Valorising Earth's Ancient Landscapes:
The case of Lake Prespa and Lanzarote

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Abstract - *Despite their geographical separation, Lake Prespa and Lanzarote share intriguing similarities rooted in their geological formations and tourism potential. Lake Prespa, nestled within the larger Ohrid-Great/Small Prespa system, part of the greater Drin Basin, stands as one of the world's most ancient and expansive tectonic lakes which retain scientific significance for its ecosystems and biodiversity richness, that, despite recent international initiatives within Albania, North Macedonia, and Greece, are currently endangered by a drastic loss of water volume and pollution caused by uncontrolled anthropic activities. The region's cross- border fragmentation, coupled with remoteness and limited infrastructural investments, has led to an overall underdevelopment, abandonment, and population decline of the towns and villages in the Albanian side of the area. On the other hand, born from volcanic eruptions around 20 million years ago within the Canary Islands, Lanzarote boasts a dynamic landscape resembling extraterrestrial terrains, captivating the scientific community's curiosity due to its resemblance to the Moon and Mars. Despite experiencing a surge in tourism, Lanzarote still retains its authentic character, safeguarding its heritage and landscapes. The present research aims to investigate the relationship between the actual environmental challenges that Lake Prespa is facing and the past-current development of the area, to visualize current issues and possible futures. To do so, Earth Observation data from the Google Earth Engine Data Catalog and GIS are used, also to outline possible future scenarios within a timeline referred to 2050. Eventually, the case of Lanzarote is taken as a virtuous case study from which it is possible to extract an approach that promotes scientific and sustainable eco-tourism, which applied to the study area of Lake Prespa and its the lake towns, such as Pustec (AL), would promote cross-border initiatives aimed at valorizing their unique landscapes, local heritage, and traditions.*

Keywords - Ohrid Lake, Prespa Lake, Lanzarote, Google Earth Engine, Remote Sensing, QGIS

Introduction

Located in the south-west of the Balkan Peninsula, the Drin River Basin (Fig.1a) is a hydrological system that takes its name from the Drin River that crosses Albania, Greece, North Macedonia, Kosovo, and Montenegro, eventually discharging into the Mediterranean Sea. Its basin and sub-basins extend over a geographical area of around 20.000 km² and support many human activities such as energy and water supply for households and irrigation, tourism, recreation, fisheries, and local labour [1] . On top of that, this complex system acts as one of Europe's biodiversity hotspots, providing habitats to many species of flora and fauna (MIO- ECSDE, 2018). At its very start, the Drin River Basin comprises two of the largest and oldest tectonic lakes in Europe and the world: Lakes Ohrid and (Small and Great) Prespa. With an estimated age of 2 to 5 million years (Stankovic, 1960), the lakes can be considered a unique system (Fig.1b) that is of high national and international importance for its geology, biodiversity, and cultural heritage (Popovska and Bonacci, 2007; Stankovic, 1960). Shared between Albania, North Macedonia, and Greece, this system is currently threatened, with consequences that might potentially endanger the overall Drin River Basin. During the last century, the level of the Great Prespa Lake has been dropping continuously, but starting from around years 1986-87 (Popovska and Bonacci, 2007; Soria and Apostolova, 2022) a dramatic water loss was registered, causing the lake to lose more than half of its volume (Kuzmanoski et al., 2022; Soria and Apostolova, 2022), with

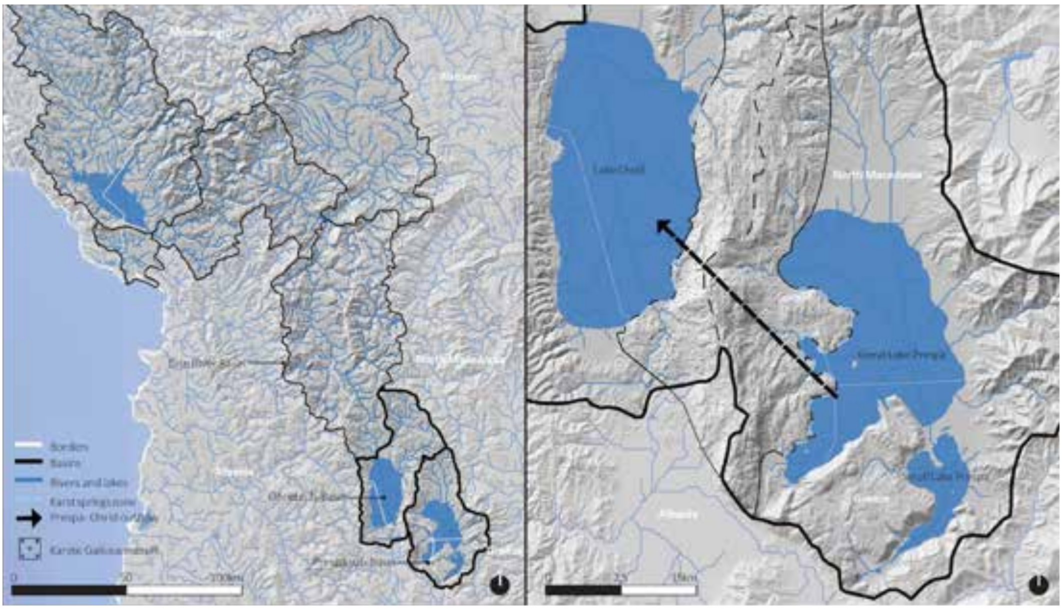


Fig. 1: a) Drin River Basin; b) Ohrid and Prespa Sub-Basins.

source/ Drin River Basin (Drin Coordinated Action); Ohrid-Prespa system (Popovska and Bonacci, 2007).

changes in its elevation, surface extension, and shores. The causes of this steep decline aren't clear. While it is possible to account for some of the loss due to natural causes such as climatic changes, there are strong indicators that uncontrolled water abstraction for human activities such as agriculture has played a pivotal role (Popovska and Bonacci, 2007; Soria and Apostolova, 2022). With the scope of coordinated management of the shared water resources of the Drin Basin, the safeguard and restoration of the endangered ecosystems, the initiative "Drin Coordinated Action" was established in 2011, with the signing of a Memorandum of Understanding from Albania, North Macedonia, Greece, Kosovo, and Montenegro. Initiatives such as the Drin Coorda and the EU for Prespa [2] not only aim to preserve the natural environment, but also to promote the sustainable development and valorization of the area, which in some of its parts is currently facing challenges such as underdevelopment, unemployment, and depopulation [2] (Catsadorakis and Malakou, 1997). The term "valorisation" is understood here following Rakitovac and Urošević (2017) as a strategic process of recognising, preserving, and activating the cultural, environmental, and economic value of heritage assets. This includes promoting local identity, improving quality of life, and fostering sustainable development through culture-driven tourism and community-based partnerships, which, in the case of Lakes Ohrid and Prespa, involve the peculiar cross-border nature of shared environments, histories, and values. For these reasons, gaining a deeper understanding of the opportunities and threats that may lie ahead, by considering the variables that might influence the possible outcomes of these endeavours, is very important. This study uses GIS and Earth Observation data to link the history of recent human development in the Ohrid-Prespa area with its effects on the natural environment. The outcomes of this analysis are used along with the practice of Scenario Thinking (Meinert, 2014; Di Giulio et al., 2018) to outline four possible scenarios within the timeline of the EU Long Term Strategy for 2050 [3] , which compare business-as-usual with sustainable development. Although geographically distant, the case of the island of Lanzarote, in the Canary Islands, is taken here as a reference for the latter, due to its successful integration of environmental preservation and sustainable tourism development (Crespi and Salvi, 2021), but also due to its remoteness condition, somewhat similar and even more extreme than Prespa's, due to its isolated location in the Atlantic Ocean. Lanzarote successfully overcame these criticalities by achieving experimental planning decisions and the creation of narratives that fostered a strong local and international identity based on the valorisation of its cultural heritage and landscapes. Given the shared features of ancient, distinctive landscapes and cultural heritage, we believe that Lanzarote could act as a reference for the Lake Prespa region to develop similar strategies to support its sustainable development and valorisation.

Literature Review

Ancient lakes: a worldwide network

Ancient lakes are a rare feature on Earth. Most of the world's lakes are less than 18.000 years old, while ancient lakes have existed for hundreds of thousands or even millions of years (Albrecht and Wilke, 2008; Hampton et al., 2018). Less than thirty of these lakes exist, and most of them originated in tectonic features such as grabens (Hampton et al., 2018). Because of their age, having experienced a wide range of climatic conditions and long history of association with human activities (Fritz et al., 2010; Stager et al., 2011; Nomokonova et al., 2010), ancient lakes constitute a worldwide network of archives of past environmental change and human history (Hampton et al., 2018), also acting as biodiversity hotspots, hosting highly endemic species found nowhere else on Earth (Rossiter and Kawanabe, 2000; Kostoski et al., 2010; Albrecht and Wilke, 2008). Most of these lakes are vital for many human communities and local and major economies, such as tourism, fisheries, and agriculture. Unfortunately, anthropogenic threats, coping with climate change, are putting these rare and delicate ecosystems in crisis: hydrogeological modifications, es. with the construction of dams, unregulated water abstraction for irrigation and urban use, heavy tourism, inappropriate

LAKE	Ohrid	Great Prespa	Small Prespa
			
Altitude (m. a.s.l)	683[a]	max.852[b](1951); min. 842[f] (2022)*	853[c]
Length max (km)	30,3[e]	27,3[e]	14,3[e]
Width max. (km)	15,6[e]	17,0[e]	6,5[e]
Surface (km2)	358[a]	max. 278,5[f](1963); min. 250[f] (2022)	53[c]
Volume (km3)	55[a]	max.4,86[f](1963); min. 2,76[f] (2022)	0,22[a]
Av. depth (m)	155[a]	14[a]	4,1[a]
Max. Depth (m)	288,7[a]	58[e]	8,4[c]
Water Residence time (yr)	70[a]	11[a]	3,4[c]
Watershed (km2)	1002[a]	1391[d]	260[c]
Countries (% of km2)	29,8 (AL); 70.2 (MK)[d]	18 (AL); 65 (MK); 17 (GR)[f]	100(GR) [d]
Inflows (%)	53 (karsic acquifers, Prespa and other groundwater);23 (direct precipitation); 23 (river inflow)[a]	56 (rivers/ catchment runoff); 35 (direct precipitation); 9 (Small Prespa and ground water)[g]	23 (catcment runoff); 30 (direct precipitation); 57 (surface flow)[h]
Outflows (%)	32 (evaporation), 1 (irrigation/ urban use), 67 (surface flow to Black Drin)[i]	52 (evaporation), 2 (irrigation), 46 (to Ohrid, via karsic acquifiers of the Galichica Mountain)[b]	49 (evaporation), 14 (irrigation), 37 (surface flow to Great Prespa)[h]

Tab. 1: Characteristics of the Ohrid and Prespa Lakes.
*source/ a Matzinger et al., 2006; b Soria and Apostolova, 2022; c Zacharias et al. 2002; d Poposka and Bonacci, 2007; e Albrecht and Wilke, 2008, f Kuzmanoski et al., 2022; g http://drincorda.iwlearn.org/drin-river-basin/lake-prespa-sub-basin; h Kolaneci, 2004; i Bojkovska, 2022. *max. and min. values according to the source.*

wastewater, and sewage treatment plants cope with massive amounts of pesticides and fertilizers due to unsustainable industrial and agricultural practices are contributing to exacerbating natural lake level changes, pollution, and eutrophication, with cascading and devastating effects to local human communities and biodiversity (Wulf, 2016; Hampton et al., 2018; Kaneko et al., 2003; Matzinger et al., 2006; Stankovic, 1960; Albrecht and Wilke, 2008). Lakes Ohrid and Prespa are not immune to these threats. They are already suffering from them.

Europe's ancient lakes: Ohrid and Prespa.

Located in the south-west of the Balkan Peninsula, Lakes Prespa and Ohrid (40°40'-41°10'N; 20°38'-21°08'E) are cross- boundary lakes, part of the greater Drin River Basin and of the European lake group called "Dessaretes" which consists of Lake Ohrid, Lake Megali Prespa, Lake Mikri Prespa, and the now drained Lake Maliq. With their shores shared by North Macedonia, Albania, and Greece, these two lakes are considered the only largest ancient tectonics lakes in Europe and among the eldest in the world, with an age estimated between 2 to 5 million years (Popovska and Bonacci, 2007; Albrecht and Wilke, 2008; Salemaa, 1994). The Lakes formed inside tectonic depression valleys bordered by high mountain reliefs and separated by a karst massif, the Galicica Mountain. Although they appear to be separate, they are connected or were in the past: until recent times, Lake Small (Mikri) Prespa was a gulf of the Great (Megali) Prespa, but due to erosion and sedimentation, they are now separated by an isthmus (Papoutsi-Psychoudaki & Psychoudakis, 2000). In 1969, the excavation of an artificial canal allowed the control of the water level of the Mikri Prespa. The Great Prespa and Ohrid are connected via karst underground conduits through the Galicica and Mali Thate karstic massifs: water from Lake Prespa flows into Ohrid on its southeastern and southern sides (St. Naum and Tushemisht Springs) (Popovska 2006). In addition to these unique characteristics, which underline these lakes cannot be analyzed independently, both have an incredible degree of biodiversity and endemism: Lake Ohrid is often considered the lake with the highest biodiversity/ surface ratio in the world (Stankovic, 1960; Albrecht and Wilke, 2008), while Lake Prespa not only hosts a wide variety of endemic fish species, but mammals and plants enlisted in the annexes "EU Habitats Directive" [4] , such as the juniper woods and the birds coming to spend the winter months above its waters and wet meadows, being one of the most relevant locations of the world for the breeding of the European Pelican species such as the Dalmatian Pelican (Management Plan of the Prespa National Park 2014- 2024, 2014; MIO-ECSDE, 2018). Due to these precious characteristics, in 2014, UNESCO declared the Ohrid- Prespa Transboundary Biosphere Reserve [5] , and large parts of the lakes and their watersheds are National Parks (Soria and Apostolova, 2022). As for many other lakes, Ohrid and Prespa have a long history of association with human civilisations that dates from the Neolithic Age to the present times. For its outstanding heritage, the Ohrid Region was included in the UNESCO World Heritage list [6] . Concerning the Great and Small Prespa, a formal request was submitted by the Permanent Delegation of Greece in 2014 [7] .

Current challenges: water loss, biodiversity, depopulation

Starting from 1986-87, the Great Prespa Lake began to experience a dramatic fall in its water level, which registered its greatest peak between 1987-1995, with significant falls between 1998-2004 and, more recently, 2012-2022 (Popovska and Bonacci, 2007; Soria and Apostolova, 2022; Kuzmanoski et al., 2022; Management Plan of the Prespa National Park 2014-2024, 2014). Between 1987 and 2000, the water level decreased to around 29,7cm/ year (Popovska and Bonacci, 2007). Recent calculations performed with the use of Earth Observation data from the NASA/ USGS Landsat satellite constellation [8] showed that from 1951 to 2022, the water level of the lake declined from 852 to 842 m a.s.l (Soria and Apostolova, 2022; Kuzmanoski et al., 2022). The data becomes increasingly dramatic when the surface and volume of the lake are considered: in 1963, the lake covered an

Subject *the theme central to the scenario thinking*

Timeframe *the theme central to the scenario thinking*

Given 1 *fixed and predictable within the chosen timeframe*

Given 2 *fixed and predictable within the chosen timeframe*

Driver 1 *variable factor within the chosen timeframe*

Driver 2 *variable factor within the chosen timeframe*

Note: *the timeframe should be appropriate to the subject of the scenarios. Given(s) can be multiple: es. climate change. The drivers must be two, es: technological development rate; planetary health.*

Fig. 2: framework for the definition of the scenarios.
source/ scenario thinking scheme created following the instructions defined in Meinert, 2014.

area of 273,85 km2, with an estimated volume of 4,86 km3. In 2022, calculations show a surface of 250,17 km2 and a volume of 2,76 km3. During the last 70 years, the water level dropped by 10 m, the lake shrank by around 23,68 km2, and more than half of its volume was lost (Table 1)(Kuzmanoski et al., 2022). Until 1975, the Micro and the Macro Prespa had the same level. The two started to diverge significantly in 1976, also because of the artificial channel excavated between the lakes, which allowed to maintain a stable level in the Small Prespa (Management Plan of the Prespa National Park 2014-2024, 2014; Albrecht and Wilke, 2008). Over the same period, Ohrid hasn't had particular volume variations (Soria and Apostolova, 2022). Ancient lakes are susceptible to shifts in climate (Hampton et al., 2018), and the decrease in the surface area of water bodies is a natural phenomenon occurring due to sediment deposition and siltation of the basin (Soria and Apostolova, 2022). However, in the case of the Great Prespa Lake, there is a general agreement that even if the water level drop was made worse by a regional drought, it is mainly accountable to uncontrolled anthropogenic activities such as hydrological modification and water abstraction for irrigation and urban uses, at least for the period 1986-87 to 1995 [9] and possibly also for current times (Popovska and Bonacci, 2007; Soria and Apostolova, 2022; van der Schriek & Giannakopoulos, 2017). Agriculture and human settlements are also connected to another challenge for the Ohrid-Prespa System, posing a threat to its biodiversity and endemism: eutrophication. Due to rudimentary or low-efficiency wastewater treatment and sewage management, all human settlements can contribute to an increase in the concentrations of phosphorus and nitrogen in the lake water. Intensive agricultural activities are also a source of nutrient input into water bodies, because of the high amounts of fertilisers and pesticides used. The increased concentration of nutrients is the cause of eutrophication in lakes that irreversibly affects their ecological integrity, causing the loss of endemic species (Hampton et al., 2018). Due to the connection between Prespa and Ohrid, the increase of nutrients in the first might, in the long run, also affect the second, where progressing eutrophication was identified and related to the increased amounts of tourists and residents since the 1940s (Soria and Apostolova, 2022; Albrecht and Wilke, 2008). As for Lake Prespa, a similar trend has occurred on the Albanian side, where the resident population has increased significantly from the 1900s to today, growing from 2,320 to 5,634 individuals. (Management Plan of the Prespa National Park 2014-2024). On the other hand, areas such as the NorthMacedonian side are currently facing depopulation and unemployment, especially among younger generations. From 2016 to 2018, the population aged 15–29 decreased by 1% [2] . Despite the uniqueness of the site and its ecological importance, tourism is small-scale and seasonal, without appropriate services and infrastructure [2] . Also, on the Albanian side, rural households lack adequate insulation to survive the harsh winter conditions, so locals harvest wood from the forests, causing impacts on the biodiversity of the area (Management Plan of the Prespa National Park 2014-2024, 2014).

Sustainable development and cultural tourism: the case of Lanzarote

In the context of development, tourism is recognised as one of the driving forces that can enhance local economies. In particular, cultural tourism—"which cares for the culture it consumes while culturing the consumer" (Richards, 2007, 1)—has the potential to act as a sustainable alternative to mass tourism, by strengthening local identity and communities, creating new jobs, and increasing the overall quality of life for residents. However, for it to be lasting and to guarantee the safeguarding of the involved communities and the natural environment, it must meet sustainability criteria. The definition of sustainable development was coined in 1987 in the United Nations Report of the World Commission on Environment and Development titled Our Common Future, also known as the Brundtland Report, stating that it corresponds to the development that meets the present needs without compromising the ability of future generations to meet their own (United Nations, 1987). In this sense, in 1995, the United Nations World Tourism Organisation

Fig. 3: Earth's ancient landscapes: Lanzarote and Lake Prespa.

published the Charter for Sustainable Tourism (UNWTO, 1995) as the outcome of the World Conference on Sustainable Tourism, held in Lanzarote, in the Canary Islands. In its 12 aims, the Charter states that sustainable tourism should make optimal use of environmental resources, help conserve natural resources and biodiversity, respect the socio-cultural authenticity and heritage of host communities, and provide socio- economic benefits to all stakeholders. Lanzarote's trajectory as a sustainable destination was rooted in a pioneering vision of territorial and cultural planning. Much of this success is due to the shared vision of César Manrique, an internationally renowned artist native of Lanzarote, and José Ramírez Cerdá, president of the Cabildo de Lanzarote, the island's maximum authority. Starting in the 1960s, supported by the political will to promote growth and tourism, they fostered a vision for the modernisation and cultural heritage, volcanic landscapes, vernacular architecture, and agricultural traditions (Scarpa, 2019). These efforts led to the Island Plan of Territorial Organisation in 1973, a pioneering instrument of urban regulation for the Canary Islands. It enabled the preservation of Lanzarote's distinctive characteristics, such as whitewashed, flat-roofed buildings, and prevented the uncontrolled expansion seen on other Canary Islands (Crespi and Salvi, 2021; Scarpa, 2019). It also supported the creation of the Art, Culture and Tourism Centres (CACT), a network of spatial interventions in areas of high natural and cultural value, whose lands were specifically acquired by the Cabildo for this purpose (Peñate, 2019). Their hybrid nature—part natural monument, part museum, part public artwork—offered a new model for sustainable territorial valorisation (Crespi and Salvi, 2021; Peñate, 2019). Manrique was well aware of the great impact that sustainable tourism would bring to the island and was convinced that the key to long-term success lay in the promotion and branding of Lanzarote's unique characteristics. Together with collaborators such as Jesús Soto and Eduardo Cáceres, he designed each CACT to valorise its specific setting—vernacular, agricultural, or natural—aiming not only to attract tourism but also to serve as sites of cultural exchange and to promote local artisanship and products (Crespi and Salvi, 2021). In this regard, it is important to note that several of these sites—such as Jameos del Agua, Cueva de los Verdes, and Jardín de Cactus—were located in landscapes that were previously degraded or neglected (Peñate, 2019). Manrique also strongly advocated for the protection of natural environments that could be endangered by mass tourism. This commitment led to the establishment of the Timanfaya National Geopark in 1974, which encompasses the entire volcanic area created during the eruptions from 1730 to 1736 (Don Andrés Lorenzo Curbelo, 2007; Sánchez et al., 2019). As a result, Manrique's pioneering vision successfully crafted a cultural tourism framework that not only endures but remains deeply embedded in the island's identity and its current sustainability and conservation efforts. Thanks to the continued engagement of local institutions, such as the Cabildo of Lanzarote and the public entity CACT, the island manages to attract millions of visitors annually, drawn to its unique character. For example, in 2016, the iconic site of Jameos del Agua received 750,552 visitors (Peñate, 2019). The island also boasts high employment rates in the tourism sector and offers several training initiatives for local youth (Crespi and Salvi, 2021). According to a recent Deloitte report, CACT activities generated €186.7 million in revenue, translating into €231 million in GDP, sustaining 6,624 jobs and returning €16.2 million in taxes—on an island with only 145,000 inhabitants (Peñate, 2019; VV.AA., 2016). Furthermore, due to its remarkable volcanic features, Lanzarote attracts scientists from all over the world for studies and international conferences, such as the recent 4th International Planetary Caves Conference [10] . Among these visitors are also astronauts and space agencies such as NASA and ESA, who train and conduct research on the island due to its similarities to the Moon and Mars, particularly concerning lava tubes (Sauro et al. 2020; Tomasi et al., 2021; Romio, 2021; Romio and Lobosco, 2025).

source/ the author. (2023)

Tools and Methodology

GIS and Earth Observation Data

A Geographical Information System (GIS) is a computer system that allows the analysis and display of geographically referenced information by attaching data to a unique location on the Earth's surface. GIS technologies are commonly used in many applications, such as Earth sciences, biology, landscape architecture, urban planning, and resource management [11] . The GIS software used in this review is QGIS, which is free, open- source, and maintained by an active community of developers and users who also provide numerous additional plugins that enhance the base capabilities of the tool [12] . One of these is the QGIS Google Earth Engine plugin [13] that integrates Google Earth Engine (GEE) with QGIS, enabling the users to access the GEE Data Catalog [14] and its capabilities directly from QGIS, allowing the users to access incredible amounts of Earth Observation datasets coming from shuttle missions [15] , satellites, and constellations such as Landsat [8] (National Aeronautics and Space Administration), Copernicus [16] (European Space Agency) and many others. On the 22nd of June 1802, the naturalist and scientist Alexander von Humboldt climbed the volcano Chimborazo in Ecuador. From that point of view, he claimed that all the natural systems are connected "like a single fabric made of thousands of threads" (Wulf, 2016), a very different concept of nature from what was the general thought at the time of his discovery. Nowadays, we can observe the interrelation of natural and anthropogenic phenomena with satellites, confirming von Humboldt's theory of the Naturgemälde. For what regards lakes Ohrid and Prespa, previous research successfully used GIS and Earth Observation data (EO) for hydrogeological studies (Kiri, 2016), to quantify the water loss of the Great Prespa between 1984 to 2022 (Kuzmanoski et al., 2022) and to observe variations in landcover (Soria and Apostolova, 2022). In the present article, the combined use of QGIS and EO allows the visualization and investigation of the interrelations between the factors identified to be the key to during the period 1986-87 to 2022, with particular attention on the relationship between the environmental systems and the human settlements development. The EO data utilised for the present study have been retrieved from the open-access Google Engine Data Catalog [14] . The datasets employed in this study are listed below (refer to Section 6.2.2 for dataset access links):

1. JRC Global Surface Water Mapping Layers v1.4: this dataset, developed by the Joint Research Centre (JRC), provides raster data on global surface water occurrence from 1984 to 2022, with a spatial resolution of 30 meters per pixel (Pekel et al., 2016);

2. MODIS Land Cover Type (MCD12Q1) Version 6.1: this raster dataset, derived from the Terra and Aqua MODIS instruments and made available by the NASA LP DAAC at the USGS EROS Center, offers global yearly land cover classifications from 2001 to 2022, at a spatial resolution of 500 meters per pixel (Friedl and Sulla-Menashe, 2022);

3. World Settlement Footprint 2015 (WSF2015): this is a 10-meter resolution raster dataset representing a global map of human settlements for the year 2015, developed as part of the World Settlement Footprint initiative (Marconcini et al., 2020);

4. GHS-UCDB R2019A - GHS Urban Centre Database 2015: this raster-based dataset identifies urban centres worldwide based on population density and built-up surface within a 1×1 km global grid. The reference year is 2015, with historical attributes reaching back up to 40 years, depending on data availability (Florczyk, A. et al., 2019).

The technique of Scenario Thinking aims to depict multiple possible futures in which the current present might result within a set timeline appropriate to the Scenario Thinking Project. Scenarios depend on factors already influential to the specific matter in analysis and the general framework. The development of Scenario Planning happened mainly during the 1950- the 60s as a military strategy to depict possible future conflicts or possible economic and social developments. Very soon, it
started to be adopted by companies, scientists, politics, and a wide variety of users because it proved to be great for policy advice, regional and urban planning, infrastructural developments, social challenges, and conflicts (Meinert, 2014; Di Giulio et al., 2018). In the present work (Fig.2), this methodology allows the presentation of four

equally complex and plausible futures in which the Ohrid-Prespa system might evolve, with a focus on the Great Prespa Lake. The timeframe of this exercise is 2050. The choice of this temporal horizon is due to both the literature on the subject, which suggests a temporal horizon of 20-25 years for regional and development planning (Meinert, 2014), and the current European Union Long-Term Strategy for 2050[3], which, at the moment, represent the heart of EU commitments towards tackling climate change. These resulting scenarios aim to make evident and allow the preventive evaluation of potential impacts that the decisions of today's governments and policymakers might have on the future of the Great Prespa, in the context of the global and local environmental challenges and need for the development of the study area to tackle major societal and economic issues (Mayor of Pustec, Personal communication).

Implementation of Lanzarote's Strategy

The present work suggests implementing practices and strategies derived from the case example of Lanzarote because of its sustainable balance between preservation and development, which are here considered similar to the needs of the area of the Great Prespa. Both are ancient landscapes of very high cultural and scientific importance (Fig.3).

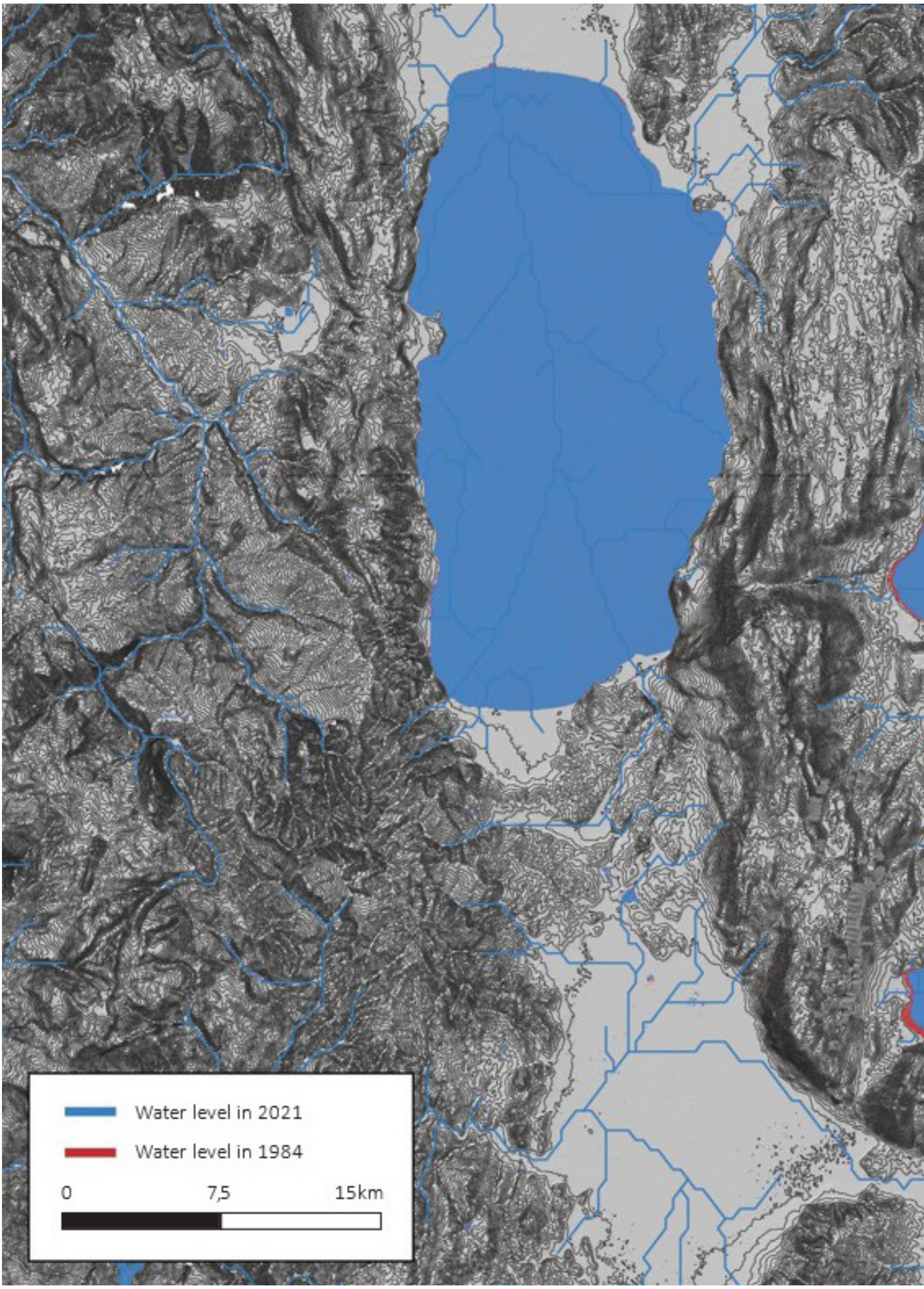


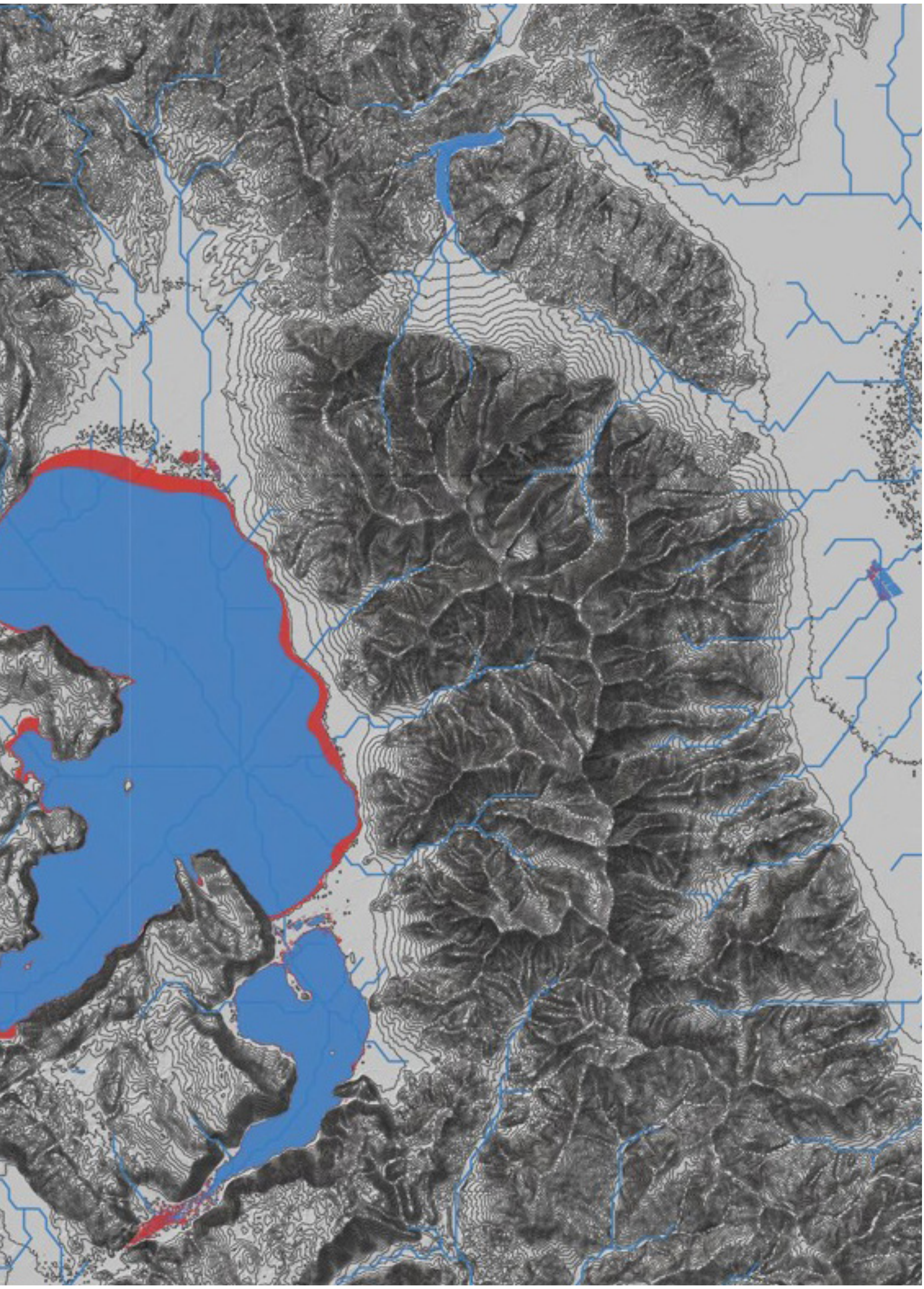
Fig. 4: changes of surface water in the Ohrid-Prespa system from 1984 to 2021.

Moreover, the strategies adopted by Lanzarote are here associated with specific actions already depicted in the Management Plan of the Prespa National Park 2014-2024 and documents such as EU for the Prespa Action Plan[2] (See Section 4.2, scenario n.4).

Discussion and Results

Environmental systems and development

From 1986-87, Lake Great Prespa suffered a loss of around 54% of its volume. Earth Observation (EO) data coming from the JRC Global Surface Water Mapping Layers, v1.4 dataset (Pekel et al., 2016) are used to investigate this phenomenon: the dataset contains the distribution of surface water from 1984 to 2021, providing statistics on the extent and changes of global water sources, including the Ohrid-Prespa system. Implementing this data into QGIS, it is possible to notice the stability of Lake Ohrid's surface water compared to the shrinkage in the southern region of Lake Mikri Prespa and the dramatic water loss faced by the Great Prespa (Fig.4). In particular, such change has had significant effect on the landscapes and shores of the latter: on the northern part, the shoreline has, in some areas, shifted more than 1km from its position in 1984. The causes of these dramatic changes were mostly related to unregulated water



source/SRTM DEM (NASA); JRC Global Surface Water Mapping Layers, v1.4 (Pekel et al, 2016).

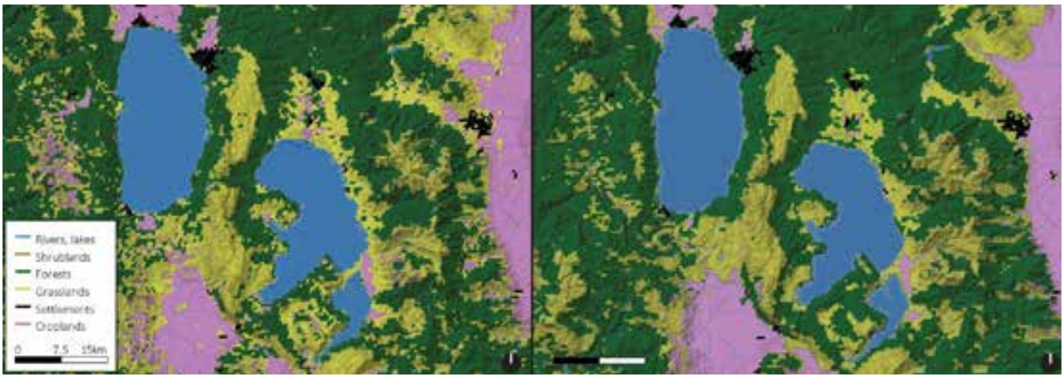


Fig. 5: a) MODIS 2001; b) MODIS 2022. *source/ SRTM DEM (NASA); MODIS (Friedl and Sulla-Menashe, 2022).*

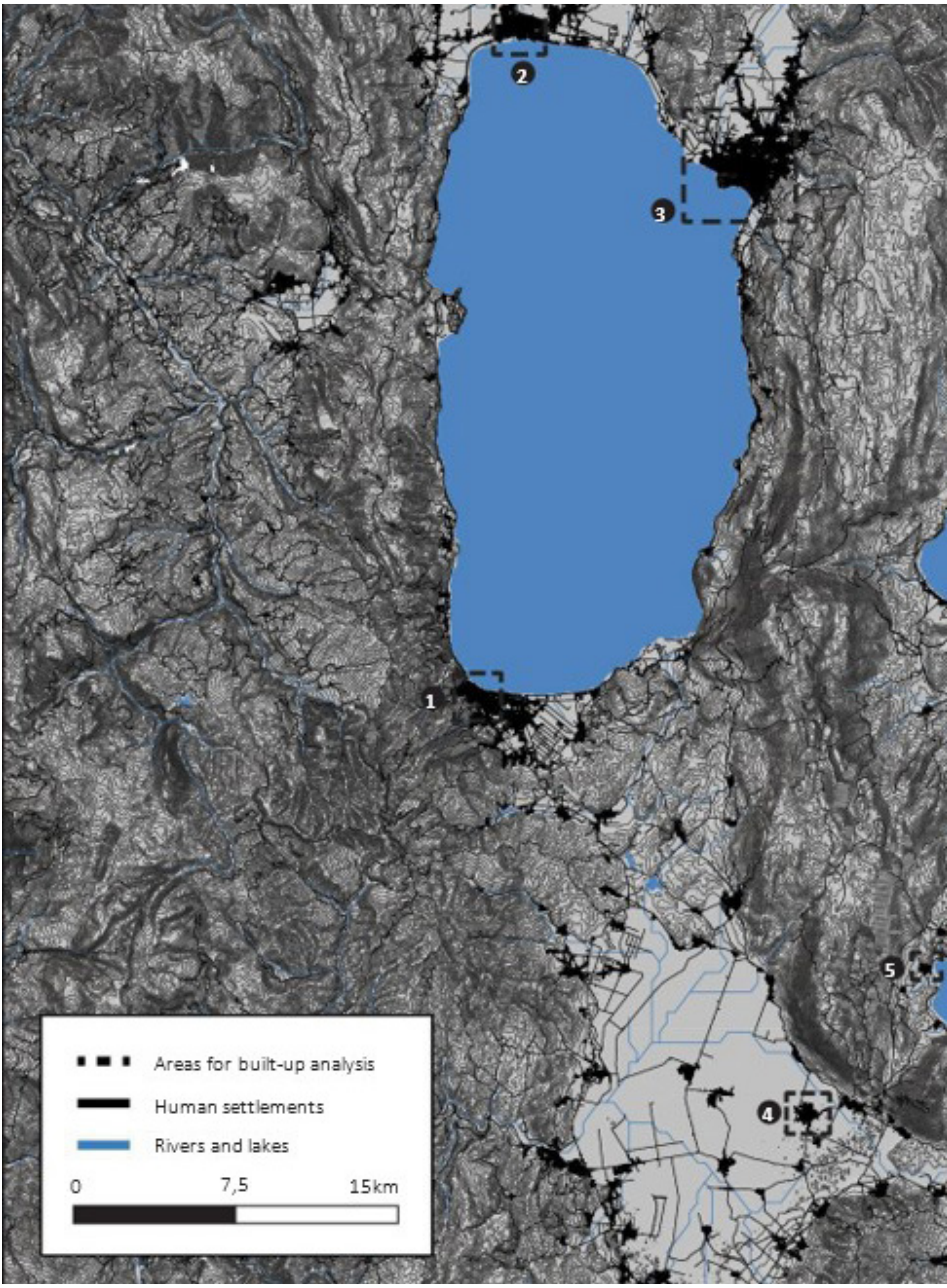
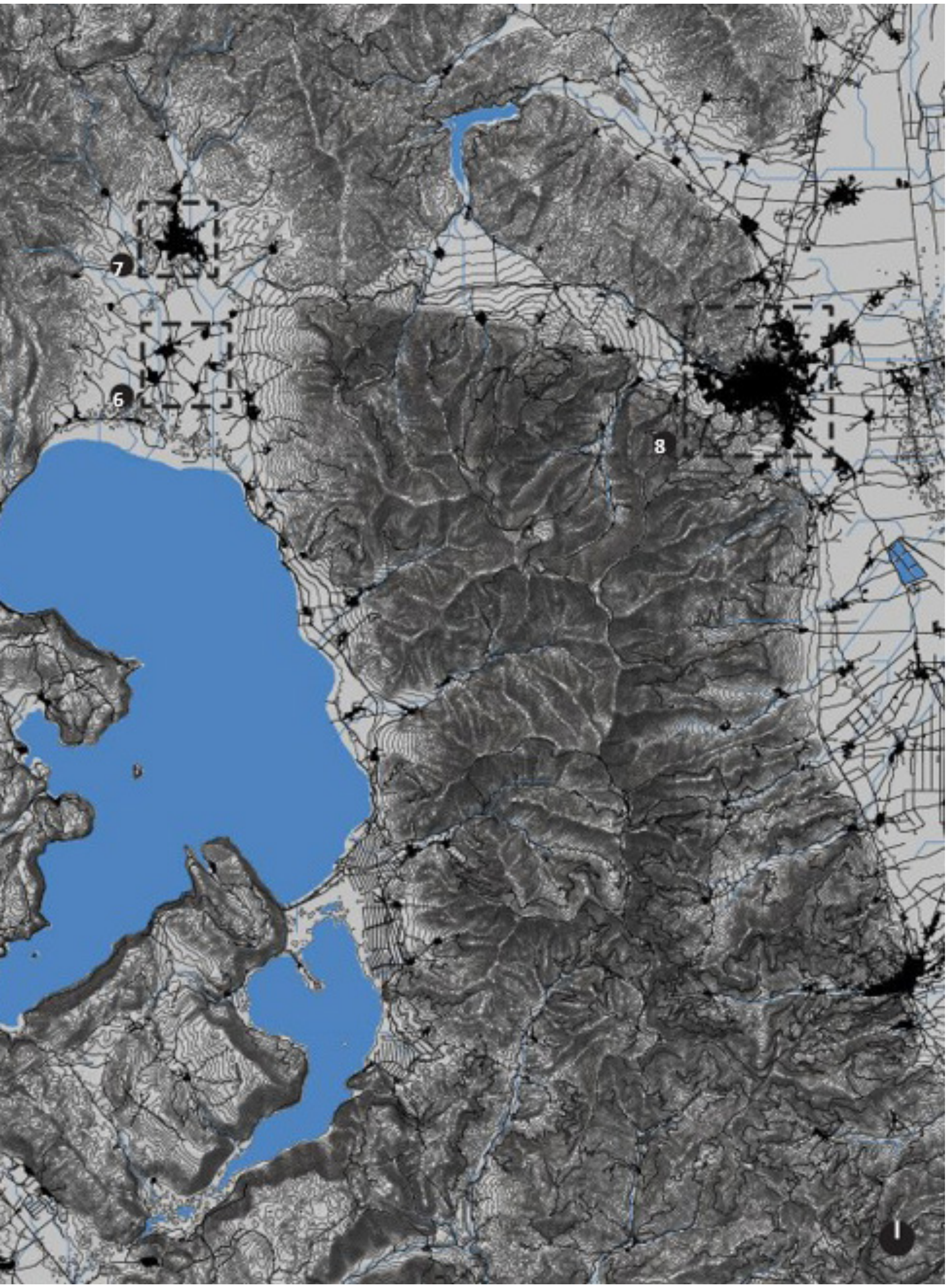


Fig. 6: human settlements and connectivity around Lakes Ohrid and Prespa.

abstraction for agricultural and urban use. To better understand the link between development and deterioration of natural resources, land usage between 2001 and 2022 in the Ohrid-Prespa area is observed with publicly available EO datasets: the Terra and Aqua combined Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type (MCD12Q1) Version 6.1 (Friedl and Sulla-Menashe, 2022). From the analysis of these datasets, it is possible to notice that the agricultural development of the Ohrid-Prespa area was carried out well before 2001 and that from 2001 (Fig.5a) to 2022 (Fig.5b) no large-scale significative changes happened: an overall increase in forested areas can be observed, with some decrease in cropland north and west from Lake Ohrid and above the Great Prespa, while croplands increased south of Ohrid and Prespa and northeast of the latter. Also, the World Settlement Footprint 2015 dataset (Marconcini et al., 2020)(Fig.6), which provides information on the extent of human settlements up to 2016, and the Global Human Settlement Layers, Built-Up Grid 1975-1990-2000-2015 (Florczyk, A. et al., 2019), which gives information regarding how the aforementioned settlements have developed between pre-1975 until 2015 (Appendix A), are used to analyze the urban development. A total of 8 settlements around Ohrid and Prespa



source/SRTM DEM (NASA); World Settlements Footprint 2015 (Marconcini et al., 2020).

Subject	*the future of Lake Prespa*
Timeframe	*2024-2050*
Given 1	*Climate Change*
Given 2	*Cross-boundary nature*
Driver 1	*Development of the area*
Driver 2	*Water level of the Great Prespa Lake*

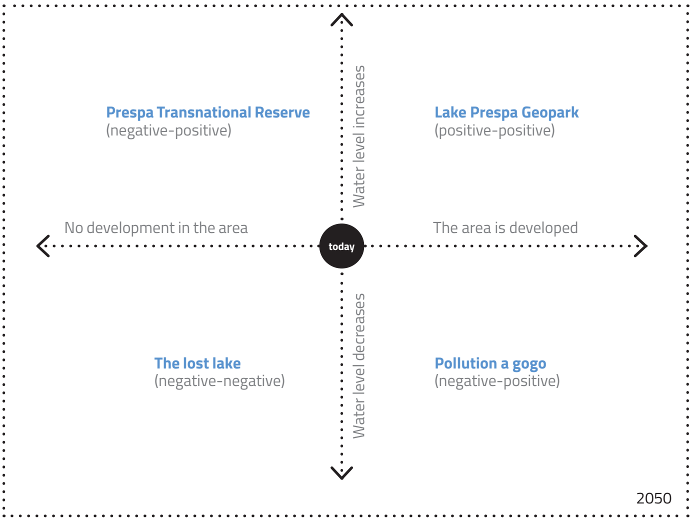


Fig. 7: creation of the scenarios

source/ the author, based on Meinert, 2014

are selected (Fig.6) and analysed (Appendix A). The outcomes of this cross-study clearly show that the main developments happened between 1975 and 1990: some settlements developed almost entirely during this timeframe (Appendix a: fig.4, 6), while only small built areas existed already in 1975 (Appendix a). Development continued until the 2000s, with only a little growth from 2000 to 2015. Matching this data with the Great Prespa lake water loss, it is possible to point out that during periods of intensive development of both agriculture and built environments, there may have been unsustainable abstraction and use of lake water, which would support claims previously made by other authors[9] (Popovska and Bonacci, 2007; Soria and Apostolova, 2022; van der Schriek & Giannakopoulos, 2017).

Future scenarios for Lake Prespa

The Lake Prespa area is currently facing several issues, such as biodiversity loss and declining lake water levels, which have led to the transformation of formerly sandy beaches into shallow, muddy coastal zones[2]. At the same time, the area holds great potential due to its unique geology, rich biodiversity, scenic landscapes, and cultural heritage. To solve these issues, local authorities seek to develop infrastructure, economies, and tourism. However, outcomes of the present and previous studies have established a clear link between past development and the deterioration of the Lake environment and resources. To explore possible futures for Lake Prespa, here it is used the methodology of Scenario Thinking (Fig.7). In particular, it is chosen a timeframe from today to 2050, within which there will be some fixed boundary conditions (given 1, 2), that climatic changes will happen and that Lake Prespa will retain its cross-boundary nature which needs cooperation between the parties, and variables (driver 1,2) which might lead to four different scenarios, all equally plausible. The variables identified in this study are: the Great Prespa water level and development. Each of these variables can either be positive (water level increases; the area is developed) or negative (water level decreases; no development in the area).

▪ Scenario 1: Lake Prespa Transnational Reserve

Due to the alarming drop in Lake Prespa's water level, Albania, North Macedonia, and Greece agreed to establish the Lake Prespa Transnational Reserve. Within this protected area, no further development was allowed, and water abstraction was limited strictly to food production and the sustenance of the local population. After 26 years, the lake's water level has risen and is now stable: pollution has been reversed, the eutrophication process halted, and biodiversity has increased once again. On the other hand, the local population is now ageing, and younger generations are increasingly drawn to opportunities in nearby cities and municipalities, where tourism infrastructure to support eco-tourism has gradually developed over the years.

▪ Scenario 2: the Lost Lake

After the severe drought of 2026, a more drastic trend of water loss began, bringing dramatic consequences for the local population, the Korça region, and the area's biodiversity. Lake Ohrid, once more resilient than Prespa, reached alarming levels of pollution and eutrophication due to the reduced inflow from the karstic springs that were once fed by Great Prespa. Now, 26 years later, Lake Prespa has vanished. A new, altered natural landscape has emerged on the polluted lakebed, while the once-picturesque lakeside towns now lie abandoned.

▪ Scenario 3: Pollution a Go Go

Despite warnings from the scientific community, local authorities in North Macedonia prioritised the development of the Lake Prespa area to prevent the depopulation of surrounding towns and cities. Albania and Greece soon followed, drawn by the potential for business opportunities. In 2026, after two intense years of planning and highly successful marketing campaigns, tourism in the Lake Prespa region experienced a dizzying surge, bringing significant economic growth and employment opportunities. However, year after year, the lake's water level dropped significantly, accompanied by increasing pollution and a cascade of local species extinctions, eventually giving way to alien and invasive species. By 2036, after a decade of touristic success, the lake's surface had shrunk to just half of its 2024 extent. The complete loss of biodiversity and the site's former uniqueness triggered a collapse of the local economy, ultimately leading to the abrupt depopulation and abandonment of the area's towns and cities.

▪Scenario 4: Lake Prespa Geopark

In 2024, principal authorities from Albania, North Macedonia, and Greece gathered together to develop a strategy that could match the need for restoration and protection of the Prespa environment with the development sought by local institutions and the population: EU funds and national incentives were used to adopt prescriptions already enlisted in the Management Plan of the Prespa National Park 2014-2024, such as better insulation for the houses, installation of renewable energy systems and improvement of the heating systems of the households, to tackle illegal woodcutting for heating during the winter months. Also, young agronomists and agriculture specialists were offered employment to work with local farmers to favour the transition from unsustainable and intensive practices to sustainable agroforestry practices. These actions fostered international attention to the Prespa Lake, favouring the adoption of similar strategies in the Ohrid-Prespa system and at other locations, such as Lake Skadar. Today, in 2050, the water level of the Great Prespa has been stable for the last 20 years, and pollution is at the lowest recorded levels. Since the '30s, thanks to the balance between protection and development, the Ohrid-Prespa system became one of the cultural and ecological hotspots in the world, attracting tourists every year who reach the destination to visit its Natural Parks, attend international conferences on biodiversity and environmental protection, visit the local cultural and art centers and the local town and sustainable food festivals.

From Lanzarote to Prespa

As outlined in the previous paragraph, the fourth scenario represents the most favourable outcome in terms of sustainable development and environmental protection. Within the proposed fictional narrative, one can discern the integration of key best practices that contributed to Lanzarote's recognition as a model of sustainable development and cultural tourism. In particular, the preservation of local identity—both of place and community—is safeguarded through planning regulations and restrictions. These measures foster the emergence of sustainable economic and social opportunities, generating long- term benefits for both the environment and the inhabitants of lake villages such as Pustec in Albania, as well as comparable communities in Greece and North Macedonia. In particular, key takeaways that can be extracted from the case of Lanzarote are the following:

▪Political will, aesthetic values and vision

Lanzarote's success would not have been possible without strong institutional support and the active engagement of key stakeholders. This achievement was the result of a convergence of vision, political will, and shared interests among several influential figures—most notably José Ramírez Cerdá, president of the Cabildo de Lanzarote, and the artist César Manrique. Ramírez Cerdá had a clear strategy aimed at improving the island's socioeconomic conditions, modernising infrastructure, and enabling the development of tourism. Manrique, on the other hand, gave tangible form to this vision through a series of experimental cultural centres that not only became iconic tourist destinations but also captured and reinterpreted the unique cultural and landscape features of the island. Similarly, the Lake Prespa region could benefit from a comparable convergence of political vision and stakeholder collaboration. A strong, unified, and transboundary strategy would foster the development of shared initiatives, requiring equal standards of modernisation and infrastructure across the Greek, Albanian, and North Macedonian shores. Such coordination could enable a cohesive touristic experience that highlights the region's diverse yet interconnected landscapes and cultural identities, ultimately promoting balanced territorial development and deeper regional integration;

▪From vision to decades of employment opportunities

As previously discussed in Section 2.4, the shared vision of Manrique and Cerdá not only offered tourists remarkable architecture and landscapes and favoured the protection and preservation of the island's culture and natural heritage, but in doing so it created substantial employment opportunities for the local population of Lanzarote, largely due to the island's strong landscape and cultural branding. Lanzarote has succeeded in generating a multi-layered tourist experience that appeals to visitors on both aesthetic and cultural levels. Tourists are encouraged to explore the volcanic landscapes of Timanfaya, to discover agricultural traditions at the Casa-Museo del Campesino—located near the vineyards of La Gería, the island's primary wine-producing region, where many producers offer tastings and guided visits. They are also drawn underground, into the lava tube of La Corona, visiting sites such as La Cueva de los Verdes and Los Jameos del Agua, where they learn about the island's unique geology and how these caves were historically used by locals for protection from pirate attacks (Romio and Lobosco, 2025). This network of dispersed attractions encourages tourists to explore multiple towns across the island, fostering a desire to immerse themselves in local life. In doing so, visitors support a distributed economy that benefits the island as a whole, rather than concentrating tourism income in just a few areas. Lanzarote thus offers a wide range of experiences: from culinary specialities found only in specific villages, to surfing, and a vibrant local artisan scene involving a large part of the resident population. To help condense these diverse experiences into short stays, a variety of thematic tours led by specialised local guides are available, creating further employment

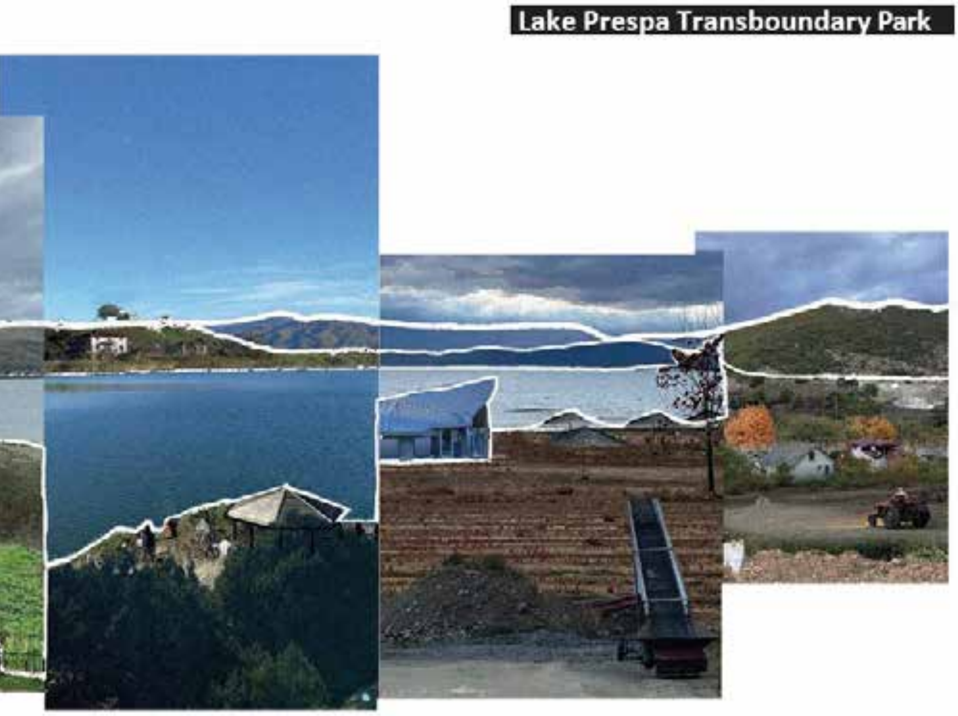
Fig. 7: postcards from Prespa: an emotional collage of transboundary landscapes and cultural heritage components.

source/ the author. (2023)

opportunities. All these factors contribute to the active engagement of the local population in sustaining and shaping Lanzarote's tourism model. A similar approach could be envisioned for the Lake Prespa region. Due to the very nature of the lake, shared across Albania, Greece, and North Macedonia, there is a strong potential for designing a transboundary tourism strategy that highlights the diversity and complementarity of its cultural and natural assets. A coordinated and balanced development of infrastructure, services, and cultural offerings across the three national shores could enable visitors to experience the lake as a unified yet plural landscape. This would not only enhance the overall attractiveness of the region but also ensure an equitable distribution of economic benefits and employment opportunities, fostering local engagement and cross-border cooperation rooted in shared heritage and ecological responsibility. Such a strategy could also revitalise local economies by promoting small-scale, sustainable production sectors— including traditional crafts, agri-food products, and eco-tourism services—that reflect the unique identity of each lakeside community (Fig.8). Supporting the development of locally rooted value chains and new market opportunities, particularly in cultural and environmental fields, could provide meaningful employment for younger generations, while preserving the social and cultural fabric of the region.

Conclusions

In this study, it has been evidenced how the case of Lake Prespa, with its exceptional ecological, geological, and cultural significance, represents both a challenge and an opportunity for rethinking development in cross-border and environmentally sensitive regions. The use of Earth Observation data and GIS systems, provide supporting evidence to what other researchers had already claimed regarding the on-going decline of the Great Prespa Lake, which poses a serious threat not only to the ecological integrity of the Ohrid-Prespa system, but also to the long-term social and economic viability of its surrounding communities. However, by envisioning alternative futures through scenario thinking, it becomes evident that a different trajectory is still possible. Among the four scenarios proposed in this study, the most desirable outcome—represented by the "Lake Prespa Geopark" vision—demonstrates how restoration and development can go hand in hand when supported by strong political commitment, cross-border cooperation, and community-based strategies. In this regard, the island of Lanzarote provides a valuable precedent. Its success in balancing environmental conservation with economic development through cultural tourism and territorial branding stands as a compelling model for Prespa and other remote, heritage-rich regions. By drawing inspiration from Lanzarote, Lake Prespa could embrace a path of integrated and sustainable development. This would require not only the reinforcement of ecological protection measures but also the promotion of local identity, cultural heritage, and place-based economies, particularly in the fields of agroecology, craftsmanship, and eco-tourism. Crucially, such a strategy would offer long-term employment opportunities and help retain younger generations, reversing ongoing trends of depopulation and underdevelopment. Ultimately, the future of Lake Prespa depends on the capacity of national and local institutions to coordinate across borders, invest in sustainable infrastructure, and engage communities in shaping a shared vision. If supported by coherent policies and adequate funding, this region has the potential to become a leading example of how environmental stewardship



and cultural valorisation can generate resilient and inclusive rural futures.

References

Bibliography

Albrecht, C., Wilke, T. (2008). Ancient Lake Ohrid: biodiversity and evolution. Hydrobiologia, 615, 103–140, https://doi.org/10.1007/s10750-008-9558-y;

Bojkovska, R. (2022, April). Lake Ohrid: transboundary monitoring. UNECE. https://unece.org/sites/default files/2022-04/Presentation_Radmila%20%20Bojkovska_UNECE_LONG_FOR_WEB%20%281%29.pdf;

Curbelo, Don A. L. (2007). Quando i Vulcani Eruttarono Fuoco: Diario di Lanzarote. Appunti sugli eventi degli anni dal 1730 fino al 1736. Lanzarote, Spain: Editorial Yaiza S.L;

Di Giulio, R., Emanueli, L., & Lobosco, G. (2018). Scenario's evaluation by design. A "scenarios approach" to resilience. TECHNE - Journal of Technology for Architecture and Environment (15), 92–100. https://doi.org/10.13128/Techne-22118;

Eftimi, R. & Zoto, J. (1997, October 24-26). Isotope study of the connection of Ohrid and Prespa lakes [Paper Presentation]. Towards Integrated Conservation and Sustainable Development of Transboundary Macro and Micro Prespa Lakes International Symposium: Korcha, Albania;

Ferrer Peñate, M. (2019). Lanzarote, César Manrique and the Creation of the Art, Culture and Tourism Centres, 1960– 1976. In: Mateo, E., Martínez-Frías, J., Vegas, J. (eds) Lanzarote and Chinijo Islands Geopark: From Earth to Space. Geoheritage, Geoparks and Geotourism. Springer, Cham. https://doi.org/10.1007/978-3-030-13130-2_12;

Florczyk, A., Corbane, C., Schiavina, M., Pesaresi, M., Maffenini, L., Melchiorri, M., Politis, P., Sabo, F., Freire, S., Ehrlich, D., Kemper, T., Tommasi, P., Airaghi, D., Zanchetta, L. (2019). GHS-UCDB R2019A- GHS Urban Centre Database 2015, multitemporal and multidimensional attributes. European Commission, Joint Research Centre (JRC) [Dataset] doi: 10.2905/53473144-b88c-44bc-b4a3-4583ed1f547e;

Friedl, M., Sulla-Menashe, D. (2022). MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V061 [Data set]. NASA EOSDIS Land Processes Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MCD12Q1.061;

Fritz, S. C., P. A. Baker, E. Ekdahl, G. O. Seltzer, and L. R. Stevens. (2010). Millennial-scale climate variability during the Last Glacial period in the tropical Andes. Quat. Sci. Rev. 29, 1017–1024. https://doi.org/10.1016/j. quascirev.2010.01.001;

Hampton, S.E., McGowan, S., Ozersky, T., Virdis, S.G.P., Vu, T.T., Spanbauer, T.L., Kraemer, B.M., Swann, G., Mackay, A.W., Powers, S.M., Meyer, M.F., Labou, S.G., O'Reilly, C.M., DiCarlo, M., Galloway, A.W.E. and Fritz, S.C. (2018), Recent ecological change in ancient lakes. Limnol. Oceanogr., 63, 2277-2304. https://doi.org/10.1002/lno.10938;

Kaneko, K., and others. 2003. Renal tubular dysfunction inchildren living in the Aral Sea region. Arch. Dis. Child. 88: 966–968. doi:10.1136/adc.88.11.966

Kiri, E. (2016). GIS: A USEFUL TOOL FOR MANAGING OF TRANSBOUNDARY AQUIFERS: A CASE STUDY FROM PRESPA LAKE BASIN. Bulletin of the Geological Society of Greece 50(2), 750–759. https://doi.org/10.12681/bgsg.11781;

Kolaneci, M. (2004, May 25-29). Hydrology Of Prespa Lakes [Paper Presentation]. Balwois 2004: Ohrid, FY Republic of Macedonia;

Kostoski, G., Albrecht C., Trajanovski, S. and Wilke, T. (2010). A freshwater biodiversity hotspot under pressure— Assessing threats and identifying conservation needs for ancient Lake Ohrid. Biogeosciences 7: 3999–4015. http://10.5194/bgd-7-5347-2010;

Marconcini, M., Metz-Marconcini, A., Üreyen, S., Palacios-Lopez, D., Hanke, W., Bachofer, F., Zeidler, J., Esch, T., Gorelick, N., Kakarla, A., Paganini, M., Strano, E. (2020). Outlining where humans live, the World Settlement Footprint 2015. Scientific Data, 7(1), 1-14. https://doi.org/10.1038/s41597-020-00580-5;

Matzinger, A., Spirkovski, Z., Patceva, S., WÜest, A. (2006). Sensitivity of ancient Lake Ohrid to local anthropogenic impacts and global warming. Journal of Great Lakes Research 32: 158–179. https://doi.org/10.3394/0380- 1330(2006)32[158:SOALOT]2.0.CO;2;

Meinert, S. (2014). Manuale Elaborazione di scenari. Bruxelles, Belgium: European Trade Union Institute;

MIO-ECSDE. (2018). The natural wealth and legacy of the Drin River Basin: inspiring our collective actions. Athens, Greece: MIO-ECSDE and Act4Drin;

Popovska, C., Bonacci, O. (2007). Basic data on the hydrology of Lakes Ohrid and Prespa. Hydrological Processes, 21(5), 658- 664. https://doi.org/10.1002/hyp.6252;

Nomokonova, T., R. J. Losey, A. Weber, O. I. Goriunova, and A. G. Novikov. (2010). Late Holocene subsistence practices among cis-Baikal pastoralists, Siberia: Zooarchaeological insights from Sagan-Zaba II. Asian Perspect. 49, 157–179. http://10.1353/asi.2010.0001;

Papoutsi-Psychoudaki, S. & Psychoudakis, A. (2000, June 23-25). Agricultural externalities and policy for sustainable agriculture in the Greek part of Prespa [Paper Presentation]. Sustainable development of Prespa region: Otesehvo, FY Republic of Macedonia;

Pekel, JF., Cottam, A., Gorelick, N. et al. (2016). High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016). https://doi.org/10.1038/nature20584;

Richards, G. 2007. Cultural Tourism: Global and Local Perspectives. New York: Haworth;

Romio, F. A.P. (2022, September 18-22). Mars Underground: a Landscape Strategy for Long Term Human Colonies on the Red Planet. 73rd IAC 2022, Paris, France;

Romio, F. A. P., & Lobosco, G. (2025). Underground landscapes: volcanism, lava tubes, and man. Tunnelling and Underground Space Technology, 162, 106618. https://doi.org/10.1016/J.TUST.2025.106618;

Rossiter, A., and Kawanabe, H. (eds.). (2000). Ancient lakes: Biodiversity, ecology and evolution, 680. p. Cambridge (Massachusetts), United States: Academic Press;

Sauro, F., Pozzobon, R., Massironi, M., De Berardinis, P., Santagata, T., De Waele, J. (2020). Lava tubes on Earth, Moon and Mars: A review on their size and morphology revealed by comparative planetology. Earth-Science Reviews 209. https://doi.org/10.1016/j.earscirev.2020.103288;

Salemaa, H. (1994). Lake Ohrid. In Martens K., B. Goddeeris & G. Coulter (eds), Speciation in Ancient Lakes. Advances in Limnolog, Vol. 44: 55–64. Stuttgart, Germany: Schweizerbart science publishers;

Sánchez, N., Romero, C., Vegas, J., Galindo, I. (2019). Geological and Geographical Setting of Lanzarote and Chinijo Islands UNESCO Global Geopark. In: Mateo, E., Martínez-Frías, J., Vegas, J. (eds), Lanzarote and Chinijo Islands Geopark: From Earth to Space. Geoheritage, Geoparks and Geotourism. Springer, Cham. https://doi.org/10.1007/978-3-030- 13130-2_2;

Scarpa, A. (2019). César Manrique: Acupuntura Territorial en Lanzarote. Lanzarote, Spain: Centros de Arte, Cultura y Turismo del Cabildo de Lanzarote;

Stager, J. C., D. B. Ryves, B. M. Chase, and F. S. R. Pausata. (2011). Catastrophic drought in the Afro-Asian monsoon region during Heinrich Event 1. Science 331, 1299–1302. 10.1126/science.1198322;

Stankovic, S. (1960). The Balkan Lake Ohrid and Is Living World. Monographiae Biologicae, Vol. IX. Den Haag, Netherlands: Uitgeverij Dr. W. Junk;

Tomasi, I., Massironi, M., Meyzen, C. M., Pozzobon, R., Sauro, F., Penasa, L., et al. (2022). Inception and evolution of La Corona lava tube system (Lanzarote, Canary Islands, Spain). Journal of Geophysical Research: Solid Earth 127, e2022JB024056. https://doi.org/10.1029/2022JB024056;

United Nations World Commission on Environment and Development. (1987). Our Common Future. Oxford, United

Kingdom: Oxford University Press;

United Nations World Toursim Organization. (1995). Charter for Sustainable Tourism. Madrid, Spain: UNWTO;

van der Schriek, T. and Giannakopoulos, C. (2017). Determining the causes for the dramatic recent fall of Lake Prespa(southwest Balkans). Hydrol. Sci. J. 62, 1131–1148. https://doi.org/10.1080/02626667.2017.1309042;

VV.AA. (2016) Análisis y evaluación de la contribución socioeconómica de los Centros de Arte, Cultura y Turismo, Deloitte;

Wulf, A. (2023). L'invenzione della natura. Le avventure di Alexander Von Humboldt, l'eroe perduto della scienza (2nd ed.). Rome, Italy: Luiss University Press;

Zacharias, I., Bertachas, I., Skoulikidis, N., Koussouris, T. (2002). Greek lakes: Limnological overview. Lakes & Reservoirs: Research and Management 7: 55–62. https://doi.org/10.1046/j.1440-1770.2002.00171.x.

Sitography

Drin Coordinated Action for a Sustainable Future. (2016). Drin Basin. Drin Corda. http://drincorda.iwlearn.org/drin-river-basin;

Republic of North Macedonia. (2021). Action Document for "EU for Prespa". European Neighbourhood Policy and Enlargement Negotiations (DG NEAR). https://neighbourhood-enlargement.ec.europa.eu/document/ download/2d7d7d81-416d-4788-9f15-1e7d47f79192_en;

European Commission. (2020). EU long-term strategy for 2050. EU Action. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_it;

European Commission. (1992). EU measures to conserve Europe's wild flora and fauna. EU Nature and biodiversity. https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en;

UNESCO. (2014). Ohrid-Prespa Transboundary Biosphere Reserve, Albania/North Macedonia. UNESCO Biosphere reserves in Europe & North America. https://en.unesco.org/biosphere/eu-na/ohrid-prespa;

UNESCO. (1979). Natural and Cultural Heritage of the Ohrid Region. UNESCO World Heritage List. https://whc.unesco.org/en/list/99/;

UNESCO. (2014). Tentative List: The Area of the Prespes Lakes: Megali and Mikri Prespa which includes Byzantine and post-Byzantine monuments. UNESCO Tentative List. https://whc.unesco.org/en/tentativelists/5864/;

NASA. (1972). Landsat Science. NASA. https://landsat.gsfc.nasa.gov;

ETHNIKO ASTEROSKOPEIO ATHINON (2016) Why the Prespa Lakes are shrinking. CLIM-HYDROLAKE. https://cordis. europa.eu/article/id/202122-why-the-prespa-lakes-are-shrinking;

LPI. (2023). 4th International Planetary Caves Conference, Lanzarote May 4-7th. LPI. https://www.hou.usra.edu/meetings/4thcaves2023/.000000;

USGS. (2024). What is a geographic information system (GIS)?. USGS. https://www.usgs.gov/faqs/what-geographic-information-system-gis#:~:text=Geographic%20Information%20Systems,resource%20management%2C%20and%20 development%20planning;

QGIS. (2024). QGIS: A Free and Open Source Geographic Information System. QGIS. https://www.qgis.org/it/site/;

Gee-community .(2024). QGIS Google Earth Engine plugin. https://gee-community.github.io/qgis-earthengine-plugin/;

Google. (2024). Earth Engine Data Catalog. https://developers.google.com/earth-engine/datasets;

1USGS. (2018). EROS Archive- Digital Elevation- Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global. Earth Resources Observation and Science (EROS) Center. https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital- elevation-shuttle-radar-topography-mission-srtm-1;

ESA (2024) Copernicus Satellites. Copernicus. https://

www.copernicus.eu/it/informazioni-su-copernicus/infrastruttura/ scopri-i-nostri-satelliti.

Database

▪ *JRC Global Surface Water Mapping Layers v1.4: https://developers.google.com/earth-engine/datasets/catalog/JRC_GSW1_4_GlobalSurfaceWater?hl=it;*

▪ *MODIS Land Cover Type (MCD12Q1) Version 6.1: https://developers.google.com/earth-engine/datasets/catalog/MODIS_061_MCD12Q1?hl=it#description;*

▪ *World Settlement Footprint 2015 (WSF2015): https://developers.google.com/earth-engine/datasets/catalog/DLR_WSF_ WSF2015_v1?hl=it;*

▪ *GHS-UCDB R2019A- GHS Urban Centre Database 2015: https://data.jrc.ec.europa.eu/dataset/53473144-b88c-44bc-b4a3-4583ed1f547e*