Lemons and Water. Resilience to climate change

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0. The Segura River Basin

The waters of the Segura River Basin drain into the Segura River, which runs through the southeast of the Iberian Peninsula and empties into the Mediterranean Sea.

In this territory 34,000 hectares of lemons are cultivated (73% of the area where lemons are harvested in Spain). Of that area, 25,000 hectares lie in the Region of Murcia (73.5% of the basin's area for cultivating lemons).

Characteristics of the basin in relation to water:

- It is one of the driest areas in Spain.
- Irregular distribution of rainfall. Long periods of time without rain. Entails uncertainty in the availability of rainwater.
- Typically torrential rainfall patterns.

Figura 1. Segura River Basin Map

1. Sources of water in the River Basin. Guarantee of water availability

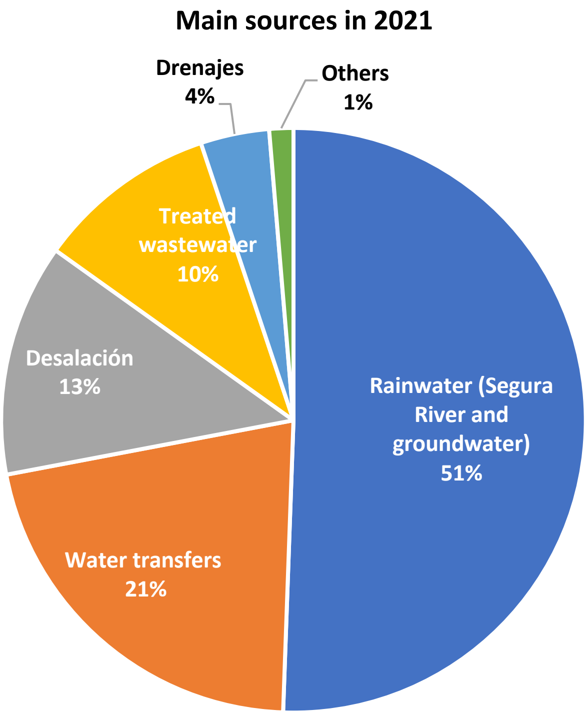
The following table shows the origin of the water resources available to the Segura River Basin.

Tabla 1. Resources of the Segura Basin according to origin (hm^3)

ORIGIN	2021 forecast
Rainwater (Segura River and groundwater)	759
Water transfers	322
Irrigation returns (drainages) (*)	57
Desalination	193
Treated wastewater	150
Other	20
TOTAL	**1,501**

(*)Drainages are the water used in irrigating crops not absorbed by the land or plants that returns to the system.

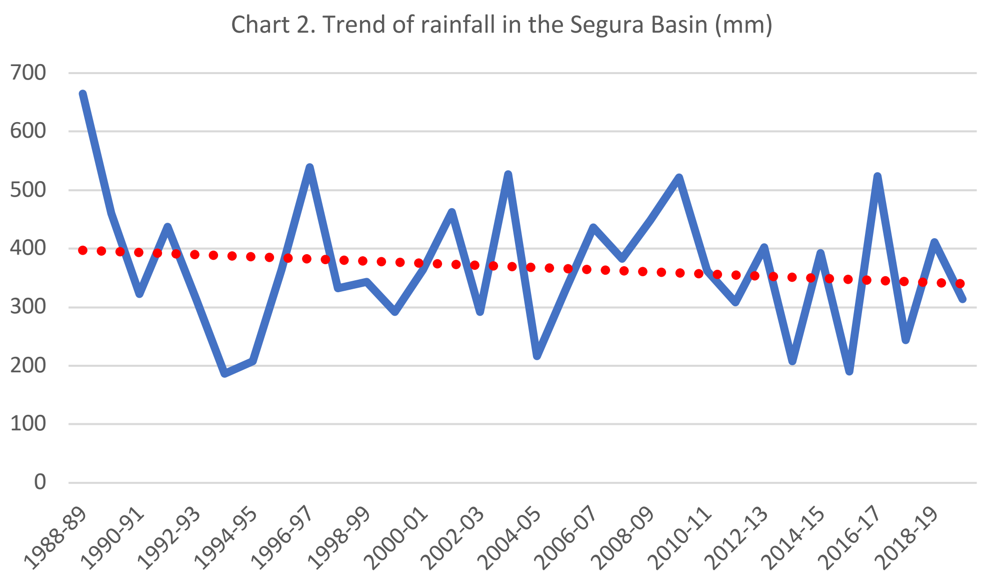
Source. Compiled using data from the Segura Hydrographic Confederation.



1.1 Rainwater. Rainfall patterns in the Segura River Basin

The average rainfall in the Segura River Basin is 370 mm per year and is usually torrential (a lot of water in a very short period of time). The pie chart shows that it is highly variable from one year to the next.

Due to this, it has a large water storage capacity in its reservoirs (1,140 hm^3) and water is available from other sources not subject to climatic variations (desalination).



Source. Compiled based on data from the Segura Hydrographic Confederation.

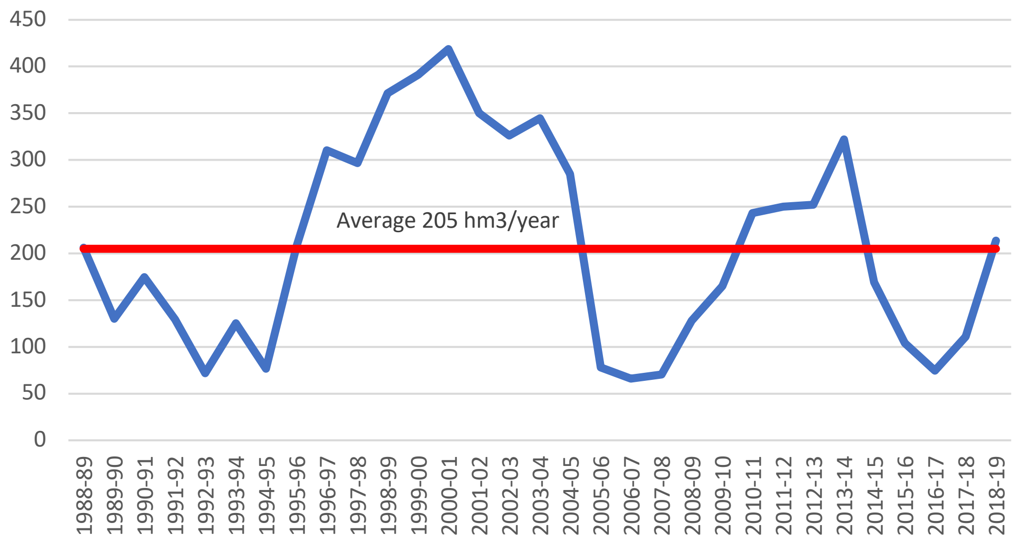
According to the above graph, rainfall has decreased slightly over the last 30 years. The Hydrographic Confederation estimates a 5% reduction in the contribution of water through rain compared to the average as a result of the effects of climate change.

1.2 Tajo-Segura Water Transfer

The average amount of water transferred to the basin from other rivers is 322 hm^3. Of this, the Tagus basin contributes 305 hm^3/year (205 hm^3 for irrigation and 100 hm^3 for human and industrial consumption). 17 hm^3/year are also transferred from the Negratín reservoir.

The following graph shows the trend of water being sent for irrigation from the Tagus River.

Chart 3. Trend of Tajo-Segura transfer of water for irrigation (hm3/year)



Source. Segura Hydrographic Confederation.

1.3 Reuse of treated wastewater

According to FAO, 10 percent of the world's surface area receives untreated or partially treated wastewater. Wastewater has proven to be a realistic option for unconventional water sources, providing more certainty that water will be available year-round, even during dry spells.

Wastewater in the world is projected to increase significantly with population growth and urbanisation. On average, high-income countries treat about 73 percent of their wastewater. The figure drops to 54 percent in upper-middle-income countries and 28 percent in lower-middle-income countries. Globally, about 80 percent of wastewater is discharged without being properly treated.

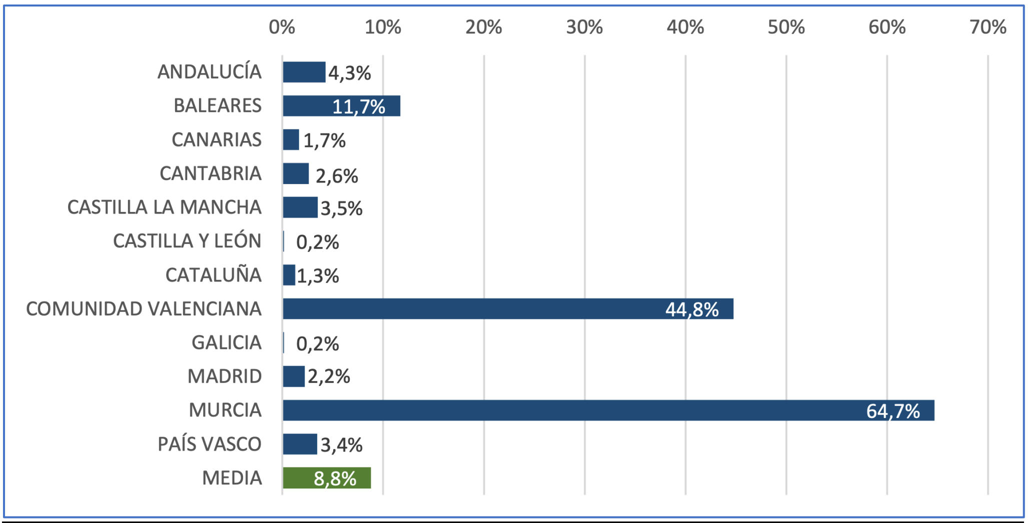
The global trend is that in the future more wastewater will be treated and its use for agricultural uses will increase.

In Spain, wastewater is used by strictly following the legal regulations for its use (Directive 91/271/EEC of 21 May on urban wastewater treatment and Royal Decree 1620/2007, of 7 December, laying down the legal regime for the reuse of treated water) that sets out:

- The basic conditions for reusing treated water.
- The water quality criteria for its reuse.

In Murcia 99.2% of wastewater is treated. Of this treated water, 64.7% was reused in 2017. It is consequently the leading region in Spain where the average use did not reach 9%. The Region of Murcia is therefore a trailblazer and exemplary in reusing treated wastewater both in Spain and in the world (see the following chart).

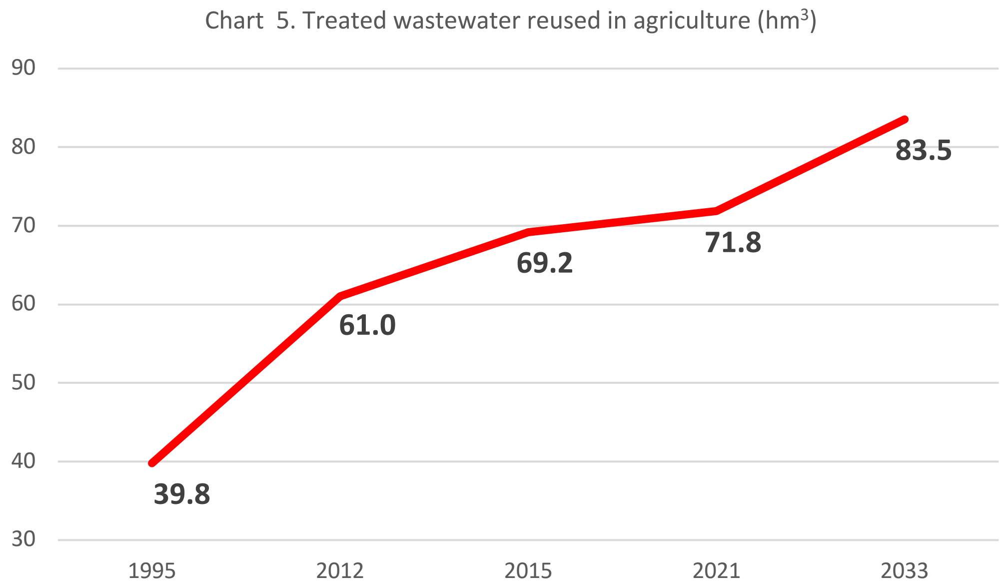
Chart 4. Percentage of wastewater reused by the total supplied by Autonomous Community.



Source. AEAS. 2017

Given the significant historical and socioeconomic importance of its irrigated agriculture in our Region, the reuse of treated water is considered an essential pillar for maintaining this sector.

The volume of treated wastewater used in agriculture in Murcia has grown significantly in recent years with 78% of treated wastewater currently being used in agriculture. As water consumption through human activity increases, so does the treated wastewater available for agriculture. Currently 70 hm^3/ year are used and the outlook is to have 83.5 hm^3 by 2033 (see the following chart)..



Source. Compiled based on data from the Segura Hydrographic Confederation.

With 70 hm^3 of residual water, 11,700 hectares of lemons can be irrigated (6,000 m^3/ha).

1.4 Desalinated water

Desalination is another attractive option to increase water supply.

The main advantage of water desalination is its condition as an inexhaustible water resource and not subject to climatic variations, which is why it is strategically ideal for systematically increasing the availability of water resources for agricultural irrigation in times when it is not possible to have enough water from rain.

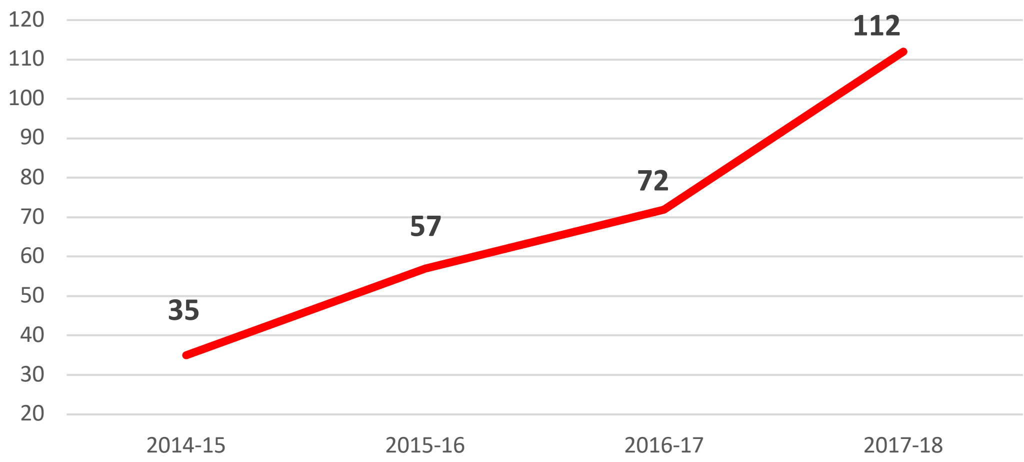
Worldwide there are around 16,000 desalination plants, which produce about 36,500 hm^3/year. The cost of desalination has always been the main obstacle limiting its application in agriculture. However, thanks to increased demand and technological advances, costs have been drastically reduced and will continue to do so.

Spain is one of the countries in the world that produces the most desalinated water. It currently ranks fourth only behind Saudi Arabia, the United States and the United Arab Emirates.

The annual production of desalinated water in Spain for supply, irrigation and industrial use reaches 1,825 hm^3/year. In the Segura Basin alone, 232 hm^3/year are produced (13% of the national total).

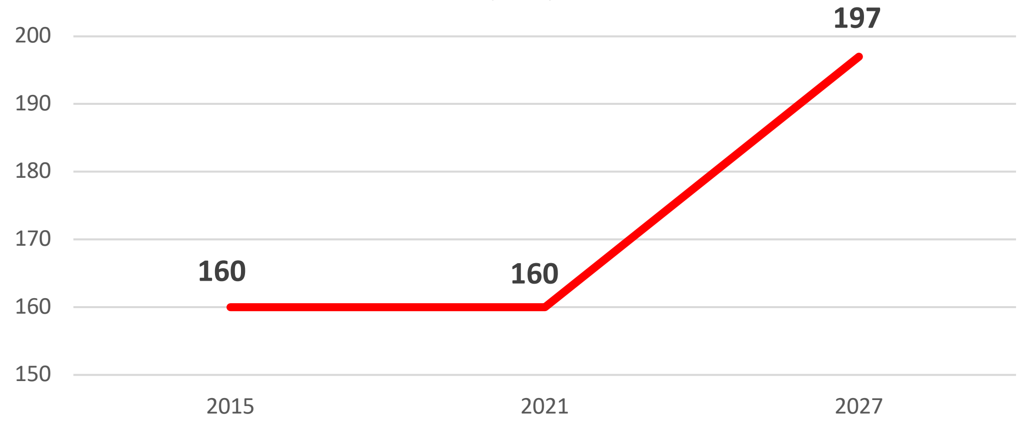
Our region is a benchmark in using desalinated water for agriculture.

Chart 6. Production of desalinated water for irrigation in the Segura Basin (Hm^3)



Source. Compiled based on data from the Segura Hydrographic Confederation

Chart 7. Potential of desalination for irrigation in the Segura Basin (Hm^3)



Source. Compiled based on data from the Segura Hydrographic Confederation

This desalination capacity will increase in the future. The forecast is that for 2027 it will be 197 hm^3/year for irrigation.

In the Segura basin, in years where the amount of water collected by rain or transferred contributions decrease, given that the potential for desalination is greater than the needs, there is the ability to desalinate a greater amount of water with the aim of guaranteeing the water needs of crops.

2. Water use in agriculture

The water needs in the Basin are 1,843 hm^3/year. In the case of agricultural activity, the demand is 1,546 hm^3/year (chsegura.es)

Lemon cultivation in the Segura Basin requires 197 hm^3 annually, 145 hm of which correspond to the Region of Murcia.

The origin of the water for irrigation is as follows:

- Rainwater (surface and underground).
- Water transfers from other rivers (Tajo and Negratín).
- Drainages.
- Treated wastewater.
- Desalination.

FAO indicates that strategies for enhancing water management, combined with best agronomic practices and improved varieties, are crucial in reducing the risks of water scarcity and achieving higher yields in agriculture to improve food security and nutrition, while helping to cope with climate change.

It also points out that investments in modernising irrigation are greater when there is high water stress since in that case, investments can have higher returns. The expected investment in drip irrigation is also higher in irrigation environments with high water stress.

This is the case of the Segura basin where, as a consequence of the irregular rainfall pattern, there is high water stress for crops, so the agricultural sector has had to innovate in reducing and optimising the available water as well as in the search for other resources, which has made us a national and global benchmark in localised irrigation and fertigation, use of treated wastewater and desalination.

That is why we are prepared to adapt to the effects that climate change may have on us in terms of the reduced water resources due to less rainfall.

2.1 Optimisation and reduction of water use for irrigation

Water consumption per hectare in Spain decreased from 8,250 m^3/ha to 6,500 m^3/ha between 1950 and 2007 (Soto M. et al, 2014).

The Region of Murcia is a model in the optimal use and management of water in local irrigation through the modernisation of the regional irrigable surface, which reaches 90 percent (García, J. 2014).

2.1.1 Effects of the improvement and modernisation of irrigation. Localised irrigation

At the distribution level.

Major investments in storage infrastructure and improvement of distribution facilities are leading to a significant reduction in water losses during transport to farms.

At the farm level. Localised irrigation.

In the Region of Murcia, 83% of the irrigated area uses localised irrigation systems. This system allows optimal adaptation of the dosage and distribution of water and the contribution of nutrients during all phases of the vegetative and production process, thus optimising the productivity of the water resource used (García, J. 2014) 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.

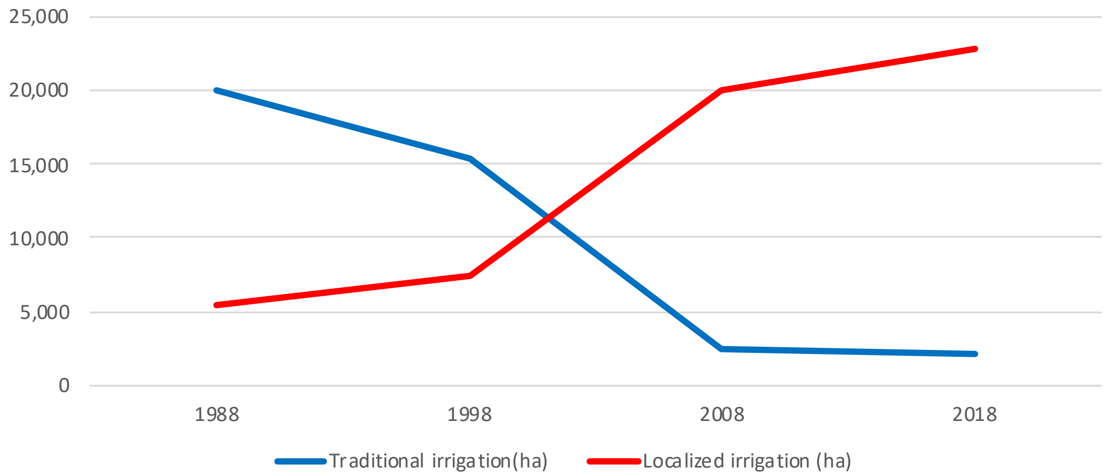
The surface area of lemons under localised irrigation in 2018 was 22,808 ha (91.9% of the total). In 1988 it was only 5,388 ha (increase of 323.3% in the last 30 years). The presence of small orchards and non-professional family farms prevents this figure from being higher.

Table 2. Trend of the localised irrigation surface area of lemons in the Region of Murcia.

Year	Lemon cultivation area (ha)	Traditional irrigation lemon area (ha)	Localised irrigation lemon area (ha)	% localised irrigation vs. total
1988	25,421	20,033	5,387	21.2%
1998	22,823	15,399	7,424	32.5%
2008	22,530	2,482	20,048	89.0%
2018	24,827	2,019	22,808	91.9%
Increase in the last 30 years			**17,420**	**323.3%**
Increase in the last 20 years			**15,384**	**207.2%**

Source. Compiled based on data from the Ministry of Water, Agriculture, Livestock, Fisheries and the Environment

Chart 8. Trend of the localised irrigation and traditional irrigation surface area of lemons in the Region of Murcia (ha)

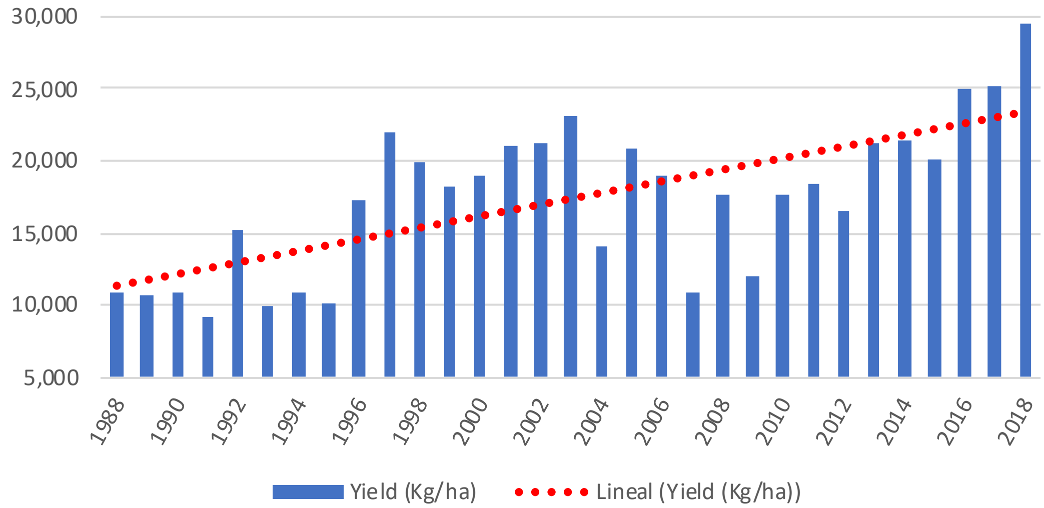


Source. Compiled based on data from the Ministry of Water, Agriculture, Livestock, Fisheries and the Environment

As shown in the following graph, the increase in the localised irrigation area has meant that, using the same amount of water, it has been possible to significantly increase the yields (production per hectare). In 1988 average yields were 10,814 Kg/ha while in 2018 they reached 29,588 Kg/ha (274% higher).

In 2018, 63% less water was needed to produce 1 kg of lemons than in 1988.

Chart 9. Lemon yield trend (Kg/ha)



Source. Compiled based on data from the Ministry of Water, Agriculture, Livestock, Fisheries and the Environment

As the following table shows, due to advances in localised irrigation and fertigation, production has increased by 167% in the last 30 years using similar volumes of water.

Table 3. Comparison of lemon production, area and yield in the Region of Murcia (2018 vs. 1988)

Year	1988	2018	2018 vs 1988 (%)
Lemon production (t)	248,150	664,157	167 %
Yield (kg/ha)	10,814	29,588	173 %
Total lemon area (ha)	25,421	24,827	-2.3 %
Lemon area in production (ha)	22,948	22,447	-2.2%

Source. Compiled based on data from the Ministry of Water, Agriculture, Livestock, Fisheries and the Environment

2.1.2 Innovations to reduce water consumption on farms.

a) Controlled deficit irrigation (CDI)

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).

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.

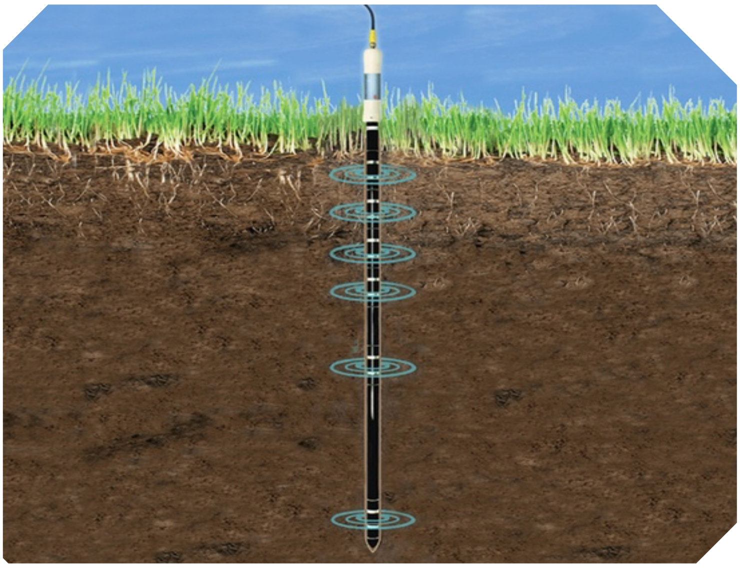
This technique is useful as an emergency measure for the subsistence of the crop in cases of having less water resources as a result of a drought. However, its application during many campaigns causes significant losses in productivity, so it cannot be prolonged for many years.

In lemons, it is possible to reduce water consumption by applying from 6,000 m^3/ha in normal irrigation to about 3,500-4,000 m^3/ha in CDI (up to 40%) although production is slightly reduced.

b) **Reduction in 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 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, the irrigation time and the intervals between watering can be adjusted to meet the demands of the plants without losing water or nutrients in depth.

Figure 2. Humidity probes



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

c) **Installing plastic mulch on the soil.**

The use of plastic mulch on the soil in growing lines entails 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) <u>Covering irrigation ponds.</u>

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.

3. Conclusions

In the Segura basin, rain is scarce and the distribution of rainfall is irregular.

The available water comes mainly from rain and water transfers. There are other sources that are essential for agricultural activity such as treated wastewater and desalinated water.

Murcia is a benchmark in reusing treated wastewater for agricultural irrigation. (Currently 70 hm^3/year).

Desalinated water makes it possible to have water resources when the contributions of rainwater and water transfers decrease, providing flexibility to the supply system. In 2018, 112 hm^3 of water were produced for agricultural irrigation. The production capacity for agriculture is 160 hm^3/year and will continue to increase in the coming years (outlook of 197 hm^3 by 2027).

Both reuse and desalination are systems that give greater certainty to the availability of water compared to other sources.

According to FAO, there is a need to improve water management and agricultural practices to reduce the risks of water scarcity and improve crop yields.

The agricultural sector in general and the lemon sector in particular have strived to optimise and reduce water consumption in recent years.

There has been a 268% increase in the area with localised irrigation in lemons over the last 30 years. These advances in irrigation and fertilisation have managed to increase the productivity of the lemon crop by 274%. Today 1 kg of lemon is produced using 63% less water than in 1988.

There are measures to considerably reduce water consumption on farms such as Controlled Deficit Irrigation or the use of soil moisture monitoring tools as well as others to avoid evaporation (plastic mulch and covering irrigation ponds).

In short, for years the lemon sector has been adapting to the lack of availability of water resources by relying on alternative water sources to those coming from rain (treated wastewater and desalinated water) as well as implementing technologies to reduce water consumption and avoid evaporation.

Therefore, we are prepared for a scenario of decreased rainfall as a consequence of climate change.

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