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EXPLORING RESOURCES

ON CULTURAL, SPATIAL AND TEMPORAL DIMENSIONS OF RESOURCECULTURES

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Content

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Water Scarcity at Sea

Historical and Archaeological Perspectives on the Preservation of Freshwater on Volcanic Islands

Keywords: hydrological resources, water stress, water scarcity, island studies, historical water systems, Mediterranean archaeology

We never know the worth of water,
till the well is dry.
Thomas Fuller (Gnomologia, 1732)

Summary

The aim of this study is to investigate from archaeological and historical perspectives how the resource water shaped the tangible and intangible world of certain island communities. Employing the academic framework of SFB 1070 RESOURCECULTURES, the historical water landscapes and architecture of two small volcanic islands, Tenerife, Spain, and Pantelleria, Italy, have been selected for analysis. Both islands display: a lack of lakes and rivers, limited or brackish groundwater, aquifers polluted with volcanic gasses, insufficient precipitation, and high rates of evaporation. The preliminary results of this pilot study show that these islands in the Mediterranean Sea and the Atlantic Ocean had some similar societal, religious, and cultural adaptations to the inherent limitations of their volcanic foundations. During both the Punic-Roman and the Spanish period, settlement locations, knowledge of weather, religious traditions and sanctuaries evolved from islanders' dependence on carefully collecting and preserving water from fog, rain, and springs.

Zusammenfassung

Ziel dieser Studie ist es, aus archäologischer und historischer Perspektive zu untersuchen, wie die Ressource Wasser die materielle und immaterielle Welt bestimmter Inselgemeinschaften geformt hat. Hierzu wurden die historischen Wasserlandschaften und die Architekturen der beiden kleinen Vulkaninseln, Teneriffa (Spanien) und Pantelleria (Italien), für die Analyse unter Verwendung des wissenschaftlichen Rahmens des SFB 1070 RESSOURCENKULTUREN ausgewählt. Beide Inseln haben kaum Seen oder Flüsse und verfügen nur über begrenztes, mit vulkanischen Gasen kontaminiertes oder brackiges Grundwasser sowie unzureichende Niederschläge in Verbindung mit hohen Verdunstungsraten. Die vorläufigen Ergebnisse dieser Pilotstudie zeigen, dass diese Inseln im Mittelmeer und im Atlantischen Ozean einige ähnliche gesellschaftliche, religiöse und kulturelle Anpassungen an die inhärenten Grenzen ihrer vulkanischen Grundlagen aufweisen. Sowohl während der punisch-römischen als auch während der spanischen Periode entwickelten sich Siedlungsstandorte, Wetterkenntnisse, religiöse Traditionen und Heiligtümer aus der Abhängigkeit der Inselbewohner von der sorgfältigen Sammlung und Konservierung von Wasser aus Nebel, Regen und Quellen.

Introduction

Current-day engineers have received prominent accolades for the reimplementation of historical water systems.[1] Looking backwards in time to inform current-day water scarcity debates have proven to be more relevant than it appears at first glance. Archaeologists and historians have long collaborated to uncover together a better understanding of the interaction between human beings and their natural environments. Insight from interdisciplinary approaches has put forward additional postulates on societal resilience, pre-modern networks, migration, and cultural adaptations to adversity. Scholars have recognised a need for further interdisciplinary studies relevant to current day questions, including historical responses to climate and environmental changes. The aim of this study is to investigate from archaeological and historical perspectives how the resource water shaped the tangible and intangible world of two island communities, Tenerife, Spain, and Pantelleria, Italy. We work within the academic framework of SFB 1070 ResourceCultures, which analyses resources together with the people, knowledge, technologies, and societal circumstances which make the use of resources possible (Bartelheim et al. 2015; Teuber/Schweizer 2020).

Water as a Resource for Volcanic Islands

The Resource Water

Beyond the two litres of water per day necessary for human survival, each additional drop of water used is culturally defined (World Health Organization 2004, 5). As one of the only naturally occurring resources that falls from the sky, civilisations over centuries have oriented their agricultural activities to the amount of available water (Bartelheim/Montero Ruíz 2009) and created religious practices involving water (Bradley 2017; Fagan 2011; Tvedt 2015; 2016). Archaeological and written sources since antiquity show a highly differentiated knowledge of water as a resource, distinguishing between different types of water (spring water, groundwater, rainwater) and how to handle them specifically (Schmölder-Veit 2009, 15–20). The Roman architect Vitruvius stated that water 'is of infinite utility to us, not only as affording drink, but for a great number of purposes in life; and it is furnished to us gratuitously'.[2] In the corpus of texts ascribed to Hippocrates, rainwater is described as the lightest, sweetest, finest and clearest water, as the sun draws the finest and lightest from water. At the same time, the storage of rainwater was seen by Hippocrates as particularly problematic; it decays quickly and acquires a putrid smell, as it is combined from mixed water sources, so it quickly becomes impure (Hipp., de aere, 8, 1–4; see Schmölder-Veit 2009, 163).[3] Specialised literature on hydraulic engineering dating back to the Roman Late Republican period gives detailed instructions on how rainwater can be used and stored: 'If no running water is available, cisterns should be built undercover and a reservoir in the open, the one for the use of people and the other for cattle.'[4] How water quality can be improved is also described. Vitruvius, for example, advises: 'If such constructions are in two compartments or in three so as to ensure clearing by changing from one to another, they will make the water much more wholesome and sweeter to use. For it will become more limpid, and keep its taste

1 For example, the Parque Natural del Marjal del Pego-Oliva in Alicante, Spain has been implemented with much success following a technology used hundreds of years earlier, designed by Muslim engineers living on the Iberian Peninsula (during the Muslim Califate in Spain, 711–1492 AD), where large cisterns in the form of a water park are used to contain flood water that can then be used during times of drought. The water containment also prevents the intrusion of pollutants into the water supply. During most of the year, the cistern parks serve also as a place of recreation and nature park for local residents. The project has received several awards, including one from the Ministry of Agriculture and Environment of Spain.

2 Vitr. 8, 1, 1: *[Aqua] est enim maxime necessaria et ad vitam et ad delectiones et ad usum cotidianum.*

3 See also Pliny n.h. 31, 33–34, who prefers water from wells instead of rainwater, because: *inficiatur halitu terrae, quo fit ut pluviae aquae sordium plurimum inesse sentiatur citissimeque ideo calefiat aqua pluvial* (33).

4 Varro, De re rustica 1, 11, 2: *Si omnio aqua non est viva, cisternae faciendae sub tectis et lacus sub dio, ex altero loco ut homines, ex altero ut pecus uti possit* (transl. Hooper/Ash 1934). See also Vitruvius 8, 6, 14: *sin autem loca dura erunt aut nimium venae penitus fuerint, tunc signinis operibus ex tectis aut superioribus locis excipiendae sunt copiae,* or Columella 1, 5, 2: *Haec quoque si deficiet et spes artior aquae manantis coegerit, vastae cisternae hominibus piscinaeque pecori struantur; quae tamen pluvialis aqua salubritati corporis est accommodatissima, sed ea sic habetur eximia, si fictilibus tubis in contectam cisternam deducitur.*

without any smell, if the mud has somewhere to settle'.[5] Thus, there is a long archaeological and historical record of sources to provide insight into how limited freshwater resources have been managed over many centuries.

When analysing the past role of water in societies, it is valuable to use the academic framework of SFB 1070, which considers the role of resources in communities as part of larger Resource-Complexes, that is the aggregate of things needed to access and make use of a given resource (see also Teuber/Schweizer 2020). The Resource-Complex of water includes not only a source of water, but also a means of conveyance and a distribution method for access. The permanent conveyance and distribution of water often require an infrastructure of architecture, technology, and knowledge. Who receives the quickest, cleanest, and largest amount of freshwater is often related to the power structures of the specific territorial unit (on water and power, see: Förster/Bauch 2014). Thus, the total amount of water in existence is never the total amount of water available for use.

The ResourceComplex of water makes it apparent that a lack of water is an economically, socially, and culturally defined amount that varies from location to location. In this regard, also the deficit of water needs to be defined more closely. According to the Corporate Water Disclosure Guidelines, developed in the framework of the UN Global Compact, one can distinguish between 'water scarcity' and 'water stress' (Schulte 2014). 'Water scarcity' refers to a volumetric lack of water supplies, typically calculated as a ratio of the human water consumption to an available water supply in a defined area. Thus, water scarcity is a physical and objective calculation that can be measured consistently across regions and over time. In contrast, 'water stress' refers to the subjective inability to meet human, animal, and environmental demands for water. 'Compared to scarcity, 'water stress' is a more inclusive and broader concept. It considers several physical aspects related to water resources, including water scarcity, but also water quality, environmental flows, and the accessibility of water' (Schulte 2014).

Water stress is a timeless phenomenon and manifold examples from past societies detail historical problems of water supplies, especially in connection with settlements and agricultural yields, as well as with how conflicts and territorial divisions were resolved through water infrastructures, treatises, and agreements. This contribution examines two small volcanic islands as locations especially affected by water stress.

Small Islands as Model Cases

In a study of ancient water harvesting techniques, Beckers et al. (2012/2013, 145) divide the natural water sources 'into those which are generated in humid regions or inherited from weather climate periods (allogenic) and those which are locally generated (autogenic)'. In mainland contexts, waters from allogenic sources which have their origins in humid areas passing through drylands (like the Nile in Egypt) or being directed artificially to a destination area, such as via aqueducts, play a crucial role for the water supply. Islands, in contrast, at least in pre-modern periods, depended totally on autogenic water sources like rainfall, local runoff or groundwater.[6] The isolated environment makes islands model cases to study how past societies dealt with water stress.

Two small volcanic islands have been selected for analysis in this chapter for several main reasons. First, small volcanic islands often lack freshwater resources.[7] Despite being surrounded 360 degrees by water, volcanic islands from antiquity

5 Vitruvius 8, 6, 15: *ea autem si dublica aut triplica facta fuerint, uti percolationibus transmutari possint, multo salubriorem et suaviorem aquae usum efficient; limus enim cum habuerit, quo subsidat, limpidior fiet et sine odoribus conservabit saporem* (transl. Morgan 1914). See also Pliny n.h. 36, 173, Frontinus 91–93.

6 See Falkland 1991 for the hydrology and water resources of small islands and Viola et al. 2014 for 'The State of Water Resources in Major Mediterranean Islands'; for water scarcity and stress on islands see e.g. Aubriet 1992; Lange/Donta 2006 and Donta/Lange 2008 for the Mediterranean Islands; Birdi 1997 for the Maltese Archipelago; Tsanis et al. 2011 for Crete or Sofroniou/Bishop 2014 for Cyprus.

7 See Santamarta et al. 2014 for an 'Introduction to Hydrology of Volcanic Islands' focusing on the Canary Islands; see Antunes/Carvalho 2018 for the Azorean Islands.

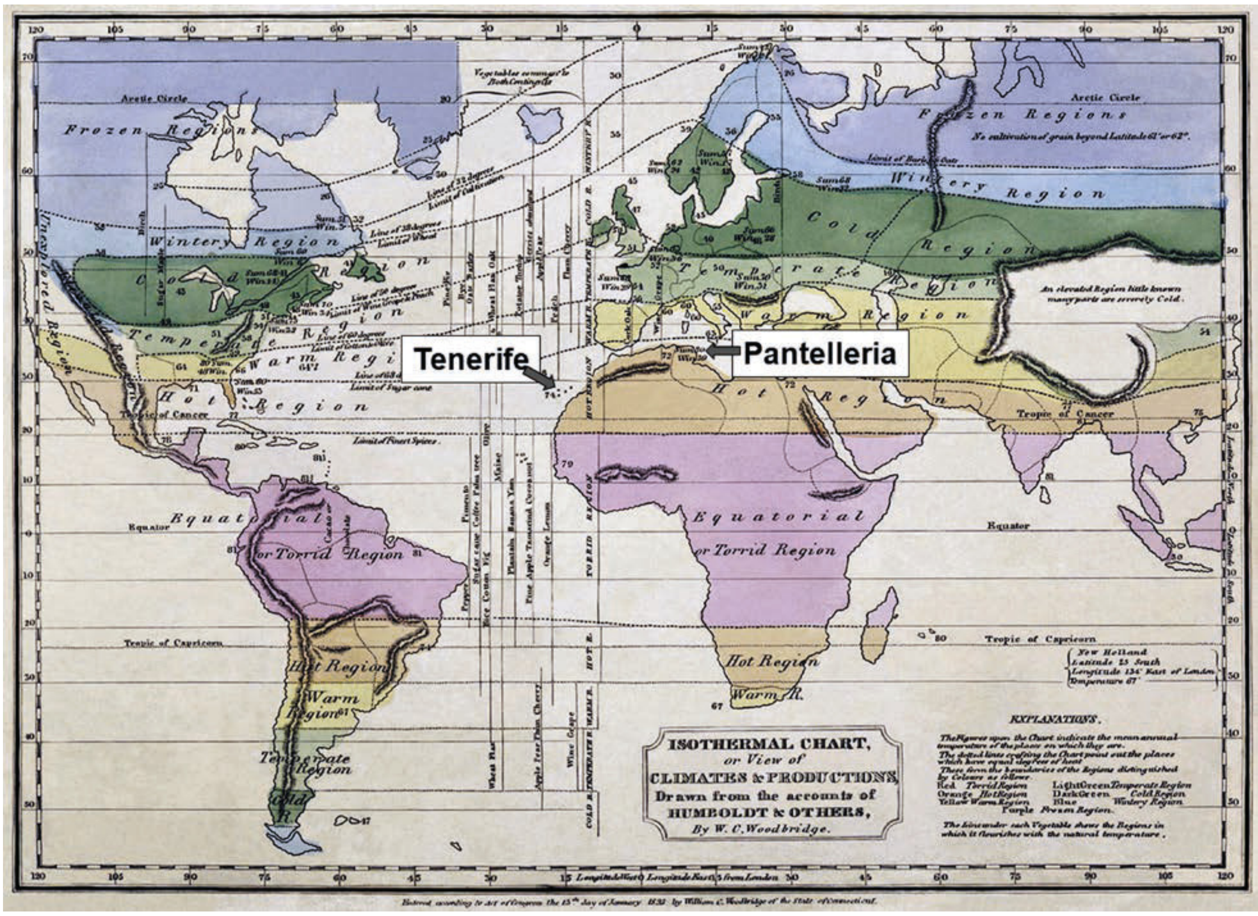

Fig. 1. Tenerife and Pantelleria (approximate areas encircled and labelled) are both located in the 'hot region', <http://digitalgallery.nypl.org/nypldigital/id?465012>. Isothermal Chart. Map produced by William Channing Woodbridge in 1823 based on Alexander von Humboldt's Data.

until today, could not use the plentiful saltwater available to them for their essential functions of human and animal consumption, agriculture irrigation, cooking, washing clothes, medicine making, and sanitation. Due to a lack of lakes and rivers, limited or brackish groundwater, aquifers polluted with volcanic gasses, inadequate precipitation, high rates of evaporation, leakage over 50% from conveyance sources to their points of delivery, and inequitable laws favouring elites, water access for many island residents was anything but a given. Even fires could only be put out with saltwater to the detriment of agriculture.

Second, the geographical isolation of small island communities and their limited physical size often make the effects of climate change more severe than on the mainland (Ratter 2018). For example, it is typical that only a few crops are grown on small volcanic islands, making the effects of crop failure detrimental for the economy and local food supplies (Royle 2004). Warm temperatures and limited hygienic supplies make the control of epidemics (often introduced by sea travellers) more difficult. There are often limited specialised labourers, such as engineers, who can offer continuous solutions to hydraulic infrastructure problems created by storms (Braje et al. 2017). In addition, island climate is primarily influenced by its 360-degree border with the sea and its respective currents, winds, and storms.

Thus, a lack of hydrological resources, disconnection from land-based water support, and exposure to the sea and its variable weather patterns often prompt islands to reveal warning signs of the adverse effects of climate and environmental changes before they appear on the mainland (Baldacchino 2007). Studying island climate and water stress can shed light on the coping mechanisms, innovation, and resilience of former settlements in light of resource scarcity and climate-related migrations (Royle 2004; Stratford 2016). As Fitzpatrick has recently argued, 'islands are

	Tenerife (Canary Islands, Spain)	Pantelleria (Sicily, Italy)
Area	2,036km²	83km²
Geological Origin	Volcanic	Volcanic
Highest Elevation	3,715m	836m
Rainfall	266mm/m²	485mm/m²
Distance to Mainland	284km to Africa; 1,342km to Spain	70km to Tunisia; 110km to Sicily/Italy
Coordinates	28.2916° N, 16.6291° W	36.82836 ° N, 11.94611° E

Tab. 1. Comparison of the Islands Discussed in this Chapter (Distances and amounts are approximate measurements).

important models for the future […] island cultures and ecosystems can be seen as microcosms of the issues we have faced as humans, and provide important insights for understanding the fate of our species' (Fitzpatrick/Erlandson 2018, 283).

We have limited the scope of this study to the two volcanic islands of Tenerife (current-day Spain), which is studied by Laura Dierksmeier from historical perspectives of the early modern era (1500 AD to 1800 AD) and Pantelleria (current-day Italy), analysed by Frerich Schön from archaeological perspectives during the classical era (500 BC to 500 AD) (*fig. 1*).[8] In table 1 we have compared the islands of Tenerife and Pantelleria with a few attributes from current-day data.

Tenerife (Canary Islands/Spain)

During the 15th cent. AD Spanish conquest, the name of Tenerife was adopted from residents of nearby island La Palma, who called the island *Tener y de Ife* (snow and high mountain) (Viera y Clavijo 1772, RSEAPT, RM-51). The history of Tenerife's name points to the dominance of its geological and geographical features, which directly affect local water supplies. Tenerife (*fig. 2*) has been selected for analysis in this section for several reasons. First, it is one of few small islands with seven different climate zones.[9] Unlike the other Canary Islands and islets, Tenerife can at the same time have snowfall and temperatures of 20° Celsius, making the amount and sources of water heterogeneous over the island landscape (Ministerio de Agricultura 2018, 20). Second, water sources on Tenerife dictated not only settlement patterns, town architecture, and local agriculture, but also influenced the largest source of overseas income of the Spanish Empire in the 18th cent.: herbal medicines (Schiebinger 2011). Third, due to its prominence as the capital during the early modern period and having the largest territory and population of the seven permanently settled Canary Islands, the range of extant source material on the topic of water is plentiful and illustrative. Fourth, since Tenerife was a melting pot for European botanical

8 This contribution stems from a collaboration initiated within the SFB 1070 work group 'Insularitäten – Insularities' at the University of Tübingen, where the results of field research are compared to identify island-specific characteristics. As both Schön and Dierksmeier concluded that water stress were central themes affecting the historical and archaeological records of Tenerife and Pantelleria, this pilot study was initiated to explore the potential for future interdisciplinary research around the resource of island water, considering the holistic and integrative approach of SFB 1070. All quotations from German and Spanish were translated into English by the authors unless otherwise stated. Whenever possible, original quotations were included in the footnotes. Transcriptions of Spanish manuscript sources are included as they appear and have not been modernised to current-day norms. e.g. 'son' appears as 'ſon' and 'muy' appears as 'mui'.

9 The climate zones are: Cardonal – Tabaibal: 0–700m, Bosques Termófilos: 200–600m, Laurisilva: 500–1,000m, Fayal-Brezal: 1,000–1,500m: Pinar: 800–2,000m, Alta montaña: over 2,000m.

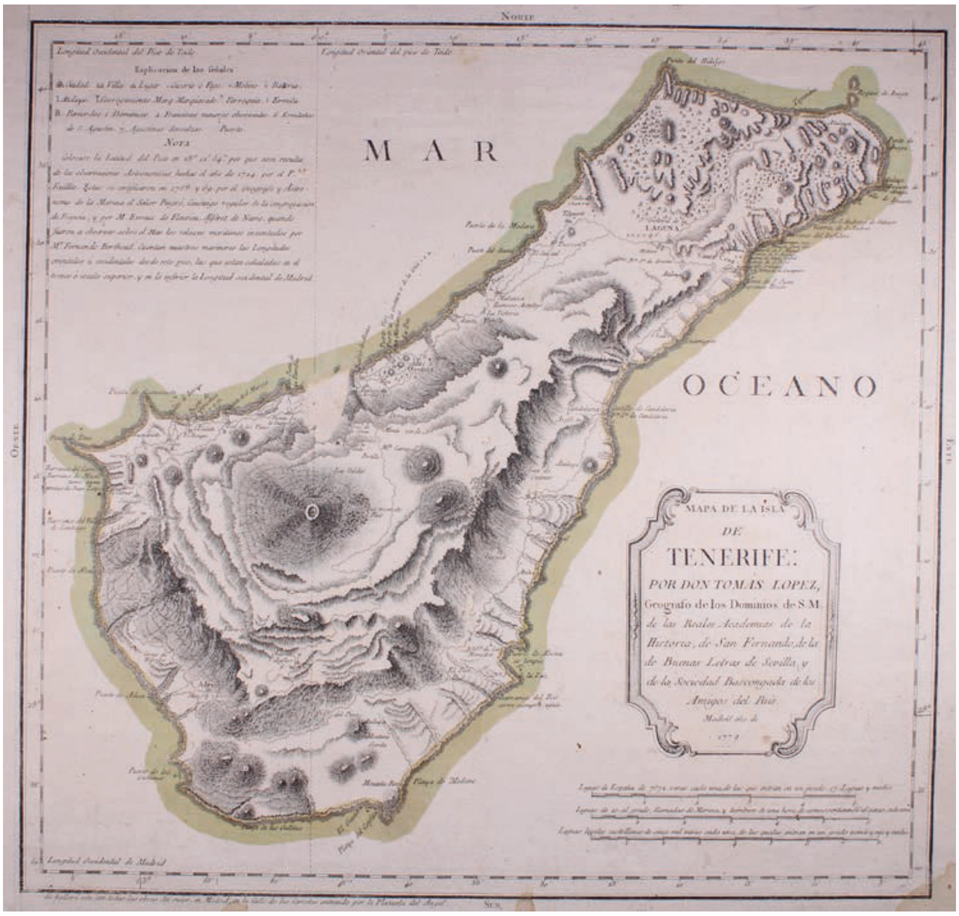

Fig. 2. La Orotava Valley mentioned in this section can be found on the northern coast in the centre. Map of Tenerife, 1779, by Royal Geographer Tomás Lopez. Image courtesy of La Real Sociedad Económica de Amigos del Pais de Tenerife.

researchers (such as Prussian Botanist and Geographer Alexander von Humboldt, 1769–1859), island scholars (for example, Historian and Botanist José de Viera y Clavijo, 1731 in Tenerife – 1813), Spanish settlers, Latin American merchants, Mediterranean sailors, Italian Engineers, and indigenous inhabitants, a variety of responses to water stress can be documented.[10]

To study Tenerife's hydrological resources from historical perspectives, this section analyses three main topics: (1) water-oriented settlement patterns, (2) reported negative effects of volcanic activity and deforestation on water supplies and (3) cultural and religious responses to water stress. The history of water laws on the Canary Islands, water-related conflicts and the implementation of a water police force have been examined previously and are not included in this discussion (see: Dierksmeier 2020; Gómez Gómez 2016; Macías Hernández 2009). Archive sources cited were accessed in the Real Sociedad Económica de Amigos del País de Tenerife (RSEAPT), and the Archivo Municipal of La Laguna, Tenerife.[11]

Water-Oriented Settlement Patterns

Alexander von Humboldt noted during his travels to Tenerife: 'the Canary Islands generally suffer

10 This section uses at times the term 'water stress' defined above, but it should be noted that this term was not used during the period under analysis.

11 Laura Dierksmeier thanks Zulaika Navarro Abreu, Daniel García Pulido and Diana Ramos Jorge at the Archive of the Real Sociedad Económica de Amigos del País de Tenerife and Miguel Gómez Gómez, A. José Farrujia de la Rosa, María Hernández-Ojeda, and Carlos Rodríguez Morales for their kindness and assistance in preparation for and during archive research.

from water scarcity'.[12] In apparent contrast, José de Viera y Clavijo stated in his 'Dictionary of the Natural History of the Canary Islands' that some parts of Tenerife 'were favoured by nature with the best fresh and potable water from their sources' even though 'strictly speaking, there are no rivers' (Viera y Clavijo 1866, 16).[13] At first glance, Humboldt's notation as a foreign observer appears to be at odds with the report of local researcher Viera y Clavijo. The complete accounts of both scholars can, however, be reconciled with one another: Many areas of Tenerife suffered from a lack of water access, but some sources from springs and the snow of the volcanic peak were available with good water quality for those able to access them.

After the Spanish conquest of Tenerife in 1496, residents settled in the regions with the most natural sources of freshwater. Especially the Orotava Valley has a long settlement history starting with indigenous settlements before the Spanish conquest (Farrujia de la Rosa 2014, 9). Alexander von Humboldt, on his one-week trip to Tenerife in 1799, was particularly captivated by the freshwater sources in the Orotava Valley. Humboldt recorded his impression of the landscape, and his description is dominated by notes on the hydrological resources: 'The Villa de Orotava makes from a distance quite a good impression through the abundance of water that runs out of the location and alongside the main streets. The source Aqua mansa, contained in two big basins, propels several mills and is then led into the vineyards of the adjacent premises. The climate in the Villa is still cooler than at the harbour, as a strong wind blows from there from ten in the morning. The water, which with high temperatures evaporated into the air, often comes back down, and thereby the climate becomes very foggy. The Villa is located some 312m above sea level' (Humboldt 1799, 98).[14]

The waters of the Orotava Valley had another settlement pull factor: the resettlement of 'exotic' plants. The role of the Canary Islands for plant commerce is highly relevant to transatlantic history, despite being often overlooked.[15] Due to the hydrological resources and fertile soil, plans were made since the 16th cent. for La Orotava to host a botanical garden (The Acclimation Garden of the Orotava Valley/Jardín de Aclimatación de La Orotava), where seeds and seedlings from China, India, and Latin America were to be planted after long sea voyages. A projected budget for the Acclimation Garden of Tenerife was prepared for the king of Spain already in the year 1544. The budget demonstrates that the highest costs would be for construction of walls, followed by the pipes to channel water to the garden, the cost of water itself, and the yearly labour of a head gardener and part-time workers (Rodríguez García 1979, 68–72). Humboldt reported about La Orotava: 'where there is artificial irrigation or frequent rainfall, there the ground is exceptionally fertile' (Humboldt 1799, 150).[16] An intermediate planting increased chances of plant survival before being transplanted again to Europe during times when peaceful sea travel was possible (Humboldt 1799, 90). Some of the first plantings failed due to torrential rains in the years of 1788 and 1789, but the garden subsequently housed a wide range of exotic plants (Rodríguez García 1979). The commerce of fragile herbal medicines from Latin America

12 'Die Kanarischen Inseln leiden im Allgemeinen an Wassermangel.' Humboldt's stay on Tenerife is memorialised in several locations today, such as at the 'Humboldt Point' where some of his sketches were drawn of the Orotava Valley and in the private botanical garden Jardín de Orquideas de Sitio Litre, where Humboldt was hosted as a guest during his stay on Tenerife.

13 'Nuestras islas, con especialidad las de Canaria, Tenerife, Palma y Gomera, fueron favorecidas de la naturaleza con las mejores aguas dulces y potables de sus fuentes que las sacian, riegan y fertilizan. No hay propiamente ríos; pero hay arroyos caudalosos, hijos de manantiales.'

14 'Villa de Orotava macht schon von weitem einen guten Eindruck durch die Fülle der Gewässer, die auf den Ort zueilen und durch die Hauptstraßen fließen. Die Quelle Aqua mansa, in zwei große Becken gefaßt, treibt mehrere Mühlen und wird dann in die Weingärten des anliegenden Geländes geleitet. Das Klima in der Villa ist noch kühler als am Hafen, da dort von morgens zehn Uhr ein starker Wind weht. Das Wasser, das sich bei höherer Temperatur in der Luft aufgelöst hat, schlägt sich häufig nieder, und dadurch wird das Klima sehr neblig. Die Villa liegt etwa 312 m über dem Meer.'

15 There appears to be only one academic publication on the role of the Canary Islands in the plant trade between Latin America and Europe published after the 19th cent., which is a meticulous study based on primary sources from the General Archive of the Indies in Seville, Spain: Rodríguez García 1979.

16 'Wo künstlich bewässert wird oder häufig Regen fällt, da ist auch der Boden ausnehmend fruchtbar.'

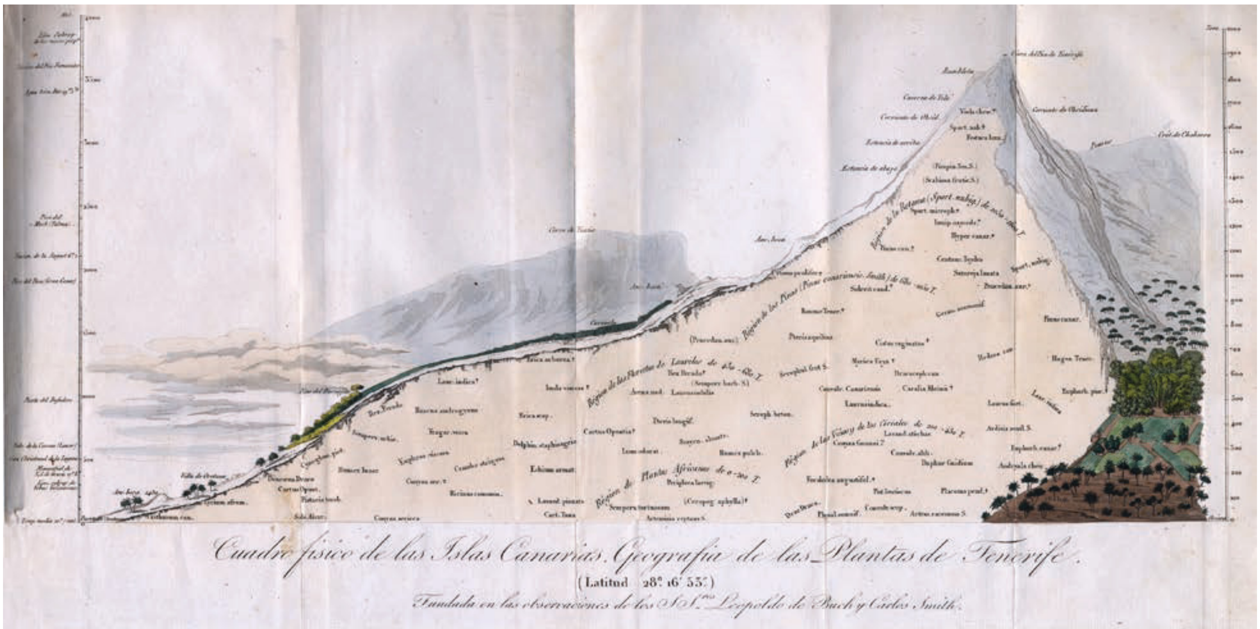

Fig. 3. Seen on this map of El Teide are Humboldt's five categories of botanical observations described in his travel log: 1. Region of African plants, 0–200m, 2. Region of wine grapes and cereals, 200–430m, 3. Region of florestas and laurels, 430–680m, 4. Region of pine trees (*Pinus canariensis*), 680–1050m, and 5. Region of *la retama* (flowering bushes), 1050–1600m. Humboldt's Drawing of El Teide Volcano on Tenerife, 3,700m.

outpaced the value of imports of gold and silver in the 18th cent. and became known as 'the green gold' (Schiebinger 2011, 119). The in-between location of Tenerife's botanical garden was of high value to the Spanish Crown. Thus, the settlement and resettlement of both people and plants were highly dependent on the availability of Tenerife's freshwater sources.

Locations with limited hydrological resources were either uninhabited or relied on rainfall collection, and the unpredictable water flows transferred via mountain ravines, called *barrancos* (Marzol Jaén 1988; Martín Rodríguez 1986). Water was transported via aqueducts, pipes made of wood or cone-shaped pottery inserted into one another to form a water-tight transfer system called *atanores* (Gómez Gómez 2016, 174). The architecture of colonial towns on Tenerife likewise reflected their dependency on freshwater storage systems, especially seen through the number of rainwater cisterns (*aljibes* in Spanish, from Arabic) and wells (González Falcón/de la Rosa Olivera 1970). Likewise, in rural areas, water cisterns of varying capacities dominated the landscape to collect and store amassed rainfall. Towns with agricultural production employed water mills, but historical sources report that it was not uncommon to see those mills standing still due to water shortages.

Effects of Volcanic Activity, Storms, and Deforestation on Tenerife's Hydrological Resources

Across the wide spectrum of water supplies on Tenerife, several environmental factors could severely disrupt the water system, such as volcanic eruptions, sandstorms from Africa, and human deforestation. With the highest mountain in Spain, Tenerife is home to the volcanic peak of El Teide at 3,718m high (7,500m above the ocean floor) (see *fig. 3*), the third tallest volcano in the world. Lava eruptions on El Teide account for the continuously changing rugged lava landscapes, which directly influence the local water supply (on Tenerife's volcanic foundations, see Bolan 1972). Volcanic activity drastically altered the landscape, affecting, among other things agricultural production.

Agriculture was the principal economic activity of Tenerife until the 1960s, despite the island's limited amount of fertile soil due to lava-covered landscapes (Morales Mato/Macías Hernández

2003).[17] The last major volcanic eruption that took place in 1798 was recorded to change Tenerife's landscape over months, as land plots previously used for food production were overrun with hot lava, destroying fertile soil, and preventing farming in certain areas (RSEAPT, 13 FAN, 16). Eruptions created pockets of lava where groundwater collected, and this water was often polluted with toxic volcanic gases and could not be used for drinking, sanitation, or irrigation. Volcanic activity also potentially decreased the islander's ability to rely on fish as a staple food source, and this, in turn, increased the importance of fertile soil and accessible water supplies to grow additional crops. According to Alexander von Humboldt, the lava streams overflowed into the sea and through the heating of the water fish consequently perished in a large circumference around the island. (Humboldt 1799, 126). Scholars of island studies recently debated why islanders often had low-fish diets at the international conference 'European Islands: Between Isolated and Interconnected Worlds, Interdisciplinary Perspectives' (Tübingen, Nov. 15–16, 2019). Humboldt's explanation could be one partial explanation as to why some islanders and their neighbouring islands had low fish diets, but alternate theories, such as the lack of equipment to catch fish deep in the Atlantic were likely also contributing factors.[18]

Thus, water resources and their effects on food production and islander diets were at the whim of volcanic activity. In addition to unpredictable volcanic eruptions, erratic storms caused major landscape changes, carrying away soil, and sometimes also farm animals and trees (RSEAPT, 13 FAN, 20 f.). The amount of water available and the fertility of the soil dictated the agricultural landscape (on Tenerife's groundwater, see: De Ascanio y León, 1921).[19] Due to the proximity to Africa, Saharan sands had long created a dense, dry fog, known as *calima*, which contributes to the drying out of the soil. The phenomenon of *calima* was recorded historically: 'due to the immediacy of the coasts of Africa, breezes fill the atmosphere with dense clouds and make the days somewhat opaque' (RSEAPT, 13 FAN, 21).[20]

The connection between forests and rainfall, or between deforestation and depletion of water supplies is underscored by Juan Bautista Bandini, author of the 1816 'Elementary lessons on theoretical, practical and economic agriculture for the instruction of students in the Canary Islands' ('Lecciones elementales de agricultura teórica, práctica y económica para la enseñanza de sus discípulos en las Islas de Canaria'): 'In this Island [Tenerife] they also had the barbarous mania to destroy the mountain forests (…) and they continue depleting each day the water for irrigation; these islanders do not want to let themselves be convinced that destroying the mountain forests, reduces the rain significantly, and as a result the springs; the mountains remain without a covering, and without fertiliser, the *calima* dries out the soil, and the winds increase considerably and there will be instability and changes during all seasons' (RSEAPT, 13 FAN, 46 f.).[21] Forest areas were cut down for use in shipbuilding at the command of Spanish officials and wealthy foreign investors, who did not

17 See for example 'Malpaís' near Puertito de Güímar, Tenerife.

18 Also access to the sea was altered through eruptions: The colonial town of Garachico, for example, remained the principal port for commerce only until 1706, when a large part of the town was destroyed by a volcanic eruption. The major port was then relocated to Puerto de la Cruz, at the base of the Orotava Valley.

19 From Güimar to Pueblo del Rio, the soil consisted of decomposed pumice stone and silica. Everywhere else, the land for cultivation was said to be composed of decomposed sands, volcanic material (*escorias*), and balsaltic volcanic rock, dominated by a clay-like quality (RSEAPT, 13 FAN, 26).

20 'En la primavera por la inmediacion á las costas de Africa ſon mui frecuentes las brisas que cargan la atmósfera de nubes denſas, y hacen los dias algo opacos.'

21 'En esta Isla ha habido tambien la mania bárbara de destruir los montes […] y por consiguiente los manantiales y las fuentes; quedaran ſin abrigo las montañas y ſin abono ſecundo las colinas; se aumentarán considerablemente los vientos y habrá inconstancia y mudanza en las estaciones todas.' The same source likewise attributed the lack of water on Fuerteventura and Lanzarote to 'their lack of mountains and forests, and not least due to the heat which is more intense than on the other islands.' 'Las islas que mas padecen por la escasez de las aguas ſon Fuerteventura y Lanzarote. La falta de montañas y de bosques, no menos que los calores que en ellas ſon mas intensos que en las otras.' (RSEAPT, 13 FAN, 25).

consider the repercussions of deforestation on local water supplies.

The above complaint, which has not lost its relevance today (see Lyra/Rigo 2019), underscores the connection between trees and freshwater collection. Especially forests of native Canarian pine trees (*Pinus canariensis*) collected water not only through their roots but also via the absorption of atmospheric precipitations through their pine needles, collecting mist, fog, and dew. Humboldt recorded the extensive pine forests of Tenerife at 680–1050m of elevation.

Climate Changes and Religious Responses

As part of the Spanish Empire, Tenerife was governed during the early modern period by both civil and ecclesiastical authorities under the King of Spain. Residents were encouraged by local officials to carry out processions to plead for the help of God for factors outside human control, such as for the safe childbirth of the queen, to expel epidemics, or to prevent natural disasters. Carlos Rodríguez Morales, director of the Archivo Histórico Provincial de Santa Cruz de Tenerife, has concluded that from 1650–1775 in La Laguna, Tenerife by far the largest number of prayer processions took place to combat water scarcity and periods of drought, followed by efforts to minimise epidemics (1672, 1703, 1712, 1741), plagues of locusts (1693, 1757), and volcanic eruptions (1704) (Rodríguez Morales 2002, 158). Archive sources accessed by the author from the Archivo Municipal of La Laguna document processions carried out for water scarcity (for example in 1684, 1761, 1778, 1779, 1785). Public prayer ceremonies beseeching God for water were interpreted contemporaneously as a punishment from God for human sins, although their performative function also was to communicate their needs to authorities who could potentially help them (Dierksmeier 2020).[22]

During prayer processions, the local statue of the virgin (la Virgen de los Remedios, la Virgen de los Pinos, or la Virgen de Candelaria) was carried on the shoulders of men, often members of local religious brotherhoods (*cofradías/hermandades*) who performed this function during religious celebrations, followed by musicians and a procession of community members.[23] Rogation ceremonies were recorded on the day they occurred, and historians investigating palaeoclimatological data have found these sources to be helpful in reconstructing precise times of historical water stress. These sources, while orientated around religious aspects, record some climate descriptions which would otherwise be unobtainable today. Noteworthy studies considering church records on mainland Spain for climatological data have been carried out by, for example, Maria Jesus Esteban Rodrigo (Rodrigo et al. 1995) and Mariano Barriendos (1995; 1997; Barriendos et al. 1993).

The distinctiveness of Tenerife's climate and terrain led to an often discernible Tenerifeño identity. For example, funeral sermons and poems referenced 'the sacred Teide', 'the wind in the aged pine trees', 'arid loneliness', 'the rugged mountains', and the 'bellowing of the waves of the furious sea' (RSEAPT, RM 70). In a location with dramatic environmental extremes, islanders self-identified through the awe-inspiring but also fear-inducing environs associated with their island life, many of which exacerbated their acute problems of water stress. The collection of funeral poems specific to Tenerife is proof that Alexander von Humboldt's wish was at least partially fulfilled when he wrote: 'it is to be hoped that the blissful islands, where man feels everywhere the blessings and the hard hand of nature, will one day find a born Poet who extols them worthily' (Humboldt 1799, 152).[24]

22 Rogatives on Tenerife are recorded in both town council meetings and ceremonies of thankfulness for the occurrence of rain following a public rogative procession. For a ceremony of gratitude for rainfall, see: Archivo Municipal de San Cristóbal de la Laguna, 1779.

23 Devotions to the Virgen del Pino can be found on Tenerife, Gran Canaria, Lanzarote, Fuerteventura and La Gomera, as well as in locations of Canarian emigrants, such as Venezuela, Cuba, and Mexico.

24 'Es ist zu hoffen, daß die glückseligen Inseln, wo der Mensch wie überall die Segnungen und die harte Hand der Natur empfindet, dereinst einen eingeborenen Dichter finden, der sie würdig besingt.'

Pantelleria (Province of Trapani/Sicily/Italy)

The island of Pantelleria offers the second model case for insular water stress of this article. The American Geologist Henry S. Washington, who visited the island at the beginning of the 20th cent., stated: ‘Potable water is very scarce, though it is furnished by some of the volcanic springs, one of which forms a public fountain in the town. This is closed except for an hour every morning, when each household is allowed to draw its allotted supply. Some of the steam fumaroles are utilised by herdsmen by covering them with brushwood, which condenses the water and gives rise to small rivulets. The rains are the main source of supply, the water being gathered on the flat, cemented roofs and preserved in cisterns beneath the houses. But after a long dry spell, as at the time of my visit, this supply is likely to fail and the whole population goes on short water rations’ (Washington 1913, 656).

Situated halfway between Sicily and Tunisia, the volcanic island forms a landmark for the navigation in the Strait of Sicily. The island lacks significant freshwater sources, no springs and rivers are available, rainfall is absorbed by the porous volcanic ground and discharged into the sea so that nearly no sufficient groundwater level can form. The volcanic history is also a constant risk for the human efforts to store water: A submarine eruption in October 1891, 5km off the north-western coast of the island, destroyed around 40 water cisterns on Pantelleria.[25] Similar events are attested archaeologically by repairs of earthquake damages in hydraulic systems in Late Antiquity (Schön et al. 2015, 287). Due to the volcanic origin of the islands’ landscape with its several inactive craters, it is characterised by a hilly and irregular surface. Flat surfaces usable for extensive agricultural cultivation are rare (Rotolo et al. 2017). The topography is dominated by two mountains in the centre of the island, the Montagna Grande (ca. 840m asl.) and Monte Gibele (ca. 700m asl.) (*fig. 4*). The climate is typical for the Mediterranean with low precipitation (ca. 400mm/year), high average temperatures (ca. 18°C) and winds that blow almost constantly (Mantellini 2015). Most of the rain arrives between September and April (more than 20mm/m² per month), while the summer period between May and August (less than 20mm/m² per month) is almost without precipitation.[26]

Fig. 4. Pantelleria Island, satellite image (2010) with the indication of the sites mentioned in the text. Satellite Image (2010), <https://commons.wikimedia.org/wiki/File:Ortofoto-piccola.jpg> CC BY-SA 3.0 (l.).

The lack of water and the morphology of Pantelleria promoted the formation of a Resource-Complex around water, understood in the sense of SFB 1070 ResourceCultures as a combination of humans, objects, knowledge and practices (Bartelheim et al. 2015), which is archaeologically attested by numerous rainwater cisterns, terraces and religious buildings connected to water. These material features show that, at least in Punic and Roman times, the periods examined in this section on the island, the cultural landscape and several aspects of life were closely linked to the resource water.

25 Deecke 1893/Riccò 1892, 48 ‘Nachdem die Insel Pantelleria vom 14. Oktober 1891 an drei Tage lang von Erdstößen erschüttert worden war, wobei viele Cisternen platzten und ihr auf dieser wasserarmen Insel so kostbares Nass ausrinnen liessen.’ See also Baratto 1892, 11: ‘(...) in quella notte, credesi per effetto del terremoto, si spaccarono pure circa 40 cisterne nella punta Tracina per la regione Kamma fino a quella nominata Scauri (...).’

26 For climate data over the period 1926–1985, see Mantellini 2015 with references. Precipitation patterns relevant for the use of cisterns are analysed in Körper 2014, 119–122.

Fig. 5. Pantelleria Island, Favare Grande. Pantelleria-Archive, University of Tübingen.

Island Water Stress in Ancient and Early Modern Perspectives

Ancient written sources name Pantelleria Island 'barren' and a 'deserted and harsh place', but nevertheless, it was densely settled in the Punic and Roman periods.[27] On the contrary, the medieval Arab geographer Muhammed al-Idrisi called the island fertile and equipped with wells/cisterns (VII, 24, 1). Several Pantellerian toponyms of Arabic origin describe devices to extract water or the controlled use of it (Staccioli 2015).

In early modern scholarship and literature, ancient topics about Pantelleria were repeated: Eberhard David-Hauber, geographer, theologian and the author of the Bibliotheca, acta et scripta magica, noted: 'Pantallerea (…). Cossura, Cossyra, Cosyra. Sie hat vortreffliches Wasser, sonst aber einen unfruchtbaren Boden. Dahero Ovidius von ihr schreibet: fertilis est Melite, sterili vicina Cosyrae' (Hauber 1741, 574 f.). In their search for curiosities, Early Modern writers were more fascinated by an insular water supply technique that was used until the 1960s, where volcanic exhalations produce drinkable water in the field of fumaroles, locally called *favare* (*fig. 5*). To catch the aqueous stream exhaling from the ground, the emersion point is supported by rock-cut niches and dry-stone walls. This construction is roofed by twigs, acting like a condenser. Water drops, falling down from the roof, were collected in a small pool at the bottom of the construction and canalised into cisterns (Ercoli 2000, 63 f. with fig. 4). Giovanni Agnolo Lottini, for example, wrote around 1600: 'Là in Pantelleria, doue una spelonca vapori esala; e quei conuersi in acqua, tutta l'Isola adacqua' (Lottini 1601, 79). Some years later, the Spanish author Jayme Rebullosa described the island 'Pantalaria (…) no tiene otra agua sino la que se recoge en una cueva, donde multiplicandose de contino los vapores y conuitiendose en agua, situen de lluvia, fuentes, y rios' (Rebullosa 1622, 338).[28] Very similarly, Johann Heinrich Seyfried wrote in his Poliologia, 'Das ist Beschreibung Aller berühmten Städte in der gantzen Welt', published in 1683: 'Pantalarea. (…) Ist eine kleine bergigte Insul, so des Ptolemei Kossyra seyn solle (…). Kein Wasser ist auf dieser Insul, ausser was in Cisternen bewahrtet wird. Die Natur aber hat durch ihre Sorgfalt mitten in der Insul in einem Felsen ein unergründlich Loch ausgehölet, aus welchem unaufhörlich starcke Dämpffe aufsteigen, so an die oben überhangende Felsen sich anschlagen, und in Wasser resolvieren, so durch Rinnen herausgeleitet wird, dessen Menschen und Vieh sich

27 Ovid, fasti III, 367: *sterili (…) Cosyrae*; Seneca, ad Hel. 6,4: *deserta loca et asperrimas insulas*.

28 See also Barezzi 1669, 353: '(…) per tutta l'Isola trouansi buon numero di cisterne; in mezzo à lei s'apre una spelonca, ò voragine, che volgarmente vien detta la fossa, dalla quale nasce di continuo tanti vapori, che conuertendosi in acqua se n'abonda tutta l'Isola non ve n'essendo altra (…).'

gebrauchen' (Seyfried 1683, 269).[29] During the Early Modern period, the main well of the town Pantelleria Centro was dug, that delivers about 1100l/min. The water is a little mineralised and is today purified by a desalination plant before it is allowed to be used (Ercoli 2000, 61). But the water has been consumed without purification over centuries. In his short description of Pantelleria, Friedrich Leopold Graf zu Stolberg noted: 'Die Luft der Insel ist gesund, ihre Einwohner sind stark. Sie trinken aus einer schweflichen Quelle, und brauchen das in Cisternen gesammelte Regenwasser zu anderen Bedürfnissen' (Stolberg 1822, 419).

Rainwater Cisterns and Terraces: The Waterscape of an Island

The water supply of the earliest permanent human occupation on Pantelleria island during the Bronze Age was based on coastal wells dug into the volcanic ground to tap the shallow water table, which might have been contaminated to a certain degree by seawater (Ercoli 2000, 63; Mantellini 2015, 408).[30] Settlement activity on the island in the Punic and Roman period depended on the storage of rainwater, collected during the rainy season in a larger scale to bridge periods without precipitation, especially the dry summer months. This technique is widespread in the Mediterranean region; it requires a basic understanding of the weather regime and the hydrologic cycle on the one hand, and the possibility of collecting and storing rainwater on the other. Both requirements are given for the Mediterranean area in the mid-1st mill. BC (Beckers et al. 2012/2013). The natural water cycle was basically understood and theorised in Greek philosophy as it is attested, for example, in the Corpus Aristotelicum (Koutsoyiannis et al. 2007; Toth/Hillger 2007–2020). In the writing 'De mundo' the origin of rainfall is described as a physical phenomenon: 'Cloud is a vaporous mass, concentrated and producing water. Rain is produced from the compression of a closely condensed cloud, varying according to the pressure exerted on the cloud; when the pressure is slight it scatters gentle drops; when it is great it produces a more violent fall, and we call this a shower, being heavier than ordinary rain, and forming continuous masses of water falling over earth'.[31] Very similar, rain is explained in Aristotle's Meteorology as a recurring – thus predictable phenomenon: 'Now the sun, moving as it does, sets up processes of change and becoming and decay, and by its agency the finest and sweetest water is every day carried up and is dissolved into vapour and rises to the upper region, where it is condensed again by the cold and so returns to the earth'.[32]

From the middle of the 1st mill. BC onwards, also the technical requirement for storing rainwater was available in the Mediterranean region (Schäfer et al. 2014). Cisterns were used to store rainwater collected during the humid period of the year for use throughout the year and to bridge drought during summer months. This principle was theorised by Aristotle in the 4th cent. BC to explain the origin of rivers, which are seen analogously to the consumption of water out of a cistern: 'It is thought that the water is raised by the sun and descends in rain and gathers below the earth and so flows from a great reservoir, all the rivers from one, or each from a different one. No water at all is generated, but the volume of the rivers consists of the water that is gathered into such reservoirs in winter. Hence rivers are always fuller in winter than in summer, and some are perennial, others not. Rivers are perennial where the reservoir is large and so enough water has collected in it to last out and not be used up before the winter rain returns. Where the reservoirs

29 See also Meyer 1721, 591 (7): 'Pantalarea. (...) Man hält sie für die alte Kossyra. Das Erdreich ist dürre und traget kein Korn. Die Einwohner sind Catholisch, reden aber Arabisch, und sind die besten Schwimmer. Mitte auf der Insul ist eine tieffe Grube in einem Felsen, aus welcher beständig ein feuchter Dampff aufsteiget, sich oben an den Felsen henget, und zu Wasser wird, wovon die Einwohner samt ihren Vieh Wasser haben, welches sonsten auf dieser Insel nirgends zu finden ist.' And very similar in Zedler 1740, Sp. 584 f., s.v. Pantalaria.

30 For possible earlier, Neolithic or pre-Neolithic frequentation of the island, see Abelli et al. 2016 and Dawson 2014, 107–109.

31 Aristotle, De Mundo 4. Transl. Forster/Dobson 1914.

32 Aristotle, Meteorology II, 2. Transl. Webster 2004.

Fig. 6a. Pantelleria, Tracino. Terraced landscape.

Fig. 6b. Pantelleria, Tracino. Rural cistern on a terraced field. Both: Pantelleria-Archive, University of Tübingen.

are smaller, there is less water in the rivers, and they are dried up and their vessels empty before the fresh rain comes on. But if anyone will picture to himself a reservoir adequate to the water that is continuously flowing day by day, and consider the amount of the water, it is obvious that a receptacle that is to contain all the water that flows in the year would be larger than the earth, or, at any rate, not much smaller'.[33]

The use of cisterns was already known in several parts of the Mediterranean during the Bronze Age, but during the 5th cent. BC it became a common feature of the water supply of urban as well as rural settlements and it relieved groundwater wells as the main technique of water acquisition.[34] This development towards the use of rainwater occurs more or less at the same time in the whole Mediterranean region.[35] A key innovation for the spread of cisterns in the Mediterranean was the invention of waterproof lime mortar that made it possible to construct impermeable water reservoirs independent from the underground (Schön 2020). The extensive collection and use of rainwater became widespread in the whole Mediterranean area and sometimes, in addition, an attribute connected to the foreign perception of some island communities, for instance of the inhabitants of Sardinia as attested by the Late Roman author Solinus: 'The winter showers are saved for the summer scarcity, for the Sardinian man has much wealth as regards rainy skies. They consume collected water, and it suffices for use where there are no bubbling rills'.[36]

During the mid-1st mill. BC Punic settlers colonised nearly the whole area of Pantelleria Island as is shown by architectural remains and pottery findings documented in several areas of the island. These settlers introduced agricultural terraces and cisterns for rainwater harvesting into the landscape of the island and transformed it with a considerable impact into a cultural landscape transformed by the adaptation to the water stress

33 Aristotle, Meteorology I, 13. Transl. Webster 2004.
34 For a general overview see Mays et al. 2013, for Minoan Greece see e.g. Cadogan 2007, for Bronze Age Israel see e.g. Faust 2012, for Bronze Age Spain see e.g. Soler Díaz et al. 2004.
35 For Greece see Klingborg 2017, for Sicily see Bouffier 2009; 2014, for the Punic Mediterranean see Schön 2019; 2020 and Fumadó Ortega 2019a; 2019b.
36 Solinus IV, 5: *Hibernae pluviae in aestivam penuriam reservantur, nam homo Sardus opem plurimam de imbrido caelo habet: hoc collectaneum depascitur, ut sufficiat usui ubi defecerint scaturrigines*, (transl. Apps 2011). For the archaeology of cisterns in Sardinia see Mezzolani 2014; Cespa 2014 and 2018.

Fig. 7. Pantelleria, Acropolis. View from south. Pantelleria-Archive, University of Tübingen.

of the island community. During extensive survey work carried out across the island since 1999 in the course of the project Carta Archeologica di Pantelleria, almost 700 rainwater cisterns were discovered, most of them in rural areas (Mantellini 2014; 2015). The survey evidence makes it highly probable that terracing was introduced on Pantelleria Island in this period to enable rain-fed agriculture (Spanò Giammellaro et al. 2008, 149–151) (*fig. 6a–b*). While there is a lack of stratigraphically excavated terraces in rural contexts, the existence of ancient terraces in the Acropolis area since the 4th/3rd cent. BC and in Scauri, a Late Roman settlement on the southwest shore of the island, confirm that this technique was well known in Antiquity (Schön et al. 2015; Almonte 2013; Marazzi/Tusa 2007). Agricultural terraces were crucial for the soil-, water-, and crop management of the hilly island landscape: terraces modified the slopes, contained soil erosion and increased soil depth; they caught and stored rainfall and moisture, they modified microclimates, eased cultivation and harvesting by providing levelled areas (Frederick/Krahtopoulou 2000; Price/Nixon 2005; Bevan et al. 2013; Gibson 2015).

Religious Cults and Water on Pantelleria Island

One could assume that stress or scarcity of water on small islands might have a particular religious dimension. Recently published studies on the role of water in the Phoenician and Punic religion seem to confirm this (Fumadó Ortega 2019b).[37] While in the Hellenistic period about half of the sanctuaries studied had water installations like wells, basins, pools, cisterns, etc., almost all sanctuaries located on the smaller Mediterranean

37 This is underlined by a late 4th–early 3rd cent. BC inscription from a Phoenician sanctuary in Kition-Bamboula (Cyprus), where also several water installations were found. It mentioned maybe a 'lord (or lords) of water', but the reading is not clear. For the sanctuary see: Caubet 1986, esp. 158; for the inscription see: Yon 1982 and Mathys 2013, 180 f.

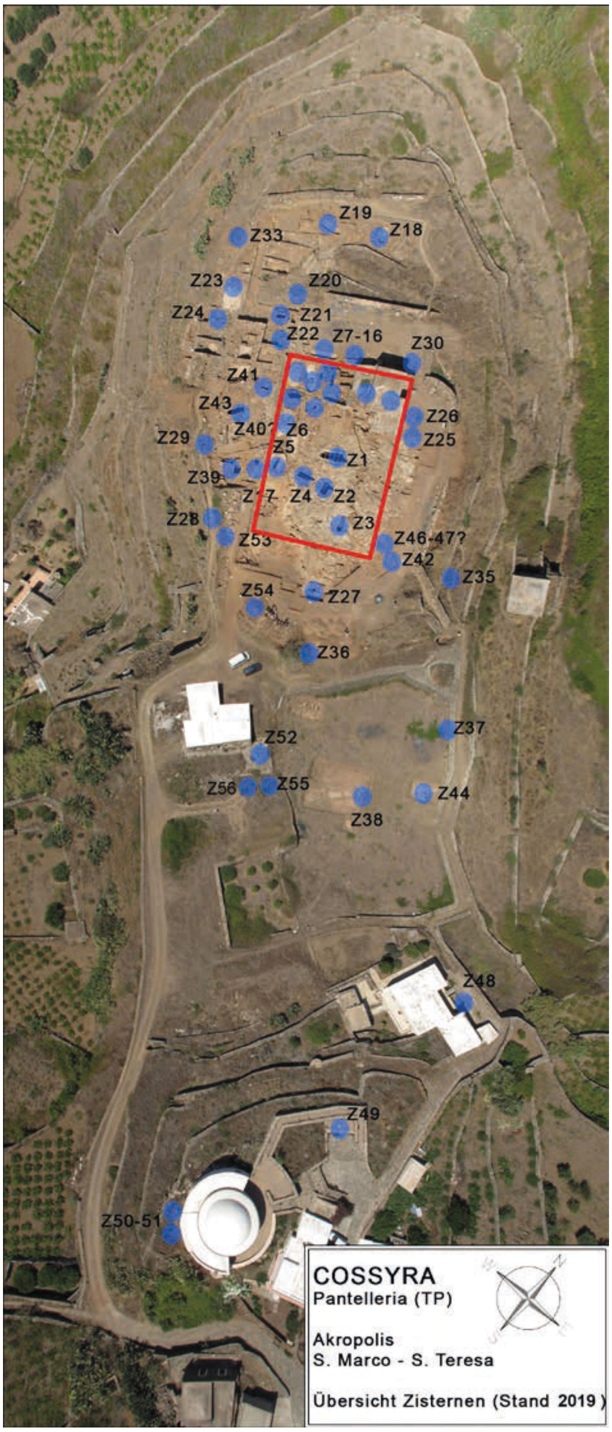

Fig. 8a. Pantelleria, Acropolis. Orthophoto with an indication of the cisterns and the sanctuary on the S. Teresa hill in the 1st cent. BC. Pantelleria-Archive, University of Tübingen.

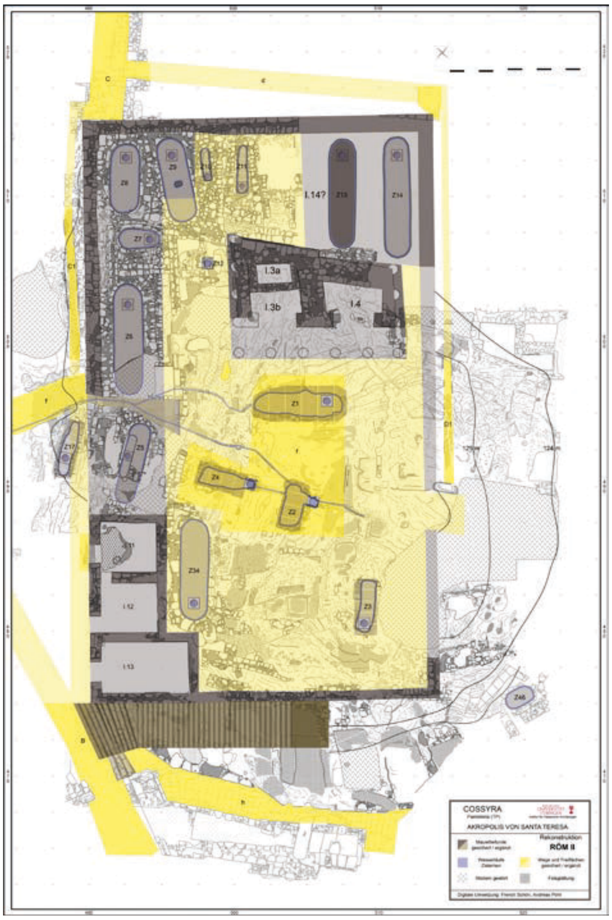

Fig. 8b. Pantelleria, Acropolis. Plan of the sanctuary on the S. Teresa hill. Pantelleria-Archive, University of Tübingen.

islands had such hydraulic infrastructures. After the Roman conquest of Punic territories in the 3rd and 2nd cent. BC, this did not change, most of the sanctuaries remained in use, and their water infrastructures were maintained or extended. Also, new sanctuaries in the Punic tradition sharing this feature were built following the Roman conquest.[38] Given the lack of written sources, it is difficult to determine which role water played exactly in the context of these sanctuaries. The placement of water installations inside a sanctuary can be explained with many reasons: Water might have been the object or purpose of cultic worship, or it was used as a medium of religious actions like purifying or healing rituals (Mathys 2013), or it was used in a profane way for the operation of a sanctuary, or – in the case of rainwater harvesting – the architecture was just used as a catchment to collect water for public water supply. One has also to consider, whether the place of the sanctuary

38 For example, the Baal-Hammon and Caelestis sanctuary of Son Catlar on Menorca Island with an important cistern, see Torres Bagur et al. 2017, or the sanctuary of Astarte/Venus Ericina in Cagliari/Capo S. Elia on Sardinia, see Angiolillo/Sirigu 2009. For the connection of temples to water sources in Roman republican Italy in general see: Edlund-Berry 2006.

was chosen because of the existence of a certain water source or whether water installations were a feature of the sanctuary independent of its setting (Garbati/Pedrazzi 2019, 231; Fumadó Ortega 2019c).

The Acropolis of Cossyra

The Acropolis of Cossyra, as the island of Pantelleria as well as its urban centre were called according to ancient written sources, was established on the summits of a double hill 1.5km south-east of the modern centre of the island (*fig. 7*). The settlement, which has been investigated since 2000 by excavations and an archaeological survey, was founded in the 8th cent. BC by West-Phoenician colonists and existed until the middle Roman Empire, when it was destroyed by an earthquake and never rebuilt (Schäfer et al. 2013; Schäfer et al. 2015). In addition to fortifications, political and domestic architecture and a road system, sanctuaries and water supply installations were excavated. Until now, 56 rainwater cisterns, constructed between the 4th cent. BC and the 1st cent. AD to supply the settlement, were found (Schön 2014; 2019; Schön et al. 2015) (*fig. 8a–b*). These cisterns were dug into the bedrock or constructed in masonry and stored the rainwater collected on the roofs, streets and courtyards of the surrounding architecture during the rainy season. Numerous cisterns with a considerable total storage volume of ca. 200m³ in the 3rd–2nd cent. BC and more than 470m³ at the end of the 1st cent. BC are connected to a sanctuary dedicated most probable to Melkart and Isis on the summit of Santa Teresa, the north-western Acropolis hill (Schön 2014, 109 Tab. 3; Schäfer et al. 2015). During the first construction phases of the temple in the 3rd–2nd cent. BC, one of the largest cisterns (64,9m³) was dug in front of the temple into the bedrock to store the rainwater collected on the roof of the temple (cistern Z1, *fig. 9a*) (Schön et al. 2015, 187 f.). The cistern is connected with an overflow channel to other cisterns on the terraces' downslope, which received surplus water from the upper cistern. A courtyard in front of the temple was equipped with an additional cistern (44m³), which was also connected to the overflow-system and had an external sedimentation basin at the inflow (cistern Z2, *fig. 9b*) (Schön et al. 2015, 167–169). The overflow system connected no less than seven cisterns on different terraces inside and outside the sanctuary. It ensured that water would not get lost when single cisterns were filled, at the same time it worked as a basic cleaning system, because the sedimentation process effected that particles sank down in the water of the upper cisterns before the overflow was led to the cisterns downslope. This cleaning technique is well known also from ancient written sources like Vitruvius (see above). Additionally, the overflow channel of at least one of the cisterns was equipped with a fine grate to clean the water from

Fig. 9a. Pantelleria, Acropolis. Cistern Z1, view from north-east.

Fig. 9b. Pantelleria, Acropolis. Cistern Z2, view from north-east. Both: Pantelleria-Archive, University of Tübingen.

adrift macro pollutants on the surface of the water (Schön et al. 2015, 166–170). These archaeologically attested, mechanical cleaning techniques effected that the water stored in the architectonical complex of the sanctuary was less clean than the water emitted to the lower parts of the settlement. Maybe further water-cleaning techniques were used, for instance, the use of carbon or the exposure of certain fishes into the cistern water to clean it.[39] Bones of fishes as well as charcoal fragments were excavated inside the cisterns, but it is not clear whether the remains were not just part of the later filling of the cistern with settlement dump after it came out of use.[40]

The water supply system connected to the sanctuary on the summit of the Acropolis hill was constructed as an integral part of the public water supply system of the settlement, as well as for the water requirements of the sanctuary itself. This is shown by the physical connection to the cisterns on the lower terraces outside the sanctuary. Nevertheless, the placing of the two main and initial cisterns of the system inside the sanctuary and in a very prominent place – the area directly in front of the temple building – might indicate that water or rain have also been the objective of cultic worship. Artefacts like *situlae*,[41] pottered, decorated, bucket-shaped water containers often used in the cult of Isis, a *louterion*,[42] a pottered water basin, or a *perirrhanterion*,[43] a marble water basin similar to a Christian stoup, found in the context of the sanctuary might indicate that water out of the cisterns was also used for religious rituals.[44]

The use of water for ritual action is probably attested also by a small sanctuary dedicated to Tanit or Tinnit, a goddess well known in the Punic world and identified with Iuno Caelestis in Roman times, that was just recently excavated close to the city gate of the acropolis.[45] A libation cavity in a mortar pavement with the inset symbol of Tanit/Tinnit indicates the use of a liquid for the offering. Most probably water was used in the libation ritual as is shown by a similar sanctuary in Carthage, where traces of sinter are attested (Niemeyer et al. 2007, 217–233; Docter 2019, 439).

Sanctuary at the Edge of the Lago di Venere

Close to the northern shore of Pantelleria, some kilometres away from the Acropolis side, a small endorheic saline lake in a volcanic crater called Lago Specchio di Venere is formed (Fornaro 2000; Calò et al. 2013) (*fig. 10a–b*). The lake is fed continuously by hydrothermal springs and seasonally by rainwater during the winter period, which leads to considerable fluctuations in the water level (Aiuppa et al. 2007). During Punic and Roman times an architectural complex, most probable a sanctuary, was built on the lower northern slope of the basin at the shore of the lake (Audino/Cerasetti 2004; Amadori et al. 2006).[46] Archaeological excavations unearthed the foundation walls of a two-room building, probably *in antis*, oriented toward the lake. The architectural decoration in ionic style, the presence of the remains of a possible altar and other archaeological findings like a fragment of a terracotta female votive supported the interpretation of the site as a sanctuary, dated by diagnostic pottery in the period between the late 3rd cent. BC to the 1st cent. BC and AD. A ground-penetrating radar survey produced evidence of an additional architectural complex of approximately 20x30m below the surface, which seems to be connected to the sanctuary (Urban et al. 2015; Murray et al. 2017). First test trenches unearthed structures of unknown function but connected to the lake sediments, so it seems clear that the sanctuary was directly connected to the

39 In modern times on Pantelleria eels were used to clean cistern water, see Visintin/Errera 1958, this technique is also attested for the Antiquity, see Palladius 1, 17, 2: *anguillas sane piscesque fluviales mitti in his pascique convenient, ut horum natatu aqua stans agilitatem currentis imitetur*.
40 For the animal remains out of two cisterns, see Steckel 2015.
41 Schäfer 2015a, 806 with Fig. 5.
42 Seifert-Paß 2015, 1031–1034 with Fig. 1–3.
43 Schäfer 2015b, 1035 Cat. 1 with Fig. 2–6.
44 For the role of water in the cultic worship of Isis, see Wild 1981.

45 The sanctuary was excavated in trench V/XVI during the summer-campaign of 2019 by the Tübingen Excavation Project directed by T. Schäfer and F. Schön, a detailed report is in preparation. For Tanit/Tinnit in Punic religion, see Xella 2019.
46 The site is currently re-studied by the Brock University Archaeological Project at Pantelleria directed by C. A. Murray, see: Urban et al. 2015; Murray et al. 2017.

lake (Murray et al. 2017, 3 f.). The dedication of the sanctuary is still not clear, but the placing and the physical connection of the architectural complex to the lake with its seasonally highly variable water table make it probable that water was the objective of religious worship. Also, healing rituals can be assumed in this context, because of the sulphurous, hydrothermal springs inside the lake.[47]

Fig. 10a. Pantelleria, Lago di Venere, view from west. Pantelleria-Archive, University of Tübingen.

Fig. 10b. Pantelleria, Lago di Venere, view from north. Photo: Giorgio Galeotti, <https://de.wikipedia.org/wiki/Datei:Lago_di_Venere_-_Pantelleria,_Trapani,_Italia_-_12_Agosto_2016.jpg> CC BY 4.0 (image cropped top and bottom).

Preliminary Results

First results from this interdisciplinary study reveal common challenges of small volcanic islands to manage the resource of freshwater. The limited precipitation and clean groundwater on Tenerife and Pantelleria Island expose the impact of geography, geology and morphology on the formation of specific ResourceComplexes around water, well attested by archaeological and historical sources. In both the ancient period on Pantelleria Island and the Early Modern period on Tenerife, the challenge of obtaining and preserving freshwater resources shaped the material and immaterial world of the volcanic island communities.

On Early Modern era Tenerife, knowledge of the locations and quality of freshwater sources influenced not only the settlement patterns of people, but also of plants sold as valuable herbal medicines. Local and foreign observers recorded environmental factors, such as volcanic eruptions, sandstorms from Africa and manmade deforestation, that exasperated water stress. As a response to both an absolute shortage of water and to natural hazards which perpetuated already scarce resources, islanders passed on religious traditions to cope with water stress, including rogative ceremonies to beseech God for water, at the same time alerting local authorities to their dire water needs.

Early Modern written sources show that also for Pantelleria island, water stress and the location of limited hydrological resources formed an integral part of the perception of the island. For the Punic-Roman period, numerous archaeological remains, such as cisterns and terraces, demonstrate that efforts to manage scarce water resources influenced the landscape and the cityscape on the island. The connection of sanctuaries to water or water installations further indicates an important religious significance of water for the islanders. The archaeological sources on Pantelleria island clearly show that during the Punic and Roman period, the physical infrastructure and cultural landscape, as well as various facets of daily life, were deeply linked to and dependent on the resource of freshwater.

The islands examined here highlight that settlement locations, investments in local infrastructure, knowledge about nature, as well as religious

47 For the use of sulphurous waters for healing rituals in Roman republican Italy, see: Edlund-Berry 2006.

traditions originated from islanders' dependence on limited hydrological resources. As the reliability, continuity, and predictability of water supplies were arguably as important as the total amount of water for agricultural production, the collection of rainwater via cisterns for periods of drought was of central importance to islanders living on parched volcanic landscapes. Freshwater supplies needed for human and animal consumption, agriculture, sanitation, and energy production via water mills influenced local island identities, memorialised in the historical sources of funeral poems and the archaeological remains of cults to water deities.

The preliminary results from this pilot study suggest that future interdisciplinary collaborations would be beneficial for a more comprehensive understanding of historical island water stress. Incorporating additional data from other academic disciplines, such as geography, anthropology, archaeobotany, philology, and literary studies, as well as from different geographical areas and historical time periods would be a welcome collaboration for future research.

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