Chapter 22

The Canary Islands

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ABSTRACT: The volcanic Canary Islands, in the Atlantic Ocean, have the characteristics of small islands in an environment varying from sub-humid to arid, and quite different from one island to another and even within the same island. These conditions produce specific water availability circumstances to be solved in each of the islands, through island Water Councils. The two most important islands, Gran Canaria and Tenerife contain about 90% of the 2 million inhabitants. Intensive groundwater exploitation for more than a century, and especially in the last half century, has produced a deep change in groundwater flow, the drying up of springs and the depletion of aquifer reserves. This has given rise to a special culture of water winning and use. To solve water problems the progressive and decisive introduction of seawater and brackish water desalination has been a key element, and more recently of reclaimed wastewater, although gradually. This forms a complex system that includes private water markets and public water offers. About 50% of water is for irrigation, at prices that occasionally may reach or exceed 1 €/m^3. The up to now unsustainable situation has had the benefit of allowing the economic and social development from an agriculture-based economy toward tourism and services. Currently it is evolving toward a more balanced economy but with high water costs and some environmental, although bearable, damage.

Keywords: Canary Islands, intensive groundwater development, water cost, sustainability issues, water markets

1 INTRODUCTION

Water and its use have special characteristics in the Canary Islands when compared with the mainland. What is presented here is contained in diverse publications or is the result of the experience of the authors during several decades. References can be found in Cabrera *et al.* (2011) and in the respective websites of the seven Water Authorities [see *Consejo Insular de Aguas* of the respective island].

The Canary Islands (the Canaries) are a volcanic archipelago consisting of seven major islands and a few small isles and islets. They are located in the eastern Atlantic Ocean, between 27°37' and 29°25' North, and 13°20' and 18°10' West, in front of the Saharan coast of Africa. Along a length of 400 km from East to West, the islands are Lanzarote (LZ), Fuerteventura (FV), Gran Canaria (GC), Tenerife (TF), La Gomera (GO), La Palma (LP) and El Hierro (HI) (see Figure 1). The main geographical characteristics are shown in Table 1.

Mean gross income in 2005 was close to 36 M€ or 17,000 €/inhabitant. The economic activity and employment are respectively 78% and 86% in services (dominated by tourism), 20% and 11.5% in industry (dominated by construction), and 2% and 2.5% in agriculture, feedstock and fisheries. There are large variations from island to island. What is presented below refers mainly to GC and TF, the most active islands, although the arid LZ and FV have important tourism activities.

The Canary Islands are an Autonomous Community of Spain, with their own Government and Parliament, which are responsible for water resources and the environment. Spanish legislation applies, but incorporating specific rules. Each island has its own local government (*Cabildo*), with important administrative, social and economic functions. Hydrologically each island is a separate Water District of Spain (*Consejo Insular de Aguas* or Insular Water Council), under the coordination of a Canarian Water Directorate.

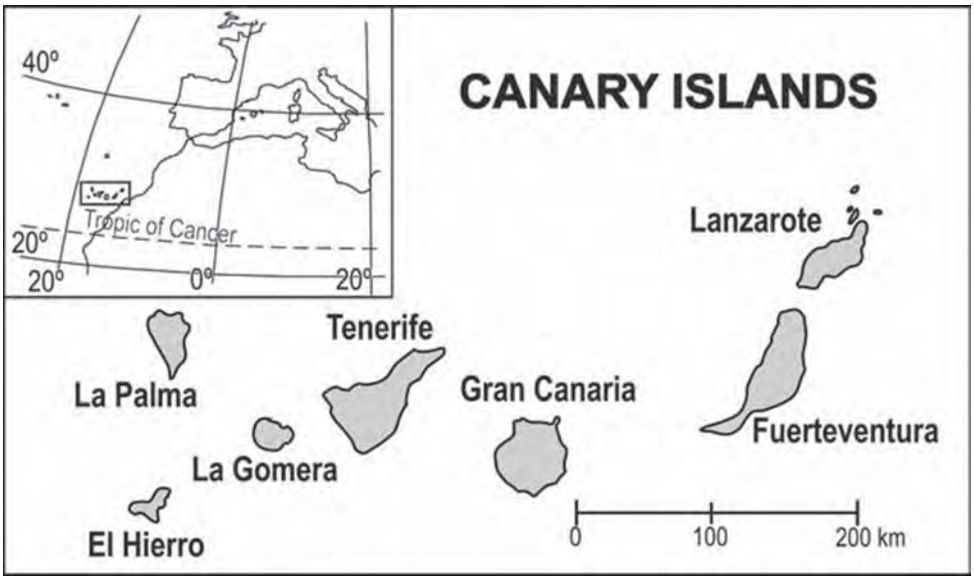

Figure 1 Situation of the Canary Islands.

Table 1 Basic data on the Canary Islands.

Island	*LZ*	*FV*	*GC*	*TF*	*GO*	*LP*	*HI*	*Total*
Surface area (km^2)	850	1,650	1,570	2,050	710	370	270	7,470
Maximum altitude (m)	670	807	1,954	3,718	2,426	1,484	1,501	
Inhabitants (thousands)	142	103	846	907	23	87	11	2,119

2 WATER RESOURCES

The Canaries are in the arid Saharan belt. In spite of this the temperature is mild since the sea is relatively cold due to an oceanic upwelling area under the influence of the humid north-easterly, mid-latitude trade winds. When the trade winds intersect the islands they are forced to ascend, producing an important increase in rainfall in the north-easterly areas of the high islands, while the coastal and southern areas remain dry but good for out-of-season irrigated intensive agricultural production. Only LZ and FV remain arid due to their relative low altitude.

Due to the relatively high permeability of the outcropping volcanic materials, surface runoff is limited to some intense rainfall events. Storage reservoirs cannot be constructed, except when old, low permeability, volcanic formations crop out in the deeply eroded areas of GC and GO. Actually GC has numerous dams higher than 15 m in a small space, but of small total capacity due to the highly sloping land.

From the hydrogeological point of view, the islands consist of a low permeability core, covered and surrounded by younger, more permeable, heterogeneous volcanic materials and some derived sediments. Circumstances vary from island to island and from site to site. Groundwater flows towards the coast, and on the way down, under original natural conditions, spring areas appeared and fed some permanent flows in some tracts of the deep gullies. Table 2 summarizes the hydrological data.

Groundwater is the most important natural water resource in the high islands. Besides direct channelling of spring water, where it is still available, groundwater is intensively developed through horizontal and vertical works. Horizontal works consist of tunnels (water galleries) to intersect the aquifer formations; they are more developed in TF. Vertical works are deep, large diameter wells (Canarian wells), excavated using mining technology. Both of them may contain secondary works, mainly water galleries and small diameter, long horizontal boreholes to increase the chance of intersecting permeable layers. More recently, deeply penetrating, mechanically drilled wells have been introduced for new emplacements or to deepen existing Canarian wells.

Seawater desalination was introduced in LZ in the early 1960s, and in the early 1970s in GC. This water is now commonly used for urban supply, but also for irrigation of some cash crops. In addition, brackish groundwater is freshened by means of reverse osmosis, mostly for crop irrigation in small, private facilities.

Reclamation of treated urban waste water for agricultural uses started in the late 1970s, but development has been slow due to high salinity and variable quality.

Table 2 Basic hydrological data.

Island	*LZ*	*FV*	*GC*	*TF*	*GO*	*LP*	*HI*	*Average*
Average precipitation, P (mm/year)								
maximum	250	200	950	1,000	900	1,400	700	
island weighted average	156	111	300	740	425	368	373	323
minimum	90	60	100	200	100	300	200	
Surface runoff, ES (mm/year)	2.5	8	19	25	45	51	27	29
Recharge, R (mm/year)	4	9	57	185	191	188	101	105

This is currently improving and salinity is sometimes reduced by reverse osmosis treatment.

Water galleries produce water continuously, so in low demand seasons it may be wasted to the sea. To reduce the wastage of groundwater reserves, in TF this water is purchased by the water authority and stored in artificial reservoirs to be sold and distributed in high demand moments. Also some bulkheads have been constructed inside water galleries to regulate the discharge when favourable conditions are found.

Table 3 shows water resources data, Table 4 their evolution and Table 5 the current water demand for the different uses.

Table 3 Average water resources in the 2000–2010 decade, when groundwater extraction started to decrease and the use of reserves was dwindling. Values in hm^3/year. [hm^3 = cubic hectometre = million m^3 = 10^6 m^3].

Island	*LZ*	*FV*	*GC*	*TF*	*GO*	*LP*	*HI*	*Total*
Total Water								
Precipitation	134	184	466	865	140	518	101	2,408
Surface runoff	1.3	5	75	20	8	1.5	0.6	111
Recharge	3.3	14.2	87	239	63	265	27	642
Available Resources								
Surface water	0.1	0.0	24	0.0	1.4	0	0	25
Groundwater	0.5	2	100	180	4.5	58	2.4	347 (*)
Springs	0	0.0	0.1	5	6.7	10	0	22
Seawater desalination	19	12	60	19	0	0	0.5	110
Brackish water desalination	0.5	2	18	0	0	0	0	20
Reuse	0	0	12	8	0	0	0.4	20

(*): A significant fraction comes from groundwater reserves depletion.

Table 4 Evolution of average water resources used in the archipelago, in hm^3/year.

Year	*1973*	*1978*	*1986*	*1991*	*1993*	*2000*	*2009*	*Current trend*
Groundwater	459	450	411	393	386	326	343	Decreasing
Surface water	25	19	20	21	21	25	27	Stable
Brackish water desalination	0	0	0	0	0	32	25	Stable
Seawater desalination	7	16	21	34	27	92	107	Growing
Reuse of urban waste water	0	0	0	0	0	21	19	Fluctuating
Total	491	485	452	448	444	496	516	Stable

Table 5 Water resources use in 2010.

Use	*Agriculture*	*Urban*	*Tourism*	*Recreation*	*Industry*	*Other*	*Total*
hm^3/year	232	171	54	19	15	2	493
%	47	35	11	3.6	3	0.4	100

3 WATER DEVELOPMENT FOR AGRICULTURE

In historical times, the inhabitants, some thousands, did not irrigate their crops. After the progressive incorporation of the islands in the Crown of Castille, between the late 15th century and the early 16th century, population and trade grew fast, thus creating a high demand for goods and crops. The new settlers obtained irrigation rights from the Spanish Crown to capture and use spring water. Descendants shared the rights and formed societies (*Heredades*). As well as irrigating staple crops and fruit trees, water was used to cultivate sugarcane to produce sugar to be exported.

This situation lasted, with slow evolution, until the mid-19th century. Then non-irrigated cacti were cultivated for dye production, until they were replaced by artificial production. At the turn of the century intensive banana cultivation was introduced, mostly to be consumed in the mainland, peaking in the 1960s, and from then out-of-season cultivation of tomatoes and vegetables to be exported was intensively introduced mostly in the sunny, dry areas. Flowers and exotic plants are third in importance for consumption in the mainland and for exportation, even if they use less than 1% of the cultivated land. This dramatically increased water demand. Since available water resources were not enough, from the late 19th century private societies were formed to develop further resources. This started with the construction of dams where this was possible (in GC), and by drilling long water galleries (mostly in TF), and afterwards through Canarian wells when pumping machinery was made available (mostly in GC). The capital resources were obtained by means of shares to be paid through a proportional fraction of the water and the benefits from selling the excess water. Farmers have also received for exploitation some public water works built with public water funds, as some reservoirs in GC.

Groundwater development was already important by the 1920s and continued to grow until the late 1970s, after which the total production of groundwater stabilized, although activities to extend wells and galleries and to drill new boreholes continued. Since year 2000, groundwater production has decreased, mostly due to the high cost, decreasing irrigated surface area, introduction of less water-demanding crops, and other water sources being made available. The number of galleries and wells is shown in Table 6. Crops have evolved from bananas in the northern slopes, mostly for consumption in mainland Spain, to vegetables under cover in the sunny southern areas, where they can be grown early in the year, when European markets demand them at competitive prices. Feedstock is of secondary importance.

Table 6 Current number of groundwater sources in use, in rounded up figures.

Island	*LZ*	*FV*	*GC*	*TF*	*GO*	*LP*	*HI*
Large springs remaining	0	0	0 (*)	0	10	10	0
Water galleries in use	1	0	10	425	2	150	3
Canarian wells and boreholes in use	10	30	1,190	170	10	75	10

(*): There were at least 15 large springs and 7 permanent streams before 1930.

4 EFFECTS OF INTENSIVE GROUNDWATER USE

The intensive use of groundwater, mostly for agriculture, has produced a continuous water level drawdown, and consequently the progressive decrease of spring flow. In fact, many springs disappeared decades ago. This is accompanied by the periodical need to deepen wells and water galleries, dramatically increasing the cost of water. Currently, in high water demand seasons, water prices go up and may approach -occasionally exceeding- those of desalted seawater.

Due to the abrupt relief and poor accessibility of many areas, environmental changes were not noticed by the population, in times of poor environmental sensitivity. Actually most people are not aware that environmental degradation happened decades ago. Only groundwater developers noticed it, especially those tapping spring flow. This was the origin of numerous complaints and legal suits, documented as early as the 19th century but especially in the early 20th century. The value of the lost natural resources is not known, nor the burden of pumping from increasingly deep water tables, despite the social benefits obtained.

Total groundwater exploitation does not exceed total recharge in any of the islands. However there is a continuous water-table drawdown resulting from hydrodynamic conditions. Since a large part of groundwater exploitation is at mid- and high elevation, a significant fraction of recharge continues to be discharged diffusely into the sea along the coast. Thus, a fraction of abstracted groundwater resources come from depletion of reserves. Theoretically, to get a large fraction of recharge the water table has further deepened, approaching sea level. This is unfeasible due to the vertical decrease of permeability, inadequacy of existing wells and galleries, loss of yield and water quality, and the enormous operation costs. Fortunately, in some cases the local aquifer structure may help in approaching sustainable results with less drawdown, a moderate abstraction decrease and the adequate emplacement of wells. To carry out effective plans, hydrogeological knowledge has to be greatly improved and groundwater users' communities are needed, as well as an adequate, accepted and updated water plan, carefully enforced by a committed water authority.

5 GROUNDWATER QUALITY RELATED TO AGRICULTURE

Groundwater quality is highly variable, from low mineral content in the high, rainy areas, to brackish in the dry parts, due to climatic aridity. Seawater intrusion affects limited areas. The excess of Na over Cl due to the weathering of volcanic materials is not a serious problem for freshwater in permeable soils. However, there are rather large areas, especially in TF, where the deep-seated $Na–HCO_3$ water cannot be used for irrigation without being blended with other water resources or after costly treatment. High F contents are found in some areas, especially in TF. There are no serious problems of high B content. Soils and groundwater have rather high natural P content.

Agriculture is predominantly practiced below 800 m altitude, and the most important irrigated cash crops are below 300 m. So, a large part of the islands' area is free of intensive agriculture-derived contamination. In the areas affected by irrigation return flows, mostly valley bottoms, coastal plains and terraced slopes, high NO_3 content can be found, with many points exceeding the 50 mg/L NO_3 threshold, up to several hundred mg/L in some areas.

The large desalination plants dispose the brine into the sea through outfalls reaching the shelf break. However the small private desalination plants using brackish groundwater, many of them for irrigation, are relatively far away from the coast, and thus brine disposal is an issue of concern. In FV, a pipeline system to collect and dispose of the brine from dispersed agricultural wells was constructed by the *Cabildo*, which also promoted the construction of the wells and the associated desalination plants. The correct operation and maintenance of such pipeline systems, where they exist, is not always guaranteed.

Agriculture is currently an important part of the landscape and land conservation in northern areas, in the mid-altitude wide valleys (*vegas*) and in the spectacular terraced sides of the steep slopes. There, irrigation is socially and environmentally important. The recent abandonment of some traditional banana crop areas has had a noticeable impact on the landscape, but probably this will be soon forgotten.

6 WATER MARKETS AND RELATED SOCIAL ISSUES

The development of water resources since the 15th century was carried out mainly by the *Heredades* and other private societies, mostly for crop irrigation, as mentioned before. After supplying the needs of the associated farmers, the excess water was sold to other farmers and to towns. When demand grew, shareholding societies were created to develop and sell new groundwater resources, mostly in GC and TF. Thus, informal water markets developed, but remained a poorly transparent, private affair. Several such markets are still active, although dwindling. In theory water markets should allow optimal access to water at the minimum price. In practice things are otherwise since markets are dominated by a few *water-holders* (*aguatenientes*) who set the prices among themselves and impose them on others. The transportation of purchased water from the producer's well or reservoir to the buyer's point of use is carried at a price by *brokers* (*intermediarios*) who own, share or rent the canals and pipes, often without alternative for the buyer. The *intermediario* often do not feel responsible for water losses or thefts during transportation, and the quality supplied may not be the same as that of the source. This is the origin of complaints, but there is no way to set them. Besides, there are markets for well and gallery shares, although these are in recession. The number of persons with water shares represents an important fraction of population, but really most of the shares are in a few hands. But this widespread popular participation in water affairs makes people aware of the value of water.

This system is imperfect and with some abuses, but it works and play an important role for mid-altitude agriculture and town supply, where other water sources are not available. Currently, conditions in some coastal areas of GC and TF may be different since the public water administration, mainly in TF, is offering water at low altitude under more controlled water quantity and quality conditions. This water comes from storage of low-priced water obtained out-of-season and from reclaimed water, sometimes with salinity reduction by blending or reverse osmosis treatment. This helps to moderate the excesses of private water markets and tame water prices.

Actually the cost of water in constant money units has been approximately stable during recent decades.

Prices paid for irrigation water in high-demand seasons may approach or exceed that of seawater desalination. Thus, only producers of highly competitive crops may afford them, or will use desalinated sea water if the plots are at low altitude. Currently a privately promoted desalination plant exists in Gáldar, northern GC, which constitutes a new kind of private water enterprise, which compete (jointly with public water offer) with groundwater. This explains the decrease in groundwater abstraction and the start of aquifer recovery in some areas.

7 ADMINISTRATIVE AND SOCIAL ISSUES

Due to the early intensive development of groundwater, which was not foreseen in the Water Act of 1876, and the large number of legal complaints related to water, the Spanish Government decided in 1924 to enforce a Special Water Regime for the Canaries, later modified in 1948. Water Services were created to administer the restrictions on private water development through the requirement for permits to carry out new works. The Water Act of 1985, which declared all waters to be a public domain, took into account the Canarian situation through a Canarian Water Act that follows the principles of Spanish law. To deal with the continuous use of groundwater reserves, the Canarian Government at the time enforced the regulation of not allowing any change in the characteristics of wells and galleries of those owners who decided to remain in the private domain without getting a public concession. This produced an intense and widespread negative reaction and precipitated the fall of that Canarian Government. The newly elected one modified this rule by considering that works needed to sustain the flow cannot be considered a change of the characteristics. This tamed the situation but not the already unsustainable groundwater reserves depletion rate. Current taming is coming through the increased cost of exploitation and the progressive decline of agriculture, at the expense of further deterioration and social damage, but allowing a smooth transition toward a new situation. The incorporation of the European Framework Directive through the Spanish Water Act has created new stress, but currently with little public reaction since the social situation is now very different.

8 CONCLUSIONS

The Canary Islands present very different hydrologic characteristics but share some common circumstances. Water is scarce and costly but sustains the local economy, which has evolved from agriculture to services, with important tourism activities. Most water development, especially groundwater, has been made by private owners, but currently public and private desalinization of seawater and brackish water is important. Groundwater development has been carried out at the expense of using part of the groundwater storage, with serious water-table drawdown and the drying out of springs during the 20th century, and the loss of natural resources, but with little public reaction. Water is expensive, but at a sustained price in constant money units.

The formerly unsustainable development of groundwater is now being tamed as new water resources become available, although they are energy-intensive.

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REFERENCE

Cabrera, M.C.; Jiménez, J. & Custodio, E. (eds) (2011). *El Conocimiento de los recursos hídricos en Canarias: cuatro décadas después del Proyecto SPA–15* [The knowledge of water resources in the Canaries: four decades after Project SPA–15]. Asociación Internacional de Hidrogeólogos–Grupo Español. Las Palmas de Gran Canaria, Spain.