

## **Human heritage and sustainable development on arid islands: the case of the Eastern Canary Islands**

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**ABSTRACT:** The islands of Lanzarote and Fuerteventura are the easternmost of the Canary Islands, and are located on the southern edge of the temperate zone, in the subtropical anticyclone belt. With less than 150 mm of rainfall a year, they are classified as an arid zone. Their inhabitants have devised original agricultural systems to combat the aridity, although low yields have historically limited socioeconomic development and population growth. These systems were used until the introduction of seawater desalination plants and the arrival of tourism in the last third of the 20<sup>th</sup> century, which improved living standards for the local population but also led to a cultural transition. Nevertheless, these farming systems have left behind an important regional heritage, with an environmental and scenic value that has played an integral role in the latest phase of development. The systems have become a tourist attraction and have been central to the two islands being designated biosphere reserves by UNESCO. This article seeks to analyze the main socioeconomic and land-use changes that have come about as a result of desalination technology.

*Keywords:* aridity, environment, Fuerteventura, landscape, Lanzarote, local heritage, small islands, socioeconomic development, tourism

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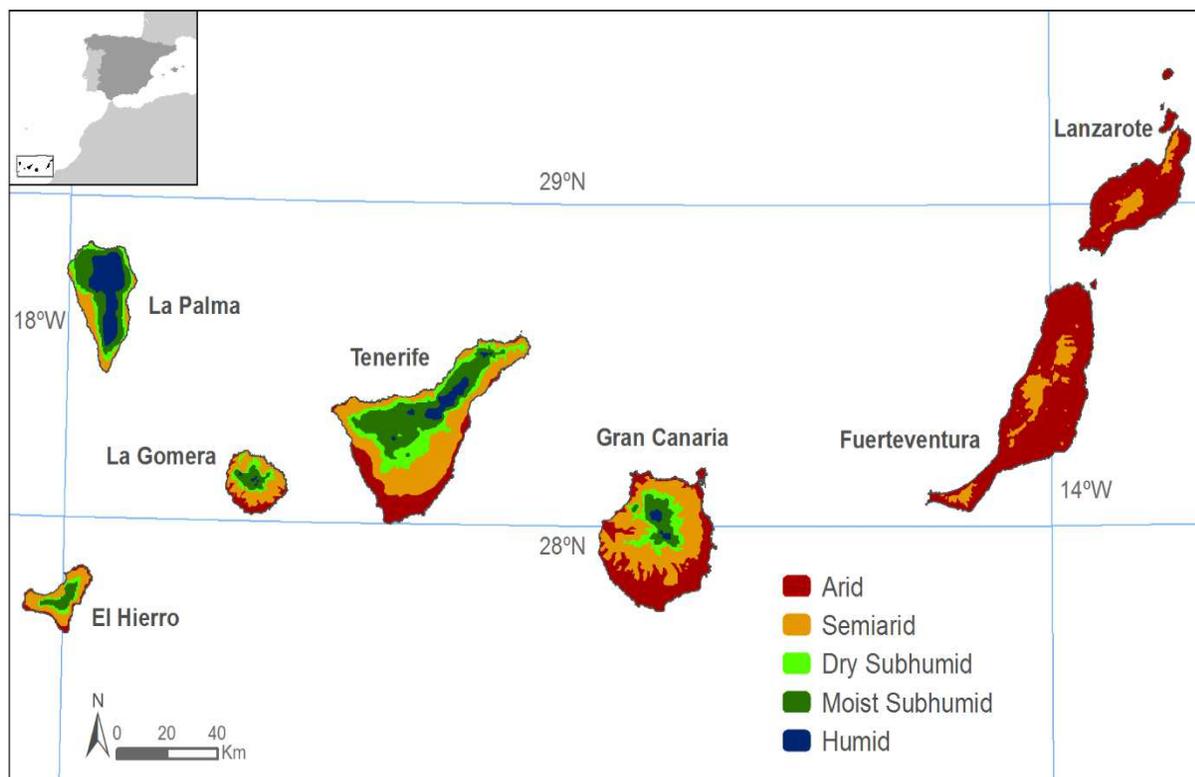
### **Introduction**

The Canary Islands are located on the eastern edge of the mid-Atlantic, at the southern limit of the temperate zone, with the Sahara Desert to the east. The islands lie in the path of the trade winds generated by the Azores High. Because of its subtropical location, the archipelago as a whole receives an average rainfall of 325 mm, although there is a marked difference in the amount of precipitation from one island to another due to their location, stretching over 500 km from west to east, in relation to the main rain-bearing northwesterly winds. Another factor is the different elevation and slope aspect of the islands' terrain. Due to these conditions, the highest average rainfall is recorded on the island of La Palma, which is the second highest island and is located at the northwestern edge of the archipelago, with an average precipitation

of around 740 mm; the lowest is recorded on Fuerteventura, located at the southeast end, and less than 100 km from the coast of Africa, with about 120 mm of precipitation; the average for Lanzarote is just 157 mm. These figures place these two eastern islands below the conventional desert threshold, the 250 mm isohyet, despite which both have been inhabited at least since the beginning of our era, as evidenced by various archaeological and documentary sources (Cabrera Pérez, Perera Betancor & Tejera Gaspar, 1999). However, historical studies of croplands on the islands suggest total rainfall has diminished over the centuries (Afonso Pérez, 1985).

The combination of these climatic factors in the interior of the islands results in a remarkable variety of landscapes and local climates, which has led tourism promoters to speak of “miniature continents” when referring to the climate of the Canary Islands. These factors, combined with other political and socioeconomic factors, meant that in 2014 the islands received nearly 12 million foreign visitors (MINETUR, 2015). Thus, and despite the modest size of the island region – a land area of 7,447 km<sup>2</sup> – climate combinations vary between arid, semi-arid, sub-humid and humid. Temperatures and average rainfall also vary, although the full diversity of local climates is only found on the more elevated islands: La Palma, Tenerife and Gran Canaria (Figure 1).

**Figure 1:** Map classifying aridity in the Canary Islands according to the Thornthwaite aridity index.



Source: Tejedor et al. (2013). Reproduced with the kind permission of the authors.

The lack of rainfall has limited socioeconomic development and population growth in the most arid areas of the region and on the two easternmost islands of the archipelago, particularly prior to the 1970s (García Rodríguez & Zapata Hernández, 1992). Because of this, their inhabitants have created original agricultural systems to combat the aridity, although crop yields have generally been low and food crises frequent, leading to constant emigration in the past. According to Zamora Cabrera's (2014, p. 2) retrospective study of Lanzarote in the 1950s,

... the easternmost island of the archipelago was then a lethargic, inhospitable place, marked by its peripheral status, its volcanic nature, the lack of basic resources such as water and a subsistence economy halfway between fishing and farming.

The situation was even worse in the case of Fuerteventura because of greater agricultural hardship and concentrated land ownership (Martín Ruiz & González Morales, 1985).

The Canary Islands are an archipelago of volcanic origin, consisting of seven relatively small islands and several islets. Their long evolution, stretching over 40 million years, is not associated with the opening of the Atlantic Ocean, as is the case of the Azores Islands; nor with the formation of the Atlas Mountains, in the northwest of the neighbouring continent of Africa (Carracedo, 1984). Rather, it is considered a separate process that began with the first submarine eruptions, which led to the creation of island structures on a pre-existing seabed, which today has an average depth of over 3,000 m.

Many theories have been put forward to explain the volcanic origin of the islands. One is the *hotspot* hypothesis, initially applied by Morgan (1971), Wilson (1973) and others to the Hawaiian Islands. Another is the *propagating fracture* hypothesis, proposed by Anguita and Hernán (1975) to explain volcanic eruptions on different islands within the same time periods, even the same historical periods. This fact is incompatible with the hotspot theory, which explains the general aging of the islands from west to east. Dating carried out by researchers since the 1960s has confirmed this temporal sequence (Abdel-Monem, Watkis & Gast, 1971), verifying that the eastern Canary Islands are the oldest of the archipelago. Despite their age, both islands have witnessed historical or sub-recent volcanism, covering older material with lava and basic pyroclasts. In the case of Lanzarote, this material dates back 19 million years, and 16.6 million years in the case of Fuerteventura. Due to their age, the eastern Canary Islands are the most denuded by erosion and have the lowest elevation, barely reaching 800 m in the highest ancient massifs of Jandía, despite recent volcanism. The geomorphological features of these islands, caused by repeated volcanic activity, the passage of time, low rainfall and agriculture, and the lack of water in their underground aquifers, resulting from the permeability of the volcanic material, have historically limited human settlement.

In these circumstances, the islanders used the soil of Fuerteventura to build *gavias*, water harvesting systems consisting of plots surrounded by low walls of compacted soil in order to increase the infiltration of episodic torrential rains that fall on the island and run down the slopes and ravines. In the case of Lanzarote, farmers used sea sand deposited on the beach of Famara and scattered by the wind through the interior of the island or the *lapilli* from volcanic eruptions to create *enarenados*. The *enarenado* technique covered cropland with these materials, which preserved the moisture from the rain and dew, and thereby improved crop yields or simply saved them from drought (Rodríguez Brito, 1986).

**Figure 2: Crops in Lanzarote growing in *enarenados* that use *lapilli* to preserve moisture.**



*Source:* Photograph taken by the authors in 2015.

Both these agricultural systems were used until the introduction of seawater desalination plants and the development of tourism in the 1970s. This gradually improved the living standards of the population, but at the same time led to the progressive decline of old farming practices, which produced little and had to compete with cheap imported produce. Yet, these ancient farming systems have left behind an important heritage, which has been put to use in recent times for its environmental and scenic value. These systems have become a major tourist attraction, particularly in Lanzarote, and have been central to the two islands being listed as biosphere reserves by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

This article offers a summative analysis of the major changes that have occurred on the arid islands of Lanzarote and Fuerteventura since the 1960s as a result of the introduction of seawater desalination plants. These modern facilities supplied the islands' thirsty towns and villages with drinking water for the first time, enabling these two eastern islands to participate in the development of mass tourism, already underway on the other islands, capitalizing on their favourable weather conditions and excellent beaches, as well as their unique natural and cultural landscapes. The development of this new activity has prompted unprecedented, and often poorly planned, urban and demographic growth and shifted the economy of the eastern islands towards construction and services. This economic conversion has led to the abandonment of traditional aridity farming practices and a marked improvement in living standards. But abandoning the land has ironically led to an awareness of its scenic and environmental value in the new development paradigm. The island governments are therefore making a considerable effort to rehabilitate and conserve their landscapes and to use them as promotional tools.

### **Aridity in the eastern Canary Islands**

The term ‘aridity’ is commonly used to characterize a region where rainwater and natural vegetation are scarce. Such are classified by various quantitative indexes which either correlate precipitation and average temperature or total rainfall and the potential evapotranspiration of existing plants, plotting out a kind of general water balance of the site in order to measure its environmental conditions for sustaining life. These varying classification criteria make cartographic delimitation of arid or desert spaces difficult in terms of their impact on animal or plant populations on a global and, above all, local scale. An example of local scale is the introduction of seawater desalination plants, intended to meet urban demand and tourism development in areas like the Canary Islands; these can change the ‘conventional’ limits of arid areas both for practical purposes and in the perception of the local population.

In practice, rather arbitrary precipitation thresholds, such as the 250 mm isohyet, are used to determine the extension of deserts, without accounting for evapotranspiration. The *Millennium Ecosystem Assessment of Spain* (EEME), promoted by the Ministry of Rural and Marine Environment to ascertain the conservation status of the country’s terrestrial and aquatic ecosystems, uses a similar approach to define arid zones in Spain: areas where annual rainfall does not exceed 300 mm. According to this criterion, arid zones occupy a reduced area of about 13,100 km<sup>2</sup>, or 2.6% of the total surface area of Spain. Of this area, 63% corresponds to the southeast Iberian Peninsula (around 8,200 km<sup>2</sup>), while the remaining 37% (about 4,900 km<sup>2</sup>) is located in the Canaries (Puigfàbregas Tomás, 2012, p. 155).

In this Atlantic archipelago, conditioned by the cold Canary Current, the area classified as arid by the EEME (2009) project represents 65.7% of the total area of the region. It is unevenly distributed amongst the different islands: the easternmost islands, Lanzarote and Fuerteventura, are considered to be totally arid; the least arid is the island of La Palma, the most northwestern, although nearly 15 percent of the island is arid. Thus, in the Canaries, aridity decreases from east to west, more specifically from southeast to northwest, in relation to the prevailing direction of the polar front that causes the climate disturbances that bear most of the precipitation that falls on the islands. But it also diminishes from south to north, particularly on the more elevated islands, as a result of the damp northeasterly trade winds.

The Thornthwaite index was applied to the various island spaces by the authors of the *Strategic plan to combat desertification in the Canary Islands* (Tejedor, Jiménez Mendoza, Díaz Peña, Rivero Ceballos, Corral Quintana & Legna Verna, 2013), to obtain this classification of aridity in the archipelago. It offers a more detailed and varied picture of the islands’ climate than that given by the Millennium Ecosystem Assessment of Spain, which is based solely on the selection of areas where precipitation is less than 300 mm. It is a classification system that therefore better reflects the diversity of ecosystems or agroclimatic zones that have been used in traditional agriculture to produce food in the archipelago, adapting farming techniques and crop varieties to local conditions. These farming customs have led to a unique agrarian culture, especially in the areas of greatest water shortage, where aridity farming (García Rodríguez, 2013, p. 126) is found. But these crops have declined dramatically in recent decades (Consejería de Agricultura, Ganadería, Pesca y Aguas, 2016); although highly original and practical agricultural systems are still conserved, such as *gavias* and *enarenados* in the eastern islands.

**Table 1: Areas classified according to the Thornthwaite aridity index, in km and %.**

Type	Arid (%)	Semi-arid (%)	Dry sub-humid (%)	Damp sub-humid (%)	Humid (%)	Total island area (km <sup>2</sup> )
<b>Lanzarote</b>	733.52 (86.8)	111.44 (13.2)	- -	- -	- -	845.96
<b>Fuerteventura</b>	1439.07 (86.60)	222.56 (13.40)	- -	- -	- -	1,659.74
<b>Gran Canaria</b>	578.87 (37.10)	666.19 (42.80)	150.81 (9.70)	144.13 (9.20)	18.25 (1.20)	1,560.10
<b>Tenerife</b>	321.07 (15.80)	779.76 (38.30)	329.19 (16.20)	519.44 (25.50)	85.50 (4.20)	2,034.38
<b>La Gomera</b>	62.20 (16.90)	190.33 (51.70)	50.00 (13.60)	62.00 (16.90)	3.38 (0.90)	369.76
<b>La Palma</b>	1.38 (0.20)	117.92 (16.70)	103.36 (16.90)	239.75 (33.90)	244.50 (34.60)	708.32
<b>El Hierro</b>	36.11 (13.50)	139.42 (52.0)	34.81 (13.0)	58.00 (21.60)	- -	268.71
<b>Total</b>	<b>3,172.85</b>	<b>2,227.62</b>	<b>668.17</b>	<b>1,023.32</b>	<b>351.63</b>	<b>7,446.95</b>

Source: Tejedor et al. (2013). *Estrategia de lucha contra la desertificación en Canarias*. Gobierno de Canarias.

**Table 2: Climate data from the Lanzarote Airport weather station.**

Year	Average humidity (%)	Rainfall (mm)	Days of rain	Average temperature (°C)
2000	81	47.1	46	20.8
2001	70	38	31	21.3
2002	65	59.7	56	21.5
2003	64.6	95	53	21.2
2004	60	147	60	21.6
2005	61.2	211.6	49	21.1
2006	61	117.1	56	21.4
2007	60.2	102.1	44	21.5
2008	63	98.2	48	21.8
2009	62.9	76.1	60	21.9
2010	65	124.3	58	22.4
2011	65	133.1	57	21.2
2012	63	61.3	42	21.9
2013	62.9	72.3	41	21.6
2014	68.5	182.6	59	21.8
2015	65.4	63.8	54	21.9

Source: Agencia Estatal de Meteorología, 2000-2015.

The areas considered arid according to the Thornthwaite aridity index occupy the coastline of all the islands (Figure 1); they add up to 3,172 km<sup>2</sup>, some 42.6% of the archipelago (Table 1).

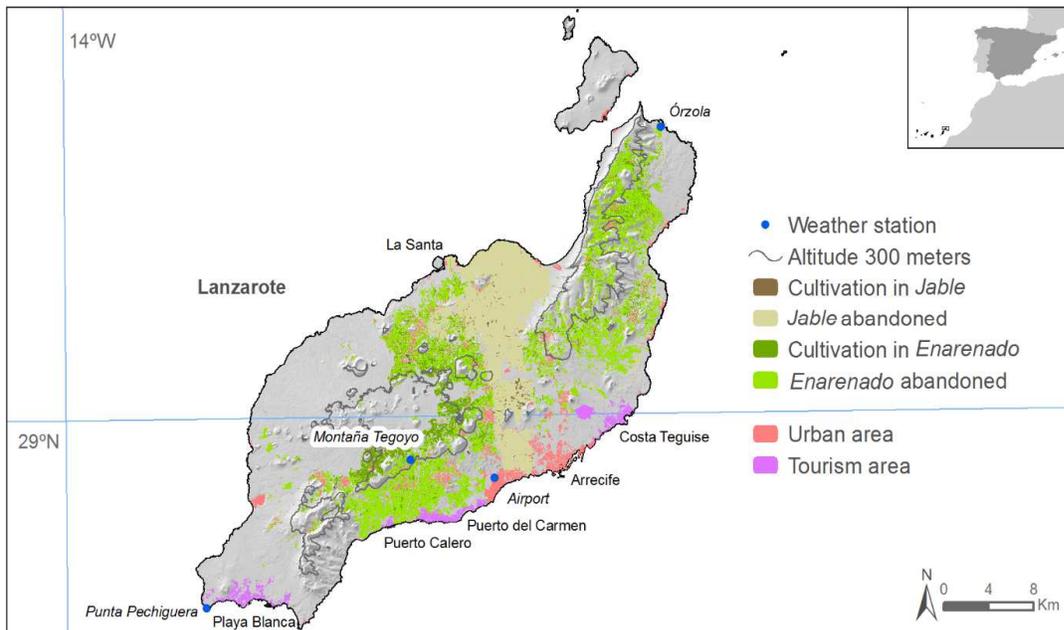
However, the differences between the islands are pronounced, with aridity increasing from west to east: from 0.2% in La Palma to 86.8% in Lanzarote and 86.6% in Fuerteventura.

Fuerteventura is the most arid island in the archipelago due to its southeast geographical position and low elevation. The El Matorral and Tefía weather stations, located respectively on the coast and in the interior of the island, produce readings that correspond to a desert climate (BSh according to the Köppen climate classification scheme), with an average temperature of over 18°C. The low, erratic precipitation in both cases falls in winter and is no more than 120 mm per year. Relative humidity is above 70% throughout the year and the average temperature does not exceed 24°C (González Morales, 1993, p. 586).

Lanzarote rainfall is similar to Fuerteventura, although there are contrasts relative to elevation and aspect. For example, Punta Pechiguera, on the coast of the southern tip of the island, receives 95.7 mm, while Órzola, on the north coast, receives 162.3 mm, and Tegoyo Mountain, located in the centre of the island, 370 m high, receives 275.6 mm (Reyes Betancort, León Arencibia, Wildpret de la Torre & Medina Pérez, 2000).

Those areas classified as semi-arid, where rainfall shortages are less pronounced, with average values between 250 and 500 mm (García Rodríguez; Hernández Hernández; Cabrera Armas & Díaz de la Paz, 1990, p. 42), are also found on all the islands, totalling 2,227.6 km<sup>2</sup>, which represents almost 30% of the total surface area. These areas are located on the coastline, especially on the outlying western islands, as well as on much of the mid-elevation vegetation belt, especially on the islands of Gran Canaria and Tenerife and the mountain ranges of Lanzarote and Fuerteventura (Figure 1).

**Figure 3: Location of weather stations and *enarenados* and *jables* on Lanzarote.**



Source: *Mapa de Cultivos de Lanzarote 2014*, Agencia Estatal de Meteorología y García Cruz, I (2013).

The semi-arid agri-environmental areas, together with the areas classified as arid from the climatic point of view, cover almost 5,400 km<sup>2</sup>: more than 72% of the total surface area, constituting most of the fragmented and diminished arable soil of the islands. The thermal

conditions are ideal for the development of a great variety of subtropical and temperate crops, as has been demonstrated by the rich agrarian history of the Canary Islands since the 16<sup>th</sup> century (Macías Hernández, 1996). But water and soil for agricultural purposes are scarce, given the recent formation of the islands and aggressive erosion processes.

### **Aridity farming systems on the eastern Canary Islands**

Volcanic soils are considered by soil scientists to be the most fertile in the world. But in many places with little overall rainfall, such as the Canary Islands, availability of water is a limiting factor for the development of agriculture. Because of this, farmers have, in the past, established various strategies to take advantage of available water for crops. In addition to directly using water from conventional and occasional rain, strategies have been designed that use runoff water and nutrients carried by it as it flows down the slopes and ravines when rain falls over a prolonged period of time. Use has even been made of the dew from atmospheric moisture that condenses in certain porous volcanic materials, such as pyroclasts, or *jables* as they are known locally, when the temperature drops at night (Rodríguez Brito, 1986, p. 27).

These agricultural practices in arid areas have led to the creation of farming systems of remarkable originality that take advantage of local materials, as in other dry areas in the world, and serve a double function: firstly, to harness scarce water resources, and secondly, to contribute to soil conservation, especially on slopes. Moreover, a unique island landscape of terraces, *nateros*, *gavias* and *enarenados* is created (Santamarta Cerezal & Suárez Moreno, 2012, p. 354): this is of immense agronomic and environmental, ethnographic and cultural interest for islands that subsist to a great extent on tourism.

In short, the remarkable diversity of climatic areas on the archipelago has led farmers to develop various strategies and crop systems in relation to the water and soil available at each location. In the case of the driest areas on the least steep terrains, with sufficient arable soil, *gavias* have been built to soak up rainwater; in minor ravines and gullies, *nateros* have been built, banking up the intermittent watercourse with successive walls to retain the fertile silt carried by the runoff water and thereby create plots; and finally, *in situ* or artificially deposited porous pyroclastic materials from volcanoes or sea sand scattered by the wind over arable land have been used to capture and better retain humidity through *enarenados* and *jables*.

These various techniques collectively represent an approach to farming in an arid environment, deemed to be sustainable from an environmental point of view (Rodríguez Brito, 1986; Sabaté Bel, 2012; Santamarta Cerezal & Suárez Moreno, 2012); although yields tend to be low. The originality of these traditional systems of land use and the healthy relationship between humans and nature have been recognized by international bodies such as UNESCO, which has declared the two eastern islands biosphere reserves.

*Gavias* and *nateros* are agricultural systems characteristic of arid and semi-arid regions, adaptations that make optimal use of rainwater. The former are found on flat or gently sloping sedimentary terrain on the islands of Lanzarote and, above all, Fuerteventura; *nateros* are found in the beds of the ravines on several islands, and are formed by sediments carried on runoff water that are retained by stone walls to bank up and create arable soil. There are methods similar to both of these systems found in the arid areas of northern Africa, southern Europe and America (Perdomo Molina, 2002; Perdomo Molina & Depuis, 2004; Santamarta Cerezal & Suárez Moreno, 2012).

In the Canary Islands, these systems have been considered to be pre-Hispanic hydraulic strategies, which would have been consolidated with the arrival of Europeans in the 16<sup>th</sup>

century (Cabrera Pérez et al., 1999, p. 143). Most of these systems are now abandoned, although they are important elements of agricultural heritage in need of rehabilitation and conservation since, as well as their unquestionable scenic, environmental and cultural value, they are agro-systems conducive to sustainable development (Santamarta Cerezal & Suárez Moreno, 2012, p. 360).

The introduction of *enarenados* as a dry farming method on the island of Lanzarote came about thanks to a combination of the actions of nature itself and the well-known observational powers of farmers. The Timanfaya historical eruptions of 1730 to 1735 and the subsequent 1820 eruption buried entire villages and wide swathes of cropland (León Hernández, 2006). After the disaster, however, the farmers must have noticed how the plants that had been half-buried in the *picón* had both survived and grown more vigorously than those left untouched by it. This was when the ‘natural *enarenado*’ was first created, and it must have been the inspiration behind the idea of digging through the layers of volcanic ash covering the former fields to uncover the buried fertile soil and then plant vineyards and figs.

The agricultural ‘discovery’ of the *enarenado* system transformed an arid and unproductive area affected by recent volcanic eruptions into an extraordinary landscape of thousands of funnel-shaped hollows called *gerias*, where mainly vineyards and some fruit trees, such as figs, are grown. The natural *enarenado*, formed in the volcanic surroundings of Timanfaya, subsequently spread to other areas of the island. The *picón* was transported from the mountains and unproductive areas to other parts of the island, where artificial *enarenados* were created, which ended up covering most of Lanzarote’s farmland with a layer of 15 or 20cm of the material, on which various varieties of vegetables and other crops were planted to supply the population and make the island self-sufficient. In some cases certain products have also been grown for export, such as onions in the sixties and seventies.

This laborious farming technique, akin to gardening and requiring abundant manpower on the small farms, made considerable agricultural productivity possible in traditional self-subsistence crops. This held true even in the case of water-intensive crops, like corn or sweet potatoes, despite dwindling and irregular rainfall on the island. These crops, along with fishing on the nearby Canary-Saharan bank, sustained the moderate population growth of Lanzarote for much of the 20<sup>th</sup> century.

Population growth on Lanzarote has been much higher, in the regional context, than on the equally arid island of Fuerteventura, whose population remained stagnant or even declined due to emigration during recurring periods of drought and famine over various decades (Roldán Verdejo, 1968, p. 7). The population of Fuerteventura depended for decades on austere dry farming of cereals, vegetables and some fruit trees that used the *gavia* and *natero* systems. It also had limited irrigated agriculture linked to local aquifers of brackish water and the low flow rates of water pumped from wells with windmills imported from Chicago in the 20<sup>th</sup> century. The traditional economy was complemented by extensive goat rearing that stripped the land of its natural vegetation. Grazing followed ancient sharecropping systems in medium to large holdings – in relative island terms – that belonged to non-local owners, who were ignorant of the permanent socioeconomic rigours endured by the island of Fuerteventura in the past (González Morales, 1989, pp. 29-30).

### **The agri-environmental role of traditional agricultural systems**

Arid and semi-arid regions are fragile environments (Pizarro Tapia, 1999, p. 1) and human activity can easily destroy their natural vegetation if it oversteps certain thresholds. When this

happens, erosion rapidly impoverishes the soil and the process of desertification begins. According to some geomorphological studies, an area of over 3,200 km<sup>2</sup> in the Canary Islands is affected by severe erosion, affecting 43 percent of the total area and producing a loss of over 12 tonnes of topsoil per hectare per year (Rodríguez, 2001).

In the case of Fuerteventura, roaming livestock have exerted and continue to exert significant pressure on the land, both on plant resources and the soil, which is resulting in gradual degradation. Grazing also has a negative impact on plant diversity, density and extent of soil cover. This pressure is one of the reasons for the absence of potential vegetation on practically all of Fuerteventura, which has been replaced by various succession plant communities, even generating landscapes devoid of vegetation, which may be classified as proper desert, as described in the *Strategy to combat desertification in the Canary Islands* (2013). Once the vegetation has disappeared, the soil is directly exposed to erosion. Moreover, the continuous trampling of the herds destroys the structure of the topsoil, making it much more susceptible to wind and water erosion (Tejedor et al., 2013, p. 34).

*Gavias* play a prominent role in the conservation of soil and water, according to the *strategy to combat desertification in the Canary Islands* (Tejedor et al., 2013), as they mitigate the effects of erosion and the salinization/sodification of the soil. They also contribute to the recharging of the aquifers and maintaining soil potential, among other factors that prevent or slow down the processes of desertification and land degradation. In areas covered by this system of *gavias*, the risk of soil erosion is closely related to their design and state of repair. When fully functional, they modify water conditions in the soil to the point that rain-fed agriculture becomes possible, since water becomes available to the plants during the winter and spring months. Conversely, in adjacent untended land and in abandoned *gavias*, where only rainwater falls, it is impossible to grow crops.

The additional water that a *gavia* receives has been calculated by the Hydrological Plan of Fuerteventura (*Plan Hidrológico de Fuerteventura*, 1999) to be around 200 mm, which, together with the rainfall averages, is responsible for the fact that rainfed crops may be harvested in these arid lands (Perdomo, 2002, p. 177). Furthermore, the *gavias* facilitate the natural renewal of the nutrients that keep the soil fertile enough to obtain yields commensurate with rainfed agriculture. This renewal is mainly due to the sediments transported by runoff water (Tejedor et al., 2013, p. 96).

Moreover, the pyroclastic layer of the *enarenados* substantially improves water conservation in the soil because of its influence on two main processes – infiltration and evaporation – thus optimizing scarce rainwater. According to the experiments conducted by researchers from the Department of Soil Science at the University of La Laguna, the moisture content of the soil covered by pyroclasts is three times higher than that of soil that is bare on the upper layers (Tejedor et al., 2013, p. 81). In addition, this pyroclast coverage carries out a protective function on the surface of the soil, intercepting the raindrops and dissipating their energy. This leads to a higher rate of water infiltration, and therefore reduced runoff and sediment loss. Similarly, the greater surface roughness of the *picón* also reduces the speed of runoff water (Tejedor et al., 2013, p. 86).

However, despite the undoubted environmental benefits of traditional farming systems, the *Strategy to combat desertification in the Canary Islands* (2013) notes that almost 82 percent of the surface of the archipelago is currently at risk of desertification. This risk does not, however, affect all islands equally, being at its maximum level on Lanzarote and Fuerteventura and only partial on La Palma because it only affects 31 percent of this island. To

address this problem, which is not only environmental but also social and affects development models, this document considers essential the joint involvement of various fields of knowledge and decision-making, such as the environment, agriculture, regional planning, education and the economy, among others. It concludes that the fight against desertification in the Canaries must undergo a major effort of coordination and integration.

### **Desalination plants, local heritage and tourism**

Since the 1970s, Lanzarote and Fuerteventura have progressively played a more active part in tourism development in the archipelago. Climate conditions hitherto considered negative, such as low rainfall, persistent wind and relative isolation have become fundamental pillars of the tourism development scheme that has been put into action on both islands in recent decades. They have also been aided by another invaluable regional resource, one that had little economic value in the past: the excellent beaches of the two eastern islands. This development of the tourism model has led to a dramatic increase in the number of visitors, which in the case of Lanzarote has grown from about 25,000 tourists in 1970 to over 2 million in 2014. Fuerteventura reached 1.8 million in the same year, having started with even smaller numbers (ISTAC, 2015). These data indicate that the Lanzarote and Fuerteventura tourism development model swiftly emulated the sector's growth dynamic on the islands of Tenerife and Gran Canaria, much like that of other international island destinations (Pons, 2014).

In this socioeconomic context of a reassessment of their own resources in the construction of the island territory, chronic water shortages were overcome with the installation of modest seawater desalination plants. Built in Lanzarote in 1964 and in Fuerteventura in 1970, these plants were public initiatives that, while they certainly consumed a significant amount of energy from oil, produced 2,500 m<sup>3</sup> and 2,000 m<sup>3</sup> of potable water per day, respectively, solving the problem of water shortage on both islands, a problem that had hitherto been alleviated by Navy tankers (Cabildo Insular de Fuerteventura, 2015).

The introduction of this powerful tool of development solved the problem of supplying water to the populations of the major tourist resorts that were being constructed. It has even enabled irrigation for some self-subsistence farming, found in the environs of many towns, in part of the Lanzarote *enarenados* and in the *gavias* of Fuerteventura. The rapid increase in water production in the eighties and nineties, facilitated by the introduction of the efficient technique of reverse osmosis, meant that, by 2014, 65,000 m<sup>3</sup> of water per day was being produced in Fuerteventura and more than 62,000 m<sup>3</sup> in Lanzarote, between public and private desalination plants (Gobierno de Canarias, 2015). It would seem that an answer has finally been found to a historical obstacle to the development of these islands: water shortage. The energy cost of desalination has been falling in line with technological advances, from 40 kWh per m<sup>3</sup> in the first evaporation plants of the 1970s, to 3 kWh per m<sup>3</sup> in today's most efficient reverse osmosis plants (Baltanás García, 2013).

### **The impact of seawater desalination**

The modest technological leap of seawater desalination in Lanzarote and Fuerteventura has led to a new approach to the use of land resources on these islands, with their arid subtropical climate and excellent beaches, on the periphery of the European Union, in a period of extraordinary growth in European demand for sun and beach holidays. This demand has been met by an increased supply in the form of investment in the building of accommodation of

different categories in the tourism sector. The result of this process of construction has been the creation, under the control of the regional planning authorities, of more than 71,000 hotel and non-hotel units in Lanzarote (the 1991 Lanzarote Island Land Use Plan blocked another 150,000 that had initially been planned), and some 67,000 units in Fuerteventura (Gobierno de Canarias, 2015). The new Fuerteventura Land Use Plan, pending final approval, proposes raising the ceiling to 115,000 tourist beds (León Hernández, 2015).

Meanwhile, construction of the infrastructure necessary for the operation of this new development scheme, such as roads, marinas and successive facility upgrades at the international airports of Lanzarote and Fuerteventura, has been completed over recent decades thanks to public and private investment. The socioeconomic and territorial impact of this process has been spectacular, transforming the limited, poor traditional farming and fishing model in Lanzarote and Fuerteventura into an urban economy based on construction and services (González Morales, Sobral García, Hernández Luis & Armengol Martín, 2012). It has transformed the aridity of the environment into a scenic and aesthetic asset, which now has a minimal impact on the daily lives of the local population, whose position in the regional and national context has improved considerably. However, their dependence on fossil fuels has been and continues to be very high, although the future of renewable energies on both islands looks to be very promising, judging by their high potential (Schallenberg Rodríguez, 2000, 2013; Calero, Carta, Padrón, 2007; Martin, Medina, Feijoo, 2011; Gonçalves, Martinho, Guedes, 2014; Schallenberg-Rodríguez, Notario-del-Pino, 2014; García del Vado, 2015).

Climate conditions have therefore gone from being considered the primary obstacle to the islands' development to becoming a singular factor of territorial differentiation and even a nature-based pull factor for European tourism. They have been used by the island authorities as an argument for inclusion by UNESCO of the two islands in the world catalogue of biosphere reserves. UNESCO valued the unique relationship established over centuries between humans and the arid environment. The aim now is to preserve the natural and human landscapes that were created in the past and to promote sustainable development, at least in socioeconomic planning, in the face of the overwhelming momentum of urbanization and unstoppable population growth (Lanzarote strategy in the biosphere, 1998; Lanzarote 2020 strategy for sustainable development, 2014).

On Lanzarote, the population has grown from about 41,000 in 1970 to about 142,000 in 2014, representing an increase of 345% in just four decades. In the case of Fuerteventura, growth has been even greater: the island's population has increased from 18,000 inhabitants to nearly 107,000, six times more than in 1970 (ISTAC, 2015). This represents a cumulative annual growth rate of 4.1%. In both cases, Spanish and EU immigration has contributed to this recent demographic spike. However, as these islands were sparsely populated in the past, especially Fuerteventura, they are still far behind the islands of Tenerife and Gran Canaria in terms of population density, despite this recent upward trend.

One of the most visible consequences of socioeconomic change in Fuerteventura has been the decline of croplands in recent decades, both on dry and irrigated farmland. As an example of this decline, the total area occupied by tomato cultivation decreased from 450 hectares in 1994 to only 33.3 hectares in 2014, according to official statistics from the Government of the Canary Islands (*Estadística Agraria de Canarias*). In the same period, the total cultivated area of the island fell from 710 hectares to 521.7 hectares, according to the same source (Consejería de Agricultura, Ganadería, Pesca y Aguas, 2016). Moreover, yields for new aridity crops, such as *Aloe vera* (L.) Burm.f., jojoba (*Simmondsia chinensis* (Link)

C.K. Schneid.) and henequen (*Agave fourcroydes* Lem), have not been very promising. According to the abovementioned document, this decline over recent decades has led to an estimated agricultural abandonment of nearly 86 km<sup>2</sup>. This equates to a reduction in farmland of 94.3 percent, the highest proportion in the archipelago, if we take the utilized agricultural area (UAA) on the island of Fuerteventura to include abandoned arable land and current farmland, as the Regional Ministry of Agriculture does in some of its statistics. At the same time, there has been a marked increase in the abundant goat livestock, part of which is stabled, and which has specialized in the production of cheese, with or without designation of origin, for the regional market. Applying the same criteria to the quantification of *enarenado* abandonment on the island of Lanzarote, the total surface area that is no longer farmed is about 18,000 hectares on a UAA of around 23,000 hectares, representing 78.1 percent of the total (*Mapa de Cultivos de Lanzarote*, 2014).

This considerable shrinking of the historical farmland of Fuerteventura has had an immediate impact on the unique *gavia* system, their abandonment causing a major environmental problem as nobody is maintaining the low retaining earth walls. As a result the process of erosion and soil loss during periods of heavy rain has increased rapidly, while also decreasing infiltration and aquifer recharge capacity in areas of cropland.

The island authorities soon became aware of the problem this posed to the island during a period of gradual reassessment of the landscape, due to tourism development. An environmental action plan was launched whose objectives were to combat soil erosion and facilitate the recharging of aquifers by maintaining the *gavia* systems, building 133 small dams in the channels of the gullies to force infiltration and replanting native vegetation in the areas most affected by agricultural abandonment and traditional overgrazing (Rodríguez Molina, 1990, p. 34).

Such mitigation measures have pushed back the deterioration impacting on the ancient farmland and the grazing areas for the herds of goats. It has also bolstered the general rehabilitation of some landscapes populated by succession plants, colonizing plant species resistant to the impact of humans and livestock. But this has not prevented, on much of the island, the encroachment of a bleak landscape with little human activity that is poor in natural vegetation; where it is possible to see the colours of bare ground, wind-swept rocky outcrops and undulating landforms eroded by the passing of time: the characteristic traces of geomorphological processes in arid areas (Criado Hernández, 1991).

### **Harnessing local resources**

The new territorial and environmental reality of Fuerteventura identifies it as a “quasi-natural” landscape endowed with excellent beaches and sparse population, which has been built in recent periods from the remnants of the past. It has served as the basis for the island and regional authorities to prepare their application for an Arid Zone National Park in the ‘wildest’ part of the island (Gallardo Campos, 2011): the westernmost strip. The objective of this project is to ensure the conservation of these landscapes and promote their use as a tourism pull factor on an island in an outermost region that is both developed and nearby for the European Union, and not in the distant heart of one of the great arid zones of the planet.

The most representative images of Lanzarote are those of volcanoes, lava fields (*malpaís*), *enarenados* and a multitude of hollows dug in the pyroclasts of La Geria in search of soil to plant vines. This labour has resulted in a unique combination of shapes and colours that make this agrarian landscape one of the island’s tourist attractions

(Martín Martín, 2000, p. 102). Thousands of tourists visit this emblematic landscape of the island every year. Its spectacular nature is due to the small semicircular walls of basalt stone, crowning the hollows where vines are grown. The trade winds that blow almost constantly across the island have made it necessary to build these windbreaks transversal to the direction of the wind to protect the vineyards. Because of its attractive landscape this place was classified as a natural park by Law 12/1987 of 19 June, the Declaration of Natural Spaces in the Canary Islands, and subsequently reclassified as a landscape protected by Law 12/1994, of 19 December, on Natural Areas of the Canary Islands.

**Figure 4: Crops grown in hollows between recent volcanic cones in La Geria, on the island of Lanzarote.**



*Source:* Photograph taken by the authors in 2015.

Due to this official classification, and faced with the possible abandonment of agricultural activity in this area because of its low profitability, the Lanzarote Island Council, along with town councils in the area, formed a consortium to coordinate the actions of local institutions to protect the agricultural landscape of La Geria and preserve traditional grape growing and wine production. They also aim to promote tourism with environmental and sustainability criteria, to help transfer resources from the tourism sector to farmers with which to finance the costly maintenance of this unique protected landscape (Cabildo Insular de Lanzarote, 2016).

## **Conclusion**

The introduction of seawater desalination plants on Lanzarote and Fuerteventura in the late 20<sup>th</sup> century has led to major economic changes based on tourism development and the construction and services sectors. This shift has resulted in a notable process of urbanization, significant cultural changes that require further study, and high population growth, driven

mainly by Spanish and European immigration. It has caused a considerable leap in living standards of the island populations, bringing them in line with other regions of Spain.

As a result, in the case of Fuerteventura, there has been an almost complete abandonment of the austere and uncertain traditional rain-fed agriculture, linked to the *gavias* and small wells of brackish water. Even promising vegetable crops for export have been neglected, unable to compete in external markets. In the case of Lanzarote, the decline in cropland has been more gradual and less pronounced, taking into account the relative inertia of the 'extensive' island vineyards and the introduction of irrigation in some internal market-oriented crops.

The abandonment of most of the traditional farmland has affected the islands' unique landscape and has increased erosion and loss of topsoil, especially on Fuerteventura, which lacks the protective coverage that the Lanzarote *enarenados* supply, although a growing portion of these have also been abandoned in recent decades. The problems of environmental degradation have forced the authorities to intervene in the rehabilitation of *gavias* and dams and the conservation of *enarenados* to fight erosion, help recharge aquifers and facilitate the partial replacement of natural vegetation. In this territory, the relationship between humans and the environment has become more aloof, despite the recent inclusion of the two eastern islands in the world network of biosphere reserves.

New development schemes for the eastern islands have re-valued their local heritage as a highly significant resource in the positioning of tourism. For this reason, interest in preserving traditional agricultural landscapes, the *gavias* and the *enarenados*, and elements of traditional architecture, has spread beyond culture to the economy, especially on Lanzarote.

The energy cost of seawater desalination is high, presently about 3 kWh per m<sup>3</sup>, but it has been supported in part by the State, so it is not a burden for the new development scheme on both islands, especially given the favourable conditions of the remaining production costs, including labour. Moreover, renewable energies seek to replace conventional energies in the near future, as is already happening in the desalination sector on Fuerteventura (CAAF, 2015). This successful demonstration of how desalination and renewable energy technologies can improve natural conditions in an arid region, traditionally limited in its socioeconomic development, is a beacon of hope for other island or mainland regions with similar climate conditions and with access to inexhaustible seawater. All that needs to be done is to provide these regions with access to these technologies under favourable conditions.

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