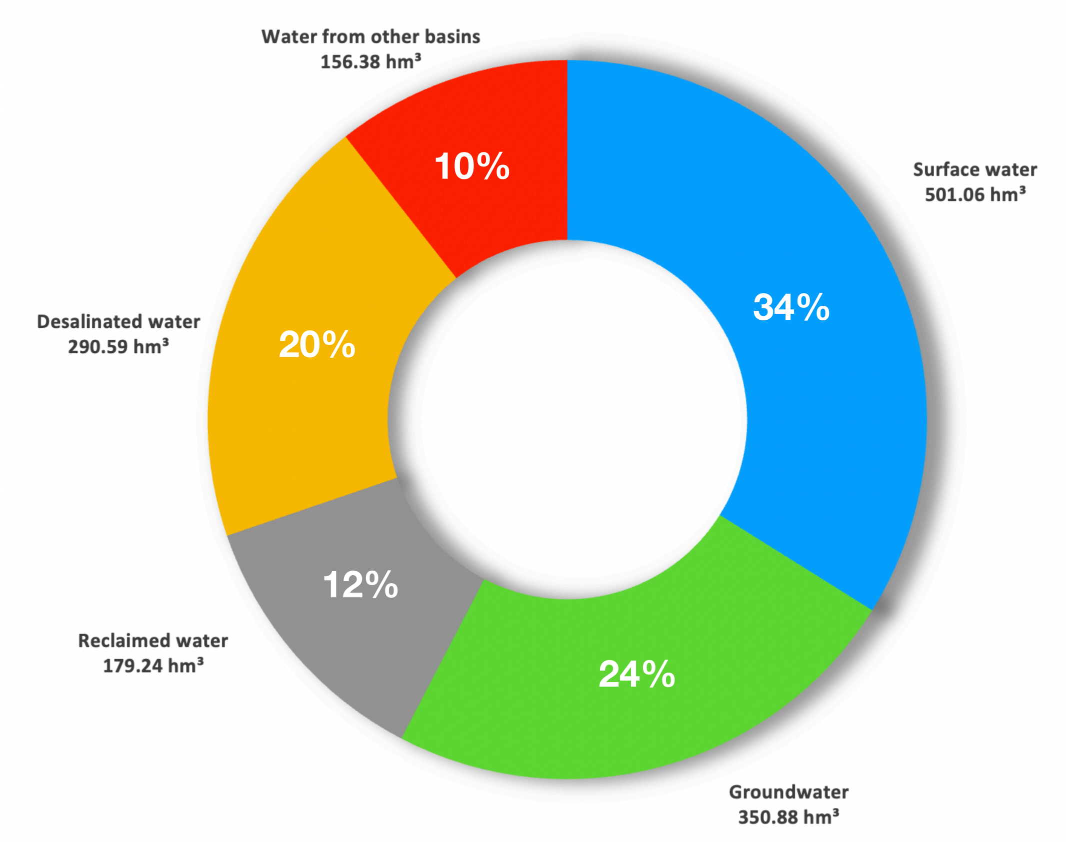
For 2039, the forecast is that there will be 1,478.15 hm^3 of irrigation water available in lemon production areas, an 18.69% decrease with respect to current availability (-339.7 hm^3), mainly due to a reduction of groundwater (-44.37% or -279.86 hm^3) as well as a 40.9% decrease in resources from other basins (-108.23 hm^3). The forecast for desalinated water continues to rise (+66.58 hm^3), but that will only help to offset a small proportion of the decrease in groundwater and resources from other basins (Table 2).

In this 2039 scenario, the foreseeable reduction in volumes coming from other basins as a result of the current Tagus Basin hydrological plan is maintained.

Regarding the availability of groundwater for irrigation, the plans envisage a continued reduction in these resources.

Regarding the water breakdown in 2039, Chart 3 shows that surface water will make up 34%, groundwater 24% and reclaimed 12%, while desalinated water and water coming from other basins would account for 20% and 10%, respectively.

Chart 3. Breakdown of water in lemon production areas 2039 (hm^3 and %)



Source. Prepared in-house

5. ANALYSIS OF THE AVAILABILITY OF WATER IN THE SEGURA BASIN NOW AND IN 2027 AND IN 2039

According to the data obtained from official statistics provided by the Regional Governments of Murcia, Valencia and Andalusia, the area dedicated to growing lemons in the Segura drainage basin is 41,100 hectares, which represents 81.5% of the area dedicated to this crop in Spain.

Given the significant size of this area, we consider it important to be aware of the current and future availability of water resources in this basin.

The Segura basin covers areas of the provinces of Jaén, Granada, Almería, Albacete, Alicante and almost the entire province of Murcia.

The basin is occupied by the Segura River and its tributaries, and the rest of the channels with direct drainage into the sea are ephemeral streams with very irregular contributions, directly conditional on the rain that falls on their catchment basins.

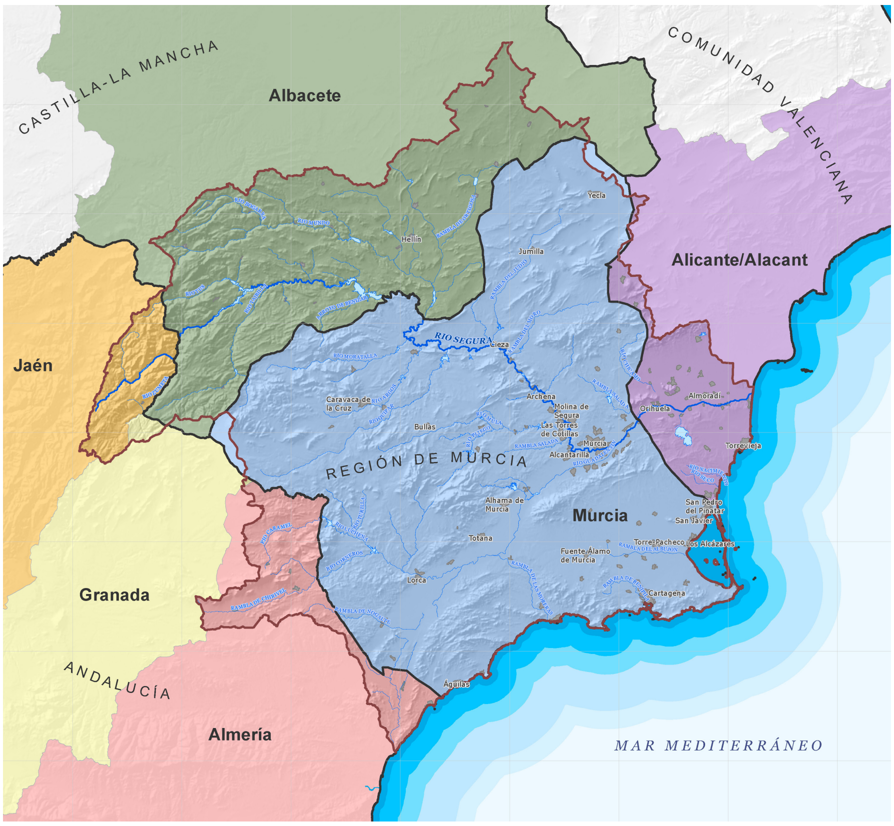
There are great climatic contrasts: from severe droughts to torrential rains and including floods, heatwaves or catastrophic frosts.

"the area dedicated to growing lemons in the Segura drainage basin is 41,100 hectares, which represents 81.5% of the area dedicated to this crop in Spain"

Rainfall is highest in the mountains located to the north-west of the basin, reaching over 1,000 mm per year, and lowest on the Mediterranean coast, at around 300 mm per year.

Temperatures follow a similar pattern, with average annual temperatures of around 10 ºC in the mountains and 18 ºC at the coast.

Figure 2. Map of the Segura Drainage Basin



WATER AVAILABILITY IN THE SEGURA BASIN

Table 3 shows information on the availability of water resources in the Segura Basin in 2021 and the forecasts for 2027 and 2039. We will analyse it below.

The causes of the decrease in available water resources due to the reduction in water transferred from other basins and from groundwater that is expected to occur in the Segura Basin are the same as for all the drainage basins as described in Section 4 of this report.

Table 3. Irrigation water in lemon production areas in the Segura Basin, according to source, in 2021 and in 2027 and 2039 (hm^3)

SOURCE OF THE WATER	2021	2027	2039	2027 VS 2021		2039 VS 2021	
				diff (hm^3)	diff (%)	diff (hm^3)	diff (%)
Surface water	428.20	428.20	423.80	0.00	0.00 %	-4.40	-1.03 %
Groundwater	425.30	202.40	178.10	-222.90	-52.41 %	-247.20	-58.12 %
Reclaimed water	135.30	135.90	135.80	0.60	0.44 %	0.50	0.37 %
Desalinited water (*)	222.80	258.20	260.10	35.40	15.89 %	37.30	16.74 %
Water from other basins (**)	214.50	121.90	121.90	-92.60	-43.17 %	-92.60	-43.17 %
Tagus-Segura Interbasin transfer	197.50	104.90	104.90	-92.60	-46.89 %	-92.60	-46.89 %
Negratín Interbasin transfer	17.00	17.00	17.00	0.00	0.00 %	0.00	0.00 %
TOTAL	**1,426.10**	**1,146.60**	**1,119.70**	**-279.50**	**-19.60%**	**-306.40**	**-21.49%**

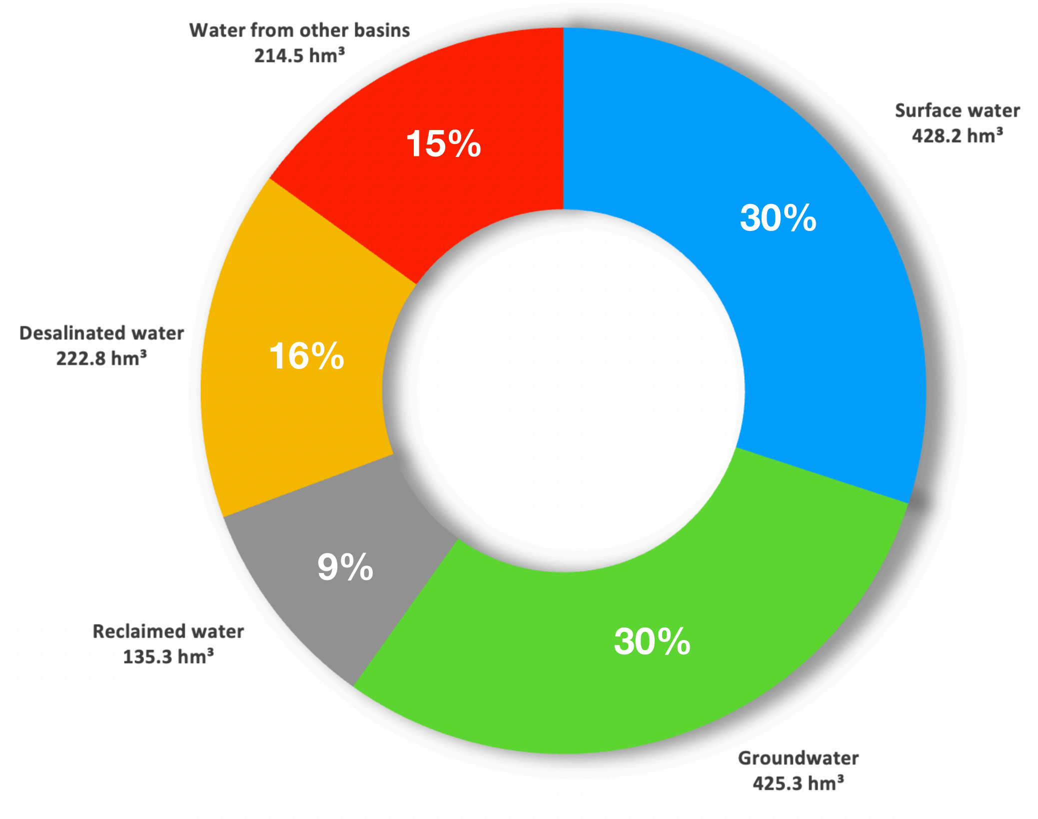
(*) Volumes may increase due to political initiatives to increase desalinated water.
(**) Tagus-Segura and Negratín Interbasin Transfer.
Source. Compiled based on data from the hydrological plan for the Segura Basin 2020–2027 and SCRATS.

5.1 AVAILABILITY OF IRRIGATION WATER IN THE SEGURA BASIN IN 2021

Table 3 shows that 1,426.1 hm^3 of water were available for irrigation in the Segura Basin in 2021.

Regarding the source of irrigation water in 2021, according to the following chart, 30% was surface water, 30% groundwater, 9% reclaimed, 16% desalinated and 15% came from other basins.

Chart 4. Breakdown of water in the Segura Drainage Basin 2021 (hm³ and %)



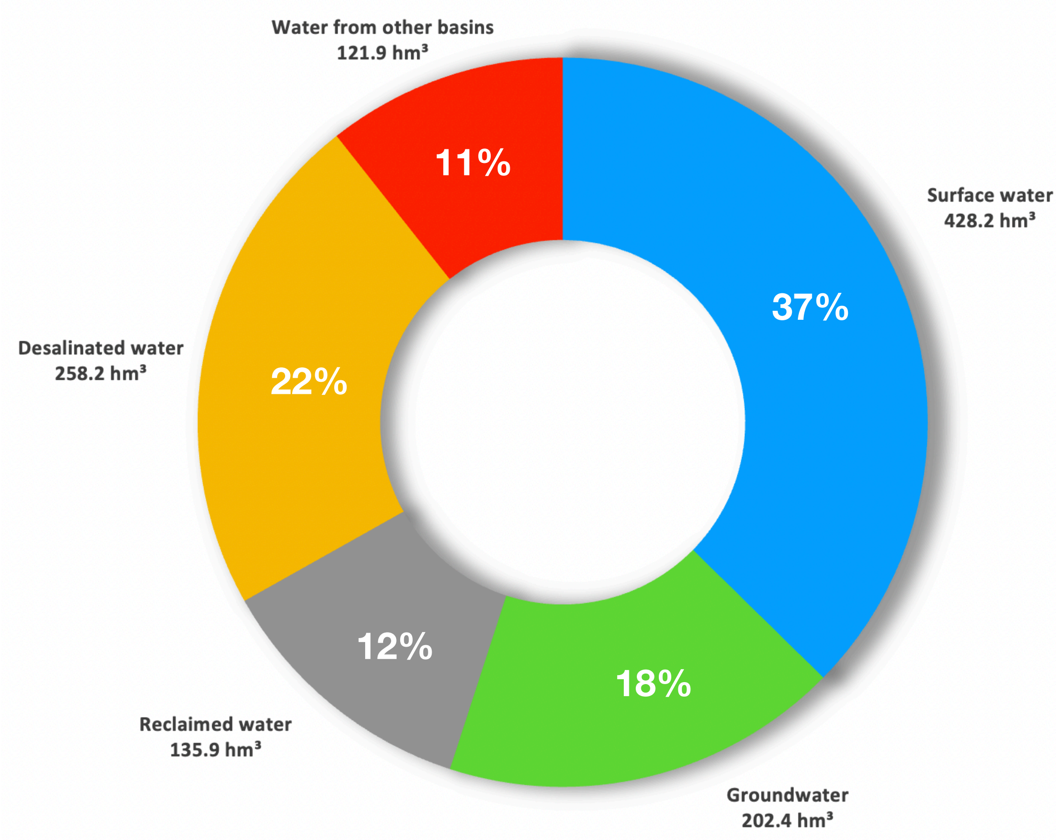
Source. Prepared in-house

5.2 AVAILABILITY OF IRRIGATION WATER IN THE SEGURA BASIN IN 2027

In 2027, 1,146.6 hm^3 of irrigation water are expected to be available for irrigation, a 19.6% decrease with respect to 2021 (-279.5 hm^3), mainly as a consequence of a reduction of 222.9 hm^3 in groundwater volumes (-52.41%) and a 43.17% decrease in resources from other basins (-92.6 hm^3). On the other hand, the higher contributions of desalinated waters (+35.4 hm^3) will help to offset, although only slightly, the decrease in groundwater and resources from other basins (Table 3).

Regarding the source of water in the Segura Basin in 2027, as can be seen in the following chart, 37% of the water available for irrigation will be surface water, 18% groundwater, 12% reclaimed, 22% from desalination processes and 11% will come from other basins.

Chart 5. Breakdown of water in the Segura Drainage Basin 2027 (hm³ and %)



Source. Prepared in-house

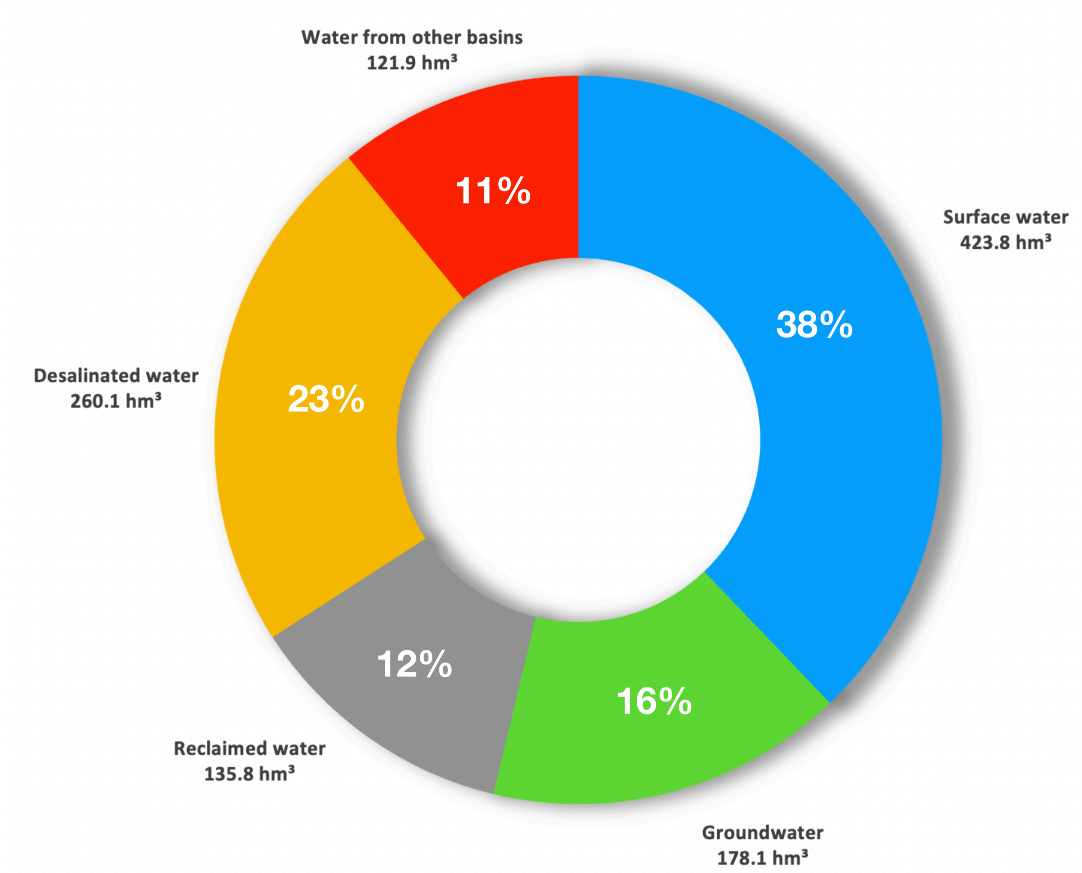
5.3 AVAILABILITY OF IRRIGATION WATER IN THE SEGURA BASIN IN 2039

"In 2039, the distribution of water by source will be 38% surface water, 16% groundwater, 12% reclaimed, and desalinated water and resources from other basins will make up 23% and 11%, respectively"

Following the trend set at the 2027 horizon, the forecast for 2039 is that 1,119.7 hm³ of irrigation water will be available in the Segura Basin, a 21.49% reduction with respect to 2021 volumes (-306.4 hm³), with the decrease being mainly in groundwater (-58.12% and -247.2 hm³) as well as a 43.17% reduction in resources coming from other basins (-92.6 hm³), which is significant. The forecast for desalinated water continues to rise (+37.3 hm³), but that will only help to offset a small proportion of the decrease in groundwater and resources from other basins (Table 3).

In 2039, as broken down in the following chart, the distribution of water by source will be 38% surface water, 16% groundwater, 12% reclaimed, and desalinated water and resources from other basins will make up 23% and 11%, respectively.

Chart 6. Breakdown of water in the Segura Drainage Basin 2039 (hm^3 and %)



Source. Prepared in-house

6. UNCERTAINTY IN THE ANALYSIS OF FUTURE HORIZONS

Regardless of the volumes of water available for irrigation contemplated in the hydrological plans for future scenarios, there are a number of factors that could change the amounts of water available in the future. They include the significant investment currently being made and the future commitments of public administrations in terms of desalination and clean energy facilities to lower the cost of desalination, making it possible to have greater volumes of water than those set out in the basin plans to offset deficits caused by a reduction in the availability of groundwater and contributions from the Tagus-Segura interbasin transfer.

Therefore, the prospective availability of desalinated water in the future will be greater than we have taken into account in this report and could help lessen the gap in the availability of water resources for irrigation between the 2027 and 2039 horizons and 2021.

“the prospective availability of desalinated water in the future will be greater”

Proof of these initiatives is the recent approval of Spanish Royal Decree-Law 4/2023, of 11 May, which adopts urgent measures in agricultural and water matters in response to the drought and worsening conditions in the primary sector as a result of the war in Ukraine and weather conditions and also promotes the use of collective public land transport among young people and prevention of occupational hazards during episodes of high temperatures, which includes significant investment into desalination and water resources (see links below).

https://www.miteco.gob.es/es/prensa/ultimas-noticias/El-MITECO-destina-1.400-millones-para-afrontar-la-sequ%C3%ADa-y-aumentar-la-disponibilidad-de-agua/tcm:30-564745

https://www.boe.es/boe/dias/2023/05/12/pdfs/BOE-A-2023-11187.pdf

“the reduction of water resources has always been more severe for the production of seasonal crops (vegetables) than for permanent crops (fruit and citrus)”

On the other hand, our drainage basins are prone to periods of drought when basin authorities decide to restrict the use of water for irrigation. In this situation, the reduction of water resources has always been more severe for the production of seasonal crops (vegetables) than for permanent crops (fruit and citrus). Therefore, in a scenario of decreased water, it is highly likely that resources will be prioritised to maintain permanent crops, as the effects of the water shortage would irreversibly affect trees, possibly even killing them.

7. MEASURES FOR REDUCING THE USE OF IRRIGATION WATER IN THE LEMON SECTOR

Even without knowing the real scope of the decrease in water resources available for irrigation in the drainage basins where we produce lemons, producers are already taking action to improve how water is used and reduce its consumption to be ready for the possible scenarios set out in this report. Here are some of those measures.

“producers are already taking action to improve how water is used and reduce its consumption”

a) Regulated deficit irrigation (RDI)

Controlled Deficit Irrigation consists of applying doses of water below the crop's needs. This reduction should be as small as possible in the most critical phases of the crop (in citrus fruits these are the flowering and setting, growth and ripening phases).

The FAO refers to deficit irrigation as an agronomic practice with a positive influence on water productivity, indicating that any reduction in yield will be insignificant compared to the benefits of saving water.

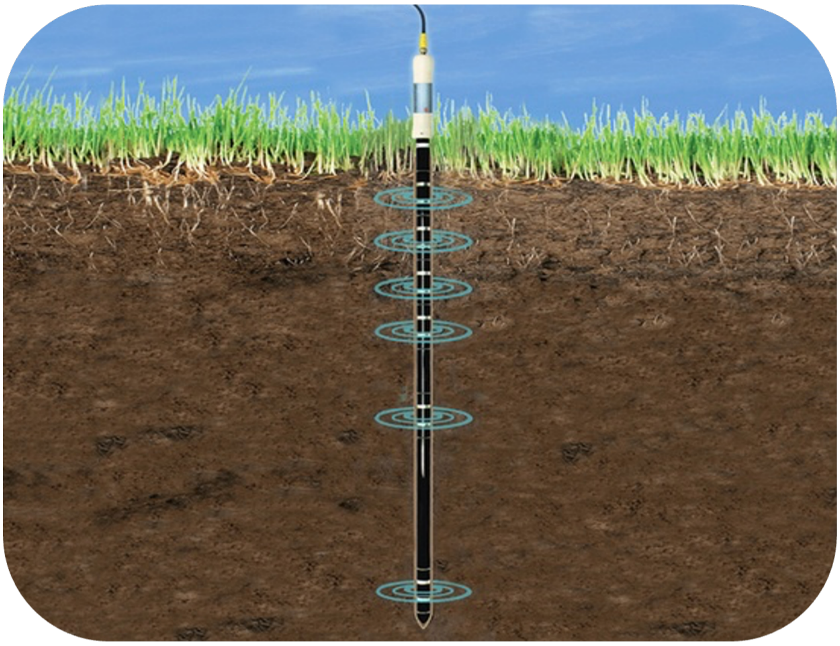
This technique is useful as an emergency measure for the subsistence of the crop in cases of having less water resources as a result of a drought. However, its application during many campaigns causes significant losses in productivity, so it cannot be prolonged for many years.

For lemons, it is possible to reduce water consumption by applying between 6,000 m^3/ha for normal irrigation and about 3,500–4,000 m^3/ha for RDI (up to 40%) even though production is slightly reduced.

b) Inclusion of technologies for monitoring soil moisture

By monitoring the water status of the soil with sensors, it is possible to monitor the status of soil moisture, finding out the 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.

Figure 3. Moisture sensor



Irrigation management using information obtained from these sensors makes it possible to reduce the amount of irrigation water used for citrus fruits by between 20% and 30%.

c) Laying plastic mulch on the soil

The use of mulch plastics on the soil in growing lines means a reduction in water losses 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% of water volumes (Intrigliolo DS, 2020).

Indirectly, the use of herbicides for weed control is reduced.

d) Covering irrigation ponds

Most of the farms have one or more irrigation ponds where the water is stored so that it can be available at the time of irrigation. 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 having covers means avoiding these losses.

e) Increasing the water retention capacity of the soil

Following regenerative agriculture practices for soil conservation prevents the loss of soil to erosion and favours an increase in organic matter. In this way, in addition to helping fix CO_2 in the soil, regenerative practices increase capacity for water retention and, therefore, greater availability of this resource for the plants, contributing to a more efficient use of water and reducing the volumes of water used.

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