THE ANTHROPOCENE AND ISLANDS:

VULNERABILITY, ADAPTATION AND RESILIENCE TO NATURAL HAZARDS AND CLIMATE CHANGE

Miquel Grimalt Gelabert - Anton Micallef - Joan Rossello Geli
Editors

Preface by
Ilan Kelman

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OPEN ACCESS PEER-REVIEWED SERIES
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Cover: imaginary representation of a tsunami that impacted an island. Source: pixabay.com

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Geographies of the Anthropocene

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Geographies of the Anthropocene

Open Access and Peer-Reviewed series

The book series "Geographies of the Anthropocene", edited by the international scientific publisher "Il Sileno Edizioni", will discuss the new processes of the Anthropocene epoch through the various worldviews of geoscientists and humanists, intersecting disciplines of Geosciences, Geography, Geoethics, Philosophy, Socio-Anthropology, Sociology of Environment and Territory, Psychology, Economics, Environmental Humanities and cognate disciplines.

Geoethics focuses on how scientists (natural and social), arts and humanities scholars working in tandem can become more aware of their ethical responsibilities to guide society on matters related to public safety in the face of natural hazards, sustainable use of resources, climate change and protection of the environment. Furthermore, the integrated and multiple perspectives of the Environmental Humanities, can help to more fully understand the cultures of, and the cultures which frame the Anthropocene. Indeed, the focus of Geoethics and Environmental Humanities research, that is, the analysis of the way humans think and act for the purpose of advising and suggesting appropriate behaviors where human activities interact with the geosphere, is dialectically linked to the complex concept of Anthropocene.

The book series "Geographies of the Anthropocene" publishes online volumes, both collective volumes and monographs, which are set in the perspective of providing reflections, work materials and experimentation in the fields of research and education about the new geographies of the Anthropocene.

"Geographies of the Anthropocene" encourages proposals that address one or more themes, including case studies, but welcome all volumes related to the interdisciplinary context of the Anthropocene. Published volumes are subject to a review process (**double-blind peer review**) to ensure their scientific rigor.

The volume proposals can be presented in English, Italian, French or Spanish.

The choice of digital Open Access format is coherent with the flexible structure of the series, in order to facilitate the direct accessibility and usability by both authors and readers.

CONTENTS

Preface

Ilan Kelman[1]

Humanity and the environment are inseparable. No way exists to avoid their mutual influence, their mutual dependence, or their mutual support. Islands as homes for life and livelihood illustrate this intertwining perfectly, demonstrated by science and by islander experience. Science and experience are also interconnected, systemising and disseminating knowledge which islanders have developed, held onto, and implemented for centuries and millennia to ensure that their island becomes and remains their home.

This book supports the prominence of island approaches through eight chapters presenting and analysing island-related examples. The focus is society-nature integration, never assuming a duality or separation which then needs to be forced together, but instead accepting as the starting point that it is not possible to have one without the other. The research presented by the diverse authors is framed within the buzzword of the so-called "Anthropocene", but also recognises that there might not be a single, linear, one-size-fits-all Anthropocene pathway. Multiple changes and influences occur simultaneously at all scales, forging numerous Anthropocenes with hierarchies and dominating factors morphing according to specific circumstances and contexts.

The richness of this approach is shown by the book's first half, comprising a quartet of chapters on Italy. Cannizzaro et al. detail the long-term process of volcanic disaster risk creation for the Catania area of Sicily while Corsale et al. cover a breadth of vulnerabilities and hazards for Sardinia. Much in both chapters relates to local decision-making generating risk—yet the decisions are made for understandable reasons, aiming for livelihoods and opportunities for the people. This theme is repeated by Gugg for earthquakes rattling Ischia and by Messina for tsunamis striking Stromboli. While it might seem odd that these dangerous hazards are apparently not prioritised in terms of risk reduction, especially given past lethal experiences, decisions are being taken within wider contexts of people viewing the places as their home and wishing to have fulfilling lives and livelihoods there.

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As such, the case studies epitomise the depth of vulnerability as a long-term process which must consider multiple factors—and this is a baseline lesson from decades of island studies. In some Anthropocene discourses, this long-term view of vulnerability (and resilience) has been frequently neglected or circumvented in favour of a perspective which focuses on climate change by preferring a superficial snapshot of the present state. The chapters here reinvigorate the need for cultural depth, historical understandings, and processual insights to identify and then tackle the real, long-term causes of vulnerabilities.

Illustrating how climate change and Anthropocene discourses can and should embrace the long-term view of vulnerability, this book's second half presents four chapters accepting the need for the contextual and processual approach to vulnerability, even for climate change. de Mesnard selects what it is effectively the only current example of communities seeking to move due to climate change: coastal indigenous island communities in Alaska. The need to relocate does not stand alone, but must be considered within the communities' cultures, histories, and indigeneities, because all of these contribute to creating and tackling the identified vulnerabilities.

Depraetere et al. continue with climate change while returning to the Mediterranean. They detail climate change's physical impacts alongside those of tourism for a slew of islands followed by a focus on Rhodes and Samos, especially with respect to fresh water. Irrespective of the physicality of climate change impacting water, they offer plenty of solutions for reducing vulnerabilities though concerted efforts over the long-term. Faye et al. continue the water theme, but head south to explore the island of Carabane situated at the mouth of the Casamance River in Senegal. They note how the changing fresh water regime emerges from both declining precipitation—as part of wider climate variabilities, not just climate change—and increasing water use. The key to dealing with the challenges is management, rather than worrying too much about the climate. The book's final chapter by Oueslati stays in Africa by covering five groups of Tunisia's isles. The necessity of the long-term view for understanding and interpreting vulnerability is evidenced by adopting an archaeological perspective.

This collection of chapters encompasses three continents, an array of disciplines, well-known and lesser-known islands, and a diversity of hazards and risks—always converging on the needed concepts of vulnerabilities.

Climate change is present, as it must be considered, but never dominates, as it never should. Anthropocenes are incorporated into the analyses, yet the focus is rightly on people and places rather than buzzwords. This book is an important step forward in using islands and islander experiences to document the realities which people face in addressing difficult situations.

While risks might not always be reduced as much as external observers might want, the reasons for these decisions are far from illogical, balancing different needs and perspectives. It does mean that sometimes disasters are being set up to happen, although the people also deal with the day-to-day disasters of not earning enough income to have enough food and water. The lesson from these island analyses is perhaps that the Anthropocene should be more about what we do to others on a daily basis to remove opportunities and to increase marginalisation and inequity, rather than highlighting large-scale environmental changes.

Introduction

Miquel Grimalt-Gelabert[1], *Anton Micallef*[2], *Joan Rosselló-Geli*[3]

Islands are, by definition, spaces with a clear spatial limitation, which determine some geographical characteristics that make them really sensible to impacts and changes. In those spaces there are conditions for a microcosm of physical and human trends, combining by the resources limitation originated by the reduced physical surface and the coastal presence. All together make island especially fragile facing problems linked to oceanic areas, usually located in geological active areas and, therefore, subject to internal risk factors, result of seismicity and volcanism.

Societies living on such territories follow particular development patterns, usually related to high human pressure on land and with economies and structures based on activities highly sensitive to

Natural hazards have a special effect on islands, both at natural and human level. Factors such as droughts, intense rainfall, landslides, volcanic eruptions and hurricanes or typhoons can originate catastrophes while, at the same time, human actions can also generate negative impacts over such limited and sensitive areas, often of difficult solution.

In terms of disruptions on the physical surroundings, is clear the importance of climate change on the island's future, worldwide. Temperatures increases, the raise of sea level and changes on rainfall distribution-and consequently on the availability of water resources-will have large effects, worsening pre-existing situations or causing their emergence in previously non affected territories.

Hence the need for an overall overview about the problems affecting insular regions, from the smallest to the largest ones, problems ranging from risks historically located in an area to the emergence of new ones, all together related to phenomena like the increase of population, the urban growth and the current climate crisis.

Due to all the above, this volume of the series "Geographies of the Anthropocene", titled "*The Anthropocene and islands: vulnerability,*

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adaptation and resilience to natural hazards and climate change" sought to bring together contributions about different aspects, affecting islands, with the objective to show how visions coming from different research areas can provide an overall vision about risks and climate change, an overview useful for geographically different regions, both for its size and for its socio-economical characteristics.

The chapters provide contributions from a large variety of geographical areas, ranging from the Pacific American coast to the Atlantic Africa shores and, finally, ending in the Mediterranean Sea. Within the Mediterranean, there are examples of subjects on African and European coasts and also from the western and eastern basins. At the same time, there is a variety of insular dynamics, depending on the scale of the analyzed regions, from the largest islands like Sicily or Sardinia to the smallest like Ischia, Stromboli or the Sahel islets.

Regarding topics, we can find chapters related to natural risk, with a special emphasis on the risk derived from tectonical and volcanical activity in the central Mediterranean Sea, while other subjects are related to climate change and its impact at different levels, from a societal view regarding the indigenous communities displacement to the variability of water resources and the loss of historical and cultural heritage with the possible disappearance of islets in the North African coast.

At all times, the contributions do not set aside the importance of the anthropogenic side of the described processes. Societies are not passive actors in front of a dangerous or a changing environment but they may, by themselves, create, accelerate, aggravate or mitigate the environmental impacts. Fully into the Anthropocene, the active account of the human factor is included in all of the chapters of this volume.

The lack of resources often leads to a dependency of external help that not always is adequately fulfilled for the islanders. Simultaneously, the inability to solve problems like the sea level increase implies the need to relocate communities that will lose their traditional lands and should find new areas to live. This view of islands as particularly vulnerable zones appears in Adèle de Mesnard chapter, regarding the sparsely populated Alaska islands, and also in Ameur Oueslati one, related to the Sahel islets, a Mediterranean land with a historical human presence and endangered heritage assets in front of a rising sea and an uncontrolled urban pressure.

Economical activities and the growing demand on water resources is the subject of the chapter from Christian Depraeterel Konstantinos X. Soulis, Demetrios E. Tsesmelis, Georgios Avgoustidos and Ioannis Spilaris, in

which the effects of the change of the rainfall regime are related to the water availability on Mediterranean touristic islands.

The population increase factor is the main subject for Salvatore Cannizzaro, Antonio Danese and Riccardo Privitera contribution, regarding the population centers around the Etna, the largest volcano of Europe, located in the largest island of the Mediterranean. The volcanic risk and its seismic derivations are studied by Messina is his chapter about Stromboli. Without volcanoes but affected by telluric movements, the island of Ischia is studied by Giovanni Gugg, analyzing an often earthquake affected land.

The societal answer in front of the risk is explained by the territorial planning and preventive actions from public administrations, both subjects developed by Andrea Corsale, Carlo Perelli and Giovanni Sistu in their chapter about Sardinia.

Finally, it is important to know how is the societal perception of risk, the resources limitation and the global change, issues analyzed by Cheikh Faye and Antoine Demba Manga regarding the island of Carabane, in the Senegal coast.

A variety of approaches about problems with a common topic, the insular perspective and a holistic vision is what is offered in this volume, nowadays available to readers.

Introducción

Miquel Grimalt-Gelabert[1], Anton Micallef[2], Joan Rosselló-Geli[3]

Las islas son, por definición, unos espacios con unos límites espaciales concretos que determinan unas características geográficas que las hacen particularmente sensibles a impactos y cambios. En los territorios insulares se dan condiciones de un microcosmos físico y humano especiales combinándose la inherente limitación de recursos marcada por el espacio reducido y por la presencia del factor litoral que las hace especialmente frágiles frente a las problemáticas ligadas a los medios oceánicos y muchas veces ubicadas en áreas geológicamente activas y por lo tanto sometidas a los factores de riesgo interno derivados de la sismicidad y el vulcanismo.

Las sociedades que habitan este tipo de territorios también siguen pautas de desarrollo particulares, a menudo con una elevada ocupación humana y dando lugar a economías y a estructuras basadas en el desarrollo de actividades económicas muy sensibles a las inclemencias del medio.

Los riesgos naturales tienen una especial incidencia en los espacios insulares, tanto a nivel natural como a nivel humano. Factores como las sequías o las lluvias intensas, los deslizamientos de tierras, las erupciones volcánicas y huracanes o tifones pueden originar catástrofes y al mismo tiempo las actuaciones humanas pueden generar sobre estos medios físicos sensibles y limitados impactos negativos de difícil solución.

En cuanto a las alteraciones en el medio físico, se hace especialmente evidente la importancia del cambio climático en el devenir futuro de las islas en todo el mundo. Los incrementos de la temperatura, el aumento del nivel del mar y las modificaciones en la distribución de las precipitaciones – y en consecuencia sobre la disponibilidad de recursos hídricos- tendrán un especial efecto agravando situaciones ya existentes o provocando su aparición en territorios no afectados hasta el momento.

Por todo ello hace falta una visión general que muestre el conjunto de problemas que afectan a los espacios insulares, desde los más pequeños hasta aquellos de mayor extensión; problemas que van desde la existencia

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de riesgos históricamente localizados en un territorio hasta la aparición de nuevos, todo ello ligado a fenómenos como el incremento del número de habitantes, la expansión de la urbanización o la crisis climática actual.

Es por ello que este número de la revista "Geographies of the Anthropocene", titulado "The Anthropocene and islands: vulnerability, adaptation and resilience to natural hazards and climate change" quiere reunir un conjunto de aportaciones sobre diferentes aspectos que afectan a las islas con el objetivo de mostrar como visiones que surgen desde diferentes disciplinas pueden aportar una visión global sobre los riesgos y el cambio climático, visión que puede ser útil para espacios geográficamente diferenciados, tanto por tamaño como por características socio-económicas.

El volumen reúne aportaciones de ámbitos distribuidos sobre una amplia variedad de espacios geográficos, que abarcan desde el litoral americano del Pacífico, pasando por el litoral atlántico africano para finalizar en el mundo mediterráneo, dentro de este último espacio diversifica con ejemplos de ambos litorales (norafricano y europeo) y de las dos grandes sub-cuencas, occidental y oriental. Igualmente se tratan dinámicas insulares diversas por la escala de los territorios analizados que varían desde las grandes islas de Sicilia y Cerdeña hasta realizar estudios sobre conjuntos insulares de tamaños notablemente reducidos como las islas del Sahel, Ischia o Strómboli.

Desde el punto de temático, encontramos por un lado capítulos dedicados a los riesgos naturales, haciendo especial hincapié en los derivados de la intensa actividad tectónica y volcánica del eje central de la cuenca mediterránea, mientras que otro conjunto de los estudios hace referencia al cambio climático y su impacto a diferentes niveles, desde el social con el desplazamiento de indígenas hasta la variabilidad del recurso agua pasando por la pérdida de patrimonio histórico-cultural con la posible desaparición de islotes en la costa del norte de África.

En todo momento las aportaciones reunidas en este volumen no dejan de lado la importante componente antrópica de los procesos descritos. Las sociedades no únicamente son factores pasivos ante un medio peligroso o cambiante, sino que también constituyen elementos que por sí mismos generan, aceleran, agravan o mitigan el impacto del medio físico. De lleno en el antropoceno, esta consideración activa del factor humano es presente en todas y cada una de los capítulos de esta monografía.

La falta de recursos provoca una dependencia del exterior que no siempre puede ser satisfecha de forma satisfactoria para los habitantes de las islas. A la vez, la imposibilidad de dar una solución a problemas como el incremento del nivel del mar, implica la necesidad de relocalizar comunidades enteras,

que perderán su espacio habitual y deberán encontrar un nuevo lugar donde vivir. Esta visión de las islas como espacios especialmente frágiles ante las nuevas condiciones planea sobre los artículos de Adèle de Mesnard referido al entorno escasamente antropizado de las islas de Alaska y de Oueslati referido a los islotes del Sahel en un territorio mediterráneo con una antiquísima ocupación humana y valores patrimoniales en peligro de desaparición ante un mar ascendente y una presión urbanizadora incontrolable.

La presión de las actividades económicas y la creciente demanda de recursos hídricos es el tema de la aportación de Christian Depraetere, Konstantinos X. Soulis, Demetrios E. Tsesmelis, Georgios Avgoustidis y Ioannis Spilaris, que repasa las consecuencias del evidente cambio del régimen pluviométrico sobre la disponibilidad de agua en los espacios insulares turísticos mediterráneos.

El factor del incremento de la población es el motivo central de la aportación de Salvatore Cannizzaro, Antonio Danese y Riccardo Privitera, en torno a los núcleos de población que rodean el Etna mayor estratovolcán activo del continente europeo, situado en la mayor isla del Mediterráneo. El mismo riesgo volcánico y sus derivaciones sísmicas son el objeto de análisis por Messina aplicados a Strómboli. Desprovisto de volcanes, pero afecto a los movimientos telúricos, el territorio de Ischia es tratado por Giovanni Gugg en referencia a un espacio repetidamente afectado por los terremotos.

La respuesta de las sociedades ante los riesgos se expresa a través de la planificación del territorio y las actuaciones preventivas de la administración, extremos que son tratados por Andrea Corsale, Carlo Perelli y Giovanni Sistu en referencia a Cerdeña.

Finalmente es imprescindible conocer como es la percepción social del riesgo, la limitación de recursos y del cambio global, en este caso analizados por Cheikh Faye y Antoine Demba Manga en referencia al territorio de l'île Carabane en la costa senegalesa.

Diversidad de enfoques sobre problemas variados con el fondo común de la perspectiva insular y una visión integrada es lo que se ofrece en este volumen que se pone en manos del lector.

Introduzione

Miquel Grimalt-Gelabert[1]*, Anton Micallef*[2]*, Joan Rosselló-Geli*[3]

Le isole sono, per definizione, spazi con precisi limiti spaziali che determinano alcune caratteristiche geografiche che le rendono particolarmente sensibili agli impatti e ai cambiamenti. Nei territori insulari esistono particolari condizioni relative a fattori fisici e antropici, coniugando l'intrinseca limitazione delle risorse segnata dallo spazio ridotto e dalla presenza del fattore costiero che le rende particolarmente fragili a fronte di problematiche legate ad aree oceaniche e molte volte localizzate in aree geologicamente attive e, quindi, soggette a fattori di rischio derivati da sismicità e vulcanismo.

Le società che abitano in questi territori seguono anche particolari modelli di sviluppo, spesso ad alta occupazione umana e che danno origine a economie e strutture basate sullo sviluppo di attività economiche molto sensibili alle intemperie dell'ambiente.

I pericoli naturali hanno un impatto speciale sulle aree insulari. Fattori come siccità o forti piogge, frane, eruzioni vulcaniche e uragani o tifoni possono causare disastri, ma, allo stesso tempo, le azioni umane possono anche generare impatti negativi su aree così limitate e sensibili, spesso di difficile soluzione.

Per quanto riguarda le alterazioni dell'ambiente fisico, l'importanza del cambiamento climatico nel futuro sviluppo delle isole nel mondo è particolarmente evidente. L'aumento della temperatura, l'innalzamento del livello del mare e le variazioni nella distribuzione delle precipitazioni - e di conseguenza sulla disponibilità di risorse idriche - avranno un impatto significativo, aggravando le situazioni esistenti o provocandone la comparsa in territori non interessati fino a quel momento.

Per tutti questi motivi è necessaria una visione generale che mostri l'insieme dei problemi che interessano le aree insulari, dalle più piccole alle più grandi; problematiche che vanno dall'esistenza di rischi storicamente localizzati in questi territori alla comparsa di nuovi, tutti legati a fenomeni

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come l'aumento del numero di abitanti e dell'urbanizzazione o l'attuale crisi climatica.

Partendo da questi presupposti è nata l'idea di questo volume all'interno della collana scientifica "Geographies of the Anthropocene", dal titolo "The Anthropocene and islands: vulnerability, adaptation and resilience to natural hazards and climate change", con l'intento di raccogliere una serie di contributi sui diversi aspetti che interessano le isole e con l'obiettivo di mostrare come visioni che derivano da diverse discipline possano fornire una visione globale sui rischi e sui cambiamenti climatici, una visione che possa essere utile per regioni geograficamente differenziate, sia per le loro dimensioni che per le loro caratteristiche socio-economiche.

Il volume raccoglie contributi da un'ampia varietà di aree geografiche, dalle coste del Pacifico americano, attraverso il litorale atlantico africano, all'area del Mediterraneo: all'interno di quest'ultima area i contributi si distinguono con esempi e casi studio su entrambi i litorali (nordafricano ed europeo) e sui due grandi sottobacini, occidentale e orientale. Allo stesso modo, vengono affrontate dinamiche insulari diverse a causa delle dimensioni dei territori analizzati, che variano dalle grandi isole della Sicilia e della Sardegna a studi su gruppi di isole notevolmente piccoli come le isole del Sahel, Ischia o Stromboli.

Dal punto di vista tematico troviamo, da un lato, capitoli dedicati ai rischi naturali, con particolare enfasi su quelli derivati dall'intensa attività tettonica e vulcanica dell'asse centrale del bacino del Mediterraneo, mentre un altro set di studi fa riferimento al cambiamento climatico e al suo impatto a diversi livelli, da quello sociale, con lo spostamento di popolazioni indigene, alla variabilità della risorsa idrica attraverso la perdita del patrimonio storico-culturale con la possibile scomparsa di isolotti della costa nordafricana.

In ogni momento, i contributi raccolti in questo volume non trascurano l'importante componente antropica dei processi descritti. Le società non sono solo fattori passivi di fronte a un ambiente pericoloso o mutevole, ma costituiscono anche elementi che, di per sé, generano, accelerano, aggravano o mitigano gli impatti sull'ambiente. Proprio nell'Antropocene, questa considerazione attiva dei fattori umani è presente in ogni capitolo di questo volume collettaneo.

La mancanza di risorse determina una dipendenza dall'esterno che non sempre può essere soddisfatta in modo soddisfacente per gli abitanti delle isole. Allo stesso tempo, l'impossibilità di fornire una soluzione a problemi come l'innalzamento del livello del mare implica la necessità di ricollocare intere comunità, che perderanno il loro spazio abituale e dovranno individuare un nuovo luogo in cui vivere. Questa visione delle isole come spazi

particolarmente fragili di fronte alle nuove condizioni si ritrova nel capitolo di Adèle de Mesnard, riferendosi all'ambiente appena antropizzato delle isole dell'Alaska e nel contributo di Oueslati, facendo riferimento agli isolotti del Sahel in un territorio mediterraneo con antica occupazione umana. I valori del patrimonio rischiano di scomparire di fronte ad un innalzamento del livello del mare e ad una pressione urbana incontrollabile.

La pressione delle attività economiche e la crescente domanda di risorse idriche è oggetto del contributo di Christian Depraetere, Konstantinos X. Soulis, Demetrios E. Tsesmelis, Georgios Avgoustidis e Ioannis Spilaris, che analizza le conseguenze dell'evidente cambiamento del regime delle piogge sulla disponibilità di acqua nelle aree turistiche insulari del Mediterraneo.

Il fattore di incremento demografico è il tema centrale del contributo di Salvatore Cannizzaro, Antonio Danese e Riccardo Privitera, attorno ai centri abitati che circondano l'Etna, il più grande stratovulcano attivo del continente europeo, situato sulla più grande isola del Mediterraneo. Lo stesso rischio vulcanico e le sue derivazioni sismiche sono oggetto di analisi da parte di Messina, applicate all'isola di Stromboli. Privato di vulcani, ma colpito dai terremoti, il territorio di Ischia è trattato da Giovanni Gugg in riferimento ad un'area più volte colpita dai terremoti.

La risposta della società ai rischi si esprime attraverso la pianificazione del territorio e le azioni preventive dei *local policy-makers*; si tratta di temi che vengono affrontati da Andrea Corsale, Carlo Perelli e Giovanni Sistu con riferimento alla Sardegna.

Infine, è fondamentale conoscere la percezione sociale del rischio, la limitazione delle risorse e il cambiamento globale, secondo il caso studio analizzato da Cheikh Faye e Antoine Demba Manga, in riferimento al territorio de l'île Carabane, sulla costa senegalese.

Questo volume, dunque, offre una diversità di approcci su vari problemi, con lo sfondo comune della prospettiva insulare, in una visione integrata.

SECTION I

Natural Hazards, Volcanism, Earthquakes and Societal Impacts

1. Riflessioni sul rischio vulcanico nei paesaggi lavici antropizzati della regione dell'Etna

Salvatore Cannizzaro[1], Antonio Danese[2], Riccardo Privitera[3]

Riassunto

Il territorio della conurbazione catanese si caratterizza per la presenza di una complessa rete di colate laviche che ha modellato, nel corso dei secoli, il paesaggio etneo. Adattandosi alle eruzioni vulcaniche susseguitesi nel tempo, le comunità locali hanno abitato questo tormentato territorio ricercando costantemente il delicato equilibrio fra insediamento urbano, luoghi della produzione agricola e aree a rischio dei periodici eventi distruttivi. Il rapporto fra uomo e vulcano, in questo plurimillenario dialogo di azione e retroazione, ha sempre restituito esiti virtuosi in termini di trasformazioni antropiche in grande equilibrio con il paesaggio naturale.

A partire, però, dal Secondo Dopoguerra si è cominciato a rompere quel reciproco "ascolto" fra comunità insediata e vulcano. La consistente crescita demografica dei Comuni a nord della città di Catania e i disordinati processi di diffusione urbana hanno investito questo territorio producendo nuovi insediamenti a bassa densità e di scarsa qualità ma hanno soprattutto generato un drastico cambiamento nel rapporto delle comunità e degli Enti istituzionali con le questioni legate al rischio vulcanico.

Lo studio qui proposto tratterà quindi i tre aspetti fin qui accennati: 1) la crescita demografica dei comuni etnei, con particolare riguardo a quelli strettamente connessi alla città di Catania e che lambiscono le zone interessate dall'eruzione del 1669; 2) la descrizione dei processi di espansione urbana che, soprattutto a partire dagli anni 50-60, hanno determinato un eccessivo consumo di suolo trasformando il paesaggio rurale etneo in campagna urbanizzata nonostante l'elevato rischio vulcanico; 3) la capacità

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Il lavoro è frutto di una riflessione congiunta e di una stretta collaborazione tra i coautori. Ai fini di una precisa distinzione, il paragrafo 1 e le conclusioni sono da attribuire a Salvatore Cannizzaro, il paragrafo 2 a Riccardo Privitera, il paragrafo 3 ad Antonio Danese.

di comunicazione istituzionale in tema di prevenzione del rischio vulcanico da parte delle Amministrazioni comunali.

Parole chiave: Vulcano Etna, Insediamenti, Demografia, Campagna urbanizzata, Rischio vulcanico

Reflections on volcanic risk in the urbanised lava fields landscapes of Etna region

Abstract

The Catania metropolitan region (Italy) is characterised by an intertwined network of lava fields that shaped the local landscape over the past centuries. Local communities living within this anguished land were adapting to the eruptions risk while trying to find the weak balance among urban settlements, farmlands and lava flows areas. The ancient humans-volcano relationship has been always providing positive effects in terms of anthropogenic transformations well balanced with the natural landscape. Even though, after the Second World War, the mutual monitoring between local community and volcano has started to be interrupted. Increasing urban sprawl and related population growth that occurred to the north of Catania, produced new low-density settlements characterised by very poor urban quality and, above all, deeply changed the approach of residents and local administrators to cope with the volcanic risk and its related impacts.

This study argues about three main volcanic risk-related topics that have been addressed according to different perspectives: 1) urban growth, across the 1669 lava fields, that has been experienced by the municipalities surrounding the city of Catania; 2) urban sprawl processes that produced, since the 50s-60s, an impressive soil sealing and transformed the traditional rural and lava fields landscape to a new urbanised countryside; 3) institutional ability of policy makers to communicate the volcanic risk-related impacts prevention strategies to the local community.

Keywords: Volcano Etna, urban settlements, urban growth, urbanised countryside, volcanic risk

1. Etna, luoghi e uomini

L'Etna, il più grande e attivo vulcano d'Europa, occupa una superficie di oltre 1.250 chilometri quadrati e supera, attualmente, l'altezza di 3.300 metri s.l.m., che varia in seguito alla continua attività eruttiva. Il maestoso edificio vulcanico è racchiuso tra il mare Ionio nel versante Est, la valle dell'Alcàntara che lo divide dai monti Peloritani, il Fiume Simeto che ne segna il limite occidentale e meridionale e la Piana di Catania che lo separa dai rilievi Iblei.

Con il suo perimetro circolare, o meglio ovoidale, che si sviluppa per poco più di 210 chilometri e per la sua imponente mole esso domina tutta la Sicilia centrorientale (Pecora, 1974).

Sebbene l'Etna sia "un'entità geografica che si differenzia notevolmente dai territori circostanti per i caratteri fisici, biologici ed antropici che lo contraddistinguono" (Di Blasi, 1997, 9) e risulti, dunque, un'unità ben definita e delineata, la "Montagna", termine con il quale è familiarmente indicata dalla popolazione locale, all'occhio di un attento osservatore appare come un mosaico di distinte e diverse realtà sub-regionali. Ciò è dovuto, non solo a fattori fisici, geomorfologici e climatici – dall'esposizione dei diversi versanti, dalle differenti stratificazioni effusive, dalle ineguali fertilità dei suoli agricoli – ma pure a fattori socioeconomici, anch'essi fondamentali nel definire le sub-aree regionali. Tale "realtà al plurale" è frutto, infatti, anche delle differenti scelte tecniche, organizzative, sociali e culturali maturate dalle comunità che vivono nelle diverse aree del vulcano, da quelle apicali a quelle a valle, e ancora della scelta di dar vita ad insediamenti nelle zone interne, nel versante Nord del vulcano, o di realizzare centri urbani verso gli orizzonti più aperti del mare Ionio e della Piana di Catania.

Nel corso dei secoli il vulcano ha subito profonde trasformazioni dovute non soltanto alle innumerevoli eruzioni e alle colate laviche, alla formazione di crateri avventizi e di depressioni, come la Valle del Bove[4], ma pure alla millenaria paziente opera dell'uomo[5] che, grazie all'attività di disboscamento, dissodamento e costruzione di terrazzamenti, ne ha reso più fertili e praticabili i terreni delle sue pendici.

Proprio "a causa del suo lunghissimo processo di antropizzazione, il vulcano e i suoi dintorni costituiscono anche una regione geografica, una delle poche individuabili in Sicilia" (Guglielmino, 2020, 14), [...]. "L'unità antropica dell'Etna si è plasmata nel tempo con la condivisione da parte dei suoi abitanti di miti, vicende storiche, tradizioni religiose, artistiche e

[4] Depressione a forma di anfiteatro conseguente a sprofondamenti del versante orientale del vulcano. Essa è larga circa 5 chilometri, profonda 1 e chiusa da ripidissime pareti.

[5] La presenza umana sul vulcano si fa risalire all'età Neolitica, tra il VI e il III millennio a.C.

culturali, nonché di modelli di vita e attività economiche praticati, di convergenza di interessi e di aspettative e dall'esistenza di un centro coordinatore, Catania, che offre ad un ampio intorno servizi qualificati ed esercita funzioni di governo e di controllo sull'intero territorio" (*Idem*).

Descrizioni alquanto particolareggiate, non solo dei caratteri fisici del vulcano, ma pure degli elementi antropici e annotazioni più o meno ricche delle caratteristiche della stessa popolazione che lì vive, vengono fornite già nei resoconti dei viaggiatori del *Grand Tour* che in particolar modo dal XVIII secolo furono sempre più numerosi. Un'importante testimonianza sulla morfologia del Monte Etna ci viene resa dalle vedute di Jean Houël, di Jean-Claude Richard de Saint-Non e di Gigault de La Salle, solo per citarne alcune, e dal repertorio di fotografie di geologi, vulcanologi e altri studiosi che, riprese numerose dal XX secolo, risultano estremamente utili per cogliere i cambiamenti occorsi negli ultimi secoli (Privitera, 2012).

L'ecosistema Etna per il suo atavico rapporto con la presenza dell'uomo rappresenta un osservatorio privilegiato riguardo alla territorializzazione della regione. La varietà del suo paesaggio naturale che si estende dal mare Ionio alla vetta fumante del cratere e che include scogliere di magma, vulcaniti, fertilissimi suoli messi a coltura, cimose boschive, grotte di scorrimento lavico e deserti lavici, ha fatto dire al De Roberto che l'Etna "non è un monte, ma il mondo" (Finocchiaro Chimirri, 1983, 71). Un mondo dove "l'uomo della montagna", nello scorrere del tempo, ha incessantemente operato cambiamenti, dapprima armonici, ma oggi alquanto aggressivi, mettendo a repentaglio l'antico equilibrio del complesso ecosistema antropico e naturale. Ciononostante, il rapporto con la "Montagna" rimane indissolubile e gli uomini che vivono in questo contesto unico, avvertono un legame forte da preferirlo a qualsiasi altro luogo malgrado le continue minacce del "gigante buono", ma terribile allo stesso tempo.

Un "Gigante" che non manca di dispensare ricchezze naturali: la caratteristica geomorfologia determina una serie di condizioni specifiche del terreno come l'alta permeabilità e la ricchezza di minerali; le particolari condizioni climatiche rendono il suolo particolarmente fertile tale da consentire la coltivazione di numerose pregiate colture. Tant'è che l'Etna incrocia la sua fama di terra del mito con quella del vino: dalle sue pendici Polifemo lanciò enormi massi contro Ulisse che lo aveva accecato dopo averlo ubriacato. Dunque, risalgono alle "cronache" dell'antichità le testimonianze dell'allevamento della vite sul monte Etna. Il vino, nel corso dei secoli, ha modellato la montagna perché pazientemente, giorno dopo giorno, i contadini hanno creato un fitto reticolo di terrazzamenti, hanno piantato viti in vaste aree, cambiandone completamente il paesaggio. Inoltre,

le fertili terre etnee sia per l'origine vulcanica dei suoli, sia per il clima variante con l'altitudine, sia ancora per la diversa esposizione dei versanti, hanno offerto all'uomo di coltivare altre pregiate varietà vegetali (Cannizzaro, 2020, 155-156).

Queste condizioni favorevoli hanno conferito al vulcano una forza attrattiva riguardo agli insediamenti umani, rendendo la regione etnea un territorio dal tessuto economico e sociale particolarmente vitale che, unitamente al ruolo polarizzante del capoluogo etneo, conferisce all'intera area geografica un ruolo significativo.

È pur vero che nell'ambito della regione etnea è possibile identificare diverse sub-regioni con specifiche vocazioni colturali e che ci consegnano differenti formazioni territoriali: d'altronde la storia delle colture è stata la storia dell'economia e dei manufatti che l'uomo vi ha realizzato, quali case rurali, palmenti, frantoi, terrazzamenti a secco e in muratura, e finanche delle strutture urbanistiche, aggregazioni edilizie complesse e insediamenti residenziali. Si sono realizzati, associati ai paesaggi agrari, veri e propri paesaggi urbani che, in particolar modo, dagli anni Sessanta hanno profondamente modificato il territorio creando un tipico paesaggio etneo urbanizzato diffuso. Da allora, nei bassi versanti meridionali ed orientali della "Montagna", le trasformazioni agrarie e lo sviluppo di reticoli commerciali e urbani sono avvenuti alquanto velocemente e finanche sulle alte pendici e nelle aree interne del vulcano, dove le ricorrenti effusioni laviche hanno reso difficile la conquista dei terreni, l'uomo è riuscito faticosamente a riconquistarne il territorio (Ruggiero, 1987, 11).

La regione geografica etnea, più ampia di quella naturale e delimitata dai fiumi Alcàntara e Simeto e dalla costa ionica, ingloba i territori della maggior parte dei comuni dell'ex provincia di Catania[6], i quali sono distribuiti in modo disomogeneo. Per la più favorevole posizione geografica, la maggiore dotazione di infrastrutture viarie, la buona fertilità dei terreni, la prossimità al mare e la vicinanza al capoluogo etneo, la maggior parte dei centri abitati si concentra nel versante sud-orientale, dove formano un fitto reticolo urbano (Guglielmino, 2020, 14-15).

Sono proprio le pendici meridionali e sud-orientali dell'Etna che mostrano un forte aumento demografico. In particolare, sono i comuni più vicini a Catania che hanno fatto registrare un consistente aumento degli abitanti, integrandosi in un'area densamente urbanizzata. Notevole è stata la crescita demografica dei centri urbani di Gravina di Catania, Sant'Agata li Battiati, Tremestieri Etneo, San Giovanni La Punta, Mascalucia, Aci Castello,

[6] Ne sono esclusi 15 comuni dell'area calatina.

Valverde, che dall'Unità d'Italia al 2016 hanno fatto registrare un aumento percentuale della popolazione anche superiore, in alcuni casi, al 1.600% (Fig. 1). Anche le cittadine situate sulla costa ionica sono risultate in grado di attrarre abitanti, allo stesso livello o anche più della stessa città di Catania (Cannizzaro, 2018).

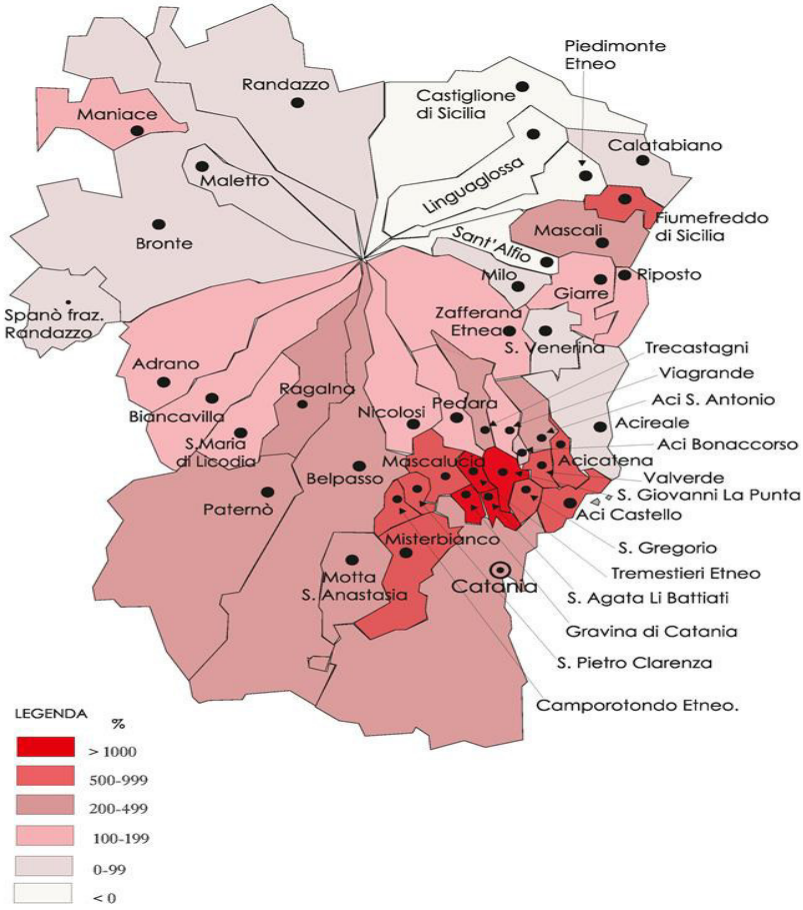

Figura 1 - *Variazione percentuale di abitanti dell'area etnea dal 1861 al 2016*[7]*. Fonte: Cannizzaro, 2018, 77.*

Diversi di questi centri urbani etnei hanno iniziato un veloce sviluppo specialmente a partire dagli anni Settanta, quando dopo una lunga fase di inurbamento nel capoluogo, già avviatosi agli inizi degli anni Trenta, molti

[7] Dall'Unità d'Italia agli anni Sessanta del XX secolo la crescita è dovuta prevalentemente all'incremento naturale, mentre dall'inizio degli anni Settanta dello stesso secolo ad oggi è dovuta al movimento migratorio.

suoi residenti hanno preferito "tornare indietro" e acquistare case in piccoli centri viciniori. Oggi, le cittadine dei suddetti versanti sono parte integrante dell'area urbanizzata che circonda Catania.

Risulta, comunque, evidente che la lunga ondata di insediamenti umani intorno alle pendici dell'Etna è stata sostenuta dalla preferenza delle persone a vivere sia vicino all'area urbana di Catania che al vulcano. Questa realtà è stata soggetta ad un forte dinamismo dovuto al ruolo metropolitano assunto dal Capoluogo, che mantiene un rapporto di forte conurbazione con i comuni limitrofi, costieri e pedemontani. La popolazione residente nel comune di Catania ha finito per traboccare, dunque, nei centri di prima corona. Infatti, mentre questi ultimi sono cresciuti intensamente, la città di Catania dopo una ininterrotta crescita dall'Unità d'Italia all'inizio degli anni Settanta, ha intrapreso un declino demografico, passando da 400.048 abitanti nel 1971 a 313.396 nel 2019 (Cannizzaro, Corinto, 2013, 51-52) (Fig. 2).

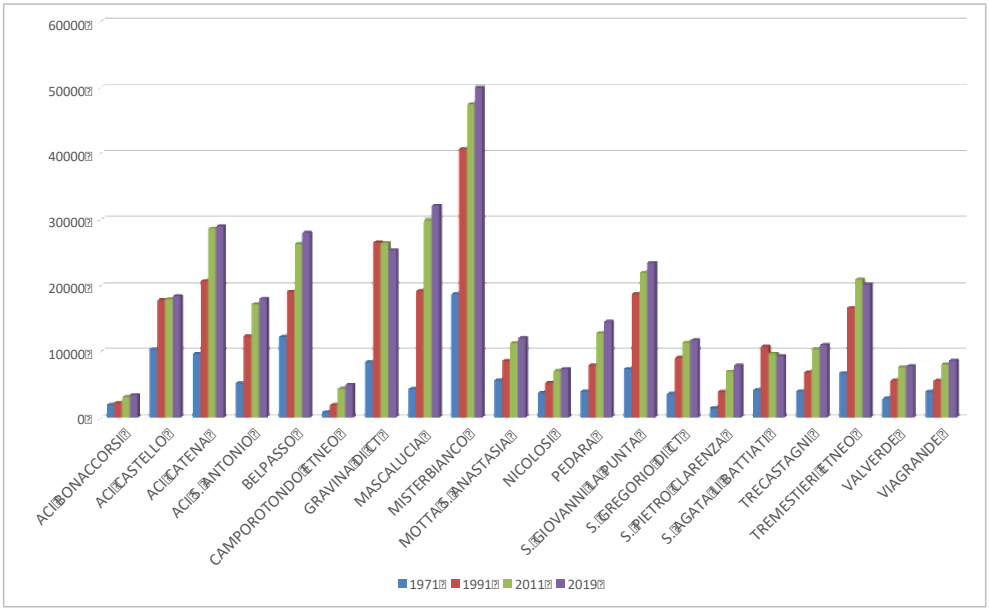

Figura 2 - *Evoluzione demografica nei comuni di prima corona al capoluogo dal 1971 al 2019. Fonte: elaborazione dell'autore di dati ISTAT.*

Diversamente dai processi demografici fin qui descritti, riguardanti le pendici meridionali e sudorientali, il versante nord-orientale e più accentuatamente quello interno nord-occidentale risultano aree periferiche, nonostante la presenza di alcuni nodi (Bronte e Randazzo) che per taglia demografica potrebbero svolgere un ruolo di volano di valorizzazione territoriale, specie per piccoli centri (Maletto, Maniace) che, per la loro

altitudine, soffrono di una condizione di isolamento che provoca difficoltà economiche e declino o stagnazione demografica (Idem).

Il versante occidentale, infine, è caratterizzato dalla presenza di grossi centri urbani (Paternò, Adrano, Biancavilla) collocati in aree collinari e, in parte, in prossimità della piana di Catania. Essi, per le ragguardevoli dimensioni e un discreto dinamismo economico, fungono da aree-cerniera e da nodi di riferimento per i vicini centri minori più disagiati.

2. Dal paesaggio rurale alla campagna urbanizzata

2.1. Il paesaggio storico Etneo

Il territorio della conurbazione catanese si caratterizza per un'armatura insediativa articolata in una fitta rete di piccoli centri che hanno rappresentato, fino agli anni '50, le polarità urbane di un vasto palinsesto agricolo alle pendici del vulcano. La presenza di una complessa e stratificata giacitura di colate laviche ha sempre condizionato e limitato l'uso agricolo dei suoli spingendo le comunità locali verso la ricerca costante del delicato equilibrio fra insediamento urbano, luoghi della produzione agricola e spazi naturali da lasciare alle funzioni fisiologiche del vulcano. Adattandosi agli innumerevoli fenomeni eruttivi susseguitesi nel tempo, le comunità locali hanno dunque abitato questo tormentato e mutevole territorio modellando, nel corso dei secoli, il peculiare paesaggio rurale etneo. La complessità geomorfologica di questo territorio ha richiesto, da un lato, una forte infrastrutturazione rurale dei fondi agricoli attraverso il disegno di grandi opere di spietramento, di terrazzamento e di canalizzazione, dall'altro, l'enorme disponibilità di materiale da costruzione naturale ha reso possibile la facile realizzazione di muretti di contenimento, percorsi di accesso per i mezzi di lavoro (rasule), pozzi, vasche di raccolta dell'acqua piovana (gebbie), canali per l'irrigazione (saje) ma anche edifici rurali per il deposito delle derrate, degli attrezzi, per il ricovero degli animali, mulini, palmenti per produzione del vino e dell'olio, edifici per la residenza dei mezzadri e dei proprietari fondiari. Il rapporto fra uomo e vulcano, in questo plurimillenario dialogo di azione e retroazione, ha prodotto straordinarie opere antropiche che hanno fatto da contrappunto al contesto naturale lavico ed hanno contribuito a costruire i grandi iconemi del paesaggio etneo (Turri, Jodice, 2001).

2.2. La colata non è di lava. La dispersione insediativa

Con la fine degli anni ’50 si è cominciato a rompere il reciproco “ascolto” fra comunità locali e vulcano che aveva invece caratterizzato i precedenti secoli di storia dell’insediamento etneo e che aveva determinato quel lento, armonioso “trapasso” dalla città alla campagna che rappresentò, per l’Italia, uno tra i massimi raggiungimenti di una civiltà millenaria ammirato e descritto da pittori e viaggiatori come Goethe, Stendhal e Ruskin (Settis, 2012). Sotto la spinta della crescita economica e della concomitante crisi dell’agricoltura tradizionale, ha avuto inizio una straordinaria fase di crescita urbana che ha pervaso tutto il vasto territorio a sud del vulcano investendo drammaticamente la campagna preesistente ed erodendo, progressivamente, i suoli destinati a vigneti, agrumeti, frutteti e uliveti ma anche gli incolti naturali, le aree a pascolo e le colate laviche colonizzate da specie arbustive autoctone pioniere. Gli insediamenti rurali di matrice storica, originariamente formatisi lungo la fitta rete di viabilità che strutturava questo territorio pedemontano, sono divenute le nuove polarità attorno alle quali si è formato un sistema urbano a bassa densità, monofunzionale, privo di gerarchie e carente in termini di organizzazione spaziale, di servizi, infrastrutture, reti tecnologiche e di qualità urbana che si è sovrapposto, in maniera indifferente ed indifferenziata, al paesaggio agrario e quello naturale preesistente.

I tessuti a ville isolate, uni o bi-familiari, le villette a schiera e le piccole palazzine multifamiliari, che saranno convertite nel corso dei decenni successivi ad uso residenziale permanente, si diffondono con una modalità centrifuga rispetto alla città eponima e producono tessuti irregolari a sempre minore densità che saturano il territorio di funzioni esclusivamente residenziali capaci di polverizzare l’armatura agro-ambientale etnea.

Lo studio sulle dinamiche di crescita urbana e delle morfologie edilizie, condotto dal LaPTA – Università di Catania (2015)[8], mostra con chiarezza i tempi e le modalità del fenomeno di urbanizzazione pervasiva che ha travolto il territorio della conurbazione catanese dal 1928 fino ai giorni nostri. Il

[8] Lo studio è stato condotto dal LaPTA - Laboratorio per la Pianificazione Territoriale e Ambientale (Dipartimento di Ingegneria Civile e Architettura - DICAR) dell’Università di Catania, su cartografia di base ATA1213, in scala 1:10.000 con il supporto di Sistemi Informativi Territoriali (Software GIS) su un’area di circa 409 kmq che comprende la città di Catania ed i 18 Comuni più strettamente correlati sul piano delle funzioni metropolitane (Misterbianco, Camporotondo, S. P. Clarenza, Mascalucia, Gravina di Catania, S. A. Li Battiati, Tremestieri Etneo, S. G. La Punta, S. Gregorio di Catania, Aci Castello, Aci Catena, Valverde, Aci S. Antonio, Aci Bonaccorsi, Viagrande, Trecastagni, Pedara, Nicolosi).

processo di crescita della struttura insediativa originaria (1928, Fig. 3a), subisce una prima e graduale accelerazione a partire dagli anni ’50 con urbanizzazioni che fino alla metà degli anni ’60 (1928 – 1964, Fig. 3a) seguono regole di crescita nastriforme lungo i fronti stradali. Il più elevato tasso di crescita si registra nel ventennio 1964 – 1985 (Fig. 3b), quando si transita verso il nuovo modello insediativo della palazzina condominiale prima, e della villa isolata dopo e durante il quale l’assetto del sistema urbano subisce una radicale trasformazione a seguito della realizzazione dei 2/3 (66%) dell’attuale patrimonio edilizio (Tab. 1). Questi ultimi modelli caratterizzano per intero lo sviluppo insediativo nei decenni successivi (1985 – 1999, Fig. 3c e 1999 – 2015, Fig. 3d) alla fine dei quali si registra una crescita complessiva, in termini di superficie fondiaria urbanizzata, del +985% rispetto al 1928 e un rapporto di copertura territoriale di quasi il 25%.

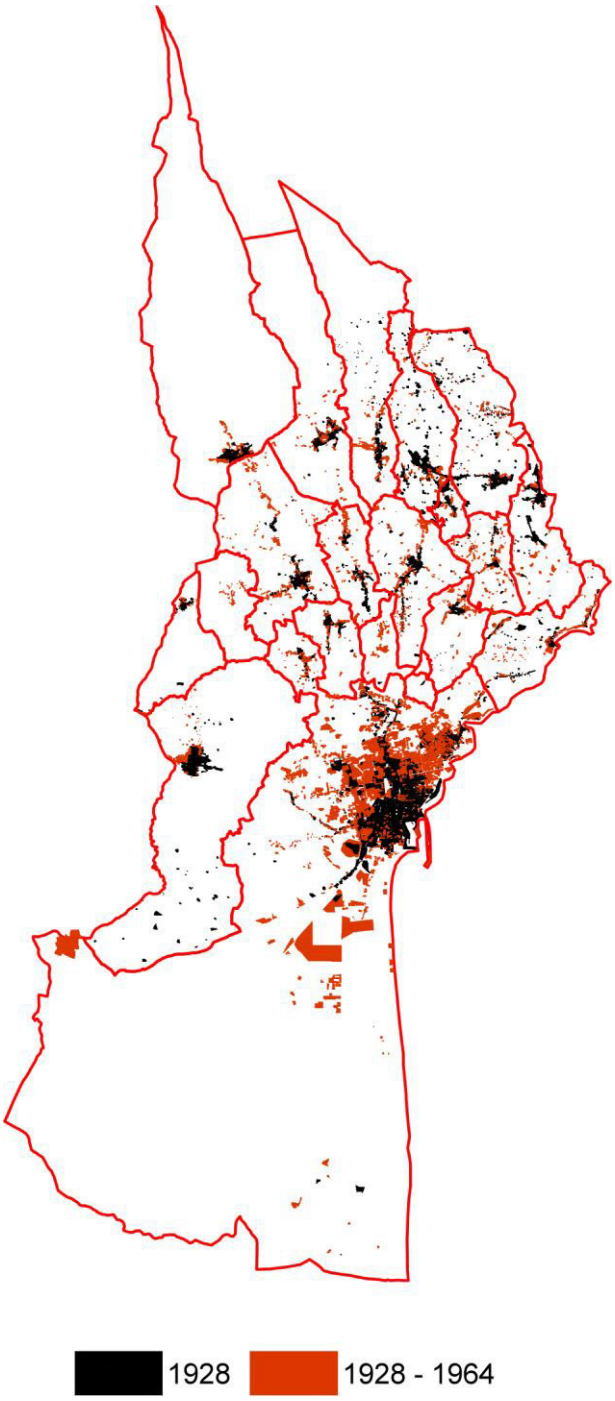

Figura 3a - *Crescita urbana nel periodo 1928-1964. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

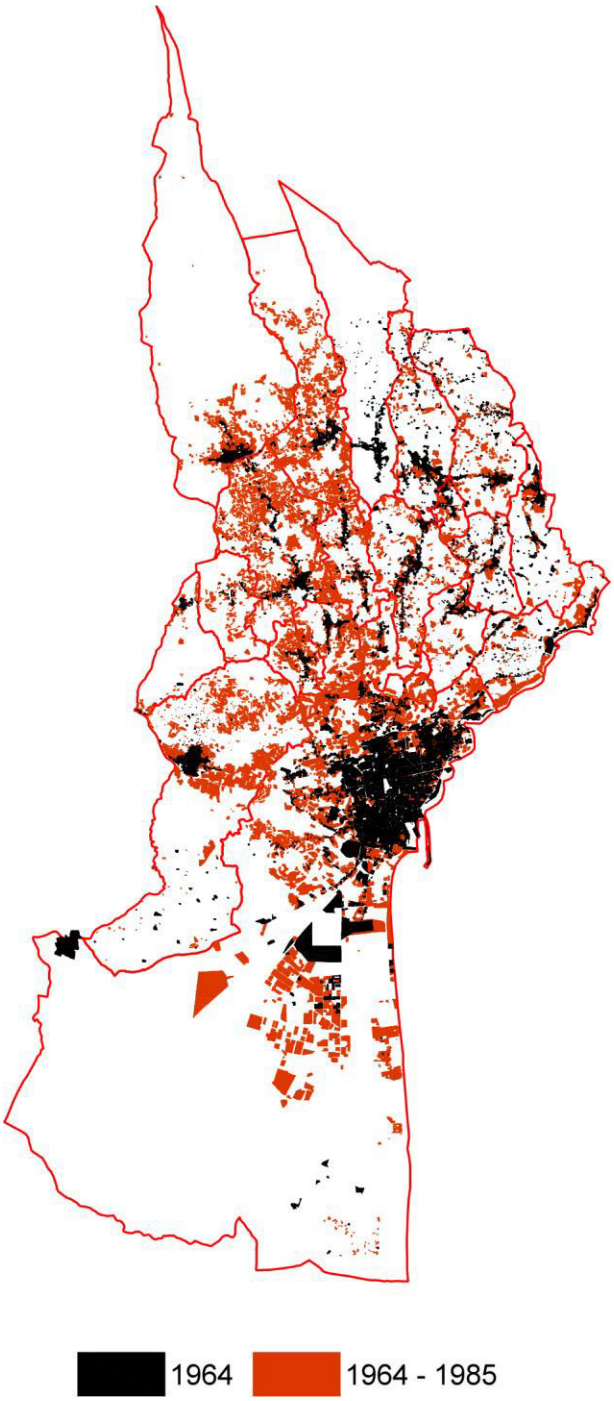

Figura 3b - *Crescita urbana nel periodo 1964-1985. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

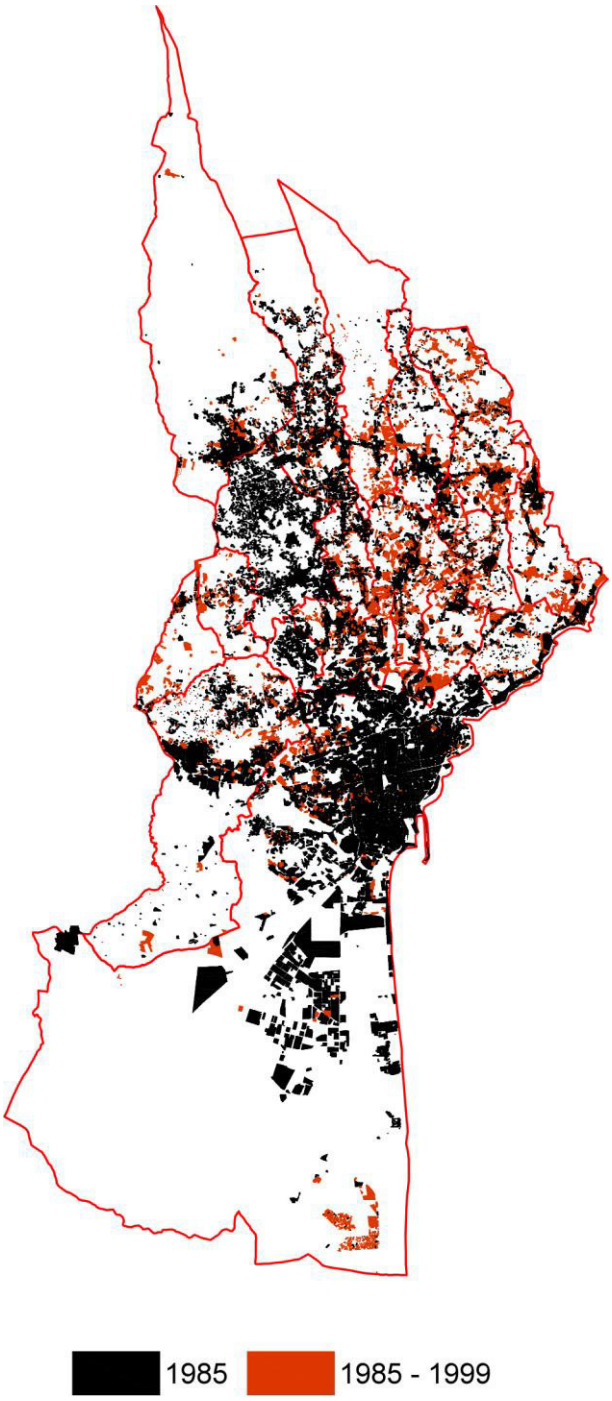

Figura 3c - *Crescita urbana nel periodo 1985-1999. Fonte: LaPTA- DICAR, Università di Catania, 2015.*

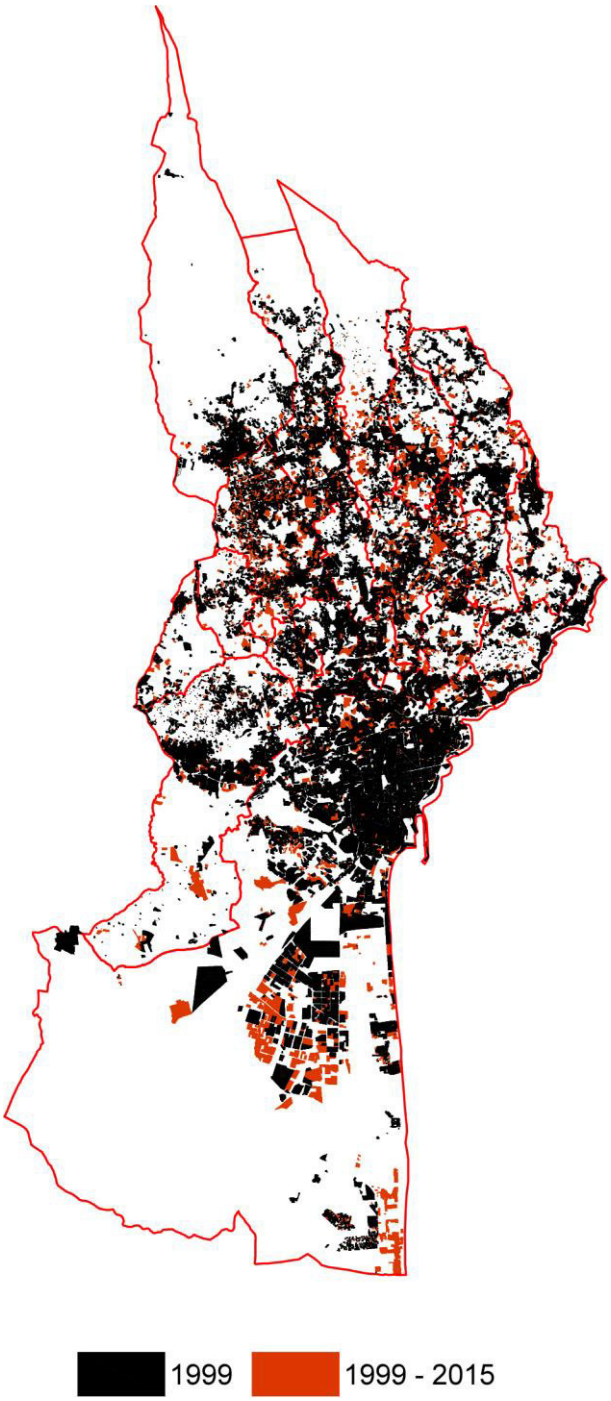

Figura 3d - *Crescita urbana nel periodo 1999-2015. Fonte: LaPTA - DICAR, Università di Catania, 2015*

Intervalli temporali	Superficie fondiaria urbanizzata (kmq)	Crescita % sul totale	Crescita % progressiva
1928	10,14	10,16	10,16
1928-1964	12,13	12,15	22,31
1964-1985	43,84	43,93	66,24
1985-1999	15,35	15,38	81,63
1999-2015	18,34	18,37	100,00
TOTALE	**99,79**	**100,00**	

Tabella 1 - *Crescita urbana nel periodo 1928-2015. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

L'analisi delle morfologie evidenzia invece come ai tipi edilizi tradizionali degli edifici storici isolati, dei tessuti a griglia con isolati chiusi e di quelli nastriformi (Fig. 4a, Fig. 5a) si sovrappongano, in una prima fase, i tessuti regolari con edifici chiusi e i tessuti regolari ed irregolari con edifici in serie aperta (Fig. 4b, Fig. 5b). La fase successiva è quella più pervicace e devastante durante la quale si assiste alla moltiplicazione, senza soluzione di continuità, dei tessuti con edifici isolati (a villa e a schiera) (che occuperanno più del 31% della superficie fondiaria totale – Tab. 2) ed ancora peggio alla polverizzazione di edifici isolati unifamiliari in contesto agricolo e naturale (Fig. 4c, Fig. 5c). I tessuti urbani specialistici (servizi ed attrezzature pubbliche ma soprattutto agglomerati commerciali, artigianali e produttivi) si sommano (per quasi il 32% sul totale – Tab. 2) alle funzioni residenziali generando nuove centralità capaci di attrarre e incentivare ulteriori urbanizzazioni (Fig. 4d, Fig. 5d).

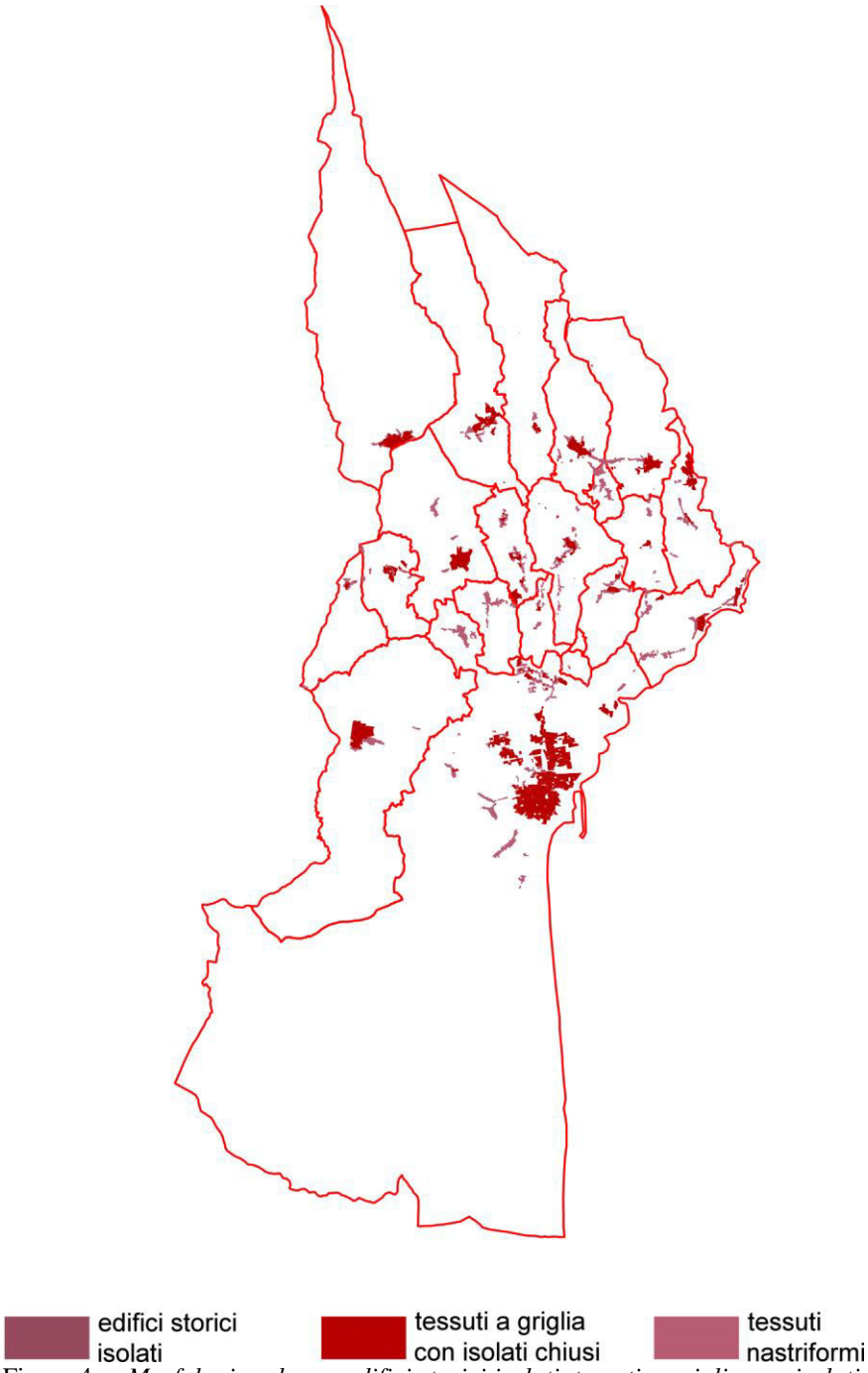

Figura 4a - *Morfologie urbane: edifici storici isolati, tessuti a griglia con isolati chiusi, tessuti nastriformi. Fonte: LaPTA -DICAR, Università di Catania, 2015.*

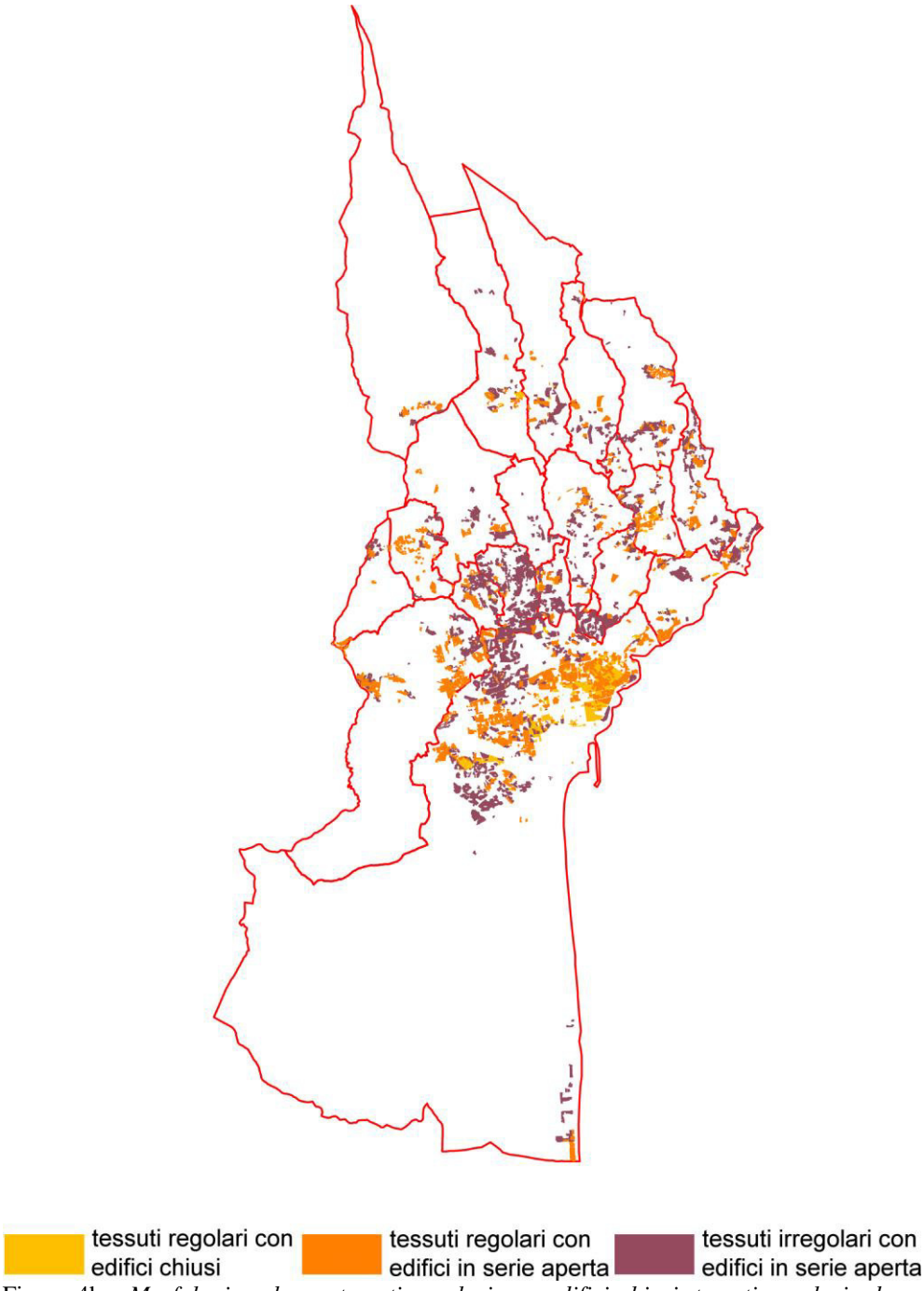

Figura 4b - *Morfologie urbane: tessuti regolari con edifici chiusi, tessuti regolari ed irregolari con edifici in serie aperta. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

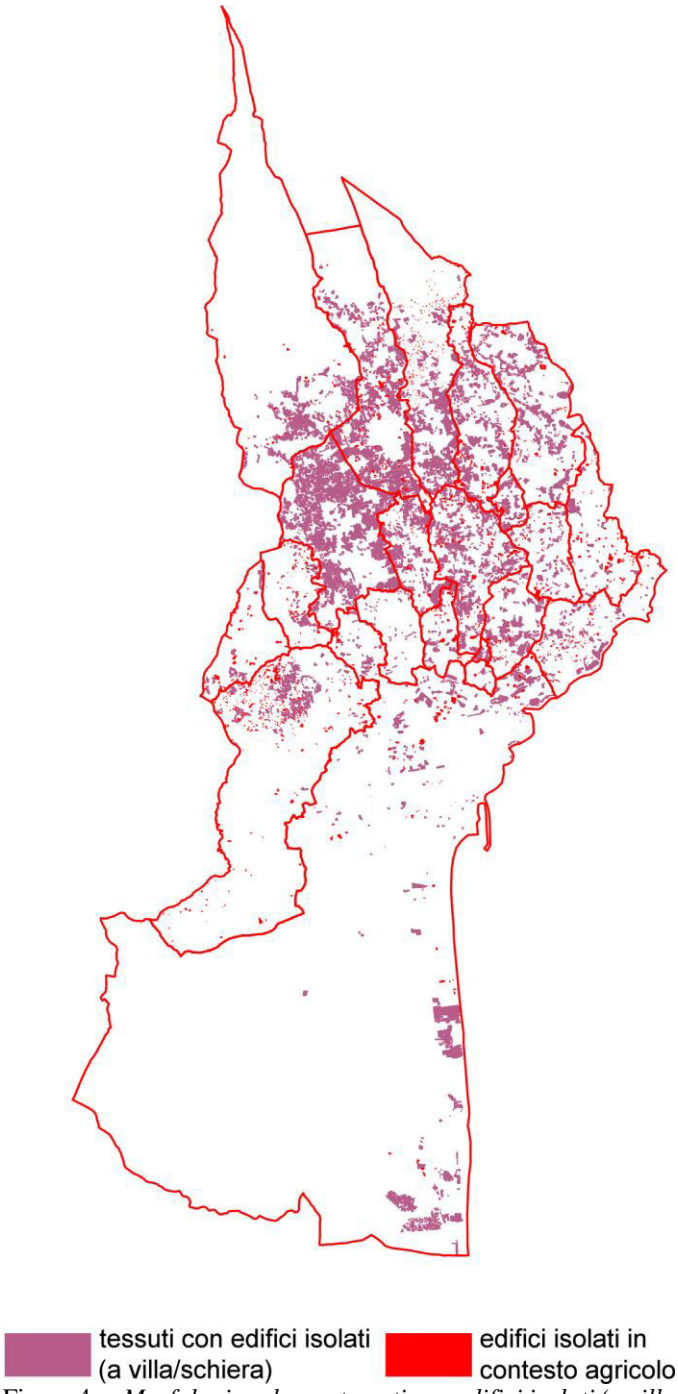

Figura 4c - *Morfologie urbane: tessuti con edifici isolati (a villa/schiera) ed edifici isolati in contesto agricolo. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

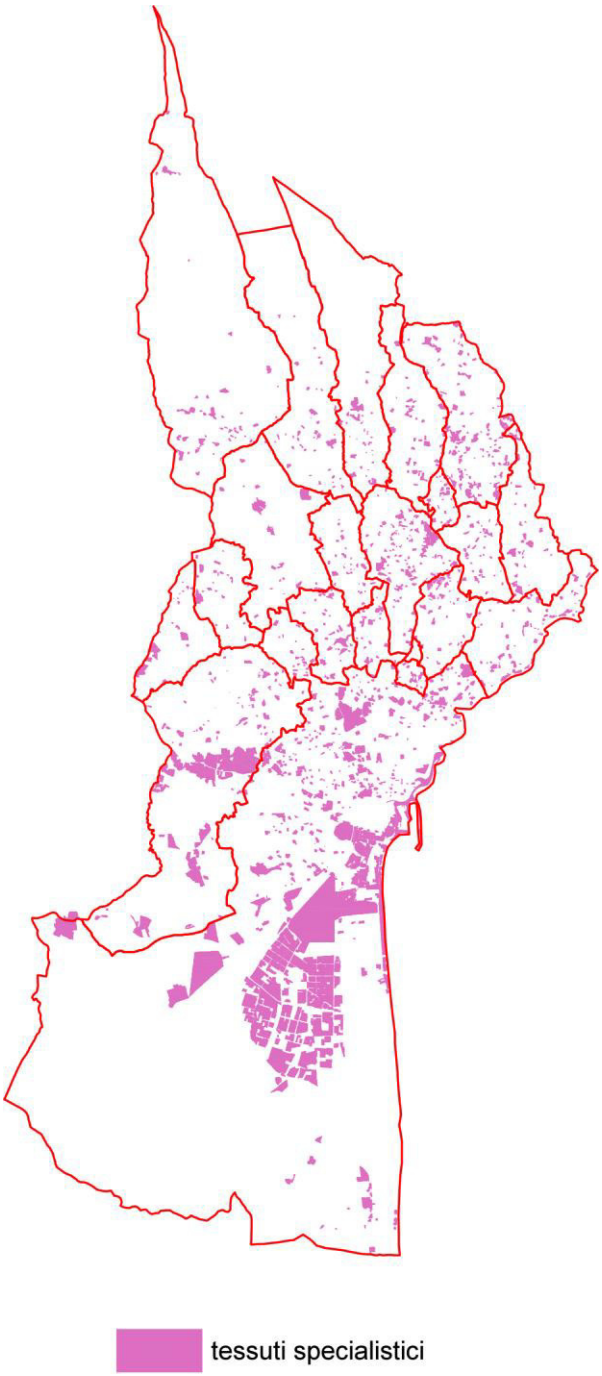

Figura 4d - *Morfologie urbane: tessuti specialistici. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

Figura 5a - *Edifici storici isolati (1), tessuti a griglia con isolati chiusi (2), tessuti nastriformi (3). Fonte: elaborazione dell'autore di immagini estratte da Street view - Google Earth, 2020 (accesso Luglio 2020).*

Figura 5b - *Tessuti regolari con edifici chiusi (4), tessuti regolari con edifici in serie aperta (5), tessuti irregolari con edifici in serie aperta (6). Fonte: elaborazione dell'autore di immagini estratte da Street view - Google Earth, 2020 (accesso Luglio 2020).*

Figura 5c - *Tessuti con edifici isolati (a villa/schiera) (7), edifici isolati in contesto agricolo (8). Fonte: elaborazione dell'autore di immagini estratte da Street view - Google Earth, 2020 (accesso Luglio 2020).*

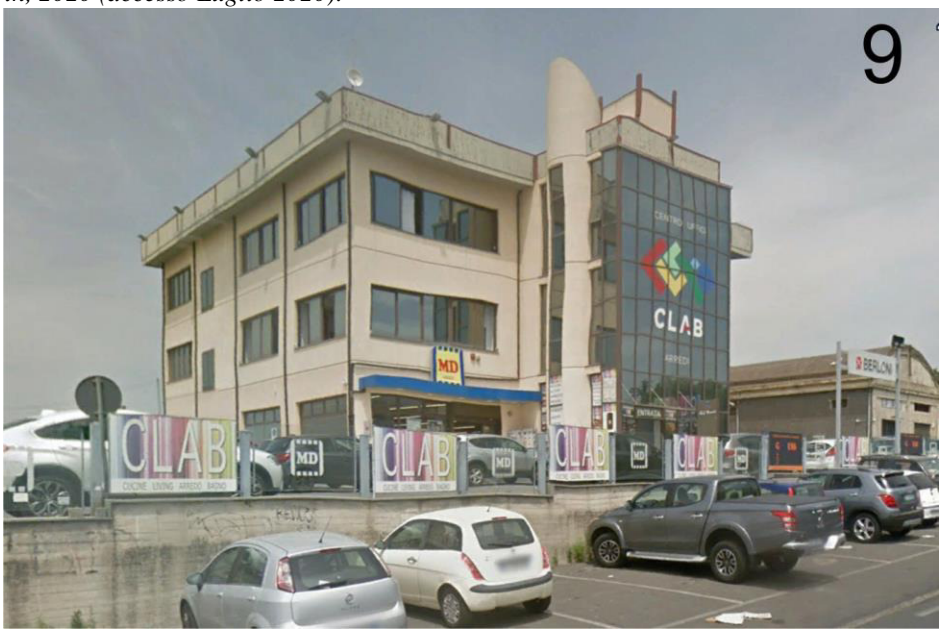

Figura 5d - *Tessuti specialistici (9). Fonte: elaborazione dell'autore di immagini estratte da Street view - Google Earth, 2020 (accesso Luglio 2020).*

Morfologie urbane	Superficie fondiaria urbanizzata (kmq)	% sul totale
edifici storici isolati	0,59	0,59
tessuti a griglia con isolati chiusi	6,06	6,07
tessuti nastriformi	2,70	2,71
tessuti regolari con edifici chiusi	1,87	1,87
tessuti regolari con edifici in serie aperta	9,89	9,91
tessuti irregolari con edifici in serie aperta	13,80	13,83
tessuti con edifici isolati (a villa/schiera)	31,16	31,22
edifici isolati in contesto agricolo	2,10	2,10
tessuti specialistici	31,63	31,70
TOTALE	**99,79**	

Tabella 2 - *Morfologie Urbane. Fonte: LaPTA - DICAR, Università di Catania, 2015.*

2.3. La campagna urbanizzata

Il vasto territorio compreso fra la città di Catania ed il versante pedemontano sud del Monte Etna è stato dunque il luogo di un intenso processo di urbanizzazione isotropa compiutosi attraverso complesse dinamiche che hanno portato allo sconvolgimento totale dei quadri paesistici e produttivi della campagna etnea e dei centri storici compatti con la conseguente perdita dei caratteri identitari tradizionali delle comunità locali e delle loro regole insediative. Il processo di inter-penetrazione tra città e campagna ha fatto emergere, nella scena metropolitana catanese, una nuova ed inedita "campagna urbanizzata" (Privitera, 2016). Un terzo soggetto non più identificabile come campagna, perché ha perso le sue funzioni produttive, ma non ancora città perché non ha espresso la complessità e l'articolazione delle funzioni urbane. La campagna urbanizzata è il luogo in cui la città si è sovrapposta alla campagna occupandone gli spazi e producendo insediamenti fatti di tasselli urbani a maglie sfrangiate completamente estranee e indifferenti alle preesistenti giaciture dei lotti agricoli e delle dorsali laviche. È la zona grigia, né città né campagna, quella terra di nessuno che ha finito con l'essere occupata da desolanti periferie senz'anima che hanno interrotto con la loro "trista invadenza" il filo di una tradizione che si era snodata con naturale continuità per decine di generazioni (Settis, 2012).

L'urbanizzazione della campagna etnea è stata incentivata, di fatto, dalla notevole riduzione di potenzialità edificatoria dell'allora nuovo Piano

Regolatore Generale di Catania approvato nel 1969. Peraltro, gli strumenti urbanistici dei comuni contermini alla città, poco attenti alle questioni di tutela ambientale e paesaggistica, alla mitigazione dei rischi naturali (soprattutto sismici e vulcanici), si sono posti a servizio di un'attività edilizia, di matrice marcatamente speculativa, che ha avuto la sola funzione di distribuire sul territorio volumetrie residenziali, sulla base di criteri meramente quantitativi.

3. Discorsi di politiche comunicative dei rischi

3.1. Protezione Civile ed Enti Locali

L'Italia è uno dei Paesi in cui le popolazioni indoeuropee, insediate da migliaia di anni nella penisola e nelle isole maggiori, hanno, con la loro azione modificatrice, totalmente stravolto l'immagine primigenia del paesaggio, determinando una umanizzazione estrema, tanto da poter annoverare il Bel Paese come uno dei più antropizzati al mondo.

In un Paese così modificato, e oggi densamente abitato, anche i rischi ambientali, legati alla fragile geomorfologia e al reiterato accadersi di importanti fenomeni sismici e vulcanici, determinano l'aumento in modo esponenziale della vulnerabilità delle popolazioni residenti. Il catastrofico evento eruttivo di Pompei-Ercolano del 79 e.v. ha costituito e costruito, in due millenni, il mito e la memoria storica collettiva di tutti gli italiani nei confronti della natura benigna e matrigna. Ma fu solo dopo l'Unità che si cominciò a prendere reale coscienza della periodicità e pericolosità di queste catastrofi, soprattutto dopo il tragico sisma del 28 dicembre 1908 di Messina-Reggio. Negli anni successivi a quell'evento molti furono gli interventi legislativi di pronto intervento varati in caso di rischio. Si dovette, tuttavia, attendere il verificarsi dell'alluvione di Firenze e la frana di Agrigento del 1966 e un altro sisma, quello del 1968 in Sicilia, affinché l'opinione pubblica italiana accettasse definitivamente l'idea che nella nostra penisola il rischio ambientale fosse sempre altissimo, e le calamità costanti e sempre più gravi in termini di danni; ciò a causa del sempre maggiore impatto della pressione demografica sul fragile territorio nazionale[9]. Fu, infatti, solo con il varo della

[9] Dall'Unità d'Italia ad oggi la popolazione è quasi triplicata, stanziata su tutto il territorio nazionale e distribuita in ogni zona altimetrica determinando, così, elevati indici di densità in molte zone della penisola. Al 31.12.2019 la popolazione italiana ammontava a 60.244.639 persone, distribuite su una superficie nazionale di 302.072,84 kmq. La densità media è di 199 ab/kmq. Le regioni più densamente popolate sono la Lombardia e la Campania (423 ab/kmq

Legge n. 996 dell'8.12.1970 che si realizzò una vera svolta legislativa, e si delineò un quadro complessivo di interventi: "*Norme sul soccorso e l'assistenza alle popolazioni colpite da calamità – Protezione Civile*" (PC). Per la prima volta il nostro ordinamento recepì il concetto di "rischio ambientale collettivo", si precisò la nozione di calamità naturale e catastrofe e venne inoltre creato il Dipartimento della PC. Fu una operazione istituzionale di grande impatto nazionale ed internazionale, in quanto prima volta a livello mondiale[10].

La nuova Protezione Civile verrà poi messa sul banco di prova operativo coi terremoti del Friuli (1976) e dell'Irpinia (1980) e con le imponenti eruzioni dell'Etna del 1980 e 1991-93 (Attanasio, 2013; Neri, 1995). E fu proprio a seguito degli eventi eruttivi etnei[11] che il 1992 fu l'anno della svolta in cui fu approvata una normativa completa, la Legge 225/92, che istituì il Servizio Nazionale di PC. Ulteriori interventi legislativi ci furono nel 1998 (decreti Bassanini), nel 2001 (Titolo V Costituzione), con la Legge 100/2012 e, dal 2018 il Servizio Nazionale è disciplinato dal *Codice della Protezione Civile* (D.Lgs n. 1 del 2.1.2018), con il quale è stata riformata tutta la normativa in materia[12]. A seguito delle riforme ogni Comune italiano è tenuto alla istituzione di un Servizio interno di PC, formato da tecnici e volontari col compito di programmare, informare, sensibilizzare, istruire, indicare a tutta la cittadinanza i rischi che corre il proprio territorio, e come attenuarli (Di Blasi, 2000). Il Servizio comunale di PC propone, inoltre, al Consiglio comunale il Piano di PC, un documento di enorme importanza, che individua

ex aequo); le meno densamente popolate sono la Basilicata (55 ab/kmq) e la Valle d'Aosta (33 ab/kmq). (www.tuttitalia.it, 2019).

[10] Con la Legge 996 dell'8.12.1970, si statuisce il concetto di Protezione Civile intesa come Organizzazione permanente dello Stato volta al coordinamento dei rischi e si individuano i compiti fondamentali affidati agli organi amministrativi per una razionale gestione delle emergenze e per far arrivare nel modo più rapido ed efficace i soccorsi alle popolazioni colpite. Si prevede la nomina di un Commissario per le emergenze che dirige e coordina i soccorsi sui luoghi del disastro.

[11] Per un approfondimento sull'eruzione etnea del 1991-93 vedasi: Calvari S. *et alii*, 1994, Etna eruption, chronology and lava flow-field evolution, in: *Acta vulcanologica*, Vol. 4, pp. 1-14.

[12] L'ultima riforma del 2018 emana un vero *Codice della PC*, con l'obiettivo di semplificare e rendere più lineari le disposizioni. Le principali innovazioni si orientano su tre campi: 1. Previsione e prevenzione; 2. Gestione delle emergenze; 3. Classificazione dei rischi, che vengono novati da "nuovi" ambiti di pericolosità quali: rischio chimico, nucleare, radiologico, tecnologico, industriale, da trasporti, ambientale, igienico-sanitario, da rientro incontrollato di satelliti e detriti spaziali, oltre ai "tradizionali" rischio sismico, vulcanico, da maremoto, idraulico, idrogeologico, da fenomeni meteorologicamente avversi, da deficit idrico, da incendi boschivi.

tutti i rischi di qualsiasi natura: ambientale, ma anche di altro tipo, come epidemie, ondate di calore, invasione di insetti, ratti, coleotteri e altro. Il Piano di PC deve indicare in modo semplice e chiaro, conformemente alla tipologia di ogni rischio, tutte le procedure di minimizzazione dello stesso.

Il Piano di PC è uno strumento che tutti gli individui della comunità hanno l'obbligo di conoscere, ma soprattutto è un documento strategico politico e operativo, che la municipalità ha il dovere di rendere pubblico e portare alla massima fruizione dei propri cittadini.

Non sempre ciò avviene con puntualità e correttezza istituzionale, in quanto spesso gli Enti Locali sono poco inclini ai compiti riguardanti la PC (Greco, 2014). Le strategie dei Comuni sono quelle della "visibilità", ovvero elaborare ed attuare atti amministrativi che diano immediati riscontri politici alla Giunta municipale. Infatti, lavorare sulla crescita della coscienza di cittadinanza, sovente non è ritenuto utile dal governo locale (Ioannilli, 2014).

Istruire e rendere consapevoli i cittadini del "proprio" rischio ambientale necessita complesse e onerose operazioni amministrative. Il Comune dovrebbe creare un efficiente Servizio di dipendenti e volontari e organizzare tutte quelle attività permanenti, ciclicamente verificabili, come le esercitazioni anti rischio (Frudà, 1997); programmare investimenti di una certa entità per l'individuazione e manutenzione delle aree di emergenza e per il coordinamento con gli altri attori di PC quali Prefettura, Forze dell'ordine, VV.FF. (Cellura, Bonfiglio, 1998); operare, inoltre, una efficace comunicazione istituzionale coi cittadini, primi beneficiari del sistema di protezione e prevenzione civile (Ligi, 2009).

3.2. Il caso studio: la prevenzione dei rischi negli Enti Locali oggetto dell'indagine

Tenendo ferme le considerazioni di cui al paragrafo precedente, si è voluto indagare sulla "prevenzione non strutturale"[13], con il fine di valutare l'azione comunicativa istituzionale delle Municipalità ricadenti nell'area oggetto di studio.

[13] La "prevenzione non strutturale" è composta da una serie di attività fra cui spiccano l'allertamento e la diffusione della conoscenza di protezione civile (da parte degli Enti Locali cointeressati) su scenari di rischio nonché norme di comportamento e di pianificazione di PC. Il Codice di PC introduce il principio della "partecipazione dei cittadini", finalizzata ad una maggiore consapevolezza dei rischi e alla crescita della resilienza delle comunità (Codice di PC, 2018).

Per far ciò l'indagine è stata condotta consultando tutti i siti web ufficiali dei Comuni – considerati come archivi digitali a disposizione della cittadinanza – al fine di rendersi conto quale sia la condotta e il grado di comunicazione preventiva realizzata da ogni singola Amministrazione, in caso di compimento di grave rischio naturale. Tentare di capire, quindi, se la compagine di governo cittadina attui strategie di minimizzazione del rischio attraverso una adeguata azione informativa che dia al cittadino la possibilità di poter, in un tempo molto breve, rinvenire tutti i dati necessarie per salvaguardare la propria e l'altrui incolumità (Leone, 2014).

Una esaustiva prestazione informativa, messa in atto sui siti istituzionali, costituirà non solo un corretto adempimento di trasparenza ma verrà, altresì, valutata come corretta azione di prevenzione non strutturale. Una carente, confusionaria o addirittura assente informativa da parte dell'Ente non potrà che essere valutata negativamente e rappresentare grave elemento di potenziale nocumento ai cittadini in caso di evento calamitoso.

3.2.1. Fase A - Il rischio oggettivo, ovvero la classificazione dei rischi da parte dell'Istat

L'area di studio proposta riguarda una parte dell'Area Metropolitana di Catania, ed in particolare i 19 comuni che si relazionano strettamente con la città capoluogo (Fig. 6). Trattasi di una piccola conurbazione, di 411 Kmq, che conta circa 617.000 abitanti (2019). La densità è dunque altissima e raggiunge una media 1.501 ab/kmq. I primi nove comuni con densità più bassa oscillano fra una media di 175 ab/kmq di Nicolosi e di 1.431 ab/kmq di Valverde. I secondi nove comuni con densità più alta oscillano fra una media di 1.978 ab/kmq di Mascalucia e di 4.937 ab/kmq di Gravina di Catania. La mediana della serie è proprio la città capoluogo, Catania, con 1.704 ab/kmq (Fig. 6).

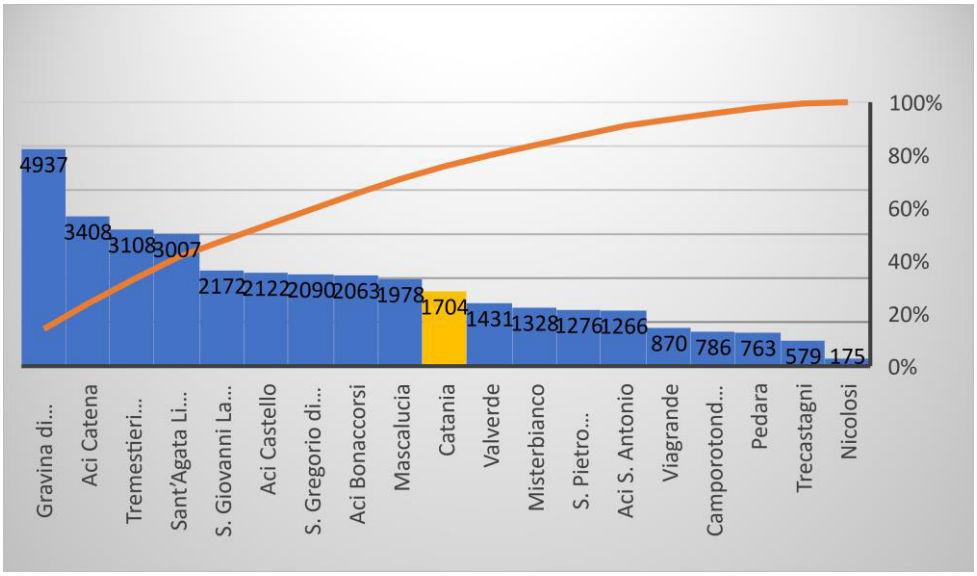

Figura 6 – *Densità della popolazione dei Comuni oggetto dello studio. Fonte: Istat 2019.*

Prima di procedere alla fase di valutazione dei siti web dei Comuni considerati, si sono volute consultare le "Mappe dei rischi comunali" dell'Istat, che costituiscono le banche dati ufficiali sui rischi dell'intero territorio italiano. Da esse sono stati estrapolati, per ogni Ente locale, tutti i fattori di rischio ivi previsti dalla normativa di PC, fra i quali la vulnerabilità sociale e del patrimonio abitativo, trattandosi di zone a forte rischio sismico/vulcanico nonché ad altissima densità[14] (Villari, 1997). Questi indicatori sono essenziali per dimostrare come la zona campione prescelta sia un'area estremamente vulnerabile in quanto soggetta a svariati rischi naturali e che, quindi, necessita di una congrua azione informativa e formativa della cittadinanza da parte degli Enti preposti. Si è elaborata, quindi, la seguente tabella (Tab. 3).

[14] Vedasi sito: istat/mappa-rischi dei comuni italiani, sezione indicatori/cartografia/metadati/documentazione.

COMUNI	rischio sismico max e min al suolo (classe 2)	rischio frana residenti sul totale	rischio alluvione residenti sul totale	rischio vulca-nico	vulne-rabilità sociale e materiale	Abitazioni per epoca fino 1980 (%)	Abitazioni per epoca 1981-2005 (%)	Abitazioni per epoca dopo 2005 (%)
Aci Bonaccorsi	0,227/0,225 Me=0,226	0	0	SI	102,04	72,12	22,02	5,86
Aci Castello	0,212/0,212 Me=0,212	518/ 18.577	0	SI	102,70	77,20	20,46	2,34
Aci Catena	0,226/0,221 Me=0,2235	380/ 29.418	0	SI	105,68	60,41	37,09	2,50
Aci Sant' Antonio	0,229/0,228 Me=0,2285	0	0	SI	103,88	52,01	38,52	9,47
Campo-rotondo Etneo	0,197/0,197 Me=0,197	32/ 5.138	0	SI	102,53	45,47	48,49	6,04
Catania	0,250/0,205 Me=0,2275	1.215/ 331.620	3.131/ 331.620	SI	107,27	87,81	11,63	0,56
Gravina di Catania	0,218/0,212 Me=0,215	0	0	SI	102,71	74,06	24,88	1,06
Masca-lucia	0,227/0,223 Me=0,225	0	0	SI	103,01	36,51	59,66	3,83
Mister-bianco	0,217/0,198 Me=0,2145	0	0	SI	105,35	72,34	25,47	2,19
Nicolosi	0,228/0,223 Me=0,2255	0	0	ALTO	101,31	64,16	32,60	3,24
Pedara	0,229/0,225 Me=0,227	0	0	SI	102,09	61,13	33,94	4,93
S. Agata li Battiati	0,230/0,212 Me=0,221	351/ 9.218	0	SI	102,77	72,39	22,65	4,96
S.Giovanni La Punta	0,226/0,218 Me=0,222	0	0	SI	103,11	64,78	33,25	1,97
S.Gregorio di Catania	0,216/0,216 Me=0,216	0	0	SI	101,94	57,60	32,55	9,85
S.Pietro Clarenza	0,218/0,213 Me=0,226	0	0	SI	104,35	37,75	53,56	8,69
Trecasta-gni	0,229/0,227 Me=0,228	0	0	SI	103,33	63,37	28,24	8,39
Tremesti-eri Etneo	0,225/0,213 Me=0,219	0	0	SI	102,31	71,69	27,98	0,33
Valverde	0,225/0,225 Me=0,225	71/ 7.851	0	SI	102,99	59,80	34,52	5,68
Viagran-de	0,230/0,229 Me=0,2285	0	0	SI	101,52	58,26	34,45	7,29

Tabella 3 – *Mappa dei rischi dei Comuni oggetto dello studio. Fonte: Istat, Mappa dei rischi, 2019.*

Tutti i comuni hanno una bassa vulnerabilità idrogeologica in quanto i territori vulcanici hanno una struttura stratigrafica che è meno affine ai fenomeni alluvionali naturali (presenza di inghiottitoi naturali per cavità laviche) e franosi, per la struttura basaltica. Altra situazione è invece il rischio alluvionale indotto da una dissennata politica di urbanizzazione e del conseguente aumento del reticolo stradale; fattori che favoriscono una forte accelerazione del deflusso delle acque a causa della notevole pendenza del territorio vulcanico.

Il rischio sismico è equamente distribuito, con valori simili, leggermente superiori per alcuni comuni e minori per altri. I valori riportati in tabella rappresentano l'accelerazione massima e minima al suolo calcolata dall'INGV. Il rischio sismico è accentuato a causa della vetustà dell'edilizia presente. Ciò appare evidente incrociando gli indici di sismicità con la percentuale di abitazioni esistenti costruite antecedentemente al 1980, come mostra il seguente grafico (Fig. 7).

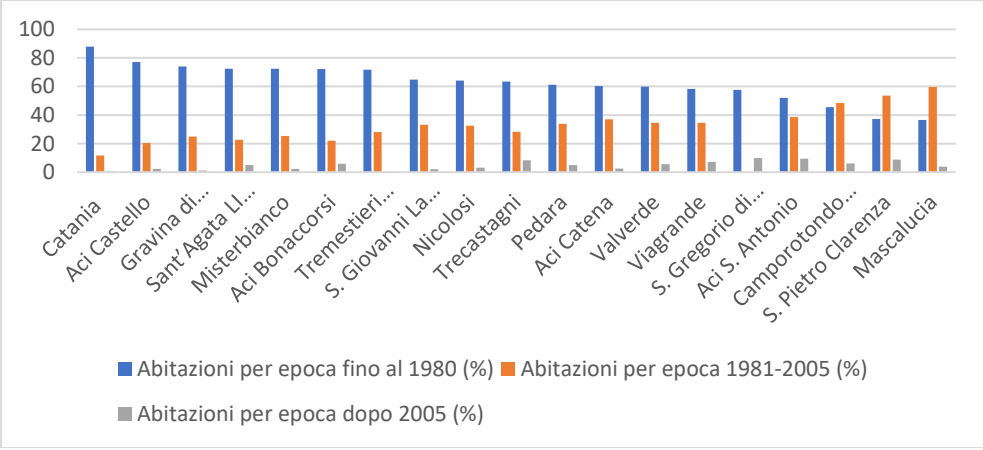

Figura 7 - *Patrimonio abitativo per vetustà. Fonte: Istat, Mappa dei rischi, 2019.*

3.2.2. Fase B – Il rischio soggettivo, ovvero l'azione di prevenzione attraverso la comunicazione istituzione degli Enti Locali

Tenendo presente la normativa di PC, che impone alle municipalità l'obbligo di informare la popolazione sul rischio locale, si sono concepiti 4 temi d'indagine per valutare quanto sia efficace l'azione di sensibilizzazione e informazione dei cittadini. Nell'ambito di ciascun tema sono state immaginate 10 *query* allo scopo di guidare la ricerca delle informazioni nei siti web con l'obiettivo di valutare l'azione comunicativa istituzionale (Tab. 4).

Tema d'indagine	Query
Accesso alle informazioni	1) La pagina dedicata è facilmente reperibile?
	2) Sono esplicitati i rischi del proprio territorio e l'entità degli stessi?
	3) Il Piano di Protezione Civile è facile da trovare e consultare?
Servizio di Protezione Civile dell'Ente	4) É chiaro quale sia l'Ufficio che gestisce l'emergenza?
	5) É chiara l'organizzazione dell'Ufficio comunale e il suo responsabile?
	6) Sono indicati in modo immediato indirizzi utili e numeri di telefono?
Come comportarsi in caso di emergenza	7) Sono individuabili le aree di raccolta in caso di rischio? I loro indirizzi?
	8) Vi sono gallerie fotografiche dei punti di raccolta? Come sostare in essi?
	9) Vi sono eventuali cartografie allegate del territorio comunale?
Riferimenti normativi	10) Legislazione Nazionale e regionale, sono indicate? Altri allegati sui rischi sono presenti?

Tabella 4 – *Temi d'indagine e corrispondenti query per la valutazione della comunicazione istituzionale. Fonte: Autore.*

Si sono quindi interrogati i siti web ufficiali dei 19 Comuni dell'area di studio, ponendo in ognuno di essi le 10 *query,* ispezionando l'eventuale presenza/assenza e il contenuto dell'informazione ricercata, la difficoltà nel reperirla, l'agilità nell'ottenerla.

Si è quindi valutato il contenuto e la qualità di ogni singolo sito web come indicatore della capacità di azione posta dall'Amministrazione nell'ambito della comunicazione non strutturale di PC. Per far ciò si è restituito un giudizio sintetico alle informazioni ottenute attraverso le 10 *query* alle quali è stato attribuito, poi, un valore corrispondente secondo una scala da 0 a 10[15] (Tab. 5).

[15] All'ultimo parametro "SI, esaustiva" è stato attribuito un incremento di valore doppio rispetto ai precedenti assegnando il punteggio totale di 10 a motivo della piena esaustività della informazione fornita.

PER OGNUNA DELLE 10 *QUERY* DELL'INDAGINE	***livelli di presenza/assenza e difficoltà/agilità***		***giudizio sintetico e valore attribuito***	
	NON ESISTE	L'informazione non esiste (non prodotta dall'Ente)	Assenza di comunicazione	0
	NO	L'informazione non è stata ritrovata	Inadempienza comunicativa	1
	Solo tramite il Piano PC	L'informazione può essere reperita solo all'interno del Piano di PC. (lungaggini nell'identificarla)	Pessima comunicazione	2
	Con difficoltà	Informazione ambigua e ritrovata solo dopo aver aperto varie sub-pagine della pagina principale. (lungaggini)	Comunicazione criptica e lenta	3
	Parziale	Informazione reperita ma incompleta. (potenzialmente fuorviante)	Comunicazione parziale	4
	Essenziale	Informazione corretta ma scarna. (potenzialmente insufficiente)	Comunicazione essenziale	5
	Non subito	Informazione completa ma reperita con difficoltà. (lungaggini di tempo)	Comunicazione completa ma lenta	6
	Quasi subito	Informazione completa e ritrovata in poco tempo	Comunicazione completa e veloce	7
	SI	Informazione completa ed immediata, senza alcun bisogno di effettuare ricerca	Comunicazione completa e immediata	8
	SI esaustiva	Informazione completa e immediata ma che integra rinvii a normative, siti d'interesse a tema o a cartografia georeferenziata	Comunicazione esaustiva e di approfondimento. Formazione più che informazione	10

Tabella 5 – *Criteri di valutazione della qualità delle informazioni restituite dai siti web istituzionali. Fonte: Autore su dati dei siti web dei Comuni interessati (ultimo accesso il 15.7.2020).*

Successivamente si è costruita una tabella di sintesi delle valutazioni (Tab. 6), nella quale si sono attribuiti i punteggi secondo i criteri fin qui individuati e riportati nelle Tab. 4 e Tab. 5.

ENTE	**Q U E R Y**	

LOCALE	1	2	3	4	5	6	7	8	9	10	Punteggio totale attribuito
Aci Bonaccorsi	0	1	1	3	4	1	1	1	1	1	14
Aci Castello	6	6	8	8	8	10	2	1	1	8	58
Aci Catena	8	8	8	6	4	5	1	1	1	8	50
Aci S. Antonio	1	1	1	6	8	8	1	1	1	1	29
Camporotondo Etneo	0	1	1	1	4	1	1	1	1	1	12
Catania	8	8	8	8	8	8	8	8	8	8	80
Gravina di Catania	0	1	1	3	4	1	1	1	1	1	14
Mascalucia	8	8	8	8	8	8	2	3	3	8	64
Misterbianco	6	4	8	6	4	5	1	1	1	8	44
Nicolosi	7	8	8	8	8	8	8	8	10	8	81
Pedara	0	1	1	3	4	1	1	1	1	1	14
Sant'Agata Li Battiati	0	1	1	3	4	1	1	1	1	1	14
S. Giovanni La Punta	0	1	1	1	1	1	1	1	1	1	9
S. Gregorio di Catania	8	1	1	3	4	1	1	1	1	1	22
S. Pietro Clarenza	8	6	8	8	8	8	1	1	1	8	57
Trecastagni	0	1	1	1	1	1	1	1	1	1	9
Tremestieri Etneo	8	8	8	1	1	1	2	8	8	8	53
Valverde	8	6	1	8	8	8	1	1	1	1	43
Viagrande	8	6	4	3	4	1	1	1	1	1	30

Tabella 6 - *Valutazione delle proprietà delle informazioni restituite dai siti web istituzionali. Fonte: Autore su dati dei siti web dei Comuni interessati (ultimo accesso il 15.7.2020).*

I punteggi complessivi ottenibili dalla somma dei valori di tutte le *query* di ogni singolo Ente Locale potranno avere un totale massimo pari a 100. Il punteggio massimo corrisponde alla piena attuazione, in campo informativo e formativo, dell'azione di comunicazione istituzionale dell'Ente Locale verso i propri cittadini. Valori che superano i 2/3 del punteggio massimo sono certamente indicativi di un'ottima azione di prevenzione comunicativa dei Comuni relativa al rischio ambientale. Il posizionamento in graduatoria dei singoli Enti, tuttavia, potrebbe non corrispondere alla reale capacità di risposta in caso di manifestazione dell'evento calamitoso, che potrebbe essere meno reattiva per un Comune che ha ben informato la popolazione e più reattiva per un Ente che poco si è adoperato per rendere percepibile il rischio.

L'istogramma finale che scaturisce da tale analisi può essere così rappresentato dal grafico seguente (Fig. 8).

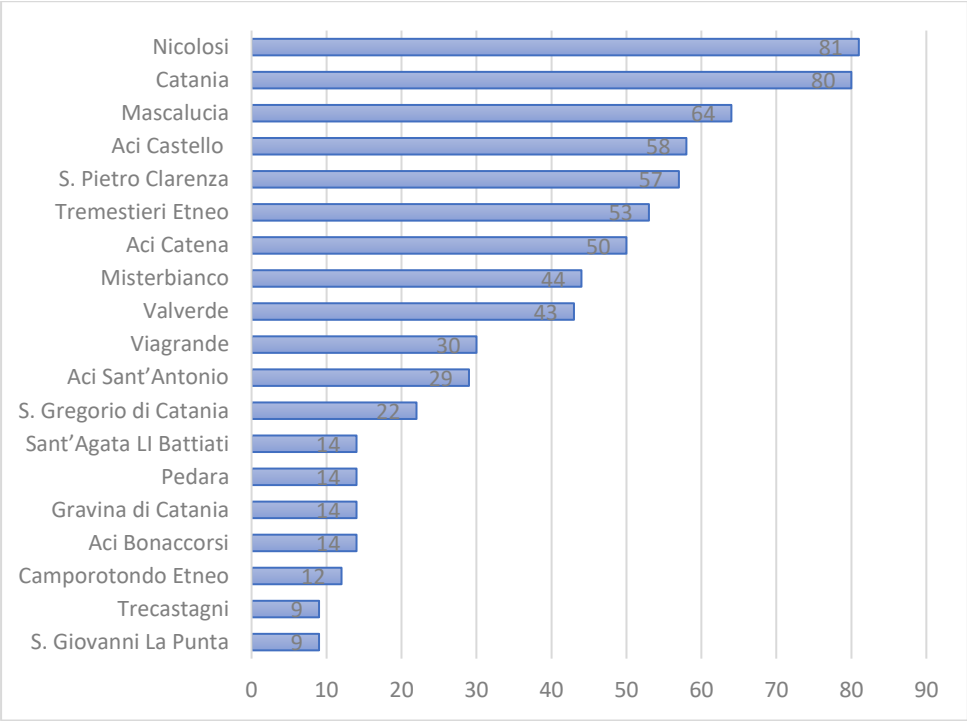

Figura 8 – *Indice di 'prevenzione non strutturale' del rischio dell'Ente Locale. Fonte: elaborazione dell'autore di dati dei siti web dei Comuni (ultimo accesso il 15.7.2020).*

Da questa valutazione si possono trarre, in prima istanza alcune importanti riflessioni. Ogni Ente locale percepisce il rischio a modo proprio, nonostante la stringente normativa e quantunque i rischi siano palesi e sempre potenzialmente replicabili. L'estrema variabilità del comportamento comunicativo istituzionale dei Comuni lo dimostra. Non vi è alcun coordinamento "interno" nelle informazioni che ogni Ente Locale ha, purtuttavia, l'obbligo di fornire ai propri cittadini per sensibilizzarli, informarli e istruirli sui rischi che potenzialmente afferiscono al proprio territorio comunale. I siti infatti sono ricchi di informazioni superflue, vetrine fotografiche e in molti casi anche di pubblicità. Quasi mai il Servizio di PC è in prima pagina web. Avere informazioni minime, come trovare le aree di raccolta, è davvero arduo. Informazioni semplici ma importanti, come numeri di telefono o il nome del responsabile dell'ufficio (in alcuni casi l'individuazione dello stesso ufficio) sono spesso impossibili da reperire. Non esiste un format condiviso per tutte le Amministrazioni (cosa auspicabile). Da un Ente all'altro non è possibile poter individuare suggerimenti per comportamenti uniformi in caso di calamità.

I siti migliori nella comunicazione istituzionale sono risultati essere quelli dei Comuni di Nicolosi e di Catania (1° e 2° posto), seguiti dal Comune di Mascalucia. Essi certamente hanno adempiuto agli obblighi della prevenzione non strutturale. Quattro Comuni hanno attuato una comunicativa sufficiente e si collocano in graduatoria con valori fra 50 e 58. Cinque Comuni hanno valori fra 22 e 44, assolutamente insufficienti a garantire anche minime richieste d'informazioni, in caso di manifestazione del rischio. Per ben 7 Comuni, con punteggi inferiori a 22, la questione "Protezione Civile" sembra non rientrare fra i propri compiti di comunicazione istituzionale. Concretamente è come se il problema di vivere in territori ad altissimo rischio ambientale non fosse percepito da questi Enti Locali. La grave carenza nella comunicazione istituzionale di PC manifesta come queste Amministrazioni non ritengano prioritario informare e formare i propri cittadini su questa primaria esigenza della vita collettiva che li coinvolge perennemente.

I risultati cui si è pervenuti costituiscono una valutazione *a priori* che si presuppone possa fornire elementi di riflessione alla *governance* politica per migliorare le azioni di prevenzione comunicativa nel campo della PC e offrire maggiore capacità di resilienza, e resistenza, alla popolazione, in caso di evento calamitoso.

4. Conclusioni

Luogo mitico e immaginifico, ricco di storia naturale ed umana, da sempre il vulcano Etna è pensato, descritto, studiato secondo linee di pensiero che ne hanno esaltano gli aspetti legati alla sua natura potente e terrifica. Fuoco e lava, neve e ghiaccio, vento e tempesta sono stati da sempre i fili conduttori del rapporto col vulcano, da sempre temuto dagli uomini ivi stanziati, che lo hanno rispettato amandolo con estrema cautela, certi che la Montagna, se violata, si sarebbe prima o poi vendicata. Ciò è successo tante volte in epoca storica e, nell'ultimo millennio, con le grandi eruzioni del 1169, del 1381, del 1536-37, del 1669, 1843, 1928, e non ultime quelle del 1991-93, la cui imponenza ha decisamente accelerato la completa riorganizzazione del Servizio di Protezione Civile Nazionale. Eppure, negli ultimi settant'anni, soprattutto a partire dagli anni Sessanta, questo rapporto sembra infrangersi sul muro della inconsapevolezza e della superficialità dell'azione umana, ignara di un lungo retaggio fatto di grande rispetto delle dinamiche interne della grande montagna vulcanica.

È proprio questa la riflessione effettuata ed esposta nei tre contributi qui riportati. Il *fil rouge* che connota gli interventi è quello della sottovalutazione del rischio legato al vulcano a partire dalla seconda metà del XX secolo, da parte delle popolazioni locali, soprattutto di quelle stanziate nella corona urbana limitrofa al capoluogo etneo.

Il lavoro di ricerca è partito dall'analisi delle tendenze demografiche prodottesi nei comuni oggetto dello studio, che hanno manifestato dalla metà degli anni Sessanta un notevole incremento della popolazione con aumenti spesso a tre o quattro cifre percentuali. Ma ciò è avvenuto soprattutto a causa di un drenaggio di residenti dal capoluogo ai centri minori, attratti dal mito della casa fuori porta. La prima frattura col passato si è quindi consumata con la produzione di dinamiche mai fino ad allora realizzatesi.

Ma l'accrescimento così importante della popolazione ha altresì infranto il limite delle superfici interurbane, violando quello spazio vissuto ed organizzato per secoli che aveva stabilito gerarchie territoriali ben definite, quegli spazi fondiari che costituivano paesaggi agrari complessi, tanto tipici dei territori vulcanici meridionali (vedi ad esempio lo stesso destino anche per le campagne vesuviane). Paesaggi ad alta biodiversità le cui produzioni di pregio alimentavano i mercati del capoluogo etneo e di tutta la provincia.

Ma il boom economico degli anni Sessanta, la cui onda lunga si protrasse in Sicilia fino alla fine degli anni Ottanta, esigeva *standard* non più accettabili fino a qualche anno prima.

È questa l'analisi del secondo contributo, che chiarisce come la grande domanda di abitazioni, causata dallo spostamento dei residenti metropolitani, trova riscontro nell'offerta di un'edilizia basata su complessi residenziali chiusi con grandi spazi condominiali, ma anche da villette a schiera isolate con ampi giardini, garage e box auto. Abitazioni che hanno ampiamente dilatato il consumo dello spazio occupato, erodendo anno dopo anno le superfici fondiarie agrarie di macchia mediterranea e boschi. Emerge qui in modo chiaro la dissoluzione dell'antico patto fra le comunità etnee e la montagna.

Qui si innesta il terzo contributo, la cui ricerca e analisi è tutta squisitamente pragmatica e rivolta a ragionare se e come il rischio ambientale, complessivamente inteso, emerga dall'azione politica degli Enti Locali del cono etneo sud, espresse attraverso i documenti di pianificazione e prevenzione dei rischi, varati dalle medesime municipalità e resi pubblici attraverso i loro siti web ufficiali. Si è valutata l'azione di informazione e formazione resa dalle Amministrazioni e come essa sia/non sia facilmente acquisibile e comprensibile alla popolazione in caso di improvvisa calamità,

determinando così quali siano gli Enti più virtuosi e responsabili verso i propri cittadini, attraverso la comunicazione non strutturale intrapresa.

I risultati sono preoccupanti e resi nella parte finale del terzo paragrafo: solo due Amministrazioni Comunali adempiono alla normativa della prevenzione non strutturale, garantendo rapide informazioni atte a minimizzare i rischi a cui le popolazioni odierne si sono ormai disabituate.

La ricerca fin qui condotta può certamente considerarsi un primo *step* per ulteriori futuri approfondimenti, soprattutto nel campo di una maggiore identificazione dei rischi, a cui è esposta l'intera popolazione etnea, connessi ai continui processi di urbanizzazione del territorio.

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2. Large island, big issues. Vulnerability and resilience in Sardinia

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Abstract

Sardinia is the second largest island in the Mediterranean Sea. In recent decades, heated political, scientific and cultural debates have shown growing concern for coastal land consumption and produced increasing awareness and sensibility on effects due to vulnerability, risks and natural hazards. Approximately half of the Sardinian surface is considered vulnerable to current or future desertification processes. Wildfires, water consumption, urbanisation and land abandonment in declining rural districts, as well as overgrazing and farming intensification in other areas, are some of the major climate-related issues. Tourism activities, which are concentrated in time (summer) and space (coastline), strongly contribute to the regional system's vulnerability. In recent decades, inadequate policies and weak territorial planning have been observed even though climate and environmental issues are increasingly recognised as crucial elements for the future of the island. This article focuses on the local level by considering the formation and consolidation of the discursive practices of the protagonists in the regional debate. Government rationalities as well as rules and policies on prevention, mitigation and adaptation practices are relevant elements for the analysis. Development and planning strategies and practices, as well as relevant official documents, are also analysed and discussed.

Keywords: Sardinia; coastal tourism; depopulation; desertification; planning strategies.

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1. Introduction

In the past few decades, Sardinia has experienced remarkable socioeconomic transformation processes, which led to a considerable improvement in living conditions. These dynamics have also resulted in a substantial growth of environmental pressures on the island. One of the most important threats is the progressive settlement concentration of the regional population along the coasts; this phenomenon has occurred along with the growth of the industrial and tourism sectors and has been accompanied by the ongoing depopulation of the inland areas of the island. These changes have considerable negative effects on the rich natural heritage of Sardinia. Furthermore, inadequate policies, such as weak territorial planning and many contradictory measures, have been observed in many municipalities even though the precious environment of the island is widely recognised as one of the crucial elements for its future development perspectives. The recent decades have witnessed an interesting debate, which stems from widespread concerns about coastal land consumption and evolves towards the mitigation of vulnerability and risk assessment related to natural hazards.

The chapter individuates in a combination of human and climate-induced issues the main challenges for Sardinia in this phase. Suitable vulnerability assessment and adaptation measures to climate change are still necessary to advance in the search for proper management tools. The hypothesis discussed is that such unavoidable continuous progress, during the last decades, has sometimes been disregarded because of various factors. Probably the most relevant one was the ubiquitous request for policy measures aiming to generate fast economic growth through coastal urbanisation and tourism. The chapter describes the formation and consolidation of discursive practices among the protagonists of this conflict between visions and priorities. Starting from the description of the main variables, it focuses on the local debate, showing government rationalities as well as rules and policies on prevention, mitigation, and adaptation practices.

2. Population and settlement

With a surface area of 24,000 km^2, Sardinia is the second largest island in the Mediterranean Sea. However, it has a relatively low population density (less than 70 inhabitants per km^2), accounting for a little more than

1,630,000 residents. From a demographic point of view, the island is characterised by a progressive concentration of settlements and inhabitants along the coastline and around the main urban poles and by a gradually declining and ageing population (Corsale, 2016; Gentileschi, 1995). For most of its medieval and modern history, the island's population was largely distributed in the agropastoral inland areas, at a safe distance from the piracy- and malaria-infested coast (Casalis, 1833). The situation started to change in the late 19th century and in the second half of the 20th century with a reverse phenomenon of redistribution towards coastal and urban areas; this phenomenon further evolved into a considerable depopulation of mountain and hill settlements, a decrease in fertility rates and an ongoing urbanisation and littoralisation (Leontidou *et al*., 1997). Overall, the demographic framework of the island has shifted from an internal to a coastal population distribution, from intense natural increase to ageing and decline and from widespread emigration to immigration from abroad (Carboni and Fois, 2016; Corsale, 2016).

Thus, at the local level, population ageing and decline is particularly intense in most inland areas, whereas the urban clusters of Cagliari, Sassari and Olbia and several small settlements scattered along the coast still register feeble growth. These areas are characterised by the expansion of tertiary activities, including tourism, as well as the agricultural, industrial and construction sectors (Bottazzi, 1999; CRENoS, 2019). Sardinia appears to be increasingly and sharply divided into two main areas: (1) a coastal belt with a constant growth trend, which is more or less pronounced in different areas and (2) the rest of the territory, which is distant from the sea and mainly rural. In the latter, depopulation is intense, thus producing an overall ring-like pattern. Immigration tends to strengthen this trend, with most migrants concentrating in the most dynamic areas and sectors (Carboni and Fois, 2016). In accordance with the Italian Institute of Statistics, the Sardinian population is expected to decrease by 20% in 2050, with a significant population growth expected only in a few municipalities along the north-eastern coast and, to a lesser extent, in some suburban centres around Cagliari and Sassari, which are characterised by tertiary and industrial activities.

3. Climate

Sardinia's climate is typically Mediterranean and characterised by considerable seasonal differences and interannual variability. In the summer season, high pressure dominates the island, causing atmospheric stability which usually leads to hot, arid and subtropical weather conditions from June to August. In the winter season, high pressure cells move southwards and let humid air flows and cold polar fronts define autumn, winter and part of the springtime weather. The complex orography of the territory and the different exposure levels to winds generate numerous climatic microregions across the island (Motroni, 2016).

The Sardinian climatic conditions show signs of change, within broader trends and projections for the entire Mediterranean Basin (Navarra and Laurence, 2013). A substantial warming (up to 1.5°C in winter and 2°C in summer) and a considerable decrease in precipitation (up to -5%) may affect the region in the 2021-2050 period compared with the reference period (1961-1990) (Gualdi *et al*., 2012).

Recorded data from weather stations located evenly throughout Sardinia show a slight increase in temperatures, particularly for maximum values (+0.7°C), especially in coastal areas and some portions of the inland. Rainfall data show a progressive decrease but also a great variability in the amount of rain and occurrence of droughts. At the same time, the frequency of precipitation events of less than 5 mm has decreased, whereas rainfall of more than 50 mm has become more frequent (Motroni, 2016).

4. Growing vulnerability and poor planning

Sardinia has undergone wide transformations in the past 60 years. 'Modernisation' via the extraordinary financial intervention of the State and consequent public and private investments has led Sardinia to face a profound change in its structural socioeconomic conditions in the second half of the 20th century. Tourism specialisation and industrialisation concentrated in coastal areas have been the driving factors of a progressive littoralisation (Bottazzi, 1999; King, 1975; Ruju, 2018). In addition to social and economic changes, a radical transformation of the coastal landscape has been observed, with long-lasting and well-documented ecosystem impacts on air quality and common resources, such as soil and water (Aru *et al*., 1994; Cipriani, 2014; Leontidou *et al*., 1997; Pungetti, 1996; Stancampiano and Deliperi, 1993).

In recent years, the crisis of several large industries (particularly petrochemical and metallurgical industries based on lead-zinc and

aluminium) has led to a rapid decrease in employment and unsolved environmental problems (Balestrieri and Ganciu, 2018; Heatherington, 2001). Moreover, domestic and international tourism grew, especially in the 1960s, because of a consolidated image of a 'dream destination' fostered by relatively low population and soil consumption (Hospers, 2003; Price, 1983; Solinas, 1997).

Tourism development has produced a spatial concentration in the sandy coastal areas, with 90% of the hotel beds concentrated in the north-eastern, north-western, southern and central-eastern areas. Conversely, tourism seasonality is concentrated between June and September, accounting for approximately 80% of the overall tourism flow (Iorio and Sistu, 2004).

The prevalence of holiday houses over hotels has resulted in negative externalities on landscape, water resources, infrastructure congestion and waste production. Meanwhile, inadequate tourism management and planning strategies have resulted in poor integration between environmental protection and local economy (CRENoS, 2019).

Only at the end of the 1980s did a relatively innovative institutional approach produce the first regional laws on urban planning, quarrying activities and protected areas.

However, the vast network of protected areas envisioned by the Regional Law 31/1989 remained largely ineffective, as national, regional and marine parks have been established in coastal areas, whereas the internal areas remain largely uncovered due to widespread opposition stemming from local stakeholders, such as shepherds and hunters. Such is the case of the Gulf of Orosei-Gennargentu National Park, which was formally established in 1998 to protect some of the most fragile and precious mountain ecosystems of the island, but has never been carried out in practice.

A potentially innovative approach, which aims to integrate nature conservation, heritage promotion and local development, resulted in the establishment of the Geo-mining Historic and Environmental Park of Sardinia in 2001 (approximately 37,500 ha distributed in eight different coastal and inland areas). However, the project has produced limited benefits due to territorial fragmentation, administrative difficulties and the costly and complex rehabilitation of polluted former mining sites (Perelli and Sistu, 2010).

5. Overturning the inertia: the 2006 PPR

The first large-scale attempt to introduce a new approach to planning issues mainly focused on coastal areas. The so-called Save Coast Law (2004) and the subsequent Landscape Plan (PPR) aimed to deal with the contradictory effects of combined tourism development and littoralisation. The history of tourism in Sardinia saw a pioneering phase of international tourism development in Alghero in the mid-1950s, followed by an international consortium which invented and created the renowned Costa Smeralda resort area in the 1960s. From that moment, often on the impulse of foreign capital, a ubiquitous real estate development resulted in a chaotic geography of new tourist centres, which were also sustained by the growing Sardinian middle class (Price, 1983).

Despite some attempts to introduce coastal conservation measures (e.g. the prohibition to construct new buildings within 150 metres from the coastline, 1976), various municipalities proposed new coastal settlement plans for approximately 10 million m^3 in the mid-1970s (Roggio, 1995; 2007). The growth rate of the holiday home sector in Sardinia exceeded 400% between 1970 and 1980. During the 1980s, the Sardinian Regional Authority and the private Costa Smeralda consortium agreed upon further real estate investments for approximately 6 million m^3; such investments mainly included holiday homes and villas in the north-eastern coastline of Arzachena, although a judicial conflict between the local municipality and the Regional Authority blocked the implementation of this master plan in 1988 (Roggio, 2007). In the town of Olbia, a consortium led by Silvio Berlusconi promoted new settlements for over 20,000 beds and, in 1983, the municipality adopted a regulation granting them over 1.2 million m^3.

In 1985, the Sardinian Regional Authority appointed several technical groups to elaborate renewed territorial plans, which are consistent with the new environmental conservation philosophy supported by the 'Galasso' national law. However, the results appeared unable to manage and curb the ongoing occupation of the coastal belt. After several years of discussion (1993-2003), the ruled illegitimacy of 13 out of 14 proposed territorial plans finally highlighted the failure of these attempts to implement coastal planning tools (Falqui, 2011). In a vacuum of protection measures, the so-called Save Coast Law introduced 'Urgent provisional safeguard rules for landscape planning and the protection of the regional territory' in 2004. These rules included a general prohibition to build new real estates within 2000 m from the coastline. The law, which is unique in the entire Mediterranean region, affirmed the priority of environmental protection over building development, in spite of persistent pressures linking tourism development to real estate development, and anticipated the vision of the

latter Regional Landscape Plan (*Piano Paesaggistico Regionale* or PPR) (Perelli, 2016).

Although the PPR does not cover the entire regional territory, it is a pioneering experience in Italy because it is the first plan which implemented the provisions of the law for Cultural Heritage and Landscape focusing essentially on the coastline. The PPR started a new era of regional plans, attempting to integrate long-lasting ecological and symbolic relations between human communities and territories.

On the contrary, some authors (Leone and Zoppi, 2016) highlighted criticism on the effectiveness of the participation processes established by the PPR, which affected the capability of the municipalities' plans to adjust to it. A lack of dialogue and understanding amongst stakeholders on the planning issues can be a serious threat when emerging complex phenomena related to climate change have to be faced; moreover, the regional and local levels need to develop stronger consensus processes (De Montis *et al*., 2018a).

6. Soil use and forest cover

Soil loss largely depends on wildfire occurrence, poor management of mining activities, road and railway infrastructure and urban expansion. With respect to soil protection, Sardinia can account for a detailed inventory provided by the *Soil Map of Sardinia* (Aru *et al*., 1991). On the one hand, indicators show that soil consumption for industrial use, service infrastructure and urban expansion is considerable in the major urban areas (Cagliari, Sassari, Oristano, Nuoro, Olbia, Alghero). On the other hand, urban sprawl significantly affects many coastal areas and the main road axes. Strong coastal pressure (particularly in the Gallura subregion) is currently associated with the urban expansion of inland municipalities near coastal tourism areas, where urban planning tools, such as the PPR, have less effect. In the same years, data from the national forest inventory (INFC, 2007) show that Sardinia is the Italian region with the largest forest cover, accounting for 1,213 ha (583 ha of proper forest and 630 ha of other wooded areas).

Despite some issues related to the legal status of forest and wooded areas and recurrent wildfires, widespread reforestation occurred since the 1950s and public forestry management considerably increased the forest cover in Sardinia in comparison with the levels of the early 1900s. Between the 1950s and the 1970s, reforestation accounted for approximately 1,500 ha

yearly. The subsequent state-funded productive forestry sector managed more than 30,000 hectares until the end of the 1980s. The EU-funded reforestation policies in agricultural areas produced further results in the 1990s, with new wooded areas estimated between 18,000 and 20,000 ha. In recent years, the crisis of sheep and goat farming resulted in a natural recolonisation of abandoned pastures, contributing to an additional increase in wooded surface (Beccu, 2000; Puddu *et al*., 2012). The key elements that mainly influence the success of public policies on forestry are, not only the still relatively widespread public ownership of the land and the consequent customary rights to forest use, but also the economic relevance of public forestation managed by the regional agency (*Forestas*). These two themes are linked, for instance, to the integrated management of protected areas and the innovative management of summer wildfires. Since the 1990s, Sardinia has managed to reduce burnt surfaces progressively through law enforcement and prevention activities, although meteorological trends affect the predictability of seasonal fires (RAS, 2020).

7. After the PPR: coping with vulnerability

At present, approximately 50% of the Sardinian surface is vulnerable to potential desertification processes because of climate change and variability. The main factors of desertification phenomena in Sardinia include extreme climatic events (droughts and floods), human pressure (overgrazing, urbanisation, pollution and depopulation of rural districts), excessive exploitation of water resources, wildfires and deforestation (Arrigoni, 1968; Camarda and Cossu, 1988; Vacca and Vacca, 2001). Soil erosion, compaction, consumption and sealing are common degradation processes in rural areas and result in a loss of ecological value and functions (Vacca, 2000). The Sardinian Regional Authority has been collecting data on desertification processes since 2002 to model them. A GIS application maps areas of sensitiveness and critical districts on a local level, where desertification signs are already observable[4] (Motroni *et al*., 2009).

[4] At the end of the 1990s, a shared vision at the continental level was adopted on the basis of the ESA model through the European project MEDALUS II; this vision is an articulate approach encompassing the entire biophysical processes that contribute to desertification.

Climate variations directly affect the availability of water resources by reducing the stock of surface reservoirs and threatening the quantity and quality of groundwater, especially during extended periods of drought (e.g. between 1997 and 2000). Given poor urban planning and insufficient maintenance of water networks, an increased occurrence of floods can be particularly destructive; several major events have already occurred in the past decades (e.g. in 1951; 1999; 2008; 2013; accounting for 19 deaths and 2018) (Silvano, 2016; Sulis *et al*., 2020). Wildfires, excessive water consumption, land abandonment in rural districts formerly exploited for agricultural or breeding activities, and farming intensification and overgrazing in other areas, are amongst the major climate-related threats in the island (Le Lannou, 1941; Manconi and Angioni, 1982; Mientjes, 2004).

Concerning wildfires, the areas which kept the same land use type counted 39,621 wildfires between 2000 and 2015 (Bajocco *et al*., 2019). The land cover type was a relevant variable with arable land and permanent crops experiencing an increase in fires, and mixed agriculture, maquis, and forests showing a considerably decreasing trend over the period. During four decades, cross-studies on demographic trends and land use proved that the areas where population grows tend to show increasing fire ignition energy. On the other hand, however, depopulated areas, while experiencing a reduction of wildfires in the short term, also show significant long-term threats due to the amassing of fuel (Bajocco *et al*., 2019). A recent study illustrates that, in the cork oak production areas, about 15,500 hectares burned in the period 2003-2015, which is particularly worrying, as Quercus suber L. woodlands are a key historical agroforest resource and are essential in keeping high soil quality standards (Salis *et al*., 2019).

Regarding land consumption, Sardinia shows good performances if compared with the rest of Italy. This is mainly due to the previsions of the Regional Landscape Plan of 2006. The latest data available (Munafò, 2020), for instance, show little less than 80,000 ha of urbanized land in Sardinia in 2019, meaning 3.2% of the island surface (7.1% at the national scale). Consumed surfaces amounted to 165 ha during 2019, among which 90 for new photovoltaic plants installed on the ground in the municipalities of Uta (60.2 ha), and Assemini (30.2). Furthermore, in 2019, the percentage of land consumed within 150 m from water bodies amounted to 2.9%, much lower than the national average of 7.1%, and its variation during 2019 was even negative (-1.8 ha), compared to a national increase of 58.2 ha. Urbanization

is a significant factor in the alteration of microclimates at the local level, resulting in sizeable temperature increase in artificially covered lands (Munafò, 2020).

Soil protection is closely related to the topic of landscape planning. Several regional land management policies, as well as those of the related sectors, have not paid enough attention to these issues. Many key documents, such as the map of hydrogeological risk, the hydrogeological plan (PAI) and the transitional plan for fluvial belts (PSFF), have not been adequately implemented. The National Government Bill principles (2013), which deal with the containment of land loss and the reuse of built soil, have yet to be introduced in the regional legislation. In particular, the PAI is a fundamental tool because it identifies risk areas for floods and landslides in accordance with the provisions of law 267/1998.

Year	***Document***	***Functions***
1990	Soil Map of Sardinia 1:250,000	Soil classification by classes of potential use
2006	Regional Landscape Plan (*PPR*)	Coastal planning and ecosystem protection
2006	Hydrogeological Framework Plan (*PAI*)	Classification by risk classes of hydraulic and landslide hazard areas, mitigation and risk control
2010	River Basin Management Plan (*PGDI*)	Delimitation of river basins to allow for a water regime which is compatible in terms of safety and eco-systemic balance
2015	Regional Environmental Energy Plan (*PEAR*)	Regional energy plan related to European and national guidelines for energy transition
2016	Flood Risk Management Plan (*PGRA*)	Planning and implementation measures to reduce the consequences of floods
2019	Regional Strategy for Adaptation to Climate Change (*SRACC*)	Planning tools for the development of effective adaptive strategies
To be defined	Regional Strategy for Sustainable Development (*SRSvS*)	Path for the implementation of the '17 Sustainable Development Goals of the 2030 UN Agenda'

Tab. 1 – *Chronology of relevant planning documents.*

The Sardinian Regional Government approved a River Basin Management Plan in 2010 (which is currently being updated) as a monitoring tool for water bodies (RAS, 2010). It identifies the main groundwater bodies in use and contributes to define integrated water management strategies. As surface and groundwater resources are part of an interconnected system, including wastewater, further coordination amongst

all stakeholders is imperative. The worsening of the quality of water supply implies additional safeguard policies for the aquifers together with more immediate surface water management actions. From this perspective, the management of interconnected water systems, such as those developed around dams, can be considered an effective adaptation policy. According to demand needs, it allows a flexible adaptation to emergency supply or restrictions in case of droughts (Cadoni, Silvano and Virdis, 2011). The plan provides a framework for the integration of alternative resources and the combined use of different water sources. Furthermore, it adopts adaptation measures that support weather and climate data improvement, drought monitoring and guidelines to improve water use in agriculture. The Sardinian experience shows that water shortage management on a long temporal scale reduces the negative effects on the economic system in comparison with less effective emergency actions that target a single extreme water shortage. Reinforcing the ongoing IT-based decision support system can help improve adaptation to extreme weather through a rational use of resources, thereby minimising hydrological risks.

The Regional Environmental Energy Plan (*PEAR*) (RAS, 2015) was approved in 2015, envisioning the year 2020 as a deadline to define effective measures for energy use efficiency, emission reduction and the consolidation of alternative source production. In January 2019, a first monitoring report was published, assessing the results attained by the *PEAR* measures[5]. The recent approval of the plan has not led to radical changes in the island's energy system. With respect to the purpose of 50% reduction in CO_2 emissions by 2030, and in comparison with the 1990s values, the report states that emissions were reduced by approximately 25% in 2017. By maintaining this rate of reduction, the goal will be achieved by 2030. General objectives, such as the transition towards an integrated energy system (OG1) and the promotion of research and participation in the energy field (OG4), appear to be advancing. By contrast, the energy security objective (OG2) seems to be less advanced because of delayed works for methanisation and a difficult transition from fossil sources. Improved results emerge with respect to the flexibility of the electrical energy system and the diffused generation from renewable sources for self-consumption. Lastly, the increased efficiency and the objective of energy saving (OG3) is advancing because of integrated network development, particularly in the

[5] www.regione.sardegna.it/documenti/1_461_20190402172259.pdf

transportation sector. Meanwhile, actions for energy efficiency in the electrical and thermal sectors remain underdeveloped.

The Flood Risk Management Plan approved in 2016 is currently being updated according to the Directive 2007/60/CE (the second planning cycle is 2016-2021). In this phase, simulation models are being developed, focusing on basin vulnerability to flood damages and assessing alternative strategies to mitigate the effects of floods (Sulis *et al*., 2020).

A recent EU-funded project has been contributing to define the strategic guidelines followed during the elaboration of the Regional SRACC in 2019[6]. The main idea was to create a collaborative process between authorities, agencies and other decision-makers at the municipal and regional scale. The strategy is grounded in a detailed preliminary study conducted by the University of Sassari (RAS, 2019a). It focuses on key domains (agroforestry, water management and hydrogeological risk control) affected by weather variability and anthropogenic pressures and is distinguished for the existence of planning tools and skills for the development of effective adaptive strategies. Consequently, the strategies and actions for adaptation identified by the Regional SRACC essentially coordinate the already existing plans and tools that cope with adaptation issues. The PPR, PAI, PGRA and PSFF already provided implicit and explicit adaptation measures, which vary from studies or monitoring to effective defensive works to reduce territorial vulnerability (RAS, 2019b).

The strategy is envisaged as a transversal framework that is oriented to highlight the deficiencies of sectoral planning and makes its objectives congruent with adaptation priorities rather than reform each specific domain directly. It implies confidence that the existing framework and skills can be optimised with minor revisions. Furthermore, it tends to reduce or avoid power conflicts related to any possible changes in the balance of consolidated political and technical skills at the regional level. In this sense, the attribution of the main coordination functions to the Department of Defence of the Environment could likely represent an opportunity for the effective implementation of the actions descending from the proposed sectoral objectives. However, this process may eventually result in the emergence of new controversies amongst various stakeholders, similarly to what had already happened in the past in these domains. For example, general objectives, strategic axes of action and adaptation priorities (either incremental, systemic or transformative) should be based on transversal or

[6] Life project MASTER Adapt (Main Streaming Experiences at Regional and local level for adaptation to climate change) (Master Adapt, 2018).

sectoral shared and participative approaches. However, their monitoring is entrusted to a pyramidal management system, which limits effective participation.

Topic	Governance and adaptation to climate change
Tools	Online questionnaires Analysis to official website and documents Analysis of regional plans
Criteria	Adaptation Strategies reference Adaptation measures Implicit or explicit measures Responsible for the identified adaptation measures

Tab. 2 - Methods and tools adopted for investigating the current regional governance of climate change adaptation and criteria selected for analysing the plans in the Regional Strategy for Adaptation to Climate Change. Source: modified from De Montis *et al*. (2018a).

8. Resilience between rhetoric and policies

The integration of the resilience paradigm in the planning strategy envisioned by the SRACC reveals a contrast between scientific awareness of the emerging scenarios and the fragility of institutional action. The decision support document elaborated by the University of Sassari outlines an integrated system that copes with complexity and uncertainty. By contrast, a lack of elasticity of the settlement model and related economies resulted in a continuous delay in considering climate change as an immediate priority. However, in this context, resilience practices emerge at the local scale (interestingly more frequent in critical socio-demographic situations) and in some important natural ecosystem components, such as forest cover. Resilience-building actions also appear in sectoral interventions in strategic policy areas, such as energy transition, urban planning, reduction of summer wildfires, water resource management policies, waste production reduction and integrated management. Essentially, the sectoral impact chain at the regional level develops through

four stages: risk recognition, source identification, vulnerable elements detection and adaptation capacity analysis (RAS, 2019a). Yet, several implementation fittings are advisable, such as wider transversal strategies, new technologies to improve high resolution territorial information systems, smoother and more inclusive public administration procedures, and further investments on education and awareness both for the general public and the specific stakeholders. For example, regarding the hydrogeological risk, red tape hurdles, inadequate monitoring and insufficient awareness among the population, in terms of behavioural impacts, are significant threats, but also show wide margins for improvement. In fact, so far, many actions still do not appear organically inserted in medium- and long-term political strategies, which are still conditioned by the need to maintain political consensus in the short term. Therefore, at the local scale, without awareness and involvement, the inhabitants can hardly act as holders of rights and responsibilities. Moreover, they can hardly activate constructive participatory policies that go beyond a lobbying approach by the most important stakeholders or a consensus-building strategy. Hence, the policy strategies ought to become a key reference for the Regional Operative Plan 2021-2027, and its implementation should probably become a direct competence of the Regional Presidency, the only authority able to effectively address the institutional actions and the common practices. Resilience, as an operational paradigm, can thus allow local actors to face regional system vulnerabilities by recognising and placing specificities and locally based solutions for local development.

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3. When the giant shakes. Anthropology of the seismicity of Ischia, an island-volcano in the Mediterranean Sea

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Abstract

Ischia is an Italian volcanic island in the central Mediterranean Sea, sadly famous in the last two centuries because in 1883 a strong earthquake destroyed the town of Casamicciola and killed over 2300 people. During the twentieth century the island has not suffered other disasters of geological origin and has seen a conspicuous increase in tourism, therefore urbanization. However, the nature of the place has not changed, so in summer 2017 a new earthquake shook the town of Casamicciola, causing two deaths and thousands of displaced people. This opened a debate on the relationship between human beings and their environment, on the type of development followed in the last century, on the model of reconstruction to be carried out, on safety in a tourist resort and, moreover, isolated in the sea. The paper addresses these issues using the analytical tools of cultural anthropology, maintaining a long-term perspective.

Keywords: Ischia island, earthquake, anthropology of disaster, tourism, development

1. Introduction: a dragon called Typhaeus

In the popular literature of Ischia, it is said that under the island resides Typhaeus, a giant with a hundred heads who, in order to realize the ambitions of his mother Gaia, rebelled against Zeus, who, however, prevailed after a fierce struggle and confined him to the subsoil of the island of *Pithecusae*, which thus began to erupt fire and hot water, as well as being shaken by the restlessness of the monster (Vuoso, 2002). Although the myth of Typhaeus was born in Cilicia, his recourse as an allegorical figure of the unstable Ischian geomorphology is due to the importance of the island in classical

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times as a «crossroads of the ancient world» (Buchner, 1994) and has adapted so well that there is a reflection of the giant also on the surface, through the popular and official toponymy that describes the places just in its function, such as the village of Panza, the fumaroles of La Bocca and other places (Di Meglio, 2007). In the founding legend of Ischia, Typhaeus is a dragon that wants to take the place of Jupiter, but that the father of the gods manages to stop by throwing the island at him, to crush him with Mount Epomeo. Trapped underground, the monster is not dead, so it occasionally wiggles and spits fire, which provides not only the subject of a popular narrative, but more deeply a picture of meaning that, from generation to generation of Ischians, has allowed on the one hand to emphasize its local belonging and, on the other, to exorcise fears and find accessible explanations for events considered exceptional.

Although the last eruption dates to 1302, Ischia, in fact, is together with the Campi Flegrei and Vesuvius one of the three active volcanoes in the province of Naples. From a geological point of view, the duration of its cycles of alternation between quiescence and active phase is typically 10000 years (Civetta et al., 2016). This involves long phases of apparent absence of activity, sporadically interrupted by earthquakes of low magnitude located at shallow depths in the north of the island and accompanied by widespread fumarolic and hydrothermal manifestations. It should be noted that, as it is still active, the volcano of Ischia has the potential to erupt in the future, with particularly worrying effects due to the intense urbanization that has affected its territory during the twentieth century.

2. A century and a half of tourism and two earthquakes

The seismic history of the island began in 1228 and has the usual characteristics of seismicity in volcanic areas, i.e., earthquakes of low energy, but of high intensity (Luongo, 2016, p. 15). Most of the seismic events recorded in the last eight centuries have as epicenter the northern slope of Mount Epomeo, the one corresponding to the municipalities of Casamicciola Terme and Lacco Ameno. The nineteenth century was the century with more earthquakes: in 1828 there were some victims and various material damages in Casamicciola, leaving the memory of itself in the collective memory for several decades, at least until the catastrophic shock of 28 July 1883, which was preceded by strong earthquakes already in 1880 and 1881. The earthquake of 1883, the first in unified Italy and the most intense ever recorded in Ischia, is also the most widely documented both in literature and

in archive sources: it caused 2,333 deaths and the destruction of the historical and environmental heritage of some areas of the island; the greatest damage occurred in Casamicciola and in Lacco Ameno, where out of 1,061 houses surveyed only 19 remained standing (only one in Casamicciola) (Polverino, 1996, p. 31).

At the time Ischia was a destination for wealthy and international tourism, attracted by the presence of spa establishments and the healthiness of its sea, so the seismic disaster had a great reverberation in the national and foreign press and a considerable emotional impact, which gave rise to a saying, soon spread throughout the country: «A Casamicciola happened», as an expression of ruin, disorder, confusion. That event marked the end of an era and a new beginning for tourism in Ischia: «The origin before [the deterioration of the relationship between nature and artifice], also in terms of architectural characterization, dates back to the time of the Casamicciola earthquake, which ended the golden season of nineteenth-century tourism and began to change the relationship with the landscape and the natural and built environment», of which twentieth-century mass tourism will be a dominant element (Maglio, 2017, p. 329).

The most famous direct testimony of that catastrophe is by Benedetto Croce, at the time seventeen years old, the only survivor of his family after the collapse of their holiday home, who tells of that terrible experience between the «Contributo alla critica di me stesso» (1918) and the «Memorie della mia vita» (1966): «I came to light at high night and found myself buried up to my neck, and the stars twinkled on my head [...].Towards morning (but later), I was taken out, if I remember correctly, by two soldiers and laid out on a stretcher in the open air. The dizziness of the domestic misfortune that had struck me, the morbid state of my organism that did not suffer from any specific disease and seemed to suffer from all of them, the lack of clarity about myself and the path to follow, the uncertain concepts about the ends and meaning of living, and the other combined anxieties of youth, took away all joy of hope and bowed to consider me withered before blossom, old before young». The earthquake changed Croce's life both in his affections and in his thoughts: «Those years were my most painful and gloomy years: the only years in which, many times in the evening, I laid my head on the pillow and longed very hard not to wake up in the morning, and even thoughts of suicide arose» (Croce, 1966, p. 23).

The earthquake in Casamicciola represents the first serious catastrophe with which the national government had to deal, which promulgated the first anti-seismic regulations in the post-unification period. The «Building Regulations for the Municipalities of the Island of Ischia damaged by the

earthquake of 28 July 1883» came into force on 15 September 1884 - with «indefinite validity» - and indicated the prescriptions for new buildings (it was recommended to use the "baraccato" (shack) system), the definition and delimitation of "dangerous zones", the regulations for damaged and dangerous buildings, the establishment of the Special Building Commission with the task of executing and having executed the provisions contained in the Regulations (Castagna, 1984). Among the many political and scientific figures who intervened on the scene of the disaster, significant work was undertaken, on a political level, by Francesco Genala, Minister of Public Works, and, on a cognitive level, by Giulio Grablovitz, founder, and director of the Casamicciola Geodynamic Observatory, who arrived in Ischia in 1884, where he would remain for the rest of his life. During the emergency and during the planning phase for the reconstruction, the choices made by Minister Genala were decisive: he stayed on the island for about a month, visited the most damaged places, followed the scientific debate that attributed the extent of the damage to the way of building and as mentioned, favored the promulgation of the Building Regulations. The year after the earthquake, on the other hand, Grablovitz landed on the island, which studied the geological nature of the territory, developing one of the first monitoring systems for an active volcano and working concretely to disseminate the results of its research to the population (Carlino et al., 2011).

One hundred and thirty-four years after the terrible earthquake of 1883, on the evening of 21 August 2017 a new, very intense, and localized earthquake shook Casamicciola and some neighboring towns: two women died and there were thousands of displaced persons, of which I write more extensively in the following pages.

The island of Ischia has been known since ancient times for the sweetness of its climate, the fertility of its lands and, above all, for the numerous thermal springs and rich in minerals, around which its tourist celebrity has developed. As Annunziata Berrino reports in her "Storia del turismo in Italia" (History of tourism in Italy) (2011), still in the mid-nineteenth century her offer of services was quite modest, because there were just «two not excellent establishments, two good houses of health - that of Dr Chevalley de Rivaz and the Maison Sauvé -, a very well maintained Ospedale della Misericordia which can hold up to 600 people, but still without drinking water» (p. 103). It was only in June 1864 that the name of Ischia went around the world because General Giuseppe Garibaldi stayed in Casamicciola to treat a wound he sustained in Aspromonte, with the thermal waters of Stabilimento Manzi (D'Ascia 1867, p. 433). From that moment, for about twenty years, the fame of the island grew, until it was abruptly cancelled by the terrible shock of July

1883, which caused the destruction of Casamicciola itself and the death of over 2300 people.

That dramatic event marked, says Andrea Maglio, the end of the «golden season of nineteenth-century tourism» (2017, p. 329), leading to a profound change in the relationship with the landscape and the natural and built environment, which would characterize the following century and its mass tourism. It was a catastrophe in the etymological sense of the term: after it, the island was no longer the same; it was a lasting and substantial fracture of the social order and the material conditions of the community, as well as the perception of itself and its sense of security. In other words, recovering from the trauma and losses was an enormous effort, which lasted decades and caused further suffering, as the numbers of emigrants at the turn of the century show. The trauma had profound psychic and cultural repercussions, as Giuseppe Mercalli testified in 1884: «When I was in Ischia the newspapers reported the prophecy (?!) of a professor, I don't know if German or French, according to which on September 15th the island of Ischia would have sunk entirely. Many people, especially women, were greatly frightened: and they wanted me to be able to say whether they really expected such a catastrophe. To reassure them, I replied that I would stay on the island until the 15th of September, so much so that I was sure that, in the present state of science, such prophecies are nothing but charlatanism of a bad kind» (Mercalli, 1884a, p. 4).

In a recent essay, the Ischian anthropologist Ugo Vuoso observed something similar for the earthquake of 21 August 2017, when in Casamicciola Terme, Lacco Ameno and Forio «rescuers were able to record several cases of inaction, reactive depression and various other degrees of psychological distress among the survivors and displaced persons. This time the trauma linked to the loss of the sense of place was detected and highlighted by the displaced people who were aware of the loss of home, of domesticity, of not being in that "world in which just before I was and now is no more"» (Vuoso, 2019, p. 28).

In both earthquakes in 1883 and 2017 there were deaths, injuries, collapses and abandonments, and in both cases the reason for the disaster was immediately attributed to the homes: old and dilapidated in 1883, unauthorized and "papier-mâché" in 2017. The blaming process is inevitable in case of disaster and is always aimed at identifying a responsibility, which on these occasions coincided with the blaming of the victims: At the end of the nineteenth century it was written that the inhabitants of Casamicciola «although they knew the danger (most of the locals in the summer, hosting the holidaymakers, lived in ephemeral dwellings, with roofs covered with

reeds and branches, as reported in the chronicles) were very careful not to share it with those holidaymakers who instead went to thicken the number of deaths» (Vuoso, 2019, p. 28); three years ago, instead, the accent was placed on the floors raised above the old barracks in order to increase the number of beds, in view of the transformation into a b&b.

The economic system developed on the island during the twentieth century led to massive tourism, which devoured land, history and culture. Over the years, the growing prosperity, the consequent cementing and motorization, as well as the overpopulation of certain areas and the flight from the countryside, have led to a radical transformation of the land and its use: in the last 50 years the urbanized areas on the island have more than tripled, going from 410 hectares to about 1300 hectares (WWF 2018) and, at the same time, the agricultural space has dramatically contracted, because in the 80's on the island there were 1000 hectares of vineyards, with 3400 farms, but thirty years later the hectares have been reduced to 240, while there are 500 farms (Di Gennaro, 2019). In a first phase, this has enjoyed the full consensus of the entire population, but in a more recent phase a need has emerged to safeguard and requalify the territory. There was a time when tourism-economic development was favorably supported by the whole community because it came from a social cohesion between political interests and population; today, instead, the growth of anthropic pressure is increasingly averted because it is associated with negative scenarios that speak of increased traffic, pollution, environmental disfigurement, marginalization of the natives, social fragilization.

As a side effect, alongside important real estate investments that have produced large land returns, over the years illegal building has developed. From a sociological and economic perspective, this is a phenomenon that can be framed in two ways. On the one hand as an apparent redistribution of income, motivated by the fact that a house, although abusive, is worth more than just land. On the other hand, as a disincentive to wage claims in the tourism sector (and not only), due first to the perception that the house owned is a social advancement and, secondly, to a convenient generalized silence about the way it has been built. On a symbolic scale, this becomes socially acceptable through self-absorption (“necessity squatting”) and self-justification (“indispensability squatting”), even when one is not confronted with cases of poverty. These concepts have no legal basis, yet they have managed to articulate an economy around themselves in which lawyers, surveyors, construction companies, material suppliers, laborer gravitate.

3. The earthquake of 21 August 2017

After 134 years of substantial seismic calm, on the evening of 21 August 2017 a new earthquake devastated the island of Ischia, in particular - as in all nineteenth-century earthquakes - the towns of Casamicciola Terme and Lacco Ameno: a six-second shock caused old buildings to collapse, irreparably damaging dozens of homes, leading to the evacuation of the Rizzoli hospital and the flight of hundreds of tourists poured over the island's piers to return to Pozzuoli and Naples. Above all, ladies Lina Balestrieri and Marilena Romanini died under the ruins of dilapidated buildings, dozens of people were injured, and three children were saved from the rubble after 16 hours of apprehension. The earthquake was of magnitude 4, but rather superficial: 1.73 km deep, near Piazza Majo, in the hilly and historical part of Casamicciola. At 8:57 p.m. a bang upsets the northern side of Ischia, in a mass of bricks and sheets, blackouts and shouting, frenetic bustle and sirens, helicopters and dog units, but in addition tourists swarming with trolleys and at a fast pace.

They dig all night long, especially in La Rita, where Ciro (11 years old), Matthias (8 years old) and Pasquale (7 months old) were buried under their house. Their rescue becomes a national case, the televisions follow the story relentlessly, hopefully of course, but also in search of the hero, who becomes the eldest brother who, after pushing the second son with him under the bed, with a broom handle beats against the rubble for a long time to be heard by the rescuers, who can only find them the next day after noon. The iconic image of the whole disaster is related to the rescue of Pasquale, the newborn baby: at 4 a.m. the firemen pull him out of the debris and, with a singular play of light and shadow due to the photoelectric cells and with a crossing of hands outstretched and glances drawn, Antonio Dilaurenzo takes a photograph that is immediately compared to a Caravaggio, between drama and hope, fatigue and miracle, chronicle, and aesthetics.

Perseverance, heroism, and emotion do not stop another type of narrative, that of urban illegality, according to which Ischia becomes «the capital island of illegalism», where one resident out of two builds outside the law, says the Civil Protection, and even, adds “Il Mattino” of Naples, in certain areas such as the place of the rescue of the little brothers «90% of the houses were built illegally on landslides». Everyone talks about illegal building, from Legambiente to the Order of Geologists, including Vincenzo De Luca, president of the Campania Region, who - overturning the paradigm - even accuses environmentalism, which «stopped everything for 25 years». Illegalism is a broad category in which a wide range of illegalities, both small and large, converge, and which historically can have very different causes, so

it should be analyzed with attention and knowledge, otherwise it risks having a double counter-productive effect: on the one hand, to blame the victims and, on the other, to divert attention from the wider problem in which this is included: the cementing - above all legal - of the now former "Green Island". The urbanization that has invaded Ischia since the 1950s certainly brings with it one of the highest rates of illegal building in Italy, and therefore in Europe, but also an anthropic pressure that has congested the space and raised the intensity of car traffic, that does not have a valid system for the disposal of urban liquid waste, that pushes to the - social and geographical - margins those who do not have the strength to keep up with the economic whirlwind and, above all, that devours land and relations like any other expanding "industry". Even in the less desirable areas of the island, the cost of housing is now prohibitive, so, explains Francesco Rispoli, «the abuse of necessity has been a powerful social shock absorber and an extraordinary device for building electoral fortunes (and economic fortunes, as far as the abuse of speculation is concerned)» (Rispoli, 2010, p. 14). If elsewhere the change - of the imaginary and land use - has been more gradual, in Ischia this process has taken place in a radical and sudden way: through the captivating image of itself that it has managed to convey, the island has turned into a laboratory of wide and branched tourist entrepreneurship affected by a real constructive "fever" that has made it explode demographically and economically, but not as much from the point of view of services and infrastructure, moreover without planning and control. A certain idea of development - unbridled and unlimited - has immoderately consumed the soil and the ecosystem; the lack of an ethic of responsibility has led to a current situation in which especially the youngest Ischians risk having a non-future, if not concrete dramas, as in 2006, when an entire family was swept away by a landslide due to soil sealing, and in 2015, when a man died for the same reason.

About the earthquake of 2017, what is evident is a progressive fading of the memory of the catastrophe of 1883, since most of the damage observed by ISPRA suggests a poor maintenance of the buildings built after the earthquake at the end of the 19th century. Although they were earthquake-proof due to the knowledge and techniques of the time, today they are very fragile, especially because the adhesive in the bricks has deteriorated and is poorly maintained. However, from the point of view of seismic engineering, buildings appear to be "burdened" by successive superfetation which, when combined with the existing ones without binding them to adjacent structures, have increased their overall vulnerability (ISPRA, 2017, p. 15).

Years later, while the state of emergency decreed by the government persists, there are more than two thousand displaced persons, all living on the

island between second homes and relatives' homes, except for a quarter still in hotels or other closed accommodation facilities; they are gathered in the "Risorgeremo nuovamente" (We will rise again) committee and are strongly willing to return to their homes in the *red zone*. The modalities for a return are beyond being defined and, as a result, the timescales still seem rather long. After an initial emergency commissioner, Giuseppe Grimaldi, appointed at the end of August 2017, on 9 August 2018 the government initiated a change of phase, appointing a commissioner for reconstruction, Carlo Schilardi, former prefect and already commissioner for calamitous events in other Italian provinces. Those involved - mayors and earthquake victims - welcomed the new appointment, which, Pasquale Raicaldo reports, «is a strong sign of optimism. [...] Ischia must now send a strong message to the world: the red zone must not be abandoned but made absolutely safe».

4. Scientific and territorial fragility

After the rescue of the siblings and the discourse on illegal building, the public debate focused on the scientific controversy regarding the calculation of the magnitude and the location of the hypocenter.

Difficulties on the measurement of magnitude (there are various types) immediately emerged, as well as on the identification of the point where the earthquake occurred, and only after four days were shared data available. On the same night of the earthquake, the INGV first shifted the magnitude from M3.6 to M4.0, then re-evaluated the hypocenter from 10 km deep to 5 km, but still locating it in the middle of the sea and not under the inhabited center, as the institute itself later ascertained. To start the comparison (which then lasted for many months) was the seismologist Enzo Boschi (former president of the INGV), who after two and a half hours from the tremor, on Twitter expressed some doubts about the first scientific evaluation: «Although without access to data, I think that 3.6 magnitude of the earthquake of Ischia is an underestimation. The depth is also to be verified». During the night, a rather heated discussion developed with the geologist Alessandro Amato (INGV researcher), who said: «Enzo, I'm surprised at you. You should know how it works. No discrepancies. Different estimates at different times. What a disappointment...». For days there were numerous statements and interviews from the director of the INGV, Carlo Doglioni, and the director of the Vesuvian Observatory, Francesca Bianco, which motivated the data released to the press, including their subsequent variations, and explained the hypotheses on which the scientists were working (among others: was it an

earthquake of tectonic or volcanic origin?), but on 23 August, on Facebook, the volcanologist Giuseppe Luongo (former director of the OV) expressed further doubts: «the data on the epicenter do not justify the effects observed on land [...], as the damage on the coast is insignificant compared to those in the inland area. With this scenario it is unlikely that the epicenter is at sea. [In other words,] the epicenter location obtained with seismic instrumentation contrasts with the epicenter of the damage. This difference, I believe, is due to the distribution of the stations on the continent, while the epicenter is outside the network». The post has been very relaunched and "Il Mattino", the main Neapolitan daily newspaper, has also dealt with it, to which the professor declared: «I have been studying the island of Ischia for over 30 years and that earthquake happened exactly where it was supposed to happen and where it has always happened historically [...]. One of the most important information for a scientist is the geological history of a site and based on stories from remote times we can reconstruct its tectonics, its volcanology». Because of this mistake, Luongo added, «scientific research is mortally wounded. [It is] too embarrassing an error, I was silent for a few days, but I couldn't go any further because I wouldn't want to make a wrong datum become historical». The following day, invited by some residents of Casamicciola, Luongo further specified this position in a press conference on the island: «One could not be silent, also because when a wrong scientific datum becomes historical, it becomes heavy: that datum conditions the future, it conditions a development of research and knowledge» (in: Mazzella 2017, p. 7), without forgetting that the first seismographic information, although provisional, has above all the function of directing first aid, so that a macroscopic error can have serious and concrete reverberations. The error derives from a technical constraint, since the first localization of an earthquake is always automatic because the system processes data coming from the various local stations and, through a model based on the speed of seismic waves, identifies an epicenter and a hypocenter. However, if such a procedure works in Irpinia or in Central Italy, where the network of seismic detectors is rather ramified, the same cannot be said for Ischia and the other so-called "decentralized areas". We find ourselves, therefore, in one of those historical conjunctures highlighted by Lorraine Daston and Peter Galison in which «objectivity is afraid of subjectivity» (Daston, Galison, 2007, p. 374). In the so-called «truth-to-nature era», i.e., the period from the 19th to the 21st century in which «truth-to-nature» reached its peak and assumed a metaphysical dimension, an aspiration to reveal a reality accessible only with difficulty, the idea of objectivity has progressively turned into an apparently absolute concept when referred to technologically advanced instruments,

although they are - still and inevitably - historical and fallible. The subjectivity explicitly claimed by some exponents of the debate does not deny the usefulness, indeed the need for increasingly precise instruments of detection and calculation: these are fundamental for that «journey into substance» - a journey of enlightenment origin at the same time geographical, scientific, artistic, philosophical - that Barbara Maria Stafford defined «the "realization" of nature» (Stafford, 1984), i.e., a rationalistic interpretation of the external world. This vision has become progressively more inert and opaque, so to claim a certain subjectivity today intends to underline the indispensable importance of mediation, of the filter, of interpretation in the light of specific historical and theoretical readings: «When the procedure is automatic - said Luongo - the error can happen, but then it takes an operator; he must put constraints, that is, the solutions can be infinite [and only by putting constraints] do the solutions shrink» (in: Mazzella, 2017, p. 9).

Already on the earthquake of 1883 the confrontation between scientists was quite heated. The controversy between Luigi Palmieri and Giuseppe Mercalli is a striking example. Where Palmieri, an eminence of the time, was convinced that «the island of Ischia [had] suffered an immense disaster, but not a great earthquake» (Palmieri, Oglialoro 1884), Mercalli in his "Memoria" (1884a) and in a further note after it (Mercalli 1884b), was based on his own field work to underline, instead, that «the disaster of 28 July [1883], although for its dynamism and the ruins it caused is less than many other Italian earthquakes, it is nevertheless an earthquake of great intensity and violence» (Mercalli, 1884b, p. 848, 849).

After more than a century, the earthquake of 2017 in Casamicciola has reopened discussions and comparisons between different sensibilities and approaches that are certainly constantly part of the scientific field, however - beyond the controversy and different interpretations of the phenomenon - it is considered «an earthquake to be understood», an event that, evidently, places contemporary seismologists before their instrumental limits, if not before theoretical adjustments and reformulation of scenarios.

In addition to spatial, individual and community upheavals, every disaster always poses a profound question: «who are we really?». In this regard, Ariel Dorfman, journalist, and witness of the Chilean earthquake in 2010, believes that every crisis is an opportunity to reflect not only on how and when to rebuild infrastructure and housing, but also «our precarious identity» (Dorfman 2010). In other words, it means addressing existential issues that allow us to rebuild the community, as well as homes. The 2017 earthquake forced us to ask ourselves some thorny, almost intimate questions: what is the island of Ischia today? What has it become in a couple of generations? What

relationship have its inhabitants developed with the ecosystem, especially about its geology?

We didn't see some distortions in time, or we ignored them, because in reality someone noticed and warned us already forty years ago. The cementification of Ischia became a national theme in 1977, when “La Stampa” published an article by Adriaco Luise entitled «A luxury hotel in Ischia on the ruins of a necropolis». It was not the authorities or politicians who denounced the destruction, but the children of the primary school of Ischia Porto, who wrote an appeal to preserve their land from devastation and violence. The Aragonese castle was being gutted by the construction of 35 residential homes and the demolition of centuries-old walls, in a conscious cancellation of the past and local identity.

Since then, entire pine forests and long stretches of coastline have been cleared and the land consumption has been incalculable, except for the dramatic outcome of too many tragedies: from the four German tourists swept away by a landslide in June 1978 on the Maronti beach, to the Buono family, wiped out in April 2006 by a mud flow from Mount Vezzi, to the terrible earthquake of 2017 between Piazza Majo and the village of Fango.

Three years after that earthquake, reconstruction has not yet begun in Casamicciola; the state funds allocated to the displaced people were only released on 3 March 2019 by the extraordinary commissioner Carlo Schilardi and since then, according to the local authorities, «the worst is behind us» (Zivelli, 2019). The statement is challenging, because the real challenge starts now: reconstruction is a very delicate phase, whose effects (positive or negative) may show themselves long afterwards. Showing caution would be the wiser choice, especially since no in-depth and contextual (and therefore time-consuming) analysis has been made of the social and functional complexity of the affected area, i.e., a reflection between the necessary pragmatism of a rapid intervention and an equally necessary consideration of how to intervene, for whom, and for what purpose. As pointed out by geographers Sara Bonati and Giuseppe Forino following the disaster of Genoa's Morandi Bridge, after a disaster it is essential to discuss urban complexity and provide a critical and detailed overview of that specific reality: «It is not just a matter of reconstructing, but of doing so in function of a dynamic context, of a city in constant change in its social and economic structure» (Bonati and Forino, 2018).

5. The social elaboration of trauma

The earthquake upsets time and space, relationships and looks; the earthquake lasts over time and tests not only the places, but also the community living in them, well beyond the emergency phase. The shock causes a "total social discontinuity" because next to the loved ones the territorial references and social relationships are lost: the disaster takes on a totalizing character that turns to disorder and disorientation, so it brings out the need for a rebalancing, sometimes a redefinition or, in any case, a reorganization - of oneself and the group. This opens up a time of crisis in which a territorial and social recomposition is attempted, with uncertainty and expectation, but also with dynamism and potentiality: we are looking for shelters, not only physical - from rubble, atmospheric agents and winter cold - but also cultural, in the sense that we want a way to elaborate what happened and to keep past, present and future together; we yearn for continuity in the break-ups or, in any case, we have recourse to a connective network that protects against disintegration and keeps the generations together.

A first step is the «pooling of the drama» (Langumier, 2008), which on the one hand attests to the truly catastrophic nature of the event and, on the other hand, relativizes the experience of individuals put in relation to what others have experienced: the event is dramatized as a whole, but at the same time the individual drama is relativized within a framework of misfortune in which one of the extremes is the victims and their relatives. This happens on various occasions and with different modalities and intensity: from institutional tributes (the Head of State visited the displaced persons on 29 August 2017) to religious rites (from the funerals of the victims to special masses and processions, passing through some folkloric practices), from interviews with the mass media to the constitution of a committee of the earthquake victims, from protest marches to the reopening of a bar among the ruins.

Shelters are sought for the present and hypothesized for the future, on several levels: some call for the establishment of a single municipality for the island of Ischia (currently divided into six different municipalities) in order to facilitate protocols and avoid bureaucratic redundancies; others propose the reopening of the Geophysical Observatory of Casamicciola and its conversion into a «European Centre for scientific research on seismicity and volcanism of the island of Ischia and the whole Mediterranean» (Luongo in: Mazzella, 2017); others still hope for greater efficiency and integration of civil protection procedures on the island, especially during the tourist season.

To share the drama means to narrate and imagine; the disaster is declined in a discourse in which the search for shelter is a life drive, between self-

determination and re-creation. In this regard, two experiences of the first post-seismic year in Casamicciola are particularly significant: the garrison in Piazza Majo and a school laboratory of creative writing.

The Majo area, the epicenter of all the earthquakes in Ischia from the nineteenth century to the present day, is an area that was completely rebuilt after 1883 and in which, today, the buildings are again gutted or supported by a grid of poles and reinforcements. In the center of the square, exactly on the surface where, until the catastrophe of the 19th century, the parish church of Santa Maria Maddalena (Luongo et al., 2006), a few days after the earthquake of 2017, a garrison of residents rose and, over the months, it gradually expanded from a simple tent to a large shack with television, refrigerator, wardrobes, tables, chairs... Of the building that is the symbol of the old square, the heart of the historic Casamicciola, for 135 years all that remains is a portion of the wall of the left aisle, recognizable by some niches in which statues of Catholic saints are preserved, yet it is on that very perimeter that the locals wanted to put down roots, as an editorial of a local web journal underlines: «these people stay at the Majo because they feel lost, lost, because they want to be a community again, because they want to be with Franco, with Maria who is also afraid of herself, with Antoniuccio and Ciro, with Duilio and with Fenina who cooks and makes coffee with Anna at all hours». Theirs is a physical narration among the wounds of the territory, a discourse in which the bodies mend the temporal fracture; the inhabitants of Piazza Majo are not holding up a hovel, but, on the contrary, they are rebuilding their identity shelter, a shelter that reconnects yesterday and tomorrow, that is able to nourish old and new sociality.

At the same time, during the school year that began a few weeks after the earthquake, the fourth-year students of two Ischian high schools, urged by Tommaso Ariemma, their philosophy teacher, elaborated numerous stories inspired by the evening of the earthquake. After analysis in class and comparisons of styles and plots, the texts were combined in a publication: “Immaginare ripari. Il terremoto a Ischia del 21 agosto in 19 racconti” (Imagine shelters. The earthquake in Ischia on 21 August in 19 stories) (Ariemma 2018). The didactic experiment is very stimulating because it is also a document on the representation and perception of the disaster: 17-year-old adolescents have elaborated and reinvented an event that will remain for their whole life in a unique dimension, fixed in their memory and, perhaps, present like few other days:

> «[That evening,] once in bed, I slept very deeply, almost as if my body had wanted to give me a clue as to what would then be

> the tranquillity that would dwell in me for the rest of my life» (Ester, p. 29); «I only feel my heart that was and still is here, in this set of fallen walls but which represent my nest, my place, my refuge» (Rossella, p. 102).

Sublimating dynamics and relationships, and developing alternative endings, the stories of the students of Ischia narrate surprises and rebirths:

> «They were together again, incredibly. The wounded island had had the power to make them find each other again» (Claudia, p. 57); «They were still alive, but the house had collapsed. We had difficult years ahead of us, but they were still with me and I felt reborn» (Luigi, p. 80).

Like a dreamlike vision that transmutes reality, the narrative of the young people of Ischia overcomes the drama by looking at the future; the protagonist of the story "Ithaca" is an emigrant who returns to Casamicciola after many decades, just after the earthquake: part of an impulse from the United States, he faces the journey with apprehension, he moves with pain among wreckage and debris, yet in the end he says that it was one of the most beautiful moments of his life: «It was an exciting day, I felt as good as ever» (Ida, p. 78). Despite the shattered country and the suffering he and his relatives suffered, the repatriated old man still found his world, the one he had left as a child, but now he did not see the shortcomings, but something more: he met his grandchildren and even his great-grandchildren, recognizing them as his own kind, that is, as the future of himself and his land.

On 21 August 2018, exactly one year after the earthquake, institutional commemorations were held in Casamicciola Terme and Lacco Ameno, such as the extraordinary municipal councils of the two towns of Ischia, but some would have preferred them jointly, given the commonality of problems; there was also a visit - unannounced and rather sudden - by the then Vice-President of the Council Di Maio, the laying of a wreath on the rubble with a minute's silence for the victims and, finally, a solemn mass in the presence of Bishop Pietro Lagnese in the harbor square. The main celebrations - civil and religious - therefore excluded the red zone, so many residents decided to desert them, preferring to remember the victims in private. Considering the choice made by the authorities yet another «further disgrace to the community», the committee of the earthquake victims made it known that they did not want to be named, nor that they would speak on their behalf, since the decision was made to commemorate the victims in an autonomous

way, putting up signs and placing flowers on the rubble, throwing balloons and lanterns, but above all finding themselves at the garrison in Piazza Majo.

The commemoration is not a formality, it serves to remember who is no longer there and to keep the memory of those who were saved, in that attempt to mend the fracture with which one wants to reconnect both the fragments of the community and the time of before with that of after. It is an opportunity to reflect on what one was and what one wants to be again, perhaps on what one wants to improve with respect to the past; an opportunity to collectively understand what has been done in the meantime and, consequently, what still needs to be done, to prevent similar disasters from happening again in the future, to become aware of the fragilities in which one is immersed, so as to commit oneself to face them with concrete actions and not only with declarations and communiqués. The commemoration is to repeat «Yes, there really was an earthquake», as the bishop reiterated three times during the homily, because in national silence it is necessary to remember it, underline it and shout it; because finally we cross that allegorical threshold of the metal tunnel in Via Spezieria which, although it does not lead to any healing or new birth as in the rites described by van Gennep, can nevertheless stimulate a sort of initiation towards another dimension, of rethinking the relationship with the territory and the interpersonal and institutional relationship. It is a still uncertain and distant dimension, perhaps utopian, but it is part of that "thinking big" to which some friends of the island have exhorted during this period of latency and suspension, neglect and distance, struggle, and resistance.

6. A forest of bureaucracy

At present, reaching the red area of Casamicciola, in the hilly part, means crossing a "narrow passage", not only in a physical sense, but above all symbolically, because it leads both to the disaster area and to a suspended time that reflects on a state of uncertainty and expectation, of contrition and torment. At the beginning of February 2018 Piazza Majo, almost isolated for the previous six months, was once again easier to reach thanks to a metal and tubular tunnel along Via Spezieria, the main artery connecting it with the coastal town of the municipality, which, by caging the surrounding buildings, makes the stretch of road safe, to transform that space into an enormous threshold. The tunnel is a sinuous and slightly uphill path, metallic and rather dark, which, without wanting to abuse van Gennep's formula on rites of passage, like a filter predisposes to a change of look: going through it, one

takes a leap back in time, a few moments after the shock, with the roofs collapsed, the walls demolished, the piles of bricks in front of the gates become crooked and immersed in a heavy silence that is broken only when the small truck of the soldiers guarding the area passes. The buildings in Piazza Majo are all propped up, as are many houses as far as Fango of Lacco Ameno, yet there, in that liminal space, years after the earthquake nothing else has happened, time has stopped or, in any case, it has begun to flow slowly, much slower than the rest of the island and the country, because only one bar has resumed its activity and just a few sparse residents have begun, independently, a restoration of their damaged home.

In just the first year after the disaster, the bureaucracy produced as many as two commissioners (the first one for emergency, then replaced by the one for reconstruction), but no specific decree, as happened in 1884, when the government of the time issued a specific "Building Regulations" for the island. Yet in that first post-seismic year there were plenty of opportunities: Italy had two executives and two parliaments, Domenico De Siano, resident on the island, was elected for a second term of office in the Senate, and Giosi Ferrandino at the European Parliament and Maria Grazia Di Scala at the Regional Council of Campania; numerous national politicians visited the earthquake sites, including the two most in view of the current legislature: Matteo Salvini and Luigi Di Maio, both party leaders and ministers for a long time. Although they held different roles and were present in different political situations, both expressed their closeness to the devastated population and their desire to revive the villages affected. The first said that «often and willingly the enemy of citizens and mayors is bureaucracy», so «in the Italy I have in mind there are full powers to local administrators in case of emergency management and in case of order and security management». The second ensured empathy and commitment to the Ischians, who «will have a friendly government», given that until now «they have been treated as inferior earthquake victims». This commitment was reaffirmed on 6 September 2018, when Prime Minister Giuseppe Conte in turn visited the disaster areas and launched a message: «Enough talk of emergency, we have to restart. And today we are here to give substance to the hope of all these people. We have a decree ready for the earthquake in Ischia. I will present it myself next week in the Council of Ministers».

Concrete opportunities to overcome controversies and announcements took place in July and September of that year. The first case was when the governmental decree no. 55 of 29 May 2018, «Interventions for the people affected by the earthquake of 2016», i.e., of the Marche, Umbria, Lazio and Abruzzo, was converted into law, and in which, as requested by the

oppositions, the inhabitants of Casamicciola Terme, Lacco Ameno and Forio could be included, but the amendment by four MPs of the Democratic Party (PD) was rejected. The second, during the discussion of the Parliamentary Commissions meeting on the decree 91/2018, «Extension of terms provided for by legislative provisions», the so-called "Decreto Milleproroghe", in which thirty members of Forza Italia proposed that the provisions of art. 9 («Extension of terms on seismic events», which supplements the converted decree 55/2018) were also extended «to the municipalities of the island of Ischia due to the seismic events that occurred on 21 August 2017», but also in this case without success. In other words, Ischia remained outside any "ad hoc" post-earthquake legislation, as Di Maio and Conte had announced, but was included in the "Genoa Decree", which became necessary after the tragedy of the Morandi bridge on 14 August 2018.

A first version of that text had found the opposition of the island's mayors because the procedures for granting and disbursing contributions to the victims of the earthquake were intended to impose the presentation of the building title, without taking into amnesties. In fact, this is a nerve that had emerged in the winter of 2017-2018, when the commissioner for the Ischian emergency, Giuseppe Grimaldi, had circulated, as usual, the forms on which the earthquake victims should have indicated the damage suffered for the subsequent quantification of the relief by the State, but on the same files they should have indicated - always as usual - also any different volumes made over time, so that today's result is the gradual stalling of the procedure.

A second text, the one presented in art. 25 of the "Genoa Decree" has provided for a real amnesty for illegal buildings, even though they are in areas at significant seismic and landslide risk. Locally there are those who interpret it as the only article that opens «an opportunity and a possibility», but the diametrically opposed opinion is Legambiente, for which it is «a building amnesty that would endanger people and relaunch new abuses», especially because it would abolish the rules on landscape and hydrogeological protection.

7. Conclusions: abandonment or rebirth?

Three years after the 2017 earthquake the situation has not changed much, with paradoxes, delays, forgiveness, and an inevitable blame. Above all, locally there is a certain discouragement, in fact the most affected part, Piazza Majo, is now defined by residents as "the New Pompeii". As local journalist Giuseppe Mazzella wrote,

> «In recent years, the "decision-makers" have produced nothing. Members of Parliament. Ministers, Governors, councilors, experts, have not produced anything concrete except to continue an "emergency", to provide the "CAS" which stands for "Autonomous Accommodation Contribution" to about 2400 displaced persons from the collapsed or uninhabitable houses of the three municipalities affected by the earthquake: Casamicciola, Lacco Ameno and Forio» (Mazzella, 2020).

That earthquake devastated various areas of the island of Ischia, but above all it turned the lives of those who lived there upside down; thousands of people are still displaced and live with chronic uncertainty about the future: will they return to Maio and Fango? Will there be reconstruction, and in what terms? If so, will they one day live safely in their new homes? We have a duty to consider the hardest hypothesis, that those centers do not resurrect; on the other hand, cities and human communities are born, grow, go into crisis, get sick, heal, but sometimes die (Gugg, 2020). So, what to do? How to "medicate" a locality wounded by a disaster? What we know is that we identify the basic factors of a virtuous reconstruction process: a community, a will, a possibility. In the case of Casamicciola, is there political and popular will to be reborn? Which cultural institutions are resisting? Does the devastated community still have any chance to meet and debate, or is it fatally exhausted and dissolved? Is there memory? Is there an idea of the future?

It is not enough to rebuild the collapsed buildings, but to build a less vulnerable city; it is not enough to bring back the old inhabitants, but to restart the economy and make it produce more equity; it is not enough to respond to the needs of the displaced people, but to recreate a sense of place. This can be done by fostering and supporting participation, cooperation, and democratic dialogue (Gugg, 2018).

It is not a question of building "resilient cities" or "resistant" in itself, because, however important and vital they may be, neither emergency practices nor anti-seismic techniques are exhaustive responses to risk, but we must aim for "urban resilience". It may seem like a play on words, but it is a radical change of perspective that focuses on the creation and preservation of a physical and social ecosystem in which memory and knowledge can dialogue, where sustainability and renewal can nourish each other, in which inclusion and relationship are the mainstays of a stronger and more far-sighted coexistence, both among the inhabitants and with the environment.

One possible tool to use is shared administration, which in Italy is still a relatively small but growing phenomenon. The principle is that alongside "material reconstruction", in which active citizens contribute significantly to improving the quality of life of all members of the community, there is also a "moral reconstruction", in the sense that taking care of everyone's goods emphasizes a sense of responsibility and belonging, solidarity and the capacity for initiative. The hope is that a new dynamism will emerge for which the term "security" takes on a meaning similar to that of "common good" (Gugg, 2016). In this sense, the interventions to be carried out on the island of Ischia and in the earthquake-stricken areas, must be inspired by considerations on living and man/environment relations, certainly perpetuating a vision of the territory centered on the sea and coastal tourism, but in a fairer and more sustainable way than those experienced in the last century. In other words, rigorous, inter-municipal and far-sighted territorial planning is necessary, the only one that can aspire to renew and perpetuate the good life of Ischia, as shown by the recent recognition given by the judges of Vinitaly 2019 to the Mazzella family of the Campagnano locality for their "best winery in Italy" (Di Gennaro, 2019).

The question that must be constantly asked can only be the following: which and for which Casamicciola is being rebuilt? Whatever future we want to pursue, it is a question of identifying a path marked by strong elements of concreteness: the example of Mazzella's winemakers shows that it is not enough to have extraordinary grapes, because it is necessary to make that system productive, that is also remunerative and dignified, otherwise the abandonment will continue and, with it, the erosion of the soil and the community. This can happen with a new collective pact, in which the attention is not placed only on the single product, but on the overall picture, which is not restricted to the "red zone", but coincides with the entire island; the look to keep must be at the same time vast and deep, transversal and complex, and above all it must scrutinize tomorrow with the awareness of the historical path that has led to the present state, with its fragilities and contradictions. It is necessary to reconstruct a vision of the island that does not yet exist, but which will come if we proceed with patience and listening skills.

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4. Le politiche di contrasto al rischio da maremoto: il caso di Stromboli.

Giovanni Messina[1]

Riassunto

Il presente capitolo, volendosi inserire in seno ai ragionamenti sulla percezione del rischio da eventi naturali estremi, intende descrivere i principali contenuti del Piano nazionale di emergenza a fronte di eventi vulcanici di rilevanza nazionale dell'isola di Stromboli (ME) predisposto nel 2015 dal Dipartimento per la Protezione Civile (DPC). L'isola vulcanica di Stromboli è infatti largamente esposta al rischio connesso alle attività dell'omonimo vulcano, specie a quello del maremoto. L'attività effusiva dello Stromboli causa infatti una decisa instabilità del versante detto Sciara del Fuoco che può indurre, come avvenuto sul finire del 2002, uno tsunami. Il contributo, muovendo da un interesse descrittivo, vuole allora presentare, problematizzandole, le politiche di intervento e le procedure operative contenute nel documento strategico.

Parole chiave: rischio vulcanico, maremoto, Stromboli, Piano di emergenza;

Policies against tsunami risk: the case of Stromboli

Abstract

This chapter, intending to be part of the reasoning on the perception of risk from extreme natural events, intends to describe the main contents of the National Emergency Plan for volcanic events of national importance on the island of Stromboli (ME) prepared in 2015 by the Department for the Civil Protection (DPC). The volcanic island of Stromboli is in fact largely exposed to the risk associated with the activities of the volcano of the same name, especially that of the tsunami. The effusive activity of the Stromboli in fact causes a marked instability of the slope known as Sciara del Fuoco which can

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induce, as happened at the end of 2002, a tsunami. The contribution, starting from a descriptive interest, therefore aims to present, problematizing them, the intervention policies and operating procedures contained in the strategic document.

Keywords: volcanic risk, tsunami, Stromboli, Emergency plan;

1. Premessa

Il presente contributo intende inserirsi in seno al multidisciplinare dibattito scientifico riguardo alle politiche di contenimento del rischio rispetto ad eventi naturali estremi (Thomalla et al., 2006; Mercer, 2010; Kousky, 2012; Newman et al., 2017; Antronico, Marincioni, 2018). Ampia risulta essere la bibliografia nazionale ed internazionale sui molteplici aspetti che coinvolgono le politiche di studio, monitoraggio e gestione del rischio da evento naturale. Nella messe di fonti, di particolare interesse risultano i due documenti delle Nazioni Unite che, adottati nel 2015, si sono concentrati sulla riduzione del rischio da evento naturale dalla forte intensità e sul contrasto al cambiamento climatico: la Carta di Sendai e l'Agenda 2030 per lo Sviluppo sostenibile (Poljanšek et al., 2019). La ricerca geografica, da sempre concentrata nel rilevare le connessioni che esistono fra spazi e comunità, consente, poi, di attivare un approccio olistico sulla questione; illuminante in tal senso la notazione di Montz e Tobin sulla rivista *Applied Geography*:

> «While the geophysical setting describes the physical processes to which a population may be exposed, it is not sufficient to understand just the degree to which people at a location are threatened by that exposure. In this regard, risk is a simple probability statement about the frequency of extreme events and the numbers exposed; however to fully appreciate hazards, dynamic human factors must also be addressed. Social and demographic characteristics of the population at risk combine with the prevailing political-economic system to determine a community's vulnerability. Through hazards research, much of which is geographically based, our conception of vulnerability and the factors that contribute to it have progressed significantly» (Montz, Tobin, 2011, 2).

Nell'Antropocene (Crutzen, Stoermer, 2000), epoca in cui si esaltano criticità e potenzialità degli intensissimi rapporti che connettono le comunità

agli spazi, la dimensione del rischio da eventi naturali estremi assume la cifra di indicatore di percezioni individuali e collettive e, insieme, di guida per le politiche chiamate a intervenire in aree particolarmente esposte all'azione distruttiva degli elementi naturali (Kasperson, Dow, 1993; Gaillard, Dibben, 2008; Shi, 2019).

Si intende, allora, presentare, attraverso un'analisi di problematiche e contenuti specifici, un caso di politiche pianificatorie volte a prevenire danni alla popolazione insulare in caso di maremoto. Se, infatti, il rischio rappresenta un'importante dimensione percettiva, la pianificazione costituisce un impianto concreto di politiche tese a mitigarne o ad annullarne gli effetti (Rolandi, 2010; Tinti, et al., 2011). Nello specifico si analizzeranno contenuti ed orizzonti del Piano nazionale di emergenza dell'isola di Stromboli, elaborato dal Dipartimento della Protezione Civile nazionale, in collaborazione con la Regione Siciliana e il Dipartimento regionale della Protezione civile (DRPC), la Prefettura di Messina e il Comune di Lipari. Il Piano[2] inquadra e individua le pratiche atte a mitigare, limitare o annullare gli effetti che un maremoto[3] innescato da una frana importante della cosiddetta Sciara del Fuoco potrebbe provocare sulla popolazione residente sull'isola.

Sebbene il vulcano Stromboli sia caratterizzato da un'attività eruttiva piuttosto regolare, è il maremoto innescato da frana, lungo la cosiddetta Sciara del Fuoco, a rappresentare la contingenza più probabile e pericolosa per la popolazione, come è, peraltro, avvenuto nel 2002. Rispetto a tale evento, riteniamo utile riportare le considerazioni di un Gruppo di Geofisici dell'Università di Bologna, durante il ventiduesimo Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida[4]:

> «Dall'epoca della sua formazione, gran parte del materiale eruttato da Stromboli viene "convogliato" all'interno della Sciara del Fuoco, con la conseguente formazione di depositi incoerenti e instabili dal punto di

[2] Piano nazionale di emergenza a fronte di eventi vulcanici di rilevanza nazionale ex art. 107, comma 1, lettera f) del D.Lgs. 31 marzo 1998, n.112, http://www.prefettura.it/FILES/AllegatiPag/1196/PIANO_NAZIONALE_EMERGENZA_STROMBOLI_1.pdf (Ultima visita, Ottobre 2020).

[3] Sugli tsunami indotti da attività vulcanica e sul rischio per le comunità, specie se isolane, si rimanda, fra gli altri, al corposo lavoro su isole e arcipelaghi del Sud-Est asiatico, *Volcanic tsunami: a review of source mechanisms, past events and hazards in Southeast Asia (Indonesia, Philippines, Papua New Guinea)* (Paris et al., 2013).

[4] GNGTS, Atti del 22° Convegno Nazionale 2015, http://www3.ogs.trieste.it/gngts/files/2003/2003/contents/pdf/09_15.pdf (Ultima visita, Ottobre 2020).

> vista gravitazionale. Detta instabilità si è manifestata in modo drammatico il 30 dicembre 2002. Ciò che si è verificato esattamente sulla Sciara non è ancora ben chiarito, ma vi è prova evidente che si sono staccate almeno due frane principali ad un intervallo di circa 7 minuti l'una dall'altra. Secondo le più recenti stime, le frane avrebbero coinvolto un volume totale di materiale pari a circa 2.5·10 m. Entrambe le frane hanno generato un maremoto. La prima, registrata alle ore 13:15, si è innescata e propagata quasi totalmente sotto il livello del mare ed ha coinvolto circa i 3/4 del materiale totale franato, mentre la seconda (13:22) è stata essenzialmente sub- aerea. Le onde di maremoto hanno attaccato con violenza le coste dell'isola di Stromboli, provocando particolari danni lungo il settore nord-orientale, dove si concentra la quasi totalità delle abitazioni. Il maremoto ha attaccato anche le altre isole Eolie, producendo alcuni danni in particolare a Panarea, ed è stato osservato in numerose località situate lungo le coste tirreniche della Sicilia nord-occidentale, della Calabria e perfino della Campania meridionale"» (Tinti et al., 2015, s.i.p.)

Il contributo, muovendo da un inquadramento geografico del contesto territoriale e degli insediamenti umani dell'isola di Stromboli, problematizzerà i principali aspetti del Piano, operativo dal 2015, riservando soprattutto attenzione alle politiche volte a ridurre la vulnerabilità delle comunità rispetto al impatto dell'eventuale fenomeno ad elevata intensità[5]. Dal punto di vista metodologico, si opererà una lettura critica del testo del Piano - fonte principale dei dati considerati - volta a fare emergere tanto il contesto geo-morfologico di Stromboli, quanto le procedure emergenziali e la catena di comando che si attiverebbero in caso di necessità.

2. Cenni sul contesto vulcanologico e territoriale di Stromboli

L'arcipelago eoliano (Villari, 1980; Carveni et al., 1986; Romagnoli et al., 1993; Barberi et al. 1994; Arena, 2003), composto, da Ovest verso Est, dalle sette isole che occupano il quadrante Sud-Occidentale del mar Tirreno - Alicudi, Filicudi, Salina, Panarea, Lipari, Vulcano e Stromboli - rappresenta, nella sua estensione di quasi 87 km, la parte emersa di un sistema vulcanico

[5] Per proporre un riferimento di ricerca internazionale sul tema della percezione del rischio da maremoto, rimandiamo all'indagine quali-quantitativa condotta fra Indonesia, Sri Lanka e Maldive pochi anni dopo lo spaventoso tsunami che, nel 2004, ha colpito le coste del Pacifico, causando oltre 220.000 vittime (Kurita et al., 2007) e la *damage spatial analysis* condotta da una *equipe* di geografi francesi a Sumatra (Leone et al., 2011).

decisamente più vasto che si sviluppa sott'acqua, grazie alla compresenza di svariati condotti di risalita che lo alimentano, con altri vulcani sottomarini (detti *seamounts*) disposti a guisa di emiciclo dischiuso in direzione Nord, lungo oltre 200 km. Tale complesso vulcanico, i cui territori dal punto di vista amministrativo dipendono dal Comune di Lipari (ME), appare disposto in una tipizzante configurazione ad Y che si configura per la compresenza di tre direttrici principali che hanno in Salina il punto di intersezione. Stromboli (Francalanci et al., 1986; Falsaperla, 1991; Napoleone et al, 1993), la più prossima alla costa della Calabria, costituisce l'estremità nord orientale della prima direttrice.

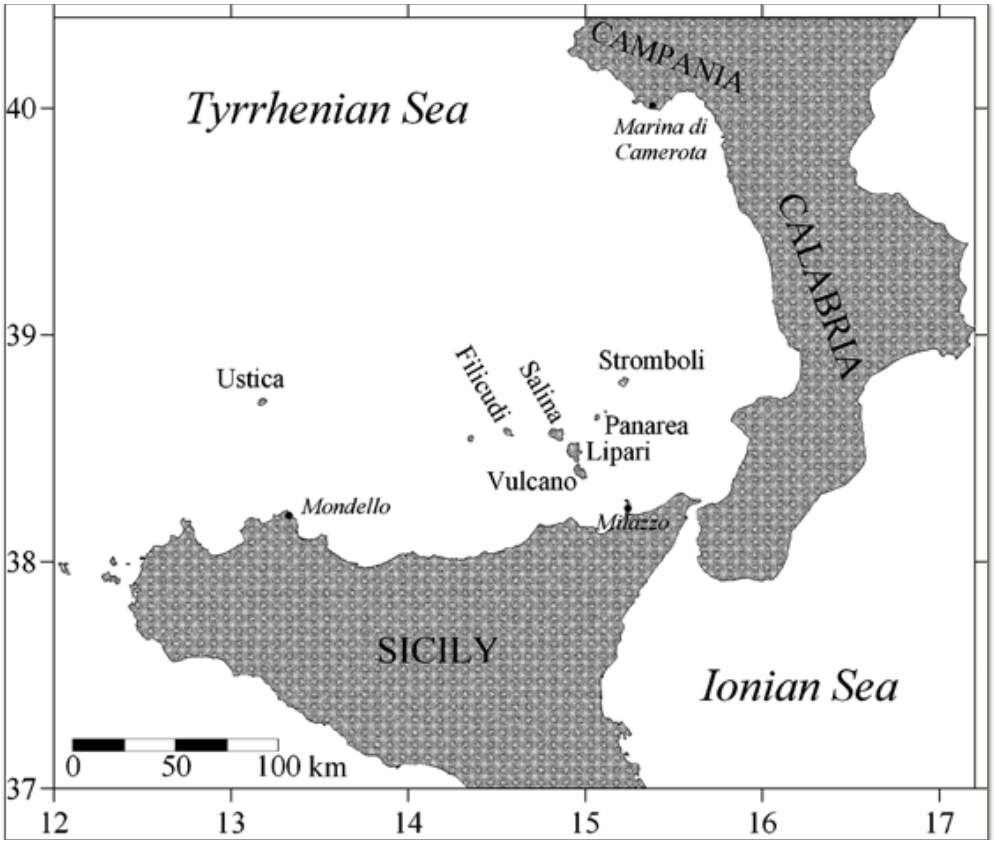

Figura 1 - *Mappa schematica del Tirreno meridionale. Fonte: Tinti et al., 2006 in Protezione Civile, 2015, 20.*

Le isole di Stromboli, Vulcano e Lipari sono le uniche dell'intero sistema ad esprimere un vulcanismo attivo, eruttività prevalentemente esplosiva (Stromboli) e manifestazioni di termalismo (Vulcano e Lipari). Il contributo, come accennato, si concentrerà sull'isola di Stromboli, amministrativamente

dipendente da Lipari. Abitata da circa 500 persone (Comune di Lipari[6]) sparse per il paese e le frazioni di San Vincenzo, ex borgo degli agricoltori, di Scari, con l'approdo storico, Piscità e Ficogrande, che anticamente era il borgo degli armatori. A Sud-Ovest, raggiungibile solo via mare, si trova Ginostra, stabilmente abitata da non più di 50 residenti. L'intera economia dell'isola gravita pressoché essenzialmente sul settore turistico; dal 2000, infatti, le isole Eolie sono state riconosciute nell'ambito del Patrimonio Mondiale dell'UNESCO.

> «L'isola di Stromboli (dal greco *Strongyle*, rotonda), una tra le ultime dell'arcipelago ad emergere dall'acqua, rappresenta l'estremità settentrionale dell'intero arco eoliano e si eleva dal fondo del mare per 2.400 m, a partire da un basamento metamorfico, attraverso un apparato di forma conica pressoché regolare che nella parte emersa culmina con le cime del Vancori poste a 924 m s.l.m. Queste ultime rappresentano il bordo sommitale di un edificio più antico di quello che attualmente dà luogo all'attività vulcanica (vulcano della Sciara), il cui volume complessivo, in gran parte nascosto sott'acqua, è almeno 25 volte più grande della parte visibile. L'apparato emerso si sviluppa su una superficie complessiva di circa 12 kmq ed è caratterizzato morfologicamente, oltre che da un allungamento in senso NE-SW sottolineato anche dalla presenza dello scoglio di Strombolicchio, da fianchi a forte pendenza (35°- 40°) e da zone sub pianeggianti poco estese su cui si sono concentrati i centri abitati principali o sparse abitazioni (Stromboli, San Vincenzo, Ginostra, Punta Lena)» (Regione Siciliana, s.d., 141).

[6] Comune di Lipari, http://www.comunelipari.gov.it/zf/index.php/servizi-aggiuntivi/index/index/idtesto/25 (Ultima visita, Ottobre 2020)

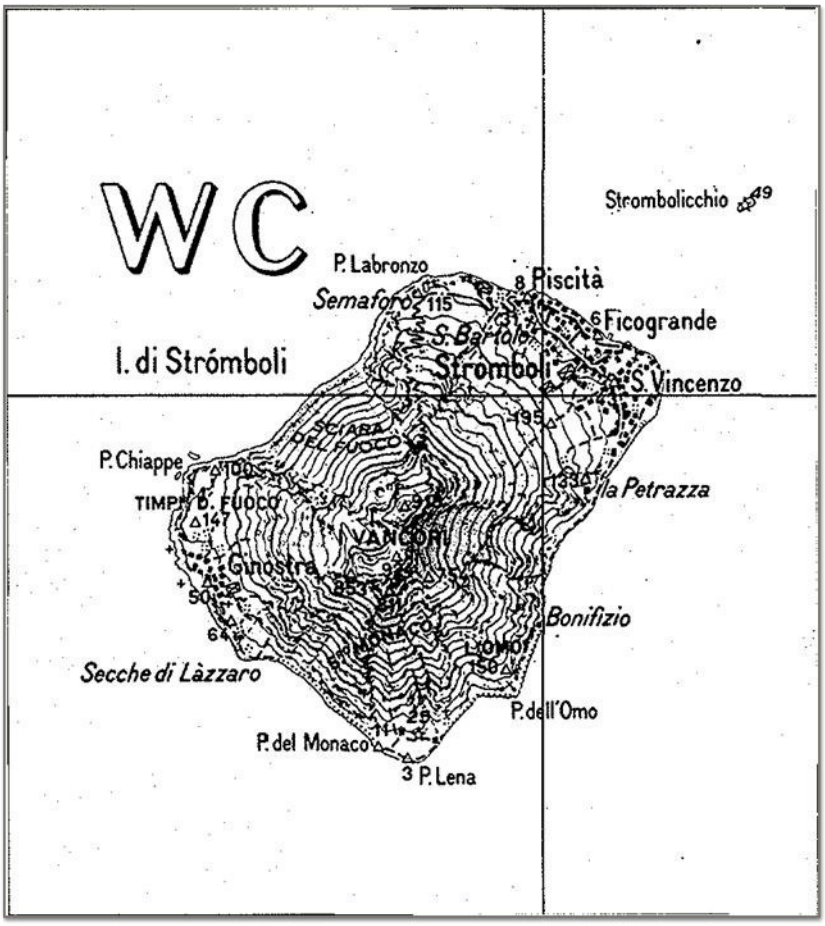

Figura 2 - *Carta topografica di Stromboli. Fonte: Archivio dell'UTC del Comune di Menfi.*

3. Il piano dell'emergenza

Richiamate, in rapidissimi cenni, le qualità e le caratteristiche essenziali del sistema territoriale in esame, vogliamo in questo paragrafo illustrare, problematizzandolo, il Piano di emergenza stilato dalla Protezione Civile nel 2015. In particolare modo ci concentreremo sulle due sezioni, la seconda e la terza, che approfondiscono maggiormente le dimensioni della parametrazione dell'allerta e della pianificazione delle operazioni in caso di rischio che meglio si attagliano agli obiettivi del presente contributo.
Dopo il maremoto occorso nel 2002, è stato fortemente implementato il sistema di monitoraggio strumentale attivo su Stromboli. Esso è funzionale a monitorare costantemente tanto l'attività sismo-vulcanica quanto gli eventuali

movimenti franosi lungo la Sciara del Fuoco. L'infrastruttura strumentale, finanziata dal Dipartimento per la Protezione Civile, consente una rilevazione di dati continua, monitorata e rielaborata costantemente dai Centri di Competenza (CDC) che fanno riferimento all'Istituto Nazionale di Geofisica e Vulcanologia (INGV) e all'Università degli studi di Firenze, Dipartimento di Scienze della Terra. L'infrastruttura installata consta di: stazioni sismiche, acustiche e termiche, stazioni geochimiche, stazioni per il rilevamento delle deformazioni del suolo e dei fenomeni franosi (EDM, GPS, tiltmetri, dilatometri, radar interferometrico), stazioni gravimetriche e magnetiche, una boa ondametrica fornita di un sistema di monitoraggio idroacustico sperimentale e telecamere termiche orientate verso la Sciara e i crateri[7]. Importante, inoltre, risulta l'approfondimento sull'accessibilità all'isola. Su di essa sono presenti i soli tre moli, quello di Scari, quello di Ginostra e quello di Ficogrande, idonei all'attracco di natanti con un pescaggio fino a 5 metri che, in caso di emergenza, possono fare ponte con i porti di Reggio Calabria, Gioia Tauro, Messina e Milazzo. A Stromboli sono, inoltre, state allestite 6 Zone Atterraggio Elicotteri. A tal proposito il Piano evidenzia alcune forti criticità:

> «In caso di emergenza, occorre verificare la fruibilità e lo stato di tali elisuperfici, in quanto gran parte di esse non sono ordinariamente oggetto di manutenzione; inoltre va ricordato che alcune di esse (Scari, Punta Lena) sono poste poco sopra il livello del mare e prossime alle coste e, in caso di maremoto, potrebbero subire danni o comunque risultare non fruibili per la presenza di detriti. Ulteriori limitazioni all'utilizzo di elicotteri in emergenza possono derivare dalla presenza di rilevanti quantità di ceneri in atmosfera liberata sia da fenomeni eruttivi sia da eventi franosi» (Dipartimento Protezione Civile, 2015, 12).

Dal punto di vista della rete infrastrutturale per le comunicazioni di emergenza, a Stromboli è stabile un ponte radio isofrequenziale tanto con la

[7] Da una nota del 5 Agosto 2020 diramata dalla DPC della Regione siciliana si apprende che: "La protezione civile regionale ha messo a disposizione del sistema di "Early Warning Maremoto", vigente nell'Isola, una infrastruttura di trasmissione dati di nuova generazione (rete mesh punto-punto) più sicura e performante rispetto all'attuale (hyperlan) utilizzato per raccogliere i dati provenienti dalle boe ondamentriche del Laboratorio di Geofisica Sperimentale dell'Università di Firenze", https://www.protezionecivilesicilia.it/it/9869-stromboli--monitoraggio-del-vulcano-piu-efficiente--prosegue-il-potenziamento-delle-reti-infrastrutturali.asp?fbclid=IwAR1Jk1TZLMT3QNsr3Nl_cgcUViR0qxLR58PnGlMpZPXcYrqmkh5CHCWO7w4 (Ultima visita, Ottobre 2020).

Calabria quanto con il Messinese. Ancora, attraverso un sistema radio che utilizza frequenze concesse dal Comune di Lipari viene coordinata una rete di 9 avvisatori acustici utilizzati tanto per allertare la popolazione quanto, fungendo da megafono, per avvisare verbalmente[8].

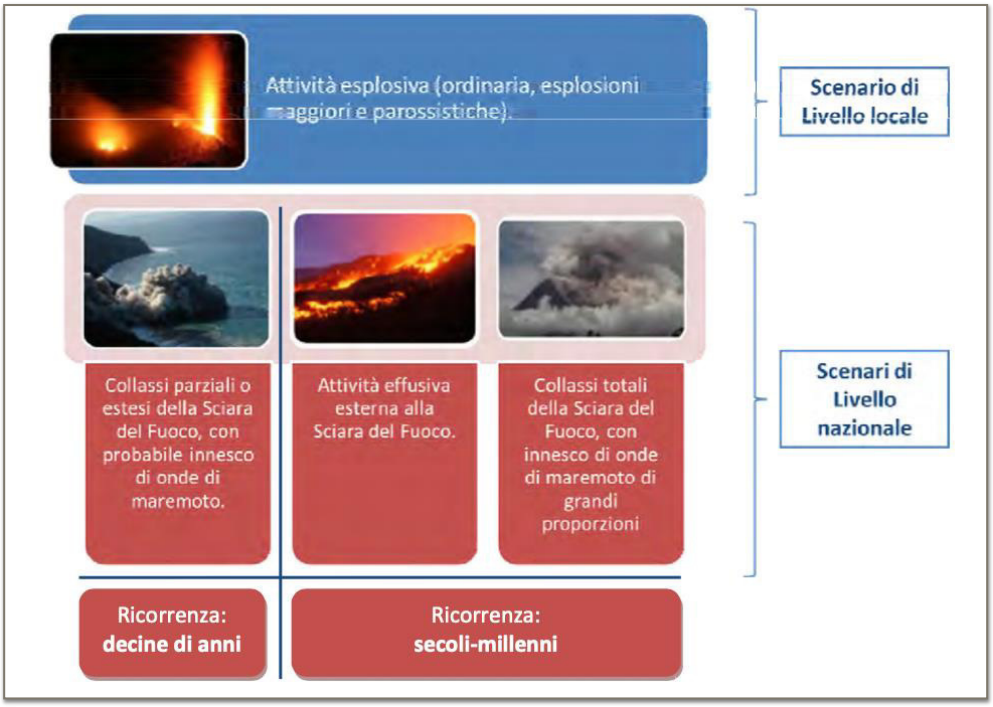

Figura 3 - *Scenarî attesi per attività vulcanica dello Stromboli. Fonte: Protezione Civile, 2015, 15.*

La Figura 3 mostra in maniera plastica gli scenari di allerta presi in considerazione nel piano. Da un punto di vista scalare, si evidenzia una differenza fra livello locale e livello nazionale rispetto all'intensità dei fenomeni e ai rispettivi possibili impatti. Sulla base delle occorrenze storiche

[8] Si rileva, in aggiunta a quanto detto, che è stata pubblicata sulla Gazzetta ufficiale la Delibera del Consiglio dei ministri del 29 luglio 2020 "Ulteriore stanziamento per la realizzazione degli interventi del territorio dell'isola di Stromboli, ricompresa nel comune di Lipari, in provincia di Messina, in relazione allo stato di attività del vulcano Stromboli, conseguente agli eventi parossistici verificatisi nei giorni 3 luglio e 28 agosto 2019". La delibera prevede lo stanziamento di 11,7 milioni di euro per il potenziamento delle infrastrutture dell'isola e per il miticamente dei rischi vulcanico e sismico; si rimanda alla notizia apparsa sulla cronaca locale https://qds.it/nuovi-fondi-per-isola-di-stromboli/ (Ultima visita, Ottobre 2020).

dei cataclismi, il Piano dichiara sin da principio il proprio orizzonte di intervento: collassi parziali, estesi o totali della Sciara del Fuoco potenzialmente tsunamogenici ed attività effusiva esterna alla Sciara del Fuoco. Restano, quindi, non contemplati dalla pianificazione e dalla gestione della sicurezza durante le fasi di allerta tutti gli eventi esplosivi, detti parossistici, caratterizzati da forte intensità. Più nel dettaglio, in relazione alle informazioni rilevate continuativamente dalle infrastrutture di monitoraggio ed elaborate dai soggetti preposti, si sono evidenziati stadi tipici dell'attività vulcanica e del grado di rischio connesso (Tav. 1); le strategie di intervento allora mutano in relazione all'intensità dei fenomeni e soprattutto alla rapidità della loro evoluzione.

Livello di allerta	**Stato del vulcano**	**Fenomeni in corso/attesi**
Base	**Vulcano in stato di equilibrio:** parametri di monitoraggio normali e/o attività vulcanica di tipo stromboliano	Attività di tipo stromboliano persistente ma ordinaria
Attenzione	**Vulcano in stato di potenziale disequilibrio:** parametri di monitoraggio anormali protratti nel tempo e/o attività stromboliana intensa	Attività stromboliana intensa o molto intensa insieme a fenomeni di *spattering*, colate laviche di bassa/media intensità lungo la Sciara del Fuoco per tracimazione dei crateri, ridotte emissioni di lava confinate in area craterica
Pre-allarme	**Vulcano in stato di disequilibrio:** parametri di monitoraggio su valori elevati e in rapida evoluzione e/o movimenti di porzioni, anche estese, nell'area craterica e della Sciara del Fuoco	Collassi di limitate porzioni dei coni sommitali con sviluppo di valanghe di detrito caldo lungo la Sciara del Fuoco; deformazioni o movimenti gravitativi lungo limitate porzioni della Sciara accompagnati da eventuale rotolamento di detrito; indizi di fatturazione esterna della Sciara; proseguimento stazionario di colate laviche alimentate da bocche effusive lungo la Sciara del Fuoco

Allarme	**Vulcano in stato di forte disequilibrio:** parametri di monitoraggio su valori elevati e in rapida evoluzione e/o movimenti di versante di ampia scala della Sciara del Fuoco con possibile sviluppo di frane nella parte subaerea e sommersa della stessa	Apertura di bocche effusive lungo la Sciara, con sviluppo di colate laviche ben alimentate; movimenti di larga scala del versante della Sciara, anche in assenza di bocche effusive, potenzialmente in grado di innescare frane di grandi proporzioni con possibile sviluppo di onde di maremoto; fatturazione in settori esterni alla Sciara con possibile sviluppo di colate laviche, specie nei settori NE e SW del vulcano.
Emergenza in corso	**Frana della Sciara del Fuoco potenzialmente tsnunamogenica** o, più raramente, **eruzione in area esterna alla Sciara del Fuoco**	

Tab. 1 - *Livelli di allerta per il vulcano Stromboli. Fonte: Protezione Civile, 2015.*

In tal senso, a chiarire le competenze chiamate in causa a seconda della rilevanza del fenomeno occorso, è utile richiamare testualmente il passaggio del Piano:

> «In caso di maremoti improvvisi o con ridotto preannuncio – innescati da eventi imprevedibili (ad esempio frane sismoindotte o esplosioni parossistiche) o a evoluzione rapida e improvvisa - il sistema si pone direttamente nella fase operativa necessaria a garantire il soccorso e l'assistenza alla popolazione secondo quanto contemplato dalla Direttiva del Presidente del Consiglio dei Ministri 3 dicembre 2008. Di contro, la gestione operativa degli effetti strettamente connessi al verificarsi di un'esplosione parossistica devono essere prioritariamente contemplati all'interno delle pianificazioni di emergenza di livello locale» (Protezione Civile, 2015, 16).

I maremoti indotti dall'attività tellurica connessa con le eruzioni sono gli eventi catastrofici che più frequentemente si sono abbattuti su Stromboli (Fig. 4) (La Rocca et. al., 2004; Nave et al., 2010); in ordine di tempo, lo tsunami del 30 dicembre 2002 è quello più recente (Fig.5). Sono essenzialmente due le dinamiche che, a partire da un'attività vulcanica decisa, provocano tale sconvolgimento: frane subaeree indotte ora dalle intrusioni di magma che

esercitano una spinta sul versante ora da accumuli di materiale - fenomeno avvenuto nel 2002 -; valanghe incandescenti prodotte da violente esplosioni. Entrambi i fenomeni tuttavia non causano immediatamente il maremoto ma creano destabilizzazioni alla struttura sottomarina della Sciara tali da innescare uno tsunami. Sulla causalità del maremoto del 2002 si impernia allora la strategia di emergenza descritta in seno al Piano del 2015.

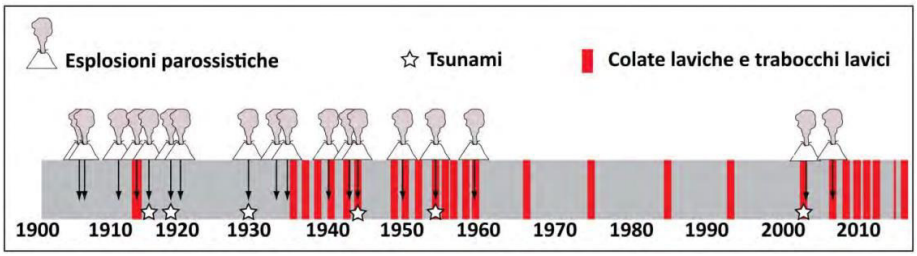

Figura 4 - *Attività del vulcano Stromboli dal 1900 al 2014. Fonte: Casagli et al., 2014, Relazione di approfondimento sull'attività di monitoraggio del Centro di Competenza DST Università di Firenze, in Protezione Civile, 2015, 18.*

Vediamo, dunque, nel dettaglio cosa preveda il Piano allorquando nell'isola si dovesse manifestare uno scenario qualificato come di "Allarme"; questa è, in effetti, la situazione critica che coinvolge in massimo grado interventi tanto sul piano locale quanto su quello nazionale:

> «Qualora fosse necessario procedere all'allontanamento, parziale o totale, della popolazione presente a Stromboli e garantire la conseguente attivazione degli adeguati assetti da porre in essere, si andrebbe a configurare, con ogni probabilità, un evento emergenziale ricadente nella fattispecie di cui all'art. 2, comma 1, lett. c) legge n. 225/1992 e s.m.i., che presuppone il coinvolgimento del Servizio nazionale della protezione civile a supporto e integrazione della risposta operativa dei soggetti a vario titolo competenti a livello territoriale» (Protezione Civile, 2015, 32).

In caso di emergenza improvvisa da maremoto, tale da configurare una potenziale compromissione della integrità di vite umane - e che possa comportare l'evacuazione e l'assistenza della popolazione presente sull'isola di Stromboli -, è previsto che, anche prima della formale dichiarazione dello stato di emergenza ad opera del Presidente del consiglio dei Ministri, possa essere disposto, sentiti il Capo del Dipartimento di Protezione Civile e il Presidente della Regione Siciliana - e, se possibile, la Commissione per la previsione e la prevenzione dei Grandi Rischi (CGR) -, il coinvolgimento

delle strutture operative del Servizio Sanitario Nazionale. L'emergenza sarà allora centralmente gestita dal Comitato operativo della Protezione Civile, con il supporto di una Unità di crisi creata *ad hoc* e, se necessario, di una Direzione di Comando e Controllo (DICOMAC) che, integrando tutti i livelli amministrativi coinvolti, gestisca le operazioni *in loco*. Essa ha il compito di attivare il congruo supporto alla gestione dell'evento estrinsecato nelle Unità di coordinamento, Tecnica e di valutazione, Assistenza alla popolazione, Telecomunicazioni in emergenza, Coordinamento attività aeree, Coordinamento attività marittime, Censimento danni, Comunicazione, Stampa, Volontariato. Il Prefetto di Messina, in accordo con il Presidente della Regione Siciliana, ha inoltre la facoltà di attivare anche il Centro di Coordinamento (CDC) dei Soccorsi. Il Sindaco del Comune di Lipari assumerà la direzione dei servizi prioritari di assistenza alla popolazione, dando attuazione a quanto previsto dalla pianificazione di emergenza comunale, anche attraverso il Centro Operativo Comunale (COC). La tabella 2 propone una sintesi dettagliata delle azioni innescate lungo la catena di comando e di controllo nella fase di Allerta.

	INGV	Altri Centi di Competenza	CGR	DPC	DRPC
Allarme	Intensifica ulteriormente le attività di monitoraggio e sorveglianza, garantendo la completa efficienza delle reti strumentali ed incrementando le osservazioni di terreno, fatte salve le valutazioni di competenza in termini di sicurezza degli operatori. Fornisce informazioni e valutazioni sullo stato dell'attività vulcanica al Comitato operativo della p.c., attraverso i propri rappresentanti presso il medesimo. Concorre alle attività della Funzione tecnico-scientifica di valutazione attivata presso il COA, con un proprio referente/coordinatore che si avvale del supporto di personale esperto delle differenti discipline del monitoraggio inviato in loco, fornendo informazioni in tempo reale sui fenomeni registrati e valutazioni sullo stato del vulcano, rendendo disponibile un report almeno bi-giornaliero nonché fornendo dati e informazioni per i report di Funzione. Rappresenta, per il tramite del Coordinamento DPC in comitato operativo o presso la DICOMAC, le eventuali esigenze di supporto logistico	Intensifica ulteriormente le attività di monitoraggio, garantendo la completa efficienza delle reti strumentali ed incrementando le osservazioni di terreno, fatte salve le valutazioni di competenza in termini di sicurezza degli operatori. Concorre alle attività della Funzione tecnico-scientifica di valutazione attivata presso il COA, con un proprio referente/coordinatore che si avvale del supporto di personale esperto delle differenti discipline del monitoraggio inviato in loco, fornendo informazioni in tempo reale sui fenomeni registrati e valutazioni sullo stato del vulcano, rendendo disponibile un report almeno bi-giornaliero nonché fornendo dati e informazioni per i report di Funzione. Rappresenta, per il tramite del Coordinamento DPC in comitato operativo o presso la DICOMAC, le eventuali esigenze di supporto logistico delle Strutture operative nazionali per sopralluoghi e attività di carattere tecnico-scientifico in loco.	Riceve dal DPC tutta la documentazione sullo stato del vulcano resa disponibile. Segue l'evoluzione dei fenomeni e della situazione in stretto raccordo con il DPC. Si riunisce periodicamente e fornisce eventuali pareri al CD DPC. Valuta e attiva le più opportune modalità organizzative e procedurali interne per garantire supporto alle decisioni del DPC.	Acquisisce e condivide con gli altri soggetti interessati le informazioni e le valutazioni provenienti dall'INGV e dagli altri CdC ovvero dalla CGR. Attiva la Funziona tecnica di valutazione in sede, in supporto alle attività del Comitato operativo; attiva la funzione tecnica di valutazione presso il COA, con il concorso di INGV, degli altri CdC e del DRPC, garantendo nel contempo l'attività in sede, sino al completo avvio delle attività in loco. Valuta il coinvolgimento, anche in loco, di rappresentanti della comunità scientifica esperti del vulcano quale ulteriore supporto alle decisioni di protezione civile. Predispone un report di sintesi della attività tecnico-scientifiche realizzate presso la Funzione di	Acquisisce e condivide con i componenti il sistema regionale di p.c., le informazioni provenienti da INGV e dagli altri CdC ovvero dal DPC fornendo alle medesime componenti le proprie valutazioni di rischio e garantendo supporto in termini operativi e di pianificazione. Partecipa alla VDC giornaliera ovvero alla Funzione tecnica di valutazione eventualmente attivata in loco.

	delle Strutture operative nazionali per sopralluoghi e attività di carattere tecnico-scientifico in loco.			supporto sulla base di dati e informazioni forniti dai partecipanti alle attività tecniche di valutazione. Rappresenta, in comitato operativo o presso la DICOMAC, le eventuali esigenze di supporto logistico, da parte delle Strutture operative nazionali, alle attività di carattere tecnico-scientifico in loco.	

Tab. 2 - *Le operazioni e la catena di comando previste dal Piano di emergenza di Stromboli durante la fase di Allerta. Fonte: Protezione Civile, 2015, Allegato D, 2.*

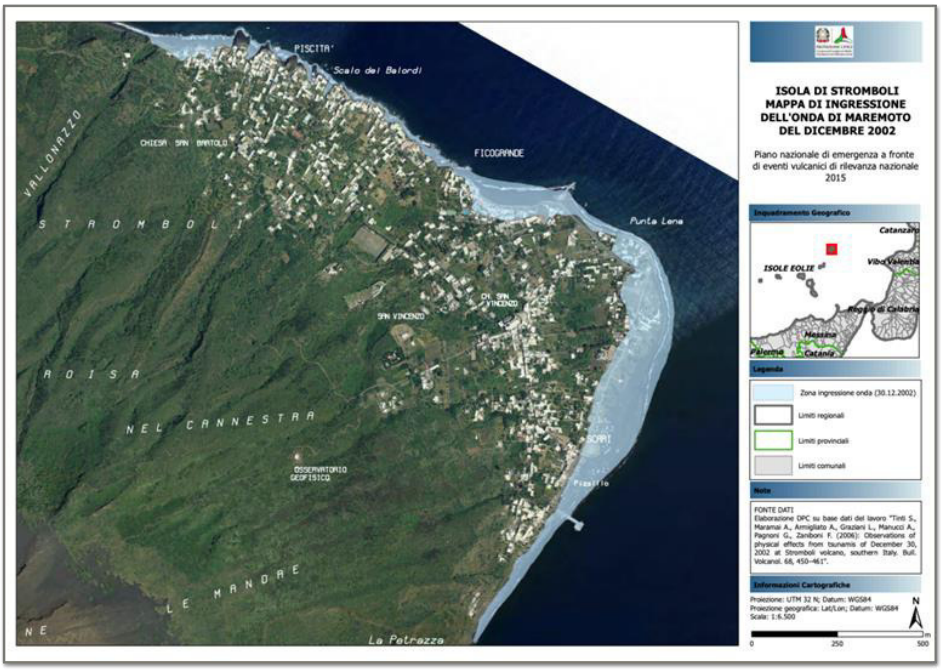

Figura 5 - *Mappa di ingressione dell'onda di maremoto nel 2002. Fonte: Protezione Civile, 2015, 41.*

Conclusioni

L'attività vulcanica, e quella tellurica ad essa connessa, presenti nell'arcipelago eoliano e, nella fattispecie, nell'isola di Stromboli hanno dato sporadicamente esito a fenomeni tsunamogenici generati essenzialmente dall'instabilità lungo il versante della Sciara del Fuoco. L'evento più recente, il maremoto occorso nel dicembre del 2002, ha reso necessaria la predisposizione di un piano di emergenza[9] atto a creare una catena di responsabilità nella filiera del controllo e del monitoraggio dell'attività vulcanica e, in caso di emergenza, della gestione operativa, integrata a tutti i

[9] Lo strumento del Piano rappresenta il principale e più diffuso approccio scientifico ed operativo per i territori maggiormente esposti al rischio indotto da eventi naturali particolarmente intensi. Per un raffronto internazionale si porta, a titolo di raffronto, l'esempio del *Samoa National Tsunami Plan* che annovera, il rischio di uno tsunami indotto dall'attività vulcanica dei monti Vailulu'u e Nafanua, citato nel documento approvato dal National Disaster Council e aggiornato al 2008, https://www.preventionweb.net/files/60548_samoanationaltsunamiplanupdated2008[1].pdf (Ultima visita, Ottobre 2020).

livelli di governo, delle operazioni tese a minimizzare il rischio per l'integrità delle comunità residenti. Lo strumento pianificatorio, articolando le politiche di intervento in maniera proporzionata all'intensità dei fenomeni e del potenziale rischio, rappresenta, in accordo con la letteratura richiamata nel primo paragrafo, il documento previsionale strategico nelle politiche di riduzione del rischio da eventi naturali di forte intensità. Il contributo, volendosi, infatti, inserire in seno agli studi sul rischio percepito delle calamità naturali, muovendo da un approccio essenzialmente descrittivo, ha mirato allora a ricostruire, per cenni, il contesto vulcanologo e territoriale dell'isola di Stromboli e a rintracciare, attraverso i passaggi principali, la logica di intervento insita nel documento.

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SECTION II

Climate and Global Change, Vulnerability, Water Resources and Sustainability

5. Climate relocation of Indigenous peoples from island territories: issues related to the misunderstanding of their indigenousness

Adèle de Mesnard[1]

Abstract

While climate relocation is gaining recognition as an adaptation strategy in the international climate regime, specificities of Indigenous peoples' relocation requires analysis of the varying contexts in which it takes places. It is not just a question of understanding climate change impacts on island Indigenous territories: a functional strategic planning can only be achieved by understanding local dynamics and the asymmetrical relationship that communities have with their national governments. Including Indigenous claims is equally important. The example of Native communities living on barrier islands in Alaska shows that community members claim to remain a community and a cultural distinct entity – the importance of choosing where they move being an essential factor – and to freely decide their future. They refuse to allow their vulnerability to climate change to be used only as pretext to deny them any possibility of adaptation. A brief analysis of legal and institutional obstacles to the recognition of their indigenousness in displacement then makes it possible to see how Native communities' climate relocation should be planned and implemented. The objective is to go beyond a static approach to Indigenous rights and identities, while considering the specificity of a collective approach. It also allows us to analyze how their demands are concretized on the national and international scene. While the Indigenous peoples do not remain passive, international organizations and NGOs are not passive either, at least not if we consider the relatively large number of instruments adopted in recent years to guide States' action. However, the main challenge remains to effectively integrate Indigenous specificities into the broader framework of climate relocation.

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Keywords: Indigenous peoples, climate change, climate relocation, adaptation, self-determination.

Introduction

While the impacts of climate change became visible in a variety of ways, what is most striking is the risk of seeing small island territories sink. Over the years, they have become the symbol of what could be the most dramatic consequences of climate change worldwide, even though greenhouse gas emissions from these island territories remain negligible. Beyond the hard-hitting nature of the press headlines, the Intergovernmental Panel on Climate Change (IPCC) continues to warn on the effects of sea-level rise and extreme weather events. In its special report "Global warning of 1.5°C" (2018), IPCC draws attention to the consequences of sea level rise on small islands, low-lying coastal areas and deltas. IPCC also informs decision-makers and the public about the risks to Indigenous peoples and local communities dependent on agricultural or livelihoods who live within these territories. In its Synthesis Report of 2014, it states that "*climate change is projected to increase displacement of people (medium evidence, high agreement). Displacement risk increases when populations that lack the resources for planned migration experience higher exposure to extreme weather events, such as floods and droughts [...] Changes in migration patterns can be responses to both extreme weather events and longer-term climate variability and change, and migration can also be an effective adaptation strategy*". By opposition to *migration* as a possible climate change adaptation strategy, *displacement* looks disordered since it would occur when populations have no sufficient resources to migrate. This distinction is in line with the one made by international organizations between forced and voluntary movement – although this can and should be discussed because of legal and political issues and of the practical and symbolic implications. Regardless of the difficulty to conceptualize environmental-induced movements, the trap to be avoided is considering that the realities of concerned individuals and groups are static, which could lead to giving them a legal status that is out of step with their expectations and needs. Such representations from outside the communities may entrench them in an inadequate legal regime, and tensions that may result can be exacerbated by existing asymmetries in their relations with public authorities. Following the Cancun Agreements in 2010, IPCC analyses, in its last Special Report "on the Ocean and Cryosphere in a Changing Climate" (2019), the third type of human mobility, i.e., *planned relocation*, as an

adaptation strategy. As defined by the expert meeting of San Remo (2014) with the United Nations High Commissioner for Refugees (UNHCR), planned relocation is a "*solution-oriented measure involving the State, in which a community … is physically moved to another location and resettled there*". Stressing that this process must be anticipated, a distinction is made with "evacuation" as moving quickly to a safer place after an emergency. This definition of planned relocation addresses two major issues: it is supposed to be a government-led measure and it concerns a collective and community-based displacement. It is worth noting that IPCC equates the term "planned relocation" with the term "managed retreat", which clearly shows that such an issue is more suitable for island territories and must be considered through the prism of coastal management strategy. In analyzing the relevance of planned relocation for low-lying areas exposed to the impacts of coastal hazards, IPCC is relatively critical, particularly in the case where "*relocation of people displaces pressure to destination areas with a potential increase of risk for the latter*". It pleads for an "*ambitious adaptation*" (without really defining what is meant by that), which should make it possible to develop "*a robust foundation for adaptation beyond 2100*" but without "*necessarily eradicate end-century risk from seal-level rise across all low-lying coastal areas*" (IPCC, 2019). Besides, IPCC remarks that its analysis is limited in that it only considers technical aspects, without consideration of the financial and social aspects. However, they are decisive, particularly in respect to the very particular situation of Indigenous communities. Indeed, public authorities need to understand that climate relocation of Indigenous peoples is not just about moving them from point A to point B, eventually to wherever it would be possible to send them.

Not only Indigenous peoples' special relationship to the land is an essential factor, but the notion of collective and the legal treatment of the 'community' must also be integrated into the relocation process. The idea of community cannot be the mere addition of individuals acting in common to achieve their individual goals but must address the fact that individuals intend to move as a group. Therefore, the following question raises: how to recognize the community as a legal distinct entity without changing its nature or undermining its cultural integrity and its ability to function according its own norms and institutions? This issue is particularly important in cases of relocation of island Indigenous peoples as their claims relate, on the one hand, to territorial continuity between the island and the mainland (which also underlies the issue of the island lands left behind) and on the other hand, to their desire to continue to develop as culturally distinct entities – the case of

barrier islands favoring the expression of a "*unified island identity*" (Grydehøj, Nadarajah, Markussen, 2018).

1. The indifference on indigenousness: lessons from failures of Alaskan Native communities' climate relocation

This research is based on the observation that Indigenous peoples face a number of legal and institutional obstacles when deciding to relocate because of climate change. There is no binding legal framework regulating their relocation and integrating Indigenous specificities on which they could invoke to challenge the actions or omissions of the State. *A fortiori*, taking the example of internal climate-driven displacement of Native communities in Alaska, no national legislation stipulates specific treatment. When we look at the situation of two communities, Kivalina and Shishmaref, they initiated their relocation more than thirty years ago, without getting any reaction from the US government until the early 2000s when climate change-related impacts and the need for permanent relocation became indisputable. They are two Inupiat communities, each residing on a barrier island in the Chukchi Sea, that are subject to increased erosion pressures. A UNESCO report (2010) mentions that in Shishmaref, more than half of land (producing 80% of the resources) has disappeared into the sea, while in Kivalina, the area of the island has decreased by 50% between 1953 and 2009. As confirmed by IPCC's special report "on the Ocean", islands are also threatened by extreme climatic events, particularly storms and subsequent flooding. In the past, the coastline was protected by the formation of sea ice, which absorbed the mechanical energy of waves. Ice now appears much later in the year and melts early, leaving the coasts more exposed to erosion and wind-driven storm surges. Waves are higher and therefore potentially more destructive of the shoreline, whose erosion allows waves to reach the village's infrastructure.

Nonetheless, climate causes should not be examined separately, but by considering the historical process of how the government has understood Indigenous specificity. Indeed, at the beginning of the 20th century, government policies of forced sedentarization to civilize and assimilate Native families into American society coerced them to settle permanently in villages created from scratch on ecologically precarious places. These chosen places were located on very small islands, practically at sea level and previously used as seasonal hunting and fishing summer camps. They were selected without the consent of Indigenous peoples and without understanding that the Indigenous political and socio-cultural system is based

on a seasonal cycle allowing to respond to the changes in ecological and meteorological conditions (Marino, 2015). Forced sedentarization on barrier islands thus also reflects the desire of the American government to contain the claims of indigenousness in a more restricted space. About the relocation process itself, public authorities did not support their choice of relocation sites, which stopped the process from moving forward. Communities claimed – and they still do – that they wanted to choose an unoccupied land they could collectively own. This place must be close to their current lands and have similar characteristic so they can maintain their identity, livelihood and way of life in their own way. They refuse to move within an existing community and to an urban area, because it could only lead to community dislocation and loss of territorial ties (Marino, Lazrus, 2015). They want to remain a community and culturally distinct entities – the islander identity being therefore mobilized in the frame of "*both self-identification and identification by others as deserving of rights accorded to originary inhabitants of a territory*" (Grydehøj, Nadarajah, Markussen, 2018).

However, these claims are facing government requirements. In Kivalina, the U.S Army Corps of Engineers' analysis of the suitability of any new location is based primarily on geotechnical considerations, dismissing any criteria that cannot be technically or economically quantified, which excludes the special relationship that Native communities have with their lands and with their environment. Primarily based on land physical properties and on the vulnerability of the infrastructure to flooding and coastal erosion, its analysis leads it to select places much further away than those chosen by Kivalina (USACE, 2006). Considering their difficulties to maintain their relationship with the ocean and to continue their subsistence activities (Shearer, 2011; 2012), communities cannot accept it. Not to address cultural or socio-political issues and to reformulate them only in technical terms can significantly reduce the ability of Indigenous communities to adapt to a new environment. Technical engineering put communities in a passive position by excluding them from the decision-making process since experts will always know better than they do what should be done to reduce climate contingencies impacts (Thornton & Manasfi, 2010; Alexander & al, 2012). This paternalism – perhaps unintentional– is exacerbated by misrepresentations of Indigenous peoples: they are not supposed to be able to understand technical solutions (Cameron, 2012; Whyte, 2017).

Another major problem is that no federal authority has the mandate and financial capacity to coordinate alone the relocation (US G.A.O, 2003; 2009). The lack of a leading entity to force federal and state agencies to work together implies a dispersal of responsibilities and a scattering of assistance

programs, combined with the difficulties for communities to be eligible for such programs. Each agency prefers to act alone so as not to risk being responsible for the entire relocation process, especially since funds lack to do so. This leads to incompatible action patterns, but also to contradictions in considering Indigenous specificities and in understanding Indigenous rights. Besides, what is called by communities as "*battle fatigue*" (Gray Glenn & Associates, 2010) is then amplified by the multiplicity of stakeholders they must deal with. Every time, the new generation must then rediscover the imbroglio of standards, reports and funding arrangements and the workings of the multiple federal and state agencies to regain leadership and re-establish dialogue. Shearer (2012) calls it "*administrative orbit*". This implies significant expertise for the communities since they must adapt their demand to each agency's objective and untenable conditions. Indeed, agencies tend to focus on a cost/benefit analysis (FEMA, no date). However, due to the high construction or transportation costs associated with communities' geographical location, Native communities' projects have a low benefit-cost ratio. The profitability-based approach exacerbates public agencies' misunderstanding of communities' social and cultural systems; agencies' projects imply a complete change in communities' way of life, without them having any real say in how they want these changes to occur.

Finally, in addition to the lack of centralized State financing, any progress is hampered by public authorities' decoupling measures to mitigate climate change's impacts *in situ* and the relocation process (Marino, 2012). When the US government is informed of the willingness of communities to relocate, it cuts climate change funding, without reallocating the funds to the relocation process. This situation let the communities hit a dead end, especially since the government does not understand that relocation takes time. This implies that, while a new village is being built, the old village will continue to be inhabited during this transition period although exposed to climate change and requires to be protected. However, Native communities do not remain passive when faced with the lack of political will on the part of the government to consider their specificities and to recognize their rights. They are mobilized to steer the debate in such a way that it is not rooted in a legal and institutional framework that they would consider inappropriate.

2. The Indigenous initiatives: to put their right to decide freely of their future back at the heart of the debate

At the national level, the example of Newtok is particularly interesting since it demonstrates the possibility of governance that would take place to effectively implement Indigenous peoples' self-determination right. Newtok, a Yupik community, is located on the bend of the Ninglick River, north of Nelson Island, about 150 kilometers from Bethel. In 1994, the Newtok Traditional Council formally began the relocation process. In 1996, after pre-selecting six potential relocation sites, community members collectively chose to relocate to Nelson Island on a site about 15 kilometers southwest of Newtok called Mertarvik. After seven years of negotiations, in 2003, Newtok obtained a land title through a land exchange agreement negotiated with the US Fish and Wildlife Service (Beck Consulting, 2012). The community was then able to start the construction of the new village, not yet completed because of the financial problems mentioned above. However, owning land was a catalyst for the formation of the Newtok Planning Group in 2006, with the assistance of the Alaska Department of Community and Regional Affairs (Bronen, 2014). Comprised of approximately 25 representatives from tribal, state and federal governments and non-governmental organizations, the Newtok Planning Group conducts the relocation efforts. The Newtok community has thus succeeded to establish collaborative governance by meeting stakeholders to convince them to participate in the same partnership. This makes it possible to fill the institutional gaps, and particularly to significantly reduce the delays caused by public agencies' responsibility spreading. It also allows the community to make its expectations and needs be heard. The relocation process is based on guiding principles defined by community's members as best suits their commitment to continue their community way of life, such as "*to remain a distinct, unique community – our own community", "to stay focused on our vision by taking small steps forward each day";* to *"make decisions openly and as a community and look to elders for guidance"; "our voice comes first – we have first and final say in making decisions and defining priorities", "development should reflect our cultural traditions*", etc. (Bronen, 2014). While Newtok Planning Group is a unique example in Alaska, this kind of collaboration seems to be the most viable way to conduct the climate relocation process. It is fully in line with developments in international law, particularly with the United Nations Declaration on the Rights of Indigenous Peoples (2007). The Declaration enshrines Indigenous people's right to self-determination (article 3) while recognizing the need to protect dynamic Indigenous culture. It also underlines

the historical injustices suffered by Indigenous peoples, "*thus preventing them from exercising, in particular, their right to development in accordance with their own needs and interests*" (§ 6 of the preamble). Climate relocation must not be a pretext for States to reproduce these injustices or to challenge their Indigenous character, arguing that it would make Indigenous peoples lose their authenticity, even though the latter is imposed by States. The effective exercise of the right to self-determination should not only reflect their right to freely decide where, when and how to relocate, but also imply the right to relocate as a community and a cultural distinct entity. While Indigenous communities must retain their decision-making power, it calls for a transformation of the relationship between them and national governments so that the latter, acting as 'trustees', do so genuinely in the interest of Indigenous communities.

At the international level, this has been particularly recalled by island Indigenous peoples on many occasions. In October 2018, a Convening of more than sixty representatives of island Indigenous communities from around the world was organized in Alaska to identify the problems they face when they must relocate because of climate change. A First Peoples' and Indigenous' Peoples Declaration (FIPD) was adopted. This Declaration echoes the Anchorage Declaration which was adopted on 24 April 2009 following the Indigenous Peoples' Global Summit on Climate Change held from 20 to 24 April 2009 in Alaska. At that time, not only Indigenous peoples were seeking recognition of their fundamental rights as affirmed in the United Nations Declaration on the Rights of Indigenous Peoples, particularly within the United Nations Framework Convention on Climate Change's (UNFCCC) agreements and principles, but they also issued "calls for action". Beyond climate change's impacts, they reaffirmed the need to ensure their full and effective participation in all decisions and activities related to climate change mitigation and adaptation through creating formal mechanisms in UNFCCC's decision-making bodies. The importance of Indigenous knowledge and practices in dealing with the climate change crisis also needed to be recognized. One of the calls concerns the significant reduction of greenhouse gas emissions, particularly from developed countries as stated in Annex I of the UNFCCC. In parallel with States working towards decreasing dependency on fossil fuels, they argue that they must take the control to ensure energy security and sovereignty. It should be noted that the notion of sovereignty is at the heart of the Anchorage Declaration. Indigenous sovereignty is debated in relation to the place of Indigenous peoples within the society as they are under the authority of the State. While they are nations with inherent rights,

the use of this notion is quite interesting. Associated with the notion of energy or food sovereignty, it deals more broadly with their struggle for autonomy and self-determination: the realization of one would be dependent on the realization of the other and vice-versa. Besides, Indigenous sovereignty is not intended to supplant that of the State but should ensure effective control over old or newly owned land. They indigenize the concept of sovereignty as the Anchorage Declaration also emphasizes Indigenous responsibilities and relationships with the lands, air, waters, oceans, forests, thus expressing their cultural and spiritual ties to their environment and the non-human world. Without falling into the trap of an essentialist vision, perpetuation of their way of life can only be achieved if they can freely decide their future. In this way, the issue of Indigenous climate displacement is firmly addressed (Call for action n°11).

In comparison, almost a decade later, and faced with the worsening of their situation, island communities are focusing on how their relocation should be planned and implemented, and thus how their right to mobility should be realized. However, the FIPD still focuses on the international climate regime, particularly on the implementation of the Paris Agreement, calling for the recognition of the rights of climate-displaced peoples. This is interesting insofar as the Paris Agreement appears to fall far short of their claims. The rights of Indigenous peoples are only mentioned in the Preamble by referring to "migrants" but not to climate-displaced Indigenous peoples as such. Although we might wonder if the international scene is the most effective arena for enforcing Indigenous rights, clearly there is a window of opportunity to compel world leaders for addressing Indigenous issues, supporting interaction and movement with the spaces in which Indigenous claims will actually take place. This political dynamic, tied to the creation of a unified Indigenous voice on a common issue, may influence the development of common norms and standards that can then influence local struggles, while rebalancing political, social, and cultural relations within international institutions. Thus, if the Declaration is organized into several calls, for States parties to the UNFCCC, for State Governments, for Indigenous leaders, etc., these calls would reinforce each other. In addition to respecting Indigenous rights and empowering communities, these parallels in these claims focus on community participation, in a proactive approach, in "*formulating, implementing, and monitoring mitigation and adaptation activities relating to the impacts of the climate crisis*" and in developing "*human rights-centered laws, policies, and strategies that address the spectrum of risks associated with forcible displacement*". Sharing experiences is also emphasized, by integrating "both traditional and modern" Indigenous

knowledge into an international framework (which therefore calls for re-valuing this knowledge as required in the Paris Agreement) as well as within the communities themselves. To conclude on Indigenous initiatives, we can mention the complaint called "Rights of Indigenous people in addressing climate-forced displacement", filed by five Indigenous island tribes in the United States, including Kivalina, in January 2020 and submitted to UN Special Rapporteurs. The complaint is based on the wrongful inaction of the United States Government, claiming its liability for the violation of fundamental rights as applied to their specific situation – such as the right to life –, and for Indigenous rights as recognized in international law, quite particularly the right of self-determination. The complaint also insists on the need to protect their cultural heritage, particularly with the question of what will happen to the land that will be left, their legal status, and the risk of irretrievably losing the connections with their ancestors. It ties up with the International Union for the Conservation of nature's policy (IUCN, 2012).

3. The international guidance: towards a progressive recognition of Indigenous specificities in climate relocation

Based upon the inadequacy of international law to effectively protect environmentally displaced persons, the approach taken by international organizations and non-governmental organization is pragmatic, i.e, providing States with tools to better understand the displacement and relocation of their populations. Drawing lessons from failures of previous climate relocations, or even referring to the lessons of forced displacement caused by development projects, these guidance or toolkits identified principles and "good practices" that States must integrate and adapt into their national legislation. The aim is to provide a coordinated approach between States, and between the administrations, individuals as well as communities, which leads us to clarify some points concerning the definition of climate relocation as an adaptation measure.

Climate relocation differs from other population movements in that it is considered as a last resort measure against the degradation of ecosystems and habitable environment. Unlike displacement caused by development projects, it can be voluntary in the sense that it is initiated by communities (albeit under the constraint of climate change). Besides, as relocation cannot only be considered as a logistical problem, each process must be related to the multidimensional contexts in which climate change occur and include a number of factors specific to each Indigenous community: its geographic

location, livelihood, relationships among its members and with the government, sharing and mutual support networks, customary rules, the range of tools and resources available to respond to hazards, etc. Two interrelated consequences can be drawn. First, it involves different perspectives, policies and tools depending on the context. For instance, while in its last report on Ocean IPCC takes into consideration the case of small Pacific Island States and the situation of Native island communities in Alaska, their realities are different not only in terms of displacements' spatiality and temporality, but also with regard to material and legal implications. In the case of Pacific Island States, it is the very existence of the State that is threatened: some States consider owning territories that belong to other States, or they have concluded bilateral agreements with neighboring States to create some special migration programs to provide Indigenous people with job opportunities. In this case, relocating is thought within an existing community. In contrast, only a small fraction of the land area of the whole State of Alaska is under threat of sinking but this one happens precisely where Indigenous communities live. This emphasizes the very situation of internally displaced communities for whom the main difficulty is much more about how relocation is planned and implemented, particularly concerning the unequal balance of power between Indigenous communities and the host State. Moreover, communities' members are at the same time US citizens and Indigenous. Thus, the *Guidance for protecting people from disasters and environmental changes through planned relocations* (United Nations High Commissioner for Refugees, Georgetown University and Brookings Institution, 2015) focusing only on internal relocations points out that "*States bear the primary responsibility under international law to respect, protect, and fulfill the human rights of people within their territory or subject to their jurisdiction*". It should be noted that in line with the Guiding principles on internal displacement, it adds that "*these responsibilities may require planned relocation in order to protect persons or groups of persons*". This obligation raises the question of the arbitrariness of displacement. The identification of exceptional circumstances that require States to compel persons or groups to protect them from themselves may be relatively easy in the context of natural disasters or pandemic whose sudden and often unpredictable nature requires an immediate response to preserve human lives. This is much less the case in the context of climate change. For instance, for Alaskan Native communities, the degradation of their island territory was proven a long time ago. However, the communities continue to live there, despite the highly degraded living conditions. The risk could be that environmental emergencies could be exploited by public authorities to legitimize actions that do not accommodate

communities' claims. Secondly, while this does not preclude looking for common legal and political references, it implies that a solution may be an effective adaptation initiative in one territory but not in another one: there is no optimal solution in absolute terms. The same is true within a community itself because of the repercussions of every decision made and the changing contexts. Adaptation must be considered as a dynamic, continuous, and evolving process, especially since the problem of how to deal with climate change impacts is also evolving (Magnan, 2009).

Moreover, a contextual analysis highlights adaptation and then justifies the communities' involvement to understand how they are affected by climate change differently and to better understand the solutions to be provided. It avoids simplistic or essentialist visions of island communities, particularly regarding the "rhetoric of vulnerability" (Walshe, Stancioff, 2018). The problem lies in the instrumentalization of the notion of vulnerability when vulnerability is considered as an innate characteristic of Indigenous peoples, or that it is reduced solely to risk exposure, associated with the geographical isolation of the islands. Both cases lead to a biased view of insularity and indigenousness, since the factors specific to each community and the socio-economic, political, and cultural processes are excluded from the analysis (Gemenne, 2010). This includes the historical and contemporary contexts of indigenous oppression, territorial deprivation, and denial of their rights. The problem is also the marginalization of their claims, particularly for self-determination. Conversely, addressing all the root causes of climate change and relocation leads to consider that all Indigenous communities are not equal by respect to climate risks and to consider the multiple specificities of their living environment. The example of island communities in the Pacific is particularly striking in this regard. For instance, several on-site surveys carried out in Tuvalu as part of the EACH-FOR program have shown that, contrary to Western representations that portray Tuvaluans as helpless and passive victims of climate change, Tuvaluans focus on the obligation for the most polluting countries to reduce their greenhouse gas emissions. Moreover, Tuvaluans' perception of the links between climate change and relocation are not unequivocal. Some Tuvaluans do not plan to relocate in the close future because of their deep attachment to their land and environment and their strong wish to preserve their right to self-determination (Farbotko & al., 2018). At the same time, for some others, mobility is seen as an adaptation strategy among others, bearing in mind that Tuvalu's history is strongly marked by inter-island displacement. The ocean is considered as an element that connects communities: people move to respond to environmental disruptions, to find a job, to care for themselves, to participate in the

governance of the region's resources, etc. (Farbotko, Lazrus, 2012). While these relationships are embedded in political and socio-cultural contexts of Pacific Islands, they are not taken into account by those outside the communities, who focus on the insularity of the islands perceived as a juxtaposition of individualized and discontinuous spaces (Chevalier, 2017). Thus, these representations do not consider that relocation is not necessarily perceived by Indigenous populations of Tuvalu as affecting their fundamental rights, unlike the way it can be implemented by public authorities, with the subsequent risk to lose their right to freely decide about their future.

It should be noted that, since its latest report (2014), IPCC includes the notion of "maladaptation" to refer to adaptation processes that undermine the social and cultural balances of the populations concerned. Maladaptation then "*arises not only from inadvertent badly planned adaptation actions, but also from deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions*" (IPCC, 2014, 837). It is therefore important, not only to think solutions in a concerted manner so as not to accentuate existing problems but also to integrate communities' needs and expectations – bearing in mind that it is sometimes difficult to achieve consensus within the community itself. Relocation should then be undertaken with a much broader perspective than just an economic one, considering that relocation projects go far beyond the mere material loss of land.

On the one hand, the Office of the UN High Commissioner for Refugees, the International Organization for Migration and Georgetown University, when designing a Toolbox to complement the 2015 Guidance, focus on five cross-cutting elements: understanding complexities related to land issues, addressing the needs and impacts of planned relocation of affected populations and ensuring their participation. They stress that the involvement of populations must be understood as a "*continuum—from passive receipt of information from authorities, to the two-way process of consultation, to enabling the active participation of affected populations in decision-making* (2017, 20). What matters is the quality of the consultation process: it must not be undertaken only to show that consultation has taken place, Indigenous members being only passive witnesses in the decision-making process, without deliberative capacity. Additional precautions must then be taken at the beginning of the process to ensure that an agreement is reached between community members and public authorities on how information is obtained and communicated and on how the planning phase should be organized – with the need for time for reflection within the community itself. In a pragmatic

way, moving beyond vertical and asymmetrical relations between public authorities and Indigenous peoples can facilitate their support to government's decisions as they would be the result of a collective reflection. It can also help to overcome blockages that may arise during the relocation process, as long as any opposition can be clearly expressed and debated without being seen as a breakdown in the decision-making process.

On the other hand, compensation for Indigenous peoples' land losses caused by climate relocation calls for moving beyond the cost-benefit approach. This one is often adopted in the case of expropriation of populations in the context of their relocation due to development projects. A "fair market value" approach does not adequately address Indigenous peoples' collective customary land rights. Reasoning in terms of "fair market value" leads to focusing on individual interests and therefore asking each member of the community if they are willing to relocate and at what cost, neglecting collective interest. While it could imply an improvement in living conditions for some individuals, it could profoundly affect the cohesion of the community. Besides, in addition to the recognition of Indigenous title deeds to the land so that their right to compensation cannot be contested, Indigenous peoples should be granted an equivalent land in quality, size, and value. A distinction must be made between the market value of land ownership and its replacement value, particularly when the land market is weak or non-existent because of the risks affecting land ownership, especially environmental degradation associated with the impacts of climate change. This replacement should not only be assessed in material terms: intangible cultural and spiritual values must be integrated, which implies that a "fair market value" cannot exist since these values are precisely non-market values. Insularity thus raises the question of the integration of these intangible values with even more acuity as the risk is that of the disappearance, in the physical sense, of small island territories by submersion.

Besides, all risks that are difficult to quantify, such as cultural, spiritual, and psychological disturbances, related to the loss of the land of origin (at both individual and collective levels) or to the social disruption, should be included in reparation policies. It should be noted that compensation is not enough. It may be insufficient to reestablish Indigenous communities after relocation, especially since it may overlook the temporal dimension of relocation while accelerating the process is costly. Thus, while they cannot replace a legal and institutional framework, investment policies can enable displaced communities to improve their living conditions once the relocation process is complete. They may ensure that changes are made under the best possible conditions, whether this involves retraining for Indigenous

individuals, cultural diversification on the new land to increase the individual of community income, a new social or cultural balance, etc. (Cernea, 2003; Cernea and Kanbur, 2002). A return to the initial state, which is not feasible in practice, would make little sense considering the highly degraded living conditions of most Indigenous communities. Besides, such investments can establish the basis for their right to self-determination.

In conclusion, there is no doubt that understanding the complex nature of a relocation process requires a more comprehensive approach well beyond an economic and operational perspective. The challenge, for the principles adopted by international organizations, however, remains the inclusion of Indigenous peoples as such. In a highly interesting way, the Guidance highlights the need to build on a rights-based framework within which "*the rights to self-determination, preservation of identity and culture, and control of land and resources are important, particularly for Indigenous communities*" (2015, 11). Addressing the issue of specific needs, the notion of "*special dependency on, and/or attachment to, land or local/localized resources/opportunities*" is also highlighted. The Toolbox takes the example of a variety of Indigenous communities and the difficulties they face, including a checklist of issues to consider, while retaining the very limits of a general framework and the use that States can be made of it. This requires tools specifically dedicated to Indigenous situations and rights. We can mention the *Peninsula Principles* that were approved in 2013 by a group of lawyers and experts specializing in climate displacement and relocation (Displacement Solutions, 2013). Peninsula Principles are based on eighteen principles that provide very concrete guidance for States about the type of obligations they must fulfill to respect the rights of climate-displaced persons at each stage of displacement and relocation. They take a comprehensive approach to internal displacement with an inclusive definition of those affected: "*individuals, households or communities who are facing or experiencing climate displacement*" (Principle n°2). The aim is clearly to go beyond the dominant individualist approach in international law. Conversely, the Agenda for the protection of cross-border displaced persons in the context of disasters and climate change adopted by 114 States on 13 October 2015 as part of the Nansen Initiative deals only with individual migration, leaving aside communities (e.g., from small island States). The only references to collective displacement are provisions for the adoption of bilateral or multilateral agreements to facilitate the cross-border movement of nomadic pastoralists and their livestock. While nomadic territories do not necessarily have the same boundaries as those drawn by States, especially when the environment (as desert) can draw unstable borders, "*pastoralists use*

migration as a traditional coping method to access water and grazing land in time of environmental stress" (Nansen Initiative, 2015, 36). The Agenda calls on States not to oppose the crossing of borders and to respect "*traditional informal agreements*". To conclude, although they do not specifically address climate-related displacement and relocation, we can mention the adoption of the Global Compact for Safe, Orderly and Regular Migration and the Global Compact on Refugees in December 2018. These two instruments can be a step towards the possible establishment of an international legal status for environmentally displaced persons, all the more since, in the first one, it is very clearly stated that States should "*cooperate to identify, develop and strengthen solutions for migrants compelled to leave their countries of origin owing to slow-onset natural disasters, the adverse effects of climate change, and environmental degradation, such as desertification, land degradation, drought and sea level rise, including by devising planned relocation and visa options, in cases where adaptation in or return to their country of origin is not possible*". The situation of Indigenous peoples is also rapidly being addressed from the perspective of reducing their vulnerabilities by establishing "comprehensive policies" that provide them "regardless of their migration status with necessary support at all stages of migration through identification and assistance, as well as protection of their human rights" (Objective n°7). We can also mention the Sydney Declaration of Principles on the Protection of Persons Displaced in the Context of Sea Level Rise adopted at the 78th Conference of the International Law Association in August 2018. The aim of this Declaration is to raise awareness on the urgency for action regarding threats posed by sea level rise, particularly displacement of affected populations. Interestingly, the Declaration is based on a certain number of resolutions adopted by the UN General Assembly which emphasize the need of inter-State cooperation and assistance of the international community so that States "*develop and implement strategies to protect themselves and their vulnerable natural marine ecosystems from the particular threats of sea level rise caused by climate change"* [even if we notice that Indigenous communities are not cited].

This brief analysis tends to show us that while there is a progressive integration (albeit sometimes insufficient) of the specific constraints Indigenous peoples are facing, it is mainly based on the recognition of their cultural specificities, and less on the basis of their right to self-determination in the broader context of their marginalization within the legal and political space of the State.

Conclusion

The current practice of States faced with the need to manage climate relocation of part of their populations illustrates the difficulties faced by indigenous peoples in obtaining recognition of their specificities, particularly their special relationship with their lands and island environment. However, these issues are at the heart of Indigenous relocation and raise the question of the place of Indigenous status in the regime of climate displacement and relocation. Even if Indigenous communities cannot move without government assistance, it should not be a pretext for States to curtail their right to self-determination. Nor should the legal and institutional obstacles they face be used as a pretext for diluting their Indigenous status in the "common law". Climate relocation should not "*lead to their double discrimination as environmentally displaced and Indigenous peoples*" (European Parliament, 2018) and calls for a specific legal protection. Community members must have the possibility to say individually and collectively how they intend to perpetuate their legal, territorial, and cultural specificities during and after relocation. Besides, the recognition of Indigenous communities as distinct legal and political entities promotes the full and effective participation of Indigenous peoples in decision making processes. Conversely, their full participation can help to reconcile antagonisms over Indigenous identity and sovereignty by creating new forms of governance.

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6. Impacts of climate change on the evolution of water resources in the context of the Mediterranean islands using as an example two Aegean Sea islands: consequences for touristic activities in the future

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Abstract

The ecological and economic stakes of the climate change impacts are posed in particular terms on islands, especially in the Mediterranean, where summer tourism is one of the pillars of the activity of island communities. The climate scenarios for the Mediterranean islands up to 2050 make it possible to better identify, at the scale of each island, the modifications that Climate Change (CC) is likely to imply on the water balance.

The results for 360 islands (104,263 km²) over the whole basin give an average temperature evolution of +2.3°C with values between +1.8 and +2.9°C. This means a rise of potential evapotranspiration of the order of 135 mm/year with local values varying between 110 mm/year and 170 mm/year. The change in relative annual precipitation varies between -11.6% and +2.9% with an average of -6.5%. The regional analysis shows that the water balance should be more impacted in the eastern part especially in the Aegean Sea and along the southern shore of the Mediterranean.

The rainfall deficit coupled with the increase in evapotranspiration would result locally in a significant reduction of surface runoff and underground water recharges, which could be of the order of 40% on average over the year. On top of interannual variations, there is a high degree of uncertainty about water resources in 2050.

At the same time, mass tourism and other forms of tourism have become the backbone of the economies of many Mediterranean islands and the trend is expected to strengthen. The water demand of this sector during the summer

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dry season only complicates the problem and is at the expense of other sectors of activity, including agriculture. Case studies are presented on the islands of Rhodes and Samos comparing the evolution of water resources and demand from the tourism sector. Results suggest that foreseeable lowering of water resources in close future should be tackled with a more efficient Integrated Water Resources Management (IWRM) especially on Mediterranean islands whose economy is based on mass tourism. An alternative would be to lesser water consumption per capita combined with a more effective recycling of sewage.

Keywords: Climate Change, Mediterranean islands, Aegean Sea, Integrated Water Resources Management, Tourism, Ecolomy.

Résumé

Les enjeux écologiques et économiques de l'impact du changement climatique se posent en des termes particuliers sur les îles, notamment en Méditerranée, où le tourisme estival est l'un des piliers de l'activité des communautés insulaires. Les scenarii climatiques pour les îles méditerranéennes à l'horizon 2050 permettent de mieux identifier, à l'échelle de chaque île, les modifications que le CC est susceptible d'impliquer sur le bilan hydrologique.

Les résultats pour 360 îles (104 263 km²) sur l'ensemble du bassin donnent une évolution moyenne de la température de +2,3°C avec des valeurs comprises entre +1,8 et +2,9°C. Cela signifie une augmentation de l'évapotranspiration potentielle de l'ordre de 135 mm/an avec des valeurs locales variant entre 110 mm/an et 170 mm/an. La variation des précipitations annuelles relatives varie entre -11,6% et +2,9% avec une moyenne de -6,5%. L'analyse régionale montre que le bilan hydrique et hydrologique devrait être plus affecté dans la partie orientale, en particulier dans la Mer Égée et le long de la rive sud de la Méditerranée.

Le déficit pluviométrique couplé à l'augmentation de l'évapotranspiration se traduirait localement par une réduction significative du ruissellement de surface et des recharges en eaux souterraines, déficit qui pourrait être de l'ordre de 40% en moyenne sur l'année. En plus des variations interannuelles, il existe un degré élevé d'incertitude sur les ressources en eau en 2050.

Dans le même temps, le tourisme dont en particulier le tourisme de masse est devenu l'épine dorsale des économies de nombreuses îles méditerranéennes et cette tendance devrait se renforcer. Les besoins en eau

de ce secteur pendant la saison sèche estivale ne font que compliquer le problème et se font au détriment d'autres secteurs d'activité, dont l'agriculture. Des études de cas seront présentées sur les îles de Rhodes et de Samos afin de comparer l'évolution des ressources en eau et de la demande du secteur du tourisme. Les résultats suggèrent que la diminution prévisible des ressources en eau dans un avenir proche devrait être abordée avec une Gestion Intégrée des Ressources en Eau (GIRE) plus efficace, en particulier dans les îles méditerranéennes dont l'économie est basée sur le tourisme de masse. Une alternative serait de réduire la consommation d'eau par habitant tout en assurant un recyclage plus efficace des eaux usées.

Mots clés : Changement Climatique, îles Méditerranéennes, Mer Égée, Gestion Intégrée des Ressources en Eau, Tourisme, Ecolomie.

Περίληψη (abstract in Greek)

Οι οικονομικές και οικολογικές προκλήσεις της κλιματικής αλλαγής τίθενται με ιδιαίτερους όρους στα νησιά, ειδικά στη Μεσόγειο, όπου ο καλοκαιρινός τουρισμός είναι ένας από τους πυλώνες της δραστηριότητας των νησιωτικών κοινοτήτων. Τα κλιματολογικά σενάρια για τα νησιά της Μεσογείου έως το 2050 καθιστούν εφικτή την καλύτερη αναγνώριση, σε κλίμακα του κάθε νησιού, των μεταβολών που πιθανόν να επιφέρει η κλιματική αλλαγή στην υδρολογική ισορροπία.

Τα αποτελέσματα για 360 νησιά (104,263 km²) σε ολόκληρη την λεκάνη δείχνουν μία αύξηση της μέσης θερμοκρασίας κατά 2.3 °C με τιμές από 1.8 έως 2.9 °C. Αυτό θα έχει ως αποτέλεσμα αύξηση της δυνητικής εξατμισοδιαπνοής της τάξης των 135 mm/έτος με τοπικές τιμές που κυμαίνονται μεταξύ 110 και 170mm/έτος. Η μεταβολή στην σχετική ετήσια βροχόπτωση κυμαίνεται μεταξύ -11.6% και +2.9% με μέση τιμή -6.5%. Η περιφερειακή ανάλυση δείχνει ότι η υδρολογική ισορροπία θα επηρεαστεί περισσότερο στο ανατολικό κομμάτι και ιδιαίτερα στο Αιγαίο Πέλαγος και κατά μήκος της νότιας ακτής της Μεσογείου.

Το έλλειμα βροχόπτωσης σε συνδυασμό με την αύξηση της εξατμισοδιαπνοής μεταφράζεται τοπικά σε μια σημαντική μείωση της επιφανειακής απορροής και της επαναφόρτισης των υπόγειων υδάτων, η οποία θα μπορούσε να είναι της τάξης του 40% κατά μέσο όρο στο σύνολο

του έτους. Επιπρόσθετα των ετήσιων διακυμάνσεων υπάρχει υψηλός βαθμός αβεβαιότητας σχετικά με τους υδατικούς πόρους το 2050.

Ταυτόχρονα, ο μαζικός τουρισμός και άλλες μορφές τουρισμού έχουν γίνει η ραχοκοκαλιά της οικονομικής δραστηριότητας πολλών νησιών και η τάση αυτή αναμένεται να ενισχυθεί. Οι υδατικές ανάγκες αυτού του κλάδου κατά την διάρκεια της ξηρής περιόδου του καλοκαιριού περιπλέκουν το πρόβλημα και είναι εις βάρος των αναγκών άλλων τομέων της οικονομίας, συμπεριλαμβανομένης της γεωργίας. Παρουσιάζονται μελέτες περίπτωσης για τα νησιά της Ρόδου και της Σάμου προκειμένου να συγκριθούν η εξέλιξη των υδατικών πόρων και η ζήτηση από τον τουριστικό κλάδο.

Τα αποτελέσματα υποδεικνύουν ότι η αναμενόμενη μείωση των υδατικών πόρων στο άμεσο μέλλον θα πρέπει να αντιμετωπιστούν με την Ολοκληρωμένη Διαχείριση των Υδατικών Πόρων ειδικά στα μεσογειακά νησιά των οποίων η οικονομία βασίζεται στον μαζικό τουρισμό. Μια εναλλακτική λύση θα ήταν η μείωση της κατανάλωση ανά κάτοικο σε συνδυασμό με μια αποτελεσματικότερη ανακύκλωση των υγρών αποβλήτων

Λέξεις κλειδιά: Κλιματική αλλαγή, Μεσογειακά νησιά, Αιγαίο Πέλαγος, Ολοκληρωμένη Διαχείριση Υδατικών Πόρων, Τουρισμός, Οικοδιαχείριση Οικοέλεγχος / Οικοχειρισμός

Introduction

The impacts of Climate Change (CC) in the Mediterranean region in the forthcoming decades must be considered in the specific context of its islands, their water resources and tourism, which is one of the backbones of most insular economies. At the scale of the entire Mediterranean basin, the climatological data of WorldClim about 1 km² resolution[6] (Hijmans & al., 2005) make them compatibles with small sized areas like the Mediterranean islands. The scenarios for 2050 are derived from three General circulation models (GCM) models[7].The Mediterranean Sea includes 2718 islands greater than 0.05 km² but WorldClim data are available for only 432 islands of them[8]. This data will be used to estimate CC and its impacts on water resource balances on this set of Mediterranean islands, keeping in mind that island context tends to amplify the vulnerability of water resources and supplies (Depraetere & Morell, 2009).

Mediterranean region is vulnerable to drought and water shortages and it is very sensitive to these phenomena with sometimes devastating environmental, social and economic impacts. Moreover, natural resources are often degraded and mostly used in an unsustainable way (Skondras & al., 2011) (Tsesmelis & al., 2019). The climate of Greece with focus on the Aegean islands will be treated in more depth later.

Generally speaking, water consumption from tourism is undermining local capacity to access fresh, uncontaminated water (Epler Wood & al., 2019, p. 14) and this phenomenon is even more intense on islands with mass tourism due to the high costs of the technical solutions or the importations from the mainland. This becomes very acute in the Mediterranean islands especially in the Balearic islands, Jerba, Mikonos or Porquerolles both from an economic and an environmental perspective. The problem becomes acute when islands face mass tourism: for instance, 14 and 20 tourists/inhabitants respectively for Rhodes and Kos (Kyriakou, Sourianos, & Vagiona, 2011) or even one million daily visitors each year[9]for Porquerolles on the French Riviera and its

[6] The resolution of WorldClim data densified from GCM (about 100 x 100 km) is in fact of 1 arc second, approximately 0.73 x 0.93 km at the Mediterranean latitudes.

[7] CSIRO (Australia, (Gordon & al., 2002)), CCCMA (Canada, (McFarlane & al., 1992)) and HADMC3 (UK, (Pope & al., 2000)).

[8]From Base de données Insulaires Mondiale BIM version 3, DATAsuds portal of the IRD (https://doi.org/10.23708/T37S0K).

[9] This means an average of 22 visitors/day/inhabitants in July and August.

130 inhabitants (Le Berre & al., 2013).With such frequentation, local water resources tend to be overexploited until it necessitates "externalize" it from the mainland or even more costliest alternatives. Nevertheless, tourism remains a major asset for islands communities despite it is considered as an “invisible burden” for local stakeholders and ecology. (Epler Wood & al., 2019, p. 11).

1. Regional analysis of CC from 1950-2000 to 2050

1.1. The regional Climate Change in 2050 on the Mediterranean islands

The regional analysis provides a general overview of CC tendencies over the Mediterranean islands from only one source of data for consistencies purposes. Sub-regional data from observation or models would be more accurate but can’t be homogenous and comparable.

Table 1 resumes the evolution of the mean annual precipitation (Pma) and temperature (Tma) over the entire set of Mediterranean islands considered in this regional survey[10]. Considering the average scenario given by the 3 GCM models (W123), the rise of temperature would be of 2.07 °C and the deficit of precipitation of 34 mm. There are small discrepancies between the GCMs:

- Temperatures: +1.93°C for HADMC3(WC3) to +2.23°C for CSIRO(WC1);
- Precipitations: -29 mm for CSIRO (WC1) to-38mm for HADMC3 (WC3).
- The CCCMA GCM (WC2) gives values that are in between and consequently are closer to the averaged dataset (WC123).

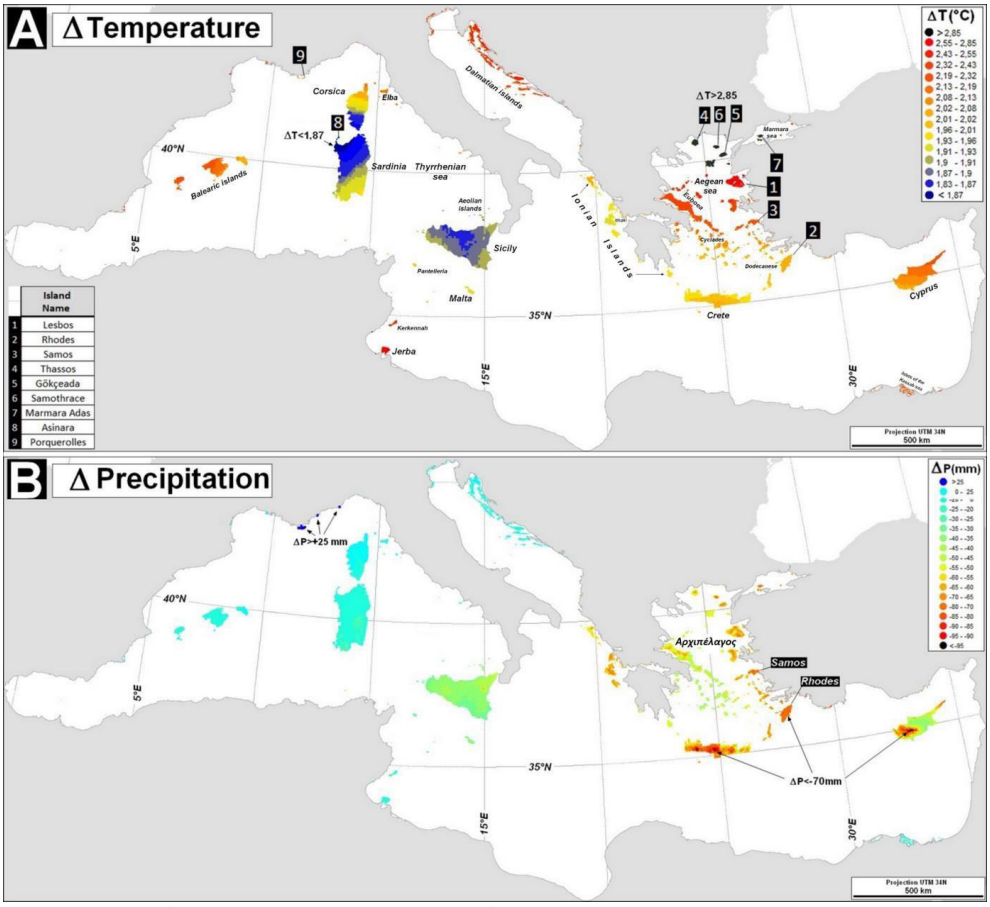
[10] This regional analysis is based on a presentation at the CEST 2015 conference held in the island of Rhodes (Depraetere, Depraetere, & Martin, 2015).

Name Data	WorldClim Data	Pma mm	Tma °C	PER Pma/(58.9 Tma)	ΔPma mm	ΔTma °C	ΔPER
WC0	**1950-2000**	**635**	**15,72**	**0,685**			
WC1	*1950 CSIRO*	*606*	*17,96*	*0,573*	*-29*	*2,03*	*-0,112*
WC2	*CCCMA*	*599*	*17,75*	*0,573*	*-36*	*2,03*	*-0,113*
WC3	*HADMC3*	*597*	*17,66*	*0,574*	*-38*	*1,93*	*-0,111*
WC123	**2050_3M**	**601**	**17,79**	**0,573**	**-34**	**2,07**	**-0,112**

Table 1: Evolution of temperatures and precipitations over the Mediterranean islands between the reference period 1950-2000 (WC0) and three GCM models (WC1, WC2 and WC3) in 2050.

WC123 corresponds to the average value of the three GCM (WorldClim data).

The Map 1 provides an overview of sub regional impact of CC regarding temperatures and precipitations. The pattern of temperature increases (Map 1A) depends on the distance between the islands and the surrounding continental mainlands: for Sicily, Sardinia, southern Corsica and Malta the rise is about 1.9°C or less for instance 1,87°C in north-west Sardinia and Asinara island. Despite their oceanic context, the Balearic archipelago, Northern Corsica, Crete and Cyprus present conditions that are close to the average values for the entire Mediterranean insular region with values between 2 and 2.2°C. For islands that are close to the continent, the evolution of temperatures tends to be much higher except for the Ionian archipelago, the Cyclades and the Dodecanese. Values above 2.6°C are only observed in the northern part of the Aegean Sea (2.85°C for Thasos), the sea of Marmara and the Tunisian island of Jerba (2.66°C). The sub regional repartition of precipitations evolution display is rather different and proceed from different climatologic factors (Map 1B). The main point is that the north-west part of the Mediterranean basin is stable with no significant depletion of the precipitations and even locally a slight rise (25 mm on the islands along the Provence). On the contrary, a sharp distinction is observed with the eastern part including the Ionian island with rainfall decrease between 50 and 100 mm: for instance the most parts of Crete, Cyprus and all the island of Rhodes have deficit above 70 mm.



Map 1: evolution of temperatures (T) and precipitations (P) between 1950-2000 (WC0) and 2050(WC123) for the Mediterranean islands.

1.2. The evolution of humidity provinces according to the Holdridge method

The Holdridge's method will be put to contribution first because it gives general insights on regional trends on the entire Mediterranean including on the potential evaporation Etp which is supposed to be proportional to the mean annual temperature Tma (Holdridge, 1947)[11]:

[1] ETp = 58.9 Tma (ETp in mm, T in °C)

By combining the mean annual values for temperatures (Tma), precipitations (Pma) and ETp, the method defines biomes associated to specific bioclimate; the "humidity provinces" of Holdridge are based on the ratio between Pma and ETp called the Potential evaporation ratio (PER):

[2] PER = Pma/ETp = Pma/(58.9 Tma)

The CC tendencies can be resume by a graphic showing the "shift" of these humidity provinces between the two considered period this basin as summarized in Figure 1. From 1950-2000 to 2050, the mean annual rise of temperatures and depletion of precipitations at the regional scale tend to decrease the PER from 0.68 to 0.57: accordingly, this suggests a shift from humid to sub humid bioclimatic conditions.

[11] See also (UNESCO, 1963) (Holdridge, 1976) (Whittaker, 1975) (Prentice, 1990).

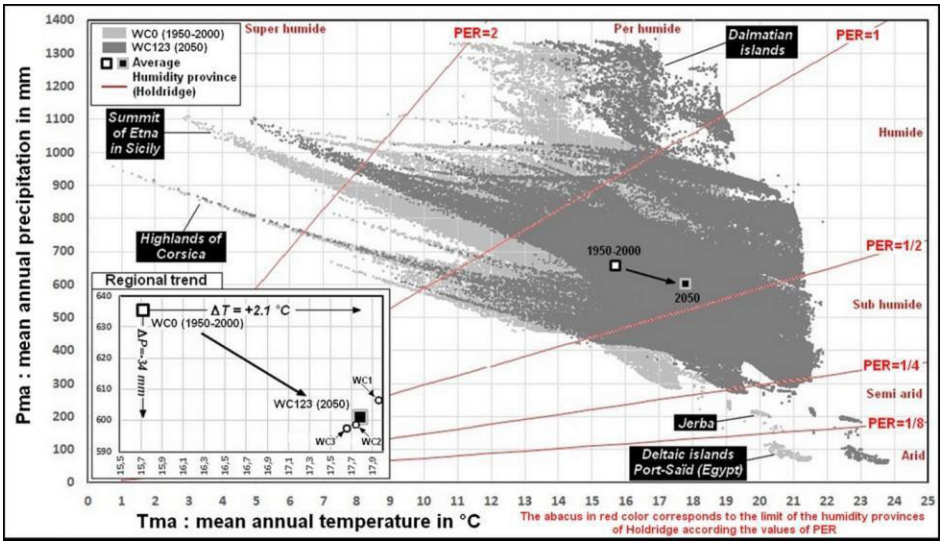


Figure 1 - *The Holdridge-Whittaker scatter plot showing the climatic evolution and subsequent « shift » of bioclimates over the Mediterranean islands between 1950-2000 and 2050. (From WC0 in 1950-2000, for 2050, WC1, WC2 and WC3 and the average evolution WC123).*

(NB: each dot represents a point of the WorldClim data and not an island average value).

A global analysis of the entire region provides a general estimation of this phenomenon by defining linear regression between the three geographical dimensions, that is to say latitude, longitude and elevation for the two climatic variables of temperature and precipitation and each of the two periods. The rise of temperatures of 2.1°C is globally independent of latitude (Figure 2A) and longitude (Figure 2B). It is worth noting that the gradient of temperatures versus latitude was -0.5°C/degree in 1950-2000 but only -0.46°C/degree in 2050, showing a lesser contrast between the southern and the northern areas of the region. The gradient of temperature according to longitude is stable for the two periods with +0.11 C/degree from west to east. Compared to the regional geographical trends of temperatures, precipitations are more scattered due to local conditions; the tendencies are also more variable depending on the period considered. The precipitation gradients of +50 mm/degree in 1950-2000 become +55 mm/degree in 2050, thus leading to a higher contrast between the southern and northern areas (Figure 2C). The precipitations in latitudes above 42°N remain more or less the same for the two periods. The correlation between precipitation and longitude appears to be very weak (Figure 2D) with almost no change in the western area and depletion of 50 mm or more in the eastern region (East of 18°E). This contrast probably reflects the stronger influence of continental anticyclonic conditions

in winter in the *pars orientalis* compared to the *pars occidentalis* which remains under the influence of the Westerlies and cyclonic circulation coming from the Atlantic during the cold season.

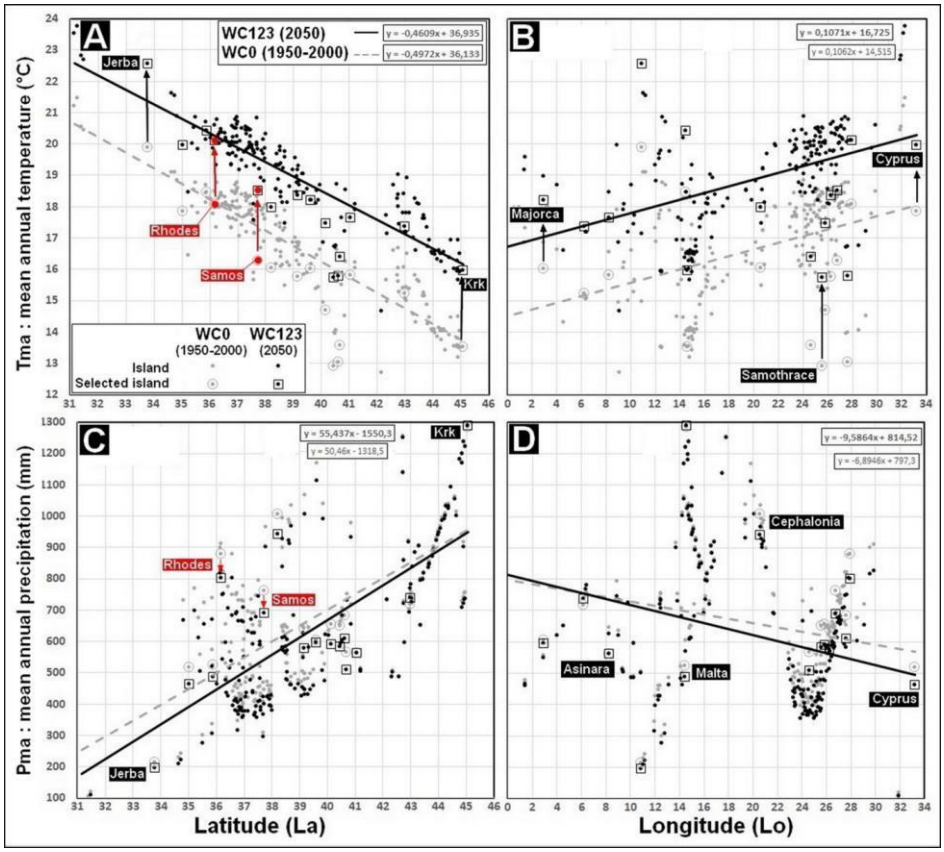


Figure 2 - *relationship between temperatures and precipitations versus latitude and longitude for 432 islands (each dot corresponds to an island average value).*

A./ Temperatures versus latitude. B./ Temperatures versus longitude.

C./. Precipitations versus latitude. E./ Precipitations versus longitude.

CC impacts also the ecosystems by forcing a latitudinal and altitudinal shift of biomes or shortly "biomic shift" (Yates, Kittel & Cannon, 2000). The dynamic of temperature is highly dependent of global and synoptic scale phenomenon whether precipitation processes are more related to mesoscale and microscale factors. Consequently, the pattern of temperature changes is more uniform on a region like the Mediterranean while it tends to be more complex for rainfall distribution which means that the spatial distribution of precipitations are more difficult to interpolate or modelized. Thus, temperatures values must be considered as more reliable than precipitations

on both considered periods. To make it simple, temperature changes present a regional pattern while the precipitation evolutions depend on the dynamic of meteorological and climatic local conditions.

For the two periods, the gradient of temperatures and precipitation according to elevation remains the same: -0.55°/100m and 16 mm/100m. The Whittaker diagram (*Figure 1*) combining temperature on the X axis and precipitations on the Y axis depicts the effect of relief on the altitude belts of bioclimates and ther(efore vegetation and its shifting due to CC. For instance, the highlands of Corsica should not be impacted while the top part of Etna in Sicily would become warmer with no change in precipitations partly as snow in winter. The trends for Dalmatian islands are similar to the Etna: warmer conditions and no evolution for rainfalls. The bioclimatic shift for Jerba suggests that this island would be almost under arid condition in the sense of the humidity provinces of Holdridge.

The previous results illustrate the humidity province shift on the Mediterranean between the reference period 1950-2000 and 2050 and can be resume as follow:

- Thermal latitudinal shift of 4 degrees northward (gradient -0.5°C/degree);
- Precipitation latitudinal shift of 1 degree northward (gradient +50mm/degree);
- A thermal altitudinal shift of 400 meters upward (gradient-0.55°C/100m);
- A precipitation altitudinal shift of 250 meters upward (gradient 16mm/100m).

On the whole just by considering the annual figures, this means more xeric conditions resulting from combined effect of precipitation depletion and rise of temperatures; this means increase of fire hazards, ombrothermic stress on ecosystems and plants, lowering of water resources and modifications on landscapes and agricultural practices. Some submittal ecosystems may disappear entirely due to a sort of « shrinking island » effect due to the upward biomic shift previously mentioned. For the piémont formations, the two possibilities are adaptation on the spot or moving northward and upward. Along the coast, new ecosystems may expand for instance arid bioclimates along the southern coast of Crete. All these elements are threatening the touristic attractivities of the Mediterranean islands for tourism becoming an activity at risk from both economic and ecologic viewpoints. For instance, the

island of Porquerolles (15 km², 200 permanent inhabitants) has 15000 visitors per day in July and August requiring the transfer of drinkable water from the continent via tanker for a total cost of 450,000 € after over exploitation of local underground water. By chance, this island along the French Riviera should not be heavily impacted by the CC but this is not the case for many islands and archipelagos in the eastern part of the Mediterranean as we will see down below.

Table 2 provides specific evolution on a subset of islands from various geographical contexts or presenting noteworthy trends. North-west islands like Porquerolles, Asinara[12] and Majorca show a moderate rise of temperature ($\Delta T<2.2°C$) and no depletion of rainfall ($\Delta P<2\%$). Mallorca is a major tourism spot with 10 million visitors each year. The Krk island along the Dalmatian coast is peculiar with a noticeable increase of temperature ($\Delta T=2.46°C$) and no change for precipitations while it is the opposite in Malta with moderate thermic change ($\Delta T=1.95°C$) and a 7% depletion of rainfalls. It is worth noting that the population of the mainland of Malta *per se* is equal to 1600 inhabitants/km² with very few surface water available in a mostly karstic geological context. On top of that, the island hosts 1 million tourists per year. The geological setting of Jerba along the desertic coast of southern Tunisia is fairly similar to Malta but in a semi arid environment and far more visitors, about few millions mostly from France. The rise of temperature would be of 2.66°C and 9% (18 mm) depletion for rainfall. Cephalonia within the Ionian archipelago has a low density of population with 36 Inh./km² and a limited number of visitors, about 100000/year. The thermal evolution would be inferior to 2°C but with a significant drop of rainfall ($\Delta P=-6,5\%$).

The projections of CC are more worrying for all the islands of the Aegean sea or close to the Anatolian peninsula. In the northern part of the "archipelago"[13], the CC is superior to the regional evolution both in terms of temperatures ($\Delta T>2.6°C$) and rainfalls ($\Delta P<-10\%$ or -57 mm) ; the maximal thermal evolution is taking place in Thassos and Samothrace ($\Delta T=2.83°C$) and the maximum depletion of rainfall is observed on Marmara Adas ($\Delta P=-10.8\%$ or -74mm) surrounded by the close mainland of Europe and Asia in the sea of Marmara. The two islands selected in the south-east of the Aegean sea are Rhodes and Samos whose main characteristic compared to the previous is a lower thermal rise ($\Delta T\approx2.13°C$) combined with a similar rainfall

[12] Asinara is a nature reserve with few visitors apart from scientists. It is the largest Mediterranean island (52 km²) with no permanent human population.
[13] Former name of the Aegean Sea.

deficit (ΔP≈9.2% or -75mm). The comparison of the impact of CC on water budget for these two islands will be analyzed in detail in the following part.

	Name of the islands	Other name	Country	Area (km²)	Longitude	Latitude	Altitude	Temperature		Precipitation		Climate change (CC)			Population		Closest mainland	
								1950-2000 (°C)	2050 (°C)	1950-2000 (mm)	2050 (mm)	ΔT (°C)	ΔP (mm)	ΔP (%)	Inhabitants	density km²	(km)	Country
West to East	Mallorca	Majorca	Spain	3645	2,958	39,608	159	16,01	18,19	604	594	2,18	-10	-1,7	924 000	254	170	Spain
	Porquerolles		France	15	6,213	42,999	16	15,23	17,35	717	738	2,12	21	2,9	200	13	2.3	France
	Asinara		Italy	54	8,284	41,055	148	15,8	17,64	562	561	1,84	-1	-0,2	0	0	1.7	Sardinia
	Jerba	Djerba	Tunisia	514	10,881	33,791	13	19,89	22,55	213	195	2,66	-18	-8,5	164 000	319	2.5	Tunisia
	Malta		Malta	251	14,444	35,886	75	18,46	20,41	523	487	1,95	-36	-6,9	402 000	1599	85	Sicily
	Krk		Croatia	413	14,615	45,068	148	13,5	15,96	1284	1289	2,46	5	0,4	17 900	43	0.5	Croatia
	Cephalonia		Greece	795	20,578	38,218	357	16,03	17,98	1006	941	1,95	-65	-6,5	35 800	45	33	Greece
	Thassos	Thasos	Greece	390	24,655	40,685	307	13,57	16,4	565	508	2,83	-57	-10,1	13 800	35	6.2	Greece
	Samothrace	Samothraki	Greece	184	25,586	40,455	436	12,9	15,73	649	582	2,83	-67	-10,3	2 800	15	36	Greece
	Gokceada	Imbros	Turkey	290	25,842	40,159	161	14,69	17,47	655	590	2,78	-65	-9,9	6 520	22	16	Turkey
	Lesbos	Mytilene	Greece	1653	26,243	39,168	213	15,76	18,34	640	577	2,58	-63	-9,8	86400	52	12.5	Turkey
	Samos	**Anthemousa**	**Greece**	**486**	**26,812**	**37,731**	**321**	**16,26**	**18,49**	**762**	**689**	**2,23**	**-73**	**-9,6**	**33 000**	68	1.7	Turkey
	Marmara Adas	Prokonnisos	Turkey	117	27,623	40,623	204	13,02	15,78	683	609	2,76	-74	-10,8	6 310	54	9	Turkey
	Rhodes	**Rhodos**	**Greece**	**1413**	**27,956**	**36,182**	**199**	**18,07**	**20,11**	**879**	**801**	**2,04**	**-78**	**-8,9**	**115 500**	**82**	**17.7**	**Turkey**
	Cyprus		Cyprus	9317	33,223	35,042	303	17,83	19,96	517	463	2,13	-54	-10,4	1 190 000	128	71	Turkey

Table 2 - *List of islands from west to east with their climatic evolution from 1950-2000 to 2050.*

1.3. The evolution of water balances with the ombrothermic method

Let's consider now the seasonal impact of CC on the bioclimat of the Mediterranean islands. We make use of the Bagnouls and Gaussen method (Bagnouls & Gaussen, 1957) (Gaussen, 1960) which is specifically suitable to analyze the Mediterranean climate by providing insights on the water budget. From the monthly values, it gives crude figures on the hydrological seasonality all year long especially on the duration of the "xeric period" when the precipitation in mm is below twice the temperature in °C. The water budget is defined as follow:

[3] P = Sw + ETp and ETp=ETa – EDs

with P the precipitation
Sw the winter water surplus (If P>2T then P-2T)
ETp the potential evapotranspiration (2T), ETa actual evapotranspiration
EDs the summer evapotranspiration deficit due to water shortage with "hydric stress" for the vegetation (If P<2T then 2T-P) called the "xeric period" by Bagnouls and Gaussen.

Another point to mention stands on the fact that the potential evapotranspiration as estimated by the method of Holdridge-Whittaker on a yearly basis is based on the assumption that ETp=58.9 T, equivalent to 5 mm/month/°C. Compared to the Holdridge-Whittaker assumption applied to all bioclimates of the globe, the Bagnouls and Gaussen method just refers to Mediterranean contexts with a hypothesis of 2 mm/month/°C.

The Table 3 resumes the results given by Bagnouls and Gaussen method for the Mediterranean islands for the two periods. There is a drop of 43 mm for the winter water surplus (-12% for Sw), a rise of the potential evapotranspiration of 50 mm (+13% for ETp) and a significant increase of the summer evapotranspiration deficit of 40 mm (+38% for EDs).

	Month (mm)	CW0 1950-2000			CW123 2050		
		Sw	ETa	EDs	Sw	PE	EDs
Autum	October	41	35	0	35	39	0
	November	58	27	0	53	31	0
Winter	December	80	20	0	74	24	0
	January	72	17	0	63	21	0
	February	55	18	0	49	22	0
Spring	March	43	21	0	38	24	0
	April	18	26	0	11	30	0
	May	0	34	4	0	38	12
Summer	June	0	42	26	0	46	33
	July	0	48	39	0	52	46
	August	0	48	33	0	53	43
	September	0	43	7	0	47	16
	Year	367	377	109	324	427	150
	P=Sw+ETa-EDs			635			601
	Δ(CW123-CW0)				-43	50	40

Table 3 - *Monthly water budget over the Mediterranean islands during the periods 1950-2000 (WC0) and 2050 (WC123).*

The monthly water balance can also be presented as "ombrothermic curves," as shown in Figure 3, within the graduation of precipitation in mm on the right being half the size of those of temperatures on the left. For the entire set of Mediterranean islands, the seasonal evolution cycle between the two periods indicates a 5% lessening of precipitation during the year and a higher temperature rise in summer and autumn (+2.23°C, maximum +2.53°C in August) than in winter and spring (+1,83°, minimum +1,76°C in March and April). Both tendencies induce a longer summer dry season in 2050 compared to 1950-2000 (Figure 3A). During the period 1950-2000, the summer dry season covers about 4.5 months starting from 10 May (Figure 3B) while it starts by the end of April and last 5 months in 2050 (Figure 3C). Daily deficits are 0.8 mm/day for the period 1950-2000 and 1 mm/day for 2050. These two tendencies suggest a significant amplification of the hydric

stress on vegetation, both in terms of duration and intensity. The impact of CC is less drastic during the wet season in autumn and winter which remains more or less concomitant with the autumn equinox but stops two weeks earlier in the spring. The intensity of water surplus does not change much with 1.5 mm/day in 2050 instead of 1.57 mm/day in 1950-2000.

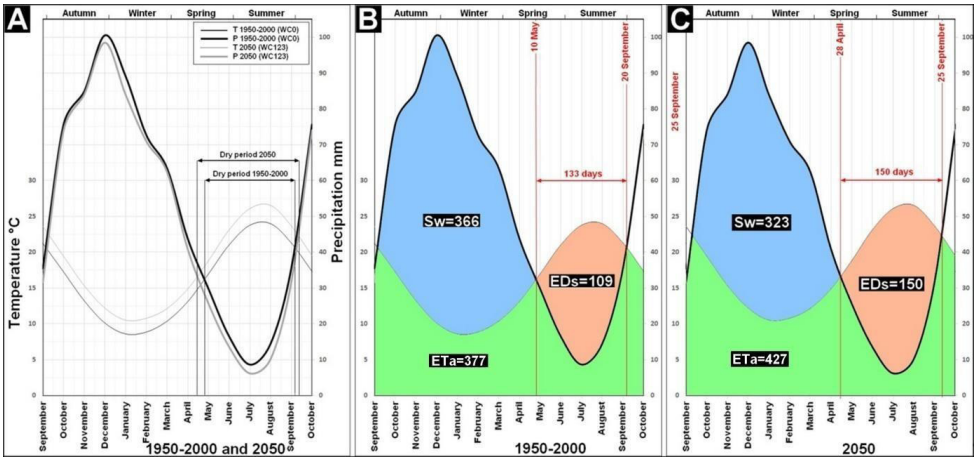


Figure 3 - *ombrothermic curves for the Mediterranean islands*
A./ Comparison between the periods 1950-2000 and 2050.
B./ Water budget for the period 1950-2000.C./ Water budget for the period 2050.

1.4. The cases of Rhodes and Samos islands

As shown on Map 1, the Aegean Sea should be more impacted by CC than other sub regions of the Mediterranean especially in its North West part. For instance in the cases of Rhodes and Samos (Figure 4), the precipitation deficit of 10% occurs mainly in winter while the dry periods of the two islands become more severe and last almost 5.5 or 6 months[14] instead of 4.5 to 5 months at regional scale. On both islands, the CC modifies significantly the water balance between winter surplus (Sw), potential evapotranspiration (ETp) and summer evaporation deficit (EDs). The following chapter presents a more detailed comparative analysis of these two Aegean islands. Those two islands were selected first of all because Rhodes appears to be a typical local economy based on mass tourism while the economy of Samos is less dependent on this activity. Second point, they are both close from the mainland of Anatolia but Samos further north into the Aegean sea whereas

[14] The results refer to the average values for each island and not a specific localization within them.

Rhodes is more “oceanic” due to its location at the limit of the Aegean inland sea and the Mediterranean open sea (cf. Map 1B). Last but not the least; climatic data from synoptic stations over a long period is available on the two islands.

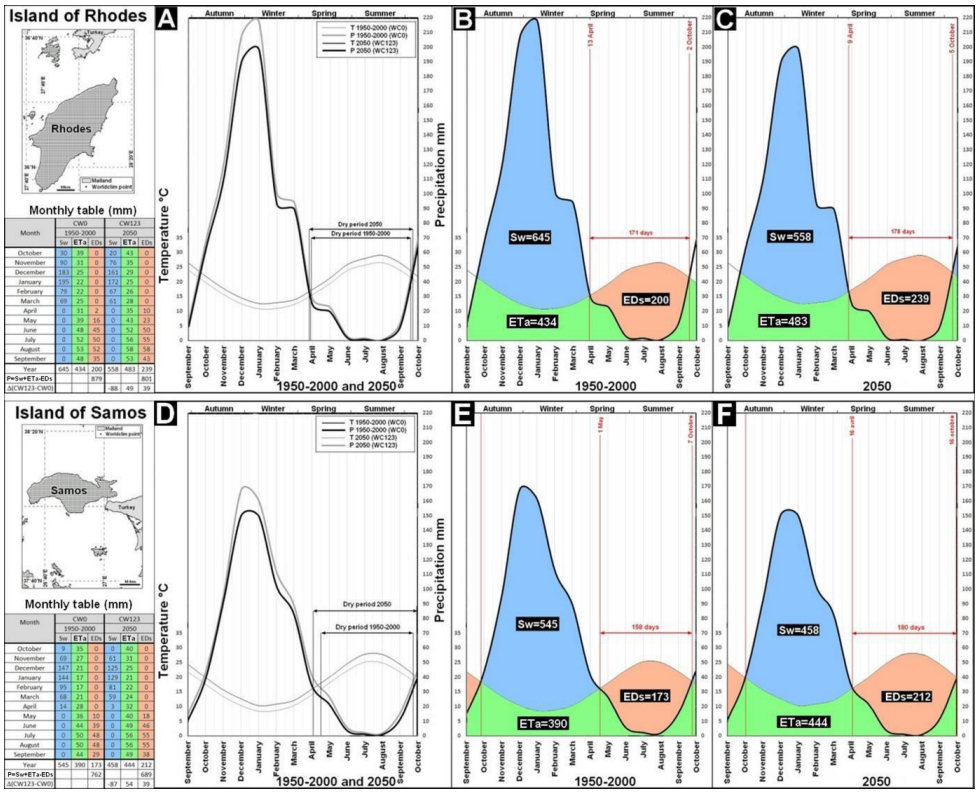


Figure 4 - *Ombrothermic curves of the periods 1950-2000 and 2050 for Rhodes and Samos*

A./ Comparison between the two periods for Rhodes.

B./ Water budget for the period 1950-2000 for Rhodes.C./ Idem for the 2050s.

D./ Comparison between the two periods for Samos.

E./ Water budget for the period 1950-2000 for Samos. F./ Idem for 2050.

2. Comparison between the islands of Rhodes and Samos

The climate of Greece is typical northern Mediterranean, with mild and wet winters, relatively hot and dry summers and, generally, long periods of sunshine for the most part of the year. Moreover, in the summer period, the tourism and agricultural sectors are the most significant water users and important for the country's economic welfare (Tsesmelis & al., 2019).

2.1. Comparison from meteorological stations for the period 1979-2019

The analysis of water budgeting at the scale of the two islands of Rhodes and Samos should reflect the general trends of the Aegean islands and Cyprus. For comparison purpose with the WorldClim data used previously, climatic observations are available at the meteorological stations of the airport of Rhodes (28.12°E 36.40°N) from 1955 to 2019 and the airport of Samos (26.92°E 37.7°N)[15] from 1979 to 2019. The linear regressions over the period 1979-2019 (*Figure 5*) suggest that the trend of rainfall decrease is far more accentuate for Samos compared to Rhodes with respectively -2.8 mm/year instead of -1.5 mm/year. Compared to the mean annual rainfall at the Samos and Rhodes stations (respectively 675 and 641 mm) for the period 1979-2019, the depletions are of 17% for Samos and 10% for Rhodes. For temperatures during the period 1979-2019 (41 years), the evolution is +1.71°C (+0.042°C/year) for Samos and +1.32°C (+0.032°C/year) for Rhodes. These trends observed on meteorological stations prove that CC was more acute in Samos than in Rhodes between 1979 and 2019.

[15] Both stations are located in the coastal lowlands and are not representative of the mountainous hinterland.

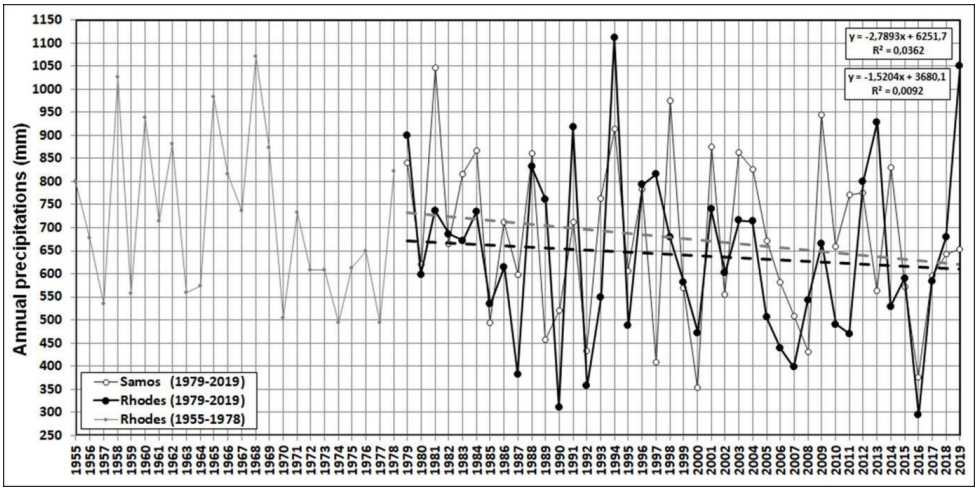


Figure 5 - *Evolution of temperatures and precipitations at the meteorological stations of Rhodes and Samos from 1979 to 2019.*

Comparison of climatic values between the two stations is worthwhile to understand the spatial relationship of rainfall and temperature knowing that the distance between the two islands is 200 km. While yearly temperatures are significantly correlated (*Figure 6*A, R=0.85), this is not the case for precipitation which is more under the control of microclimatological factors, for instance windward and leeward localization depending on the dominant of advective air masses (*Figure 6*B, R=0.23)

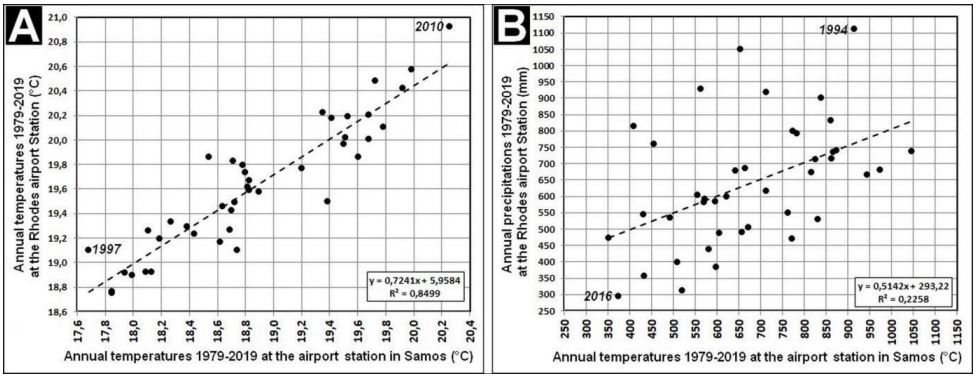


Figure 6 - *Correlations of annual temperatures (A) and rainfalls (B) at the two stations of Rhodes and Samos from 1979 to 2019.*

The seasonal cycles on the two islands as given on Figure 7 are fairly similar; the minor differences concern more precipitation in Samos in December and a "xeric" period starting one week later in Samos but with the

same duration of 181 days, about 6 months. Consequently, their water budgets are almost identical with about 457 mm for the actual evapotranspiration (ETa), between 381 and 453 mm for winter surplus (Sw) and 225 mm for summer deficit (EDs xeric period). We notice also that the annual amplitude of temperature is slightly higher is Samos compared to Rhodes[16].

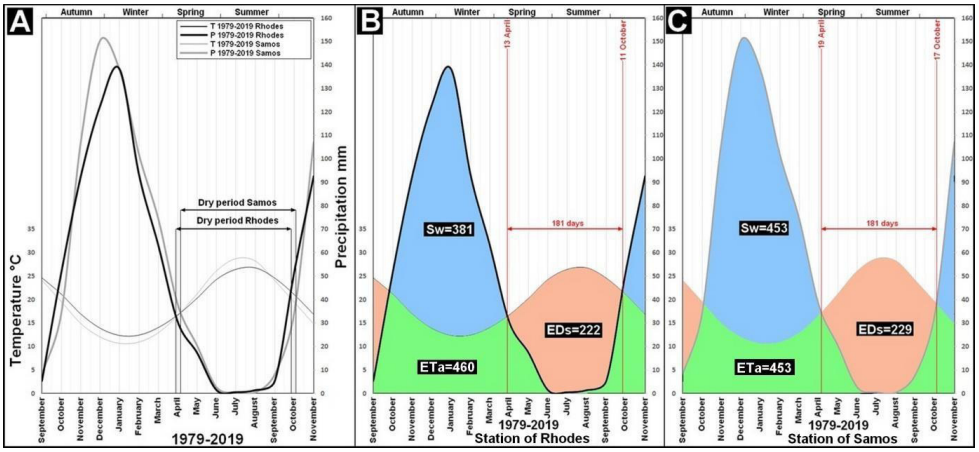


Figure 7 - Ombrothermic curves for the stations of Rhodes and Samos for 1979-2019.
A./ Comparison between the two stations.
B./ Water budget for the ARIMA
station of Rhodes (28.12°E 36.40°N).
C./ Water budget for the station of Samos (26.92°E 37.7°N).

2.2. Evolution from 1950-2000 (current, WC0) and 2050 (WC123)

It is worth comparing the figures at the meteorological airport station of Rhodes for the period 1955-2000 (691 mm/year) with the interannual data at the equivalent WorldClim grid point for 1950-2000 (894 mm/year) (*Figure 8*A). The major discrepancy occurs from November to January with a 44% over estimation of rainfalls of WorldClim data (568 mm) compared to data of the meteorological station (395 mm). The same calibration was done at the meteorological station of Samos for 1979-2000 with also an over estimation of rainfalls with 762 mm instead of 683 mm/year resulting from precipitation from September to January (496 mm at the grid point instead of 429 mm at

[16] These results can be compared to the same ombrothermic curves computed from WorldClim data over the period 1950-2000 and 2050 in Figure 4.

the station). Those discrepancies will mostly affect the cold season water surplus (Sw) as it is the case on Rhodes.

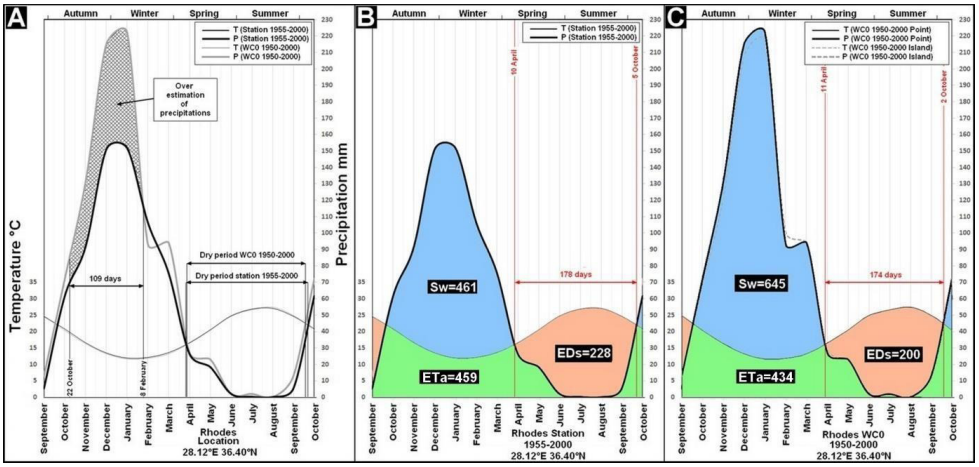


Figure 8 - *Ombrothermic curves at the location of the station of Rhodes airport*

A./ Comparison between the station (1955-2000) and the WorldClim point (WC0 1950-2000).

B./ Water budget et the meteorological station of Rhodes airport (1955-2000).

C./ Water budget of the WordClim grid point (WC0 1950-2000) at same location.

These differences can be interpreted as an interpolation bias in the WorldClim data. For consistency between the various sets of data, this suggests that specific correction factors[17] have to be applied for both islands and the two periods 1950-2000 and 2050 on the WorldClim data (WC0 and WC123). The same calibration has been performed for Samos:

[4] Correction factors for Pma 1950-2000 and 2050:
for Rhodes CF_{Rhodes}=691/894=0.77, for Samos CF_{Samos}=683/762=0.9

[17] As shown on Figure 8A for Rhodes, rainfalls over the months November to January given by the WorldClim dataset are overestimated compared to the data from the synoptic station. This also true from Samos.

2.3. Estimation of streamflow depletion due to rainfall deficit

This climatic evolution has direct consequences on the water balance of islands and their catchment basins within them, including streamflow. The conceptual model MEDOR[18] specifically developed for mountainous Mediterranean basins is used to transform the annual precipitation *Pma* into mean annual streamflow *Qma* (Hreiche, Najem, & Bocquillon, 2007) and provide an adjusted function as shown on Figure 9:

[5] Qma = 1.23 Pma²/(Pma+2500) with Qma and Pma in mm.
Relative percentage of streamflow : S%= 100.Qma/Pma

This proves that river discharges are drastically influenced by the variability of annual precipitations on mountainous Mediterranean catchments.

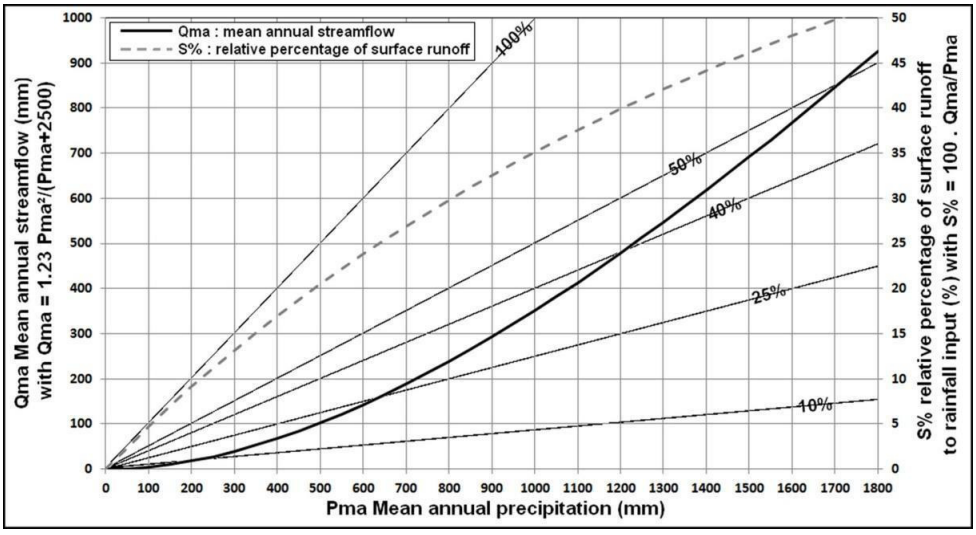
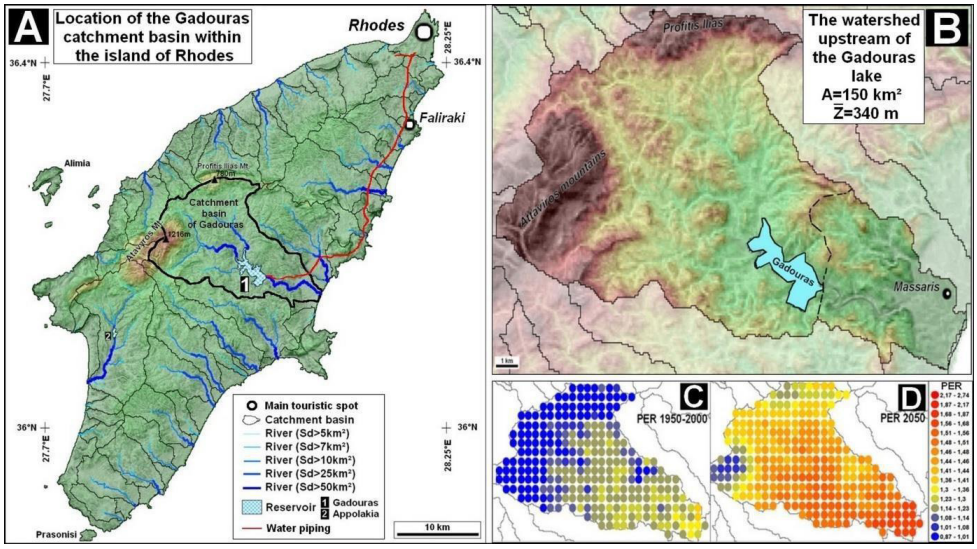


Figure 9 - *relationship between the mean annual precipitation (Pma) and the mean annual streamflow (Qma) according to the MEDOR model.*
The lines correspond to the abacus of the streamflow percentages (S%).

[18] This model has been calibrated on the Nahr-Beyrouth catchment basin with 216 km² in Lebanon. This simple empirical model is used because the general bioclimatological and morphostructural setting of the Gadouras basin is quite similar to the Nahr-Beyrouth watershed. It reflects a more generic relationship between rainfall and streamflow not only observed in the Mediterranean region but also on other climatic zones.

For instance, the Gadouras is the main watershed of Rhodes (190 km²). The construction of the Gadouras dam began in 2001 but the fill up of the reservoir from the upstream area (150 km²) only started in 2005 and finally reached full capacity (67.5 million m^3) and extent (4.37 km²) during winter 2011, after a prolonged period of rainfall (Corsini-Foka, 2009). The averaged streamflow per year minus the water balance of the lake itself (Q_{MEDOR}-WB_{LAKE}) is consistent with observation of Corsina-Foka (Figure 10). Considering the average values for the period 2005-2019, the possible water abstraction should be about 23 million m^3 per year thus 63 000 m^3 per day. Nevertheless after 2011, precipitation and even more streamflow show a strong interannual variation with almost no river flow during the dry year of 2016 (300 mm); conversely the streamflow in the wet year of 2019 (1050 mm) is five time superior to the average annual figures.



Map 2 - The island of Rhodes with the catchment basin Gadouras and its reservoir.
A./ Hydrographic map of Rhodesand location of the Gadouras catchment.
B./ The Gadouras catchment (184 km²)and its reservoir with upstream area of 150 km².
C./ Potential Evaporation ratio (PER) 1950-2000 on the Gadouras catchment D./ PER 2050.

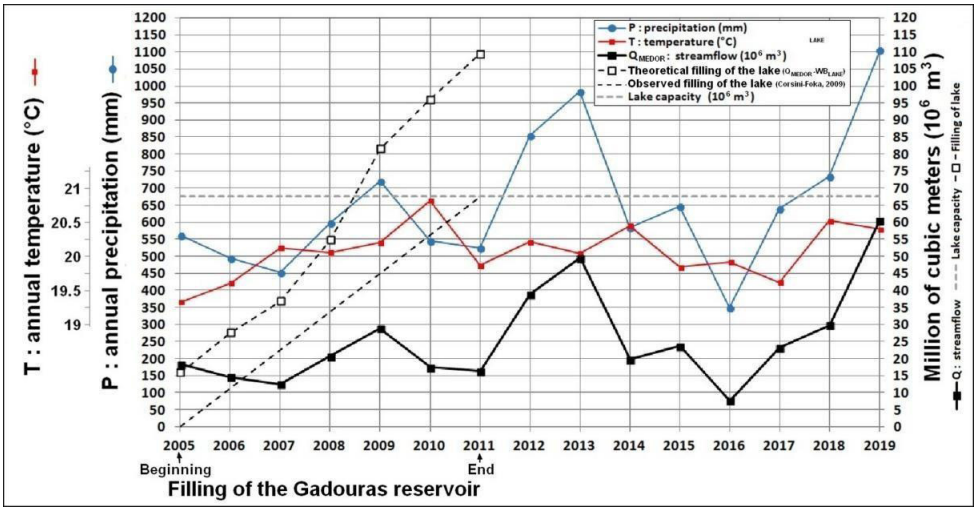


Figure 10 - *The catchment basin upstream from the Gadoura dam (150 km²) from 2005 to 2019.*

(Temperature T and precipitation P from the station at the airport, Q estimated from Pwith the MEDOR method)

The water balance of the Gadouras prior to the beginning of the dam construction (2001) was estimated from previous hydroclimatic data more or less equivalent to the WorldClim data over the period 1950-2000 (WC0). The impacts of CC (Tma and Pma) in 2050 on the water balance of the upper Gadouras catchment (145.5 km² Table 4A) should be as follow: depletion of precipitation (-8.8%), streamflow (-13.5%), groundwater recharge (-18.8%), rise of summer water deficit (+28%) and actual evapotranspiration (+4.9%). For the lake itself (4.75 km² Table 4B), the loss resulting from free surface evaporation may increase of 85% by comparing the reference period 1950-2000 (WC0) with the projection for 2050 (WC123).

As a reminder, the mean annual precipitations Pma of the reference period 1950-2000 (WC0) are overestimated as described before in Figure 8. Therefore, the correction factor CF_{Rhodes} has been used for precipitations for period 1950-2000 and also for 2050.

Upper Gadouras basin (145.5 km²)			
	1950-2000	2050	Trend (%)
Tma (°C)	17,3	19,4	2,03
EDs (mm)	116	144	28
Pma=ETa+Q+GWr	10^6 m^3	10^6 m^3	%
Pma*	112	102	-8,9
ETp	148	166	11,9
ETa	33	35	4,9
Sw=Q+GWr	79	67	-14,6
Q_{MEDOR}	32	28	-15,2
GWr=Sw-Q_{MEDOR}	46	40	-14,3

Gadouras lake (4.37 km²)			
	1950-2000	2050	Trend (%)
Tma (°C)	18,6	20,7	2,03
EDs (mm)	138	151	13
Water Balance	10^6 m^3	10^6 m^3	%
Pma	*2,78*	2,54	-8,7
ETp	*4,79*	5,32	11,1
WB_{LAKE}= Pma-Etp	*-2,01*	-2,78	38,3

Table 4 - Water balance of the upstream area of the Gadouras reservoir (A) and of the lake (B):

Tma and Pma from WorldClim WC0 and WC123, ETp, ETa et Sw by Bagnouls and Gaussen method, Q(MEDOR) from the MEDOR method.

**with correction factor of 0.7 for November, December and January (Cf. Figure 8A)*

This case study on the Gadouras reservoir and its upstream catchment basin illustrates the issues of the surface water damming and exploitation on Mediterranean islands in the context of CC.

2.4. Estimation of the water balance evolution with a hydrological model

For consistencies purposes, the water balance can be estimated and projected with other methods than the previous noticeably from hydrological models. The AgroHydroLogos model (Soulis & Tsesmelis, 2017) computes the water balance from current climatological conditions or from 2021-2050 scenario estimated with the seasonal ARIMA[19] forecasting method (Table 5). This method deserves some explanations; Statistical forecasting has been widely used in a plethora of disciplines and especially in cases where management and decision making should take place. However, a variety of forecasting methods and trend extrapolations seems to be the one predominantly used (Karavitis, Vasilakou, & Tsesmelis, 2015). According to Shatanawi (Shatanawi, Rahbeh, & Shatanawi, 2013), various methods can be used for extrapolation and predictions based on historical records assuming no threshold phenomena. However, the ARIMA models introduced by Box and Jenkins (1976) may be considered as the most relevant tools for the study

[19] Precipitation and temperature values from January 2021 to December 2050 were used as input for the future projections in the AgroHydroLogos mode, including Seasonal ARIMA (Auto Regressive Integrated Moving Average) model with a seasonality of 15 years (https://www.ewra.net/ew/pdf/EW_2015_49_04.pdf).

of time series. These particular models have been widely used in water resources management and drought forecasting. The generalized form of ARIMA models, as well as their customization according to the needs are called to serve, is described in pertinent literature."[20]

The depletion of precipitation is about the same on both islands and equal to the previous estimation: between 9 and 10%. The runoff evolution is also similar on both islands with a decrease of 6% which is far less than the 15% expected with the MEDOR statistical method. The case of groundwater recharge appears to be more contrasted between the two islands. While the figure for Samos indicates a lessening of nearly 50%, it becomes even worse for Rhodes with a drastic reduction of 71% of the recharge. These scenarios for the groundwater evolution as given by the hydrological model are far superior to the estimate of 15% depletion coming from previous method in particular on the upper Gadouras catchment basin (cf. table 4).The drastic reduction of ground water recharge could be attributed to the reduced rainfall depths in conjunction with higher potential evapotranspiration rates under future projections as well as to the expected more uneven distribution of rainfall (i.e. fewer and more intense storm events) favoring surface runoff. The above results highlight the vast uncertainties involved in any future projections hampering management plans.

To conclude about the various estimations, the AgroHydroLogos model suggests a moderate reduction of runoff of only 6% while the MEDOR statistical method predicts a streamflow decrease superior to the rainfall depletion of 10%. The most striking fact, if the evolution of the groundwater recharge given by the model would be confirmed, is that most of aquifers and coastal water lenses might be shrinking to the point where this resource could not be exploitable anymore in the forthcoming decades or even earlier. Considering also that coastal aquifers are more sensitive to sea water intrusion, the problem may be even worst in smaller islands.

[20] Cf. (Box, Jenkins, & Reinsel., 1994), (Papamichail, Antonopoulos, & Georgiou, 2000), (Montanari, Rosso, & Taqqu, 2000), (Mishra & Desai, Drought Forecasting Using Stochastic Models, 2005), (Hana, Wang, Zhang, & Zhu, 2010), (Mishra & Singh, 2011) and (Manakos, Georgiou, & Mouratidis, 2011).

Water balance (Pma=Gwr+R+ETa) and total abstraction		Rhodes (1408 km², 152 538 inhabitants)							Samos (479 km², 33 339 inhabitants)						
		Current			2050			Trend	Current			2050			Trend
		mm	10^6 m^3	%	mm	10^6 m^3	%	%	mm	10^6 m^3	%	mm	10^6 m^3	%	%
Pma	Mean annual precipitation	593	835	100	535	753	100	-10	714	342	100	649	311	100	-9
Gwr	Ground water recharge	83	117	14	24	34	4	-71	153	73	21	78	37	12	-49
R*	Runoff	183	258	31	172	242	32	-6	242	116	34	227	109	35	-6
ETa	Actual ET	327	460	55	339	477	63	4	319	153	45	344	165	53	8
A**	Total Water abstractions	26	36	10	No scenario				10	5	3	No scenario			

** From runoff plot 1000 m². ** the percentage (%) refers to 100 A/(Gwr+R).*

Table 5 - Water balance estimated for the current period and 2050 (from AgroHydroLogos and ARIMA models)

3. Consequences for future development of tourism in the Mediterranean islands from the examples of Samos and Rhodes

3.1. Tourist abstractions on Rhodes and Samos

The ability to provide sufficient water quantity to various settlements has always been a major concern for islands. In Samos, the Tunnel of Eupalinos, constructed in the 6th century BC, was an aqueduct transferring water from the north to the south part of the island, where the ancient capital (today Pythagoreio) was located. Cisterns, public and private, were a very widespread practice in order to collect rainwater during the rainy season and use it during the drought period. Until the beginning of the tourism era in the 1970s, important parts of the islands and almost all the villages did not have tap water; consequently, the water consumption was limited. The situation in agriculture regarding irrigation was not very different; most of the cultivations were arid using seeds adapted to the local conditions. The electrification of the Greek islands allowed the easier transfer of water and consequently the situation changed substantially. The consumption of water skyrocketed even when local population and agriculture activity were declining, at the exception of Rhodes where the population increased. At the same time, the building of new hotels, rooms to let and private houses used for resorts as well as tourist arrivals were increasing dramatically.

Figure 11 shows the evolution of arrivals at the islands both by air (domestic and international/charter flights) and by sea (ferryboat). The two islands had a quite different evolution during the last 20 years; Rhodes saw an increase of total arrivals by 48%, but Samos had a decrease of -18.6%. In 2018, 2,431,397 tourists arrived on Rhodes and 207,591 on Samos. They stayed for 15,487,998 and 1,370,100 overnights respectively.

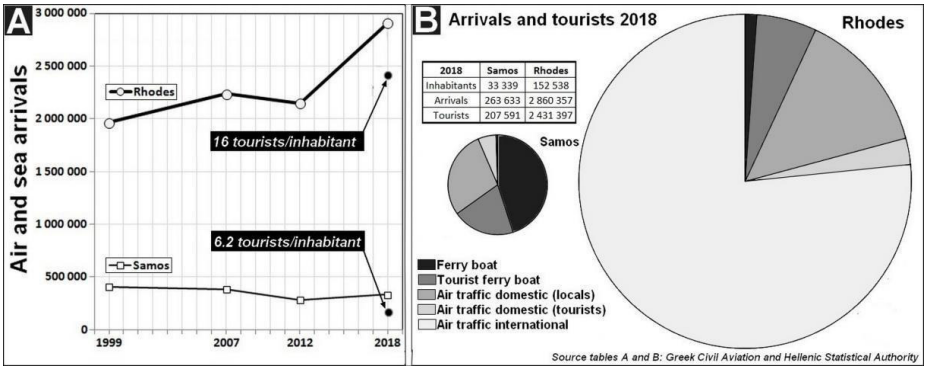


Figure 11 - *Air and sea arrivals in the islands of Rhodes and Samos.*
A./ Evolution from 1999 to 2018. B./ Tourism data on the islands in 2018.

Tourism pressure on an island can be estimated through the following indicators (Spilanis, Vayanni, & Glyptou, 2009):

(1) Number of tourism beds per population: There are two possible calculations: the first considers only the commercial tourism beds while the second also incorporates the private houses that are used as summer resorts. Rhodes has a higher pressure (0.85 and 1.42) compared to Samos (0.43 and 1.62), the latter having a higher number of private houses. This means that any day of the year (mainly the pick of the season) the population on the island of Rhodes can be almost two times higher than the local population. These scores place them in the middle of the Aegean Islands' scale as there are islands with very few beds (even lower than 0.1 bed per inhabitant) while others that have more than 2.0 (i.e. Santorini has 2.39 and 3.93 respectively).

(2) Number of tourism beds per surface: For this indicator, the pressure on Rhodes and Samos is even lower: 29.8 for Samos and 70.5 for Rhodes when in Santorini there are 480 beds per square kilometre.

(3) Number of tourist overnights per number of locals: Based on the total arrivals on the islands by the two only ways that someone can enter an island (by boat and by plane), we estimate the number of tourists and their total number of nights spent. By dividing the total amount of tourist overnights with 365 we calculate the "*inhabitant equivalent tourist*" which gives us a better grasp of the total tourism pressure on an island (+36.7 for Rhodes, +11.4 for Samos).

The total consumption of drinking water in Rhodes is roughly 26,470,000 m^3 including surface and pumped water (Table 6A and Figure 12) for a total population of 157,922 inhabitants including 42,432 tourists (inhabitant equivalent) and 115,490 locals. Keeping in mind that the water piping system

on both Rhodes and Samos is quite old and inefficient and that is in some Greek cities the water losses can be more than 50% (Moutsopoulos & Petalas, 2018), we assume that there is an approximately 30% water loss. So, the average consumption per capita about 117.33 m^3 per year and 0.32 m^3 per day, or 0.516 m^3 per tourist and 0.25m^3 per local and the yearly total consumption attributed to tourism is estimated at approximately 7,990,538 m^3. It is important to note that the consumption of drinking water is higher than the consumption for irrigation which shows that the pressure of human activity and mainly tourism is high on the island. The quality of the aquifer is considered as good on the whole island. Only in the Kalathou-Gadoura area at the centre of Rhodes the risk of salinization is high as 90% of the available water is consumed including 62% for drinking water.

The total consumption of drinking water in Samos (Table 6B and Figure 12) is approximately 4,690,000 m^3 for a total population of 36,730 inhabitants including 3,753 tourists (inhabitant equivalent) and 32,977 locals (:(Spilanis, Vayanni, & Karampela, 2007) (Spilanis, Vayanni, & Glyptou, 2014)). This gives an average per capita consumption of 89.38 m^3 per year and 0.245 m^3 per day. The daily average consumption is 0.288 m^3 per tourist and 0.24 m^3 per local and he yearly total consumption attributed to tourism is estimated at approximately 394,215m^3 [21].The consumption of drinking water is lower than the consumption of irrigation. The consumption is non-existent in the industry and extremely low in the animal husbandry. The pressure on the aquifers is not the same on the whole island as the availability and the consumption of water varies for different areas. From the available data we can conclude that there are two areas on south Samos in which the water consumption is more than the water infiltration and there are signs of salinization. In one of the areas (Kampos) agriculture is the main consumer, but in the other (Messokampos), the consumption of drinking water is higher.

[21] The sharp difference in the daily consumption per tourist between Rhodes and Samos is explained by the fact that while in Rhodes 70% of the tourist beds belong to 4 and 5 star hotels, in Samos only 20% of the beds belong to these categories.

Cubic meters (10^6 m^3) Aquifers of Samos	Average annual supply	Average annual consumption	Irrigation	Water Supply	Animal husbandry	Status
Kerketea (A and B)	15,66	0,34	0,2	0,15	0	Good locally bad
Idrousa - Marathokampos	5,09	1,73	1,36	0,37	0,01	Good
Karvouni	11,62	0,79	0,77	0,02	0	Good
Imvressou	4,08	0,65	0,54	0,1	0	Good
Vourlioton - Milon	4,53	0,8	0,29	0,51	0	Good
Mytilinion	8,14	2,06	1,43	0,63	0,01	Good
Kampos (A)	1,15	0,99	0,87	0,12	0	Good
Kampos (B)	0,34	0,34	0,34	0	0	Bad
Vathi	15,26	1,42	0,4	1,01	0	Good
Mesokampos	0,29	0,64	0,07	0,58	0	Bad
TOTAL (m^3)	66,19	9,76	6,27	3,49	0,02	
TOTAL (%)	100	14,7	9,5	5,3	0,035	

Cubic meters (10^6 m^3) Aquifers of Rhodes	Average annual supply	Average annual consumption	Irrigation	Water Supply	Animal husbandry	Status
North section of Rhodes (A)	34,98	15,18	6,37	8,73	0,08	Good
North section of Rhodes (B)	4,44	2,13	0,66	1,46	0,01	Good
Prophet Elia	3,91	0,01	0,01	0	0	Good
Epta pigon	6,06	2,32	1,22	1,1	0,01	Good
Kalathou – Gadoura	3,4	3,07	1,15	1,91	0	Good
Central Rhodes	63,09	6,51	5,16	1,32	0,02	Good
Attavirou	6,72	0,22	0,22	0	0	Good
Apolakkia	4,48	1,87	0,8	1,06	0	Good
Gennadiou	8,19	2,99	0,7	2,29	0,01	Good
TOTAL (10^6 m^3)	135,27	34,3	16,29	17,87	0,12	
TOTAL (%)	100	25,4	12	13,2	0,091	

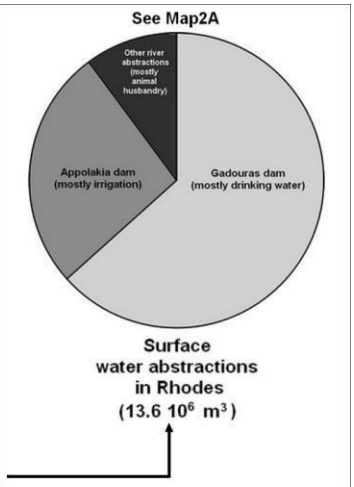
Table 6 - *Annual infiltration and consumption in the aquifers of Rhodes (A) and Samos (B).*

Source A and B: First revision of the water basin management plan of the water department of the Aegean Islands (2017).

Data refers to various years and periods between 2012 and 2015 depending of the island and the aquifer.

A RHODES Water system name	Type of water system	Annual consumption (10^6 m3)	Uses		
			Drinking water	Animal husbandry	Irrigation
Gadoura dam	Dam	8,621	*	*	
Apolakkia dam	Dam	3,601		*	*
Platis	River	0,489	*	*	
Kolonitis	River	0,451		*	*
Argiros	River	0,273		*	
Gadouras	River	0,1192	*	*	
Loutanis	River	0,009		*	
Pelemonis	River	0,007		*	
Sianitis	River	0,006	*	*	
Karavas	River	0,006		*	
Kremasteikos	River	0,006		*	
Makaris	River	0,004		*	
Kolovrechtis	River	0,003		*	
Fonias	River	0,003		*	
Petaloudes	River	0,002		*	
Kipirionas	River	0,0015		*	
Asklipinos	River	0,001		*	
Lahania	River	0,001		*	
Hohlakas	River	0,001		*	
TOTAL RHODES	Mostly dams	13.60	[4]	[19]	[2]

B SAMOS Water system name	Type of water system	Annual consumption (10^6 m3)	Uses		
			Drinking water	Animal husbandry	Irrigation
River R.	River	0,76	*	*	
Imvresos	River	0,62	*	*	*
Fourniotikos	River	0,24	*	*	
Amfilyssos	River	0,14	*	*	*
TOTAL SAMOS	Rivers	1,76	[4]	[4]	[2]



Source A and B: First revision of the water basin management plan of the water departement of the Aegean islands (2017)
Data refers to the various year between 2012 and 2015 depending of the island and the water system

Figure 12 - *Consumption of surface water resources of Rhodes (A) and Samos (B).*

Even though not related with tourism, the refugee crisis which peaked in 2015 with nearly a million asylum seekers passing through Greece had a strong impact on those Aegean islands that received huge amounts of people. Samos was and still is one of those islands (Figure 13). After the EU-Turkey agreement on March 2016, the number of new arrivals dropped substantially but the average stay of the asylum seekers on the islands increased from a few days/weeks to many months or even more than a year. As a result, the inhabitant equivalent of Samos in 2019 was increased approximately by 5,000 compared to pre-refugee crisis levels. The average daily water consumption of the people living on the Vathi Hotspot is estimated at approximately 0.064 m^3 per person. For the beneficiaries of the ESTIA Accommodation Scheme[22] the average daily water consumption is approximately 0.17 m^3 per person. For 2019 the total estimated water consumption of refugees and asylum seekers was about 128,885 m^3. Assuming 8,000 refugees with equivalent

[22] UNHCR's Accommodation Scheme is part of the ESTIA programme (Emergency Support to Integration and Accommodation), co-funded by the Asylum, Migration and Integration Fund of the European Union. The scheme provides rented housing to vulnerable asylum-seekers and refugees in Greece.

consumption of local people, the amount of water abstraction should have been 730,000 m^3.

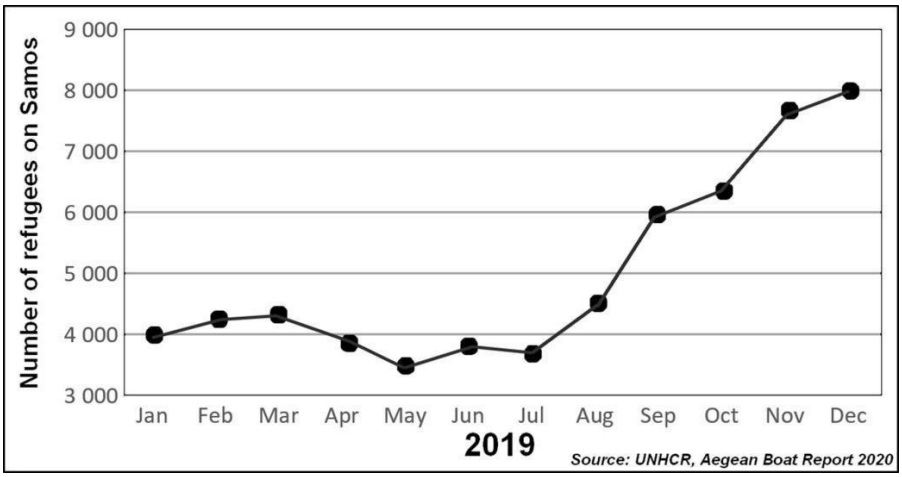


Figure 13 - *Number of asylum seekers and refugees on Samos in 2019.*

3.2. Tourist abstractions versus resources on Rhodes and Samos at present and in the future

Table 7 gives estimations on few elements of the water balance and abstractions compiled from the various previous data and methods. In the case of Samos, the pressure on water due to tourism is moderate: 0.33% of total resources and 4.7% of total abstractions. For Rhodes, the same figures 1.76% and 13.19% indicates a much noticeable use of water resources and supplies (Table 7A). Assuming in Rhodes a 9.34% depletion of rainfall and a 32.6% diminution of surface and ground water in 2050 (Table 7C), the same tourist abstraction would become 2.61 % of total water resource (Table 7B). For Samos, the projection for 2050 remains moderate. It is worth mentioning that for this island there are possibilities to build several hydropower stations on small catchments (Soulis & al., 2016, p. 230).

A	Water balance	Data and	Rhodes (610 mm)		Samos (700 mm)	
2000	and abstraction	methods	10^6 m^3	%	10^6 m^3	%
Pma	Precipitation	WC0 and ARIMA	858,7		335,1	
Gwr+R	Aquifer+Runoff	ARIMA, MEDOR	358,5	41,8	164,9	49,2
A	Total abstraction 2018	Cf. previous tables	47,9	13,4 (A/(Gwr+R))	11,5	7,0 (A/(Gwr+R))
At	Tourist abstraction 2018	Nb. Tourists x Nb. Days x 0.4 m^3/day	6,32	1,76 (At/(Gwr+R))	0,54	0,33 (At/(Gwr+R))
At	Tourist abstraction 2018	Nb. Tourists x Nb. Days x 0.4 m^3/day	6,32	13,19 (At/T)	0,54	4,7 (At/A)

B	Water balance	Data and	Rhodes (553 mm)		Samos (635 mm)	
2050	and abstraction	methods	10^6 m^3	%	10^6 m^3	%
Pma	Precipitation	WC123 and ARIMA	778,5		304	
Gwr+R	Aquifer+Runoff	ARIMA, MEDOR	241,7	31	129,6	42,6
At	Tourist abstraction 2050*	Nb. Tourists x Nb Days x 0.4 m^3/day	6,3	2,61 (At/(Gwr+R))	0,5	0,42 (At/(Gwr+R))

** Hypothesis: same At as 2018*

C	Evolution of	Data and	Rhodes		Samos	
2000-2050	water balance	methods	10^6 m^3	%	10^6 m^3	%
Pma	Precipitation	Mean (Kostas and WC0)	-80	-9,34	-31	-9,29
Gwr+R	Aquifer+Runoff	Kostas, Ioannis, MEDOR	-117	-32,6	-35	-21,4

Table 7 - Synthetic water balance from various data and methods.

A./ Up to 2000 or nowadays. B./ Scenario for 2050. C./ Evolution between the two periods.

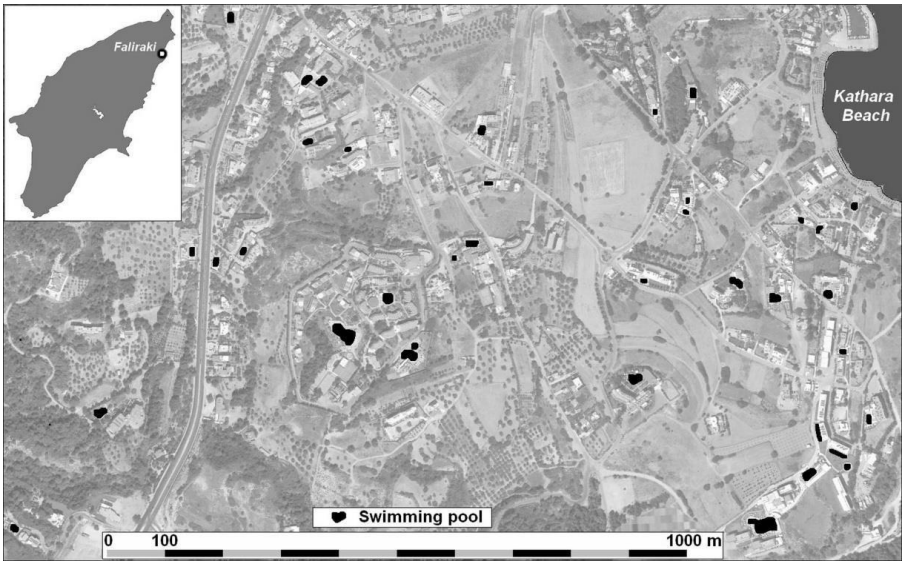
Even though the annual tourist consumption in Rhodes seems to be marginal, decision makers have to take into account three elements concerning tourism and water resources: the inter annual variability of precipitations, groundwater recharges and streamflow and the fact that most of the tourist abstraction takes place during the hot and dry period of July and August. All these factors jeopardize the water resource supply of the main economical activity of the island. This is what economist call a risk of "water stress" on the supplies (Skrimizea & Parra, 2019) and consequently urges for more intensive exploitation of aquifers as well as surface streamflow with somehow provisional solution as illustrated by the construction of the Gadouras dam.

Taking it as an example, the mean annual abstraction from this reservoir (2012-2015, 8.6 10^6 m^3) is almost equivalent to the annual consumption of tourists (2018, 6.3 10^6 m^3). If the direct evaporation loss from the lake is taken into account (1950-2000, 2 10^6 m^3), this means that more than 10 10^6 m^3 are diverted from the natural cycle every year with impacts on the ecology of the river and the coast downstream. About one third of the mean annual stream flow of the catchment is thus put to contribution.

In most cases, only direct uses of water by the tourist are taken into account. On top of that, several other supplies are also needed and must be considered as indirect pressure on the resources. This is the "invisible burden" as suggested in this sentence: "*Tourists] take showers more often, use pools,*

and frequent beautiful gardens, which are irrigated to retain perfect image for the guest." (Epler Wood & al., 2019, p. 13). The fact that the water from the Gadouras reservoir on Rhodes (photo 1) is used to fill the pools in the region of Falikari is also illustrating emblematically the under estimation of the water needs of the tourist sector (Map 3).

Photo 1 : the Gadouras Lake with the Atavyros Mountains in the background (C. Depraetere, September 2015)



Map 3: swimming pools in the southern part of Faliraki, one of main touristic spots of the north east coast of Rhodes. The density is about 35 pools over 1.5 km² (image 2019 from Google Earth).

Conclusion

For decision-makers and planners in the tourism sector, questions of resources are often considered secondary when compared to other key economic variables. In Mediterranean islands with economies relying strongly on tourism, the management of water resources could be seen as unimportant; just by looking at figures for Rhodes, direct water consumption from tourists accounts for less than 1% of total rainfall, about 2% of surface and groundwater, and 13% of total water supplies . A hasty and slipshod conclusion might be "much ado about nothing"; this could be like throwing the baby out with the bathwater.

The pressure on local water resources is, however, much worst on Mediterranean islands, particularly in the Aegean Sea for instance Mikonos, Delos, Kos or Patmos islands. Patmos, for instance, obtained most of its drinking water from Rhodes until recently but depends now on desalinization plants. The ongoing climate change and its consequences on water balance, as discussed in this article, could overburden the regional capacities to cope with growing needs, leading to overexploitation of a partly renewable local resource with outsourcing solution being costly and most often provisional.

To make the point clearer using a simple example taken on Rhodes, the construction of the Gadouras dam in 2001 had become a necessity as stated in the document project:

"*The overuse and excessive exploitation of water resources has resulted in a severe drop of groundwater levels and very soon led to brackish water inflow in several areas of the island* [Rhodes]. *The construction of the dam managed to solve the important and crucial water supply problems of the wider Rhodes urban area, of all the coastal settlements on the east and northwest side of the island as well as the neighboring arid islands*"[23].

In the context of Mediterranean islands with large tourist influxes, an Integrated Water Resources Management (IWRM) policy is necessary to prevent water stress or shortage[24] that may directly jeopardize local

[23] Project objective of the "water supply for Rhodes from Gadouras dam" (2001). Ministry of Infrastructure, Transport and Networks and then Region of South Aegean (https://www.een-gadoura.gr/en/objective/).

[24] From the ratio between population (including visitors) and water resources,(Engelman & Leroy, 1993) define two states: "water stress alert" below 1700 m^3/inh./year and "chronic

economies, especially those based on tourism. The water resource issue stands like a sword of Damocles hanging over societal and ecological conditions. The threat of climate change is just underpinning the problem with uncertainties on the future of water resources. Last but not least, sustainable tourism goes hand in hand with environmental quality. The specific context of touristic Mediterranean islands could become the bellwether of a local but not closed sustainable "ecolomy"[25] that our contemporaries are calling for. The IWRM is an example of ecolomical practice that could be relevant to overcome the multi sectorial, ecological and ethical Gordian knot challenging the future of the Mediterranean islands, its inhabitants and for sure their touristic alluringness.

water shortage" below 1000 m^3/inh./year (cited in (Azonsi & Depraetere, 2002). Supposing the same number of inhabitants and tourists for Rhodes in 2050, this ratio would be 1400 m^3/inh./year. A period of dry years could then create the conditions for a chronic water shortage especially during summer.

[25] Ecolomy: from the Greek *οἶκος*, house, heritage, … *λόγος* "logos", rationality, speech, knowledge... and from "*νομία*" nomos, management. Ecolomy means optimizing the synergy between ecological and economical issues. This term is freely inspired by the book of Arthur Lyon Dahl « The ECO principle : ecology and economics in symbiosis »(1996) with the agreement of the author. An equivalent in Greek would be *Οικοδιαχείρισ*η.

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7. Caractérisation des ressources en eau et leurs facteurs de dégradation dans l'île de Carabane

Antoine Demba Manga[1]*, Cheikh Faye* [2]

Résumé

La problématique de l'eau occupe une place de choix dans l'amélioration des conditions de vie des populations. Les ressources en eau ont un impact direct sur le développement socio-économique d'une région. Ainsi, il est indispensable avant toute mobilisation et gestion des ressources en eau de bien étudier leur contexte géographique. En Casamance, la conjoncture climatique se caractérise, depuis les années 1970, par une pluviométrie en baisse à laquelle s'ajoute une explosion démographique qui a mené à une mobilisation intensive des ressources en eau disponibles. L'objectif de cet article est d'évaluer les ressources en eau et les facteurs naturels comme anthropiques de leur dégradation dans l'île de Carabane. La méthodologie adoptée s'articule autour d'une recherche documentaire et d'une enquête ménages. Les résultats obtenus montre que, du fait des déficits pluviométriques, l'eau est disponible dans l'île mais elle est de nature saumâtre à salée, une qualité non favorable aux usages domestiques et agricoles. Ces différentes contraintes (baisse de la pluviométrie et hausse du niveau du fleuve) ont eu des impacts sur les ressources en eau parmi lesquels : la salinisation des nappes et de certaines parcelles cultivables etc. Face à cette situation où l'offre en eau est inférieure à la demande et compte tenu du coût souvent revu à la hausse, il serait impératif de procéder à une mobilisation plus rationnelle des ressources en eau dans l'île et d'assoir sa gestion plus durable.

Mots-clés*:* évaluation, ressources en eau, facteurs de dégradation, gestion, île de Carabane

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Characterization of water resources and their degradation factors in Carabane Island

Abstract

The water issue occupies a prominent place in improving the living conditions of the populations. Water resources have a direct impact on the socio-economic development of a region. It is therefore essential before any mobilization and management of water resources to properly study their geographic context. In Casamance, the climate has been characterized, since the 1970s, by declining rainfall, to which is added a demographic explosion which has led to an intensive mobilization of available water resources. The objective of this article is to assess water resources and the natural and anthropogenic factors of their degradation in the island of Carabane. The methodology adopted is based on documentary research and a household survey. The results obtained show that, due to rainfall deficits, water is available on the island but it is brackish to salty in nature, a quality not favorable for domestic and agricultural uses. These various constraints (drop in rainfall and rise in the level of the river) have had an impact on water resources, including: salinization of groundwater and certain cultivable plots, etc. Faced with this situation where the water supply is lower than the demand and given the cost often revised upwards, it would be imperative to proceed with a more rational mobilization of water resources on the island and to support its management more sustainable.

Keywords: evaluation, water resources, degradation factors, management, Carabane Island

1. Introduction

L'eau représente la clé principale pour atteindre le développement durable, et la question de l'eau et de son approvisionnement est devenue un grand défi pour l'humanité (Djaffar et Kettab, 2018, p. 642). L'Afrique, le continent le plus pauvre de la planète dispose d'importantes ressources en eau. En revanche, il manque les infrastructures de distribution et d'assainissement qui permettraient aux populations d'accéder à l'eau potable. Un tiers de la population africaine, soit 330 millions, n'a pas accès à l'eau potable et presque la moitié des Africains souffre de problèmes de santé dus au manque d'eau potable. L'Afrique est en effet le continent où l'accès à une eau de qualité est le plus limité au monde, à peine 60% de l'Afrique sub-saharienne

est alimentée en eau potable. En rapport à la diminution progressive de ces ressources et de l'augmentation de la consommation, la proportion de la population africaine risquant d'être soumise à une carence en eau augmentera de 38 % en 2013 à 74 % en 2040, affectant 28 pays (Sakho, 2018, p. 1).

Le Sénégal dispose globalement de ressources en eau suffisantes pour l'alimentation des populations (Faye et Dieye, 2018, p 450 ; Faye *et al.*, 2019, p 6). La diversité des ressources en eau permet d'exploiter les eaux de surface ou les eaux souterraines (CONGAD, 2009, p 61). Toutefois, le pays a connu une période de sécheresse durant les années 1970 qui a entrainé une baisse des nappes phréatiques et perturbé ainsi les ressources en eau du Nord, le Sahel comme au Sud, la Casamance (Faye *et al.*, 2017, p 17). Selon le rapport du programme alimentaire mondial en 2003 au Sénégal, seulement 38% des villages ont des forages pour obtenir de l'eau potable, 27% des puits cimentés et 21% des puits traditionnels (FAO, 2003, p 20).

L'inventaire national des points d'accès à l'eau potable au premier trimestre de 2015 a été mis en œuvre sur 15.992 localités avec l'appui des dispositifs décentralisés de collecte des données. Après exploitation des données, il en ressort que le taux d'accès amélioré global à l'eau potable en milieu rural s'établit en 2015 à 86,6% contre 84,1% en 2014 ; ce qui donne une progression satisfaisante de l'accès à des points d'eau modernes avec une hausse de 2,5 points. La performance est très satisfaisante même si elle reste un peu inférieure à la période antérieure où la progression interannuelle était de +3,5 points. En intégrant les statistiques sur les réalisations nouvelles d'infrastructures d'accès à l'eau enregistrées en 2015, le taux d'accès global à l'eau potable pour décembre 2015 est estimé à 87,2%. Le taux national d'accès par adduction d'eau potable s'établit à 74,0% contre 69,85% en 2014 ; soit une bonne évolution positive de 4,15 points. A contrario, l'accès par puits modernes diminue sensiblement et s'établit à 12,6% contre 14,25% en 2014. On note donc que l'amélioration de la qualité et de la sécurité de l'accès à l'eau a nettement bien évolué sur la période 2005-2015 à travers des tendances linéaires dans la hausse du taux d'accès par adduction d'eau et la baisse du taux d'accès par puits (Ministère de l'Hydraulique et de l'Assainissement, 2016, p. 1).

L'eau est un liquide si précieux et indispensable à toute existence, à toute forme de vie. Sans eau, ni le monde animal, ni le monde végétal n'existerait pas. Parmi les ressources qui contribuent au développement des activités humaines, l'eau présente plusieurs caractéristiques qui la distinguent de toutes les autres ressources (Baechler, 2012, p. 5). Dans certaines zones rurales du Sénégal, l'approvisionnement en eau se fait toujours à partir des puits traditionnels, des mares, des eaux de pluie… Dans d'autres zones, les

ouvrages hydrauliques ne peuvent plus assurer une bonne distribution en eau, du fait de leurs vétustés et de la forte croissance de la population. En plus, dans certaines zones, les points d'eau douce se trouvent à des kilomètres par rapport aux ménages. Face à la crise de l'eau qui reste le plus souvent liée à la pénurie absolue de la disponibilité physique (Bohbot, 2008, p. 7), il est apparu alors que seule une nouvelle forme de gestion de cette ressource est susceptible de garantir la durabilité entre l'offre et la demande ou entre les ressources disponibles et les besoins (Diouf, 2013, p 12).

Plusieurs raisons motivent une évaluation des ressources en eau et une caractérisation des facteurs naturels comme anthropiques de leur dégradation dans l'île de Carabane. S'il est vrai que l'eau est un élément indispensable à la vie et aux activités socio-économiques, une quantité d'eau importante, capitale, semble être fragile face au variabilité climatique. Dès lors, il est important de comprendre les facteurs qui rendent vulnérable ces ressources pour mieux s'adapter aux changements climatiques. Face aux besoins croissants en eau, à la surexploitation et à la dégradation des ressources, des démarches de restauration du bon état quantitatif et qualitatif des masses d'eaux doivent être engagées. Aussi, la mise en œuvre de nouvelles ressources doit s'effectuer dans le cadre d'une démarche raisonnée et respectueuse de l'environnement. La présente étude fait une évaluation des ressources en eau et une caractérisation des facteurs naturels comme anthropiques de leur dégradation dans l'île de Carabane.

2. Zone d'étude

La présentation géographique de l'île de Carabane porte sur la situation de l'île par rapport à la commune de Diembéring et dans le bassin versant de la Basse-Casamance (Figure 1). La carte 1 nous offre l'optique d'identifier les villages environnants qui sont entre autre l'île de Diogué, les villages d'Elinkine, de Kachouwane, Gnikine, Dimassane, Samatite et Kagnoute. Ce qui concerne le fleuve et les bolongs (chenal à eau salée) qui constituent l'île, au Sud-ouest nous avons le Cachioune bolong, au Sud-est, nous avons le bolong d'Elinkine et le reste est formé par le fleuve Casamance (Figure 1) (Manga., 2019, p. 21).

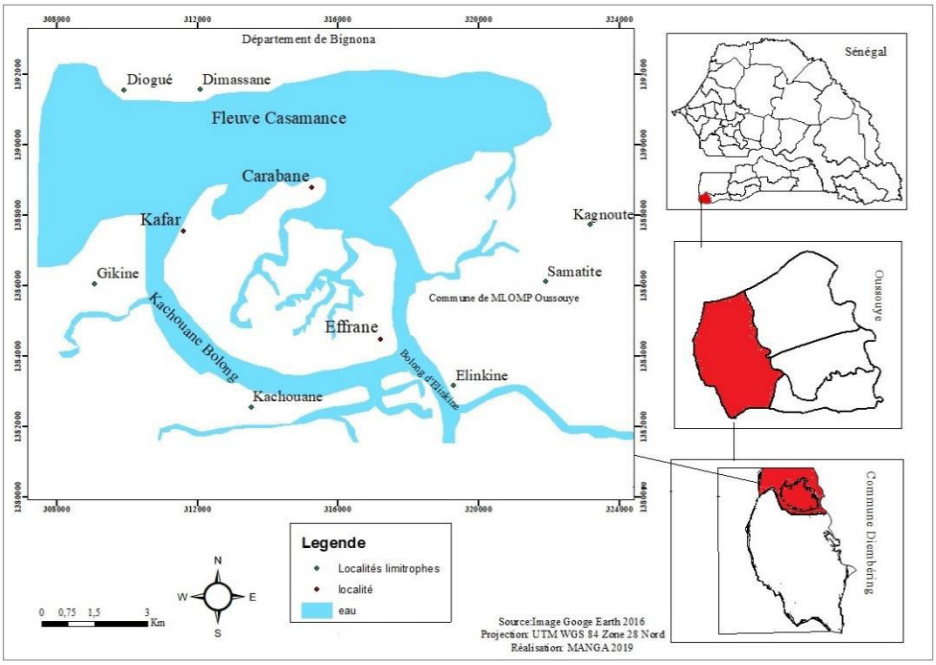

Figure 1 - *Présentation de l'île de Carabane (Source : Manga, 2019).*

D'une superficie totale de 57 km^2, l'île de Carabane est la principale et dernière île dans l'embouchure du fleuve Casamance, en rive gauche, face à la pointe de Diogué. Composée d'un village (Carabane), et de deux hameaux (Kafar, Effrane), l'île est située par 12° 32' de latitude Nord et par 16° 43' de longitude Ouest.

3. Données et méthodes

3.1. Données socio-économiques

La collecte de données primaire et secondaire a été utilisée pour cette recherche, car une bonne fusion des deux méthodes fournit une gamme de sources nécessaires pour produire des résultats de recherche de haute qualité. La collecte des données primaires s'est faite principalement sur la base d'enquête de terrain. Pour la collecte des données socio-économiques sur le terrain, la confection d'un questionnaire a été nécessaire afin de collecter les informations relatives aux ressources en eau (cadre climatique et ressources en eau dans l'ile de Carabane, vulnérabilité des ressources en eau dans l'ile de

Carabane, gestion des ressources en eau et stratégies de lutte contre leur vulnérabilité). Il nous a permis d'obtenir des données quantitatives. L'échantillon utilisé pour effectuer les enquêtes est l'échantillon systématique. Ainsi, nous avons interrogé tous les ménages existants dans l'île de Carabane (Tableau 1). Ce choix s'est basé sur le fait que l'île est petite et il n'existe qu'un village (Carabane) et de deux hameaux (Kafar et Efframe) dans cette zone, nous avons jugé nécessaire d'interroger tous les chefs ménages disponibles dans l'île (Manga., 2019).

Nom Localité	*Nombre de Concession*	*Nombre de Ménage*	*Homme*	*Femme*	*Population totale*	*Chef de ménages Interrogés*
Village de Carabane	44	60	203	205	408	60
Hameau de Kafar	4	4	5	15	20	4
Hameau Efframe	2	2	4	4	8	2

Tableau 1 - *Nombre de ménages interrogés dans l'île de Carabane. Source : Commune de Diembéring, 2013.*

3.2. Données physico-chimiques de l'eau des puits

Les données physico-chimiques sont obtenues à partir des mesures *in situ* de l'eau, réalisées dans 12 puits du village de Carabane. Les instruments de mesure paramètres physico-chimiques de l'eau comme le conductimètre et le réfractomètre sont utilisés pour faciliter l'analyse. Toutefois, du fait de l'absence de piézomètre, des sceaux ont été utilisés pour extraire l'eau dans les puits et mesurer les paramètres physico-chimiques de l'eau de ces puits. Parmi ces paramètres, sont analysés ici principalement le pH, la conductivité, la salinité et la température de l'eau des puits choisis.

L'outil GPS nous a permis d'obtenir les coordonnées géographiques de chaque point où les mesures sont effectuées. Les données sur la salinité sont obtenues à partir du réfractomètre. Pour effectuer les mesures avec le réfractomètre, nous avons prélevé une toute petite quantité d'eau de chaque puits (une goute) à l'aide d'une pépite poire. Cette eau a été ensuite vidée sur la lamelle du réfractomètre, ce qui a permis la lecture de la valeur.

En outre, le conductimètre qui mesure à la fois le pH, la température et la Conductivité électrique, a permis d'obtenir les données sur l'acidité et la minéralisation des eaux des puits. La mesure de ces deux paramètres est effectuée en plongeant l'appareil dans l'eau pendant quelques secondes.

4. Résultats et discussion

4.1. Evaluation des ressources en eau selon la population locale dans l'île de Carabane

Dans cette partie les différents types de ressources en eau existantes dans l'île de Carabane sont caractérisés et quantifiés. Dans l'île de Carabane, les eaux utilisables sont les eaux de pluie, les de surface et les eaux souterraines. L'île de Carabane est dotée d'importantes ressources en eau. Le fleuve Casamance couvre presque la totalité partie de l'île par ses réseaux hydrographiques. Les nappes souterraines constituent l'essentiel des ressources exploitées pour les différents usages domestiques, agricoles... Cependant, la gestion coordonnée des prélèvements pose des problèmes aigus : l'augmentation des besoins a coïncidé avec le moment où les ressources subissent sans cesse les assauts de la variabilité climatique (une baisse du niveau de certaines nappes, une percolation directe des eaux superficielles dans les eaux souterraines, absence d'alimentation de ces nappes du fait de la baisse des pluies…). Les ressources souterraines sont en général douces mais elles sont de plus en plus affectées par le sel du fait de l'intrusion marine et la baisse des pluies (Mahé, 2006, p 78). La pluie (ressource pluviale) est en général régulière dans l'île de Carabane mais elles sont de nos jours de plus en plus vulnérables face à la variation climatique. Les ressources superficielles sont représentées par le fleuve Casamance, le cachouane bolong et le ourong bolong.

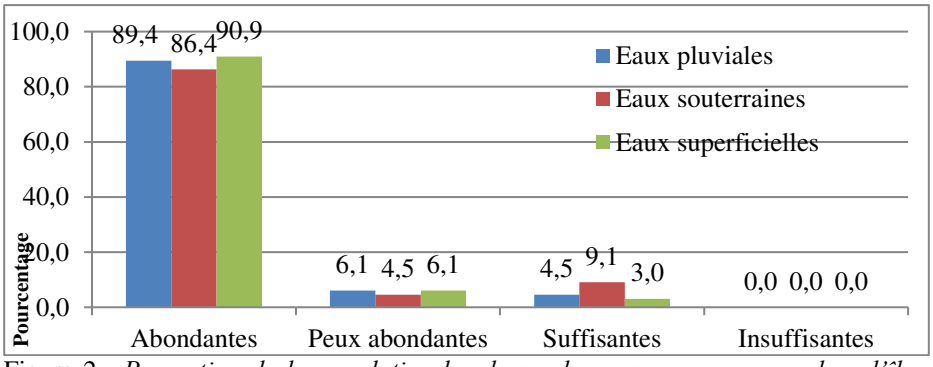

Figure 2 - *Perception de la population locale sur les ressources en eau dans l'île de Carabane (Source : Enquêtes Manga, 2018).*

Les données d'enquêtes révèlent que les ressources en eau sont abondantes dans l'île car parmi les 66 ménages interrogés, 90,9% (Figure 2) sont favorables à l'idée selon laquelle les ressources en eau sont suffisamment abondantes dans l'île du fait de la présence en abondance du fleuve, des nappes plus ou moins affleurantes et une pluviométrie régulière. Toutefois, la qualité reste à apprécier surtout pour les ressources souterraines qui sont généralement saumâtres.

4.1.1. Perception de la population locale sur la pluviométrie dans l'île de Carabane

La caractérisation des ressources pluviales dans l'île de Carabane se réfère au fait que ces ressources sont saisonnières. On les retrouve pendant la saison des pluies. L'analyse de la figure 9, nous montre que sur 66 ménages interrogés, 89,4% ont jugé la ressource eau pluviale abondantes dans l'île de Carabane du fait de la régularité des saisons des pluies, 6% des ménages soutiennent que la ressource est peu abondante car selon eux, la ressource tend à baisser au fur des années. Par contre parmi ces ménages interrogés, 4,5% estiment que cette ressource est suffisante car elle parvient à satisfaire au moins leur besoin en eau de pluie. Cependant un seul ménage déclare que cette ressource est insuffisante et qu'elle ne peut pas satisfaire les besoins quotidiens des ménages (Figure 2).

4.1.2. Perception de la population locale sur les ressources en eau superficielle dans l'île de Carabane

Pour la caractérisation et la quantification des ressources eau superficielle dans l'île, nous avons utilisé les données obtenues durant les enquêtes menés dans le village de Carabane. Parmi les 66 ménages interrogés à Carabane, 90,9% ont pu constater un taux abondant des ressources en eau superficielle existantes dans l'île (Figure 2). Cette partie de la population ont basé cette remarque sur la présence en permanence du fleuve Casamance dans la zone (carte 4). Mais 6% des ménages estiment que cette ressource est peu abondante. Selon eux, cette remarque est basée sur le fait que la qualité de cette ressource reste à désirer. Les ménages interrogés soutiennent que l'eau douce insuffisante car les eaux de surface disponibles se sont pas potables et ne satisfont non plus les besoins quotidiens de la population de Carabane. La Figure 1 met également en exergue la quantité abondante de la ressource en

eau superficielle dans l'île de Carabane matérialisée par le fleuve Casamance et les deux bolongs. Elle est en d'autres termes la ressource en eau la plus représentative dans l'île.

4.1.3. Perception de la population locale sur les ressources en eau souterraine dans l'île de Carabane

Par rapport aux ressources en eau souterraines, parmi les 66 ménages interrogés à Carabane, 86,4% ont pu constater un taux abondant des ressources en eau souterraines existantes dans l'île (Figure 2). Cette partie de la population ont basé cette remarque le fait que la nappe est peu profonde. Mais 5% des ménages estiment que cette ressource est peu abondante. Selon eux, cette remarque est basée sur le fait que la qualité de cette ressource reste à désirer et 8% pensent que cette ressource est suffisante dans l'île. Certains ménages interrogés soutiennent que les ressources en eau souterraines comment à devenir insuffisantes, ne sont plus potables et ne satisfont non plus les besoins quotidiens de la population de Carabane.

Malgré toutes ces potentialités en eau, la population de l'île a du mal à trouver de l'eau douce pour la consommation. Cela est le problème majeur qui ronge cette belle île de l'embouchure du fleuve Casamance.

4.2. Caractérisation des facteurs de dégradation des ressources en eau dans l'île de Carabane

Dans cette partie, il est indiqué comment par le biais des facteurs naturels, le changement climatique impacte sur les ressources en eau de l'île de Carabane, mais aussi les liens existants entre les actions anthropiques et les ressources en eau.

4.2.1. Impacts des facteurs naturels sur les ressources en eau dans l'île de Carabane

Dans l'île de Carabane, plusieurs facteurs naturels rendent les ressources en eau vulnérables. Il s'agit entre autres l'intrusion marine (93% des répondants), de la remontée du biseau salée (66,7%), de l'augmentation des températures (47%), de la rareté des pluies (42,4%), de la progression de la sécheresse (27,3%), du ruissellement des eaux de pluies 6,1%), du

déferlement des vagues (1,5%)… (Tableau 2). Quant au niveau de vulnérabilité des ressources en eau, il est généralement jugé fort (supérieur à 60%) par les populations interrogées pour les différentes catégories de ressources en eau (Figure 3).

Paramètres	*Nombre*	*Pourcentage*
Rareté de pluie	28	42,40%
Augmentation des températures	31	47,00%
Progression de la sécheresse	18	27,30%
Intrusion marine	62	93,90%
Remontée du biseau salée	44	66,70%
Ruissellement des eaux de pluies	4	6,10%
Déferlement des vagues	1	1,50%
Autres	1	1,50%
Total	66	

Tableau 2 - *Facteurs naturels rendant les ressources en eau vulnérables dans l'île de Carabane. Source : Enquêtes Manga, 2018.*

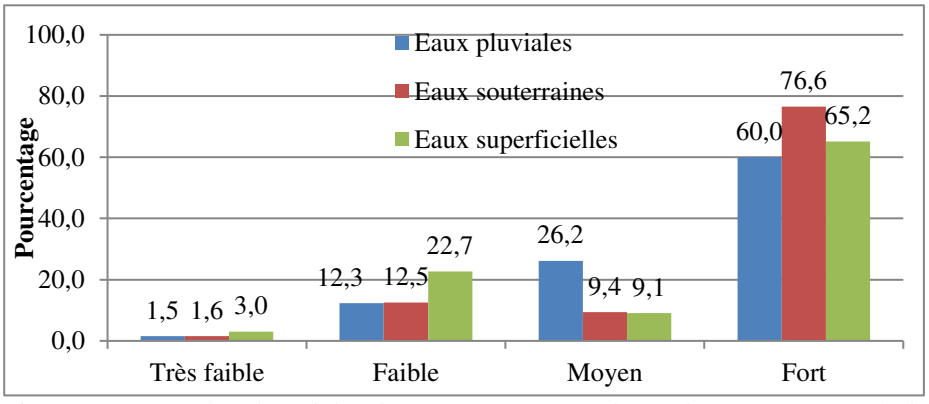

Figure 3 - *Niveau de vulnérabilité des ressources en eau du fait des facteurs naturels dans l'île de Carabane (Source : Enquêtes Manga, 2018).*

4.2.1.1. Sur les ressources en eau superficielles dans l'ile de Carabane

Dans l'île de Carabane, la dégradation des ressources en eau superficielles est due en grande partie aux facteurs naturels tels que la variabilité climatique. En d'autre terme, les effets ou manifestations de la variabilité climatique influencent directement sur les ressources superficielles dans l'île de Carabane (Tableau 2). Selon les enquêtes menées dans l'île de Carabane, l'effet le plus marquant sur les ressources superficielles est l'érosion avec

98,5 % des réponses de la population interrogées. L'augmentation des plans d'eau (45,5% des réponses), l'élargissement des lits du fleuve (65,2%) et la salinisation des marigots (59,1%° impactent aussi sur la disponibilité en eau dans l'île de Carabane (Tableau 3).

Paramètres	*Nombre*	*Pourcentage*
Diminution des plans d'eau	11	16,70%
Augmentation des plans d'eau	30	45,50%
Erosion	65	98,50%
Elargissement des lits des marigots/ensablement des mares	43	65,20%
Salinisation des marigots	39	59,10%
Total	66	

Tableau 3 - *Effets de la variabilité climatique affectant les resources en eau superficielles. Source : Enquêtes Manga, 2018.*

4.2.1.2. Sur les ressources en eau souterraines dans l'ile de Carabane

Au niveau de l'île de Carabane, les ressources en eau souterraine subissent les multiples assauts des effets de la variabilité climatique qui en retour rendent la population locale très vulnérable et dont les conséquences sont sans équivoques. Selon la population locale, l'intrusion marine (93,9%) et la remontée du biseau salée (66,7%) sont les principaux facteurs de la dégradation des ressources en eau souterraines. La salinisation des eaux du fleuve remonte jusqu'à atteindre le continent, particulièrement l'île de Carabane (Tableau 4). Cependant quant aux nappes superficielles de l'île, elles sont de plus en plus atteintes par le biseau salé, hypothéquant ainsi l'approvisionnement en eau potable des populations ainsi que leurs activités agricoles et touristiques. Ainsi, avec la diminution des totaux pluviométriques qui rechargent naturellement les nappes de l'île, on note donc une intrusion marine et une remontée capillaire pour combler ce déficit. En effet, la remontée capillaire est la contamination par envahissement souterrain des nappes des eaux douces par les eaux des nappes salées (Gomis, 2017, p 33). C'est pourquoi, la population ayant des difficultés de trouver de l'eau douce dans le village, est dans l'obligation de conserver les eaux de pluie dans des bidons ou des bassines pour satisfaire leur besoin.

Paramètres	*Salinité (mg/l)*	*pH*	*Conductivité (µS/cm)*	*Température (°C)*
Puits 1 (école Primaire)	9	7,41	4,55	39
Puits2 (Badjicounda)	7	7,5	9,15	29,4
Puits 3 (Porton)	5	7,47	3,85	29.3
²Puits 4 (Chez Héléna)	5	7,4	7,1	31,4
Puits 5 (Baracouda)	3	7,9	1,36	28
Puits 6 (école spéciale)	1	7,6	0,9	28,8
Puits 7 (Chapel)	4	7,5	2,5	31,1
Puits 8 (Sarrcounda)	2	7,41	1,32	35
Puits 9 (chef du village)	1	6,98	1,76	28,1
Puits 10 (forage)	1	7,15	0,76	29,8
Puits 11 (Après CEM1)	1	7,65	0,24	29
Puits 12 (Après CEM2)	1	7,21	0,48	30,1
Normes	0,2 mg/l	6-9	250 µS/cm	20-30°C

Tableau 4 - *Résultats des analyses des paramètres hydrologiques de 12 puits dans le village de Carabane. Source : Manga, 2018*

Cette analyse porte sur la salinité, le pH, la conductivité et la température de l'eau de 12 puits existants dans le village de Carabane (Tableau 4 et Figure 4). Les échantillons traités et ont été pris à la fin de la saison des pluies.

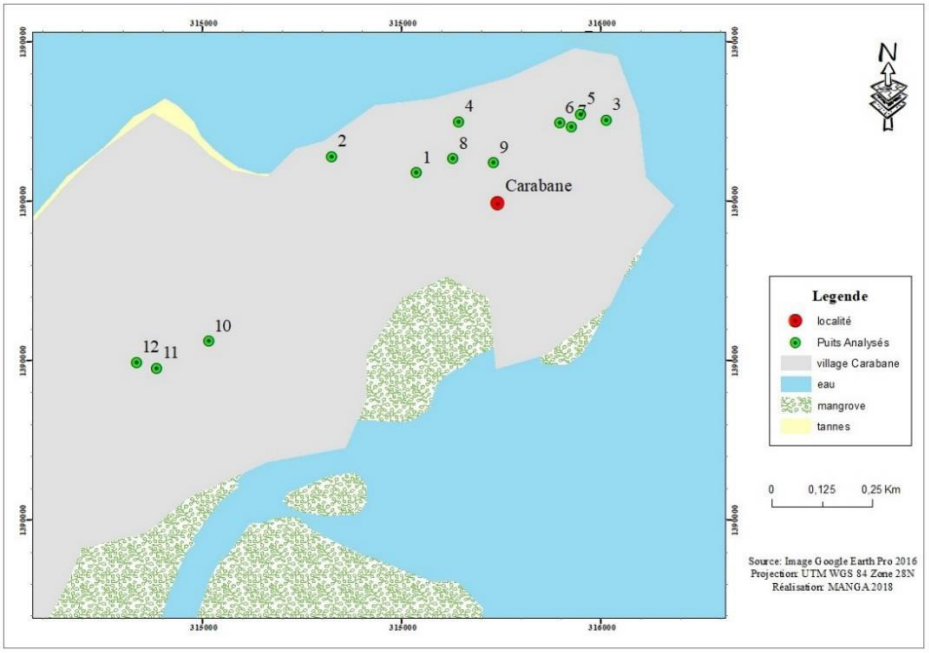

Figure 4 - *Localisation des différents puits analysés dans le village de Carabane (Source : Manga, 2018).*

4.2.1.3. Sur les ressources en eau pluviales dans l'île de Carabane

Au niveau de l'île de Carabane, les ressources en eau pluviale subissent les impacts des effets de la variabilité climatique qui en retour rendent la population locale de Carabane très sensible face aux effets de ces variations. En effet, avec les changements climatiques, on note une baisse drastique de la pluviométrie dans cette zone. Cette diminution de la ressource en eau pluviale se ressent nettement dans l'île car selon certains ménages interrogés, ces dernières années, le stock des eaux de pluies ne couvre plus la saison sèche contrairement aux stocks des années passées qui ils parvenaient à couvrir toutes l'année. C'est ce qui pousse certains à faire des kilomètres pour trouver de l'eau douce dans l'île de Carabane. De plus, on note une irrégularité des saisons des pluies dans l'île de Carabane. Les changements climatiques ont beaucoup contribué à la baisse de cette ressource en eau pluviale.

Au niveau de l'île de Carabane, les ressources en eau pluviale subissent les impacts des effets de la variabilité climatique qui en retour rendent la population locale de Carabane très sensible face aux effets de ces variations. En effet, avec les changements climatiques, on note une baisse drastique de la pluviométrie dans cette zone (Tableau 5). En se basant sur les enquêtes,

81,8% des ménages interrogés estiment que le début de la saison des pluies a connu un retard pendant ces dernières années. Pour cette partie des ménages interrogés, ce retard est causé essentiellement par les changements climatiques. En plus, 74,2% de ces ménages déclarent qu'ils observent une baisse de la pluviométrie. Selon eux, la variabilité climatique, reste le seul facteur de cette diminution.

Paramètres	*Nombre*	*Pourcentage*
Augmentation de la pluviométrie	6	9,10%
Diminution de la pluviométrie	49	74,20%
Retard dans le démarrage de la saison	54	81,80%
Pluies précoces	10	15,20%
Total	66	

Tableau 5 - *Perception de la population de l'île de Carabane sur la pluviométrie Source : Enquêtes Manga, 2018.*

4.2.2. Impacts des activités socioéconomiques sur les ressources en eau dans l'ile de Carabane

La multitude de menaces importantes qui pèsent sur les ressources en eau découlent toutes principalement des activités humaines. Ces menaces sont entre autres la souillure, la pauvreté, la croissance urbaine et les transformations du paysage telles que la déforestation. Chacune de ces menaces a un impact non négligeable, le plus souvent directement sur les écosystèmes, avec des répercussions sur les ressources en eau. Ainsi, les facteurs anthropiques jouent un rôle majeur dans l'accélération du processus de la dégradation des ressources en eau dans l'île de Carabane (Tableau 6).

Paramètres	*Nombre*	*Pourcentage*
Surutilisation des ressources en eau	22	33,30%
Pauvreté excessive (problèmes économiques)	25	37,90%
Augmentation des besoins due à la hausse de la population	24	36,40%
Utilisation et gestion archaïque des ressources en eau	16	24,20%
Pollution	34	51,50%
Autres	8	12,10%
Total	66	

Tableau 6 - *Facteurs anthropiques impactant les ressources en eau dans l'île de Carabane. Source : Enquêtes Manga, 2018.*

La dégradation des ressources en eau est en effet liée à la croissance démographique de plus en plus élevée. Les principaux facteurs anthropiques de cette dégradation sont la souillure (51.5%), l'augmentation des besoins en eau due à la hausse de la population (36.4%), la pauvreté (37.9%), la surutilisation des ressources en eau (33.3%) mais aussi l'utilisation et la gestion archaïque de ces ressources (24.2%). Néanmoins, les personnes interrogées ont indiqué un niveau de vulnérabilité des ressources en eau, du fait des facteurs anthropiques, dans l'île de Carabane généralement faible (plus de 55% pour les différentes catégories d'eau) (Figure 5).

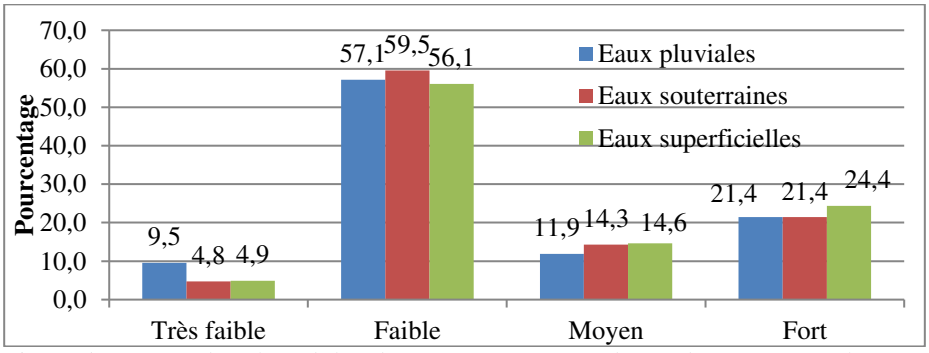

Figure 5 - *Niveau de vulnérabilité des ressources en eau du fait des facteurs anthropiques dans l'île de Carabane (Source : Enquêtes Manga, 2018).*

4.2.2.1. Souillure du lit majeur du fleuve et des bolongs dans le village de Carabane

La souillure est le fait de jeter un produit potentiellement toxique ou de nature dans l'environnement afin de perturber le fonctionnement d'un élément naturel comme les ressources en eau (fleuve, marigots, nappes…) ou d'un biotope (Hassane, 2013). Elle peut nuire aux ressources en eau et aux écosystèmes aquatiques. Les principaux polluants comprennent notamment les matières organiques et organismes pathogènes rejetés avec les eaux usées, les engrais et pesticides provenant des terres agricoles etc. Cependant, l'action anthropique favorise très fortement la souillure et la pollution de ces ressources en eau et les rendent de plus en plus vulnérables. Selon la population locale, la souillure de ces ressources est le facteur le plus marquant dans l'île (51.5% des réponses).

Ainsi, dans cette île, on peut constater que les familles qui habitent près des marigots du fleuve ont l'habitude de jeter les ordures dans les chenaux du fleuve (Figure 6) qui impactent directement sur ces ressources,

particulièrement les ressources en eau superficielles (marigots et fleuve) et les ressources en eau souterraines (nappes). Comme la population locale utilise sans cesse ces ressources, elle est ainsi exposée à de nombreux risques comme l'apparition de beaucoup de maladies telles que le choléra, la diarrhée et des autres infections dues à la mauvaise qualité de l'eau consommée.

Souillure du lit majeur du marigot de Carabane

Souillure du lit mineur du marigot de Carabane

Figure 6 - *Souillure des lits mineur et majeur du marigot de l'île de Carabane (Clichés Manga, 2018).*

Dans ce lieu, la plupart des eaux des nappes existantes sont le plus souvent sombres du fait de la pollution. Selon une partie de la population, le fait de jeter des ordures dans les marigots est la raison principale de la pollution de ces ressources en eau (même souterraines), les marigots et le fleuve étant parfaitement connectés aux nappes souterraines.

4.2.2.2. Augmentation des besoins en eau due à la hausse de la population

A la recherche de meilleur condition de vie, l'homme se déplace sans cesse et s'installe dans des zones plus favorables à son développement. Ainsi, l'île de Carabane est parmi l'une des îles les plus belles de la basse Casamance et avec un meilleur temps, une histoire bien parfaite et connue et une zone touristique. Ainsi, on assiste à des arrivées massives des personnes dans cette île dont la majorité finit par s'y installer de manière définitive. Cela participe à l'augmentation de la population locale de Carabane et qui en retour à des impacts très importants sur les ressources en eau. En effet, la population locale de Carabane (avec 36.4% des réponses) affirme qu'avec la hausse de la population, on note une augmentation sans cesse des besoins en eau potable dans l'île pour les besoins agricoles, les tâches ménagères et la consommation…

Les prélèvements d'eau douce ont beaucoup augmenté dans l'île de Carabane, en partie sous l'effet de la croissance démographique. La population de Carabane, qui s'élevait en 2003 à 223 habitants, est aujourd'hui

estimée à 428 habitants (Commune Diembéring, 2013). Dans le même temps, la demande supplémentaire en eau augmente de plus en plus chaque année. Ainsi, plus la population augmente, plus les besoins en produits agricoles et domestiques s'accroissent. Si rien n'est fait pour rationaliser l'utilisation de l'eau dans l'agriculture et dans les tâches ménagères, les besoins en eau devraient augmenter de plus en plus alors même que l'île tend à atteindre déjà l'état de stress hydrique. Cela se traduit par la baisse considérable du niveau des nappes phréatiques durant la saison sèche mais aussi l'assèchement temporaire de certains puits de l'île sur la même saison.

4.2.2.3. Surutilisation des ressources en eau

Dans l'île de Carabane, on assiste à des phénomènes de surexploitation des ressources en eau, plus précisément l'eau douce des nappes phréatiques. En effet, l'eau souterraine subit une pression non négligeable de la part de la population locale du fait de l'agriculture en particulier du maraichage dans cette l'île. Dans ce lieu, la majorité des femmes font le maraichage et que cette activité consomme beaucoup d'eau. Ainsi, avec cette problématique de trouver de l'eau douce dans cette île, ces femmes sont dans l'obligation de surexploiter cette faible ressource afin de satisfaire les besoins journaliers en eau douce des plantes cultivées.

Figure 7 - *Puits taris pendant la saison sèche du fait de la forte utilisation de l'eau à Carabane (Clichés Manga, 2018).*

Même si l'agriculture pèse très lourde sur cette forte exploitation de ces ressources en eau, on a aussi les besoins domestiques qui à leur tour impactent sur ces ressources en eau dans l'île. Selon les enquêtes menées, l'activité touristique est bien présente dans cette petite l'île avec plus de 4 campements, un hôtel et plusieurs résidences. Ainsi, l'exploitation des ressources en eau devient très probable. Cependant, avec le problème de retrouver de l'eau douce en abondance dans l'île pour la satisfaction des besoins en eau, la population de Carabane se voit juste dans l'obligation d'exploiter cette maigre

ressource pour maintenir leurs activités touristiques comme ménagères. Par conséquent, cette surexploitation a des répercussions non négligeable sur ces ressources en eau, particulièrement celle souterraine, car on assiste à une baisse sans cesse du niveau des nappes phréatiques, en atteste la baisse du niveau des puits et leur tarissement durant la saison sèche (Figure 7).

4.2.2.4. Pauvreté et forme de gestion traditionnelle des ressources en eau

La population de Carabane est très pauvre (PDD Diembéring, 2013) et utilise de manière traditionnelle les ressources en eau, favorisant leur vulnérabilité face au changement climatique. En effet, l'eau non potable et un mauvais assainissement entraînent insalubrité et maladies. Dans cette île isolée et très enclavée, les femmes et les enfants passent souvent plusieurs heures par jour à marcher vers la source la plus proche pour rapporter de l'eau au village. Ce temps passé sur les chemins empêche les jeunes d'aller à l'école. Cette situation les enferme dans un cycle de pauvreté dont les conséquences sont dramatiques. Du fait de la pauvreté, la population va chercher de l'eau douce dans la forêt avec des bassines, des bidons ou des sceaux, bien que cette eau ne soit pas toujours potable, et donc peut être source d'infection et de transmission de maladie. Cet état de fait pousse d'autres habitants de l'île de Carabane à recueillir les eaux de pluies afin de s'en servir comme eau de boisson alors que la conservation reste à désirer. Ce qui rend certains des habitants et les ressources en eau très vulnérables face aux impacts du changement climatique dans de l'île de Carabane.

5. Conclusion

Cette étude est menée dans le souci de faire une évaluation des ressources en eau et une caractérisation des facteurs naturels comme anthropiques de leur dégradation dans l'île de Carabane. Les disponibilités en eau sont évaluées en fonction des résultats obtenus durant les enquêtes et les entretiens effectués dans l'île de Carabane et les résultats montrent que l'eau est effectivement disponible en quantité suffisante en raison des niveaux d'eau plus ou moins importants durant toute l'année, la présence en permanence du fleuve et une nappe affleurante. Toutefois, il faut retenir qu'il s'agit en grande partie d'eau saumâtre à salée, ce qui fait que l'accès à l'eau douce reste un grand problème dans cette zone du bassin versant de la Basse-Casamance. Ce phénomène est inhérent à la dynamique hydrologique ou encore au comportement

hydrologique de l'île qui est fortement alimenté par l'eau du fleuve. Sur le plan socio-économique, la variabilité de ces ressources rend la population locale très sensible face aux assauts de la variabilité climatique. Les activités qui sont menées dans l'île sont tributaires aux ressources en eau. C'est le cas du tourisme, de la pêche et de l'agriculture. Par conséquent la des ressources en eau face aux changements climatiques impacte directement sur les activités socio-économiques des habitants de l'île de Carabane.

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8. Les îlots du Sahel (Tunisie orientale) : variété, intérêt géoarchéologique et risques

Ameur Oueslati[1]

Résumé

Les espaces insulaires du Sahel tunisien sont toujours de la famille des îlots petits et bas. Ils recèlent pourtant une variété paysagère importante ainsi qu'un patrimoine archéologique indéniable. Ce dernier offre des repères importants pour la reconstitution de l'évolution récente et ses tendances. Sont révélés, en particulier, l'importance des effets des changements du niveau marin et du comportement du sol ainsi que le grand intérêt que peuvent revêtir ces îlots y compris les plus petits d'entre eux, pourtant souvent négligés. Le travail traite aussi des caractéristiques de l'évolution actuelle et du coût paysager et patrimonial de l'anthropisation, accélérée, des dernières décennies. Il revient sur différentes interventions imprévoyantes soldées par des formes de destruction déplorables et d'accentuation d'une vulnérabilité déjà naturellement importante et appelée à s'aggraver dans le cadre du changement climatique annoncé.

Mots clés : Tunisie, îles, îlots, géoarchéologie, patrimoine, niveau marin, aménagement, risques.

The islets of the Sahel (Eastern Tunisia): variety, geoarchaeological interest and hazards

Abstract

The insular areas of the Tunisian Sahel pertain always to the category of small and low islets. However, they show an important landscape variety and contain an undeniable archaeological heritage. The latter offers important benchmarks for the reconstruction of the recent evolution and its trends. Are revealed, in particular, the importance of the effects of changes in sea level and soil behavior as well as the great interest that these islets, yet often neglected, can have even the smallest ones. This paper also deals with the

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characteristics of the current evolution and the impacts of the recent accelerated anthropization on the landscape and the natural and cultural heritage. It considers various unpredictable interventions resulting in deplorable forms of destruction and the accentuation of a vulnerability already naturally significant and which will grow with the predicted climate change.

Keywords: Tunisia, islands, islets, geoarchaeology, patrimony, sea level, management, hazards.

Introduction

Avec une soixantaine d'îles et d'îlots, le littoral tunisien est celui, de toute la berge sud de la Méditerranée, qui compte le plus d'espaces insulaires (Oueslati, 1995a). Il s'agit souvent d'archipels la plupart du temps peu étendus à part l'île de Jerba et les îles de Cherguia et de Gharbi dans l'archipel des Kerkena qui sont d'ailleurs les seules îles habitées de nos jours. Ces espaces sont abordés dans une littérature variée et parfois abondante. Cependant, les travaux géoarchéologiques sont, dans l'ensemble, restés peu nombreux. Une étude menée par une équipe d'archéologues et de géomorphologues dans le cadre d'un projet géoarchéologique tuniso-français déroulé sur une dizaine d'années a déjà permis d'apporter une contribution intéressante sur ce plan (Slim *et al*., 2004). Mais couvrant l'ensemble du littoral, elle ne pouvait s'attarder sur tous les aspects et détails. Plus récemment, deux contributions ont été consacrées aux îles de la façade nord du pays à travers le cas l'archipel de la Galite (Oueslati, 2016b) et aux îles et îlots de la partie méridionale de la façade orientale (Oueslati, 2016c). Ceux du Sahel, toujours de la famille des îlots, apparaissent comme relativement négligés et en tout cas évoqués que de façon très brève dans les travaux géomorphologiques et géoarchéologiques, sans doute à cause de leur petite taille. Ils nous ont paru mériter un travail à part pour mieux rendre compte de leur spécificités et intérêt.

Cette contribution tente, après une présentation générale de ces espaces insulaires, de montrer l'importance qu'ils offrent pour une reconstitution de l'évolution déroulée au cours des temps historiques et une connaissance de ses tendances utiles à la compréhension de l'évolution actuelle. Celle-ci est abordée sous l'angle des risques liés à la dynamique sous l'effet des agents naturels en action et de l'accélération de l'anthropisation au cours des dernières décennies. La démarche s'inscrit aussi dans un essai de contribution

à une meilleure réflexion sur la vulnérabilité de ces espaces et leur résilience face à la convoitise accrue des aménageurs mais aussi face aux changements annoncés au niveau du climat, notamment l'augmentation du niveau marin.

1. Des îlots variés par leur nature et leur genèse ainsi que par leur place dans le paysage côtier et par leur contenu archéologique

Le littoral du Sahel compte, en plus de quelques écueils et îlots très minuscules, quatorze îlots organisés en petits archipels et appartenant majoritairement à la côte de la presqu'île de Monastir et aux eaux qui la devancent (fig. 1). Il s'agit aussi d'îlots peu étendus couvrant une superficie totale de quelque 427ha et ont en commun leur topographie basse (tabl. 1). Mais ils offrent une grande variété tant par leur nature, leur genèse et leur position par rapport au continent que par l'attraction qu'ils ont exercé sur l'homme au fil du temps et partant, leur contenu archéologique. Ce qui rend difficile, ou peu précise, une présentation commune et exige de passer en revue les différentes situations. C'est ce que nous tenterons de faire dans cette partie en suivant un ordre géographique du Nord vers le Sud, depuis l'archipel des Kuriate au large de la ville de Monastir jusqu'aux îlots El Far sur la côte de Melloulèche au Sud de la ville de Chebba.

Nom	*Nombre des îlots*	*surface (ha)*	*Altitude max. (m)*	*Numéro sur la fig. 1*
îlots des Kuriate	02	308	5	1
îlots de Monastir	06	55,57	13	2
îlot d'Ed Dzira	02	30,5	2	3
îlot Kaboudia	02	29	3	4
îlots El Far	02	4,2	3	5

Tableau 1 : *Les îlots du littoral du Sahel et leurs superficies (Sources des données : O.T.E.D.D., 2015 et mesures effectuées sur différents documents cartographiques).*

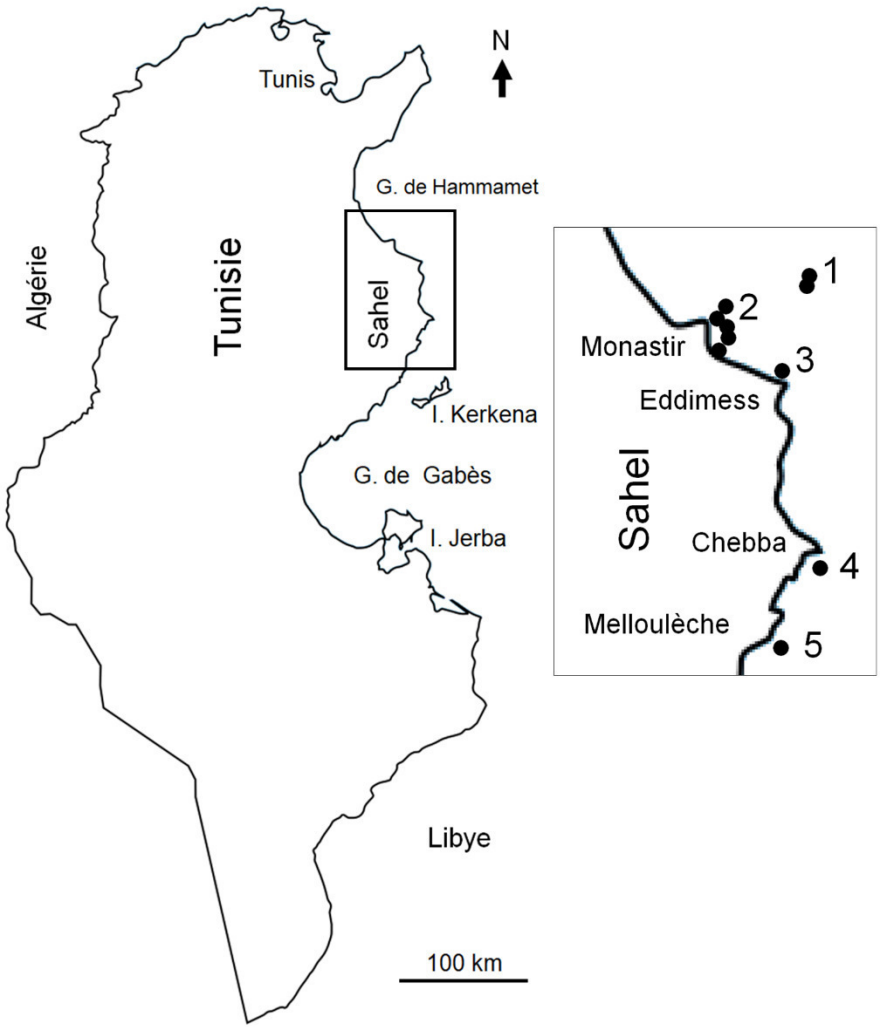

Figure 1- *Localisation des sites des îlots ou groupements d'îlots du Sahel.*
1-Archipel des Kuriate, 2-Archipel de Monastir, 3-îlots d'Eddimess, 4-îlots de Rass Kaboudiya, 5-îlots El Far.

1.1. Les Kuriate

Les Kuriate (Qûriya en arabe), sont deux îlots principaux, Qûriya El Kbira ou El Kbira (la grande) et Qûriya Essghira ou Essghir (la petite) appelé aussi, dans différents textes, Conigliera en raison de la «*quantité de lapins qu'on y rencontre* » (Perpetua, 1883). La carte topographique de Moknine à l'échelle 1. 25 000 basée sur des vues aériennes de 1988 et un complètement sur le terrain en 1992, représente, en plus, un alignement de très petits îlots

prolongeant la pointe sud d'Essghir. Ceci se retrouve sur des cartes plus anciennes. C'est le cas par exemple, de la « Carte du Royaume de Tunis » de Thomas Shaw (1743) où l'archipel est représenté par trois îlots que l'auteur identifie comme les îles Joweries ou *Tarichiae*. Plus tard, Henry (1824) écrit, dans son portulan de la Mer Méditerranée à propos des Kuriate qu'il identifie par le nom des Conillières et décrit comme deux écueils à environ douze milles à l'est de Monastir, que « *Lorsqu'on y va mouiller, il est bon d'observer de ne pas trop ranger l'écueil le plus est, il faut s'en tenir écarté au moins de trois câbles, pour éviter une langue de roche qui va beaucoup dans l'est* ». De son côté, Charles Tissot (1888) note, en décrivant l'archipel, que la petite Kuriate « *est flanquée, au sud-ouest, d'une roche étroite et allongée* ». Mais au seizième siècle, un portulan du capitaine géographe Piri Reis (1554) ne représente que les deux îlots les plus grands.

Cet archipel qui se trouve à environ 16 km au large de la ville Monastir est le plus étendu de tous les espaces insulaires sahéliens, couvrant une superficie de l'ordre de 258 et 50 ha, respectivement pour les grands et les petits îlots. Le premier est le moins bas, culminant à environ 5 m au niveau d'un phare toujours fonctionnel. Dans le second, les altitudes sont toujours inférieures à 2m. Cette faiblesse topographique se prolonge en mer, mais l'archipel est bien ouvert sur le large et ses parties exposées aux vents des secteurs septentrionaux, dominants dans la région, se caractérisent par un mode battu.

Du point de vue géologique, seule la grande Kuriate montre, en surface et sur une superficie assez importante, un matériel résistant préquaternaire. Sa partie septentrionale correspond à un mamelon fait par des grès jaunes coquilliers du Pliocène supérieur sur lequel reposent des placages discontinus d'un grès coquillier et parfois oolithique qui rappelle le faciès de la formation Rjiche si caractéristique sur la côte du Sahel et attribuée au dernier interglaciaire (Oueslati *et al*., 1982 ; Paskoff et Sanlaville, 1983). Dans l'autre îlot, le grès pliocène apparait de façon très ponctuelle sous des sols salés (Slim *et al*., 2004) occupés par un paysage de sebkhas, de chotts et de marais. Ce paysage domine en fait dans les parties basses des deux îlots. Il se termine souvent, au bord du rivage sur des microfalaises ou sur des plages sableuses accompagnées de petites dunes. La végétation est souvent halophile et cède la place à des espèces pasmmophiles sur les dunes ou à une formation steppique, herbacée mais parfois ponctuée de petits buissons, sur les quelques éminences topographiques d'El Kbir.

Sur le plan archéologique, la grande Kuriate renferme les traces les plus anciennes, de tous les îlots du Sahel. Ces traces, remontent à la Préhistoire et ont été trouvées dans la partie centrale de l'îlot, surtout au voisinage du phare (Oueslati, 1995a). Elles sont constituées par des fragments d'œuf d'autruche

et de nombreux éclats de silex dont plusieurs retouchés. L'analyse de ce matériel par notre collègue préhistorien Abderrazak Gragueb, a permis d'identifier une industrie microlithique typique du Néolithique (trapèzes, pièces à retouche envahissante...). A cette époque la navigation était pratiquée (Camps, 1977). De son côté, l'îlot d'Essghir renferme, dans sa partie occidentale, les vestiges très dégradés d'une pêcherie de thon (*tonnara*). Faut-il rappeler enfin, que ces îlots ont longtemps joué un rôle important pour l'orientation les navigateurs et des pêcheurs ainsi qu'un refuge pour par mauvais temps (Henry, 1824).

1.2. Les îlots de la ville de Monastir

Au nombre de six, ces îlots sont, du Nord au Sud, les îlots El Hmam, El Ghdamsi, El Oustaniya (ou îlot de la Quarantaine), El Mida El Kbira (la grande), El Mida Essghira (la petite, appelée aussi Maklouba) et El Enf. Ce sont en fait autant d'appellations significatives. L'îlot El Hmam (pigeons en arabe) doit son nom aux « *pigeons et colombes qui nichent par milliers dans le creux de ses rochers* » (Piesse, 882). El Ghdamsi est le nom d'un marabout situé dans l'île, Sidi Abou El Fadhel El Ghedamsi et sa koubba (coupole). Cet îlot a aussi abrité un établissement pour la pêche du thon ce qui lui a fait donner le nom de *Tonnara*. Il aurait également porté le nom de l'îlot de Salah ainsi que le rapporte Sayadi (1979), se référant à Grenville. El Oustaniya a été appelé ainsi à cause de sa position, le terme *Oust* signifiant milieu en arabe. Les îlots El Mida et El Maklouba doivent sans doute leur nom à leur forme et au pendage des couches géologiques qui constitue leur ossature, le terme *makloub* signifiant, en arabe, renversé alors que le terme *mida*, utilisé pour désigner le caractère plat du sommet, signifie table. Enfin, le nom El Enf (nez en arabe) pourrait s'expliquer par la forme étirée de l'îlot parallèlement au rivage et du côté de la face d'une presqu'île importante, celle de Monastir.

A la différence des Kuriate, ces îlots sont situés à très peu de distance du rivage. Celle-ci varie d'une centaine de mètres pour El Mida à 1km pour El Hmam. Leurs altitudes sont également faibles mais, avec ses 13m, El Ghedamsi est le plus haut de tous les îlots du Sahel. Il se distingue aussi par un sommet très plat et assez spacieux, s'étendant étendu environ 12 ha. Mais partout le couvert végétal est très faible, voire absent. Il ne montre une certaine importance que dans l'îlot El Hmam qui échappe encore à une fréquentation humaine importante et dont la surface porte une formation herbacée steppique relativement dense, avec localement un taux de couverture supérieur à 40%. A El Enf, des touffes dispersées de plantes

psammophiles s'observent sur le substrat sableux alors que des plantes halophiles colonisent les parties les plus basses et la face interne de l'îlot.

Du point de vue géologique, à part l'îlot El Enf, formé d'un matériel sableux, tous ces îlots ont une ossature de grès souvent très coquillier, caractéristique du faciès astien du Pliocène supérieur. Des placages de dépôts marins attribués au dernier interglaciaire apparaissent, ici et là, à leur sommet, surtout à El Ghedamsi. On retrouve en fait le prolongement de la géologie de la presqu'île de Monastir à ossature pliocène et dont la surface, portant une importante couverture marine contenant de nombreux strombes, est interprétée comme une plate-forme façonnée par la mer lors du dernier interglaciaire (Paskoff et Sanlaville, 1983).

La nature gréseuse de la plupart des îlots, l'exposition aux vents dominants dans la région et l'importante ouverture sur la mer ont favorisé malgré la faiblesse de la bathymétrie et de la topographie la formation de falaises vives et bien marquées dans la morphologie. La variété est accentuée par la couleur jaunâtre de la roche mais aussi par le profil abrupt et accidentée de ces falaises reflétant l'exploitation différentielle, par les vagues, des inégalités de résistance, des nombreux plans stratigraphiques et du pendage des bancs de grès pliocène. Tout cela est à l'origine d'une importante variété paysagère et explique l'attractivité, notée depuis longtemps, du site. Dans un texte remontant à la fin du dix-neuvième siècle par exemple, on lit que « *Les îles de la madrague de Monastir nommées El Havisan, Sidi-bou-el-Fadel-el-Ghedamsi et El Oustani, pittoresques quoique nues* » (Perpetua, 1883). Cette attractivité va, on le verra, être exploitée au maximum au cours des temps récents, mais non sans problèmes.

Les traces anciennes les plus variées de présences ou d'interventions humaines se trouvent dans l'îlot El Ghdamsi. Ils correspondent, sur le rivage, à des carrières anciennes dont certaines remontent à l'Antiquité (Slim *et al*., 2004). A l'intérieur de l'îlot, différents écrits ont signalé des puits ou silos antiques souvent dits en forme de bouteille (Tissot, 1888 ; Carton et Deyrolle, 1904) ainsi que des citernes creusées dans le rocher qui remonteraient à l'époque punique (Tissot, 1888). Le Comte Filippï signale aussi des racines de murs, des pavements de mosaïque romaine et des tombeaux antiques (Société française d'histoire d'outre-mer, 1926). D'un autre côté, différents écrits se sont attardés sur un bassin creusé dans le rocher au pied de la falaise dans la partie nord-est de l'îlot et auquel les habitants donnent le nom de *Hammam Bent Essoltan* (le bain de la fille du roi). Tissot (1888) le décrit comme un « *bassin, dans lequel la mer pénètre par deux coupures, est entouré d'un banc ménagé dans le rocher, et se termine au sud-ouest par une sorte de réduit semi-circulaire et voûté, également entouré d'un banc* ».

Carton et Deyrolle (1904) en font un rapprochement avec un autre aménagement balnéaire ancien dans la falaise du côté du continent, aujourd'hui appelé El Kahlia. Cet îlot porte aussi les vestiges de la Tonnara déjà évoquée. Enfin, des recherches archéologiques récentes de l'Institut National du Patrimoine ont confirmé l'existence à son extrémité nord d'un Ribat (fort) d'époque islamique (Slim *et al.,* 2004).

Mais l'un des aspects qui ont le plus retenu l'attention dans ces îlots de Monastir est celui de l'existence de grottes de forme géométrique creusées dans les parois gréseuses. On les rencontre à El Ghedamsi, à El Mida et surtout à Oustaniya. L'atlas préhistorique (Mtimet *et al*., 1992) ne confirme pas leur existence dans l'îlot El Hmam. Mais un travail plus ancien y signale l'existence de « deux séries de grottes » (Ministère de l'instruction publique, 1887).

Certains ont vu dans ces grottes, au départ, des chambres creusées par des pêcheurs ou qui *« auraient servi à l'époque chrétienne de retraite aux moines, puis, plus tard elles auraient été habitées par des passagers faisant quarantaine. De là serait venu le nom de l'île*» (Bournand,1893). Mais l'interprétation qui sera retenue est celle de chambres funéraires, tombes remontant à l'époque punique. Dans le travail de Tissot (1888), on trouve que l'îlot El Oustaniya est « *percé d'une cinquantaine de cellules carrées, hautes de 2 mètres environ et mesurant pour la plupart 2m,5o sur chaque côté. Quelques-unes de ces cellules sont isolées, d'autres communiquent entre elles. Toutes présentent dans leurs parois latérales des niches qui semblent indiquer que ces grottes artificielles ont été habitées. Barth suppose qu'elles ont été utilisées pour la pêche du thon. Il leur attribue d'ailleurs une origine fort ancienne, et elles paraissent effectivement dater de l'époque punique*». Deyrolle, le premier à les examiner de près, les interprète comme des tombes du type haouanets. Il établit des analogies avec des groupes de haouanets au lieu-dit El Harouri dans le Cap Bon au Nord-Est du pays et décrit les 33 haouanets, les mieux conservés (Carton et Deyrolle, 1904). On découvre alors qu'il s'agit de chambres situées à différents niveaux avec parfois des communications et portant différents éléments d'architecture. Plus tard, Sayadi (1979) a donné un relevé d'une partie de ces haouanets montrant la complexité de leur agencement. Malheureusement, tout ce patrimoine ainsi que l'îlot ont, on y reviendra, disparu récemment suite à différents aménagements.

1.3. L'îlot Eddimesse

Cet îlot, connu aussi sous l'appellation Eddzira ou Al Jazira, fait face au promontoire qui porte les ruines de l'antique *Thapsus*. Aujourd'hui, on voit un seul îlot séparé du continent, au niveau de sa pointe orientale, par un chenal de presque 100m de largeur mais celle-ci devient plus importante du côté ouest atteignant quelque 250m. La carte topographique de Moknine à l'échelle 1: 50000, établie sur la base de travaux de terrain exécutés en 1895 et complétée en 1931, représente un deuxième îlot secondaire. Ceci revient aussi dans des textes datant de la fin du dix-neuvième siècle (Perpetua, 1883 ; Tissot, 1888). Perpetua cite deux îlots en les désignant par les « Sœurs ». Cependant, une carte dressée au Dépôt de la guerre d'après les observations de Falbe, Pricot et Ste Marie et éditée, en 1857, sous le titre de « Carte de la régence de Tunis » ne mentionne que l'îlot principal. De son côté, une carte un peu plus ancienne établie par le cartographe Pellissier (1853), montre deux îlots bien tranchés. Mais aucun des documents n'indique une continuité avec le continent.

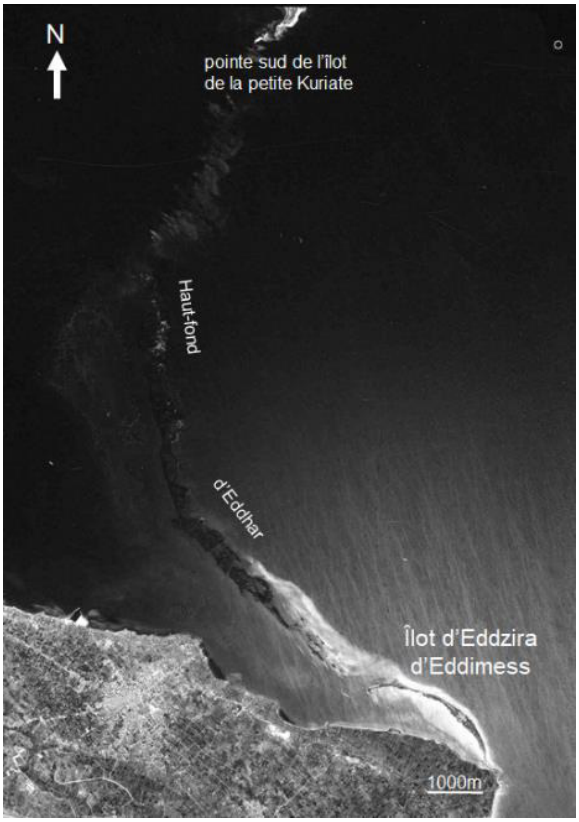

Figure 2 - *L'îlot d'Eddimess et le haut-fond d'Eddhar.*

L'île principale a toutes les caractéristiques d'une plage du type île barrière dont la partie médiane est légèrement dunifiée et occupée par une végétation psammophile très clairsemée. Le seul affleurement consolidé que nous y avons rencontré, par points très localisés sur le rivage oriental, correspond à un grès jaune probablement pliocène ou même à un beach rock récent. On pourrait penser, au premier abord, à une flèche littorale, formée par les apports de la dérive qui court ici du Sud vers le Nord, puis isolée par érosion de sa racine. Mais il semble qu'on a davantage affaire, même si la dérive littorale a pu intervenir, à l'émersion, par accrétion verticale, de la partie méridionale d'un haut-fond qui s'étire en direction des îlots des Kuriate (fig. 2). Connu sous l'appellation d'Eddhar (le dos en arabe), ce haut-fond se caractérise par la grande faiblesse de sa profondeur. La carte marine intitulée « Du Ras Dimas au Ras Kapudia » et datée de 1887 en représente la partie méridionale sur une longueur de l'ordre de 10 km. On y voit que les profondeurs sont toujours inférieures à 1m.

Quoiqu'il en soit, la morphologie d'îlot n'est pas très récente. Elle est mentionnée par les écrits, déjà évoqués, datant du dix-neuvième siècle et aurait même existé au cours de l'Antiquité : « *Le port marchand de Thapsus n'était probablement pas autre chose que le chenal qui s'étend entre la terre ferme et la longue île sablonneuse et basse, accompagnée d'un îlot, qu'on remarque au nord du cap Dimas* » (Tissot, 1888). Cependant, et en dépit de son voisinage des importantes ruines de *Thapsus*, cet îlot ne renferme pas des traces d'une occupation humaine ancienne. Le seul vestige est un fragment de mur mis au jour sur l'estran oriental de sa partie centrale. On ne sait pas encore s'il constitue ou non la partie apparente de vestiges plus importants disparus par érosion marine ou encore cachés sous le sable des petites constructions éoliennes ? Des vestiges importants ont en effet, parfois été révélés suite au retrait du rivage ou après des tempêtes dans d'autres rivages sableux de la Tunisie. Ce fut le cas par exemple, dans la plage de Rejiche lors de la tempête qui a frappé la côte du Sahel en mars 2012 (Oueslati, 2016a).

1.4. Les îlots de Rass Kaboudia (ou Rass Kabo)

Ici aussi, il s'agit d'un petit archipel avec un îlot principal (El Gataia), un îlot secondaire (Jbel) et de quelques îlots beaucoup plus petits à minuscules. L'ensemble appartient à la côte de la ville de Chebba et se trouve en face de la pointe du promontoire de Rass Kaboudia. Tout comme pour le cas de Rass Eddimesse, il s'agit d'îlots sableux, un modelé de plage du type île barrière légèrement dunifiée dans sa partie médiane. Mais on n'y voit pas de matériel

géologique ancien ayant pu servir d'ancrage. Les rares affleurements indurés correspondent à un *beach-rock* très faiblement cimenté, formé en fait, comme on le verra, parallèlement au retrait du rivage. Les altitudes sont toujours très basses et ne dépassent 1m qu'au niveau de petites constructions éoliennes parsemées par des touffes d'une végétation herbacée pasammophile.

En fait, El Gtaia n'a pas été toujours en situation d'îlot. Dans différents documents, il est représenté collé au continent ce qui a permis de l'interpréter comme une flèche littorale formée par les apports de la dérive littorale qui vient du Nord (Paskoff et Oueslati, 1982). C'est le cas sur la carte marine de 1887. C'est le cas aussi sur la carte topographique de Chebba à l'échelle 1:50 000. Cependant, la carte, plus ancienne, du Dépôt de la guerre (1857) représente un îlot bien détaché du continent. La même représentation apparait sur d'autres cartes de la même époque. C'est le cas par exemple, de la carte de Pellissier (1853), même si l'îlot est placé plutôt du côté nord du Cap Kaboudia. En fait, il s'agit aussi, en plus de la dérive littorale et comme pour l'îlot d'Eddimesse, d'une évolution influencée par la position dans le prolongement d'un haut fond. Ce dernier, très net sur la carte marine précitée, s'étend en direction du Sud sur une longueur d'environ 17km avec une largeur variable, pouvant atteindre localement 3,5km. Partout, il est à une profondeur inférieure à 1m. C'est au niveau de ces parties les plus hautes qu'apparait l'îlot Jbel ainsi que les autres îlots beaucoup plus petits. Notons aussi que les profondeurs augmentent de façon assez brusque sur la face externe du haut-fond. Ce qui explique l'importance du rôle que peuvent jouer les vagues surtout que cette face est exposée aux vents du Nord-Est dominants dans la région.

Enfin, contrairement à tous les autres îlots du Sahel, les observations effectuées dans ce petit archipel ne nous ont permis de trouver aucun indice d'une occupation humaine ancienne.

1.5. Les îlots de la côte de Melloulèche ou de RassEddzira

Il s'agit d'abord de deux îlots situés en face du petit promontoire de Rass Eddzira (Cap de l'île) et dont le plus grand est connu sous l'appellation de Dziret El far (l'île du rat). Trois autres îlots plus petits et parfois minuscules, mais non sans importance pour la compréhension de l'évolution récente de la côte comme on le verra, existent du côté nord.

Tous ces îlots devancent une côte très basse et sont à l'intérieur de l'isobathe de 1m qui se trouve parfois à 3km au large du rivage du continent, selon la carte marine levée en 1884 et publiée en 1888 par le service

hydrographique de la marine sous le titre « *Du Ras Kapudia à Sidi Makhluf* ». A cette faiblesse topographique et bathymétrique s'ajoute une faiblesse de la houle du fait de la position dans une baie et de la protection assurée par le promontoire de Rass Kaboudia contre la houle du Nord-Est. Par contre, le marnage prend de l'importance par rapport aux sites des îlots précédents. On est déjà dans la partie nord du golfe de Gabès connu par l'importance de sa marée.

L'îlot El Far n'est qu'à quelque 750m du rivage du continent. Sa superficie est de l'ordre de 4ha avec une longueur maximum de 360m pour une largeur moyenne d'une centaine de mètres et des altitudes atteignant à peine 2m (1m sur la carte topographique de Chebba à l'échelle 1: 25 000). Les autres îlots sont beaucoup plus petits et ont respectivement, du Sud au Nord, une longueur de 100m, de 120m et de 32m et une largeur de 35m, de 20m et de 15m. Le plus méridional et le plus septentrional n'émergent vraiment que par mer calme et marée basse.

Dans un tel cadre, la végétation est très faible ou réduite, en fonction des légères variations topographiques, à une formation herbacée steppique discontinue ou à des plantes halophiles formant parfois une couverture assez continue du type chott. Des taches plus ou moins importantes sans végétation existent aussi offrant un paysage de petites sebkhas.

La géologie est la même que celle du rivage du continent. Les coupes offertes par les petites falaises d'El Far par exemple, montrent la même succession que celle des petites falaises du promontoire d'Eddzira. L'essentiel correspond à une croûte calcaire épaisse de quelques décimètres et plus résistante dans sa partie supérieure. Elle surmonte des argiles mio-pliocènes et est couverte par des placages de dépôts marins à serpulidés et *Strombus bobonius* attribués au dernier interglaciaire (Paskoff et Sanlaville, 1983). Le tout passe sous deux nappes alluviales limono-sableuses. La plus ancienne montre des formes d'encroûtements calcaires et est considérée comme würmienne. La plus récente est meuble et emballe des tessons d'une poterie romaine (Slim *et al*., 2004), elle est bien connue en Tunisie où on pense que sa mise en place a commencé sous les yeux des anciens (Oueslati et Marzougui, 2017). A l'intérieur de l'îlot, les traces de l'occupation humaine sont des restes de structures bâties ainsi que des tuiles et amas de moellons. La céramique associée à ces vestiges est comparable à celle étudiée dans l'important site archéologique qui occupe le promontoire de Rass Eddzira précité où elle a été attribuée à l'époque byzantine (Slim *et al*., 2004). Dans les autres îlots, on retrouve surtout les niveaux supérieurs de cette succession, également taillés par une microfalaise.

Figure 3 - *L'îlot El Far, vu depuis le promontoire de RassEddzira, au premier plan, le matériel caillouteux provient des ruines. Il est accumulé au bord de la mer comme forme de protection, par les paysans, contre le recul de la microfalaise.*

2. Depuis l'Antiquité : des modifications dans la configuration des rivages, dans le cadre d'une montée marine aux effets parfois accentués par une subsidence active

L'idée d'un changement important au niveau de la configuration de l'ensemble du littoral de la région au cours des temps récents n'est pas nouvelle. Le terrain offre, en particulier, par certaines de ses caractéristiques, comme la faiblesse de la bathymétrie et de la topographie ainsi que la configuration des rivages et la morphologie sous-marine, des conditions de sensibilité aux variations du niveau marin. Despois (1937) pensait, déjà au cours des années 1930, que les îlots des Kuriate formeraient vite une presqu'île en tombolo si le niveau marin s'abaissait seulement de 3 ou 4 mètres. En effet, avec un tel niveau et même avec seulement une baisse du niveau marin de 1m, le haut-fond d'Edhar serait largement exondé. C'était vraisemblablement une voie que l'homme a emprunté à certains moments de l'histoire de la région pour se rendre aux îles Kuriate. En fait, ce haut-fond a retenu l'attention de façon particulière. Il est présent dans différentes cartes anciennes où il est parfois mis en relief, sans doute à cause de sa forte perception par la population (fig. 4). Il revient aussi dans différents textes (Tissot, 1888, Avezac, 1948). Tissot est allé jusqu'à y voir les «*vestiges d'un ancien archipel qui représentait lui-même les restes d'une terre basse, submergé*», que les Kuriate sont probablement les *Tarichiae* indiquées par Strabon entre Hadrumète (Sousse) et *Thapsus* et que les hauts-fonds représenterait les «*îles nombreuses et serrées* ». En partant d'indications du Stadiasme, le même auteur pense que la submersion se serait produite, entre

l'époque punique et le premier siècle de notre ère et qu'elle s'est continuée au second siècle.

Pour notre part, en partant des données du terrain, deux secteurs nous ont paru offrir des éléments expressifs de possibles modifications importantes, postérieurement à l'Antiquité, dans la configuration d'ensemble de la côte et des îlots ainsi que dans les liens de ces derniers avec les rivages qu'ils devancent. Le premier secteur appartient à la côte de Melloulèche au Sud de la ville de Chebba, plus précisément au niveau des îlots El Far. Le second correspond à la côte de la presqu'île de Monastir et ses îlots rocheux.

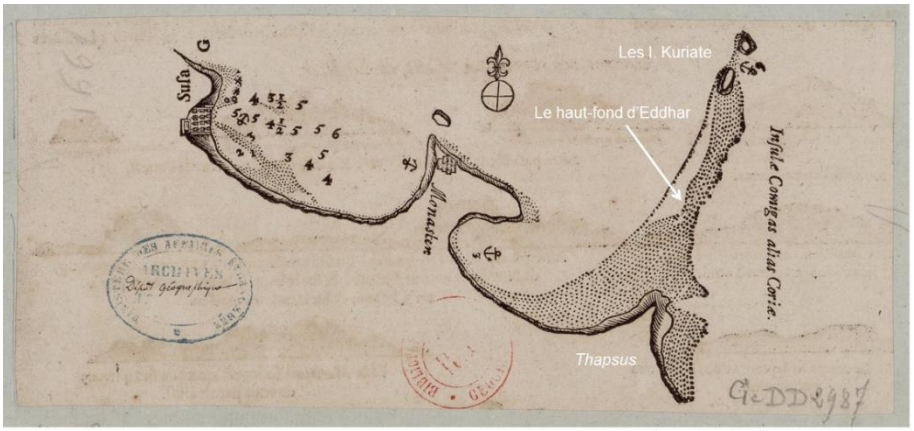

Figure 4 - *Carte « Monasten, Insulae Comigas alias Coriae » ; date d'édition 1600-1699. Source : Bibliothèque nationale de France, département Cartes et plans, GE DD-2987 (7991).*

2.1. Les îlots de la côte de Melloulèche

L'îlot El Far offre, par sa forme ainsi que par sa position et son contenu, les témoins d'une évolution sensible postérieurement à l'époque romaine. La parfaite ressemblance entre sa géologie et celle du continent voisin, la contemporanéité de ses vestiges archéologiques avec ceux du site qui occupe Rass Eddzira auquel il fait face et surtout l'existence d'une nappe alluviale emballant une céramique antique impliquent qu'il était encore collé au continent jusqu'à, au moins, l'époque romaine. Sinon on ne comprendrait pas comment ont été mis en place ces dépôts dans un espace aussi exigu et sans pente ni bassin-versant. Pour les mêmes raisons, l'îlot qui se trouve à environ 350m au Sud-Est de lui, devait lui être soudé au cours de l'Antiquité. La localisation et la forme de ces îlots ainsi que ceux situés plus au Nord, d'ailleurs, ne manquent pas aussi d'expressivité. Ils sont très souvent d'ilots

localisés au droit de promontoires et allongés dans la même direction qu'eux. Ils ne seraient en fait que des formes résiduelles, des témoins apparus consécutivement au retrait du rivage et à leur tronçonnage.

Un telle évolution suppose une érosion marine importante. Or, le rivage est en partie rocheux et les vagues sont sans grande énergie à cause de la faiblesse de la bathymétrie et du caractère abrité de la côte. L'explication doit en réalité se trouver, comme dans d'autres rivages de la moitié nord du golfe de Gabès dont fait partie le site, dans une conjoncture marquée par une variation positive du niveau marin accentuée par une subsidence active. Sur la même côte, à une quinzaine de kilomètres au Sud de Rass Eddzira, le port de l'antique *Acholla* est de nos jours sous plus d'un mètre d'eau. Dans l'archipel des Kerkena, appartenant à la même aire géographique et situé à une quarantaine de kilomètres vers le Sud-Est, ont été décrits des indices d'un important retrait du rivage ainsi que de nombreux vestiges archéologiques romains submergés. La tranche d'eau qui couvre ces derniers dépasse souvent un mètre et atteint parfois deux mètres. De telles valeurs, supérieures à la moyenne (20 à 40 cm) de la montée marine enregistrée depuis l'Antiquité dans les parties jugées tectoniquement stables du littoral tunisien, sont expliquées par le caractère subsident du terrain (Oueslati, 1995a ; Slim *et al*., 2004, Oueslati, 2016c).

On serait alors tenté de penser que le rivage s'est trouvé lors de l'Antiquité, au moins, au niveau de la limite externe de la zone située entre le rivage actuel et l'isobathe 1m et représentée par le symbole de marais sur la carte marine et la carte topographique de Chebba au 1:50000. Il n'est pas exclu que certains des hauts fonds de forme circulaire situés un peu plus vers les larges signalés par un point d'interrogation sur la figure 5 soient des îlots déjà ennoyés d'autant que certains d'entre eux se trouvent dans le prolongement des petits promontoires qui accidentent le tracé du rivage du continent. Les tous petits îlots faits d'un matériel géologique en place prennent ainsi, en dépit de leur taille, une grande importance. Ils constituent, à la différence des îlots sableux dont l'évolution peut parfois s'inscrire dans des modifications localisés dans le temps et commandées par la dynamique sédimentaire en cours comme on le verra, les témoins ou jalons d'une tendance évolutive du littoral auquel ils appartiennent. Les plus petits d'entre eux seraient d'ailleurs, dans le cadre de la même évolution, en cours d'une disparition qu'accentuera l'élévation marine annoncée dans le cadre du changement climatique. Une telle situation ne manque pas, par certains de ses traits, de rappeler ce qui aurait prévalu à la veille de la disparition, évoquée par différents textes anciens, d'autres îlots dans le golfe de Gabès et ses abords méridionaux. On pense en particulier à l'îlot de Zizou cité par Idrissi au douzième siècle à l'Est de l'île de Jerba, à

l'îlot de Secco di Palo qui se trouvait, il y a encore quatre siècles seulement, en face de la côte de Zarzis (Burollet, 1979) ou à l'îlot El Beit au large de la côte nord-est de l'archipel kerkenien évoqué dans différentes relations de voyages au Moyen Age comme celles d'El Bekri et d'El Idrissi (Oueslati, 1995a). Des illustrations expressives d'une réduction importante de la superficie d'îlots ou d'un changement sensible de la configuration de leur rivage ont également été décrites dans l'archipel des Kneiss (Trousset *et al*., 1992).

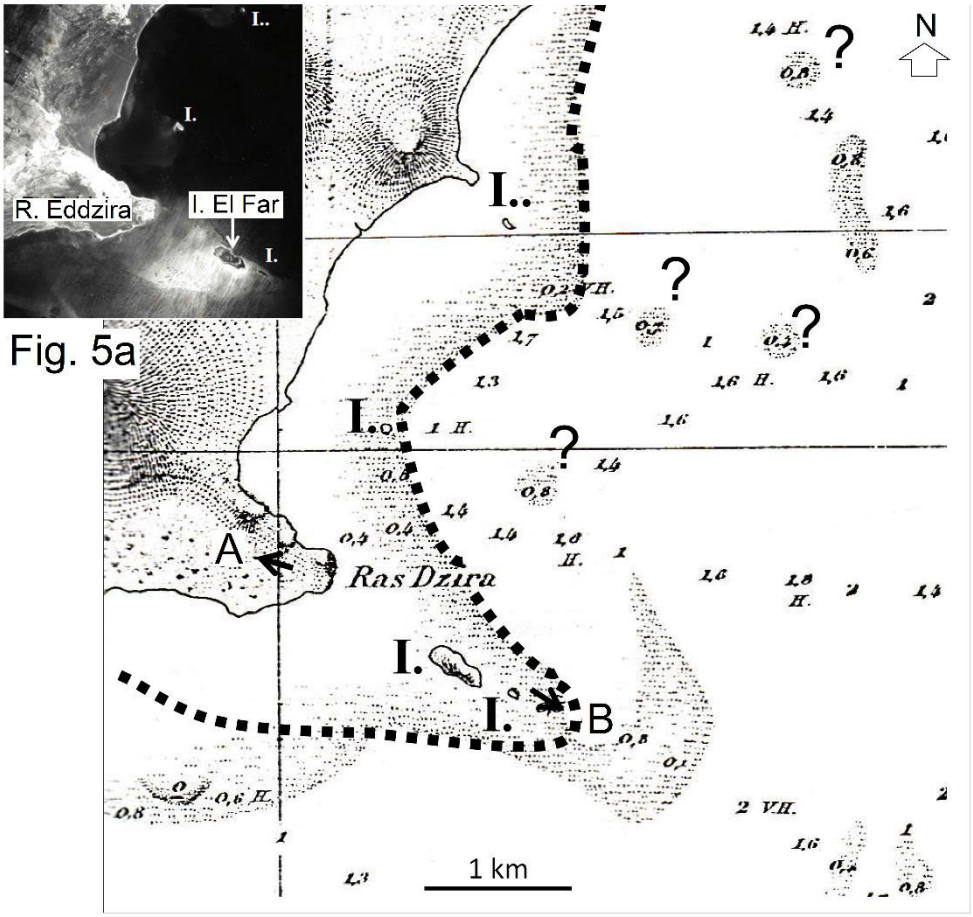

Fig. 5a

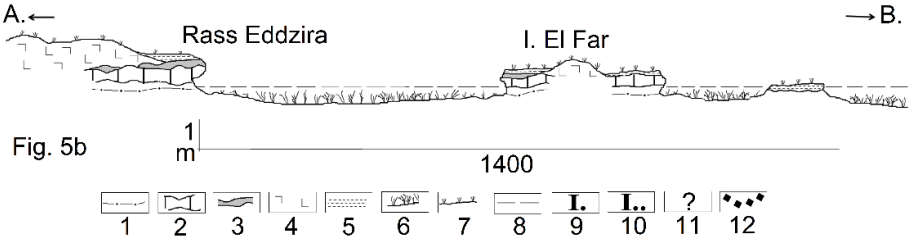

Fig. 5b

Figures 5a et 5b - *Les îlots des environs de Rass Eddzira dans la côte de Melloulèche, leur position par rapport au rivage du continent (sur un extrait de la carte marine de 1888 et un extrait d'une photographie aérienne -Photo N°2, mission LXXXII/250, 1963) et coupe A-B entre le Cap et les deux îlots qui lui font face.*

1-argiles sableuses mio-pliocènes, 2-croûte calcaire du Quaternaire moyen ou ancien, 3-placcages marins tyrrhéniens, 4-ruines romaines, 5-alluvions remaniant une céramique tournée antique, 6-Cymodocées et herbier de posidonie, 7-végétation halophile et steppique, 8-niveau de la mer par marée haute de vives eaux, 9- îlot , 10-îlot représenté sur la carte marine et sur la photographie aérienne et non sur les cartes topographiques récentes, 11-probable îlot submergé, 12-tracé minimum du rivage au cours de l'Antiquité.

2.2. Les îlots de Monastir

Dans ces îlots, on est interpellé, en particulier, par les grottes interprétées comme des tombes ou Haouanets d'époque punique. Car, on pourrait se demander sur la raison qui a poussé leurs auteurs à les creuser dans des îlots baignés par des eaux d'une côte à mode battu. De plus, par gros temps les vagues atteignent des hauteurs dépassant le niveau des tombes les plus basses (fig. 6). Une justification par la nature de la roche qui se prête bien à la taille ne parait pas suffisante. Car, la même roche affleure dans différentes parties de la falaise du côté du continent.

Aussi, différents questionnements peuvent-ils se présenter. S'agissait-il vraiment d'un choix délibéré d'une population qui a opté pour une traversée de l'eau, par les différents types de temps, avec leurs morts ? N'aurait-on pas plutôt une indication d'un changement dans les conditions du milieu et de la position du rivage, depuis ? Les îlots n'étaient-ils pas baignés par une eau beaucoup moins continue ou bien moins profonde que de nos jours surtout du côté de leur face donnant sur le continent ? N'étaient-ils pas reliés à la terre ferme, par des plages du type tombolos par exemple, ou même par une plage large, épaisse et continue ou tout autre type d'accumulation permettant une marche les pieds secs ? Cette accumulation serait constituée par exemple, par des épandages de matériaux arrachés, par le ruissellement, à la falaise de Monastir dont le front est par ailleurs découpé par plusieurs ravins aujourd'hui largement estompés par différents aménagements (Oueslati, 1992). Ceci est d'autant plus légitime qu'on sait que postérieurement à l'Antiquité une phase d'alluvionnement importante a eu lieu. On en a vu des témoins même dans des terrains sans relief comme dans le cas de l'île El Far et ses environs présentés ci-dessus (Oueslati, 1995b). Dans la partie méridionale du golfe de Gabès, les accumulations liées à une telle phase ont réussi de repousser le rivage sur plusieurs hectomètres transformant des

falaises, comparables par leur commandement à la falaise de Monastir, de falaises vives en falaises mortes (Oueslati, 2002).

Figure 6 - *Dans la face ouest de la partie sud de l'îlot de Ghedamsi : un hanout, peut-être deux selon Mtimet et al. (1992), vu que le mur de séparation a disparu. La photo est prise par mer très calme, en été. La ligne blanche discontinue marque le somment de la partie noircie de la roche qui donne une idée sur le niveau régulièrement atteint par les vagues de mer en agitation courante. Elle souligne aussi le sommet d'une encoche de profondeur dépassant parfois 1,5m. Mais lors des tempêtes l'eau envahit les haouanets (photo Google Earth).*

Ces questionnements sont d'autant plus légitimes qu'on sait que le niveau marin actuel est supérieur à celui de l'Antiquité. Une variation positive d'au moins quelques décimètres est aujourd'hui établie (Oueslati *et al*., 1987, Slim *et al*., 2004). La côte de Monastir en donne des preuves parmi les plus significatifs. En effet, près du marabout de Sidi Mansour, dans le quartier El Karraiia situé à quelques centaines de mètres au Sud des îlots, on peut observer sous l'eau des cuves submergés (fig. 7) interprétés comme des viviers à poisson antiques (Slim *et al*., 2004). Or, un relevé bathymétrique (fig. 8) réalisé récemment dans le cadre d'une étude sur la vulnérabilité du littoral tunisien à une élévation du niveau marin (Apal-PNUD-IHE, 2012) montre que l'île El Oustaniya qui compte, on l'a vu, le plus grand nombre de tombes, ainsi que les îlots El Mida et la partie interne de l'îlot Ghedamsi sont baignés par des eaux dont la profondeur est inférieure à 1m. L'isobathe de 1m est située à plusieurs décamètres au large des îlots El Mida et de la partie occidentale El Oustaniya.

En considérant la remontée marine enregistrée postérieurement à l'Antiquité ainsi que le déplacement du rivage et l'érosion qui a dû l'accompagner dans ce littoral à mode battu, sans doute aussi un abaissement du fond dans le milieu infralittoral, on est tenté de pencher vers l'hypothèse d'un changement sensible dans les conditions du milieu. Les îlots étaient, très

vraisemblablement, à part celui El Hamam et la partie externe de l'îlot El Ghdamsi, en contact direct avec la terre ferme, au plus, les vagues atteignaient seulement leur face externe. L'îlot El Hmam dans lequel sont signalés des haouanets ne serait pas encore isolé de l'îlot El Ghedamsi. La distance qui sépare ces deux îlots n'est aujourd'hui que de quelques décamètres, donc plutôt négligeable en comparaison avec l'évolution enregistrée dans le cas du secteur de Rass Eddzira où le rivage a reculé de plusieurs hectomètres dans un milieu à bathymétrie très faible. Doit-on aussi rappeler au passage, qu'à Mahdia, toujours sur le littoral du Sahel, existent des tombes puniques (Ben Younès, 1981) creusées dans le même type de roche et qui ont été en partie annexées au domaine marin. Elles sont aujourd'hui étalées sur le domaine supralittoral et la partie interne du domaine médiolittoral. Ici, la tranche d'eau qui les couvre est épaisse de deux à quatre décimètres (Oueslati, 2004).

Figure 7- *L'une des cuves submergées interprétées comme viviers à poisson antiques. La photo est prise par marée basse. D'autres bassins ont été couverts par l'enrochement.*

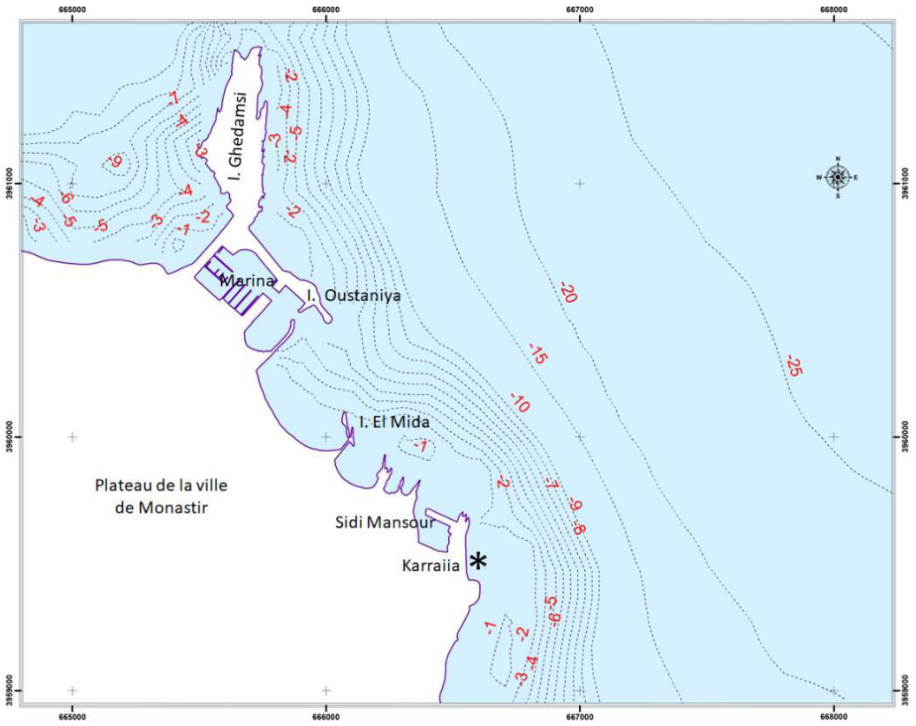

Figure 8 - *La bathymétrie autour des îlots de Monastir (les chiffres donnent la valeur, en mètres, des isobathes). A noter que le croquis représente les îlots dans leur état actuel, reliés au continent, aspect qui sera évoqué dans la dernière partie de l'article. L'étoile indique l'emplacement des viviers à poisson antiques submergés. (Carte établie dans le cadre de la carte de la vulnérabilité du littoral tunisien à l'élévation du niveau de la mer due aux changements climatiques -APAL-PNUD-IHE, 2012-, communiquée par Rafik Ben Charrada que je remercie).*

3. Aujourd'hui, une tendance érosive dominante et une anthropisation parfois très destructrice

Les îlots du Sahel n'ont pas bénéficié, à la différence d'autres parties ou espaces insulaires du littoral tunisien, de travaux importants visant leur conservation et protection. Les quelques efforts méritant d'être signalés ont porté sur des questions en rapport avec la biodiversité sous-marine, la protection de quelques points particuliers dont notamment des zones humides pour l'avifaune qu'elles accueillent ou les Kuriate considérés comme la principale aire de nidification, en Tunisie, pour la tortue caouanne *Caretta caretta* (Programme des Nations Unies pour L'Environnement-Plan d'Action pour la Méditerranée, 2008). Les formes de dégradation par érosion ou par destruction de différentes composantes du patrimoine naturel et culturel suite

à une anthropisation parfois excessive et imprévoyante sont en tout cas bien plus nombreuses et ne semblent pas connaitre un freinage efficace. Les dégâts les plus lourds, et souvent incompréhensibles, sont causés par les aménagements ayant conduit au rattachement des îlots au continent.

3.1. Des îlots grignotés par la mer

Seuls les Kuriate montrent quelques segments de rivages sans érosion nette ou qui connaissent une forme d'extension aux dépens de mer (fig. 9). Une telle évolution caractérise surtout les secteurs tournés vers le continent et apparait comme la contrepartie de l'érosion des autres parties de la côte ouvertes sur le large et à mode bien plus battu. De fait, ces îlots ayant une forme allongée, la houle est diffractée sur leur face septentrionale la plus exposée, les courants qui en résultent poussent les débris vers les rivages méridionaux abrités. C'est en somme une dynamique qui rappelle celle à l'origine des plages en forme de queues de comètes. Dans la grande Kuriate, un modelé de rides légèrement dunifiées et séparées par des sillons occupés par des marécages s'est formé parallèlement au déplacement du rivage. On le voit clairement sur des images de Google Earth récentes. Il faut préciser toutefois que les accumulations sont les plus nettes, sur les images prises au cours de la saison estivale. Un renversement de situation, provisoire, peut apparaître sur celles prises au cours de la saison hivernale. Mais le bilan est pour la progradation.

Dans les autres parties de ces îlots ainsi que dans les autres îlots du Sahel, les formes d'érosion dominent et leurs effets sont les plus apparents là où les vagues ont affaire à des corps très bas et faits de matériaux tendres ou contrastés. Les aménagements imprévoyants ont accentué le problème. Dans l'ensemble, il est possible de distinguer trois principaux types de situations : les rivages faits d'un matériel rocheux assez homogène, les rivages très bas faits d'un matériel hétérogène et les rivages des îlots sableux.

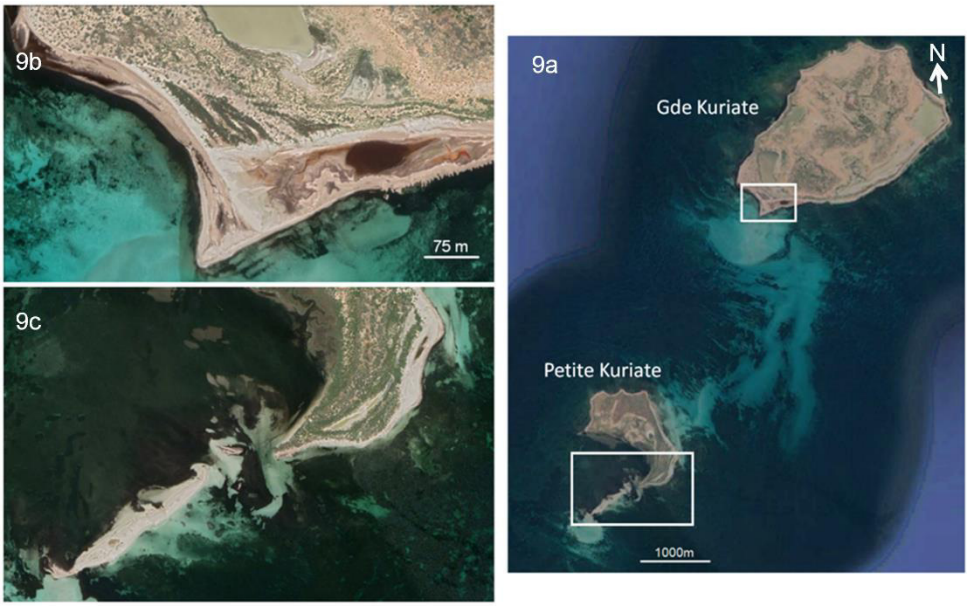

Figure 9 - *La partie méridionale des îlots des Kuriate (9a) (sur une image Google datée du 28 mai 2019): dans la grande Kuriate (9b), on reconnait des rides sableuses (alignements clairs) séparées par des espaces marécageux (parties sombres) ainsi qu'un tentacule de plage prolongé par une zone d'atterrissement de sédiments sous l'eau. Dans la petite Kuriate (9c), la langue de sable est en fait allongée dans le même sens du haut-fond d'Eddhar, visible sur les figures 2 et 4 et couvrirait le matériel rocheux évoqué par Henry (1824) et Tissot (1888).*

3.1.1. Les rivages faits d'un matériel rocheux assez homogène

Ce type de situation intéresse tous les îlots de l'archipel de la ville de Monastir, excepté l'îlot El Enf. Il intéresse aussi la face nord de la grande Kuriate. Les vagues s'attaquent au grès pliocène, très coquiller et riche en calcaire. Ce qui a favorisé une érosion biochimique (corrosion). L'évolution est lente mais elle est parfois à l'origine d'un modelé caractéristique de lapiés et de mares à encorbellement. Dans la grande Kuriate, la topographie étant très basse, le rivage correspond à une microfalaise dont le front est fortement déchiqueté. Les éléments délogés par les vagues sont parfois poussés, par les tempêtes, sur plusieurs dizaines de mètres en arrière du rivage. Dans les îlots de Monastir, caractérisés par une falaise plus haute, la corrosion est à l'origine d'une encoche profonde (fig. 6). Le modelé de mares et de lapiés est beaucoup plus apparent avec des mares à encorbellement dont le diamètre dépasse fréquemment 1m. Un tel modelé apparait parfois dans les parois des carrières anciennes ainsi que dans les parois de certains haouanets. Si bien que, s'il ne

parait pas poser de problèmes particuliers aux îlots, ce type d'érosion est en train de défigurer des éléments du patrimoine.

3.1.2. Dans les îlots très bas faits d'un matériel hétérogène

Ceci est le cas dans les îlots des environs de Rass Eddzira, notamment l'îlot El Far. Le rivage correspond, comme présenté plus haut, à une microfalaise taillée dans une superposition de matériaux hétérogènes. Ce qui a favorisé une érosion différentielle active et efficace en dépit de la grande faiblesse de l'énergie des eaux et de la bathymétrie. Les vagues façonnent, dans la partie inférieure de la microfalaise, correspondant aux argiles mio-pliocènes ou à la partie la moins résistante de la croûte calcaire, des encoches parfois profondes de quelques décimètres. L'écroulement des parties en porte-à-faux, constituées par la croûte ainsi que les matériaux qui la surmontent dont du matériel archéologique antique, est indéniable. De nombreux éboulis encombrent en effet le pied de la microfalaise et se suivent parfois jusqu'à quelques décamètres dans l'eau. L'évolution est encore plus rapide dans les îlots les plus bas et les parties du rivage où les vagues s'attaquent surtout à la couverture alluviale. Elle est attestée par des touffes de végétation déchaussés ou prêtes à basculer dans l'eau. Les nombreuses mottes de terre qui jonchent l'estran sont parfois encore accompagnées de leur végétation.

3.1.3. Dans les îlots sableux

L'évolution a été parfois suffisamment rapide pour entraîner, au cours du dernier siècle, des modifications sensibles de la position du trait de côte et parfois de la configuration des îlots. Elle est la plus manifeste là où des aménagements ont perturbé la dynamique sédimentaire. Ceci apparait bien à travers les cas des îlots Eddimess et Rass Kaboudia.

3.1.3.1. L'îlot Eddimess

Des indices d'érosion existent surtout dans la partie orientale de l'îlot où ils sont attestés par une microfalaise taillée dans le petit bourrelet de nebkas de haut de plage ainsi que par la mise au jour par les vagues d'un beach rock et des arases d'un mur ancien (Oueslati, 1993). De plus, une comparaison de photographies aériennes de 1948 et 1962 avait déjà permis de noter la rapidité

avec laquelle évoluait le tracé de la côte (Paskoff et Oueslati, 1982). L'îlot s'est allongé vers son extrémité occidentale et s'est surtout aminci dans sa partie centrale. Des photographies aériennes prises en 1988, puis les images de Google Earth encore plus récentes, révèlent la continuation de la même évolution (fig. 10). On voit que l'îlot ne cesse de se rétrécir dans sa partie centrale tout en s'étirant vers le Nord-Ouest. En même temps se forment des tentacules et bifurcations provisoires à son extrémité mobile. Il s'agit en fait d'une évolution caractéristique des îles barrières édifiées dans les milieux côtiers parcourus par une dérive littorale active mais monodirectionnelle comme c'est justement le cas ici.

On pourrait penser, la dérive littorale dominante venant du Sud, que l'érosion responsable du retrait du rivage de l'îlot est accentuée par un déficit sédimentaire causé par l'obstacle dû au port de pêche construit sur le promontoire d'Eddimesse et l'emplacement d'une jetée antique. Mais ceci n'expliquerait pas tout surtout que l'îlot est séparé du continent par un chenal où les courants ne sont pas négligeables. L'essentiel de l'évolution doit plutôt s'inscrire dans la conjoncture actuelle marquée par faiblesse des rivages sableux, surtout ceux ne bénéficiant pas d'une alimentation sédimentaire importante (Paskoff, 1993, Oueslati, 2010 et 2017).

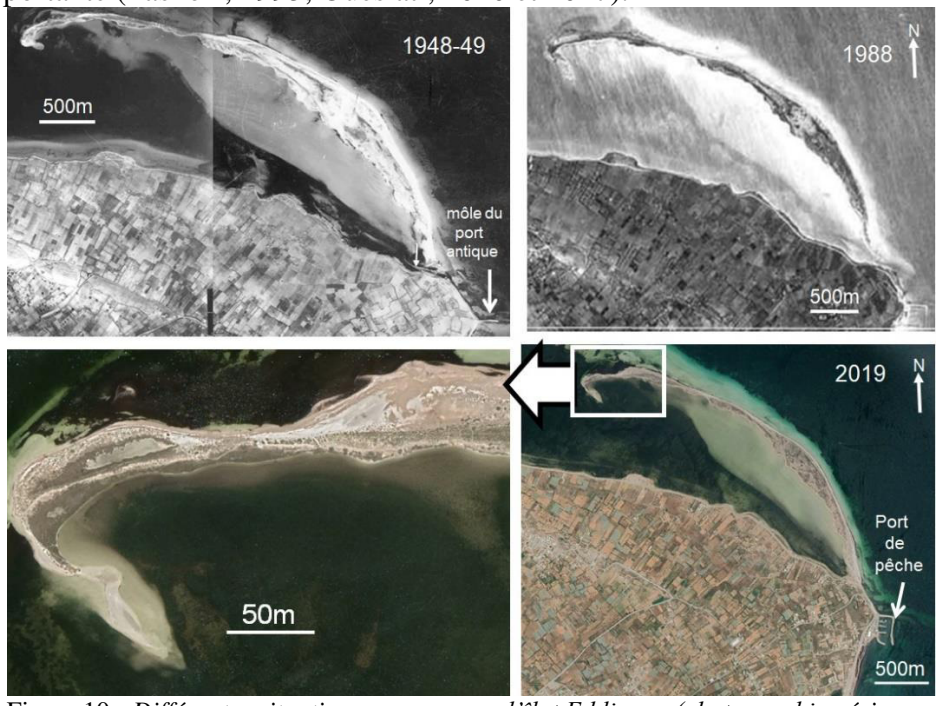

Figure 10 - *Différentes situations connues par l'îlot Eddimess (photographie aérienne et image Google Earth). On note le rétrécissement continu de la largeur de la partie centrale de l'îlot et la mobilité de son extrémité occidentale.*

3.1.3.2. L'îlot de Rass Kaboudia

Cet îlot se trouve, tout comme celui d'Eddimesse, au niveau de la racine d'un important haut-fond et a, comme lui, connu une évolution rapide. Mais il s'en distingue par le fait que le rôle de l'homme est plus direct et important surtout depuis la création d'un port de pêche aux dépens de sa partie septentrionale, la plus proche du continent. Une comparaison de documents cartographiques et photographiques étalés sur un siècle (carte marine de 1884, photographies aériennes des missions 1948, 1963, 1974 et 1985) ont permis de noter une réduction de sa largeur, accélérée à partir des années 1940. Entre 1948 et 1963, le retrait s'est fait à une vitesse supérieure à 7m par an. De 1974 à 1985, la largeur de l'îlot a été réduite de quelques 150m dans sa partie centrale, soit à un rythme annuel d'environ 13m. Corrélativement, un allongement de l'îlot a eu lieu, dans le sens de la dérive littorale principale qui porte ici vers le Sud. Il a atteint quelque 350m entre 1963 et 1974 (Paskoff et Oueslati, 1982, Oueslati, 1995a).

La création du port a causé une coupure de l'îlot des apports de la dérive littorale dominante. Les sédiments poussés par ce courant sont arrêtés par la longue jetée nord pour s'accumuler contre sa racine ou sous les eaux qui la devancent. La partie nord de l'îlot est ainsi passée d'une zone de réception à une zone de départ de sédiments. L'examen des images récentes de Google Earth montre que les conditions sont devenues nettement plus favorables au processus de l'allongement de l'îlot vers le Sud. Le transfert des matériaux arrachés aux secteurs en érosion a fini par colmater un important chenal sous-marin situé sur son chemin ce qui a accéléré l'évolution. Ce chenal avait jusque-là constitué un obstacle contre la fuite du sable, c'est ce qui explique d'ailleurs la forme, large et trapue, qu'avait l'îlot au départ et les tentacules parallèles qui caractérisaient son extrémité indiquant plutôt une évolution par élargissement (fig. 11).

Ainsi, l'îlot a fini par perdre d'importants traits de sa silhouette de départ, devenant de plus en plus long et de moins en moins large et donc plus vulnérable à l'action des vagues. Cette même évolution a, en permettant la progression de quantités de sable de plus en plus importantes vers le Sud et sur des distances plus grandes, favorisé l'îlot Jbel et semble préparer à une émersion d'autres parties du haut fond. Mais la dynamique est également en train de se faire dans le cadre d'une migration de l'ensemble du prisme sableux en direction du continent comme en témoignent les deltas de marée (*washover fans*) qu'on voit clairement sur la photographie aérienne et sur l'image de la figure 11. Ceci est en fait un signe de vulnérabilité qu'une élévation du niveau marin accentuera davantage.

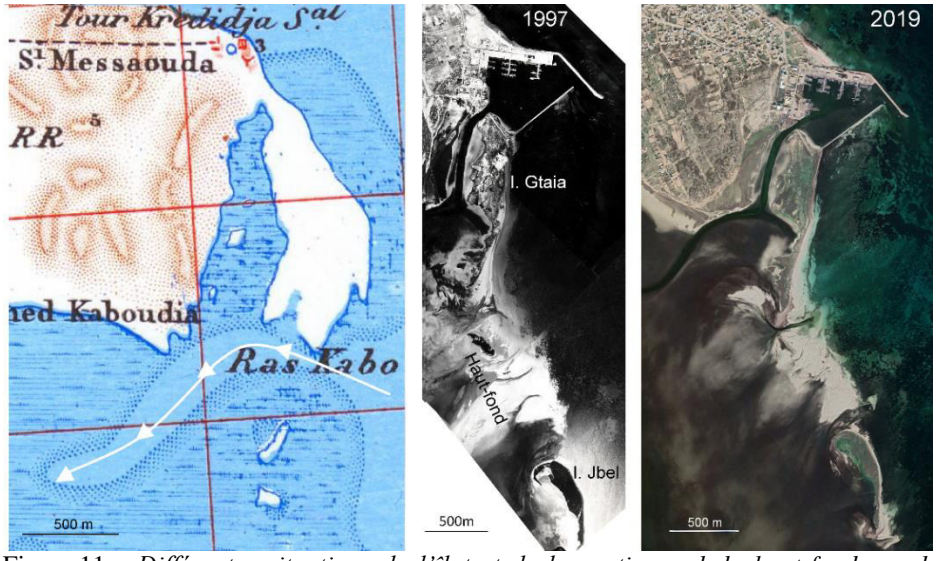

Figure 11 - *Différentes situations de l'îlot et de la partie nord du haut-fond sur des extraits de la carte topographique de Chebba (1:50000), de photographies aériennes et d'une image Google Earth. La ligne en blanc avec des flèches indique le chenal qui s'opposait à l'extension de l'îlot vers le Sud.*

3.2. Du coût environnemental et patrimonial de l'anthropisation et du rattachement des îlots au continent

La densification récente des aménagements du front de mer dans différentes parties de la côte sahélienne a commencé, depuis quelques décennies, à s'étendre aux îlots. Certains de ces derniers ont fini par être rattachés au continent et subi une artificialisation parfois excessive, perturbatrice de la dynamique naturelle du milieu, voire à l'origine de formes de destruction alarmantes. Ceci est pour le moment le cas des îlots situés à peu de distance du continent, en face des agglomérations urbaines les plus grandes. A Chebba, le cas de Rass Kaboudia a permis de donner une illustration des conséquences d'un dérèglement, par un aménagement portuaire, de la dynamique sédimentaire sur l'évolution de la physionomie de l'îlot du même nom. Mais c'est à Monastir que les effets de l'anthropisation sont les plus prononcés et leurs conséquences les plus déplorables.

3.2.1. L'exemple de l'îlot El Enf

Cet îlot, que Perpetua (1883) présente comme une « *petite île cultivée* », ainsi que la lagune de Khnis qu'il barrait ont commencé à être défigurés à la suite de la création d'une station d'aquaculture. L'îlot a été en grande partie transformé en digue, renforcée par les produits de dragage et autres travaux d'ingénierie, pour fixer le trait de côte et abriter les bassins. Mais la partie septentrionale, épargnée par cet aménagement, donne une idée sur la tendance de l'évolution qui caractérisait ce littoral. On relève en particulier les témoins d'un recul rapide du rivage matérialisé par des casiers, annexés à la mer, d'une ancienne saline. Ces casiers qui se trouvaient, au départ, en arrière du corps sableux, dans l'aire de la lagune ont été en bonne partie annexées à la en mer. Un tel retrait est, au moins en partie, dû à la diminution des apports de la dérive littorale qui vient du Nord, suite à la construction, en 1990, du port de pêche de Monastir (fig. 12). Cette érosion a en fait commencé dès avant les années 1990 avec la création d'une première digue au niveau de l'emplacement du même port. Une exploitation des photographies aériennes des missions de 1962 et de 1996 avait déjà permis de conclure à un retrait du rivage de 20 à 80m, soit à une vitesse annuelle variant de 0,58m à 2,35m (El Ati, 2000). Quoi qu'il en soit, aujourd'hui, tout ou presque, est passé sous les remblais et les constructions en dur. L'îlot, tel que Perpetua a eu la chance de voir à la fin du dix-neuvième siècle, n'est plus.

Figure 12 - *Photos prises au niveau de ce qui était encore visible en mai 2008 du corps sableux et de la lagune qu'il barrait. En bas, les vestiges des casiers des salines qui, au départ, se trouvaient du côté de la face interne de l'île.*

3.2.2. De la destruction du patrimoine archéologique

Les formes de dégradation ou de destruction d'éléments archéologiques existent dans différents îlots. Dans la grande Kuriate, les traces néolithiques ont presque disparu. La Tonnara de la petite Kuriate est aujourd'hui réduite à un paysage désolant de murs ou fragments de murs fortement corrodés. Les cuves interprétées comme des viviers à poisson antiques, décrits plus haut sont au nombre de sept et étaient tous visibles lors du déroulement du projet géoarchéologique cité en introduction. Aujourd'hui, la plupart sont passées sous une grande digue d'enrochement du port El Karraia (fig. 7), s'inscrivant dans cette série de menaces liées à la forte anthropisation et témoignant d'une continuité dans la sous-estimation du patrimoine local, souvent par insuffisances dans la connaissance de ce littoral et de la valeur de son contenu. Mais les formes de destruction n'ont cessé aussi de se multiplier dans les îlots rocheux de la ville de Monastir qui ont, à part celui d'El Hmam, pour le moment sauvé par sa position assez engagée vers le large, perdu leur insularité suite à leur rattachement par différentes digues au continent et sont devenus joignables à pied et parfois en voiture (fig. 13, 14 et 15). Les exemples les plus poignants appartiennent cependant à l'îlot El Ghedamsi et surtout à l'îlot El Oustaniya.

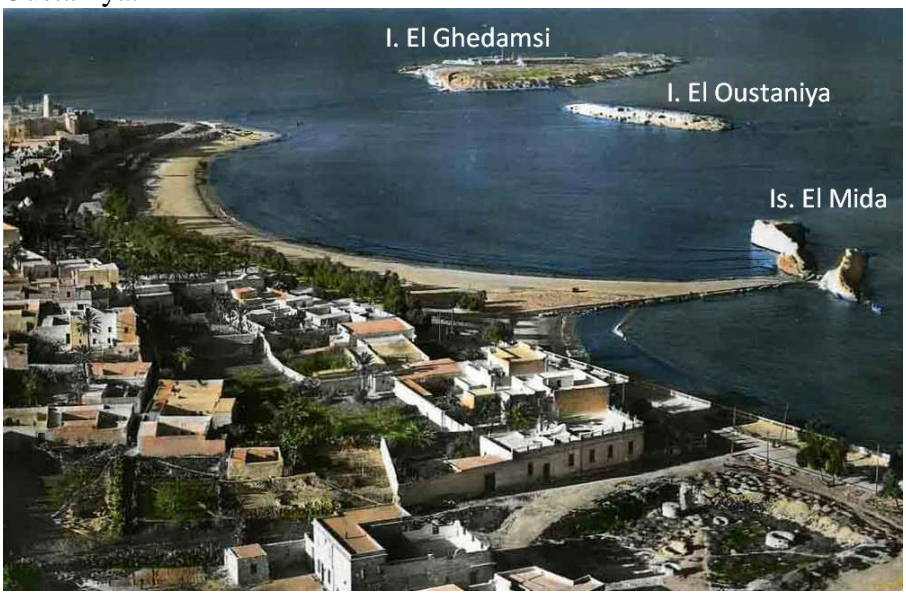

Figure 13 - *Les îlots de Monastir : la situation avant leur rattachement au continent (photo publiée par Sayadi en 1979 mais qui doit être bien plus ancienne, El Oustaniya étant déjà rattachée par les digues d'un port comme on peut le voir sur des photographies aériennes de 1963).*

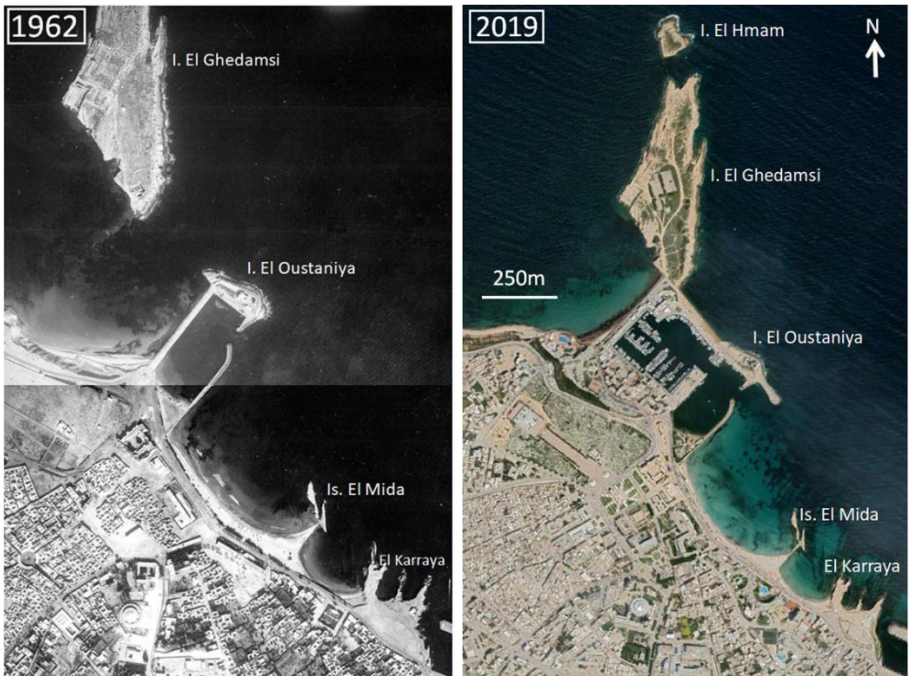

Figure 14 (à gauche)- *Les îlots de Monastir : la situation sur des photographies aériennes de la mission de 1962 (TU. 028/70, photos N° 538 et 542).*

Figure 15 (à droite) - *Les îlots de Monastir : la situation actuelle sur une image Google Earth datée du 14 avril 2019.*

3.2.2.1. Dans l'îlot El Oustaniya

L'évolution a commencé, surtout, avec la création d'un premier port conçu, comme on peut le voir sur des photographies aériennes datant de 1962 (fig. 14), de telle sorte que l'îlot, allongé Ouest-Est, serve d'écran contre les vagues et de bordure externe pour le bassin. Ce dernier est délimité, sur les autres côtés, par deux longues digues disposées perpendiculairement à l'orientation de l'îlot et dont la plus importante relie ce dernier au rivage du continent. L'anthropisation s'est intensifiée plus tard avec la création de la grande marina de Monastir qui a fini par relier, par des digues longues et imposantes l'îlot El Ghdamsi au continent et à El Oustaniya (fig. 15).

Le paysage qu'offrait l'îlot El Oustaniya, tant décrit dans différents textes, qui interpellait depuis le rivage par ses grottes et qui était programmé comme l'un des points de visite lors des excursions (Carton et Deyrolle, 1904), n'est plus (fig. 16). La description donnée par ces auteurs, il y a maintenant plus de 115 ans, est pourtant bien suggestive quant à l'originalité du lieu et partant, de l'ampleur des dommages causés: « *L'îlot de la Quarantaine (Djezeïret-el-*

Oustania) montre du rivage de Monastir les ouvertures de 23 grottes tranchant sur la belle teinte dorée des couches de grès et de sables gréseux plongeant régulièrement vers le nord ». Dans un texte plus ancien, on peut lire que l'île de la Quarantaine «*est très visitée des voyageurs, car elle renferme un grand nombre de petites grottes carrées de 2 mètres de haut sur 1^{m},80 de large* » (Bournand, 1893).

Aujourd'hui, l'îlot git sous un important enrochement et sa crête est occupée par un grand bâtiment administratif. Sa face qui offrait le paysage décrit par Carton et Deyrolle (1904) et bien d'autres auteurs archéologues et non archéologues, donne désormais sur le bassin du port. Sa base est couverte par le matériel d'une banquette large et épaisse couvrant l'emplacement des haouanets ou ce qui aurait pu en rester et échapper à la destruction des engins mécaniques.

Figure 16 - *L'îlot El Oustaniya : En bas : dessin de Deyrolle (1904) montrant la face interne de l'îlot avec ses haouanets et un relevé donnant une idée sur leur organisation et forme. En haut : photo actuelle, l'îlot fait désormais partie des digues des aménagements portuaires, il est occupé par un bâtiment récent (photo Google Earth).*

3.2.2.2. Dans l'îlot El Ghedamsi

Comparés à ceux d'El Oustaniya, les dégâts n'ont pas le même écho, dans le paysage. Mais ils sont loin d'être peu importants. La Tonnara qui apparait sur certains documents comme une construction importante est aujourd'hui réduite à des ruines très dégradées. Mais son édification a dû à son tour détruire un patrimoine plus ancien, l'îlot renferme, on l'a dit, des témoins variés d'une occupation antique. En fait, les formes de destructions se sont

produites à différents moments de l'histoire de la région et par différents moyens et acteurs. Des passages rencontrés dans certains écrits apportent des informations permettant de penser que la valeur patrimoniale a longtemps été reléguée au dernier des soucis de la population qui fréquentait l'îlot et partant, de l'autorité publique. Dans son « *itinéraire dans quelques régions du Sahar* », le Compte Filippi écrit que « *Sur l'îlot où est placée la Thonnare il y a des restes d'antiquités : j'y ai surtout remarqué des tombeaux qu'on m'a dit avoir été fouillés : à côté de ceux-ci j'ai découvert le pavé d'une chambre en superbe mosaïque composée de marbre blanc avec un contour et des fleurs soignées en différentes couleurs. J'étais dans l'intention d'en enlever une partie et lorsque j'y retournais à cet effet, je le trouvai détruit par des matelots*» (Société française d'histoire d'outre-mer, 1926).

Aujourd'hui, la mécanisation des travaux a, dans bien de situations, accéléré la destruction. La surface de l'îlot est occupée par des courts de tennis dégradés et abandonnés. Les enrochements des digues de la marina couvrent une partie des estrans rocheux de la partie sud. Ils ont condamné des carrières anciennes et peut être des haouanets comme ceux qu'on voit encore à peu de distance de ces enrochements imposants (Fig. 6).

Conclusion

Il apparait donc que les îlots du littoral du Sahel, souvent négligés et en tout cas peu étudiés sans doute à cause de leur petite taille, sont importants à différents titres et ont dû mériter un sort bien meilleur que celui qui leur a été réservé jusqu'ici. Ils montrent une variété importante de situations et de paysages. Ceci s'explique par la nature de leur matériel et la variété des milieux qui les encadrent. Mais leur importance tient aussi au patrimoine archéologique qu'ils renferment et qui malheureusement n'a pas bénéficié de suffisamment d'attention. Ce contenu offre, outre sa valeur intrinsèque, des repères précieux pour apprécier l'évolution récente du niveau marin et les changements survenus dans les conditions du milieu ainsi que les mutations paysagères et les modifications dans la position du rivage. Il est apparu que, depuis l'Antiquité et parfois au cours des temps plus récents pour certains îlots, de tels changements ont été parfois sensibles. L'exploitation des repères archéologiques antiques témoigne d'un changement parfois profond dans la configuration de segments côtiers étendus, avec une possible disparition de certains îlots petits sans doute mais expressifs pour l'évolution d'ensemble. Aussi, de tels repères offrent-t-ils, par la reconstitution des paléopaysages qu'ils permettent, l'occasion pour l'amélioration de notre connaissance des

tendances de l'évolution des rivages au cours des temps récents. Ceci doit aider à une meilleure réflexion prospective notamment dans une perspective d'élévation du niveau marin. Les îlots les plus petits, dont les plus négligés, y compris au niveau des représentations cartographiques, se sont souvent révélés particulièrement importants pour cet aspect. D'ailleurs leur taille réduite est, elle-même, la conséquence d'une telle évolution.

L'évolution actuelle est malheureusement en défaveur de la majorité des îlots. Ceci apparait déjà au niveau de la tendance que connaissent leurs rivages, presque partout en cours d'érosion. Celle-ci prend des dimensions inquiétantes dans les îlots les plus bas et faits de matériaux tendres ou hétérogènes favorisant une attaque différentielle par les vagues. Dans les îlots sableux le retrait du rivage est net et la situation a parfois été profondément aggravée par la perturbation de la dynamique sédimentaire causée par des aménagements. Tout, révèle en tout cas, la grande vulnérabilité de ces îlots, vulnérabilité qui doit s'accentuer avec l'élévation du niveau marin annoncée pour les prochaines décennies. A la liste des îlots disparus suite à la variation positive du niveau marin enregistrée depuis l'Antiquité, parfois accentuée par une subsidence active, s'ajouterait une nouvelle liste.

Mais ce sont les aménagements qui ont, dans le cadre de l'anthropisation effrénée du littoral depuis quelques décennies, porté le plus de préjudices à ces îlots. Rattachés au continent, plusieurs d'entre eux ont perdu leur insularité. Des dommages ont été causés à une dimension paysagère, parfois unique, et à différents composants du patrimoine. L'évolution a parfois même fini par entrainer une destruction totale de certains îlots sableux (El Enf) ou rocheux (El Oustaniya). Ce dernier a connu la situation la plus déplorable : disparu ainsi que ces nombreuses tombes puniques sous une digue en enrochement imposante et un grand bâtiment !

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