Climate Change Management through Adaptation and Mitigation

Editors

Riccardo Privitera, Daniele La Rosa
Viviana Pappalardo, Francesco Martinico

MAGGIOLI EDITORE

Focusing on the major topics raised by the AdapTM Project, this book explores and conveys new insights into the state of the art of Climate Change management between the sea and the land. The contributions provide an extensive overview on adaptation and mitigation strategies and solutions across a wide range of urban and natural biotopes and regions and argue about the importance of tackling climate change issues for building a better and more sustainable future.
The book aims to emerge as a valuable contribution for enhancing knowledge and expertise of students, teachers, public administrations and other stakeholders interested in the management of climate-related issues, which are going to stress the area of Mediterranean with great strength. The building process of knowledge and awareness on climate change related issues is urgent and represents the only way to tackle the risks that our planet will face in the next challenging times.

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Preface

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About the Project

Climate Change Management through Adaptation and Mitigation (AdapTM) is a three year project (2017-2020, extended to July 2021 due to the Covid-19 pandemic) funded by the Education, Audiovisual and Culture Executive Agency (EACEA) of the European Commission, in the framework of the Erasmus + Programme (Action KA2 - Capacity building in the field of Higher Education). The network of Partners includes eight Higher Education Institutions from five different countries: University of Catania – Italy (Lead Partner), the Programme Partners of University of Klaipéda (Lithuania), Euro-Mediterranean University (Portroz, Slovenia), National Observatory Athens (Greece) and the Project Partners of Alexandria University (Alexandria, Egypt), Arab Academy for Science and Technology and Maritime Transport (Alexandria, Egypt), Suez Canal University (Ismailia, Egypt) and South Valley University (Qena, Egypt). The University of Catania acts as coordinator and leading partner of the Project, offering its contribution in the general management of the project, the scientific support for the development of customised curricula, the setting up of updated contents of the new courses for MSc, along with the organization of seminars and workshops for presentation of the curricula and the organization of local dissemination events, the development of didactic material and the organization of activities and lectures for an e-learning platform.

The AdapTM Project aims to continue the reform of the Higher Education system in the field of Environmental Sciences and to improve the quality and efficiency of educational process in Egypt according to the requirements of Bologna Declaration (1999) and Strategic Framework for European Cooperation in Education and Training (ET 2020). The main objective of the project was to ensure the design and implementation of an interdisciplinary Master Degree Study Programme in the field of climate change, in order to support Egyptian Universities with the integration of emerging technologies in climate change management in a competence-based education system, hence advancing higher education according to the European standards for quality of education. The eight partners have

been working on designing, accrediting and delivering the Master Degree 'Smart Environment and Climate Change Management (SECCM)' focused on Physical and Environmental Sciences and fully compliant with ET2020 and the Bologna Declaration.
Among the preliminary activities, the re-training of Egyptian Universities academic staff has been delivered for developing their teaching expertise and improving their ability on organise courses in climate change management with the integration of Information Technologies.
For supporting SECCM with innovative teaching materials, AdapTM network worked on conceptualising, editing and publishing newsletters, textbooks, mobile lectures, e&m-learning modules. With the objective to provide innovative learning methods, AdapTM network also implemented a Collaboration Platform (Google Suite) as learning and academic environment to share materials and information among scholars, lecturers and students and to establish their joint participation in the educational process and research. Last but not least, AdapTM consortium has been organising mobility of students and teachers between European and Egyptian Universities. European Universities academic staff have been travelling to Egypt for giving lectures within the SECCM Master Course modules whereas European students had a chance to attend selected modules taught by Egyptian academic staff. From Egypt, SECCM local students will be travelling to visit European Institutions (Covid19 restrictions permitting) for finalising their Master thesis. This on-going and in-coming International mobility (possibly to be replaced with online tailored lectures and activities in case of persisting pandemic) has been designed within AdapTM Project in order to maximise the opportunity to get a wider, deeper and effective educational and cultural experience.
The students and teachers mobility that has been already implemented, as well as the intense work for the master preparation and accreditation, was a valuable experience, useful to overcome organisational and cultural differences among the project partners. This can be considered one of key outcomes of the project.

About the Book

This Book focuses on the major topics raised from the AdapTM Project through exploring and conveying new insights into the state of the art of Climate Change management. The contributions provide an extensive overview on adaptation and mitigation strategies and solutions across a wide range of urban and natural biotopes (from urban coastal areas to marine environment and meteorology) and countries (from Lithuania to Egypt) and argue about the importance of tackling climate change issues for building a better and more sustainable future.
The Book is dived into three Topical Parts covering three thematic areas related to Climate Change management.

Part One ‘Cities and coastal areas’ comprises five chapters and provides a comprehensive knowledge on how mitigation and adaptation policies and strategies can be explored in urban core and coastal areas and integrated to urban planning practices.

The chapter ‘Avoid the unmanageable and manage the unavoidable. Cities between mitigation and adaptation to climate change’ outlines the idea of cities as an asset for carbon storage and sequestration through extensive and comprehensive urban afforestation an tree-plantation strategies. The transition to a climate-neutral society is both an urgent challenge and an opportunity to build a better future and this contribution re-states the crucial role of Urban Planning on managing this complexity. Keeping focused on urban planning as the most relevant among decision making processes for cities, the second Chapter ‘Sustainability and resilience of Mediterranean regions: urban policy and planning frameworks in Egypt’ discusses how international policy frameworks are informing the policy and urban planning strategic vision in Egypt, identified as one of the most critical tiles of the Mediterranean region mosaic, because of the difficult democratic transition and potential dramatic impacts on urban areas caused by the combination of population growth and climate-related risks. The focus on coastal areas is undertaken by the other three contributions that provide different perspectives of adaptation and mitigation to climate change at regional scale. ‘Natural and anthropogenic pressures in the Baltic Sea region’ argues about anthropogenic pressures induced by natural variability and human activity, such as coastal erosion, land cover change, and bio-invasions in the Baltic Sea region. ‘Risk Assessment of Climate Change on the Coastal area of Quseir, Red Sea, Egypt’ and ‘Adaptation of Sea-level Rise impacts in coastal areas due to Climate Change’ deal with the sea-level rise issues in Egyptian coastal areas. The former runs a risk and ecological effects characterisation by identifying as set of specific and related variables; the latter proposes a list of potential regulatory, spending, tax and market-based measures as well as comprehensive plans as a powerful tool by which local governments can guide development.

The ‘Marine environment and Maritime Industry’ are investigated in Part Two. This part collects five contributions that extensively deal with topics related to climate change effects on oceans, seas and related human activities. Relevant indicators (such as sea level, surface temperature, ice cover, wind wave regime, euphotic depth) are explored in ‘Indicators of Climate Change: Case of the Baltic Sea Region’ as a major instrument for investigating climate change and its impact on both the balance of the natural environment and marine ecosystems, as well as human socio-economic activities. Exploring in detail the oceans acidification and its biochemical cycles, the chapters ‘Climate Changes and Marine Microbes: Consequences and Adverse Impacts’ and ‘Biogeochemistry and Climate change’ provide a critical understanding about the implications of anthropogenic pollution on marine ecosystems and microbial community composition, the former proposing strategies such as physiological responses and evolutionary adaptation and the latter identifying climate engineering and blue carbon as the most promising to mitigate or reverse anthropogenic-induced climate change. Implications on Maritime Industry are then discussed within the two chapters 'Recent Sea Level and Tidal Characteristics in Alexandria Western Harbour, Egypt' and 'Legal Regime of Climate Change and Impact of International Maritime Transport Industry on Oceans and Marine Life'. The former, analyses sea level data inside the Alexandria western harbour (Egypt) in order to investigate the characteristics of tidal components and its potential effects on marine activities such as commercial shipping, marine construction, recreational boaters and even chart datum collections for nautical charts production. The second paper presents an overview of international frameworks, conventions and laws that relates oceans to climate in order to better understand how mitigation and adaptation measures should be improved and applied to set the maritime industry sector on a pathway compatible with the Paris Agreement and other Climate Change international relevant standards. Effective measures are needed to incentivise leading players and stakeholders of the international maritime industry to invest in low carbon and carbonless ships and operate the maritime industry in ways that reduce emissions.

Third part of the book 'Weather, Modelling and Monitoring' provides an important insight on the role of data collection and surveys, technological instruments, tools and advanced software for modelling, predicting environmental, weather and climate change and support mitigation of related risks and hazards. 'Weather-related hazards and community response in the Mediterranean region: the case of Greece' undertakes a study of the relationship between hazards and individual perception, while highlighting the need for a bottom-up approach to enhance the preparedness and adaptability of the citizens and achieve a more effective risk prevention in the country. The fundamental role of the mathematical-based approaches is highlighted in the chapter 'Climate in the Computer: Climate Change Mathematical Modeling' that widely argues about the different computing power and methods for modelling the Climate and proposes the Critical Breaking Point theory. Finally the potentialities of applying remote sensing and GIS for understanding and monitoring environmental changes (such as land-use/land cover, water resources, dynamics of sand dunes) are shown in 'Application of remote sensing and GIS in environment monitoring'.

This Book represents one of the most relevant deliverables of the AdapTM Project and has been designed to support and sustain its long-term durability while highlighting the fundamental role of a joint research and educational network of Mediterranean countries committed in climate change management. To this aim,

most of authors of contributions have been selected among the members of the AdapTM Project and other scholars who contributed to its implementation.
The book will go well beyond merely informing on scientific community and will try to reach a broader audience. It aims to emerge as a valuable contribution for enhancing knowledge and expertise of students, teachers, public administrations and other stakeholders interested in the management of climate-related issues, which are going to stress the area of Mediterranean with great strength. The building process of knowledge and awareness on climate change related issues cannot be postponed and represents the only way to tackle efficiently the risks that our planet will face in the next challenging times.

The Editors

PART ONE
Cities and coastal areas

1 Avoid the unmanageable and manage the unavoidable. Cities between mitigation and adaptation to climate change

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1. Introduction

Human activities are massively altering the climate and the earth temperature through adding tremendous amounts of greenhouse gases to those naturally occurring in the atmosphere.
The Kyoto Protocol (UNCCC, 2008) identified three main greenhouse gases responsible for global warming: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2) and the three more fluorinated gases such as hydro-fluorocarbons (HFCs), per-fluorocarbons (PFCs) and sulphur-hexafluoride (SF_6). Indeed, increasing concentrations of CO_2, CH_4, NO_2 and fluorinated gases increase the greenhouse effect through trapping the sun heat flow in the atmosphere and consequently generating a global warming.
The increase of greenhouse and fluorinated gases directly comes from the sectors of energy (47%), industry (30%), transport (11%) and building (3%) (IPCC, 2014). Burning fossil, coal, oil and gas produces large amount of CO_2 and NO_2; fertilisers containing nitrogen produce further amounts of NO_2 for a total 6% of the greenhouse gases emissions; intensive livestock farming produces methane through the food digestion process of cows and sheep, that is responsible for 17% of emissions. Finally, fluorinated gases, even if emitted in smaller quantities, are 23,000 times stronger and trap heat flow more effectively than CO_2. On the other side, deforestation decreases the amount of trees that help to regulate the climate by sequestrating CO_2 from the atmosphere so when they are cut down that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding and extra layer of greenhouse effect.
Thus, carbon dioxide definitively represents the most commonly produced greenhouse gas by human activities and it is responsible for 64% of the total global warming (IPCC, 2014).

Reducing CO_2 - and other greenhouse and fluorinated gases – in the atmosphere is on top of the agenda of several international bodies that are committed to climate change mitigation and adaptation policies. The clear influence of human behaviours on climate changes, that have had widespread impacts on anthropogenic and natural systems, pressed United Nations to adopt since 1997 the Kyoto Protocol that entered into force on 2005. The target for the first commitment period of the Protocol was cutting emissions of the selected greenhouse and fluorinated gases through identifying and assigning the maximum amount of emissions – measured as the equivalent in carbon dioxide – that the 192 parties might emit over the commitment period in order to comply with its emissions target (UNCCC, 2008). Since 1997 many other conferences, studies, reports and international agreements have been delivered. In 2015 at the Conference Of Parties 21 in Paris, members of the United Nation Framework Convention on Climate Change reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future (UNFCCC, 2016). The Paris Agreement built upon the Convention and brought all nations into a common cause to undertake ambitious efforts to keep a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Additionally, the agreement aimed to increase the ability of countries to deal with the impacts of climate change, and at making finance flows consistent with a low greenhouse gases emissions and climate-resilient pathway.

2. Climate change mitigation and adaptation

The two most common strategies for dealing with climate change are basically to reduce its impacts and to cope with its impacts. The former is mentioned as mitigation the latter as adaptation and they represent two different, even if inherently interlinked, responses to climate change.
Actually, mitigation has traditionally received greater attention than adaptation, both scientifically and from a policy perspective (Füssel, 2007). Mitigation is widely discussed and successfully applied in various contexts at the international, national, regional, local and even at individual behaviour level. Indeed, the reduction of greenhouse gases emissions represents the most effective long-term mitigation strategy that allows reducing risks related to climate change (Nakićenović et al., 1993). It includes energy efficiency improvements, renewable energies, clean fossil and zero-carbon energy technologies, infrastructural investments and even energy consumption reduction by private citizens opting for bicycle or public transportation or turning off a light.

Nevertheless, the real feasibility of mitigation policies and strategies is highly dependent on local governance aptitude that is strictly related to the capability to provide robust evidences and get high level of political and social agreement (IPCC, 2014). Mitigation strategies can be addressed through a number of regulatory, management, and market-based instruments. The degree to which these instruments can be implemented alongside the cities greatly varies, as well as the actual potential to generate public revenues or require government expenditures diverges according to the administrative scale at which it is applied (IPCC, 2014). Above all, mitigation requires a long-term horizon and is understood as a global responsibility, because by only reducing greenhouse gases in each country or city, the respective authorities can contribute to reduce impacts felt by the planet as a whole (Laukkonen et al., 2009).

However, while the contribution of greenhouse gases emissions is global, the impacts of climate change occur at local level. At this level, where the heaviest climate change impacts are experienced, adaptation is most appropriately implemented.

IPCC-AR4 defined adaptation as "the result of a deliberate policy decision, based on awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state" (IPCC, 2007). Thus at local level, cities face significant impacts from climate change because they are home to more than 50% of the world's population, are growing rapidly, and often concentrate economic activities, population, and infrastructure in high-risk locations (Araos et al., 2016). Urban climate change-related impacts include rising sea levels and storm floods, heat islands and heat stress, extreme precipitations, inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution with widespread negative impacts on people (and their health, livelihoods, and assets) and on local and national economies and ecosystems (IPCC, 2014).

In these urban contexts, adaptation is about planning and building settlements that can adjust better to the consequences of all these changes. Predominantly, urban planning measures can help on protecting and enhancing green spaces that have evapotranspiring and permeable features. This action is specifically related to adaptation, since urban green spaces can provide many relevant functions for coping with climate change. They can stabilise the climate through carbon storage and sequestration and regulate the micro-climate features (in terms of air temperature and urban heat islands reduction) through trees evapotranspiration processes and shading effect; they can control stormwater runoff through soil permeability, reduce noise through greenery canopy biomass, enhance air and water quality through air pollutants removal and provide compost biomass and soil protection (McHale et al., 2007; Henneberry et al., 2020). In addition, adaptation measures are relevant in physical planning since their consequences go beyond the environmental pollution and climate change challenges. Green spaces are fundamental to increase urban quality creating more pedestrian friendly and visually pleasant settlements. Landscape planning and management should be based around multi-functional green networks or green infrastructure (Handley et al., 2007).

3. Cities as an asset for carbon storage and sequestration

3.1 Quantifying and valuing carbon storage and sequestration

Carbon storage and sequestration potential provided by urban greenery may support different priorities and demands on land and is crucial to many climate change adaptation strategies.

Trees, shrubs, herbaceous vegetation, grass, lawns are able to remove carbon from the atmosphere and accumulate it in their woody tissues (branches, trunks, roots) and soil, reducing the amount of this greenhouse gas in the atmosphere. Trees and other vegetation species show different carbon storage and sequestration potentials that can be estimated through the application of a carbon sequestration rate for each vegetation species. Several studies provide properties of carbon storage and sequestration rates of herbaceous, shrubby and arboreal species that are usually measured in terms of kilograms of CO_2 – stored or sequestered – per unit of tree-canopy surface ($kgCO_2/m^2y$). Nowak et al. (2013) provided an average value of 1.02 $kgCO_2/m^2y$ for trees, Marchi et al. (2014) calculated 1.5 $kgCO_2/m^2y$ for shrubs and for herbaceous vegetation has been delivered a value of 1.36 $kgCO_2/m^2y$ (Getter et al., 2009).

A clearer understanding of the nature, distribution and value of this carbon storage and sequestration potential produced by trees and other greenery can help better to inform decisions about the management and the prospected enhancement of urban green spaces within the cities. In this light, monetary valuation of carbon storage and sequestration is best understood as a powerful tool for raising awareness about the importance of the public value of urban nature.

Different money-based valuation methods can be used to assess the non-marketable value of carbon storage and sequestration (Nikodinoska, et al., 2018). Particularly, the replacement cost method (or avoided costs method) is usually used to assign an economic value to carbon storage and sequestration based on the costs of replacing such nature-provided function with a suitable technology (Sundberg, 2004). This method can be applied to the valuation of non marketable values whether i) the technology is capable of providing the same services generated by natural ecosystems, ii) the chosen technology is the least costly available alternative for the investigated ES, and iii) there is a public demand for the chosen technology when the nature-provided service is scarce or available no longer. The main shortcoming of the replacement cost method is that often the technological alternative to the nature-service/s provides only one or a limited set compared to the multi-functionality of ecosystems that allows the co-production of multiple services. The i-Tree Eco Project (Rogers et al., 2015) calculated for the London urban forest case study the monetary value of carbon storage and sequestration. According to the Carbon figure of 62.00 £/ton derived from Appendix 1 of DECC (2014), an economic value of £ 6,573.29 and £ 214.39 per hectare of tree-canopy per year has been estimated respectively as a benefit delivered by Carbon storage and Carbon sequestration.

3.2 Urban afforestation and other suitable land uses: trees plantation strategy

Carbon storage and sequestration levels depend on different types and amounts of vegetation species covering green spaces. Selecting species and planting configuration schemes is therefore a key issue for balancing carbon sequestration and climate proofing. Concurrently, new greenery for carbon sequestration allows decreasing the water runoff through supplementary permeable soils, while large tree canopies reduce urban noise and its leaves support air pollution removal.

In order to compensate emissions of carbon due to human activities and enhance the carbon sequestration potential, a strategy of new trees plantation within cities could be suitable to increase the overall vegetation cover. Different intensity levels of trees, shrubs and other species plantation can be addressed in order to produce different levels of carbon sequestration.

Urban afforestation is one of the most effective policy to improve the urban environment which is implemented through large-scale tree planting strategies. Afforestation in urban areas became a clear and consistent political priority in Europe during the last frame of the 20th century and remains a high priority at both EU and national level (Konijnendijk, 2000). Afforestation has increased in pace and extent in recent years, as policies for greenhouse gas mitigation drive the conversion of other land uses into forests (Berthrong et al., 2009). Studies on the impacts of afforestation have focused primarily on the ability of newly created forests to sequester carbon in tree biomass and soils (Vesterdal et al., 2002). Though much of this work has focused on the establishment of plantation forests in natural areas, afforestation projects are also increasingly common in cities. There, as in natural lands, projects are intended to capture carbon as well as

improve air quality, lower air temperatures, increase storm-water infiltration and create wildlife habitat (Oldfield et al., 2013).
The Conference of the Parties, by its decision 19/CP.9, adopted modalities and procedures for afforestation and reforestation project activities under the Clean Development Mechanism in the first commitment period of the Kyoto Protocol. It requested the Subsidiary Body for Scientific and Technological Advice to recommend a draft decision on simplified modalities and procedures for small-scale afforestation and reforestation project activities under the Clean Development Mechanism and on measures to facilitate these project activities. In order to support small-scale projects, have been identified measures such as financial and technical assistance resources to small-scale project promoters, at the lowest cost possible and through a transparent financial mechanism, for pre-feasibility and baseline studies of small-scale afforestation and reforestation project activities; means and instruments for technical assistance in formulation and monitoring of small-scale afforestation and reforestation project activities with IT technologies and remote sensing tools, as applicable, to these activities; training, at the adequate level, to local and regional experts, as well as to local communities involved in the implementation of projects (UNFCCC, 2004).
Recent related studies showed that radical greening scenarios of 100% tree plantation can produce even more than 30% of carbon uptake increasing (Privitera and La Rosa, 2018; Privitera et al., 2017). Such tree plantation strategies represent a scenario aimed at maximising carbon sequestration. However, these strategies prove highly theoretical since a total tree coverage, such as an urban forest, is not realistic when designing urban green spaces which on the contrary implies to identify different zones for sport, leisure, relax and rest such as lawns, water bodies, pathways, benches, bike lanes, outdoor gym equipment and playgrounds. A more suitable and flexible strategy could take into account alternative urban land uses as well as mixed plantation of trees, shrubs and herbaceous vegetation. La Rosa and Privitera (2013) proposed complementary land-use types suitable to the public and private open spaces among and within the dense urban patterns: local urban parks, urban gardens, informal recreational areas, and playgrounds. Local urban parks represent green areas characterised by the remnants of native trees, playground equipment and lawn for sports (Syme et al., 2001) which can offer places for rest and leisure to neighbourhood inhabitants (Oh and Jeong, 2007). Urban gardens are highly accessible outdoor areas close to apartment houses, providing a stress-free environment and including green spaces designed mainly for decorative purposes and ecosystem functions with very limited human presence (Carbó- Ramírez and Zuria, 2011). Informal recreation areas are intended as green spaces available for public access and enjoyment, but with only low-key provision of facilities. These areas consist primarily of lawns for informal recreation,

but may also have trees, play areas and paths, and sometimes have toilets and parking areas (DTLR, 2002). Finally, playgrounds are safe and highly accessible small areas with recreational equipment and facilities for playing informal games and for social encounters between families with children and/or senior citizens (Jansson and Persson, 2010). Urban agriculture can be also planned and designed in different forms and to different scales to contribute to biodiversity conservation and provide carbon storage and sequestration as well as a massive range of ecological benefits for urban residents (Deelstra and Girardet, 2000). The integration of urban agriculture into densely populated areas might greatly extend opportunities for mixing food production with social, cultural and recreational functions of urban green spaces (Taylor Lovell, 2010). Particularly, urban agriculture can be explored in cities through different forms, extents and management approaches of productive activities. Agricultural Parks are large farmland areas where productive uses (usually organic farming) are implemented along with rural landscape protection and enjoyment. These parks are an innovative and scalable model that facilitates land access for beginning and immigrant farmers, local food provision for diverse communities, natural conservation, public education and job training opportunities. Urban Farms represent the primary form of urban and multifunctional agriculture (Aubry et al., 2012) and are characterised by the production of fresh products. They clean up the city by recycling waste, provide landscape and socio-educational functions and contribute to urban employment and reduction of inequalities (Dubbeling et al., 2010). Urban Farms are often run according to a Community Supported Agriculture model (Wells and Gradwell, 2001) and can be of varying sizes and different density of orchards and vegetable (Van En, 1995). Furthermore, allotment gardens are places for leisure and integration of older people and socially deprived groups where gardening is the main activity (Rubino, 2007).

The New York City Afforestation Project (NY-CAP) is an ecological research component of MillionTreesNYC, an initiative launched as part of New York City's sustainability-driven agenda PLANYC2030 to increase native tree canopy and to promote human and environmental health. The research opportunity for the NY-CAP arose from the allocation of US$400 million over 10 years to the New York City Department of Parks and Recreation to plant 600,000 trees, including the restoration of about 800 ha of urban forest. The NY-CAP proposed a comprehensive approach through combining scientific research with landscape architecture to advance understanding of urban afforestation (Felson et al., 2014). This project allowed implementing between 2009-2010 the Kissena Corridor Park in Queens with more than 5,000 trees and 1,800 shrubs while producing an urban research platform facilitating experimentation to guide urban forestry, urban design, and land management (Fig. 1).

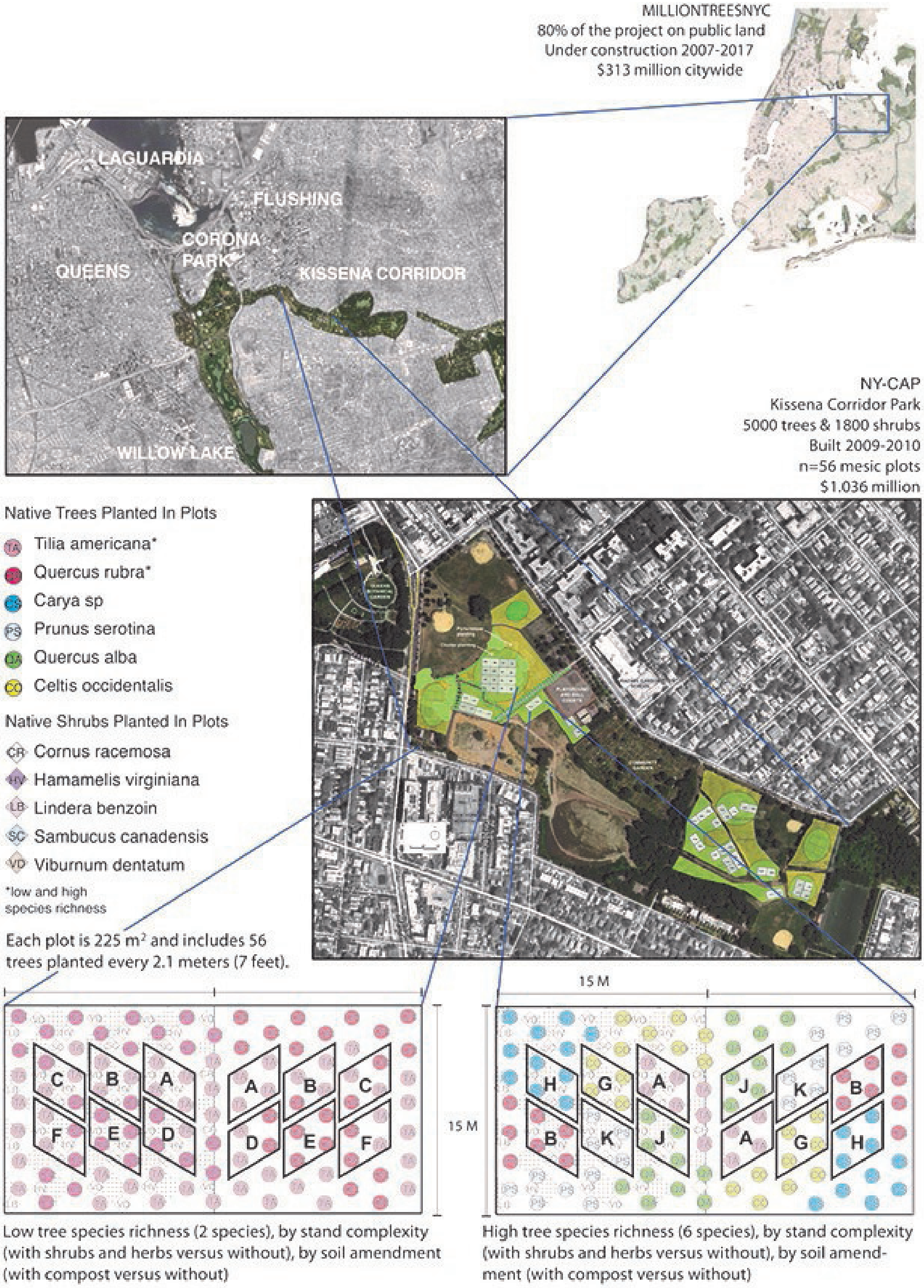

Figure 1. The New York City Afforestation - Million Trees Project (Source: Felson et al., 2014)

Urban layouts, where the amount of greenery could be limited as well as the opportunity to increase its extent and size, can be transformed according to carbon storage and sequestration strategies through land-use regulation. Accordingly, increasing of carbon sequestration potential can be carried out through the evaluation of the suitability of different urban configurations in order to accommodate new land uses with supplementary vegetation cover and evapotranspiring surfaces. The feasibility of these scenarios faces several difficulties and limitations for its real development and management, especially in urban dense contexts. This is mainly due to a general lack of areas belonging to municipalities or other public bodies to be used as public spaces for developing new carbon sequestration assets and, therefore, to its related economic viability. The implementation would require the public acquisition of private plots, which is often economically unsustainable for local administration and faces resistance from private landowners (Bengston et al., 2004). On the contrary, the issue of economic feasibility for regulating land from the perspective of carbon sequestration could be addressed through incentive-based approaches, including the Transfer of Development Rights (Brabec and Smith, 2002). Development rights could be assigned to strips of private land parcels that are designated for public acquisition. Development rights can be transferred from these portions of parcels to the adjacent ones and used for increasing the amount of current development within the same or contiguous parcel. As a result, the involved parcels can be densified through increasing their volume and the strips can be transferred to public property (Privitera et al., 2017). Alternatively, economic incentives could be to assign development rights to strips of private land parcels for increasing the square footage or height of existing buildings within the same parcels. Single private landowners could be also restored through tailored Tax Credits for collecting the earned revenues from the development rights and channelling it into a fund to be managed for recovering local tax bills and other fiscal duties (Tapp, 2019).

Compensation approaches for managing transformation of urban fabrics in private land parcels can also be used, such as the Carbon Offset Fund. This approach allows to reduce the net carbon emissions of new development, retrofitting or regeneration projects by collecting investment from developers and channelling it into a fund that is invested in a range of projects that deliver carbon savings (O’Rourke, 2010).

4. The transition to a climate-neutral society

Climate change poses complex challenges that require complex responses. Adaptation and mitigation - to effectively address climate change responses within urban settlements – imply the understanding of cross-cutting issues as well as the inclusion of different actors on the decision-making process. Urban dynamics of cities, as centres for economic and social development, involve direct and indirect interactions between socio-economic sectors and the natural environment at local, national and global levels. Therefore, responses to climate change from human settlements depends not only on the knowledge of the impacts of extreme weather events, but also in the inclusion of a comprehensive approach that considers all stakeholders within different levels, and the availability of resources and institutional capacity.

Avoid the unmanageable and manage the unavoidable is the main challenge that mitigation and adaptation respectively launched to climate change (Laukkonen et al., 2009).

Despite the obvious benefit on combining these two strategies, conflicts might arise between adaptation and mitigation – particularly when coordinated efforts to support these strategies under a common vision are lacking. Shaw et al. (2007) exemplified the potential conflicts that can occur within the built-up environment. On one hand, promoting more compact developments can help to decrease the commuters' distances, reduce the fossil fuel consumption and minimise the consequent greenhouse gases emissions. On the other hand, a denser built-up environment and further impervious surfaces can contribute to increase the urban heat islands, the likelihood of urban flooding and, simultaneously, lowering the potential introduction of new urban green spaces or supplementary tree cover which helps reducing the demand of cooling needs. Even if these possible contradictions, incorporating both strategies to reduce the impacts of climate change is necessary and represents an essential component to achieve a long-term sustainable development (Shaw et al., 2007). Accordingly, mitigation and adaptation should be simultaneously pursued because they are inherently complementary strategies (McKibbin and Wilcoxen, 2004). As shown by Sharifi (2021), measures related to green infrastructure have received in scientific literature the highest amount of attention among different categories. While attention has primarily been on adaptation benefits, considerable evidence has also been reported on the mitigation co-benefits that are mainly related to carbon sequestration, and cooling effects that indirectly lead to reduced energy consumption (Fig 2).

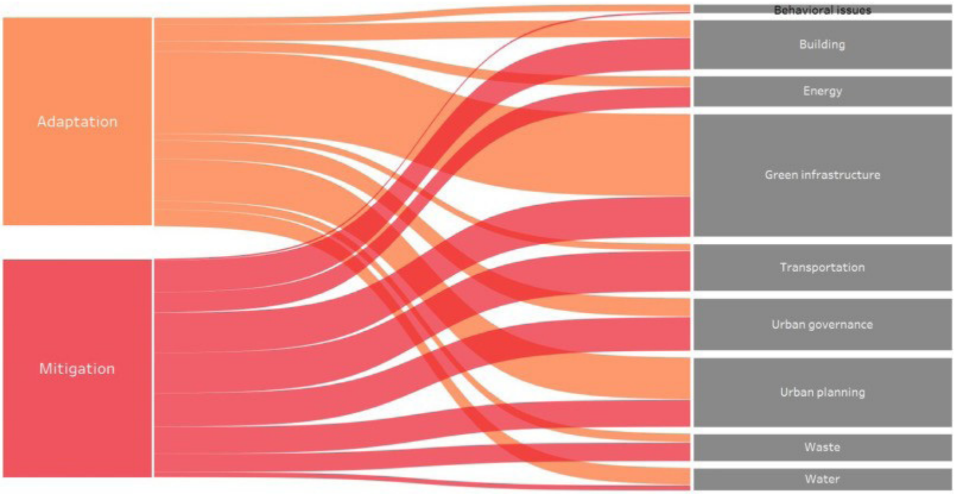

Figure 2. Categories of measures that provide adaptation and mitigation co-benefits (Source: Sharify, 2021)

In order to effectively respond to climate change, actors at different levels – such as policy makers, administrators, stakeholders, local community – require to be supported by both methodologies and tools in the decision-making process. Supporting means would be able to establish a mechanism to effectively coordinate efforts and set priorities within a human development approach towards climate change. On the other hand, the tool should allow actors to identify if adaptation or mitigation, or adaptation and mitigation are needed to best cope with climate change.
Urban Planning can have a crucial role on managing this complexity. Indeed, to develop feasible and successful urban policies aimed at implementing more effective mitigation and adaptation strategies, the multifaceted relationship among different land uses, land covers, public and private actors, the public and private property assets, the economic and financial assets in the built environment requires a better understanding. This is even more important for cities where greenery is lacking and the possibility to new trees plantation is strongly reduced. Indeed, increasing greenery equipment for enhancing carbon storage sequestration potential of cities is decisive for cities to cope with climate change adverse impacts.
To this end, comprehensive-planning policies should be firstly supported by analyses and assessment of carbon storage and sequestration potentials in biophysical terms and then valued in money units (Nikodinoska et al., 2018). The monetary valuation of the otherwise hidden benefits derived from carbon storage and sequestration, should be the basis for any assessment of the economic viability of

nature-based public investment. Mitigation and adaptation strategies should be delivered through checking and assessing the public benefits (above all citizens health, safe and well-being), the involvement of private stakeholders and related costs (loss of private/shared open spaces, parking plots, view blocking) and benefits (building energy savings, gained development credits). This would be the route for a reliable management of climate change while creating safer and more healthy and sustainable cities.
The transition to a climate-neutral society is both an urgent challenge and an opportunity to build a better future. Fighting climate change and achieving the transition to increasingly lower climate-proof cities will require significant investments, research and innovation, new ways of producing and consuming, and changes in the way to work, use transport and live together.

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2 Sustainability and resilience of Mediterranean regions: urban policy and planning frameworks in Egypt

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1. Introduction

After the Fifties, the Mediterranean regions started to host an unprecedented growth of cities, which formed one of the largest circle of urban agglomerations populated by millions of inhabitants (Chaline, 2001). In particular, the Middle Eastern and North African part is among the regions with the highest population growth (Malek and Verburg, 2017) and extremely vulnerable to expected climate change impacts (Frihy and El-Sayed, 2013). The Egyptian country represents one critical example in the southern Mediterranean foremost because is ranked as one of the fastest greenhouse gas growing emitters in the world and among the most vulnerable regions towards climate variability, water scarcity, loss of agriculture land and threats to food security, sea level rise and degradation of coastal resources (Abutaleb, 2018). The combination of population growth and climate-related risks challenges the difficult democratic transition and the sustainable economic growth. This is dramatically affecting metropolitan areas, which host the majority of a population that is expected to reach 130 million people by 2050 (Mirkin, 2010), with the prevalence of low income, poor educated and unhealthy communities (Attia, 2001). Particularly, the metropolitan areas of Cairo and Alexandria have historically attracted migrants from rural and poor developed villages, which have determined an unprecedented increase of congestion and pollution, informal development of slums, breakdown in urban services, loss of agricultural land and crises of food supply in the last three decades (Abdelaziz Attia, 2001).
On the global level the world confronts with multiple crises for global sustainability where cities represent the most fruitful place for rethinking approaches to disease and injury prevention (Grant et al., 2017), to recognition of inequalities in climate and environmental justice (Bulkeley et al., 2014; Wolch et al., 2014), to integrate smart urban technologies in planning the built environment (Graham,

2002). The sustainability policy agenda is continuously stressed in urban governance (Barnett and Parnell, 2016). At the same time, the concept of urban resilience has been widely explored in connection with policies related to risk assessment and management, adaptation and mitigation to climate change and general urban sustainability across developed and developing countries (McPhearson et al., 2018; Zhang and Li, 2018; Baravikova et al., 2020). Scientific literature abounds with definitions, frameworks, case studies and reviews which aim to codify tailored domains but it has become clear that policymakers, practitioners and academics continue to wrestle with the complexity of risk, resilience and sustainability, and the related necessary transdisciplinary focus (Becker, 2014). The apparently trivial clue of considering the concepts of risk and resilience as intrinsic of the idea of sustainable development may turn out to simply solve the above endeavour. So much so that, in the most recent update of the global sustainable development agenda (Transforming Our World: The 2030 Agenda for Sustainable Development), the United Nations (UN) adopted seventeen SDGs (2015-2030), that advocate 'inclusive, safe, resilient and sustainable' cities and human settlements for both developed and developing countries (SDG 11) based explicitly on targets directly related to risk assessment and management and resilience enhancement.

Urban planning is the most relevant among decision making processes for cities able to translate into practice most of the SDGs, and can lead to climate change adaptation and disaster risk reduction of urban systems (Borie et al., 2019). In the following sections, we discuss how international policy frameworks are informing the Egyptian policy and urban planning strategic vision. Particularly, we present a brief review of main policy and planning documents for the Egyptian context, analysing their relation with the different international policy frameworks and finally discussing the degree of integration and maturity.

2. Case study and methodology

2.1 The Egyptian urban contexts

Egypt is an highly populated country, with a growth rate of 2.3%. Most of the population is concentrated in only 4% of the country's land, leading to an average population density of 1435 people per km2 (Abutaleb, 2018). The unbalanced distribution of population among the regions and provinces of Egypt is unmistakable: while there are 219 cities in Egypt, Cairo and Alexandria alone contain about 43 percent of the total urban population (Hegazy, 2020). A large percentage of the population inhabit coastal cities, and potential social tensions could arise, related to lack of prospects, water and sanitation conditions in slums within such cities (United Nations 2010). Analyses of the sea level rise scenarios in the Alexandria Governorate, for example, indicates that, if no action is taken, up to an area of about 30% of the city will be lost due to inundation. Almost 2 million people will have to abandon their homeland; 195,000 jobs will be lost and an economic loss of over $3.5 Billion, are expected, over the next century (El-Raey,1999).

Processes of urban sprawl started at the beginning of 1970th decade and are still threatening the limited highly fertile land in Egypt (El Ghorab and Shalaby, 2016). This reduction in agriculture land will increase unemployment rates and the immigration to larger cities. As a consequence, the rapid population growth worsens the problem of urbanization and unemployment increase, with the limited possibility of developing new areas as desert reclamation projects have been of limited success (Abutaleb, 2018). The larger urban environments can become the setting for conflict, brought in from the rural areas (Maninger 2000). An example is Cairo, situated in one of the most fertile areas of Egypt, where the city growth intensifies a constant conflict between agricultural land use and possible improvements of living conditions in the city. (Abutaleb, 2018). Major urban areas are mostly deteriorated and characterized by old and destroyed buildings, small size building and land blots, high population densities, narrow and tortuous road networks causing major mobility issues (El Ghorab and Shalaby, 2016). Informal areas have arisen due to the absence of a general spatial planning, developed in contradiction to building laws and planning rules, as residents build houses on state-owned land or on privately-owned agricultural land without getting permission to build (Khalifa, 2011). Both deteriorated urban areas and slums lack of all types of facilities, basic services and infrastructure including water, electricity, schools, transport networks, resulting in deprived settlements with insufficient standard of living (World Bank, 2008).

Egyptian cities and large urban areas are associated with environmental pollution of air, soil and water, which emerges as a result of many factors, including concentration of population, economic, industrial and traffic activities in urban centres that increase emissions, inadequate sewage disposal and solid waste management systems (El Ghorab and Shalaby, 2016).

All the previous represent difficult challenge that should be faced, in developing large scale planning strategies as well as urban development plans, with creative policy and planning solutions to reduce the pressure on the exiting urban mass, cut down sprawl and go toward sustainable development (Hegazy, 2020).

2.2 The framework to review the Egyptian planning and policy documents

The review of policies and planning documents was performed in March, 2020 by means of a query in the ResearchGate database (to check the potential availability of scientific papers on the topic) and in the Google search engine to select relevant grey literature on the topic. In particular, the following combination of terms was used for the search in Google: ("mitigation" AND "adaptation" AND "planning" OR "policy" AND "Egypt"); ("sustainable cities" AND "Egypt"; "resilient cities" AND "Egypt"; "sustainable planning" AND "Egypt"; "Egyptian cities"; "planning" AND "climate change" AND "Egypt"). After the first screening of titles and abstracts, only papers and documents explicitly referring to policies and planning instruments were actually reviewed. Other documents concerning theoretical studies, conference presentations and research articles with generic reference to sustainability and urban resilience were discarded (Pappalardo and La Rosa, 2020). The performed screening has resulted in the collection of twenty documents in total, including reports, articles and studies whose contents have resulted in referring to, analysing and discussing the main documents issued by governmental bodies and officially representative of the Egyptian policy and planning stance (five out of twenty documents).

Aiming to focus on returning basic information on the Egyptian official policy and planning references and to discuss the main directions of current Egyptian policy and planning strategies, emerging priorities and perspectives for future urban actions, the five official planning and policy documents were further analysed at a more detailed level by applying the method illustrated in Fig. 1. It relies on three well known and acknowledged policy frameworks: Sendai Framework (SF) in column A; the SDGs in column B; City Resilience Framework (CRF) (2014) in column D. Column C includes the factors critical to the achievement of the CRF goals at the level of urban practices. These factors, in particular, are used to evaluate qualitatively the alignment of the five main Egyptian policy and planning documents with the 11th SDG targets, which are grouped in four corresponding classes (i to iV). Thus, the five documents were analysed searching for the references of each factor throughout the contents of each document.

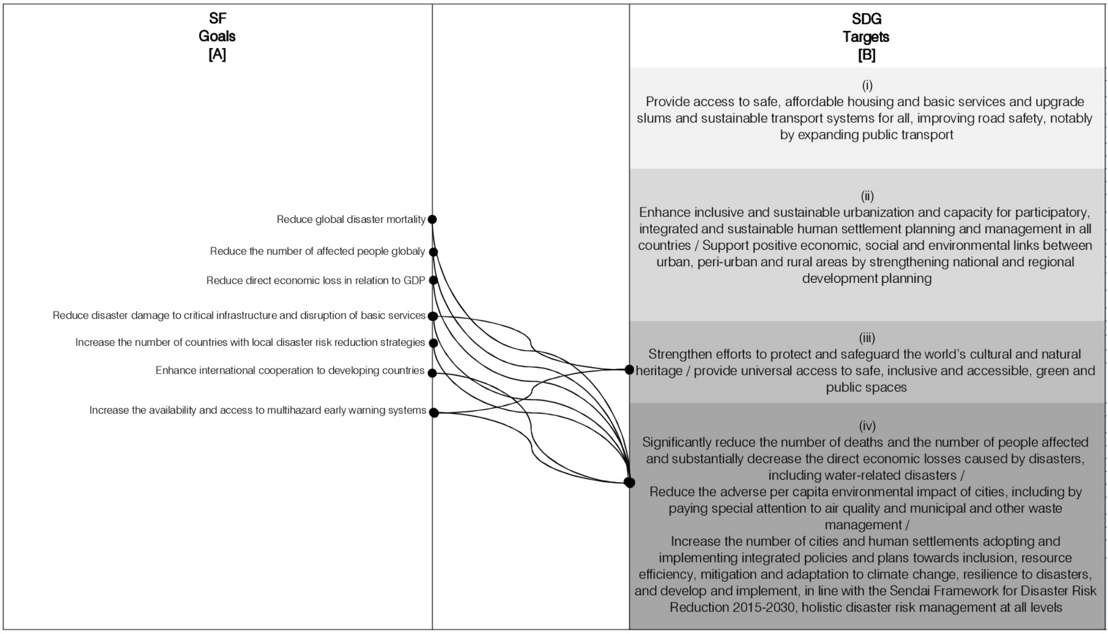
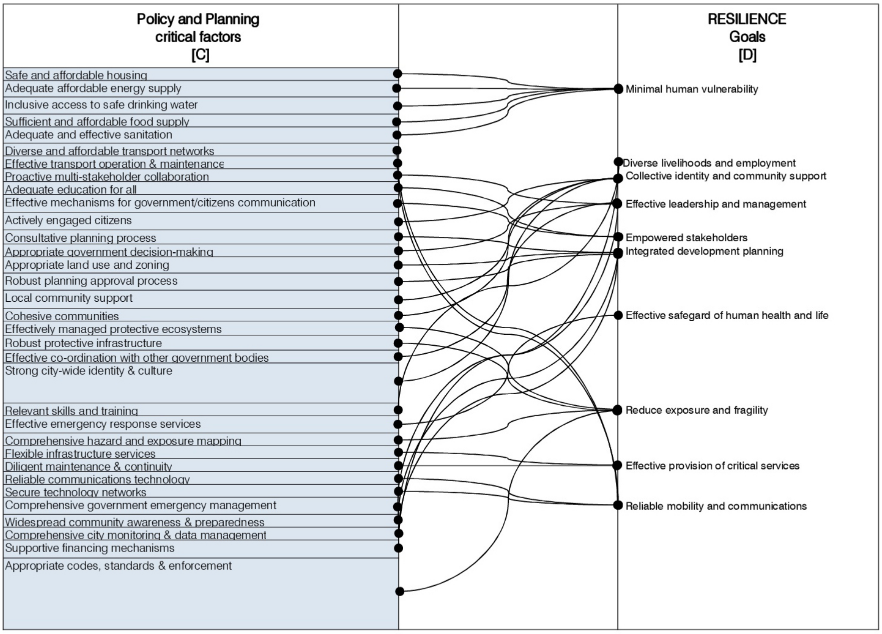


Figure 1. List of critical factors to be searched in the policy and planning documents review stage in order to evaluate the alignment with the SDS goal of making cities resilient and sustainable


Policy and Planning
critical factors
[C]
RESILIENCE
Goals
[D]
Safe and affordable housing
Adequate affordable energy supply
Inclusive access to safe drinking water
Sufficient and affordable food supply
Adequate and effective sanitation
Diverse and affordable transport networks
Effective transport operation & maintenance
Proactive multi-stakeholder collaboration
Adequate education for all
Effective mechanisms for government/citizens communication
Actively engaged citizens
Consultative planning process
Appropriate government decision-making
Appropriate land use and zoning
Robust planning approval process
Local community support
Cohesive communities
Effectively managed protective ecosystems
Robust protective infrastructure
Effective co-ordination with other government bodies
Strong city-wide identity & culture
Relevant skills and training
Effective emergency response services
Comprehensive hazard and exposure mapping
Flexible infrastructure services
Diligent maintenance & continuity
Reliable communications technology
Secure technology networks
Comprehensive government emergency management
Widespread community awareness & preparedness
Comprehensive city monitoring & data management
Supportive financing mechanisms
Appropriate codes, standards & enforcement
Minimal human vulnerability
Diverse livelihoods and employment
Collective identity and community support
Effective leadership and management
Empowered stakeholders
Integrated development planning
Effective safegard of human health and life
Reduce exposure and fragility
Effective provision of critical services
Reliable mobility and communications

3. Results

The focused official policy and planning documents are listed in the Table 1 that distinguishes policy-oriented contents developed at the global national level from strategic planning contents prepared at the regional scale. Results of the second-level analysis obtained from the application of the method in Fig.1 are commented thereafter in sub-sections 3.1-3.2, with the support of the Figure 2 and Figure 3. Both figures are created as radar charts to visually compare each policy and planning document against each class of SDG targets. Thus, they show the rate of each policy and planning document on several aspects that are widely considered fundamental to sustainability and resilience of urban settlements. In particular, the alignment value in each direction is obtained as the ratio between the number of references of critical factors counted in the text and the total number of critical factors corresponding to the group of SDG targets. Therefore, this value ranges between 0, when no alignment with the group is observed, and 1, when the alignment is complete.

National Policies	Sustainable Development Strategy – Egypt's vision 2030
	National Strategy for Disaster Risk Reduction (NSDRR 2030)
	The National Adaptation Strategy (to Climate Change and Disaster Risk Reduction) (NASCC)
	Green Pyramid Rating System (GPRS)
Strategic and regional planning	Strategic National plan for urban development (SNPUD-2052): – Strategic Plan for Greater Cairo Region 2052 – Strategic Urban Plan for Alexandria 2032

Table 1. Main official policy and planning documents on sustainable urban development in Egypt

3.1 National Policies

Out of a general consciousness of climate change impacts and potential consequences of unsustainable urban development models, Egypt has provided the international community with proofs of its efforts in addressing the global complex sustainability challenges.

The "Sustainable Development Strategy – Egypt's vision 2030" represents the top ambitious attempt to guide the development of Egypt towards sustainability and social justice. It is a complex, multilevel and multisector plan of intents, explicitly inspired by the United Nations 2030 Agenda. The strategy should be considered as an integrated general policy framework, based on certain major pillars with regard to the basic obstacles facing Egyptian society.

The urban development is included in those pillars underpinning the environmental dimension, and is expected to pursue a balanced management of land and resources to reform spatial development and improve urban liveability. Finding a quite good match for the critical factors targeted to the 11th SDG in the description of the Egyptian urban development programs to 2030 was effortless. However, the issues of affordable housing and provision of facilities as well as inefficiencies of planning and administrative local authorities are much more commonly recognized than urban risk management concerns, which are definitely less addressed by the same pillar. For example, security of urban areas is highlighted with regard to informal settlements phenomenon whilst climate-related risks and general impacts due to natural and anthropogenic hazards are discussed under different pillars such as the environmental one.

Actually, the separation of strategies and objectives according to thematic "pillars", which expressly refers to the conventional subdivision of sustainability in the economic, social and environmental dimensions, may culminate in missing a systemic vision and is likely to cause an underestimation of critical matters, especially for urban areas as complex systems.

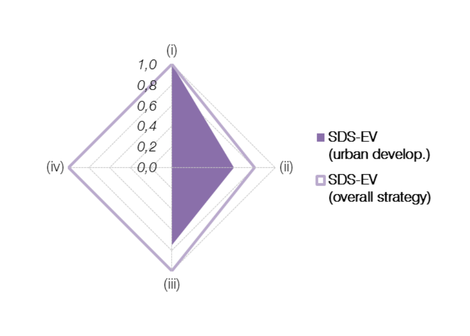
On the whole, the main objectives to be achieved by Egyptian cities are related to urban growth and expansion. Accordingly, a range of indicators are proposed to measure cities' performances in terms of urban development, such as the rate of population settlement, the housing gap indicator, the urban area growth rate, the average localization of population in new urban communities proportional to population increase. Environmental issues are clearly and explicitly underlined focusing on the sole aspect of the achievement of green and sustainable building methods' spread. On the contrary, the factor of strengthening national and regional development planning and capacity for decision making is particularly noteworthy. In fact, the reformation of the institutional infrastructure and the enhancement in governance of the urban development planning and management system is the first programmatic point and is followed by the activation of municipalities' role in execution and management of urban plans.

The Fig. 2a shows simultaneously the more pronounced alignment of the document contents with the first two classes of SDG targets, if considering the section dealing with the urban development, and the overall isotropic consistency, if considering the totality of sections of the policy framework.

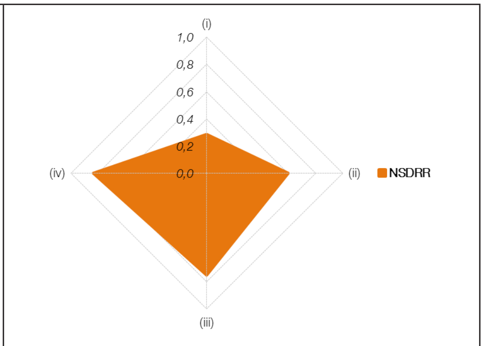
Yet in 2011, the "National Adaptation Strategy to Climate Change and Disaster Risk Reduction" (NASCC) dealt with climate change induced risks and disasters and their impacts on different sectors and activities, presenting several recommendations in the fields of housing, buildings, and roads, tourism, water resource management and agriculture. Clear reference is made to the usefulness of directing city planning and architectural design towards the requirements of a green and

sustainable paradigm. Recommendations cover the efficient utilization of energy, rationalization of water use, issuance of a green architecture code, adoption of an energy code for residential and commercial buildings, environmental compatibility of buildings, promotion of climate change teaching in the academic programs (Pappalardo and La Rosa, 2020). It recommends integrating sector specific adaptation plans with national development programmes; enhancing community participation and building a 'Safety First' culture; promoting regional and international co-operation; and engaging in continuous monitoring of progress.
The NASCC can be considered a comprehensive policy that partially aligns with the SDGs overall framework according to the different targets considered in turn (Fig.2c). Not surprisingly, the last target, which is related to a holistic disaster risk management at all levels in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, was already well conceived in Egypt some time in advance. On the contrary, it is quite surprising the high representativeness of participatory processes enhancement, which foremost depends on the proposal for large scale campaigns for education, acknowledgment of political will at all levels as determinant and proactive multi-stakeholders collaboration.
Very recently, Egypt has completed the review and update of the National Strategy for Disaster Risk Reduction (NSDRR), that implements the Sendai Framework and considers achievements and future aims planned within the Egyptian Sustainable Development Strategy "Egypt's vision 2030". In fact, incorporating the concept of disaster risk reduction into sustainable development policies is highlighted as the first objective of the NSDRR 2030. Many policy and planning critical factors for making the human settlements resilient and sustainable are mentioned throughout the document. As better pointed up in Fig.2b, the principal aspects that are stress are related to: the development and implementation of a holistic disaster risk management at all levels; the reduction of the number of deaths and people affected; the direct economic losses caused by disasters. Similarly, the incorporation of investments as priorities for the protection of natural reserves, coastlines and agricultural lands and the protection of museums, monuments and places of historical value, goes in the direction of strengthening efforts to protect and safeguard the world’s cultural and natural heritage. Moreover, building partnerships with the civil society and the private sector is pursued as an activity of major importance to raise awareness on disaster risk reduction.
The Egyptian government has also proven a novel interest in promoting green buildings as part of its policy leanings on sustainable development. Three building energy codes were introduced in Egypt between 2005 and 2010, introducing mandatory energy performance requirements respectively for residential, commercial, and governmental buildings (Hanna, 2015). The energy efficiency codes were the first steps towards the development of the “Green Pyramids Rating System”. It was approved by the Egyptian Green Building Council and specifically addressed

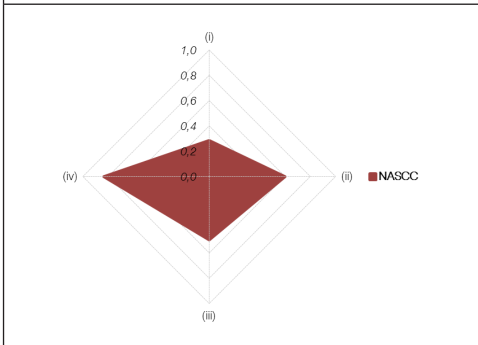
to satisfy energy efficiency and environmental conservation urgencies as well as to allow innovative solutions and designs in the building sector. The methodology employed in the GPRS system is a point weighting system divided per categories. To earn a Pyramid Certification a project has to fulfil all the mandatory minimum requirements and may obtain credit points by meeting certain criteria in terms of water and energy efficiency, indoor environmental quality, usage of materials and resources, accessibility and ecological characteristics of the building site and so on. The GPRS policy expresses the Egyptian efforts in allocating some support to the construction and retrofitting of sustainable, resilient and resource-efficient buildings, providing appropriate codes and standards, working on community awareness and on city monitoring. As a result, the Fig. 2d illustrates the contribution offered by the policy reference to critical factors for the last class of SDG targets.



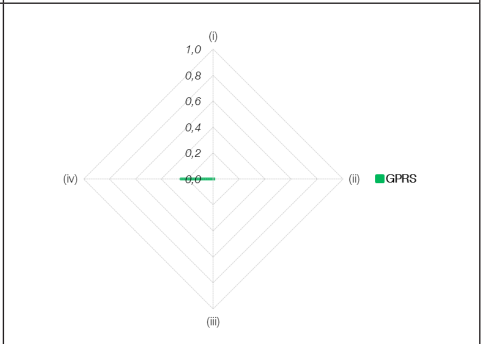
a. Sustainable Development Strategy – Egypt's vision 2030 alignment to 11th SDG's targets



b. National Strategy for Disaster Risk Reduction (NSDRR 2030) alignment to 11th SDG's targets



c. National Adaptation Strategy (to Climate Change and Disaster Risk Reduction) alignment to 11th SDG's targets



d. Green Pyramid Rating System (GPRS) alignment to 11th SDG's targets

Figure 2. Alignment of national polices with the 11 SDG targets

3.2 Strategic regional planning

Strategic planning was introduced in Egypt around the 2000s and officially adopted by the planning authorities in 2006 (Serag, 2018). The General Organization for Physical Planning (GOPP) is the main specialized body responsible for all spatial planning activities in the country under the authority of the Ministry of Housing and Public Utilities and is involved in organizing the planning process at all levels (regional, urban and detailed, from of existing to developing urban settlements) (Shaalan, 2016). It is asked to execute an agenda addressed to institutional transformations and developed the Strategic National Plan for Urban Development (SNPUD-2052), approved in 2013 (Arab Republic of Egypt, 2016). This strategic Plan constitutes the main reference document expressing the vision for current and future development of Egyptian human settlements, much related with the hope for a desirable fulfilment of the local communities' needs, enhancement of the built environment and improvement of the stagnant situation generally characterizing many Egyptian settlements.

The SNPUD strategy is focused on a paradigm of sped-up development with extensive programs of housing for resettlement of citizens, regeneration of slums, building development axes along the coasts of the Mediterranean, the Red Sea and the Gulfs of Suez and Aqaba.

Regional plans are presented as the chief tools to mitigate the urbanization pressure on the more congested cities, such as Cairo and Alexandria, levering the migration trends from most deprived areas, such as those of Upper Egypt, which could attract investments, expand and progress in turn.

Repeatedly all through the document, the principle of sustainable development is quoted but not precisely articulated, resulting in an utterance of rhetoric.

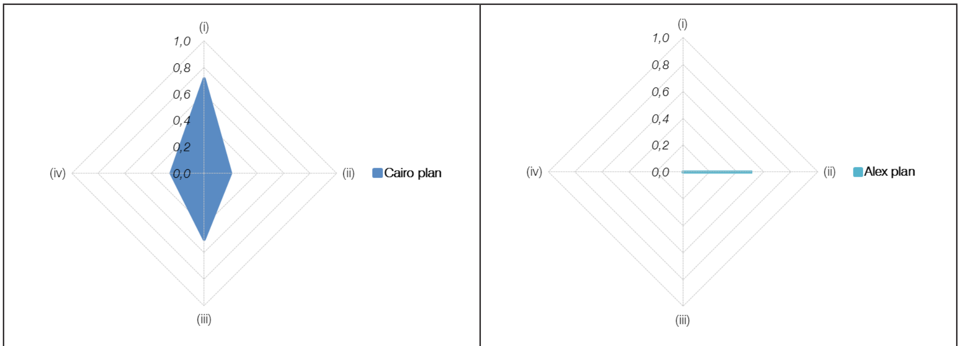
Sustainable pillars are more clearly encompassed within the Strategic Plan for Greater Cairo Region and the Strategic Urban Plan for Alexandria, for which it was however difficult to source some information regarding spatial development projections.

GOPP is preparing the strategic plan "Cairo 2052" and the strategic plan "Alexandria 2032", to achieve development and respond to the challenges facing the major metropolitan cities. It is also preparing strategic plans for 130 cities of the 231 Egyptian cities, the general strategic plans for 4409 villages out of 4673 Egyptian villages and development plans for 15 new cities (Arab Republic of Egypt, 2016). However, no official documents, maps, guidelines or other materials referring to the above planning outcomes are available to date.

The vision underlying the Strategic Plan for Greater Cairo Region has been built on eight key elements among which "Improve environmental conditions and achieve sustainability". This main target has been structured in sustainable pillars. As represented in Fig. 3a, critical factors to sustainable targets such as the provision of equal access to safe, affordable housing and basic services and the upgrade of slums are explicitly taken into account whilst determinants for coping with urban risk issues and disaster impacts are not well focused. Mainly, special attention is directed to air quality enhancement by means of targeted public transportation policies and development of new infrastructure networks, but actions addressed to comprehensive effective emergency response services, diligent maintenance and continuity of infrastructure functioning or widespread community awareness and preparedness are not expressly considered. In particular, improving the standard of living, the ability to enjoy an appropriate residence and to have a better quality of life is linked to supply deprived areas with facilities and basic urban services, including health care and education. Better environmental sustainability is addressed through the approval of environmental legislations and regulations, upgrading of public transportation focusing on strengthening mass and public transit, the development of potentials and capabilities of solid wastes management, the increase of reliance on renewable energy and the increment of green areas. The preservation of historical and archaeological areas is very much related to tourism expansion.

Similarly, to the case of the Cairo plan, also for the Strategic Urban Plan for Alexandria all information gathered are essentially indirect and make difficult to analyse in details the general vision for the metropolitan development as well as of the detailed actions programmes. Moreover, the Plan for Alexandria is not yet fully developed nor implemented.

From the review documents and research articles, it is known that the strategy is being designed as a physical plan, a participatory process, and the result of a consensus-building and a capacity-building tool to improve the capabilities of the local administration in urban development (Barthel et al., 2019). The Fig.3b is thus limited in portraying the alignment of the strategic plan with the objective of making Alexandria inclusive, safe, resilient and sustainable. It could barely report the firm will to adopt an effective participatory approach (Sirry, 2018).



a. Strategic Plan for Greater Cairo Region 2052 | *b. Strategic Urban Plan for Alexandria 2032*

Figure 3. Alignment of strategic and regional planning with the 11 SDG targets

4. Concluding remarks

It must be highlighted that the review method is subject to some limits: the use of English keywords only, the selection of policy and planning critical factors to meet SDG targets and the use of databases that are potentially very unlikely to include scientific references to the kind of documents of interest, returns research results which cannot be consider exhaustive of the entire Egyptian context. However, focusing on Egypt and its newly development strategies, this study could serve as a basis for starting the discussion about the policy and planning current stance on the challenges awaiting urban sustainability in part of the South Mediterranean context. In this regard, the transition of Egypt towards sustainability and resilience is definitely boasted at the strategic and programmatic level whilst validation on the level of local policies and urban practices is still at early stages and should not to be taken for granted.

Since sustainability and resilience have become a refrain around which multiple but differing interpretations have been fostered by specific agendas and associated priorities (Borie et al., 2019), important conflicts may arise among stakeholders, especially at the stage of translating into action such concepts.

Particularly, since the enactment of the strategic planning approach in Egypt, several aspects are being questioned in relation to its implementation. For example, in terms of vision, the transition from the strategic plan to detailed plans and projects is usually affected by the personal interests of some of the stakeholders, with the risk of seeing neglected in the final stage the original strategic vision. With regard to finalization, the plan making process always undergoes substantial delay and most analyses performed at the beginning become obsolete at the moment of plan implementation. Finally, public participation seems to be only fake whilst the opinion of the wider public and needs of citizens find rooms for expression when it is too late (Serag, 2018).

Plans, although good on paper, have been never really fully implemented or not implemented at all (Serag, 2018). Furthermore, also the gap between theoretical systems and corresponding practical systems, increases the problem of deterioration in all life systems of built environments (Hegazy, 2020), mainly because policies have emphasized the physical aspects of development without addressing the actual liveability of the urban environment.

These barriers to an effective implementation of policies and strategic planning for sustainability and resilience may depend upon complex and interrelated reasons: the instability of the political context, proper identification of interested stakeholders and their effective consultation against monopoly in decision-making, the administrative, fiscal, and political centralization, lack of funding and conflict when it comes to land ownerships, widespread corruption (Serag, 2018; Kenawy and Shaw, 2014; Nada, 2014).

Further research is thus necessary to investigate and monitor the capacity of Egypt to equip urban areas against natural and man-made risks and to prioritize tailored actions addressed to improve the quality of life both in mega cities and minor villages as well as steer the growth of new urban settlements based on correct models of development. Indeed, in light of recent socio-economic developments and expected climate change impacts, the goodness and success of policy and planning implementation processes should be extended including other south Mediterranean developing countries, recognizing that lots of regions where new agglomerations are growing, are no longer capable to absorb an increasing population without compromising their natural resources and deteriorating the urban and rural environments. Despite similar needs and problems characterizing most Mediterranean cities, their order of priority and implications vary considerably between the Northern cities and the Southern and Eastern ones (Chaline, 2001). The degree of readiness and willingness to practise urban sustainability through relevant policies and planning tools at national, regional and local level is uneven and cities of Mediterranean exhibits numerous and important imbalances deserving additional attention of policy makers, researchers and practitioners.

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3 Natural and anthropogenic pressures in the Baltic Sea region

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1. Introduction

According to IPCC (2001) the climate change is referred as "*any change in climate over time, whether due to natural variability or as a result of human activity*". Therefore, it is important to monitor both, natural and anthropogenic changes, as the systematic observations of the global environment are fundamental in order to understand the impacts on our lives. The preparedness against the growing effects on natural disasters and emergencies are crucial (Obasi, 1994). This is also important for the assessment of the best management strategies to maintain the ecosystem integrity and sustainable resources.

Climate change and increasing anthropogenic pressures due to population growth and urban development are expected to cause drastic changes in the global environment in the near future. The interaction between climate change and other anthropogenic pressures may intensify the climate-induced changes and are already increasingly affecting all ecosystems on Earth (IPCC, 2014). This includes marine ecosystems, that are among the most ecologically and socio-economically vital on the planet (Harley et al., 2006). Coastal areas undergo intense and continuous environmental stress caused by human activities, marine pollution and climate change (Cabral et al., 2019). No exception is the Baltic Sea, where both, natural and anthropogenic factors contribute to the environmental problems, making the marine environment of the Sea very vulnerable, especially due to the effects of human activity that lead to the eutrophication, pollutants, erosion and transfer of alien species (Leppäranta and Myrberg, 2009).

Baltic Sea is a small, landlocked, shallow sea (mean depth 54 m) connected to the North Sea and the Atlantic Ocean via narrow Danish Straits. The coastal area of the Sea is quite shallow (20–40 m) and relatively large, playing a specific role here (Leppäranta and Myrberg, 2009). A detailed study by Reusch et al. (2018) identifies the Baltic region as one of the most intensely studied coastal areas that can also serve as a tool to study consequences and mitigation of future coastal perturbations in other regions. Reusch et al. (2018) also emphasises that although many coastal areas in the world show a better ecological state on an absolute scale, Baltic Sea management has been able to reverse several detrimental trends, thus, the region is an ideal illustration of a complex governance setting in which environmental management has to operate.

In the following sections the topics that are relevant on the regional and global scales will be tackled based on cases from the Baltic Sea region. These examples could be beneficial for managing anthropogenic pressures in the other areas in a relation to adaptation and mitigation to climate change. Bearing in mind that the interaction of human and natural pressures are multi-fold, we will only discuss several of the pressures induced by natural variability and human activity, i.e. coastal erosion, land cover change, and bioinvasions in the Baltic Sea region.

2. Coastal erosion: climate change vs anthropogenic pressures

Half of the world's beaches could disappear by the end of the XXI century due to the coastal erosion, according to a new study led by the Joint Research Centre of the European Commission (Vousdoukas et al., 2020). Sandy beaches of the Eastern Baltic Sea coast are popular recreational spots for people and are important economic drivers for the local economy, also provide important habitats for wildlife. At the same time, they are extremely dynamic environments due to altering wave conditions (Soomere and Viška, 2014), sea level (Zhang et al., 2004, Dean and Houston, 2016) and winds (Prahalad et al., 2014), as well as geological factors and human activity (Hirschfeld and Hil, 2017; Aretano et al., 2017).

The major problem facing sandy beaches is an erosion, that will worsen due to the climate change induced the rise of sea level (Zhang et al., 2004; Valdmann et al.; 2008, Purvis et al., 2008) and due to increasing anthropogenic pressures (Brown et al., 2016; Neumann et al., 2015), including coastal infrastructure and different recreational activities on the coast (Aretano et al., 2017; Schlacher et al., 2007; Brown and McLachlan, 2002; Aouiche et al., 2016; Williams et al., 2018). The key issue for the nearshore communities is to identify most sensitive areas to erosion (Ramieri et al., 2011) since it may have significant socio-economical effect through the destruction of infrastructure, loss of land and property on the coast, as well loss of valuable beach areas used for the recreational purposes.

As an example, we will analyse one of the hot spots of the coastal erosion on the SE Baltic Sea coast (Bagdanavičiūtė et al., 2018), i.e., Palanga resort area (Figure 1).

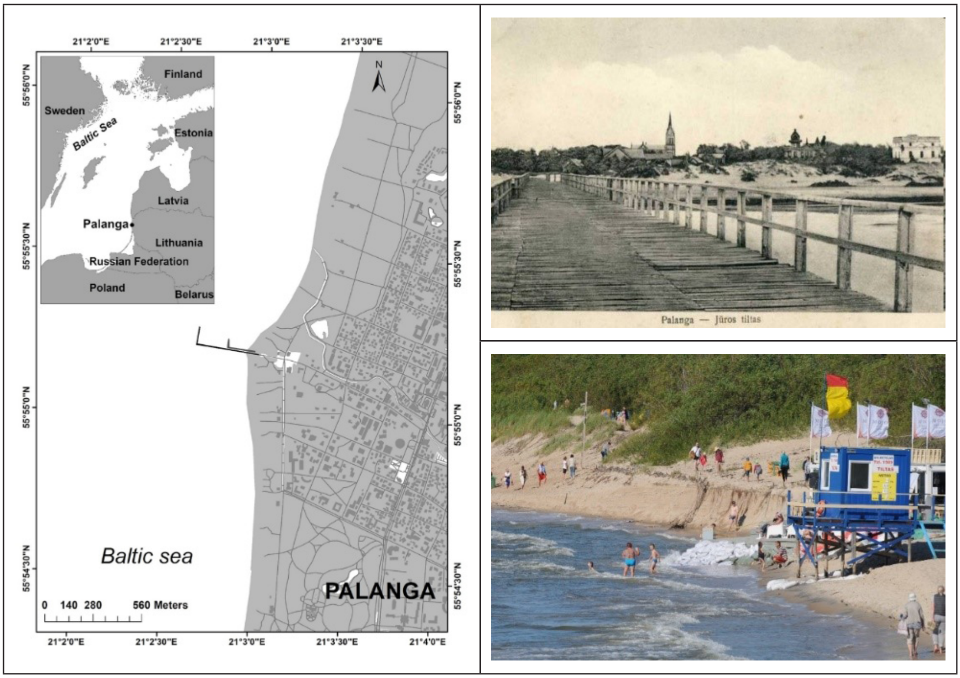

Figure 1. Palanga, Eastern coast of the Baltic sea (left). Palanga in the beginning of the XX century (upper right, from www.palanga.lt) and 8th of July 2016 (lower right, photo made by authors)

Palanga Beach is the major recreational region at the south-eastern part of the Baltic Sea. This relatively short stretch of the straight, exposed, sandy coast is massively visited in high tourist season (more than 100 000 visitors per season) (Povilanskas and Armaitienė, 2011).
History of the Palanga resort starts in 1889 when the first pier with a timber-piling groyne was built (Figure 1). The pier was impermeable to the water currents and sediment transport, thus, as the result, in 1892 it was no longer possible to moor here due to shoals that formed near the pier. After that, the pier was transformed to the promenade bridge and was adapted to the needs of a newly formed resort.
Due to human interaction, until the 1910 the seashore line moved seawards by ~400m and until 1947 it had additionally moved 100 metres (Dubra, 2006). In 1990 it was decided to rebuild the Palanga promenade so it would be permeable to the currents and sediment transport. And then the coastal erosion processes started. Significant losses in the beach width appeared after the storm "Anatoly" which occurred in December 1999 (Dubra, 2006). Then, in order to stop the erosion processes on the shore, the groins were rebuilt in 2000 (Žaromskis, 2005)

and the dynamical equilibrium state of the coast (Dean and Dalrymple, 2002) was destroyed and the beach loss became predominant process not only during stormy season. To restore Palanga beach, several beach replenishment companies were performed since 2000 until nowadays (Borisenko et al., 2020).

However, even if the hydrotechnical structures are claimed to be the main reason for the coastal erosion (Brown and McLachlan, 2002), in a long-term perspective climate change creates situations when the extreme hydrometeorological conditions evoke short-term (scale of weeks) coastal erosion accidents (Zhang et al., 2004). Following such devastating events, more attention should be devoted to the policy development in a relation to climate change in coastal areas, especially to the climate change adaptation and/or mitigation strategies in the next century.

In addition, the combination of the negative short-term coastal erosion events, anthropogenic pressure etc. create conflict situations when the needs and goals of stakeholders are diverse (Prenzel and Vanclay, 2014). Therefore, the coastal management measures should be implemented in a coordinated manner to ensure that coastal protection actions in one section of the coast do not harm the state of the coastline of a neighbouring section.

3. Land cover changes: natural or human impact? The example of the South-Eastern Baltic Sea region, the Curonian Spit case study

Land is one of the three major factors of production in classical economics (along with labor and capital) and the change in land use is, therefore, necessary for the economic development and social progress (Wu, 2008). In turn, human activities play a major role in the land use and land cover (LULC) changes. Consequently, these changes interact with the environment and have significant impacts on the ecosystems at the local, regional, and global scales and then directly or indirectly influences the global climate, becoming a force of global importance (Foley et al., 2005; Deng et al., 2013).

It is widely believed that before the year 2100 water levels on average will rise by approximately 25–123 cm. The results of this rise would mean that around from 0.2% to 4% of the population of the World's coastal cities would become homeless (Hinkel et al., 2014). Such real threats, precipitated by the global climate change, encourage us to focus our attention on the most vulnerable areas, which typically are the low-lying coastal regions. We must carefully analyse the situation and understand the processes taking place so that we are able to predict future outcomes and take action to mitigate unwanted effects.

As a transitional area between land and sea, coastal zones hold some of the most valuable and productive habitats on Earth. Huge amounts of energy circulate in these zones, which attracts all sorts of human interest and activities (Reguero et al., 2018; Rivis et al., 2016; Schlacher et al., 2014; Sperb et al., 2006). In turn, understanding of land cover change is an important aspect of coastal management, environmental change and its consequences (Buynevich et al., 2015). Many countries have vulnerable coastal areas, thus the changes in these areas might establish early warning signs for future changes likely to be experienced elsewhere.

The Curonian Spit located in the South-Eastern Baltic Sea region is a good example where there is a delicate interplay between the environment and our use of the land, with both leading to permanent changes to the landscape (Galinienė et al., 2019). Here, the physical and environmental processes that affect and alter the land use and land cover (LULC) in the Curonian Spit, which is a unique, thin strip of land emanating from the Kaliningrad region (Russia) in the south and reaching towards the city of Klaipeda (Lithuania), will be discussed.

The Curonian Spit is 98 km long, with a width that varies between 400 m and 4 km, forming a sandy barrier that separates the Curonian Lagoon from the Baltic Sea. This has always been an interesting area for scientists in different fields due to its landscape, specific composition, history of formation and the high levels of influence that humans have on the formation, morphology and development. Some of these changes are anthropogenic, instigated by humans either using the land for new activities, or as a result of management policies. This area is particularly interesting to study since data is available for the period of pre- and post-1990s, when the political situation changed, heralding new environmental, forest management, urban planning and management practices in the test zones. Therefore, land cover changes in the Curonian Spit were chosen as an exemplary case study.

In the Curonian Spit, dune movement was always an interesting research topic including the influence of human activities. Policies dating back to the beginning of the XIX century have been utilised to protect the dunes on the Curonian Spit from erosion and to prevent dune movement (Dikšaitė, 2016). There is still a great discussion how to best preserve the dunes of the Curonian Spit. Some say that it is necessary to cut the trees and reduce vegetation, since these are hiding the natural sand dunes, while others say that this cover of vegetation and trees protects dunes from sand movement and prevents the erosion. For many years, in different ways, National park managers have sought to keep the balance between nature and human manipulation in order to protect this UNESCO landscape.

The growth of grassland on the top of the Great Dune Ridge was a consequence of a successful forest and the national park management strategy, the aim of which was to stop the movement of the dunes that form the ridge. The land in the territory of Great Dune Ridge that is covered with sand has decreased each year in the areas of dunes due to the corresponding expansion of the grassland zones. The croplands that, over the years were transformed to grassland, were used by

National Park management as a protective base in order to stop sand movement and erosion from the top of the dunes. This particular relationship between dunes, vegetation and forest should be studied more thoroughly before any further changes to policy are made.
Anthropogenic land-use and land-cover changes have profound climate and environmental impacts (Comarazamy et al., 2013), therefore LULC has been shown to have a significant effect on the climate in a multiple ways (Gogoi et al., 2019). The link between land-use and land-cover and the climate is complex. i.e. while land use change is an important driver of climate change, a changing climate can also lead to changes in land use and land cover.
This example shows that the tracking of data dealing with land cover has the potential to explain many ongoing processes, predict their development and hence, influence decisions regarding further actions (Galiniene et al., 2019). It should also be highlighted, that a set complex research methods should be used, i.e. remote sensing methods together with statistical, historical data, computer vision and image processing while considering the potential subsequent use of LULC data in the further research in order to understand our changing environment, and to monitor the on-going changes in real-time or for comparison over longer periods of time.

4. Challenges of biological invasions

Biological invasions as a field remains a regular target of criticism – from outright deniers of the threat to scientists questioning the utility of the discipline (Courchamp et al., 2017). As humans have accelerated the spread of species around the Earth, it should also be stated in the definition of alien species. Human-induced anthropogenic introductions of species are a major aspect of rapid ecological change globally (Lowry et al., 2013). Therefore, in this chapter, the definition “alien” is defined as an organism, gametes or propagules that may survive and subsequently reproduce, occurring outside of its known or native range.
The world-wide dispersal of species has increased by orders of magnitude, and this has contributed to some regions now being invaded by several new species per year (Cohen and Carlton, 1998; Reise et al., 1998; Coles et al., 1999). One of the hypothesis argues that 10% of species established will become invasive/pest species (Williamson and Brown, 1986; Jeschke et al., 2012), while other studies shows that establishment of invasive species percentage various from 5-20% (Jeschke et al., 2014). The framework of the typical invasion processes: transportation, introduction, establishment, spread, adaptation and impacts (Fig. 2).

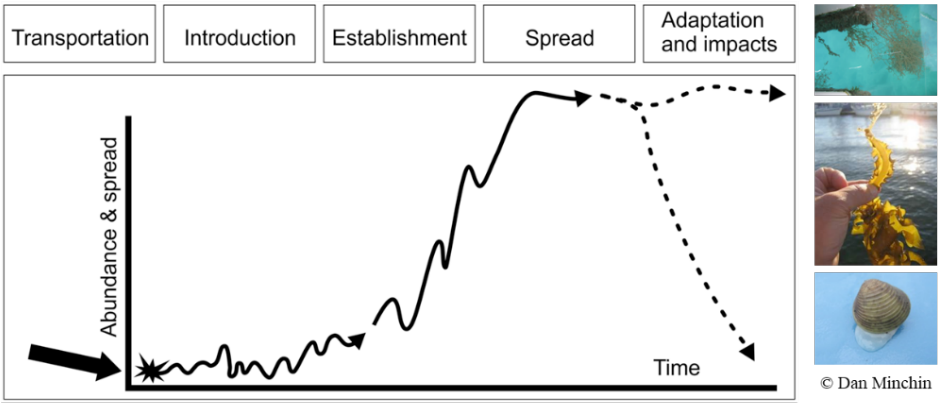

Figure 2. A typical invasion sequence (Reise et al. 2006; Olenin et al. 2011)

Typically alien species may arrive and enter a new region mainly through three broad mechanisms: importation of a commodity, arrival in a transport vector and/or natural spread from a neighbouring region where the species is itself alien (Hulme et al., 2008). The ecological impacts are various from negligible changes till tremendous "cascade effects" (Thomsen, 2013). Invaders can pose ecological consequences: displacement of native species (Grosholz, 2002), changes to community structure (Occhipinti-Ambrogi and Savini, 2003) and food webs (David et al., 2017), expand geographical distribution (Zimmermann et al., 2010), which can result in pathogens and disease outbreaks (Crowl et al., 2008; Mazza et al., 2014). Consequences can also be evolutionary type, e.g. the hybridization with native species (Allendorf et al., 2001; Bouchemousse et al., 2016), population differentiation and physiological adaptation (Strong and Ayres, 2013). It is notable that same species can take different types of impacts depending on the surroundings.

The Baltic Sea is an especially problematic area regarding bioinvasions. Being a recipient, transit and donor area of alien species, it has become an important node in a global network of alien species transfers (Leppäkoski and Olenin, 2000). The increasing number of alien species is an indicator of global change in the Baltic Sea. According to Leppäkoski (Leppäkoski et al., 2002) the number of alien species is lowest in the northernmost parts and highest in the lagoons in the south as well as in the Kattegat. It is also noted that open sea and deep bottoms were almost without introductions until the early 1990s. After introduction of North American spionid polychaete *Marenzelleria cf. viridis* and the predatory Ponto-Caspian water flea *Cercopagis pengoi* after establishment of these species, full expansion in the Baltic sea took less than 10 years (Leppäkoski et al., 2002).

According to the latest alien species introduction events, the number of alien species is still increasing, based on data stored in the information system on aquatic non-indigenous species, AquaNIS (2019). During the last period of 2000-2018, total number of 149 introduction events involving 75 alien species in the countries of the Baltic Sea region was detected. Germany had the highest (34 alien species) and Lithuania the lowest (7 alien species) number of alien species during assessment period (2000-2018) (Srėbalienė, 2019). While the records of introduction events are higher than the number of species, it is explained that once species is introduced into the Baltic Sea, it spreads through the secondary spread and does not count as new species in the region. Mostly species were introduced firstly in the Baltic Sea region, and then spread through the secondary spread into neighbouring countries.

Rising numbers of invasive species brings new challenges for managers and scientists. In recent years' scientific community and policy frameworks are developing and applying a set of internationally agreed indicators to assess the status of biological invasions (McGeoch et al., 2006; Olenin et al., 2016; Latombe et al., 2017; Rabitsch et al., 2016). Assessment process should be quantitative and generic, method should be transparent, repeatable and testable (Sandvik et al., 2013). Because introduction does or is likely to cause harm to human health (IUCN, 1999) by assessing impact these features should be included. Still using indicators is scarce, the lack of indicators stemmed either from the lack of monitoring data, or from the lack of expert's time for further development of indicators. The assessment is depending mainly on the available data that can be gathered (Early et al., 2016).

In addition, climate change can fundamentally alter the behaviour, spread, and harm caused by alien species and the effectiveness of the management activities. After impact of alien species on environment, it can increase the decline and collapse of ecosystems (Stachowiczet al., 2002). Anomalous temperature stress can cause mass mortalities in benthic organisms (Cerrano et al., 2000) that result in empty niches for new colonizers (Occhipinti-Ambrogi, 2007). For the process of the effective control and limitation of spread and damage caused by invasive species, it is critical to understand and predict how climate change will affect species invasions and the efficacy of the tools used to combat these invasions. The effects of warming climate are primarily a cause for physiological stress, which acts more strongly on species already near their tolerance limit (Laubier, 2001).

5. Conclusions

Our climate is changing. And so is our population. And no matter what the causes of these changes are, they have significant effects to the natural environment, e.g., ecosystem health, land cover changes, biodiversity of species, water availability etc., and play an important role regarding human health, food security, infrastructure, and, therefore, has multiple effects on the key socio-economic sectors.
Human-induced warming reached approximately 1°C above pre-industrial levels in 2017, increasing at 0.2°C per decade (IPCC, 2018). The current world population of around 7.6 billion is expected to reach 8.6 billion in 2030 with the current estimates of roughly 83 million people added to the world's population every year, according to a new United Nations (2017) report. And alongside demographic growth, the ecological impacts per person have risen with human activities significantly changing the planet: from the acidity of the oceans to the fragmentation of the landscapes and the global climate change (Otto, 2018).
The aforementioned issues are also relevant for the Baltic Sea, which is a small sea on a global scale, yet it is one of the world's largest semi-enclosed bodies of brackish water. Its special geographical, oceanographic, and climatological characteristics makes the Baltic Sea ecosystem highly vulnerable to the environmental impacts and human activities at sea and in its catchment area (HELCOM, 2010). As it was argued by Reusch et al. (2018) "*the Baltic Sea can serve as a time machine to study consequences and mitigation of future coastal perturbations, due to its unique combination of an early history of multistressor disturbance and ecosystem deterioration and early implementation of cross-border environmental management to address these problems*". Therefore, the understanding of natural and anthropogenic pressures in the Baltic Sea region could be beneficial while managing changes induced by natural variability, including climate change, and human activity, in other regions as well.
As the presented case studies has shown, more emphasis should be given to the impacts of climate change and anthropogenic activities in the coastal areas, as they undergo intense and continuous environmental and anthropogenic stress, particularly making the climate change adaptation and/or mitigation strategies for the next century of a high importance. It highlights the importance of setting the guidelines that enable the integration of the information on natural and anthropogenic changes into development, planning, and implementation by decision-makers, stakeholders, and society at local, regional, and international levels in order to foster the socio-economic growth and sustain healthy environment, as the success of managing various pressures requires involvement and participation of all stakeholders, including non-governmental organizations, civil society, private sector and academia.

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4 Risk Assessment of Climate Change on the Coastal area of Quseir, Red Sea, Egypt

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1. Introduction

Climate change and the associated global warming cannot be neglected. The atmosphere of the earth and the oceans are getting hotter, primarily due to greenhouse gases derived from human activities. Global warming and the expected sea level rise will be associated with an increase in the intensity and frequency of extreme events. Natural resources and socio-economic conditions will be affected by these climate changes and seriously impact the sustainable development in the Red Sea. The response of the coast to these changes can be severe such as inundation of the low laying lands, erosion of the exposed raised coral reefs, shoreline changes, increased sedimentation and contaminants, smothering seagrass beds and coral reefs, mangrove retreat, and coral bleaching. As mentioned before by Blanchon et al. (2009) turbidity on fringing reefs from 0.2m of sea level rise can be increased through re-suspension of fine sediment on reef flats and by coastal erosion and transport of fine sediments to the nearby reefs. Flash floods and the high rates of development projects and increase settlement without proper control place also pressures on the Red Sea coast. These pressures are exacerbated by growing development, lack of awareness, and inability to apply regulations and laws.
Quseir is one of the Egyptian gateways and one of the oldest and historical cities on the coast of the Red Sea. It is located 140 Km south of Hurghada, 133 km north of Marsa Alam (Fig. 1). Quseir is one of the cities subjected to several pressures of climate changes and the associated extreme events such as floods. Quseir area is selected for this study to be used as a case study to assess ecological risks for the Egyptian Red Sea coast. Institutional and human capacities are very important for sustainable development and therefore risk assessments of climate change are the urgent need.

2. Materials

The study area covers about 100 km long north and south of Quseir along the coast (Latitude: 25° 45' - 26° 20' north, Longitude: 34° 5' - 34° 30' east) and extends from Wadi Abu Hamra El Bahari in the north to Wadi Wezer in the south (Fig. 1). The area is characterized by a narrow coastal zone parallel to the shoreline. As elsewhere along the Red Sea, the fringing reef is the seaward extension of the coastal plain (Mergner and Schuhmacher, 1974). The depressions of coastal plain are mostly valley mouths, locally called "sharms" or "marsas" (Mansour, 1995) with small pocket beaches. These sharms or small bays are partly landlocked by coral reefs and are, therefore, sheltered and wave action is minimal. Such protected shallow bays, sharms and lagoons provide favorable habitats for the growth of mangroves. Raised coral reefs in the form of a ridge-furrow system extend from the intertidal zone to few meters above the level of the high-tide. The coastal zone host phosphate mines and some of the industrial activities including phosphates and other mineral shipments. Hamrawein phosphate factory and port occur along the coast about 20 Km north of Quseir port. These two ports are the main trading and transportation centers and considered attractive to employment from the nearby cities of the Nile Valley. Fishing is also one of the income generation for inhabitants of Quseir area.

Water circulation in the study area driven by winds, tides, and currents is critical for transportation and distribution of sediments, nutrients, contaminants, and other water-borne materials. NW to NE winds are dominant and the southern winds are rare. The northerly wind effect, especially the NW trend carrying sediments from the nearby coasts into the water southward. Winds create a mainly NE – SW oriented distinct wave motion and also drive longshore currents affecting sedimentation. In Sharm El Bahari and Sharm El Qibli waves redistribute terrigenous sediments on the rocky tidal around the sharm (Mansour, 1995). The tide is semidiurnal, maximum peak every 12 h with a mean tidal range of about 0.8 m. Water temperature ranges between 28-29°C in summer and 22-23°C in winter, but the extreme shallow areas record higher values due to solar radiation.

Impacts of climate changes on the Red Sea natural resources, tourism and public health cannot be ignored. The lacking of institutional systems for risk assessment and risk management could be harmful, especially with the expected increase of frequencies and severities of extreme events. Risk assessment of potential impact of climate changes on the coastal area is important to identify and assess options for adaptation.

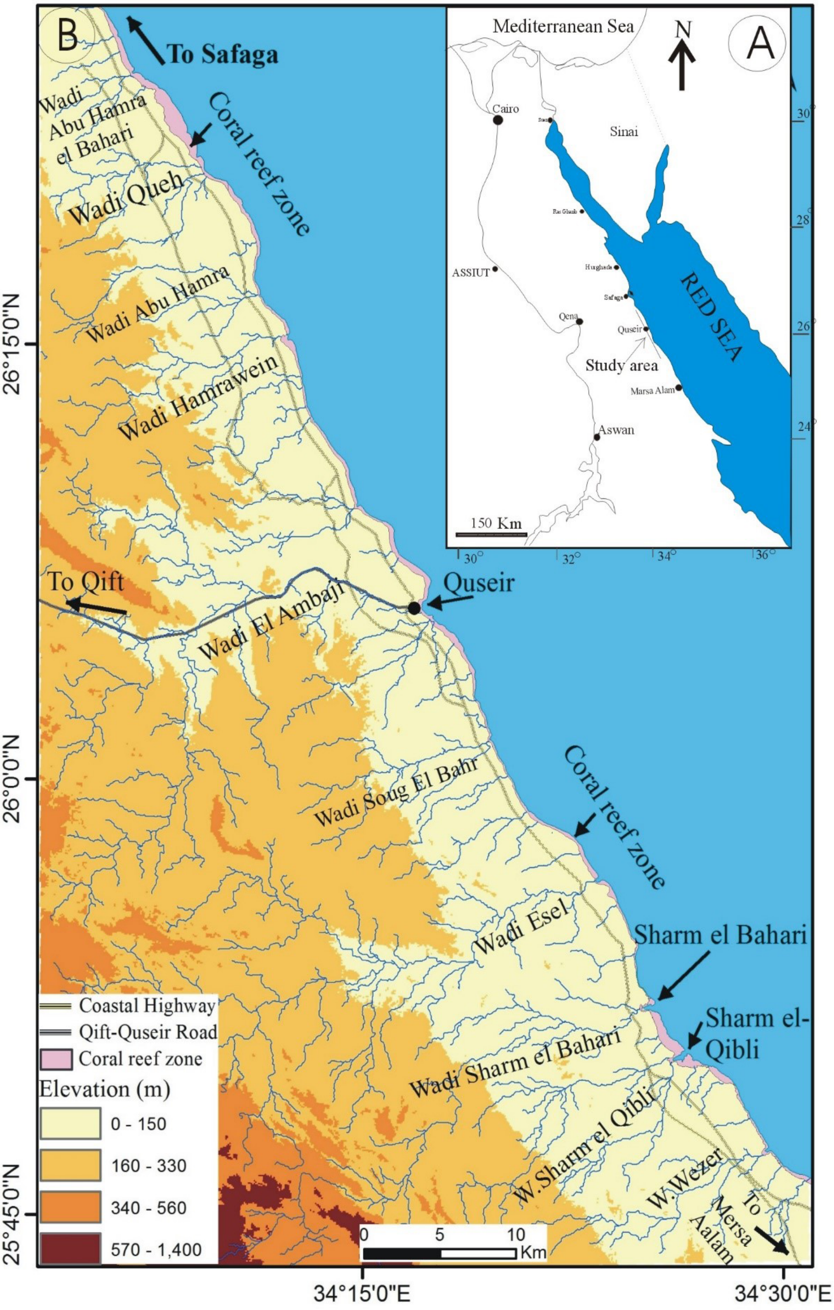

Figure 1. Location map (A), and Quseir area shows the dry valleys and coral zone (B)

To start the problem formulation review of data, inspection of topographic maps and Landsat image of the coastal plain of Quseir area are important. The following comprehensive survey should focus on the unconsolidated, exposed, ecologically effective and/or inhabited areas that can be at high risk. These sensitive areas are identified and determined. Geographic locations of mangroves, associated wetlands, and other severely sensitive segments like inhabited areas of Dry Valleys (Wadis) outlets are identified, carefully studied and mapped.

3. Risk Characterization and Ecological Effects on Natural Resources

The high mountains extending along the coast characterize the inland geomorphology. Many wadis fan-out of these hills and the raised coral reef terraces higher than current sea level, being dry most of the time with sporadic and abrupt fluvial activity. Detrital sediments and contaminants of the wadis are brought into the sea from these fluvial activities. The coarsest material remains on the beaches and progressively finer particles reach greater distance and depth, where they are strongly diluted by biogenic material. The beach and nearshore zone is one of the most dynamic coastal environments. Beyond the beach, the seaward limit is placed at the coral zone. The natural resources along the coast are exposed to many stressors from growing development, tourism and climate changes.
For undertaken a risk characterization and ecological effects of climate change on natural resources, this section will show a Risk Characterization and a Characterization of ecological effect of climate change of different natural resources such as Reef flat, Tidal flat, Seagrass, Sand facies, Mangroves, Beach, Raised Coral Reefs, and Wadis.

3.1 Reef flat (coral zone)

This zone is narrow and clearly appear along the coast and on both sides of the sharms. Corals starts to grow in the intertidal zone after a few tens of meters from the beach and increased in density and diversity in the reef flat seawards. The coral zone is sharply bordered by the reef slope, which is very steep leading to the sand bottom in the shallow parts and the coral carpet in the deeper waters. Coral genera of *Pocillopora* and *Stylophora* characterize the reef flat and species of the genera *Acropora* and *Porites* dominate the reef slope, but in the more shallow parts *Millepora* also exist.

– *Risk Characterization*
  Coral reefs are subjected to some stressors such as global warming, sewage, excessive nutrients, sedimentation, diving activities, and anchor damage. Exposure pathways include sewage outfalls, municipal plants, urban centers, individual treatment plants, groundwater seepage.
– *Characterization of ecological effects*
  Coral mortality and algal growth resulting from global warming, increased temperature from desalination effluents, sewage pollution, sediment re-suspension, contaminants, and diving activities.

3.2 Tidal flat

Most widespread and prominent along the coast are rocky tidal flat with a rough surface covered with gravel and sand which are partly cemented into beachrock in the uppermost intertidal zone. The contact to the subtidal zone is either abrupt (e.g., margins of sharms) or gradational (e.g., landward entrance of sharms). The depressions in the tidal flats are covered with a sand layer and exhibiting sometimes sparse seagrass growth (*Halodule uninervis*). *Ophiurids*, along with the gastropods *Nerita albicilla* and *Cerithium caeruleum*, are abundant; mass occurrences of the *mytilid* bivalve are also characteristic (Mansour, 1995).

– *Risk Characterization*
  Tidal flat and its water quality are subjected to many stressors such as oil, industrial effluent, and sewage, pollutants from urban areas. Turbidity from beach sediment withdrawal, erosion of raised reefs or during flash floods also impact water quality. Sewage outfalls, industrial point sources, oil spills, phosphate mining, discharge of desalination plants (increased salinity), sedimentation and contaminants, solid waste (and litter) are the exposure pathways.
– *Characterization of ecological effects*
  Increasing salinity, pollutants and sediments from different sources highly impact the marine environment. Global warming with increasing water temperature exacerbates the mortality of corals and seagrass.

3.3 Seagrass

This zone is characterized by its more or less dense stands of seagrass, mainly *Halophila stipulacea* and *Halodule uninervis*. Seagrass occur as narrow strips parallel to the coast or as isolated patches. Variations in density of plant growth depend on the composition of bottom sediments, where areas abundant with sand

and fine sediments such as the valley mouths are rich with seagrass meadows (Mansour, 1995). *Soritids* among the larger foraminifera and mass occurrence of *Strombus fasciatus* among molluscs are the observed fauna of seagrass meadows.

– *Risk Characterization*
  Sedimentation, increased salinity, and terrestrial contaminants represent the main stressors. Proximity to pollutant sources, or wadi mouth are the exposure pathways
– *Characterization of ecological effects*
  Seagrass is very important environment for some sea species. Sedimentation and contaminants will change the bottom sediments composition and lead to smothering seagrass and mortality.

3.4 Sand Facies

The Sand facies occurs mainly at the valley mouths and bays, and at the lagoons of the tidal flat and vary in width from a few tens of meters to a few hundreds of meters (Mansour, 1995). The sand facies grade into subtidal zone seawards and become exposed at low tide landward. Various burrows, attributed to crustaceans, mostly destroy the primary structures and textures of sands.

– *Risk Characterization*
  Sedimentation, terrestrial contaminants, and tourist activities represent the main stressors. Occurrence at the valley mouth and proximity to pollutant sources are the exposure pathways.
– *Characterization of ecological effects*
  Sand is rich with crabs, worms, molluscs, and other marine fauna. Tourist activities, sedimentation and contaminants from floods will change the bottom sediments composition, and impact marine fauna.

3.5 Mangroves

The largest swamp area, which covers few acres occurs at about 37 Km north of Quseir at the northern outlet of wadi Queh (Fig. 2). Small mangrove areas (few meters wide) are located in sheltered areas of both sharm El Bahari and sharm El Qibli (Fig. 1). A small swamp without mangrove is located in front of Wadi Wezer. The mangrove vegetation is represented by a single community dominated by *Avicennia marina* (Mansour, 1992 and Madkour et al, 2013). Its occurrence is restricted to a small and sparse patches in a form of bushes. Crab, worm burrows, or snail trails are frequent features of mangroves. Mangroves at Sharm El Qibli are covered by a light brown microbial mat. Molluscs, mainly alive gastropods, occur in clusters on the sediment surface and on the vertical roots of *Avicennia marina*. *Peneropolis* and *Sorites* are the two dominant types of foraminifera.

– *Risk Characterization*
  Human stresses include overgrazing, solid waste disposal, oil, overfishing, and tourist constructions, beside the changes in hydrological patterns. Sea level rise, sedimentation, hypersalinity are projected stressors on the mangroves and wetlands. Ground water seepage, sediment deposition, evapotranspiration, oil spills or bilge pumping are the exposure pathways.
– *Characterization of ecological effects*
  Mangroves are not only rich ecological systems, but also buffers between the land and sea interface. Dependence of mangroves occurrence on the sea level and climate change is an important topic. Deterioration of mangroves will impact shoreline stabilization and filtration function for terrestrial sediments and the pollutants along coastal shores. Modification of exposure pathways may be weaken these functions. Therefore and according to Law Nos. 102/83 and 4/94 and by Prime Ministerial Decree Nos. 1067/1983 and 642/1995 all mangrove areas in Egypt are protected.

3.6 Beach

The beach is 3 to 8 m wide, and varies between few centimeters to about 50 cm high. Slopes of 8^o - 15^o have been recorded. The sediments consist of gravel and sand, and contain abundant shell material swept up from the sea. Beach sediments varies from terrigenous at the mouth of valleys and carbonates a few meters away. Sometimes, however, these materials are partly cemented into beachrock that exhibit a typical appearance with a seaward dipping. Various burrows attributed to crustaceans occur in the beach sands.

– *Risk Characterization*
  Debris, land filling, fine sediment withdrawal beside solid waste and oil are the main stressors on the beach. Improper disposal of solid waste and litter; oil spills; hazardous materials are the exposure pathways.
– *Characterization of ecological effects*
  Coastal process dramatically influences the distribution of solid waste, contaminants, oil, beach nourishment, and land filling. The stressors can physically smother land features, change shoreline, bottom topography, and impact marine ecosystem. Beach erosion exposed the nearby fixed structures to the direct

impact of storm waves, high tide, and will be damaged or destroyed unless expensive protective measures are taken. Therefore, any significant increase of sea level directly impact coastal inhabitants.

3.7 Raised Coral Reefs

Raised coral reefs are the main geomorphologic features along the coast, and extend from the intertidal zone to about 10 m above the level of the high-tide in some places south of Quseir. Their thicknesses generally decrease northward (Mansour, 1993). In many places the coral reefs disappear beneath a cover of Quaternary clastic sediments. The reef frame is usually massive and cavernous, with voids filled by internal sediments.

- *Risk Characterization*
  Raised coral reefs are subject to some stressors such as erosion, destruction and deformation due to resorts construction (Fig. 2). Groundwater seepage is the exposure pathway either from the sea as the salt water intrusion or from the resorts and urban areas as treated waters and contaminants.
- *Characterization of ecological effects*
  Include distortion and changing the topography of the area. Rock fragments and debris spread on the beach and tidal flats, and threat the terrestrial and marine environment and tourists.

3.8 Wadis

There are many valleys that originate from high mountains and flow into the sea. The largest of these dry valleys are Wadi Ambaji at the southern border of Quseir city and Wadi Queh north of Quseir (Fig. 1). Flashfloods bring a lot of sediments and rock debris into the coastal plain by these wadis. However, several embayments and small pocket beaches occur at the mouth of these wadis.

- *Risk Characterization*
  Most of these wadis are frequently subjected to severe flash floods with excessive sedimentation and contamination, following intense, short-lived rainstorms.
- *Characterization of ecological effects*
  Along wadi Ambaje is the main highway connects the Nile Valley and the Red Sea. Along the coastline is the major Red Sea highway, which traverses the wadis outlets. Flash flooding seriously damage these two highways and many homes of the town of Quseir situated within the course of wadi Ambaji are

subjected to risk from flood inundation. Sediments, contaminants and debris deposited in the valley and those were thrown into the sea severely damage the terrestrial and marine environments. Destruction of settlement and loss of other properties also impact humans. Flood events and sediment flow, and contaminants directly impact nearshore environments, such as mangroves, seagrass beds, and coral reefs.

Figure 2. Mangroves north of Wadi Queh (upper one). The photo shows the ridge-furrow system of raised coral reefs (left), beachrock covered with oil and the man refers to it, and the mangrove swamp at the end. The lower photo shows destruction (left) and erosion (right) of raised coral reefs

4. Climate Changes and Risk Assessment Variables

Sea level rise poses the biggest challenge facing most coastal areas as it changes environmental conditions through coastal floods, destroying property, and coastal habitats, as well as the degradation of groundwater quality. Changes in water temperature and sea level lead to coastal and marine ecosystems degradation. Also, any increase in the water temperature can lead to the deterioration of the symbiotic relationship between coral and algae and lead to coral bleaching or even death. Coral calcification and formation are also affected negatively by increasing the rate of carbon dioxide in the atmosphere. According to the nature of Quseir area and due to the above mentioned stressors of climate changes the following variables can be utilized for risk assessment: direct inundation, salt water intrusion, extreme events, loss of biodiversity, socio-economic and health implications.

4.1 Direct Inundation

Generally, the narrow coastal plain of the study area lower the susceptibility to flooding because the area that can be submerged with water is limited. However, the wide backshore at the valley mouth is subject to severe inundation by sea level rise or very high tide. These areas directly exposed to waves and therefore, the risk of inundation is high. Sea level rise causes the waves to reach the coast strongly, and consequently sediment transport and coastal erosion will be high which negatively impacting coral reef ecosystems and inhabited areas. Larger amounts of sediments raised from the slopes of coral reefs and those pulled from the shore due to increasing wave power will increase water turbidity that could damage coral reef ecosystems.

The rocky nature of raised coral reefs decreases their vulnerability to waves, whereas unconsolidated sediments in the beach pockets, small bays, sharms are more likely to be affected by the wave action and, therefore, they are severely exposed to inundation by the sea level rise and flash floods. Moreover, growing unplanned urbanization, coastal land filling, flash floods, pollution, and the negative impacts of tourism increase losses of habitats along the coast.

4.2 Salt water intrusion

Along the coastal zone, groundwater resources and soil quality are directly subjected to salt water intrusion. The result impacts are increase of soil salinity, deterioration of land productivity and socioeconomic and health implications.

4.3 Extreme events

Flash floods, storm surges heat waves, and dust storms are extreme events impact the Red Sea coast. The severity and frequency of these events are expected to be exacerbated by sea level rise. While the average annual precipitation is less than 5 mm/year, historically, Quseir has seen annual precipitation as high as 60 mm

(Badawy, 2008). Rainwater fills rapidly the wadis, which flows down the high mountains into the sea. As the water travels it gains strength, which creates a destructive force, extremely dangerous to the main highways, marine environments and human safety. Flash flood caused severe damage to the phosphate mines railway network of wadis Queh and El Ambaji, the Qift–Quseir road, and the coastal highway (Quseir–Marsa Alam road). The large amount of sediments that torrents carry with them makes the entrance of sharms free from coral reefs.

4.4 Loss of Biodiversity

Sea level rise will limit the light that reaches deep lying coral reefs and consequently, the sustaining growth of corals is doubtful. Increased turbidity caused by high sediment loads from flashfloods degrades the marine ecosystem. Besides, significant biodiversity loss will occur from drilling, landfilling and beach nourishment. The coastal region is characterized by the direct relationship between global warming, increasing ocean salinity and the biological diversity of coral reefs, marine life and inland fauna. Sea water acidification and coral bleaching severely impact tourism and national income.

4.5 Socioeconomic and health implications

Raised coral reefs and nearshore resources highly damaged from growth of tourist development and hotels construction without following the regulations and laws, through activities such as destruction of coral reefs, land filling, excessive sedimentation and contaminations. Large numbers of fishermen enforced to move away from the fishing grounds because of the loss of biodiversity and productivity. Sea level rise and salt water intrusion in ground water aquifers impact health and increase water-borne disease. Therefore, the environmental risks associated with global warming, sea level rise and unplanned development along the coast are very important for the quality of both environmental and human health.

Risk assessment reflects the net response of the coastal zone resources to global warming, sea level rise and the unplanned settlement. The coastal zone is generally, rich in coral reefs, and mangroves, which are sensitive to global warming, their occurrence provides natural protection against high waves. As mentioned above, sea level rise will impact the coral reef ecosystems and consequently waves will strongly hit the shoreline. However, the assessment indicates that Quseir city, valleys mouth, bayes, pocket beaches and the marine ecosystem facing these changes are under pressures and suffer high risk. The intrinsic nature of these areas along the coast has increased the susceptibility to sea level rise. The wide coastal flats

of mangrove ecosystems at wadi Queh, wadi sharm El Bahari and wadi Sharm El Qibli are at high risk caused by their exposure to strong waves result from sea level rise, and on the other side from flashfloods. Moderately sensitive areas mainly comprise the raised coral reefs at the southern side of sharms or the bays due to their exposure to the strong waves caused by the NW-NE winds. Moreover, these sharms or bays are free from fringing reefs and therefore there is no protection of the waves hit the exposed raised coral reef ridges. Raised coral reefs between the small bays or sharms partially exposed to waves are considered protected from the consequences of climate change and thus represent the least vulnerable parts.
Sea level rise may either resilience with the tectonic uplift of the Red Sea coast or may be higher and impact the ecosystems. The rocky and cliffy nature of the coast in Quseir area, combined with flashfloods and the seismic activity at Abu Dabab south of Quseir possess a potential hazard for raised coral reef destruction and spreeding rocky blocks and debris on the beach and intertidal flats. Sea level rise will impact coastal flats, sharms, and bays over which Quseir town, Hamrawein village, resort villages, hotels, and the ports occur.
The slow rise in the sea level by few centimeters should submerge tens of meters behind beaches around the bays and sharms, whereas any unexpected rise of the water level by high waves due to tectonics of 2 or 3m height would inundate most of the areas along the coast. However, a detailed study is recommended. Biological resources, such as mangroves and seagrass, which occur at the mouth of some wadis are within the sensitive regions to sea level rise as they are linked to the intertidal zone. Based on the type of mangroves, the trees my either resilience with the sea level rise or may submerge or retreat. Nature of coastal shoreline, changes of sedimentation and organic accumulation may change species composition and zoning in mangroves. The raised reefs, which are mostly occupied by resort villages are generally far from inundation by the slow sea level rise. However, some parts of these resorts are not protected if any sudden high waves occur.
Human activates also impacts coral reefs and other marine fauna and flora through pollutions from different sources, ranging from contaminants of flash flooding, oil spills to dumping of treated wastewater. Oil pollution is observed on the shores of mangrove areas (Fig. 2). Construction of new coastal resorts release sediments and wastewater that could potentially impact coral reef ecosystems. To minimize risks, human settlement, and tourist villages and related activities should occur away from wadis because floods can transport large amount of sediments and contaminants from land use practices without proper controls.

5. Conclusion

Study of various aspects of impacts and possible responses to climate changes on the coasts of Quseir indicate that a large portion will be affected to a combination of flash flooding, inundation and erosion, with consequent loss of marine ecosystems and developed projects. The coast of Quseir is vulnerable to potential impacts of climate changes with varying degrees. Low-laying areas along the shoreline, sandy flat beaches at the sharms and bays, and marine ecosystems are the most sensitive to the climate change which reveal high risk, whereas the surrounded raised coral reefs exhibit low risk. On the other hand, raised reefs exposed to NE-SW waves at the southern side of sharms and bayes are at moderate risk.

Extreme events, especially flash floods constitute high risk to Quseir city and the marine ecosystem of the area and thus, institutional capacities for risk reduction is necessary. Proper implementation of development projects requires strong enforcement of environmental regulations.

The seriousness of climate change impacts to the income generation and socio-economic conditions leads us to focus our studies on the risk assessments and take serious steps to manage these risks. Finally, risk management and action programs should be designed to minimize the risks. This management and action plan can then serve as a feedback mechanism for continued risk analysis and evaluation.

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5 Adaptation of Sea-level Rise impacts in coastal areas due to Climate Change

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1. Introduction

Adaptation refers to the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. It can also represent all those responses to climate change that may be used to reduce vulnerability. Vulnerability refers to the propensity to be adversely affected by the hazards, exposure is the presence of people, livelihoods, resources, environmental services or any other assets of value in places that can be affected, and weather and climate events or natural hazards are the physical phenomena that can be potentially dangerous or harmful (IPCC, 2014).

Sea-level rise (SLR) is one of the most significant consequences of climate change pose a serious threat to large numbers of people living in these areas. This is resulting in a range of impacts including increased flood risk and submergence, salinization of surface and ground waters, and morphological change, such as erosion and wetland loss. Actual impacts will depend on a range of change factors in addition to the amount of SLR and climate change, including a number of factors which are human-controlled such as coastal land use and management approaches. Accordingly, it is important to identify adaptation options and implement adaptation measures that lower the risk and actual losses from climate change impacts. Without assessment of such adaptations, the impacts researchers could well overstate the potential negative effects of climate change. An additional reason for assessing adaptation is to inform policy makers about what they can do to reduce the risks of SLR due to climate change.

This work represents the potential impacts of SLR on the coastal areas and the proposed adaptation measures to cope with the negative impact to achieve its sustainable development.

2. Sea-level rise impacts on coastal areas

The major consequences of SLR on the coastal areas are described as follows:

2.1 Physical Impacts of Sea-level Rise on the Coastal Zone

SLR in terms of marine inundation will shift the coastline landward, erode beaches, accelerate cliff failure, destroy some coastal habitats, and loss coastal infrastructure (Dawson et al., 2009). Furthermore, it can contribute to the degradation of coastal aquifers by raising the interface between intruding salt water and overlying freshwater (Werner and Simmons, 2009).

2.2 Socio-economic Impacts of Sea-level rise on coastal areas

SLR has potential threats to infrastructure, transportation, agriculture and water resources within the coastal zone, as well as tourism and provisioning services (fishing, aquaculture and agriculture). While some impacts will be applicable to all coastal types, different coastal types will respond differently to the impacts of climate change.

3. Response to Sea-level Rise

Responses to SLR impacts on the coastal areas can be categorized in two ways: (1) reactive or proactive responses and (2) structural or non-structural responses. Communities that respond proactively have more flexibility. First, reactive responses are actions that a government takes after impacts have already occurred. Reactive response can include rebuilding restrictions, requirements that rebuilt structures be retrofit to be more resilient to impacts, and buyouts of lands with damaged structures. Alternatively, a proactive response involves advance planning and implementation of measures that are designed to pre-emptively mitigate the negative consequences from natural hazards and human responses to those hazards (Grannis, 2011).

4. Adaptation measures to Sea-level Rise impacts

Following adaptation measures is reviewed by considering the previous initiatives such as: Nicholls (2002), Grannis (2011), and IPCC (2014). Accordingly, these measures were classified into four classes as follows: comprehensive plans, regulatory measures, spending measure and tax and market-based measures.

4.1 Comprehensive plans

Comprehensive plans are a powerful tool by which local governments guide development. Comprehensive plans are a long-range planning tool. They present a community's vision for its desired future development over 15 to 20 years. In the plan, local governments map present conditions by identifying the location and character of lands and facilities. Based upon studies of population growth and development trends, a plan designates areas for future development, preservation they are implemented through a legally enforceable zoning ordinance, and proposed public improvements, among other things. Plans typically do not have a direct legal effect, but maps (SC Adapting to Shoreline Change, 2010).

4.2 Regulatory measures

Regulatory measures may provide the most expedient solution, but they can also be perceived as unfair by regulated parties. Governments may have difficulty building political will to impose such measures:

a) Zoning and Overlay Zones
Provide the legal framework that governs the use and development of land in a specific area. Zoning maps allocate the area into various regions based upon the permitted types of uses (e.g., residential, commercial, or industrial) (ReCAP, 1999). Subsequently, within each zone different rules specify the design requirements that govern development (e.g., setbacks, building heights, building densities). Overlay zones have additional regulations on an existing zone according to special features of that zone (e.g., floodplains and historic districts). Governments could create zones based upon their adaptation goals (protection, accommodation, retreat, or preservation) (IPCC, 2007). Retreat and accommodation are decreased human influences on the coast while protection controls human impacts by soft or hard engineering.

b) Floodplain Regulations
Structures in floodplain areas must be built to reduce flood damage impacts (e.g., elevated) Grannis, 2011).

c) Building Codes and Resilient Design
Building codes can be used to regulate the construction of structures to maximize their capacity to withstand flooding (e.g., elevation and construction techniques and materials). Design requirements are different in different zones and are different for different types of development (non-residential structures must be designed to a higher standard than residential structures).

d) Setbacks/Buffers
   Setbacks are building restrictions that launch a distance from a boundary line where building structures are not allowed. In urban areas, the boundary line is typically a street. In waterfront areas, the boundary line is often the tide line. There are several different mechanisms for establishing setbacks and buffers:
   - Fixed mandatory setbacks need that all structures, including sea walls, be set back a specific distance from a predetermined point (e.g., 100 feet from the mean high tide line or the vegetation line) (IPCC, 1999)
   - Erosion-based setbacks are determined by a projected shoreline position that assumes a specific increase in sea-level and erosion rates over a specific time frame such as the life of the structure (e.g., sixty times the annual rate of erosion) (Jenkins et al., 2008)
   - Tiered setbacks require a lesser setback or buffer for smaller structures and a greater setback for larger structures that are more difficult to move if they become damaged and put more people at risk.

e) Conditional Development and Exactions
   Regulators often carry out special conditions when issuing development permits for new development and substantial redevelopment (i.e., renovation or expansion of existing structures). Regulators impose conditions when approving a special-use permit or subdivision permit. Special-use permits allow regulators to allow more intense development ("special uses") if the landowner agrees to certain measures to mitigate the impacts of those special uses. Regulators must have a statutory basis for imposing the condition: the zoning ordinance will specify the special uses that may be permitted and the mitigation measures to be involved as a condition of the permit. For example, a zoning ordinance may allow development of an apartment complex in a single-family residential zone if the developer agrees to provide additional setbacks or dedicate open space. The development permit is then recorded so that the conditions bind future owners (Grannis, 2011).

f) Rebuilding Restrictions
   Rebuilding restrictions regulate a property owner's capability to rebuild structures destroyed by natural hazards such as flood damage to be more resilient (e.g., requiring redevelopment to be elevated or set back from the coast).

g) Subdivisions and Cluster Development
   Governments can use clustered development programs to ensure that new development is more resilient to SLR and less harmful to natural resources. Subdivision decrees could be used to promote the development in upland areas or areas at lower risk and to restrict development in low-lying areas vulnerable to erosion and

Flooding. By clustering, developers can reduce the cost and size of any armoring that may be required in the future to protect the development (Brower et al., 1989).

h) Hard-Armoring Permits
hard-engineered structures used to protect coastal areas from flooding and erosion. Hard armoring can be built onshore or offshore and includes bulkheads, sea walls, revetments, dikes, tide gates, storm surge barriers, and groins (Mastrandrea et al., 2010). In deciding when to armor, decision makers will need to balance many trade-offs, such as the degree of threat to people and property, cost to build, value of the threatened property or infrastructure, long-term costs to maintain, environmental impacts, the physical conditions of the property (such as geology and elevation), aesthetics, and impacts to public access (NRC, 2007).

i) Soft-Armoring Permits
Due to the undesirable impacts caused by hard coastal armoring, many authorities have started promoting use of soft armoring techniques. Soft armoring uses man-made barriers that refill natural buffers or elevate land so that structures are less vulnerable to flooding, storm surge, and erosion. Examples of soft armoring include beach nourishment, dune creation, re-vegetation, wetlands restoration, and living shorelines.

4.3 Spending Measures

a) Capital Improvement Programs
Adopt a flexible mechanism by which public entities can preserve land in its natural state while allowing land to remain in private ownership. Therefore, Landowners contribution an easement accepting to limit development of the land often for compensation or tax benefits.

b) Rolling Conservation Easements
A rolling boundary that is aimed to maintain the ability of the shoreline to migrate inland.

4.4 Tax and market-based measures

a) Tax incentives
Support favoured development patterns and can take the form of special assessment programs, tax abatements, and tax credits.

b) Transfer Development Rights
Confine development in one area ("sending area") and allow the transfer of development rights to more appropriate for intense use ("receiving area").

c) Real Estate Disclosures
Require sellers of real estate to disclose certain property defects to prospective buyers prior to close.

5. Conclusion

SLR has significant physical and socioeconomic impacts on the coastal zone. Therefore, it is important to identify adaptation options and implement adaptation measures that lower the risk and actual losses from these impacts. Without assessment of such adaptations, the impacts researchers could well overstate the potential negative effects of climate change. In this work, adaptation measures were classified by (1) the type of power exercised to implement it (planning, regulatory, spending, or tax and market-based tools); (2) the policy objective that it facilitates (protection, accommodation, planned retreat, or preservation); and (3) the type of existing or potential land uses that the tool can be used to adapt (critical infrastructure, existing development, developable lands, and undevelopable lands).

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PART TWO
Marine environment and Maritime Industry

6 Indicators of Climate Change: Case of the Baltic Sea Region

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1. Introduction

Climate change indicators help identify how the climate is changing in different areas. Studies of the trends in climate parameter variations are relevant not only for the knowledge of climate change processes but also for the development of the strategies of adaptation as the consequences of these processes. Thus, it is important to determine how all parts of the climate system change: the lithosphere, the atmosphere, the cryosphere, and the hydrosphere.

The climate change indicators consist of a set of parameters: air surface temperature, sea surface temperature, sea-level change, atmospheric composition, heat and water balance, and their components, which describe the changing climate and trends. They are sensitive to climate change and apply similarly for research on both a global and regional scale to better understand change trends and adaptation measures that could be applied in recent times and the nearest future.

The climate can fundamentally change many features of the oceans and seas. The planet Earth is “blue” because its surface is covered by about 71 percent (361 million km2) of the oceans and seas. Oceans cover nearly three-fourths of the Earth’s surface and hold 97 percent of the total water volume. The world’s oceans play a crucial role in the distribution of heat on the Earth’s surface. The specific heat of water is more than 4 times that of air and also of the land, so the ocean, having the largest mass of all the elements of the climate system, can accumulate the most heat which is then passed on to other climate spheres. More than 90 percent of the warming that has happened on Earth over the past 50 years has occurred in the oceans (Dahlman and Linsey, 2020). The ocean is the primary heat sink of the global climate system. Since 1971, it has been responsible for storing more than 90% of the excess heat added to the Earth system by anthropogenic greenhouse-gas emissions (Durack et al., 2018).

Recently many researchers are concerned about the effect of global climate change in the oceans and seas. The higher temperature of the oceans and seas is contributing to sea-level rise. In the last decades, climate change has caused impacts on natural and human systems on all continents and across the oceans (Rhein et al., 2013). The investigation of climate change in different regions and seas is important in both scientific and practical aspects as the global processes take place under a particular agency of local factors.

As in other parts of the world, research on climate change is now a major interest in Europe, including the Baltic Sea region. The Baltic Sea is a young semi-enclosed intra-continental shallow sea with a specific environment uniqueness due to its special geographical, climatological, and oceanographic characteristics. The Baltic Sea is shallow, narrow, and continues for about 1600 km from south to north. Sea surface temperature and salinity are lowest in the northern part, which is the furthest from the Danish straits connecting the Baltic Sea with the North Sea of the Atlantic Ocean. The continental (mediterenian) Baltic Sea is one of the largest brackish water areas in the world. The Baltic Sea is characterized by its large differences in salinity from South to North parts. From approximately 14-25 g kg^{-1} in Kattegatt and Danish straits, it decreases to 7-8 g kg^{-1} in the southern Baltic Sea and is down to only 0-3 g kg^{-1} in the northern part of Baltic - in the Gulf of Bothnia and the Gulf of Finland.

The Baltic Sea in Northern Europe is surrounded by nine countries: Denmark, Germany, Poland, Lithuania, Latvia, Estonia, Russia, Finland, and Sweden (Fig. 1). The drainage area of the Baltic Sea is inhabited by around 85 million people. Regional monitoring and assessment of the Baltic Sea are one of the core tasks for the inter-governmental Helsinki Commission (HELCOM). It is aiming to maintain good ecosystem health, including adaptation and management of climate change, and regional collaboration.

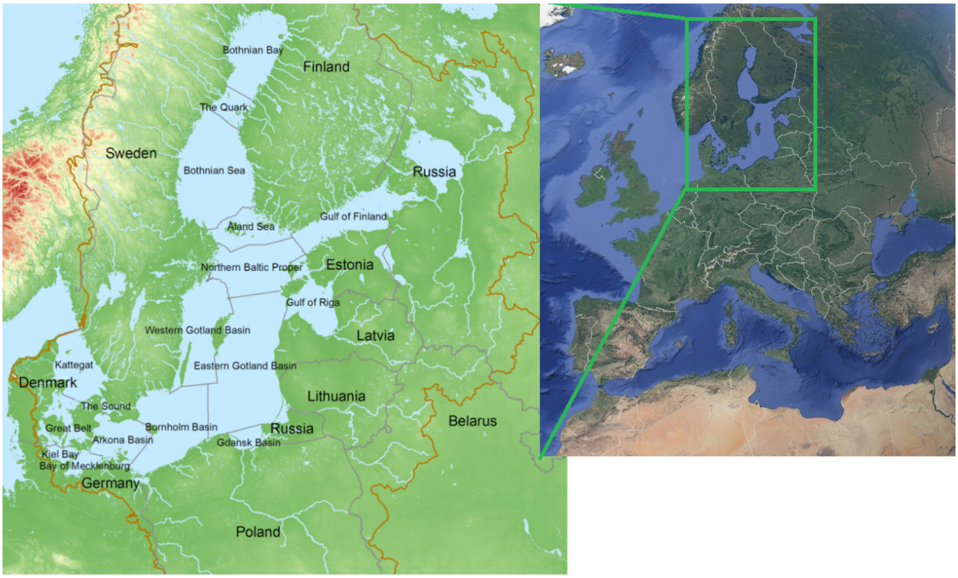

Figure 1. The Baltic Sea is surrounded by nine countries, covers an area of around 420,000 km^2, and has a drainage area around four times its surface area. (source: HELCOM, http://stateofthebalticsea.helcom.fi/in-brief/our-baltic-sea; Google Earth map)

Baltic scientists are collaborating to investigate the effects of climate change in the Baltic Sea region. Baltic Earth is the scientific network that strives to achieve an improved Earth System understanding of the Baltic Sea region as the basis for science-based management in the face of climatic, environmental, and human impact in the region (www.baltic-earth.eu). The Baltic Earth Assessment of Climate Change (BACC) in the Baltic Sea region was created, introduced, and first published in 2008. In 2015 the authors' team reported more about climate change and its' impact on the Baltic Sea catchment. You can find out more about all the indicators of the Baltic Sea basin, describing climate change and its impact on both the balance of the natural environment and ecosystems, as well as human socio-economic activities in these reports (BACC Author Team, 2008), (BACC II Author Team, 2015).

2. Baltic Sea geological history and age

The Baltic Sea is linked with the last 2.6 million years long geological period – Quaternary, when due to changes in the orbital configuration of Earth's rotation around the sun (BACC II Author Team, 2015), the climate became colder and many glaciations originated in Scandinavia covered northern Europe, including the current region of the Baltic Sea.

Geologically, the Baltic Sea is very young – as a result of tectonic movements of the Earth's crust and glacial erosion, the first marine basins in this area occurred during the Holsteinian Interglacial (410–390 thousand years ago), and later – during the Eemian Interglacial (126–115 thousand years ago) (Uscinowicz, 2011). The current Baltic Sea basin started to develop only after the decay of the Last (Weichselian) Glaciation ending around 12,000 years ago when the Scandinavian ice sheet retreated and the Baltic Sea area has gone through a series of different marine/brackish and freshwater basins and water level rise/decrease phases (Harff et al., 2011).

The Holocene climate history showed three stages of natural climate oscillations in the Baltic Sea region: short-term cold episodes related to deglaciation during a stable positive temperature trend (11,000-8000 year before present (BP); a warm and stable climate with air temperature 1.0-3.5°C higher than at present (8000-4500 year BP), a decreasing temperature trend; and increased climatic instability (last 5000-4500 years), when the configuration of the Baltic Sea as a brackish inland (mediterenian) sea was established (Borzenkova et al., 2015).

Till now the Baltic Sea area is also strongly impacted by vertical movements of the Earth's crust- regional glacioisostatic adjustment (uplift) of the in the northern part of the basin and the subsiding which is prevailing along the southern coasts of the sea. The most important effect of the modern sea level change in the Baltic Sea is an interplay between the global sea level rise due to an increase of the ocean volume, and the mentioned tectonic movements of the Earth's crust.

3. Baltic Sea level change as a climate change indicator

The Intergovernmental Panel on Climate Change (IPCC) pays much attention to studies of sea-level change as one of the main indicators of climate change (IPCC, 2013). During recent decades, the impact of global climate change on the sea level rise has drawn a bigger interest, since the coastline changes have ecological, economic, and social impacts on the coastal areas. Scientists of various countries, including those of the Baltic States, analyzed the historical measurement data that had been collected over more than one hundred years in an attempt to assess the change in sea level and to recommend preventive measures that enable protection of the natural and economic objects.

The sea-level variations in the Baltic Sea are determined by these main factors: the Fenoscandinavian mainland's post-glacial earth's crust land uplift process, the global eustatic water level rise, and the atmospheric circulation. The Baltic sea-level change has been analyzed regarding the eustatic and the isostatic land uplift process. Land uplift has been ongoing in the Baltic area throughout the Holocene and its magnitude ranges from 0 millimeters per year (mm year^{-1}) in the south up to 9 mm year^{-1} in the Gulf of Bothnia in the northern part (Leppäranta and Myrberg, 2009). Thus, relative sea level is decreasing in the northern Baltic Sea region where the continental crust is rising, while sea level is rising in the southern Baltic Sea region where the continental crust is sinking (BACC II Author Team, 2015).

Analysis of measurements of sea level data collected for the vertical land movements indicates that Baltic Sea level may have risen during the 20th century at a rate of around 1.5 mm year^{-1}, which are close to the rate of the global sea level rise. The Global average sea-level rose at an average rate of 1.8 (1.3 to 2.3) mm year^{-1} over 1961 to 2003 (IPCC, 2007). Global eustatic sea level rose at least 1–2 millimeters per year in the 20th century (Melillo et al., 2014), (Doyle et al., 2015). It is important to highlight that the observed intensive rise of sea level takes place at many Baltic Sea tide gauge stations at the end of the 20th century (Johansson et al., 2004), (Dailidienė et al., 2006, 2011), (Ekman, 2009), (Stramska and Chudziak, 2013), similar to the global average sea level trend. According to the European Environment Agency report (2017) the rate of Global sea level rise since 1993, when satellite measurements became available, has been significantly higher, at around 3 mm year^{-1}.

Based on IPCC climate change scenarios in the 21st century (IPCC, 2013), modeling sea level variation scenarios, 2081–2100 during the period under the optimistic Low Emission Scenario (RCP 2.6), sea levels in European seas can rise in the range of 0.26 to 0.54 m and in the high emission scenario (RCP8.5) range from 0.45 to 0.81 m. Similar scenarios for rising water levels have been developed for the Baltic Sea (Meier et al., 2004). Global-scale sea level rise will affect the south and middle parts of the Baltic Sea, including the northern part of the Baltic which will be counteracted by glacial isostatic adjustment, too.

The atmospheric circulation and air pressure in the North Atlantic sector plays an important role in the climate and sea-level change in the Baltic Sea (Hurrell et al., 2003), (Dailidiene et al., 2006, 2011, 2012), (Jaagus and Suursaar, 2013), (Hünicke et al., 2015), (Post and Kouts, 2014), (BAAC II Author Team, 2015). Variables describing the intensity of westerlies' zonal circulation, such as the North Atlantic oscillation indices (NOA), and the frequency of the circulation form West according to the Global atmosphere air mass dynamic correlate with storminess and sea-level change on the coast of the Baltic Sea. The highest seawater levels are formed on the southeastern and eastern coast of the Baltic Sea when dominating westerlies air mass transfer. If the NAO positive (negative) phase, the Icelandic Low and the Azores High are enhanced (diminished), resulting in a stronger (weaker) than normal westerly flow (Hurrell et al., 2003), (Hurrell and Deser, 2008), (Omstedt et al., 2014). It is well known that a positive index indicates increased storm surges and more mild winters in North Europe, also in the Baltic Sea region (Meier et al., 2018a). The variability of annual sea level, as well as its extreme values, increased most dramatically since the beginning of the 8th and 9th decades of the twentieth century when the NAO (North Atlantic Oscillation) winter index was nearly exclusively of the positive phase. For example, very high sea level horizons have been observed only 1-2 times per 50 years period at the beginning of the 20th century, and for the last decade, it is observed every 5–7 years (Fig. 2).

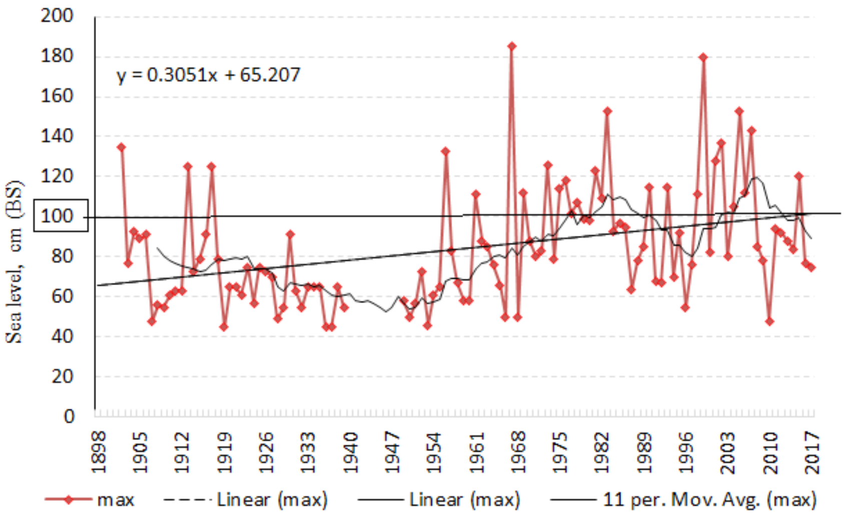

Figure 2. Changes in maximum sea level in the Southeastern part of the Baltic Sea from 1898 till 2017. It is more often than 100 cm (in the BS height system) above critical in recent decades

4. Air and Sea surface temperature change

The Baltic Sea is one of the marine areas with the highest recorded near-surface air temperature increase during the past century, and this increase is almost certain to continue (Rutgersson et al., 2014).

Specific warming started in the Baltic Sea region from the 1970s–1980s like in many regions all over the globe (BACC II Author Team, 2015). Linear trends are positive in the annual mean air temperature anomalies from 1871 to 2011 were 0.11°C per decade north 60°N and 0.08°C per decade south of 60°N in the Baltic Sea basin (BACC II Author Team, 2015). Air temperatures in the Baltic Sea region have already risen over the past century. The increase has been about 1.0°C in the northern Baltic Sea and by about 0.7°C in the southern areas of this basin (BACC Author Team, 2008), (BACC II Author Team, 2015).

Recent reports from the United Nations Intergovernmental Panel on Climate Change (IPCC 2018) state that since the 20th-century global air temperatures have been rising much faster than in previous centuries and even millennia since the beginning of the 1990s and are now more than 1 °C above pre-industrial levels. According to climatologists, more pronounced climate change has been observed since the 9th decade of the 20th century. For example, since then, the average annual temperature in Lithuania has risen by 0.7–0.9 °C. The air temperature has risen the most during the winter months, and the changes during the warm season and the autumn season are less pronounced. Winters in the Baltic Sea region have mostly warmed up. Compared to the 17th – 19th centuries, the winter season in Lithuania (in the south-eastern part of the Baltic Sea) is warmer by about 2–2.5 °C (the temperature rose from -6 °C to -3.2 °C in the coldest month). The temperature of the spring season is also rising - it has also risen by about 2 °C. The average summer temperature has changed slightly for a long time but since the 20th century. At the end of the 19th century, temperature curves began to rise rapidly and are now 1.4 °C higher. The warmest season was the slowest and the autumn season changed the least (0.3–0.4 °C per century).

Water temperatures generally follow air temperatures but have smaller fluctuations and more moderate trends (Rukseniene et al., 2017). Specific warming sea surface temperature (SST) of the Baltic Sea started in the 8-9th decade of the 20th century, and it seems that climate change processes occurred in many regions all over the globe (IPCC, 2007). Similar warming trends were observed in the air temperature and SST of the Baltic Sea (BACC Author Team, 2008), (Lehmann et al., 2009), (MacKenzie and Schiedek, 2007), (Dailidiene et al., 2012). For instance, between 1961 and 2005, the air temperature and surface water temperature measured in 1991-2005 in the Southeastern Baltic Sea had maximal bias (anomalies) compared to those measured in a normal (climatic) period of 1961-1990: air temperature increase +0.9 ºC, the surface water temperature rose +0.6 ºC. The average increase in the mean air temperature and the mean SST near the SE coast of the Baltic Sea was about 0.06°C yr^{-1} and 0.04°C yr^{-1}, respectively from 1991 onward (Dailidienė et al., 2012).

Global sea surface temperature is approximately 1°C higher now than 140 years ago and is one of the primary physical impacts of climate change (Coppini et al., 2007). The same source relates that the sea surface temperature (SST) in European seas is increasing more rapidly than in the global oceans. For instance, in the North Sea (0.05°C yr^{-1}) and Baltic Sea (0.06 °C yr^{-1}) temperature increased five to six times faster than the global average SST (0.01°C yr^{-1}) in the period 1982-2006, and three times faster in the Mediterranean Sea (0.03°C yr^{-1}).

The Baltic Sea average temperature increase, but in fact, warming can vary substantially from one sea geographical region to another. In the Baltic Sea, with some regional differences, a positive trend in the yearly mean sea surface temperature (SST) increase about 0.8°C from the beginning of the 20th century (Siegel et al., 2006). Global climate models, and the regional models based on them, generally agree that the Baltic region is to warm up about 2–4°C by the end of the 21st century (Elmgren et al., 2015).

It should be noted, that the biggest long-term rise of the SST had been observed during the summertime. Every summer from the end of the 20th century is distinguished for a longer warm-up period. It was observed that the SST rises above 20°C. The increase and shift in the warm period and the frequency of hot summers may have a greater impact on changes in marine biological and hydrochemical processes in the nearest future. These seasonal changes in the last decades, the water surface temperature of the warm period shift into autumn approximately half months (Rukšeniene et al., 2017), and it confirmed that is necessary to clarify the spread of marine pollution and increasing seasonal eutrophication.

Future scenarios for the Baltic Sea shows that the surface temperature in the Baltic Sea is expected to be on average higher by 2.0°C to 4.0°C in the 2071–2100 period compared to the normal (climatic) period of 1961–1990 (BACC Author Team, 2008).

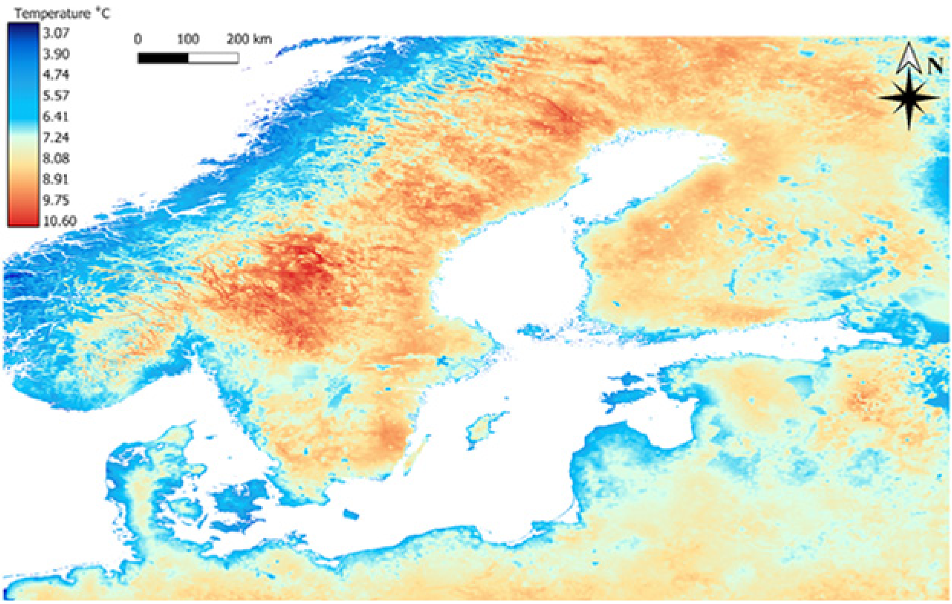

Figure 3. Surface air temperature's mean monthly amplitude map of 1970-2000 period (Dailidė et al., 2019)

The extent to which the Baltic Sea influences air temperature in its coastal areas is an important factor for determining local coastal climates in the Baltic region (Dailidė et al., 2019). The geographical location of the Baltic Sea and zonal positioning leads to different expansion of local climatic zones, and the predominance resulting contrasts in coastal climate illustrates the distinguishable effect of the Baltic Sea on its coastal areas air temperature (Fig. 3). The increasing rise in air and water temperatures since the late 20th century in the Baltic Sea region may have contributed to these larger differences in the near future.

5. The Ice cover of the Baltic Sea

Every year the Baltic Sea is partially covered by ice. The Baltic Sea ice season usually lasts for six to eight months (BACC II Author Team, 2015). The sea surface water of the Baltic Sea is frozen at average temperature and is about minus 0.7 °C (when average water salinity is 7 g kg-1). Water salinity and SST are determining factors of the ice-covered formation. The Baltic Sea surface freezes every winter in the northern part of the Gulf of Bothnia and the Gulf of Finland, where the surface temperature of the water is cooler for a longer time and there is less salinity. During the winter season, ice thickness is formed up to about 70 cm. The average freezing period shortens from north to south. In the southern part of the Baltic Sea, due to more warm air and water temperature, as well as higher sea salinity, ice forms only in harsh winters. The ports of Klaipeda, Liepaja, Ventspils, and Baltijsk are already considered to be frost-free. Although ice is formed here, it is thin and shipping is possible without icebreakers. The other parts of the Baltic Sea do not freeze due to warmer air and sea temperature with two exceptions – shallow lagoons in the Southeastern Baltic Sea, – the Curonian and Vistula lagoons.
The annual maximum ice extent of the Baltic Sea is the most widely used indicator of climate change and sea ice changes because it integrates winter period weather over the entire basin (BACC II Author Team, 2015). Historical records and observations show that the interannual variability of the Baltic Sea ice cover is very high. Typically, on average, the ice-covered area is greatest in March, when the maximum ice extent in the Baltic Sea is about 165,00 km^2, or 40 % of the total area of the Baltic Sea (BACC II Author Team, 2015). For the last 60 years, the area covered by ice varied from 49,000 km^2 (2008) to almost 400,000 km^2 (1987) (Eremina et al., 2014). The trend of the maximum ice extent of the Baltic Sea for the past 100 years was 3400 km2 10 year-1 or about 2 % per 10 years (BACC II Author Team, 2015). The increased advection of relatively warm, humid air-masses is responsible for mild winters over the Baltic Sea, and, consequently, for the trend of decreasing duration of the Baltic ice season. Therefore, a change towards mild ice winters has been observed which are characterized by a decreasing trend in maximum ice

extent, ice thickness, and ice season period duration (HELCOM, 2013), (Elken et al., 2015), (BACC II Author Team, 2015).
The ice season and dates of freezing and break-up of the ice cover have also been widely used as climatological indicators of ice season severity. Naturally, as the sea surface temperature increases, the number of days conducive to ice formation decreases, and the length of the ice season also decreases. In the Bothnian Bay, which has the longest ice season, the trend is -18 days per century (BACC II Author Team, 2015). The duration of the ice season in the South-Eastern (SE) Baltic Sea decreased by 50% during the period 1961–2005 (Dailidiene et al., 2012). Results correspond with the atmospheric-ocean model prognosis that was foreseen for the 21st century. The length of the ice season forecast scenario which highlights that ice season could decrease by as much as 1-2 months in northern parts and even 2-3 months in the central Baltic (Meier et al., 2004), and the ice extent in the sea decrease by some 50-80 % (BACC II Author Team, 2015).

6. Wind wave regime change as a climate change indicator

Wind waves now are recognized as one of the climate change indicators (Keevallik and Soomere, 2008), (Weisse and Storch, 2010), (Soomere and Räämet, 2011a, 2011b), (Wernberg et al., 2016). According to the same resources, analysis shows no significant change in average wave activities in the Baltic Sea basin. However, the discussion regarding changes in wave climate as well as in storminess is still full of controversies. There is no overall agreement on whether the frequency and intensity of storms, significant wave heights have increased or will increase in the future. The changes in the Baltic Sea wave climate were insignificant from the late 1950s until the late 1980s (Kriezi and Broman 2008). The situation changed in the 1990s, however, when a drastic increase in wave heights was reported in both the eastern and western coasts of the northern Baltic Proper (Broman et al., 2006b), (Zaitseva-Pärnaste et al., 2009), (Zaitseva-Pärnaste et al., 2011), (Kelpšaitė and Dailidienė, 2011). It is known that different sub-basins of the Baltic Sea have different features of the wave climate.
Regional studies have even revealed different trens in average and extreme wave conditions that are probably due to systematic change in wind direction (BACC II, 2015). Many studies have shown several intriguing patterns of the long-term behavior of the Baltic Sea wave fields. The most important change is the observed rapid increase in the annual mean wave height in the northern Baltic Proper from the mid-1980s until the mid-1990s and a rapid decrease since then (Broman et al., 2006b), (Zaitseva-Pärnaste et al., 2009). Interestingly, similar decadal variations were much at the Lithuanian coast (Kelpšaitė and Dailidienė, 2011). The high-resolution long-term numerical simulations of the Baltic Sea wave proper-

ties with the use of adjusted geostrophic winds show basic characteristics of the northern Baltic Sea wave climatology from 1970 to 2007 (Räämet et al., 2010), (Räämet and Soomere, 2010). The pattern of the average wave intensity over 38 years reveals several areas with relatively high average wave heights. In the 1970s the most notable increase in wave heights occurred in the northern Baltic Proper. Even larger increase, up to 6 cm decade^{-1} (by more than 8% from the average of 73–74 cm in this area over 1970–2007), was highlighted by the model in the south-eastern (SE) Bay of Bothnia (Soomere and Räämet, 2014). In the 1980s the wave heights rapidly increased in the entire sea at an atypical rate of about 6–8cm/decade. In the 1990s the wave activity decreased almost in the entire Baltic Sea, and the simulated changes during the years 2000–2007 were less significant compared to those in the previous decade (Soomere and Räämet, 2014).
Wave properties react to the changes in wind fields and can be more easily measured as capture changes not only in the extreme values but also in the mean values. These changes can be noticed not only in the decadal wind-wave climate change but also in different seasons. Valuable knowledge is also presented in spatial changes of the wind-wave climate, which shows climate change patterns overall Baltic Sea.

7. Euphotic Depth Changes in the Baltic Sea

Stratification plays an essential role in the marine system, also in the shallow Baltic Sea. The shallow mixed layer is one of the preconditions for the enhanced primary production in the ocean (Tiblik et al., 2020). Therefore, both the euphotic level and the stratification of the sea, the depth of its upper mixed level, can be used as indicators in the analysis of long-term and seasonal changes in the Baltic Sea ecosystems. The research results indicate a rapidly decreasing euphotic depth in the Baltic sea with an even faster decreasing rate of yearly variations for colder seasons of the year. Light absorption in water bodies highly depends on its turbidity, which directly correlates with organic matter dissolved in the water (CDOM) and suspended particles. The turbidity plays an important role in the Euphotic zone depth. The Euphotic zone is a specific depth of z1%, where photosynthetically available radiation is 1% of its surface value. This value is a measure of water clarity, which is not only a quality index of an ecosystem but also an important property for primary production and heat transfer in the water column. The research results of a calculated euphotic depth represented in time-series (Fig. 3) show a gradual decrease of euphotic depth in the Baltic Sea area over the last decade. During the research period of 2003-2018 larger euphotic depth dominated southwestern and southern parts of the Baltic Sea (Fig. 4). For the research, the data used was the MODIS AQUA L3 that consists of monthly mean data in 1 km resolution for the period of 2003-2018, gridded to 4 km resolution for computational reasons.

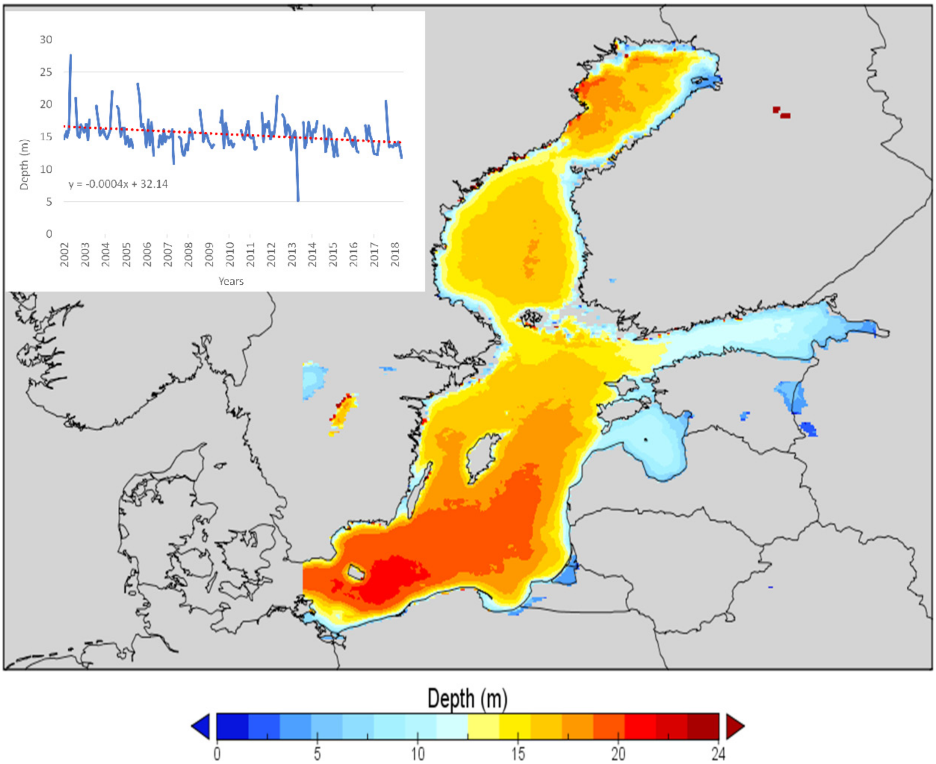

Figure 4. Map of the Average euphotic depth of the Baltic Sea and the yearly variation in 2003-2018 period of euphotic depth for the Baltic Sea (except winter months), MODIS Aqua

Upper mixed layer with a typical depth of 10–20 m forms in spring and is separated from the rest of the water column by seasonal thermocline. The mixed layer warms up to 15–24 °C (Stramska and Białogrodzka, 2015), (Liblik et al., 2020) and thermal stratification strengthens until August. The mixed layer deepens down to the Baltic Sea bottom or in the deepest areas to the halocline average at 40–80 m depth in autumn-winter (Leppäranta and Myrberg, 2009). However, studies show that the stratification of water mass could be changed due to the warming climate and winters. For example, scientists have demonstrated by in-situ measurements and numerical modeling that haline stratification at the depth comparable to the euphotic zone depth occurs in the Gulf of Finland during wintertime, well before the onset of thermal stratification in spring.

8. Regional climate change impact on socio-economic environments

Regional climate change is one of the multiple drivers, which have a continuing impact not only on the environment but also on the socio-economic environment. In recent years, society has faced a significant increase in economic and insured losses from weather and climate-related hazards. It is necessary to mention that recently the community started to pay more attention to the human impact on climate change. The majority of climatic models are predicting different climatic scenarios because of a growing population: land cover change, increasing atmospheric pollution, carbon dioxide (CO2), methane, and other (human activities gases) emissions that amplify the greenhouse effect. 21st-century challenges are associated with an increase in the number of people and consumption. As an example, we are currently facing an increasing number of marine litters. A significant increase in marine litter (macro) quantity is investigated in different Baltic Sea areas. The major type of marine litter is plastics (Helcom, 2018), (Schernewski et al., 2018). According to the "Marine Litter Socio-economic" study, typical items founded on urban beaches usually are bottle caps, plastic bags, plastic food containers, wrappers, and plastic cutlery. In general, 48% of marine litter is caused by household-related waste, and 70% of marine litter are plastics in the Baltic Sea (Helcom, 2018). Research of geographical sustainable consumption becoming more relevant to consumer behavior on marine litter in different Baltic Sea coastal areas, including the Lithuanian seacoast.

As the warmer period lasts longer, the anthropogenic pressure on the coastal zone will increase because of different human activities, including longer season duration for tourism and recreation. As a result of the relatively small size and the vulnerability of its ecosystem, the Baltic Sea is particularly sensitive to climate change.

9. Conclusions

The oceans and marine basins systems play a critical role in our climate. Understanding the physical process and hazards of our oceans in a varying and changing climate is critical to sustaining Earth as an environment blue planet.

Climate change research is necessary for global, regional, and local levels. Global warming means higher temperatures, but it also requires more knowledge of how it will affect temperature changes and other parameters of climate change. Different study results suggest that the rise in the sea level, increase in the air and water temperature, decrease in the ice cover duration - are probably related to the changes in atmospheric circulation and climate change in the Baltic Sea region. In

this case, climate change indicators help to identify climate change patterns in different areas. Studies of the trends in climate parameter variations are relevant not only for the knowledge of climate change processes but also for the development of the strategies of adaptation to the consequences of these processes.
The climate change, intensification of westerly atmospheric circulation from North Atlantic, ocean warming and eustatic processes are closely related to the change of climate parameters (indicators) in Baltic Sea region: the increase in the sea-level, including changes in mean and extreme sea level and wind-generated waves, air temperature, change of the precipitation, periods of snow and ice cover are decreasing, intensification of the extreme storm events, and waves regime change in the Baltic Sea region. Specific warming 'jumps' observed in all physical parameters started in the 8-9th decade of the 20th century.
The complexity of physics and dynamics of the Baltic Sea extends far beyond the typical features of many other water bodies of comparable size (BACC Author Team, 2008), (BACC II Author Team, 2015). This basin is characterized by extremely complex geometry, highly varying wind fields, extremely rough wave conditions at times, extensive archipelago areas with specific wave propagation properties, and ice cover during a large part of each year. Environmental problems are caused by its specific characteristics, such as shallowness, enclosure by the surrounding continents, large catchment area compared to the basin, slow water exchange by the narrow straits, combined with the intensive human activities (BACC Author Team, 2008), (BACC II Author Team, 2015), (Leppäranta and Myrberg, 2009). As a result of relatively small size and the vulnerability of its ecosystem makes the Baltic Sea particularly susceptible to climate change. The Baltic Sea constitutes a moderate ecosystem, which is constantly changing in response to climate variations and the rise of human activities.
Ocean and sea observation operational and historical data, reanalysis data, remote monitoring data and the latest smart technologies such as space radars and their complexes plays a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policymakers in making sound decisions concerning the protection of our environment.

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7 Climate Changes and Marine Microbes: Consequences and Adverse Impacts

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1. Introduction

Marine environment presents two thirds of the total Earth's surface that encompasses various kinds of ecosystems ranging from tropical, shallow water coral-reef to deep ocean trenches. Within these miscellaneous habitats, ocean represents 97% of the planet's biosphere where diverse groups of marine microorganisms survive (Dash et al., 2013). Although world climate has remained stable for over 12,000 years, tremendous human activities has the potential to seriously and adversely affect the climate and the marine ecosystem functioning that lead to unprecedented extinction of the animal and plant biodiversity on Earth (Ripple et al., 2017).

Climate change usually refers to the recent and on-going increase in the average global temperature as a result of an increase of greenhouse gases in the atmosphere due to anthropogenic activities. Throughout the world, the distribution and abundance of microbial communities change in response to temperature changes, producing alterations in the ocean primary production, with extensive implications for the biosphere. Global warming and climate change present the most prominent issues of the current environmental scenario (US EPA, 2015). Such changes in the ocean could have major consequences for the planet as a whole.

Climate change is driving global declines of marine habitat-forming species through physiological effects and through changes to ecological interactions, with projected trajectories for ocean warming and acidification likely to exacerbate such impacts in coming decades (Qiu et al., 2019). On the other hand, marine microbes may be harbingers of change and could monitor climate change effects on marine ecosystems and have the potential to mitigate the effects of climate change (Hutchins and Fu, 2017). As the oceans warm, marine microbial life might start to pump more carbon dioxide into the air with the increase in the greenhouse gas levels and warm the oceans to increasing temperatures. The large diversity of marine microorganisms harbored by oceans plays an important role in planet sustainability by driving globally important biogeochemical cycles; all primary and most secondary production in the oceans is performed by microorganisms. The present chapter aims to provide a critical understanding about the implications of global climate change and anthropogenic pollution on marine ecosystems and microbial community composition, physiological responses and evolutionary adaptation.

2. Global warming and consequences on marine microbial communities

Over timescales, temperature is the main environmental stressor and drives physiological adaptations in marine organisms. Temperature governs the rate of chemical reactions and pathways on organisms, thus exerting strong selective pressure, and is one of the most important forces in shaping the composition of microbial communities (Sharp et al., 2014). Over the past decades, the global average temperature of both land and ocean surface has risen by 0.65 – 1.06°C and oceans have stored more than 90% of the excess heat (Roemmich et al., 2012). Moreover, ocean warming leads to reduced oxygen content (>2%), ventilation from stratification and changes in circulation (Keeling et al., 2010, Schmidtko et al., 2017). As the ocean surface warms, it tends to reduce nutrient supply and alter the diversity of photosynthetic primary producers (Morán et al., 2015). Moreover, melting of the Arctic sea ice due to temperature increase is likely to cause salinity changes which affect water currents and stratification as well as cause the release of trapped organic matter and contaminants (Glöckner et al., 2012).

Rising temperature has a direct effect on the abundance and metabolic activities of marine microorganisms. When temperature exceeds the optimum, acclimatization may fail, mortality risks increase, fitness is reduced, and populations may decline or become locally extinct. Thus, such changes may enforce the selection of microorganisms that are better adapted to higher temperatures and the existing ones may become extinct when temperatures move outside their normal tolerance range (Brown et al., 2004). Species can respond to climate change by many mechanisms, either due to microevolution (i.e. genetic adaptation through mutations or selection of existing genotypes; or due to plasticity, which provides very short-term physiological responses at the individual level (Peck, 2011).

Sarmento et al. (2010) reported that heterotrophic marine bacteria play a pivotal role in the food web and the biogeochemical cycles of the marine environment with high adaptive potential. On the other hand, marine microbial communities possess tremendous resilience that is better adapted to higher temperatures, forged by their long evolutionary history in a constantly changing ocean environment (Riebesell and Gattuso, 2015). In addition, Altizer et al. (2013) highlighted that climate change could adversely affect the spread of diseases in marine biota, threatening the productivity and stability of the food web that also impacts the supplies of human food.

Notably, warming water temperatures can expand many secondary opportunistic infections by marine microbial species that take the advantage when the host organism is stressed by other conditions. Viruses are indirectly influenced by the changing climate through:

- Potential impact of altered primary production and phototrophic community composition on viruses, their life cycles and virus–host interactions
- Changes in prokaryotic metabolism and shift in prokaryotic community compositions
- Shift from lysogenic to lytic infections or an alternative shift in life strategy.

Moreover, as the growth rate of prokaryotes increases the length of the lytic cycle decreases and burst-size increases that lead to higher rates of virus production (Danovaro et al., 2011). Evidence that rising sea-surface temperatures will affect the associated virus communities can be inferred from examining the relationships between viral abundance and temperature for different oceanic regions where a temperature increase of only a few degrees was associated with a doubling of viral abundance.

In addition, the presence of aggregates of mucus-like organic matter in the water column is collectively known as "*marine mucilage*" or "*sea snot*" (Precali et al., 2005). Such mucilage is released by marine organisms and traps pathogenic species from the surrounding seawater that makes the seawater unsuitable for bathing because of the bad smell produced, and the adherence of the mucilage to the bathers' skin and consequently provokes serious economic damage to tourism and fisheries (Rinaldi et al., 1995). The increasing frequency of mucilage outbreaks is closely associated with the temperature anomalies, thereby increasing the spread of pathogenic bacteria (Simon et al., 2002).

Furthermore, global warming is expected to alter the geographic range of most estuarine habitats (increase, decrease, and/or shift) and alter the ecological range of many organisms, including pathogenic bacteria which could have negative public health and economic impacts due to the potential increase in the risk of disease from seafood consumption and the emergence of human epidemics that has been absent for decades (Deeb et al., 2005).

3. Ocean acidification and adverse effects on marine microbes

Apart from the rise in the ocean temperature, the levels of anthropogenic emissions of greenhouse gases like CO_2 and CH_4 to the atmosphere have increased and cause a wide range of direct and indirect impacts on the marine environment (Tian et al., 2016). Oceans present a huge sink of carbon dioxide (~ 90% of the world's CO_2) by a process that is known as the biological pump where CO_2 dissolved in the water is converted into biomass by phytoplankton (Reid et al., 2009). Increase in oceanic CO_2 uptake is the predominant factor driving ocean acidification, which involves a series of chemical changes in seawater, including elevated aqueous CO_2 and total inorganic carbon as well as reduced pH which could cause the dissolution of calcium carbonate forming coral reefs (Doney et al., 2009). Hurd et al. (2018) reported that oceans have become acidified by ~0.1 pH units since preindustrial times, with further predicted reductions of 0.3–0.4 units by the end of the century.

Bunse et al. (2016) reported that species of marine microorganisms that are less adept at regulating internal pH will be more affected by ocean acidification, and factors such as organism size, aggregation state, metabolic activity and growth rate influence the capacity for regulation. Moreover, lower pH causes bacteria and archaea to change gene expression in ways that support cell maintenance rather than growth (Cavicchioli et al., 2019). Furthermore, ocean acidification may also directly cause tissue damage in organisms such as fish, potentially contributing to a weakened immune system that creates opportunities for bacterial invasion (Frommel et al., 2012).

Danovaro et al. (2011) reported that ocean acidification may have a profound influence on the overall functioning of the microbial communities and on virus–host interactions. The growth of the cyanobacterium, *Synechococcus* sp., under the predicted future low pH values showed adverse effects not only on the cyanobacterium but also on the infectious cyanophage viruses (Traving et al., 2014). On the other hand, Capone and Hutchins (2013) showed that the change in pH affects biogeochemical cycling processes of marine microbes rather than microbial diversity. Moreover, using a culture dependent microcosm approach, Krause et al. (2012) investigated that even a small pH shift can have direct effect on bacterial community composition from the North Sea where groups of Gammaproteobacteria, Flavobacteriaceae, Rhodobacteraceae and Campylobacteraceae respond remarkably to differences in pH. Furthermore, reduced pH has shown to cause an increase in growth of many pathogenic microorganisms such as Vibrionaceae and Alteromonadaceae in corals (Meron et al., 2011).

Krause et al. (2013) showed that fungal abundance strongly increases with small reductions in seawater pH. On the other hand, high fungal loads in recreational beach areas were reported to be potentially hazardous to humans. Furthermore, marine fungi comprise numerous pathogenic species where rising fungal abundance is also a reason for concern, as it may affect the diverse interactions of fungi with marine algae and animals, such as fish, crustaceans and shellfish, which are commercially important (Seyedmousavi et al., 2018).

4. Conclusion

Currently, there is general consensus on the fact that (i) bacteria, although neglected in global-process model studies, play a key role in carbon fluxes and biogeochemical cycles revealed to be essential in shaping the ocean response to climate changes (ii) a large number of species is usually required for the maintenance of ecosystem processes in changing environments; and (iii) microorganisms associated to critical ecosystem services, particularly in the polar regions, may be vulnerable to the same impacts that climate changes are producing in complex organisms.

The direct effect of pH on fundamental microbial processes (such as the nitrogen cycle) suggests that the adaptive capacity of the microbial system to pH will be quite low. However, further research on the impacts of acidification on microbial community dynamics and microbial function is required before this can be fully determined.

In order to gather ample information regarding adaptation of marine microbes to global climate change, there is a need of long-term experiments in addition to the functional genomic level studies. Furthermore, current understanding about marine microbial physiology is inadequate to sufficiently understand the consequences of adverse climate changes. Moreover, extending studies to the open ocean is also technically very demanding. In addition, further studies are needed to evaluate how the effects of oceanic pH will affect microbial detoxification processes in marine ecosystems and start to identify interactions resulting from global climate change and anthropogenic pollution in order to mitigate known and novel environmental threats.

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8 Biogeochemistry and Climate change

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1. Introduction. Biogeochemistry and Climate Dynamics

Biogeochemistry is a relatively new multidisciplinary science that deals with global or localized cycles of certain key elements, such as carbon, nitrogen, phosphorus, iron, etc., and their interaction with other components of the natural environment. Biogeochemistry explores the interlinked processes and interactions between the atmosphere, hydrosphere, biosphere, and Lithosphere. There is a mutual influence amongst those components. The comprehension of these cycles has proven to be of necessity in understanding the global changes of the Earth's systems (Libes, 2009).
Climate change is a global problem with profound global drivers and impacts. As the perceivable global implications increased, immense efforts are being made for understanding and mitigating the natural and human-driven deviations to the climate (IPCC, 2014). The global climate is largely controlled by the oceans which play a pivotal role in the biogeochemical cycle of all elements. The key link between climate variations and biogeochemistry is the global carbon cycle (Buesseler et al., 2001). On one hand, the increased emissions of carbon dioxide to the atmosphere have altered the global biogeochemical carbon balance, consequently resulting in human-driven climate change. Increasing levels of atmospheric carbon dioxide and other "greenhouse gases" have resulted in "global warming". On the other hand, the biological sequestration of carbon by living organisms through photosynthesis is considered the ultimate carbon sink (Libes, 2009; Luisetti et al., 2013; Schulze et al., 2001). Therefore, the understanding of global biogeochemical cycles of components that are involved in or affected by climate variability is essential in recognizing the drivers, the effects, and the tools of mitigation of global climate change.
The Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time

periods". Climate change has severe projected impacts on all physical, ecological, and socioeconomic levels. The foremost projected physical impacts of human-driven climate change are non-uniform globally rising temperatures, disrupted weather cycles, and frequent extreme weather events. Global biodiversity and ecology are severely vulnerable to these impacts (IPCC, 2014).

This chapter sheds the light on the relation between the global biogeochemical cycles, particularly the carbon cycle, and climate change. It provides some insights into the biogeochemical processes and elements involved in climate variations and how these processes can be studied and used to manage or mitigate the projected climatic changes. The chapter explores concepts such as ocean acidification and climate engineering and blue carbon.

2. Anthropogenic Inferences in Global Biogeochemical Cycles and Climatic Feedbacks

Changes in Land-use, industrialization, and burning of fossil fuels have raised the atmospheric concentrations of carbon dioxide to levels high enough to cause "global warming". Other anthropogenic greenhouse gases are becoming equally momentous to CO_2, including methane, water vapor, nitrous oxide, halocarbons, and ozone.

The most prominent driver of climate change is CO_2. The earth's crust is the largest carbon reservoir mostly in the form of inorganic minerals, and minor amounts of organic matter contained in shale and fossil fuels. The crustal reservoir is followed by the oceanic and the terrestrial reservoirs, however, the smallest of the reservoirs is the atmospheric one, made primarily of CO_2. The levels of CO_2 in the atmosphere were doubled from the preindustrial period from an average of 280 ppm to 367 ppm (Schulze et al., 2001).

Climate change can have an effect on the carbon cycle in an interactive "feedback" process, as models suggest that the interaction of the climate system and the carbon cycle is one where the feedback effect is positive i.e. climate change results in higher levels of CO_2 release to the global ecosystem which in turn induces climate change. The global carbon cycle essentially is controlled by biological processes. Photosynthetic organisms (terrestrial or marine) uptake the inorganic CO_2 and transforms it into organic material. This process of primary production is balanced by the eventual death and decomposition of this organic debris into inorganic or simple organic forms. Over millions of years, organic debris may be buried or become trapped into rocks or hydrocarbons. Naturally, volcanoes or uplift and erosion can release the lithospheric carbon. Humans have boosted this probability through the burning of fossil fuels (Libes, 2009; Schulze et al., 2001).

In the oceans, a significant portion of the organic materials produced by primary productivity and inorganic carbon may sink and be buried in the ocean floor in the form of particulate inorganic and organic carbon (PIC and POC). Most of the POC burial (95%) occurs on the continental margin. This makes the oceans the ultimate reservoir of anthropogenic carbon, able to exert control on other reservoirs. The oceans have the potential to absorb as much as 85% of the anthropogenic carbon on a millennial time scale, but the continuous anthropogenic contribution to the atmospheric carbon will persistently have a significant effect on the ocean-atmosphere biogeochemistry and therefore on the Earth's climate for a long period of time (Libes, 2009).

Another perspective on the effects of the rising levels of atmospheric and oceanic CO_2 and its consequential effect on the biogeochemical balance of global cycles in several ways is their cascade effects. The Increasing levels of atmospheric CO_2 have resulted in a commensurate increase in oceans' CO_2 levels. When oceanic waters become enriched with CO_2, the pH of the ocean waters is decreased. This phenomenon is called "ocean acidification" (Doney et al., 2009; NOAA, 2013). Because efforts in monitoring ocean acidification worldwide are only beginning, it is currently impossible to precisely predict how ocean acidification impacts will cascade throughout the marine food chain and affect the overall structure of marine ecosystems. Generally, ocean acidification results in the reduction of the carbonate ion concentration, and the saturation states of biologically important calcium carbonate minerals. Consequently, the decline in oceanic biomass productivity results in the reduction of the amount of carbon sequestered by the oceans, and the dissolution of inorganic carbon reservoirs (predominantly carbonates) which release more CO_2 into the water. Over the last decade, there has been much focus in the ocean science community on studying the potential impacts of ocean acidification. Studies have estimated a decrease of about 0.1 in the pH of the oceans since the expansion of industrialization, which is equivalent to a 30% increase in acidity (Agostini et al., 2015; Doney et al., 2009).

Another negative expected feedback resulting from climate change is the thawing of the permafrost. Global warming in the higher latitudes is expected to cause an immense degradation in the icecaps and permafrost, which in turn will result in the release of methane gas that is to the atmosphere, further contributing to the greenhouse effect (Gao et al., 2013).

Human activities contribute to other greenhouse gases to the environment, including nitrous oxide, methane, aerosols, and water vapor. Nitrous oxide is a component of the nitrogen cycle, while methane is an organic component of the atmospheric carbon reservoir. Postindustrial level of atmospheric methane (CH_4) has reached 250% of the preindustrial level, while postindustrial level of nitrous oxide (N_2O) has increased by about 16% compared to the preindustrial level (Schulze et al., 2001).

3. Paleobiogeochemistry, Paloeooceonography, Paleoclimatolgy

It is crucial to be able to discern natural versus anthropogenic contributions to the changes in biogeochemical controls of the climate and to understand the natural role of the ocean in the cycling and variability of CO_2 levels. One of the most interesting fields of study that provide information about old global biogeochemical cycles and its linkage on paleoclimatic variations is paleobiogeochemistry. Polar ice-core and sedimentary-core records have provided a window on the natural dynamics of atmospheric and oceanic composition and the relationship between atmospheric composition and the continual climatic variations (Andrews et al., 2008; Doney et al., 2014; Howarth et al., 2011; Jickells et al., 2005).

Paleobiogeochemistry extends its focus to studies of the major atmospheric components such as CO_2 and mineral dust, and minor constituents such as methane, nitrous oxide, aerosols and isotopes of carbon and oxygen as well as biomarkers which provide historical context for organic matter sources (Abbott et al., 2015; Doney et al., 2014; Jickells et al., 2005; Libes, 2009; Moore & Braucher, 2008; Schulze et al., 2001).

Data on biogeochemical tracers provide complementary knowledge about the mechanisms and processes associated with natural changes in the abundances of these constituents. The abundance of greenhouse gases in the atmosphere and oceans have varied widely during the past half-million years in a somehow systematic manner, relative to the earth's orbital variations (i.e. Milankovitch cycle) and glacial-interglacial periods (Schulze et al., 2001). Since the link between biogeochemistry and climate variability is a multi-dimensional process with intervening perspectives, high-resolution models are utilized to face the challenges and reduce uncertainties in studying paleobiogeochemistry.

4. Biogeochemistry and Climate Engineering

As biogeochemistry provides a means to understand the process of climate change and its potential impacts on a global scale, it otherwise serves as a very promising tool for controlling, reducing and mitigating the anthropogenic influence on climate change and vulnerability of sensitive ecosystems. The 21st United Nations Convention on Climate Change (UNFCCC) has made a consensus to keep the increase in global average temperature to well below 2˚C above preindustrial levels, with efforts to pursue the limit of 1.5˚C. The Kyoto Protocol required the reduction of the atmospheric abundance of greenhouse gases in order to mitigate the risks of global warming. The concept of "climate engineering", also referred to as geoengineering, is primarily focused intervening on a global scale to mitigate the effects of climate change (Crooks et al., 2011; Lauvset et al., 2017; Luisetti et al., 2013).

Two approaches are suggested for climate engineering, including solar radiation management (SRM), and removal of greenhouse gases such as CO_2 removal (CDR). Radiation management methods include stratospheric aerosol injection (SAI), marine sky brightening (MSB), and cirrus cloud thinning (CCT) (Lauvset et al., 2017). Stratospheric aerosol injections (SAIs) suggests creating a layer of reflective particles in the stratosphere to reduce the amount of solar radiation reaching the Earth's surface. Marine sky brightening (MSB) suggests spraying sea salt particles into the low-lying stratiform clouds over the tropical oceans to increase the condensation nuclei needed to form available clouds, thus increasing the concentration of smaller cloud droplets and the reflectivity of the clouds. Cirrus cloud thinning (CCT) suggests seeding high ice clouds with highly potent ice nuclei, thus depleting their longwave trapping and increasing the amount of outgoing longwave radiation. All these techniques are still theorized and approached using global biogeochemical models of the Earth system. However, there are too many complex factors to be taken into consideration before any plans for implementation.

CO_2 removal (CDR) is primarily done by converting atmospheric CO_2 into living biomass. This process is referred to as carbon sequestration. Afforestation and biomass burial are terrestrial methods used to transform atmospheric CO_2 into the biomass of terrestrial plants(Schulze et al., 2001), however, blue carbon sequestration, i.e. sequestration of carbon by coastal and marine organisms, is the more commonly suggested approach to absorb large amounts of CO_2 from the atmosphere. The blue carbon approach revolves mainly around the use of coastal ecosystems and open oceans as carbon sinks. In coastal ecosystems, wetlands, mangroves, salt marshes, seagrass meadows serve as natural carbon storages (Crooks et al., 2011; Luisetti et al., 2013). Characterized by high productivity and biodiversity, they can absorb significant amounts of anthropogenic carbon and sequester it into biomass and POC. The UNFCCC promotes the enhancement of these natural sinks and reservoirs. Policy and economic efforts of conservation, rehabilitation, and wetland engineering aimed at meeting the challenges of climate change through the principle of integrated ecosystem modeling and management. In contrast, the concept of ocean fertilization suggests the enhancement of open ocean primary productivity through calculated fertilizations by micronutrients (such as iron, nitrates, and other essential trace metals) to induce carbon sequestration (Lampitt et al., 2008).

There are three ways (pumps) through which modern oceans uptake carbon. These are the solubility pump, biological pump, and air-sea interface pump. Ocean fertilization aims at augmenting the biological pump to sequester more carbon into POC that sinks into the deep oceans (Libes, 2009). There are several suggested methods for ocean fertilization including the supply of large quantities of macronutrients (or nutrient cocktails) or micronutrient supply designed to facilitate the efficient usage of existing macronutrients.

Nevertheless, large scale studies are still undergoing to fully understand the consequences of such approaches on global levels (Moore et al., 2002), for example, the international programme of GEOTRACES. This programme is a collaboration between 35 nations and aims to improve the understanding of biogeochemical cycles and large-scale distribution of trace elements and their isotopes in the marine environment in all major ocean basins (Charette et al., 2016). The negative consequences of ocean fertilization may include anoxia of ocean waters, eutrophication, and changes in pH and biogeochemical balances. Elaborate efforts, which usually require international collaborations, are being made to approach this issue through field measurements and empirical models.

5. Biogeochemical Modelling: Climate Change Perspective

Biogeochemical studies require large interdisciplinary data sets because of the interdependence of physical, chemical, biological, and geological processes. Data should be collected simultaneously and cover large spaces or time periods to produce a complete picture on global levels. Both climatic and biogeochemical processes are extremely complicated, with complex inputs of variables and controls, and a wide range of outcomes (Gregg et al., 2003; Moore et al., 2013).
Biogeochemical modeling aims primarily to diminish this complexity and increase the reliability of data to facilitate the understanding of the link between global climatic variations and climate change and aid in policy designing and decision making of climate engineering and vulnerability mitigation (Bonan, 1995; Felzer et al., 2005; Libes, 2009; Moore et al., 2013; Schulze et al., 2001). These models are based on previous paleobiogeochemical data and possible future scenarios.

6. A Future Perspective

Even though global biogeochemical cycles and climate change are inherently linked and mutually interfering, there is still a significant knowledge gap. There is a considerable challenge in accurately projecting future patterns of modification of global biogeochemical balances as a result of climate change. The relation between climate change and the global biogeochemical cycles is inherently complex and interlinked with mutual influence. As natural paleoclimatic variations had left their signatures in ice cores and sediment records, anthropogenic-driven climate change had been a result of the disturbance of the global biogeochemical cycles; essentially that of carbon. The understanding of these complex relations is key to not only understand the dynamics and drivers of climate change but also to mitigate its effects. We should not rely solely on numerical simulations and models to understand and study global biogeochemistry. Research and monitoring of ocean climate, biogeochemical trends, laboratory, and field studies are otherwise essential to understanding ecosystem sensitivities to global warming or cooling, ocean acidification, past, and future climatic variations as well as improving the numerical models. It might be possible that climate engineering is the most promising to mitigate or reverse anthropogenic-induced climate change.

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9 Recent Sea Level and Tidal Characteristics in Alexandria Western Harbour, Egypt

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1. Introduction

The relationship between tidal and terrestrial vertical datum is of importance to provide essential data to many users including those involved in; hydrographic surveying, commercial shipping industry, marine construction, recreational boaters, coastal area planners, chart datum needed for nautical charts, and also military operations (amphibious warfare). So, updating oceanographic information especially sea level data is always needed for continuous validations of nautical charts production, and for laying harbours plans.
Observed sea level variation depends on many factors; among which are storm surges, astronomical harmonic components, the seasonal cycle inter-annual to secular variability, and finally variations at geological and interglacial scales (Pugh, 1987; Davidson et al., 2012; Jorda et al., 2012).
In Egypt, the geodetic vertical datum network has been set as the mean sea level (MSL) in Alexandria. This datum was first derived based on sea level observations for eight years from 1898 to 1906 (Cole, 1939), and found that this imaginary surface level (MSL) was (33.8 cm) above zero of a fixed tide staff in Alexandria western harbour tide well. This MSL was named as Survey Dept. Zero Level Datum or zero of the Egyptian Survey Authority (ESA) datum 1906. In Alexandria, height of chart datum referred to the (ESA) was (-0.34 m) (UKHO NP202, 2015). Since then, there were no additional researches have been made in Egypt concerning the connection between terrestrial datum and tidal datum. Due to the global warming fact, the sea level has been risen in all over the oceans and specifically in the Mediterranean Sea according to IPCC (2013). However, records and measurements showed that sea level has been steadily rising since 1900 at a rate of 1 to 2.5 mm/ year. Moreover, it is projected for SLR to increase by the end of the 21st century to levels from 18 cm to 58 cm (Boko et al., 2007). In Alexandria, the astronomical tide contributes with 0.005–37.63% while, surge contributes with 62.37–99.995% in the observed sea level as discussed by El-

Geziry et al., (2012). This might refer to the meteorological and climatic effects, developed at Alexandria region.
As in the whole Mediterranean basin, the observed sea level variation in Alexandria results mainly from the combination of two elevations: astronomical tides and surges. While the former is of minor importance; being ±20 cm, the latter may reach 1.0 m elevation under the effect of the meteorological factors such as air temperature, the wind system, the atmospheric pressure and the steric effect (Sharaf El-Din, 1975; Eid, 1990; Saad et al., 2011). The effect of winds on the observed sea level varies from one location to another and depends largely on the morphology and position of the location itself. In 2005, Faisel concluded that Mean Sea Level (MSL) in Alexandria, Egypt has risen 11.6 cm from 1906 to 2003 with a rate of 1.7 mm/year, while Tsimplis et al., (2013) found that MSL rose significantly from 1993 to 2011 by approximately 3.0 cm/decade. However, zonal, and meridional wind speed has only a small effect on the sea level variations as described by Tonbol et al., (2013). The effect of winds on the observed sea level within the AWH is generally related to wind with speed greater than 2 m/s as demonstrated by El-Geziry, (2013). Consequently, and due to the temporary change in SL, accurate re-definition of the Egyptian tidal datum referred to a specific geodetic vertical datum is always essential, and it needs additional research investigation.
Generally speaking, wind will raise sea level in the direction towards which it is blowing, i.e. a wind blowing straight onshore will pile up the water shoreward building a setup. The main aim of this paper is to analyze sea level data inside AWH, Alexandria on the Egyptian Mediterranean coast to investigate the characteristics of tidal components.

2. Data and Methods of Analysis

Alexandria Port is located at the west end of the River Nile between the Mediterranean Sea and Mariot Lake (Figure1). It is the second most important city and the main port in Egypt. Theharbour handles approximately 75% of all ship-borne foreign trade cargo of the country. Alexandria port consists of two harbours (East and west) separated by a T-shaped peninsula. Eastern harbour is a semi-enclosed shallow basin and not used in navigation. Western harbour used for commercial shipping. Two converging breakwaters enclosed the harbour with an area of about 31 km^2. Harbour is connected to the open sea by a narrow entrance and the basin is protected from the prevailing North West winds. The water depth inside the harbour ranges from 5.5 m to 16 m and lies between latitudes (31° 9.6´ & 31° 12´ N) & longitudes (29° 50.4´ & 29° 52.5´ E).

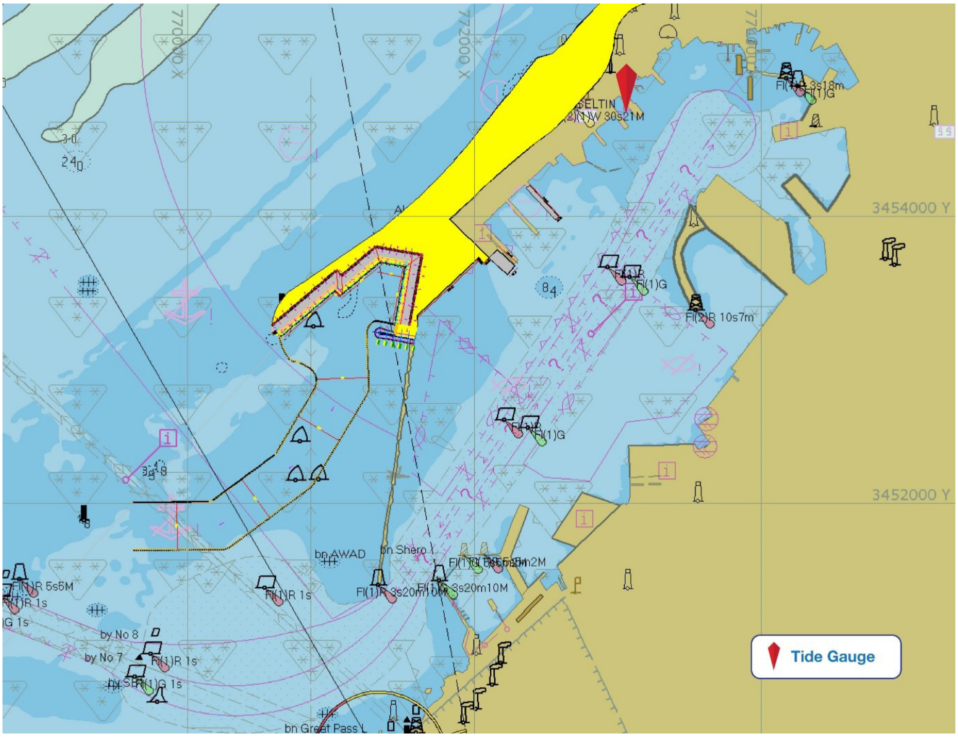

Figure 1. Area of the study inside Alexandria Western Harbour (AWH) and location of tide gauge

2.1 Data collection

Two sea level data sets inside (AWH)were acquired in 30-minutes time step using Aqua-tide PS3100.The first set covered a period from 11thof September 2008 until 2ndof November 2010, and the second from 30th of April 2012 until 26th of January 2014. The study area and location of the tide gauge are shown in Figure 1.

2.2 Geodetic realization of the tide gauges control points (TGCP's)

According to the international federation of surveyors (FIG) and in order to increase the efficiency of bathymetric surveying, there is always a need for creating of offshore vertical reference surface (FIG, 2006). That is referred to a specific geodetic vertical datum, which is a unified reference surface such as the International Terrestrial Reference Frame (ITRF) using GRS80 ellipsoid (Altamimi, et al.,

2008). Therefore, recorded sea level data sets were referred to the (ITRF-2014). The International Global Navigation Satellite System GNSS (IGS) was precisely realized at the tide gauge control point (TGCP) from coordinate computations. Two geodetic sessions were made, after establishing 2 control points (CPs) at Ras El Tin Naval Base, in front of a stilling well, started first by choosing appropriate positions of the (TGCP), according to minimum requirements in manual of hydrography (M13, 2005). First session was made for establishing the geodetic information of sea level data set CP in 22nd of April 2012 for almost 6 hours, while second session was made in 28th of June 2015 for calculating coordinates of data sets.
Both control points coordinates were computed using Ashtech proflex-500 RTK dual frequency GPS receiver, processed using Australian positioning services online GPS (AUSPOS), to get Latitude, Longitude and Ellipsoidal heights of control points with positional uncertainty (95% C.L.). Levelling was made from the (TGCP) to tide gauges zero level (TGZL), using SOKKIA levelling instrument, in order to assign the ellipsoidal height of the (TGZL), and consequently the ellipsoidal heights of the observed sea levels and computed tidal levels referenced to ITRF-2014.

2.3 Methods of Analysis

The recorded sea level data at AWH was used and both astronomical tidal constituents and residual elevations were obtained using Delft-3D hydrodynamic model tide suit (Delft, 2015). The package permitted separation to time series of water level measurements into its tidal and non-tidal components using a selective least squares harmonic reduction resulting up to 34 tidal constituents. Delft-3D is principally based on the concept of the ability of expressing the tidal amplitudes at any location as the sum of all the harmonic components (Pugh, 1996), as in (1):

$$\eta(t) = Z_0 + \sum_n f_n A_n cos\left(\frac{2\pi}{T_n}t + \varphi_n + \ k_n\right) \tag{1}$$

Where,

$\eta(t)$:The vertical displacement of the sea surface as a function of time (m)
Z_0 : The Mean Sea Level (MSL)
f_n : The lunar node factor for nth constituent
A_n : The amplitude of a harmonic component (m)
T_n : The period of a harmonic component (s)
φ_n : The nodal phase of harmonic component
k_n : The phase of the nth constituent for the time origin in use

The method used by Delft-3D to analyse a water level time series is known as Harmonic Analysis Method of Least Squares (HAMELS). This is a simple but powerful means of obtaining tidal constituent amplitude () and phase (), the so-called tidal harmonic constants neededfor tidal predictions using (1).
Classical harmonic analysis by means of least squares technique for the chosen tidal constituents for a period of time (782 and 636) days respectively were made, considering the Rayleigh Criterion (ω) of all data sets using the following equation to avoid criterion violation:

$$\Delta\omega = \frac{360°}{T} \tag{2}$$

Where T is the duration of the observation in hours, and (Δ ω) is the minimum frequency difference between two adjacent constituents that can be resolved for a given time series.
In the present work, the four main tidal components: O1, K1, M2 and S2 were produced using the output from harmonic tidal analysis, type of the tidal cycle off Alexandria was determined according to the value of the Form Factor (Pugh, 2004).
Amplitude percentage calculated from sea level amplitude absolute values, power percentages of both tidal and residual signals were calculated referred to the total sea level signal using the following formulas:

$$\text{Residual Power Percentage (RP \%)} = \frac{\text{Mean Residual Power}}{\text{Mean Residual Power} + \text{Mean Tidal Power}} * 100$$

The most predominant tidal harmonic constituents were obtained from frequencies of highest significant peaks according to the output file acquired from Delft-3D tide analysis.
Results of sea level harmonic analysis used to acquire vertical tidal datum inside AWH, such as Highest Astronomical Tide (HAT), Lowest Astronomical Tide (LAT), Mean sea level (MSL), Mean High Water Spring (MHWS), Mean Low Water Spring (MLWS), Mean High Water Neaps (MHWN), and Mean Low Water Neaps (MLWN) all referred to ITRF-2014.
Power spectral density (PSD) has been done by Matlab package to acquire resolvability from the energy percentage of both tidal and non-tidal signals compared with recorded sea level.
Lastly, using hourly data set of wind blowing over Alexandria from Ras El-Teen meteorological station during the investigated period of sea level data records, correlation coefficients were investigated between the obtained surge and wind

components (alongshore & normal to shore), beside correlation with atmospheric pressure measurements. The trend of mean sea level was also investigated to re-calculate the annual rates of sea level rise.

3. Results and Discussion

3.1 Recorded sea level

While the first sea level data set at AWH covers 782 days with 22 days of missing data, the second data set was for 636 days with only 3 days of missing data. However, statistically speaking, the missed days do not critically affect the quality of the proposed investigation.

Figure 2 shows the recorded sea level of the two observed sea level data sets. The basic statistics of sea level is represented in TABLE 1. The half hourly minimum sea level record was (-0.01 m) and the maximum one was (0.95 m) in the first data set, while in the second data set the hourly minimum sea level record from tide gauge was (-0.06 m) and the hourly maximum one was (0.76 m). The range of sea level variation in the first data set was about (0.96 m), while in the second data set (0.82 m).

Sea level data sets duration	Series length in days	Min. (m)	Max. (m)	Range (m)
11/09/2008 – 02/11/2010	782	-0.01	0.95	0.96
30/04/2012 – 26/01/2014	636	-0.06	0.76	0.82

Table 1. Statistical Result Values of all Observed Sea Level Data Sets

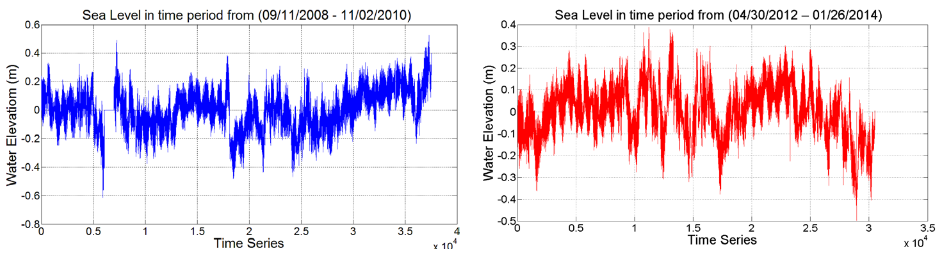

Figure 2. Sea level variation at the two data periods

3.2 Astronomical tidal elevations

The results of the present HAMELS analysis showed that the astronomical tidal elevations at AWH varied between 0.25 to 0.60 m and 0.19 to 0.53 m respectively (Figure 3) during the period of investigation for the two data sets. The maximum tidal range in both data sets were 0.35 and 0.34 m.

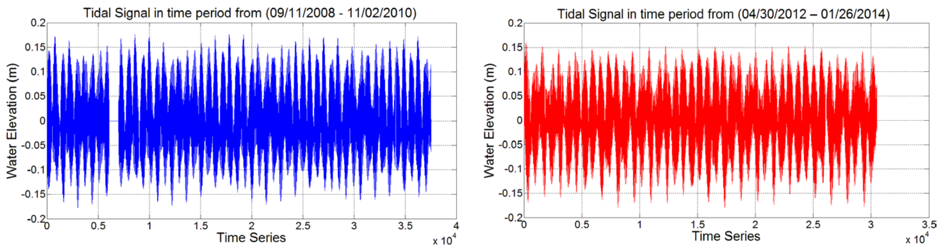

Figure 3. Astronomical tides at AWH during the two data periods

After harmonic analysis of the sea level data records, amplitudes and phases of the four main significant components in the harmonic signal were summarized in TABLE 2 and were compared with the findings of previous studies. It is clear from the TABLE 2 that the obtained amplitude (H) and phase (σ) values of the four tidal major components in the two data sets are very close despite the discrepancies in data length duration. Results are also in good agreement with the values of the previous studies (Rady, 1979 and Moursy, 1989). Using the software outputs (TABLE 2), the F factor for AWH is 0.24 0.25 in the two data sets respectively. The type of tides at the AWH has been, therefore, determined to be semidiurnal tides. Figure 3 reflect this semidiurnal behaviour.

	HARMONIC	M2		S2		K1		O1	
	Ref.	H (cm)	σ (Deg.)	H (cm)	σ (Deg.)	H (cm)	σ (Deg.)	H (cm)	σ (Deg.)
Previous	Moursy (96)	7.19	325	4.34	309	1.64	317	1.34	300
	Rady (79)	7.09	256.1	5.20	225.8	1.66	280.5	1.23	249.8
Current Study	First Data Set	7.4	301	4.5	315	1.7	303	1.3	272
	Second Data Set	6.9	324	4.1	340	1.6	315	1.3	286

Table 2. Comparison between Amplitudes and phases of the Four Major Constituents Obtained in Present Work and Previous Studies at AHW

3.3 Residual tidal elevations

Residual tidal elevations are defined as the meteorologically induced components of the observed sea level, i.e. surge level (Hicks et al., 2000). This expresses the observed sea level after omitting the effect of the astronomical tides from the record data sets. At AWH, the residual tidal elevations varied from-0.05 to 0.87 m and from -0.13 to 0.71 m as shown in Figure 4.

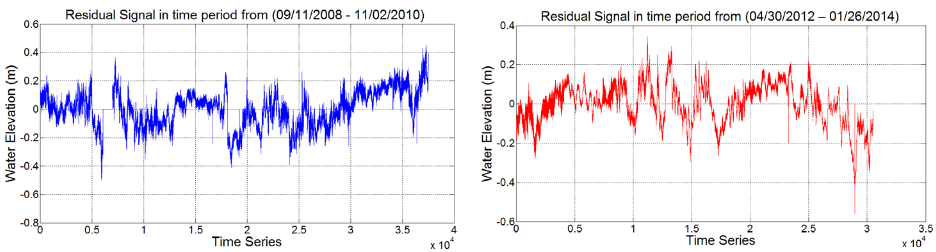

Figure 4. Residual elevations at AWH during the two data sets

Table 3 shows that the surge in the first data set represented about 77%, while in the second data set was about 72% from the total sea level elevation. This result agrees with El-Geziry et al., (2012).

Sea Level components		11/09/2008 – 02/11/2010 782 (22)	30/04/2012 – 26/01/2014 636 (3)
Data sets Power percentage	Residual Power	77%	72%
	Tidal Power	23%	28%

Table 3. Data Sets Durations and (Gaps) in Days and Associated Residual and Tidal Power as Percentage of the Total Sea Level Signal

3.4 Sea Level Power Spectral Density (PSD)

Figure 5 displays the power spectral density (PSD) or the tidal periodogram, with all significant tidal constituents up to a band of 6 cycles /day. In tidal analysis process, tide tool was forced to use the higher frequencies between neighbouring tidal components according to the use of Rayleigh Criterion status. From Figure 5, it appears that the energy peaks associated with these significant frequencies are at the order of diurnal pattern such as (Q1, O1, M1, P1, K1, J1, SO1, OO1) and semidiurnal such as (2N2, M2, S2, L2, K2, N2, MU2, NU2), and also in the terdiurnal such as (MO3, M3, SP3) which are the dominant constituents.

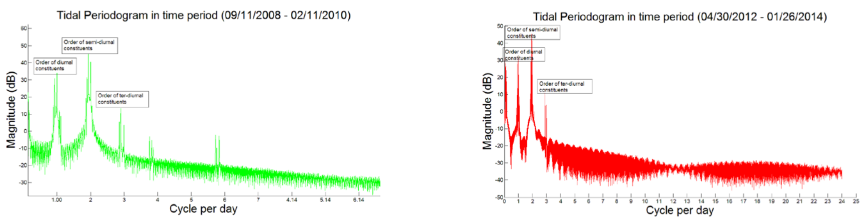

Figure 5. Sea Level Power Spectral Density for the two data sets

3.5 Datums

In the present work, tidal datums in AWH were calculated referred to the ITRF-2014, using values of the four major harmonic constituents (M2, S2, K1, O1) appreciated from harmonic analysis, in addition to values of mean sea levels ellipsoidal heights referred to the ITRF-2014 . Based on the following theoretical terms by (Doodson, 1957):

- Mean high water spring (MHWS) = MSL+ (M2 + S2).
- Mean low water spring (MLWS) = MSL- (M2 + S2).
- Mean high water neaps (MHWN) = MSL + (M2 - S2).
- Mean low water neaps (MLWN) = MSL - (M2 - S2).
- Highest high-water level (HHWL) = MSL + (M2+ S2+ K1+ O1).
- Lowest low water level (LLWL) = MSL - (M2+ S2+ K1+ O1).

Since 1906, there was no additional study made concerning the connection between terrestrial datum and tidal datum in Egypt. Therefore, tidal datum calculations referenced to ITRF 2014 was done for the first time to refer the tidal datums in AWH to specific geodetic datum. It is clear from the calculated values that tidal levels are all within average values as illustrated in Table 4.

	First Data Set	**Second Data Set**	**Mean**
M2	0.07	0.07	0.07
S2	0.05	0.04	0.04
MSL (Z0)	14.78	14.73	14.76
K1	0.02	0.02	0.02
O1	0.01	0.01	0.01
MHWS	14.90	14.84	14.87
MLWS	14.66	14.62	14.64
MHWN	14.81	14.75	14.78
MLWN	14.75	14.70	14.73
HHWL	14.93	14.86	14.90
LLWL	14.63	14.59	14.61
LAT	14.50	14.47	14.49
HAT	15.05	14.97	15.01

Table 4. Tidal Datums Referenced to ITRF-2014 in AWH

Realizing the ellipsoidal height of LAT level as chart datum is prominent in places where no homogenous vertical datum exists, and when there is scarce of constituent sea level data along coastline. In Egypt there was no study made concerning relation between terrestrial datum and tidal datum since 1906, except in 2007 when Sharaf El-Din, et al., (2007) calculated the monthly tidal levels above Chart Datum. Sharaf El-Din, et al., (2007) conducted that LAT level is (-0.3 m) refereed to Mean Low Water Spring (MLWS) which means relating two tidal datums in their results, however in the present study LAT level value is (-0.15 m) from MLWS, beside it's referred for the first time in AWH to an accurate geodetic vertical datum which is the ITRF-2014.

3.6 Wind Pattern

The wind roses of hourly wind speed and direction during the two periods of investigation is shown in Fig.5. During the two data sets, the average wind speed was 5.7and 5.2m/s respectively, and 25% of the blowing wind was Northwest (NW) during the first data set while during the second data set, 25% of the blowing wind was North-Northwest (NNW).

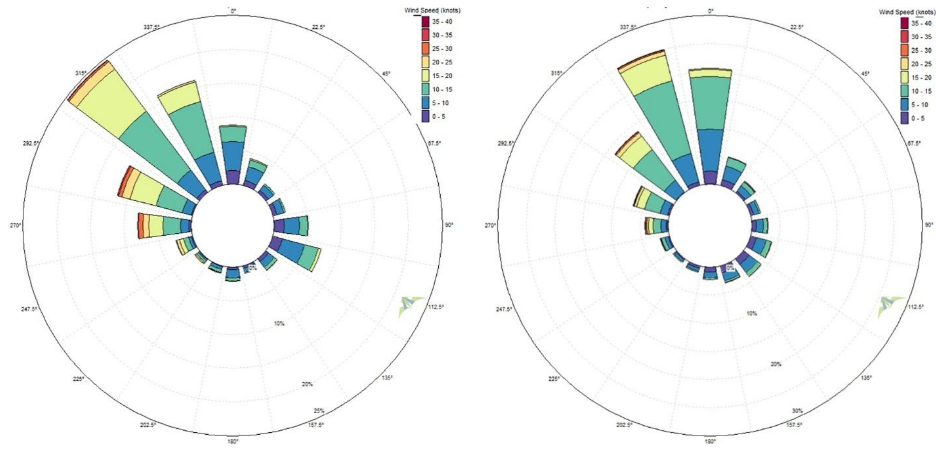

Figure 6. Wind rose over AWH during the two data sets periods

Correlation coefficients were calculated to examine the association of non-tidal component of sea level (surge) variation with both the wind blowing and atmospheric pressure at the same intervals. Correlation was also checked between residuals of sea level and long & normal to shore (U & V) components of the wind forcing. From TABLE 5, it was concluded that there is a good inverse correlation between surge and atmospheric pressure, besides a weak direct correlation between surge and wind and wind components (U & V) as given.

Correlated factors	First data set	Second Data Set
	Correlation coefficient	Correlation coefficient
Wind Speed & Surge of tide-gauge	0.20	0.30
Surge (TG) & Wind (long-shore U- components)	0.19	0.19
Surge (TG) & Wind (long-shore V- components)	0.20	0.29
Surge (TG) & Atmospheric Pressure	-0.47	-0.50

Table 5. Correlation Coefficients Comparison between Data Sets.

4. Conclusion

The sea level variation within the AWH is the result of two contributors: astronomical tide and surge. Alexandria, along the Egyptian Mediterranean coast, is not an exception. The present paper draws the sea level pattern off Alexandria over two data sets. With the use of sea level data, astronomical tide and surge were separated.

The obtained amplitude (H) and phase (σ) values of the four tidal major constituents in the two data sets showed close similar values despite the difference in data length duration. Results are also in good agreement with the values of the previous studies (Rady, 1979 and Moursy, 1989). The type of tides at the AWH has been determined to be semidiurnal tides.

The results of the present research show that astronomical tide contributes with 23% and 28% while, surge contributes with 77% and 72% in the observed sea level. This might refer to the meteorological, oceanographic and climatic effects, which significantly affect Alexandria region. Moreover, the developed local seiches may have some impact on the observed surge elevation [8]. The greater contribution of surge over tidal elevation assures the nature of low tides at Alexandria, as in the whole Levantine Basin. The great impact and strong contribution of surge in sea level variation concluded in the present paper is, indeed, in agreement with Eid (1990), Moursy (1989; 1994), and Saad et al. (2011). In the current study, it appears that the energy peaks of the tide are associated with these significant frequencies at the order of diurnal, semidiurnal and terdiurnal.

Despite of earlier studies in AWH, this study is the first to refer the tidal datum to ITRF 2014, a specific geodetic datum throughout the Egyptian Mediterranean coast.

In AWH, there is a good inverse correlation between surge and atmospheric pressure, besides a direct correlation with wind components. This means that surges in AWH are affected to less extend by the wind due to the sheltered location of the tide gauge inside the harbour and the constructed breakwaters that largely damps the effect of the wind.
Linear regression where made for the two data sets to calculate the sea level trend in the AWH as in (3):

$$MSL = 41.3 + 0.16 * X \tag{3}$$

Where X is the month serial number, which indicate that there is a sea level rise in the mean sea level with annual rate 1.6 mm and 1 mm for the two data sets respectively, which agree with earlier studies Alam Eldin et al. (2007) and Shaltout et al. (2015).

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10 Legal Regime of Climate Change and Impact of International Maritime Transport Industry on Oceans and Marine Life

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1. Introduction

Over the past fifty years, the world has encountered increased concern about the climate change phenomenon. Earth's climate is changing now faster than at any time in the history of modern civilization, primarily because of anthropogenic activities. Climate change is one of the hottest topics and defending issues of our present time. It is now more confident than ever, based on many lines of evidence, that the Climate of the Earth is affected due to humans' activities. The atmosphere and oceans are getting warmer day by day, which has been accompanied by sea-level rise, a sharp decline in the ancient arctic ice, and many other climate-related changes.

The impacts of climate change on people and nature are increasingly apparent. Such consequences have cost billions in damages. Habitats are undergoing rapid shifts in response to changing temperatures and precipitation patterns. Oceans, seas, and marine resources are growingly threatened, degraded, or destroyed by climate change, marine pollution, and other human activities, reducing their ability to provide vital ecosystem services. Indeed, the deterioration of coastal and marine ecosystems and habitats is negatively affecting human well-being worldwide.

The United Nations Framework Convention on Climate Change (UNFCCC) is the international legal framework response to climate change. This convention was adopted at the Earth Summit in 1992 to combat climate change and set-up the essential obligations on the 196 Parties (States) plus the European Union. It came into force in 1994. The supreme decision-making body of the convention is called

"Conference of the Parties (CoP)." The CoP held annually to review, evaluate, and approve the progress in implementation and amending the convention. The first CoP of the convention was born in Berlin in 1995. To date, 25 CoPs have been conducted, and the last one held in Madrid, Spain, in December 2019. The CoP-26 is scheduled to take place in Glasgow, the UK, during 2021. (UNFCCC, 2020).

A new platform was launched last year in Madrid that aims to integrate sensible ocean-based solutions into climate targets. In September 2018, the Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, launched a Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC). The report revealed that the impacts of climate change are already significant and will be increasingly dangerous if the world does not urgently take mitigation and adaptation actions (IPCC, 2018). Also, a new international initiative at the 25th Conference of Parties (CoP25) of the (UNFCCC) was recorded in Madrid aimed to kick-start the search for solutions. A new Platform of Science-based Ocean Solutions was created to enhance the sharing of knowledge generated by various stakeholders in the ocean and climate community to improve ocean-climate action. While the ocean is directly affected by the impacts of climate change, the ocean also holds solutions, which can help the world mitigate and adapt to climate change. A new study (University of Oxford), scientists discovered that the oceans are absorbing 1000 times more energy than all humans use every year. The results of the study highlight the influence of ocean circulation changes due to the massive amounts of the accumulated heat in the ocean and associated sea-level rise and low- to-mid latitude air-sea interactions. Changes in wind and air-sea fluxes, including those due to cloud feedbacks, may play an increasing role under anthropogenic climate change. "In the future, we do expect further changes in ocean transport," lead of the project Dr. Laure Zanna.

To reduce the destructive anthropogenic impacts on the marine ecosystem, good governance, enabling environment, sustainable land- and marine-based human activities, and adequate measures are required. Better sustainable use of resources, changes in production and consumption patterns and improved management and control of human activities will be required, as well. Human well-being cannot be achieved without the protection and conservation of the Earth's ecosystem. To maintaining the quality of life that the oceans have provided to humankind and sustaining the integrity of their ecosystems, a change will be required in how humans view to manage and use oceans, seas, and marine resources. Figure 1 shows the constant increase in the international primary energy supply and consumption since the 1990s of the last century, which was directly reflected in the levels of CO_2 emissions.

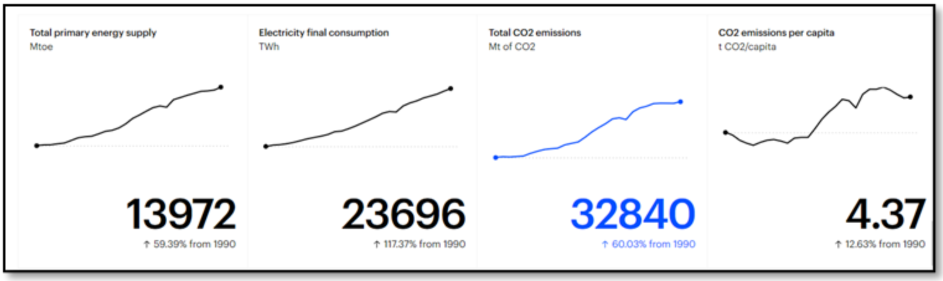

Figure 1. International energy supply and levels of CO_2 emissions since the 1990s (Source: IEA)

As shown in Figure 2, Global energy-related CO2 emissions stabilized in 2019 at around 33 gigatons (GT), following two years of increases, this resulted mainly from an apparent decline in CO2 emissions from the power sector in advanced economies, as a result of the expanding role of renewable sources (mainly wind and Solar Photovoltaic "PV"), fuel switching from coal to natural gas, and higher nuclear power output.

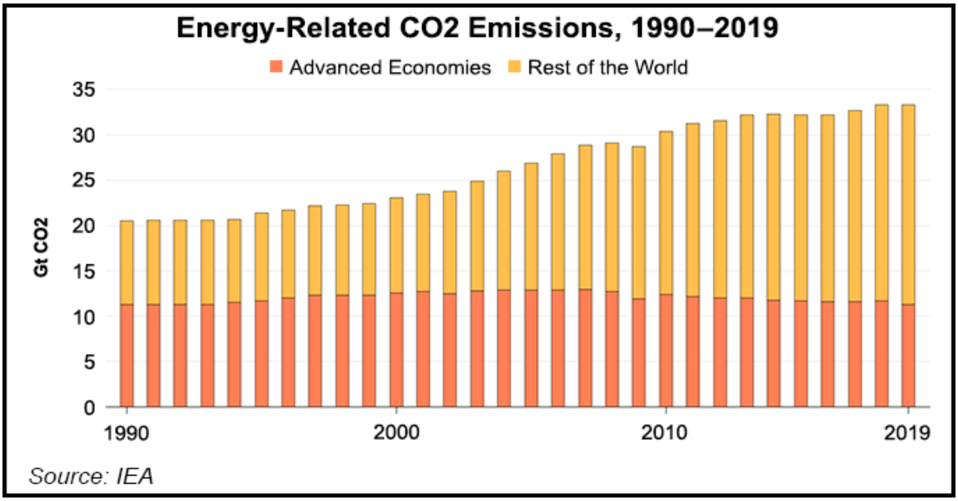

Figure 2. Energy-related CO_2 emissions (1990-2019) (Source: IEA)

Subject to the IEA "Global Energy Review 2020" and as a result of the Covid-19 crisis, CO_2 emissions are expected to drop 8% in 2020, or nearly 2.6 gigatons, to levels 10 years ago. This year-on-year reduction would be the largest ever,

six times larger than the previous record low of 0.4 gigatons in 2009 - due to the global financial crisis - and twice the total size of all previous cuts combined since the end of World War II. There are many international legal instruments & entities supports mitigating the adverse effects of climate change on marine living and non-living resources such as the United Nations Convention on the Law of the Sea (UNCLOS-82). The current most significant challenge of climate change in the international maritime industry to make big emitters agree to work in concert to reduce anthropogenic greenhouse gas emissions.
During the UN Sustainable Development Summit in September 2015, all the UN member states adopted the 2030 Agenda for Sustainable Development, with 17 SD Goals (SDGs) at its core. Eventually, UN SDGs considers as the blueprint of the UN to achieve a better and more sustainable future for humanity, and it addresses the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice. UN 17 SD Goals are all interconnected, and it is planning to be achieved all by 2030. Moreover, the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization on 5th December 2017, adopted at the twenty-ninth session a proposal for an international decade of ocean science for sustainable development. The proposed decade is in the period between 2021–2030 beginning on 1st January 2021, within existing structures and available resources, and calls upon the Intergovernmental Oceanographic Commission to prepare an implementation plan for the decade in consultation with the Member States and other intergovernmental organizations, non-governmental organizations and relevant stakeholders.
In parallel with this concept, the United Nations General Assembly mandated the UN Decade of Ocean Science to achieve the Sustainable Development Goal number 14 “life below water – keep the oceans clean”. The main target of Goal 14 is the conserve and the sustainable use of the oceans, seas, and marine resources for sustainable development.
Generally speaking, beyond their goals, their contents and the context of their negotiation, the two main legal tools of marine and maritime domains “UNCLOS and the UNFCCC” are still considering ideological and political thinking in their understanding of global environmental issues. While the United Nations Convention on the Law of the Sea considers the “region” as a common heritage of humankind (Article 136), the United Nations Framework Convention on Climate Change represents an ideological retreat by making climate change a common concern only for humankind (the preamble). This concept has no legal force. Despite the international awareness regarding the negative impact of the climate change, there is increasing concern within the international community that the global legal framework, based as it is around the doctrine of the freedom of the high seas is

no longer adequate in so far as the conservation and use of biodiversity in areas beyond national jurisdiction that concerned.
This article discusses the main tools and legal regime of climate change. Also, study the reasons, impact, action plans, preparedness and corrective actions of the relevant international bodies to achieve the UNSDGs in the context of combating the climate change.

2. The leading international bodies & conventions concerned by Climate Change

2.1 International bodies

Now a day, the world is at crossroads within number of sight crises: catastrophic climate change, rapid ecosystem and biodiversity decline, Desertification and increasing economic inequality despite a reduction in extreme poverty.
The linkages between ecosystem and marine environment from one side and climate change from other hand are of particular concern to The United Nations (UN) and its relevant organizations, including the need to recognize both the existential threat human-forced climate change presents to biodiversity, and the role of nature-based solutions in mitigating greenhouse gases missions.
The United Nations founded in 1945 after the Second World War to maintaining peace and security, developing cooperative relations among nations, and promoting social progress, better living standards and human rights. The UN works on a broad range of fundamental issues, from sustainable development, environment to human rights, economic and social development and international health, clearing landmines, expanding food production. The UN works with world countries (currently, 193 sovereign states) to achieve these goals and coordinate efforts for a safer world for future generations.
In terms of climate change, there are many bodies concerned can be classified into two categories "governmental bodies" (including intergovernmental organizations) and "non-governmental bodies" NGO, as follow:

- The Intergovernmental Panel on Climate Change (IPCC) as the United Nations body for assessing the science related to climate change. The IPCC created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO)in 1988, it has 195 Member countries.
- The Conference of the United Nations Framework on Climate Change Convention (UNFCCC), the Kyoto Protocol and the Paris Agreement. Adopted on 9th May 1992 at the Earth Summit in Rio de Janeiro in June 1992 and entered into force in March 1994.

- United Nations Environment Programme (UNEP), The United Nations Environment Programme is responsible for coordinating the UN's environmental activities and assisting developing countries in implementing environmentally sound policies and practices.
- The International Maritime Organization (IMO), one of the UN specialized organization, The IMO is the UN responsible body for regulating shipping. The IMO was established following agreement at a UN conference held in Geneva in 1948, and the IMO came into existence ten years later, meeting for the first time in 1959.
- World Meteorological Organization (WMO), the U.N-based international organization, is an intergovernmental organization with a membership of 193 Member States and Territories. It is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces and the resulting distribution of water resources.
- The Global Commission on Adaptation (UPSC). The UPSC is a non-governmental international Commission works to accelerate adaptation action and increase political support for building climate resilience through inspiration various international actors to prepare for and respond to the devastating impacts of climate change with urgency, determination and foresight. The UPSC is recommending several action tracks to scale up climate adaptation solutions. The Commission is led by well-known distinguish personnel, such as Ban Ki-moon, Kristalina Georgieva and Bill Gates, and co-managed by WRI and the Global Center on Adaptation. It is consisting of more than 30 Commissioners and 20 convening countries.

There are many international legal instruments and conventions adopted to support the conservation and sustainable use of marine resources outside the areas of national jurisdiction by many international bodies under the umbrella of the UN and its relevant intergovernmental organizations. In the following section discusses the main conventions that are concerned by limitation the impact of climate change on marine life and the marine ecosystem.

2.2 The United Nations Convention on the Law of the Sea (UNCLOS-82)

Every coastal state has jurisdiction over the oceans and seas, the limits of which are defined by international conventions, and national regulations must conform to international law. In 1982 and after very long and sophisticated discussions and negotiations among the world's countries (in specific, it took 585 days of debate), the final UNCLOS-82 was finally adopted in New York by 72 Countries.

UNCLOS came into force on 16th November 1994. UNCLOS includes standards and regulations in many different aspects starting from ships construction and operation, ports safety and security passing through Maritime Zones, Limits and Boundaries delimitations, states sovereignty and jurisdiction till the provisions of marine scientific research and protection of marine environment and biodiversity. UNCLOS for international maritime community considers the primary source of most International Maritime Conventions (Mother of all Maritime Conventions) including those conventions that relevant to conversations and protection of marine environment and biodiversity such as (MARPOL 73/78) as amended.
From the marine environment conservation perspective, the convention enforcing the following standards:

- Every state has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles.
- Contiguous zone up to 24 nautical miles from the shoreline for purposes of enforcement of customs, fiscal, immigration, or sanitary laws.
- Exclusive economic zone up to 200 nautical miles from the shoreline for purposes of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil.
- Establishing international rules and standards to prevent, reduce and control pollution of the marine environment from vessels.
- The resources of the seabed and ocean floor and subsoil thereof beyond the limits of national jurisdiction are the common heritage of humankind.
- An International Seabed Authority will organize, carry out, and control activities associated with the exploitation of the resources of the international seabed.
- A parallel system will be established for exploring and exploiting the international seabed, one involving private and state ventures and the other involving the authority.

In theory, States always have the possibility of enforcing high seas marine protected areas not on the high seas but in their ports, making access to their ports conditional on foreign vessels having acted or refrained from working in a particular way in the relevant part of the high seas. Flag State is the only body own the necessary jurisdiction, hence with the absence of a specific multilateral enforcement mechanism redress of breaches of the rules will remain primarily subject to flag States enforcement.
To follow-up amendments and implementation, the rules of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), the UN established three institutions:

- the International Tribunal for the Law of the Sea (ITLOS)
- the International Seabed Authority (ISA)
- the Commission on the Limits of the Continental Shelf (CLCS).

Structure, composition, and area of competence of these institutions are quite different. However, their common task is to serve the states parties to the UNCLOS in ensuring its coherent and efficient implementation, thus also securing the peaceful uses of the seas and the undisputed exploitation of maritime resources as a matter of common interest. In terms of Climate Change, the UNCLOS makes no explicit reference. It only considers the occasional climatic aspects of its relationships with the ocean. But in recent years, climate change has emerged as an issue rationally subject to ocean management issues. The Law of the Sea now faces adapting challenge to fight against Climate Change and to highlight the "regulating" role of the ocean. Although the UNCLOS has no direct articles about climate change and Greenhouse Gas emissions (GHG), the provisions of Part XII of the Convention entitled "Protection and preservation of the marine environment" are relevant to address these issues. It provides that "States have an obligation to protect and preserve the marine environment", including "rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life" (art. 194.5). Such general obligation supposed to be applied to ecosystems including coral reefs and species affected by climate change, particularly global warming, and ocean acidification. Moreover, Part XIII of UNCLOS on Marine Scientific Research provides an innovative legal regime governing research activity carried out by States and international organizations such as the WMO and the UNESCO Intergovernmental Oceanographic Commission (UNESCO-IOC), anywhere at sea. For better understanding, the impact of climate change on the ocean, many pieces of research have been conducted in the marine and maritime sectors. (Guilloux, B. & Schumm R., 2016).
In the respective consideration of Ocean and Climate under the Law of the Sea and the Climate Law and the challenges facing the response of the international community to global environmental is still limited in Law and Practice. However, the experts of climate change pretend that the current challenges still require urgent and compelling answers on all scales.

2.3 United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol & Paris Agreement

During the Earth Summit in Rio de Janeiro, three important Conventions were adopted. First convention was an international environmental treaty, which was adopted in May 1992 and opened for signature in June 1992. This convention named the United Nations Framework Convention on Climate Change (UNFCCC) and entered into force on 21st March 1994.

The UNFCCC's ultimate objective is to achieve the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. The 195 countries that have ratified the convention are called Parties to the convention and the Convention matters are regulating through a body called Conference of the Parties (CoP). The CoP considers the supreme decision-making body of the convention. The Parties meet annually to review progress in the implementation of the convention where other instruments that support the implementation of the convention are proposed, evaluated and approved. The first CoP was held in Berlin in 1995. To date, 25 CoPs have been held, the last one in Madrid, Spain, in December 2019. CoP26 is scheduled to take place in Glasgow, the UK in 2021.

The convention was extended by Kyoto Protocol international treaty to commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that (part one) global warming is occurring and (part two) it is extremely likely that human-made CO2 emissions have predominantly caused it. The Kyoto Protocol was adopted in Kyoto, Japan, on 11th December 1997 and entered into force on 16th February 2005. There are currently 192 parties (Canada withdrew from the Protocol, effective December 2012) to the Protocol. This Protocol provided an overview map of states committed to greenhouse gas (GHG) limitations in the period between (2008–12).

Kyoto calls for relatively modest reductions in GHG emissions, setting an average goal of 5% below 1990 levels for developed countries. The Protocol does not set reduction targets for developing countries on the principle that the developed countries that have created the problem should take the first steps to clean it up. However, rapidly developing economies such as those of China and India will have a significant impact on GHG emissions in the future. Lack of developing country commitments is one of the reasons why the United States refused to ratify Kyoto.

Also, under the UNFCCC, the Paris Agreement was adopted in December 2015 and entered into force in November 2016. The agreement was the outcome of the negotiations launched in 2011 at the 17th Conference of the Parties in Durban. The main aim of the convention is to develop a legal instrument applicable to all Parties to cut GHG emissions. The agreement implementation through 2020 phase considers a separate instrument under the UNFCCC rather than an amendment of the Kyoto Protocol.

Until the Paris agreement was finalized at the end of 2015, the significant climate agreement in force was the Kyoto Protocol which tasked developed countries to work through the IMO to cut emissions. The Paris agreement is different. Unlike Kyoto, which had specific emission targets only for developed countries, the Paris agreement requires all parties to address all emissions. Parties are required to establish 'economy-wide' emission reduction targets, and shipping is a key part of the economy. During the years led up to the Paris Agreement, many scientific and technical inputs provided to international community stressed that while biodiversity and ecosystems are threatened by climate change, conservation, restoration and sustainable management generate significant and practical nature-based solutions to climate change. These solutions must contribute to both mitigation and adaptation objectives under an internationally agreed framework. The Paris Agreement clearly recognizes the need to enhance and ensure environmental integrity and invites Parties to conserve and enhance GHG sinks and reservoirs, including biomass, forests, and oceans as well as other terrestrial, coastal and marine ecosystems. The central aim of Paris Agreement is to strengthen the global response to the threat of climate change by keeping the global temperature rise within this century below 2 degrees Celsius and above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Furthermore, the agreement established an ambitious mechanism to reach Net Zero emissions and climate resilience by 2050. Figure 3. Paris Agreement set-up a well-defined approach to climate mitigation, the key elements of the approach consist of collective long-term goals, accompanied by several elements: nationally determined mitigation efforts; five-year review cycles of progress in implementing individual efforts toward the collective goals; and a commitment to increase ambition as part of the five-year review cycles to ensure that collective long-term goals are met.

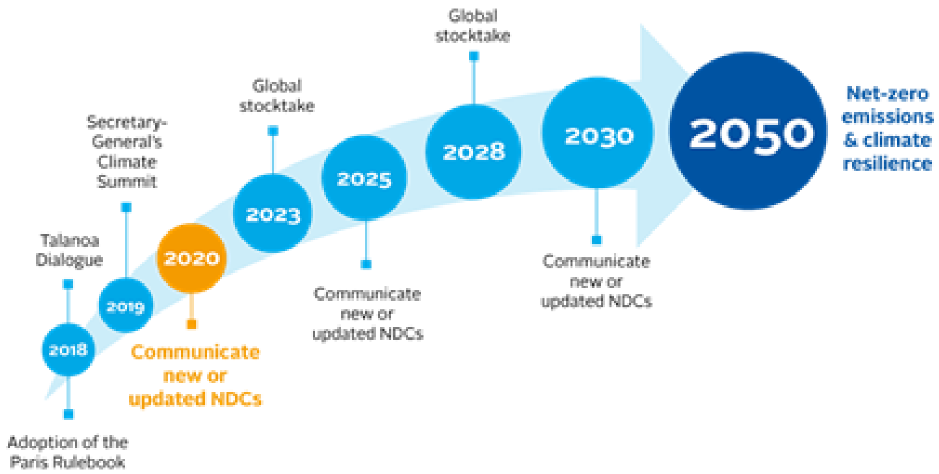

Figure 3. Ambition Mechanism in the Paris Agreement (Source: wri.org/publications/ NDC-enhancement by 2020)

2.4 The Convention on Biological Diversity (CBD) 1992

The Convention on Biological Diversity (CBD, 1992) is the principal instrument of international law concerned with the conservation and sustainable use of biodiversity. CBD-92 Signed by 150 government leaders at the 1992 Rio Earth Summit “entered into force 1993”, the Convention on Biological Diversity is dedicated to promoting sustainable development.

Conceived as a practical tool for translating the principles of UN Agenda 21 into reality, the convention recognizes that biological diversity is about more than plants, animals and micro-organisms and their ecosystems, it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live. Its jurisdictional scope is as follows: As regards the “elements of biological diversity” it applies only within the land and marine areas under the national jurisdiction of States, it generally applies as regards processes and activities carried out under the jurisdiction or control of a State. The CBD imposes a set of duties on its State Parties regarding in situ conservation. These include the establishment of protected areas and the conduct of an impact assessment of proposed projects, policies and programmes in cases where there are risks of significant adverse impacts on biological diversity, intending to avoid or minimize such effects.

The CBD also sets out a regime, further developed in the Nagoya Protocol, concerning access to and the benefits from the use of genetic resources, primarily for the biotechnology sector. As the CBD must be applied consistently with UNCLOS, this means that States acting singly or together cannot establish marine protected areas beyond their national jurisdiction that are binding on non-participating States and the provisions on access and benefit-sharing do not apply to genetic material sourced from such regions.

In October 2010, the tenth meeting of the Conference of the Parties (CoP10) held in Nagoya, Aichi Prefecture, Japan, decision X/2 was adopted, revised and updated a Strategic Plan for Biodiversity, including twenty Biodiversity Targets, for the 2011-2020 period. It is known by “20 Aichi Biodiversity Targets”. The plan provided an overarching framework on biodiversity, not only for the biodiversity-related conventions but for the entire United Nations system and all other partners engaged in biodiversity management and policy development.

It concerned how the ambitious 20 Aichi Biodiversity Targets, which was adopted by the international community in 2010, will be met by the end of 2020. These call for at least 10 % of coastal and marine areas (especially those of ecological importance) to be conserved through effective systems of marine protected areas and other effective area-based conservation measures. 20 Aichi Targets are under four main Goals:

– Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society.
– Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use.
– Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
– Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services.
– Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building.

As mentioned above, the current "Aichi targets" strategic plan will be reached by the end of this hard year "2020". Therefore, the post-2020 global biodiversity framework was adopted under the call "2050 Vision". The new strategic plan established in decision 14/34 of the Conference of the Parties to the Convention on Biological Diversity in 2018, a regional consultation meeting was held in Germany in April 2019 and the overarching framework on biodiversity "post-2020 global biodiversity framework" announced as a stepping stone towards the 2050 Vision of "Living in harmony with nature".
Although the previously mentioned efforts, totally absent from the picture is an overall mechanism for coordinating efforts to preserve marine biodiversity in areas beyond national jurisdiction, certain bodies such as the CBD Conference of the Parties and Intern Union for Conservation of Nature (IUCN) have taken steps to promote awareness of the topic. Also, the United Nations General Assembly (UNGA) has played an increasingly important coordinating role in this regard.

3. Conclusion

The interactions between Ocean and Climate Schemes are challenging to visualize together legally because existing frameworks are disintegrated and complex to understand. On the one hand, the international law of oceans can be described as a comprehensive framework, build global planning. It contains a broad range of sectorial and regional arrangements, within the unified legal framework of the 1982 UN Convention on the Law of the Sea.
The constitution for the oceans is the result of the categorization process of the law of the sea and the formation of new legal rules (e.g., the Exclusive Economic Zone (EEZ) or the status of archipelagic States). It describes the constitutional rights and responsibilities of States organizing maritime activities (exploitation of mineral resources, navigation, marine scientific research, etc.), according to a zonal category of seas and oceans into zones under national authority (internal waters,

regional sea and adjacent zones, EEZ, continental shelf) and, zones beyond the limits of the national territory (High seas). The topics of significant concern are the collapse of most fisheries stocks, the destruction of marine and coastal habitats and biodiversity loss, the sustainable use and conservation of biodiversity of areas beyond national jurisdiction, land-based and marine pollution, and, in recent years, climate change impacts.

Oceans and climate under the Law of the Sea and the Climate Law and the challenges facing the response of the international community to global environmental is still limited in Law and Practice. However, the experts of climate change pretend that the current challenges still require urgent and compelling answers on all scales.

Despite all the efforts, plans and many successive rounds of negotiations, the IMO has so far failed to adopt reduction measures to set the maritime sector on a pathway compatible with the temperature goals of the Paris Agreement and other Climate Change international relevant standards. Additional measures are needed to incentivize leading players and stakeholders of the international maritime industry to invest in low carbon and carbonless ships and operate the maritime industry in ways that reduce emissions.

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PART THREE
Weather, Modelling and Monitoring

11 Weather-related hazards and community response in the Mediterranean region: the case of Greece

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1. Introduction

Weather-related hazards, especially the hydrological and climatological ones, cause extensive damages (MunichRe, 2018) and a significant number of human fatalities worldwide (Petrucci et al., 2019a, 2019b; Rappaport, 2014). In Europe, disasters caused by weather and climate-related extremes accounted for 83% of the monetary losses over the period 1980-2017 (EEA, 2019). Notable were the storms that caused floods and mass movements, repeatedly, affecting the Mediterranean region and especially the countries of Italy, Spain, France and Greece (Michaelides et al., 2018). There are already signs of an increase in the occurrence of catastrophic floods and heavy storms, prolonged droughts or heatwaves and forest fires in the region (Alfieri et al., 2015; Gariano & Guzzetti, 2015; Flannigan et al., 2000). Especially as regards the Eastern Mediterranean region, the likelihood of increase in the frequency and intensity of weather-related hazards is very high according to the scientific studies analysed by the Intergovernmental Panel on Climate Change (Cardona et al., 2012).
At the local level, the impact of severe weather events varies, as many parameters affect its magnitude. It is proven that both environmental and socio-economic factors play an important role on the extent of the disaster (IPCC, 2014). Land-use practices, urban development, and building in flood-prone areas have been shown to aggravate the impact, as people and property become highly exposed to hydrological as well as to climatological hazards (Bathrellos & Skilodimou, 2019; Piazza et al., 2016). The adaptation of local communities to the risks of climate change will ultimately depend to a large extent on understanding the vulnerability and behaviour of society against weather-related hazards. In order to better address an uncertain future, understanding the local context and individual motivations can be used as a means to improve planning and implementing risk mitigation measures. Individual preparedness has already been acknowledged as a

crucial element of a community's resilience against natural hazards. International strategies such as the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) are incorporated into national law, emphasising the need for cooperation between central authorities, local communities and citizens.

The purpose of this analysis is to provide insight into the response of communities to the occurrence of hazardous weather-related phenomena, focusing on the role of citizens. The objectives are to understand the particular meteorological, environmental and social conditions that contribute to the level of preparedness and adaptability of the citizens before the onset and during the outbreak of a potentially dangerous phenomenon. The target area is Greece, a country with a typical Mediterranean climate, which is often affected by severe weather-related events, mainly flash floods, extreme temperatures, and forest fires (Lagouvardos et al., 2019; Papagiannaki et al., 2015; Kotroni et al., 1999; Lagouvardos et al., 1996). Starting with a look back at the episodes of the last decades, we will expand on the assessment of impacts, with particular reference to the human losses from floods and the profile of the victims. We will then assess the precautionary behaviour of Greek citizens against risk and outline cognitive and behavioural characteristics related to prevention and self-protection. The analysis is based on a series of surveys that reached a large audience and provided extended feedback on community responses to weather-related hazards through the experience and perspective of citizens. Finally, we will summarize the lessons learned from the study of the relationship between hazards, individual perception and adaptability, while highlighting the need for a bottom-up approach to achieve more effective risk prevention in the country.

2. Weather-related hazards with societal impacts

Weather-related hazards in the Mediterranean often associate with significant economic losses, human fatalities and adverse effects to society and the ecosystem. Especially hydrological hazards in the Mediterranean countries tend to be greater in magnitude compared to the inner continental countries (Gaume et al., 2009), while they occasionally produce catastrophic damages (Llasat et al., 2013; Lastoria et al., 2006). Greece experiences a variety of weather events that are frequently followed by adverse consequences on the socioeconomic activity (Papagiannaki et al., 2013; Diakakis, 2012). Even though they do not usually appear with the catastrophic power of other natural hazards, such as earthquakes, their overall impact on society and the economy is very serious. Figure 1 depicts the annual distribution of an exhaustive list of weather-related phenomena that caused adverse societal effects during the 20-year period 2000-2019 in Greece. Data derive from the database of high-impact weather events in Greece, which is developed by the METEO unit of the National Observatory of Athens (Papagiannaki et al., 2013) and is systematically updated and available online (https://meteo.gr/weather_cases.cfm). The list of addressed events includes flash floods and floods, windstorms, hailstorms, tornados, heat waves and thunderstorms. The total number of damaging events varies considerably from year to year, exhibiting a weak, however, positive trend (Poisson R^2 .29, Prob > chi2 .00) during the analysed period. Flash flood ranks as the most frequent type in all years examined. Over the 20 years, damaging flash floods account for the 52% of total events. The second most frequent phenomenon is windstorm, which is responsible for the 14% of total damaging events.

Especially in the case of catastrophic flash floods, the developed database for Greece extends back to 1980 to comply with the standards of the FLOODHYMEX database across the Mediterranean (Llasat et al., 2017). Analysis of the flash flood records since 1980 suggests a significant increase in the number of records during the last decades. The recorded increase in flood episodes with severe impact cannot be justified only by a possible increase in the frequency of extreme precipitation. The societal impact of flash floods varies and depends on the hazard intensity and the vulnerability of the affected area as measured by its topographic and demographic features, the quantity and quality of the materials exposed, the anthropogenic interventions and the effectiveness of the prevention measures taken by the local authorities (Papagiannaki et al., 2015; Tsakiris et al., 2014; Diakakis et al., 2012).

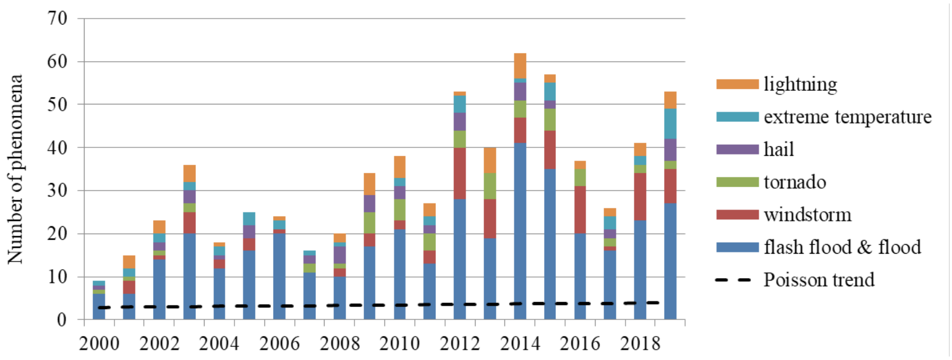

Figure 1. Annual distribution of impact-related weather phenomena by type, for the period 2000-2019. Data derive from the active NOA database of high-impact weather events in Greece (Papagiannaki et al. 2013)

While the increase in high-impact flood events, and especially in the catastrophic ones, is a measure of increase in damages and properties at risk, a similar trend in fatalities is not necessarily expected as it largely depends on the individual's attitude towards risk. Flood fatalities in the wider Mediterranean region have been recently studied by Petrucci et al. (2019a; 2019b) and Vinet et al. (2019). In these studies, the authors homogenise the different national or regional databases to develop the MEFF DB (MEditerranean Flood Fatalities Data Base) addressing flood fatalities across the Mediterranean Basin (Petrucci et al., 2019a), and its extended version, the EUFF DB (EUropean Flood Fatalities Data Base), that includes European countries of the wider region (Petrucci et al., 2019b; Vinet et al., 2019). Namely, the data include flood mortality information from documentary sources from eight countries/areas, for the period 1980-2018. The studied countries/areas are: Greece, Italy, Czech Republic, Israel, Portugal, South France, Catalonia and the Balearic Islands. Apart from the geographical analysis of data, they provide data on the profile of victims and the circumstances under which people die during flooding. Figure 2 shows the annual variability of the number of fatalities and the number of fatalities per events for the whole database and for Greece separately. A relatively small increase in the total number of deaths and a relatively small decrease in the number of fatalities per event are recorded in the studied area. For Greece, this increase is larger, while an increase in the number of fatalities per event is also evident. The patterns of flood fatalities among the subareas, namely the eight countries, indicate a common lack of risk awareness among citizens. Therefore, behaviours were observed that can be characterized as dangerous, i.e., capable of being to some extent responsible for the fatal outcome. Since mortality and material losses are indicators of the effectiveness of prevention measures in dealing with weather hazards, understanding the role of the behaviour of individuals is essential.

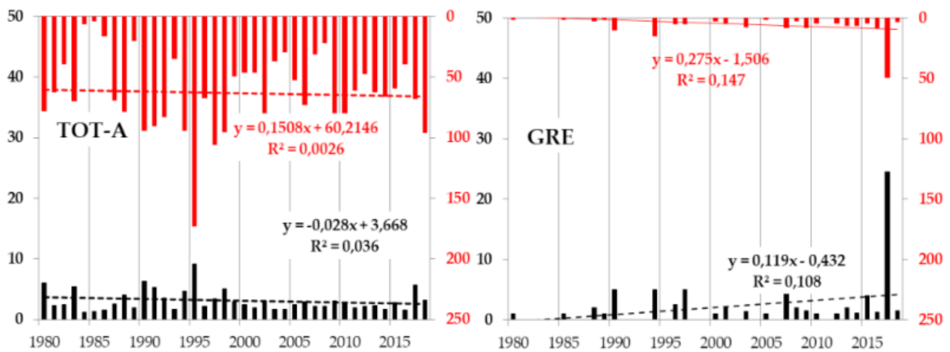

Figure 2. Annual variability in the number of fatalities (#FF, in red) and in the number of fatalities per event (#FF/#EV, in black), complemented by their linear trends, for EUFF areas (left) and Greece (right). (Source: Petrucci et al., 2019b)

3. Individuals’ coping responses to an emergency event

Overall, there is evidence of an upward trend in societal impacts caused by weather-related hazards in Greece, especially by flash floods. Because flash floods are extreme and sudden events that are hardly predictable, many studies have focused on lessening the impact on humans by addressing behavioural coping responses. These studies have contributed to the understanding of the range of behaviors and critical hydrometeorological parameters that might affect humans (Becker et al. 2015; Diakakis and Deligiannakis 2013; Llasat et al. 2008; Papagiannaki et al. 2015; Petrucci and Pasqua 2012). Although rainfall severity was found to affect the level of flash flood impact severity, there was evidence that other factors are also important. According to this literature, it was obvious that events with comparable hydrometeorological characteristics might affect local communities differently because of the difference in the vulnerability of those communities. As individual behaviour is part of social vulnerability, it is considered as a critical element of an effective community's response to flood risk. A recent behavioural survey provided insight into the factors that affected the citizens’ coping responses to a severe storm event that affected Attica, Greece, on 22 October 2015 and produced extended flash flood incidents and 4 fatalities (Papagiannaki et al., 2017). The perceptual and behavioural responses of 800 witnesses of the rainfall episode were analysed, in order to test the influence of the rainfall severity and urban characteristics on the level of adaptation, namely the effects the event had on people’s travel patterns and daily activities. One of the research questions was how important the meteorological effect was on individuals’ risk perception.

According to the results, people’s judgment on the event’s severity, at the time the storm peaked at a certain location, was found to be significantly correlated with the total accumulated rain (since the storm onset) at the same location (Figure 3). Therefore, individual risk perception can be considered objective enough to worth considering as an indicator of protective behaviour. During the emergency crisis, both risk perception and fear were found to play a role in the protective response. Deeper feelings of worry were found to be correlated with more significant adjustment on scheduled travels and activities (Figure 4), while risk awareness (being timely alerted) was found to prevent last minute changes. Citizens that were timely and effectively informed about the anticipated weather severity, being thus more aware of the risks, were found to have less need for adjustment. Residents of the areas most exposed to floods also took more drastic initiatives. In other words, the citizens reacted according to the seriousness of the local effects. It is, however, important to note that the level of risk awareness was found to be quite low, although the affected areas are among the most urbanized in Greece. The percentage of the respondents that declared themselves alerted ranged from 30% to 38%, depending on area.

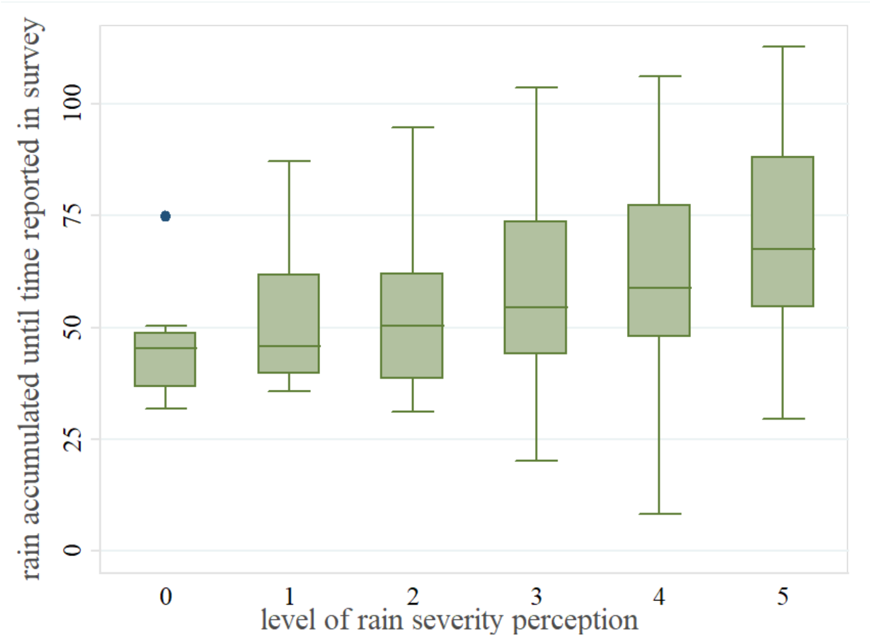

Figure 3. Level of rain severity perception at the time the storm peaked according to the respondents' judgment, in relation to the accumulated rain at the respondents' position (Adapted from: Papagiannaki et al., 2017)

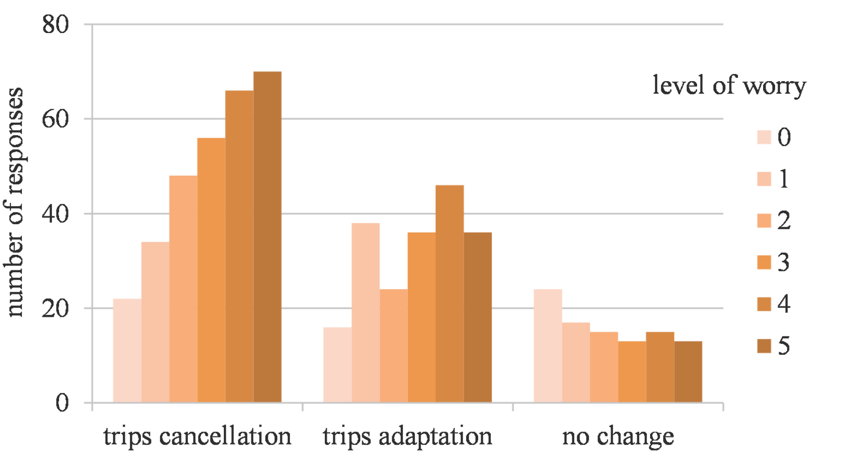

Figure 4. Number of responses to the online behavioural survey concerning the type of adaptive travels at various levels of worry (Adapted from: Papagiannaki et al., 2017)

4. Individual precautionary behaviour

In addition to dealing with emergencies, prevention is just as crucial to building a resilient society. Flood losses have been shown to be significantly reduced when private precautionary measures are taken (Kreibich and Thieken, 2008). Therefore, a better understanding of the determinants of individual preparedness can help policy makers improve risk management. A recent survey that attracted 1855 responses examined the mechanisms of flood-risk precautionary behaviour among Greek citizens (Papagiannaki et al., 2019a).
Overall, the results supported the hypothesis that perceptual and emotional processes constitute mechanisms driving flood-risk precautionary behaviour. Both risk perception and negative emotions seem to trigger a willingness to be prepared, in the presence of an environment that raises awareness about flood risk, as well as it raises doubts about the authorities' ability to deal with them. An earlier severe experience, awareness of local vulnerability and targeted risk communication were found to motivate people to take precautions, partly due to the intervention of perceptual and emotional mechanisms. According to the survey, residents in more urban areas show more confidence in the authorities and lower awareness of vulnerability. In accordance with the findings of the previous survey of the individuals' emergency coping responses (Papagiannaki et al., 2017), the urban environment was found to be associated with reduced precautionary behaviour. These findings suggest the high dependence of urban citizens on local authorities, which may create an undesirable complacency. It should be noted that the existing level of preparedness as well as the preparedness intention were found to be low. Therefore, there is significant potential for improvement of the overall preparedness of citizens, with support from the local authorities. Finally, the profile of the survey participants showed that Greek people tend to perceive low risk from flooding, although people who more accurately appreciate their exposure to flood risk may perform higher risk perception.

5. Risk perception, coping appraisal and preparedness in a multi-risk environment

Risk perception has been recognized as a driver of individual precautionary behaviour and is therefore considered a crucial element in flood risk management. In addition, the perception of risk by the general public often plays a role in shaping the public agenda and, therefore, in the way government policies are designed to increase resilience and mitigate risk (Beck, 1992). Especially in a multi-risk environment such as Greece, where the ability and expertise of civil protection

organizations are tested in very different types of natural hazards, it is important to consider the risk perception among those hazards.
This was addressed through a survey of citizens that collected 2330 responses to investigate the views and perceptions of hydrogeological and climatic hazards against geophysical hazards in a Mediterranean area where they are all present at a significant level (Papagiannaki et al., 2019b). The study also assessed citizens' self-estimated coping capacities and precautionary attitudes against the various hazards. According to the results, people consider earthquake the most dangerous and worrisome hazard, followed by wildfires and floods. Hydrogeological hazards seem to cause less concern, although phenomena such as floods occur more frequently and cause in total more damage. Moreover, risk communication and access to high-quality information was not translated into higher risk perception, but rather into greater self-confidence about the ability of the individual to cope with the risks. On the contrary, prior experience of disasters was found to stimulate threat perception and preparedness. As far as climate risks are concerned, however, the positive impact of the experience seemed to weaken over time. Interestingly, the perception of earthquake threat was not affected by the time elapsed since the most recent experience, suggesting a strong imprint of these events on people's minds. Of particular interest are the results that show a higher estimate of the ability to deal with an emergency due to an earthquake, which probably reflects the systematic education of earthquake emergency response in schools and in many public and private companies. However, unlike earthquake threat perception, climate-related and mostly hydrogeological threat perceptions were found to motivate preparedness, in terms of the amount of precautionary measures taken, except the insurance purchase which was shown to be purely a matter of economic criteria. Private insurance coverage for weather-related damages is actually not in the culture of Greek citizens, while no campaigns to shift this attitude have been launched in the country. Finally, overall preparedness was found to be low, which is in line with the results of the aforementioned surveys.

6. Conclusions

Adapting a community to climate change risks cannot be achieved without the involvement of citizens (Seebauer et al., 2019). Authorities and risk managers need to understand the need for a bottom-up approach in prevention strategy and convince the citizen to actively participate by adopting individual precautionary behaviour. Moreover, as the need for individual preparation and response to prediction and alert systems is of paramount importance, a major challenge for risk management is to understand the factors that drive precautionary behaviours.

In this chapter, we present the published results of a series of original, extensive surveys of the preparedness and adaptability of Greek citizens to weather-related hazards. The information they provide both on the level of preparedness and on the factors that affect it are of particular importance for shaping policies to approach citizens. An important element of the overall study is the low levels of preparedness, risk awareness and access to specialized information. In addition, findings indicate a low degree of individual response to risk alerts, limited knowledge of local risks and ineffectiveness of risk communication, as well as low trust in authorities. These results point out a noticeable gap in the risk communication process or a highly inefficient top-down risk management. Both cases may constitute significant weaknesses of communities' resilience to weather-related hazards such as flash floods, which constitute the greatest hydrogeological hazard in the area under consideration.

Despite the low scores on awareness and preparedness, their positive correlation and the supportive role of risk perception and emotional outreach confirm the usefulness of citizen-oriented risk mitigation policies and show how to perform them. Any interventions should aim at influencing perceptions of the seriousness of climate risks at the local level, through systematic information and scientific documentation. Public awareness campaigns could include experiential techniques to stimulate risk perception and convince the audience of the effectiveness of preventive behaviour.

Overall, the study shows that society is significantly concerned with certain climate-related risks, which are however underestimated in a multi-risk environment where geophysical hazards have a strong presence. This tendency in the perception of citizens has the potential to influence public debate and political priorities, ultimately affecting the allocation of available resources for prevention. Therefore, weather related natural hazards should be highlighted as significant threats, especially given the unfavourable climate change projections for the region in terms of frequency and intensity of flooding, mass movement and forest fires (Alfieri et al., 2015; Flannigan et al., 2000; Gariano and Guzzetti, 2015). Strengthening public opinion in this direction could even have a positive effect on the public agenda on preventing and protecting against such risks.

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12 Climate in the Computer: Climate Change Mathematical Modeling

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1. Introduction

If sometimes it is difficult to forecast the weather for the day after, how can we pretend to know what will be the conditions of the climate on the Earth in a century? The technological progress of the last fifty years and the development of the parallel massive calculation are bringing to solve many of the problems linked to the indeterminism of the climate forecast. Through these methods and power calculation, we are now able to reach reliability of 98% in the forecasting of the first twenty-four hours. That expectably in the field of the pressure ranges. Differently, the forecast of more complex analysis just like cloudy or rainfall is estimated with an accuracy of only 85%. Anyway, that was an unthinkable target just only 30 years ago. So, in order to better understand how it will be possible in the future to forecast the temperature or the rainfalls on the Mediterranean Sea or on the Alps in a range of 100 years, it's necessary to better understand what are the numerical models and how they work (Davolio and Buzzi, 2004).
The bottom line parameters in meteorology for a forecast are: the min-max temperature if the sky will be clear or cloudy and from what direction will the wind blow (Manabe and Wetherald, 1967). Moreover, if clouds will be forecasted, will be interesting to know if these clouds will be high and tiny or threatening cumulonimbus clouds. If possible, at what time they will be formed and if they will discharge rainfalls or showers.
All these questions imply an extremely detailed forecast that has to consider also the local conditions and morphology of landscapes.
The numerical quantity of calculations necessary to elaborate a forecast of this type is impressively complicated. For example, is sufficient to think that the number of complex operations to be solved in only one hour for a forecast of 10 days from GCM is about 60 million of billions (Mercalli, 2018). To that is to be added a Local Forecast Modeling (LAM) that starting by the Global Modeling is able to deeply detail a forecast on local limited parts of territory (National or Regional). Anyway, no climate expert could ever forecast the weather in New York or in

another city in 2080. On the other hand, something that could be rather sure is the forecast of the average temperature on Earth between 2070 and 2100. Indeed the statistical distribution on a big amount of data (based on the physical laws regulating the climate) says that with a big probability the increase in the Earth's temperature will range between 0.3 and 4.8 degrees (The Environmental Change Institute, 2020). That will depend for a large part on the increasing or decreasing of greenhouse gas emissions. Therefore, through the help of climate regional modeling, it will be possible to determine how the average temperature will increase in local zones of the Planet evaluating if some regions will increase their temperatures more than others.
Even for what concerns the rainfalls we can determinate if on the Alps or on the Mediterranean Sea it will rain more or less than nowadays. Or even if the rainfalls will be distributed in a different way during any seasonal period. So that we can proceed to show how the scientific bases affect the climate and meteorology forecasts.

2. Scientific Bases: from the meteorological models to the climate models

To forecast the evolution of a physical system is necessary to know its initial state at the time t0. Then we have to apply the dynamic laws from t0 to t1 (a future instant time). In mathematical language, this operation is described as " equation integration". The multiple variables at play in this game are many and it's very difficult to gather all this information in only one equation that expresses the trend of the system. Just for instance some of these variables are related to atmospheric motions. In this case, we have to apply the classic mechanic's laws to a fluid in motion (the atmosphere) related to: conservation of the quantity of motion, conservation of air and water mass. Moreover, we have to consider the interaction with energy conservation. Finally, in the total equation we have to add the ideal gas law (equation of state):

$$PV = n \cdot R \cdot T$$

where P, V, T are the pressure, volume, and temperature; n is the number of mole of gas, and R is the ideal gas constant. At an high level, this law means that the state of an amount of gas is determined by its pressure, volume, and temperature. All the precedent formulas have to be combined with the "hydrostatic pressure formula" pressure in a liquid at a given depth is called: hydrostatic pressure. This can be calculated using the hydrostatic equation:

$$P = (\text{rho}) \cdot g \cdot d$$

where P is the pressure, (rho) is the density of the liquid, g is gravity (9.8 m/s^2) and d is the depth (or height) of the liquid. So, because of the complexity of all these forces and physic processes that enter the game, all those equations contribute to generating a complex formula. Moreover, we need to consider the Earth rotation, the centrifugal force, gravity force, friction, the pressure gradient, the air density, and the wind speed.

All these variables affect the conservation of the mass, the changing of the state of the water, and the exchanging of the mechanical and thermodynamic energy.

Going further, the mathematical expression of the atmospheric motions is very complex. Variables at play are interdependent and the system contains non-linear terms. All these constraints don't allow solving the equations directly; in mathematical terms, this means that the system doesn't have an analytical solution or any accurate solution. So, in order to be solved the system needs integration, or in other words we find an approximate solution.

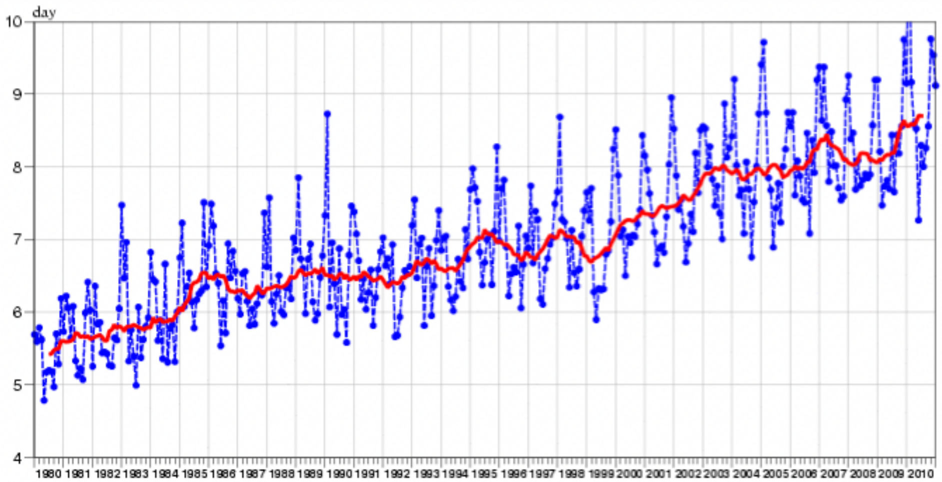

Figure 1. The graphic shows the method of integration of the temperatures from 1980 to 2010. Source: https://www.azimuthproject.org/azimuth/show/Global+warming

Fig. 1 shows the method to integrate temperatures. This method was conceptualized and implemented by the English mathematician Lewis Fry Richardson. In his famous, pioneering book (Fry Richardson, 1922) he suggested a method to integrate equations of motion in the atmosphere. So, for example the temperatures registered every 4 hours from a meteorological station of Cervinia on the Alps, during 3 days of sampling are discretized from a "candle" form to a graphic form.

The graphic in Fig. 1 shows how from a discrete view we can plot a graphic with a continuous line. For example, if the temperature is sampled every minute, during 3 days of samplings we will obtain a “candle“ graphic that shows a discontinuous trend. In order to visualize the line of the trend, scientists use to link the points obtaining a sinusoidal curve. This is an approximation of the reality but gives a good image of what is the global trend of temperatures registered during the time of sampling. Using the same method, if we want to discretize the distribution of the temperature of a Continent or of the entire Globe we have to sample the values only just in correspondence with the nodes of a specific grid (in Fig. 2 is represented as a schematic model the Global Atmospheric grid). This grid will have a width ranging from about 10 kilometers to 30 kilometers. The more the nodes are closer to each other the more the sample will be accurate. Using this method in 1950 John von Neumann (the inventor of the computer), together with meteorologist Jules Charney, was the first to elaborate a prevision on a huge calculator opening the way for the development of the dynamic models of simulation of the atmosphere (Charney et al., 1950).

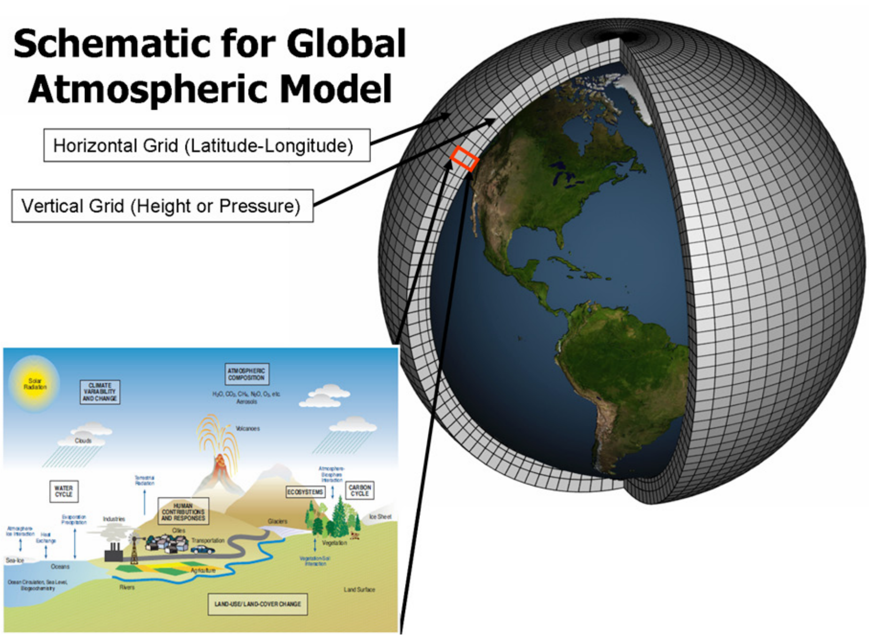

Figure 2. Schematic for Global Atmospheric Model (Source: https://www.carbonbrief.org/CarbonBrief-clear on climate)

3. The Evolution of Computing Power and Methods to Modeling the Climate

Through using modern computers and a grid of 10-30 kilometers is possible to elaborate a prevision at 10 days in only 6 hours of calculation. Local models with more specific grids get beside the macro-models defining a more accurate forecast (1-4 km of the grid). Despite modern computers becoming more and more powerful, the chaotic nature and non-linearity of the atmospheric phenomena poses a physical limit to their predictability. Right now, this limit in a deterministic way is of 10 days and sometimes his reliability could be even shorter.

The evolution of a chaotic system is highly dependent on the initial conditions. Minimal variations of these initial conditions can lead to very different future final states. This last concept recalls a very famous theory known as the "butterfly effect" that shows as a minimal variation of the initial condition could bring about a very different final development of expected values (Lorenz, 1961).

As the predictive models don't incorporate the exact initial conditions of the atmospheric system, that presupposes that every initial variable in all the infinite points must be known in advance. For that purpose, the initial state condition is calculated interpolating the measures obtained by the detection stations located on the earth and in the sea on the ships and fixed at the ocean buoys. In total there are more than 30,000 stations located on the Earth's surface. Besides the Earth's stations, there are orbital satellites to detect the state of the atmosphere. But this number is really exiguous compared to the extent of the Earth and Atmosphere. Since the forecast error is time-dependent, it remains acceptable within 5-7 days but increases progressively after this period.

For this reason in order to avoid any limit, during the late '90s, a new generation of meteorological models called "ensemble" was developed (Thirel, 2008). These mathematical models used a probabilistic approach to carry out a prediction of more than 20 days. Instead of using a deterministic forecast that gives only one result, they started from a set of artificially generated initial states N very similar to each other. To this model were applied the laws of motion in order to obtain N final states or better a set of N different predictions (called members of ensemble) among which will fall the real forecast. On that basis, the most probabilistic meteorological evolution on the N final states were obtained. So, instead of making a prediction like: "in ten days the sky will be clear" (Deterministic model) it will be: "there is a probability of 75% that in ten days the sky will be clear" (Stochastic model).

Now we can take into consideration the climate models obtained by meteorological forecasts. The climate system is very complex and is based on the interaction of different variables. These interactions concern not only the atmosphere but also oceans, cryosphere, and lithosphere. The scheme in Fig. 3 represents the interconnections and variables that play a role in the climate system.

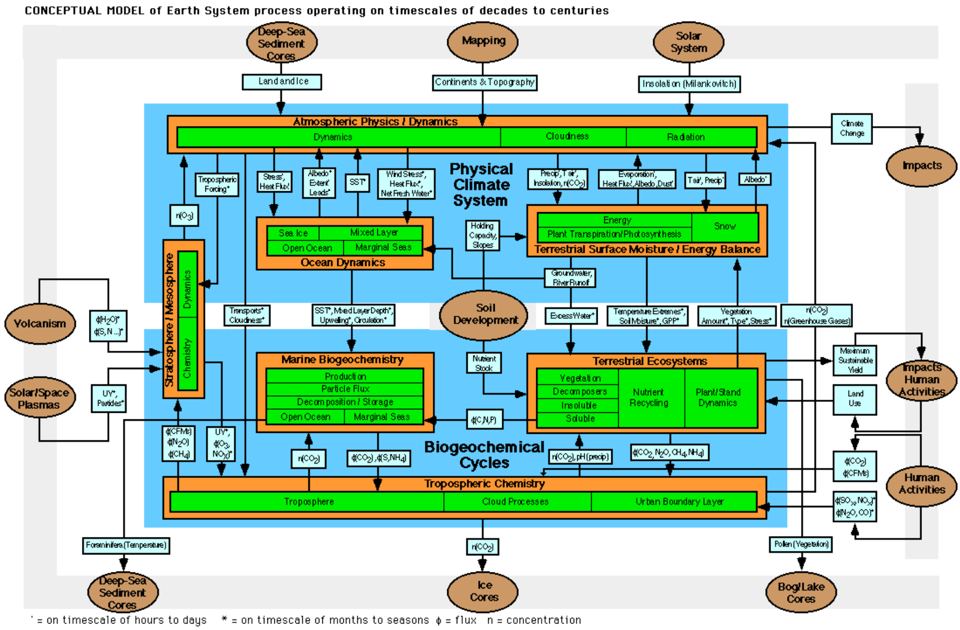

Figure 3. Conceptual model of Earth System process operating on timescales decades to centuries (Source: http://kejian1.cmatc.cn/vod/comet/nwp/climate_models/navmenu.php_tab_1_page_7.0.0_type_text.htm)

So the difference between Meteorological and Climatological predictions is that the first is implemented in the regional area and in a temporally limited time, the second instead is a long time climate forecast and on large scale. In particular, in the climate models that work on a time range of decades or centuries, it's possible to neglect the phenomena that occur on a temporal limited scale, thus avoiding the need for a detailed territorial prediction. In fact, the climate models that work on a global scale have an average resolution of about 100 km on the atmosphere, whereas the regional models work with less than 20km resolution. On the Oceans the grid is bigger: about 200 km, while some of them could be shorter especially in the Tropical area where El Nino has its influence. In this area indeed the effects on climate are more difficult to modeling.

As we have seen the mathematical models for meteorology start from an "initial condition model" and evolve in a certain period of time. The initial state of prediction is determined by some "invariant conditions" such as orbital configura-

tion, radiative budget, physic of atmosphere, and topography. After observation of some decades an “average climate status” can be determined that is the equilibrium between all the variables playing in the game.
This is the “point zero” or better the starting of the climate in a certain area of the Planet. In their publication Peixoto and Oort (1992) said that “*the set of the differential equations at the partial coupled derivatives is a right mathematical problem and determines the core of any model of mathematical simulation of the climate*”. So, it looks like only after implementing such an initial model we are able to start to perform a simulation of the future and make an attempt at the forecasts of future climate change.
From the early ’50s with the studies of the first pioneers of climate modeling systems to now the predictions have become more and more numerous. But a very important goal was reached in 1967 when Manabe and Wetherald (1967) understood the role of the transportation of the thermal heat on the atmosphere because of convection and water vapor. In their article “ *Thermal Equilibrium of the Atmosphere with a given distribution of Relative Humidity*” they demonstrated that: the effect of doubling CO2 in the Atmosphere will be to increase by 2c the temperature of the air.
Just to compare the computing power that was employed in the processor running Manabe's model, it was a calculator of just 5Kilobyte of RAM. The time elapsed to simulating the model was of 55 days, in order to determine the motion of the air and of the oceans over 3 centuries. The Supercomputing System operated with 5 Petaflops in 2018 (5M of Billions of operations per second). This enormous computing power allows to include in the dynamic simulation also the chemical and biology of the model.

4. Models for climate change

Theoretically, it seems that if we are able to predict the concentration of Greenhouse Gases for the future, humanity can implement socio economic policies for the next decades. In other words, the economy of the Planet is extremely conditioned by Climate modeling predictions. For this purpose, Intergovernmental Panel on Climate Change (IPCC, 2000) has identified forty futuristic scenarios, grouped into 4 categories (families). Among them, 2 are oriented towards growing globalization (A1, B1) and 2 are oriented towards an increasing regionalization of the economic, social, and environmental politics (A2, B2).
Family A1 (rapid growth convergent scenario): describes a world in which population and economy will grow very fast. It goes hand in hand with the introduction of new technologies (demographic pic in 2050 with 8.7 Billion people).

Family A2 (scenario of fragmented world): it's characterized by a more heterogeneous world in which the economic and political decisions are very different on a regional scale. The consequence will be higher population growth (15.1 Billion in 2100). The emission of Greenhouse gases is more elevated against other scenarios.
Family B1 (scenario of the global sustainability): consider the evolution of growth similar to group A1 with a pic of a population nearby 2050, but the economic structures will be evolving very fast towards an economy based on services and information. This scenario points its interest at a world characterized by the massive introduction of clean technologies and energy efficiency, so greenhouse effects will be lower than in other scenarios.
Family B2 (scenario of local sustainability) forecasts just local growth of the solutions deployed into economic, social, and sustainable problems. With this scenario, the growth of population will fall between those forecast by the families A1 and A2 (10.4 Billion in 2100) and the economic and technological development will be slower than other scenarios.
These groups of scenarios have recently been substituted by 4 " Representative Concentration Pathways" (RCPs).
Usually, the climate models are tested before being adopted. In particular, the ability of the model to show past and present climatic conditions has to be confirmed before advancing any hypothesis regarding the future. When the model is considered stable it could be adopted. But there is a problem in this method: the models work because the hypothesis is supposedly unchanged. In different circumstances, we have observed a sudden change in the climate. What are the causes and the effects of those climate changes?

5. The Theory of the "Critical Breaking Point"

During the first global Covid-19 Lockdown (March-June 2020) something of devastating magnitude for humanity happened. The Covid-19 Virus blocked most parts of the world, cut the production and use of petroleum almost to zero, and shuttered many manufacturing companies all around the world, thus changing perceptibly the ecosystem. The world entered a state of catatonic immobility which caused an incredible regeneration of vital functions on the Earth in a so short time.
As shown in the Carbon Brief Report (2020), the CO_2 started to decrease immediately since the third week of lockdown and the CO_2 level estimated is around 4.0% in respect of 2019. This is an unprecedented and unbelievable value.
Another estimation is that during the period of the lockdown the level of CO_2 decreased by 17%on the planet (Carbon Brief, 2020).

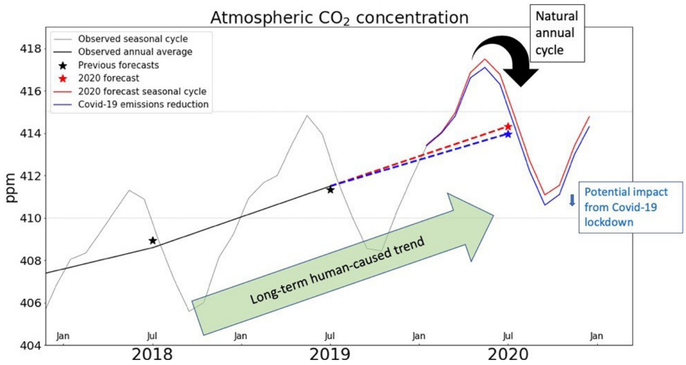

Figure 4. Atmospheric CO_2 concentration drop off (Source:https://www.carbonbrief.org/)

In the above figure (Fig. 4) is represented the observed and forecast CO2 concentrations at Mauna Loa Observatory (Hawaii), showing both annual and monthly values. The graphic illustrating the impact of a potential 8% reduction in global CO2 emissions caused by Covid-19 lockdown, on the predicted rise in concentrations. But this is not the only abrupt change and adjustment of the climate during the history of the world. Since the beginning of its life, the Earth has been shattered by violent mutations. One was over 65 million years ago with the extinction of Dinosaurs. It is also known as Azolla Event and is accepted by most scientists.

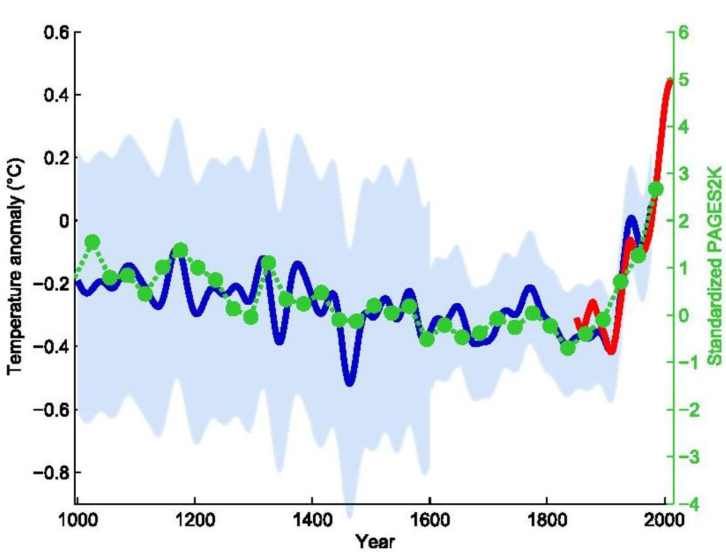

Figure 5. Hockey Sticker Image graph (https://en.wikipedia.org/wiki/Hockey_stick_graph)

Another event that drastically changed the climate and the world happened probably about 11,600 years ago. To better understand what could have happened we take into consideration a strange mystery not yet completely solved about the ices that cover Greenland and Antarctica regions. It's well known that regions with the higher layers of ice receive today a lower quantity of snowfalls. The current theories are unable to explain this phenomena. However it could be explained if we suppose that the North Pole and the South Pole suddenly changed their position, or better if the Earth crust changed its position (Hapgood, 1958). This theory could easily explain why Greenland and Antartica have now the most quantitative layers of ice on the Earth without being stormed by snowfalls (Hapgood, 1970). Based on this theory also called "*Precession of the Equinoxes*" it is possible to design a new scenario among the above mentioned climate changes. The following hypothesis can be formulated: the statistical predictions are valid during a period of relative stability of the system. But, when the system reaches a critical point, it will adjust by itself by removing all the substantial causes of its imbalance.
About this, the term "Hockey Sticker" has been published by the climatologist Jerry Mahlman to denote an abrupt change of the temperatures in the last 100 years. The graph shows a very fast growing up, which causes a similitude with the sticker used by Hockey's players.When considering the Hockey Sticker Image Graph (as represented in the Fig. 5) it can noted very easily that the trend of the graphic is increasing more and more after a certain period. If the trend of this graphic will augment exponentially humanity's destiny will be irrevocably sealed. But such events as an "Equinox precession" or a pandemic can drastically change the direction and break the state of things. Now the question is: how mathematically forecast the breaking point? It is arguable that there is no mathematics able to predict a drastic change, but a mathematical model based on our precedent knowledge can be implemented. We can monitoring and stay alert analyzing the conditions that can determine a high increase or decrease in some variables parameters of human life and on the Planet. If parameters such as CO_2, temperature, and grade of rainfall start to mute considerably in a period relatively short, then an action have to start to be taken. If the action is not taken or is taken too late, then the conditions will re-adjust by themselves and will change forever the life of the inhabitants of the Planet.

6. Conclusion

This chapter has analyzed the scientific bases that bring from the meteorological models to the climate models. It has been exploring the method of integration of the temperatures to integrate equations of motion in the Atmosphere (Fry

Richardson, 1922). That brought to define a new approach "to grid" the Globe to develop the dynamic models of simulation of the Atmosphere (Charney et al., 1950).
In the section of "Evolution of Computing Power and Methods to Modeling the Climate” has been explained how the augment of the computer power enables sophisticated mathematical models used for a probabilistic approach to carry out a prediction of more than 20 days. This section has also examined the difference between meteorological and climatological forecasts. Because of that, Manabe and Wetherald (1967) demonstrated the binding effect of doubling CO_2 in the Atmosphere that increases by 2c the air temperature.
These topics are essential to understand how climate change impacts conditions sensitively to the Planet's economy, mainly caused by the greenhouse gas effect. For this purpose, the Intergovernmental Panel on Climate Change (IPCC, 2000) has identified a strategy dividing the Planet into futuristic economic scenarios.
Finally, starting from analysis about the period of lockdown (Carbon Brief, 2020) caused by coronavirus pandemic, it’s easy to arrive at the deduction that statistical predictions are valid during a period of relative stability of the system. But, when the system reaches a critical point, it will adjust by removing all the substantial causes of its imbalance.

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13 Application of remote sensing and GIS in environment monitoring

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1. Introduction

1.1 Remote sensing and GIS

The science of remote sensing deals with recording, processing and interpreting of electromagnetic energy that are either emitted or reflected from the target. Remote sensors collect information from the object that covering different wavelength regions of the visible (0.4 to 0.7 μm), infrared (0.7 to 300 μm) and microwave (1 mm to 1 m) electromagnetic radiation (EMR). Passive sensors onboard satellites have the capabilities to record the reflected or emitted EMR; however "active" sensors are employ to send and receive the reflected or backscattered EMR from the Earth's surface or atmosphere (Mather and Koch, 2011). Such acquired data and information can be handled using Geographic Information System (GIS) approaches which represent a computer-based tool for manipulating, visualizing, extracting, and analyzing features.

Remote sensing technologies combined with GIS techniques allow for observing landscapes at a span of spatio-temporal scales. Since numerous sensors onboard satellites have been launched into orbit in the early 1960s, advances have been done in surveying and monitoring the Earth planet and its environment (Sahu, 2007). On October 4 1957, the first man-made satellite (Sputnik-1) was launched its orbit by the former Soviet Union's (Tatem et al., 2008). Since that time, several satellite remote sensing have followed e.g., Sputnik 2 (November 1957), the first US satellites, Explorer-1 (January 1958), Vanguard-1 (March 1958) and the earliest U.S meteorological satellite TIROS-1 (April, 1960). On July 1972, the Earth Resources Technology Satellite (ERTS-1) was effectively launched its orbit by NASA. Shortly, ERTS-1 satellite renamed Landsat-1 that represents the first in a Landsat series, the most recent being Landat-8 (launched on February 11, 2013). Such series witnesses progress in spatial, multi-temporal coverage, spectral and

radiometric resolution that appropriate for assessing and monitoring Earth's surface. Since 1960 up to date, significant advances in technology and sensors allow launching tens of remote sensing satellites that providing valuable measurements on the Earth's surface that varies in resolutions.
This chapter summarizes some applications of remote sensing and GIS towards understanding and monitoring environments.

1.2 Remote Sensing and GIS capabilities for environment monitoring

Observations of the Earth from space, by quickly collecting sizable information on the Earth's surface, have offered significant opportunities to environment monitoring systems. Due to the modern progress in spatial, temporal, radiometric and spectral resolutions of remote sensors, remotely-sensed data have offered a key attitude for environmental monitoring (Li et al., 2020). The Earth's planet has witnessed a remarkable revolution in climate and natural resources in recent decades; and thus, monitoring and mitigating the interplay of the human activities and environment is vital. Modern space agencies provide wide array of remote sensing datasets that have different image characteristics. Such data have the capabilities for promoting different levels of accuracy and allowed mapping any changes of land, water and atmosphere. Combining visible and microwave remotely-sensed data allowed mapping natural resources of the environment including land, water, biological and climate resources, which impacts the persistence and expansion human beings' (Li et al., 2020). Microwave, infrared and visible radiation methods and their applications are briefly discussed and some applications are demonstrated as below.
Infrared images have the capabilities to detect and monitor the oil spills. Radiation emitted by the (sea) surface at infrared and microwave wavelengths is characteristic for its temperature providing data about gradients and fronts (Apitzer, 1986). Moreover, thermal information is useful to monitor eruptions and thermal anomalies on the land. Using microwave InSAR data, the deformation can be inferred. Opposite to the IR and microwave, the visible EM radiations have the capability to penetrate the sea surface. The existence of different kinds of suspended and dissolved particles in the water column (Apitzer, 1986), promoting the variations on backscattered of EM radiations (ocean color) that reflect the content of water. Furthermore, many ecological indices based on remote sensing are proposed to reflect ecological conditions. Since the 1960s, space-borne satellite data has utilized to monitor variation in vegetation on the Earth's surface. Such indices can be estimated from the inverse relationships between red and near-infrared reflectance wavelengths associated with healthy green vegetation. Vegetation indices are effective and observed indicators that reflect the vegetation level on the land

and describe ecological characteristics. Such indices can be utilized to examine climate trends (Eklundh and Olsson, 2003), estimate water content of soils remotely (Sandholt et al., 2002), monitor drought (Wan et al., 2004), monitor drying up and plant transpiration (Kustas and Norman, 2009) and assess changes in biodiversity (Pettorelli et al., 2011).

Integration of radar remotely-sensed data and GIS techniques allowed monitoring flash flood hazards in arid regions in order to providing updated information on ongoing disaster events in promising areas of future sustainability to prevent rapid damages (Abdelkareem, 2017). The utilizing Shuttle Radar Topography Mission data (SRTM) revealed geometric characteristics of the watersheds and solve several geologic, geomorphic, paleohydrologic features and structural problems (Abdelkareem and El-Baz, 2016 & 2017). Furthermore, processing and interpretation of microwave remote-sensed data have offered valuable information for mapping and monitoring of subsidence, deformation and landslide events (Monserrat et al., 2014). Coherence change detection technique using radar data allowed mapping the dynamic of sand dunes and their impact on human activities and infrastructures (Abdelkareem et al., 2020).

Remotely-sensed data also allowed monitoring and managing of coral reef biomes. The availability of the long-term collection of Landsat series images that of most cost-effective present advantage on observing and monitoring long-term of changes on sea coast and coral reef habits. Using airborne LIDAR systems provide valuable evidence on the characteristics of bathymetry and quantify the topographic complexity in coral reef environments (Brock et al., 2006).

Remotely-sensed data represent the extremely vital source for change detection investigations because of its variable resolutions along with its digital format that appropriate for image enhancement and transformation methods (Chen et al., 2012). Change of the land's surface data and information represent more substantial in planning and observing the natural resources in local and regional scales. Since remotely-sensed data employs in various aspects such as damage assessments, disasters observing and managing, urban expansion, and planning and land management.

2. Data and methods

There are many examples of operational space-borne missions (platform/sensor) that can be employed for observing land, water and atmosphere. Below are few examples of satellite remote sensing (Janssen et al., 2004) that cover the electromagnetic spectrum range from visible light to microwave of different spatial resolutions.

- The high-resolution panchromatic sensors with a pixel size between 0.5 m and 6m (QuickBird/PAN, Ikonos/PAN, OrbView/PAN, Spot/PAN, EROS/PAN) have the capabilities to provide changes in small to large scale features on the ground.
- There are many multispectral sensors that described by a pixel dimension between 4 m and 30 m (Landsat/OLI, Terra/Aster, IRS/Liss3, Ikonos/OSA, Spot/HRG, Sentinel-2).
- A large number of weather satellites and other low-resolution sensors with a pixel size between 0.1 km and 5 km (NOAA/AVHRR, Terra/MODIS, Spot/VEGETATION, Meteosat/Seviri, GOES/Imager, Insat/VHRR, Envisat/Meris, and IRS/WiFS).
- Imaging radar satellites that indicated by a cell dimension between 8 m and 150 m (Envisat/ASAR, ERS/SAR, Radarsat/SAR, ALOS//PALSAR, Sentinel-1).

The present case studies utilize remotely-sensed data including Landsat, Sentinel-1 and high resolution data from Google Earth. Landsat 1, 2, 3, 4 and 5 launched in July1972, Jan 1975, March 1978, July 1982, March 1984. Landsat-6 was lost during the launch stage on October 5, 1993. Landsat 7 was reached orbit on 1999. Landsat 8 is operating normally after its successful launch on February 11, 2013. Two scenes (P175R42) of Landsat-5 (September 13, 1984) and Landsat-OLI (April 21, 2015) were used in the present investigation in order to revealing the differences in vegetation covering the area between 1984 and 2015. Normalized Difference Vegetation Index (NDVI) was applied on Landsat data. NDVI = (NIR-Red/NIR+Red).
The European Space Agency (ESA) SAR sensor, Sentinel-1, reached its orbit on April 3, 2014. It utilizes the microwave C-band of electromagnetic region at 5.405 GHz with a time-based resolution of 12-day. Two images of Sentinel-1 of VV polarization were acquired on June 3, 2017 and January 12, 2019. The interferometric SAR (InSAR) coherence technique was applied on Sentinel-1 data. Such technique is employed to detect surface variations and dynamics in the space and time (Havivi et al. 2018; Abdelkareem et al., 2020). The interferometric coherence (ɣ) of the two SAR scenes can be computed using the below equation (Seymour and Cumming, 1994).

$$\gamma \cong \frac{\left|\sum_{i=1}^{L}\sum_{j=1}^{M} Sc_1(x_i, z_j) Sc_2^*(x_i, z_j)\right|}{\sqrt{\sum_{i=1}^{L}\sum_{j=1}^{M}\left|Sc_1(x_i, z_j)\right|^2 \sum_{i=1}^{L}\sum_{j=1}^{M}\left|Sc_2(x_i, z_j)\right|^2}}$$

Where Sc1 and Sc2 represent the information of the 'master' and 'slave' scenes. The coherence of each cell is revealed by kernels means with L × M pixels. The (ɣ) values range from 0 (high change) to 1 (non-change).
Maximum Likelihood classifier was applied using different thresholds to obtain the land-use/land cover classes. It can obtain minimum classification error under the assumption that the spectral data of each class is normally distributed. Five regions of interests (ROIs) of the study area are interactively identified. Then the image is classified into 5 classes including urban area, water, agricultural area, barren lands and Limestone Plateau. Vegetation class is clearly recognized using NDVI index. The classes then imported, collected and saved to the ArcGIS software packages in order to compare the changes in land-use/cover between years 1984 and 2019.

3. Results and discussion

3.1 Change detection of Land-use and land cover

3.1.1 Monitoring land-use/cover

Change detection represents the means of detecting variations in the character of an item or event by monitoring it through times. The existence of satellite data collection is consent for long-term change detection and monitoring the differences in land-use/cover in space and time. For agriculture monitoring, the NDVI Index obtained by the Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) sensors at a 30 m pixel size was used to analyze and extract maps to reveal the presence and extension of vegetated cover. Moreover, urban, water and barren lands are identified using supervised classification method. The extracted classes are corresponding to water (blue), agricultural areas (green), urban (magenta), barren lands (white), and limestone plateau (brown). Using NDVI index, the agricultural areas in years 1984 and 2015 are approximately 49596.17 acres (28.807 %) and 65102.97 acres (37.861 %), respectively (Fig. 1). In 1984, urban areas cover about 8786.54 acres (5.103%), and in 2019 about 19882.54 acres (11.563%). The surface water class that represented by the Nile and irrigation canals covers 4529.45 acres (2.631%), and 4041.58 (2.350%) in years 1984 and 2019, respectively. The barren lands (desert fringes) cover 107987.9 acres (62.72%) in 1984 and 82924.13 (48.23%).

Class	1984 Percentage	1984 (Areas in acres)	2019 Percentage	2019 Acres	Changes (Areas in acres)	Change Percentage
Agricultural	28.807%	49596.17	37.861%	65102.97	+15506.8	+9.05%
Urban	5.103%	8786.54	11.563%	19882.54	+11096	+6.46%
Water	2.631%	4529.45	2.350%	4041.58	-487.87	-0.28%
Desert lands	62.72%	107987.9	48.23%	82924.13	-25063.8	-14.50%

Table 1. Change-detection in land-use/cover of the study area from year 1984 to 2019

The study area has been subjected to remarkable changes in land-use/cover over the last few decades. The detected changes are based on the multi-temporal land-use/cover patterns that mapped using series of Landsat data including 1984, and 2019. Land-use/cover changes maps were performed with the help of ENVI and GIS software packages. NDVI index is applied here because, the specific pigments in plant leaves have the capacity to absorb Red wavelengths of EMR. Furthermore, they have the ability to intensely reflect the invisible near-infrared wavelengths of EMR. The entire differences in agricultural areas in the studied area between Qena and Dishna cities from 1984 to 2015 are about 15506.8 acres, represent an increase of about 9.05% of the study area. The revolution in the agricultural activities increased from year 1984 to 2019 because the increasing of human settlements and rapid variation in the agriculture purposes in the studied plain west of Qena Governorate which is one of the major promising region for future expansion in southern Egypt. Furthermore, the area is a portion of the Egyptian national project that points to reclaim about "1.5 Million Acres" to initiate new cities and new agricultural areas far from the old fertile soil of the Nile.

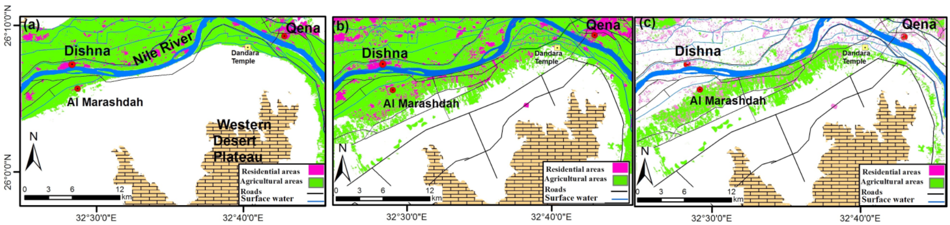

Figure 1. Land-cover/use change detection using NDVI and supervised classification in the area west of Qena Governorate (a) agricultural, urban and surface water cover of 1984; (b) agricultural, urban and streets and surface water cover of 2019; (c) change in agricultural, urban and surface water cover between 1984 and 2019

Based on the change detection techniques remarkable changes in urban activities have been done in the span between 1984 and 2019, particularly on the old fertile soil of the Nile Valley. The changes in urban increased about 11096 acres, positively covers +6.46% of the area under investigation. The expanding in urban activities impacted the majority of old Nile Valley soil rather than the desert fringes; however, the growing in agriculture activities were compensated on the desert fringes in the plain west of Qena Governorate as the vast areas of the plain was cultivated (Fig. 1c).

The change detection approach revealed that the surface water decreased about - 0.28% of the entire area (Table 1). This change can be neglected because the changes in the water levels in the Nile Valley and canals can cause these small differences between the surface water 1n 1984 and 2019. Moreover, the limitation of accuracy of the remote sensing classification technique should be considered.

Based on comparing the differences between years 1984 and 2019, the desert fringes recorded loss in areas that reached to - 25063.8 acres with about - 14.50% of the area under investigation. This shrinkage positively related to the expansion in agricultural and urban activities due to the expansion in population. This growth allowed constructing street networks in the Nile Valley and desert fringes area.

3.1.2 Monitoring water resources

Monitoring water resources employing remotely-sensed data can be conducted using visible, IR and even microwaves regions of the EM spectrum including (Abdelkareem and El-Baz 2015). Four main lakes "Tushka lakes" that covering a surface area about 1450 km^2 and filling about 25 billion m^3 of water were developed from the connection of Lake Naser through a man-made canal to transport water for irrigating the reclaimed lands in Wadi Tushka. The monitoring of the Tushka lakes region and its inventory preparation are being under taken using Landsat images. Landsat series are providing interesting archive in recording and monitoring land cover/land-use since 1972. So as to monitor the existence of water in three of Tushka lakes, at south Egypt, series of Landsat data for the years 1999, 2002, and 2011, and 2019 were inspected (Fig. 2). The data are acquired from the Landsat-5, 7 and 8. The images were classified and saved in ArcGIS software packages. A comparison between these scenes revealed obvious switch in the water levels and extension of many lakes in Tushka. In years 1999, 2002, 2011 and 2019, the surface water that filling the lakes in the studied areas are approximately 349, 1141, 282, and 120 Km^2. The vegetated areas and swamps that contain vegetation are covering about 47, 121, 612, and 523 Km^2.

The Landsat image of 1999 indicates that there is no existence of sizable amount of water that filling the present site of Tushka lakes, except one lake which its surface covered by 349 Km^2 in the southeastern corner of the study area (Fig. 2). The vegetated areas that cover about 47 Km^2 occur along the borders of the lake and in the northwestern part of the study area. Landsat-7 image of March 2002 showed that the three lakes are completely filled with water which covers about 1141 Km^2. This year represents the maximum water filling with increasing about 791 Km^2 more than November 1999, and utmost of development of water resources for Tushka project. The vegetated areas increased about 74 Km^2 than in 1999 due to the expanse of the surface water areas against the bare lands. The expanse of surface water declined from 1141 Km^2 in year 2002 to 282 Km^2 in July 2011, with decreasing about 858 Km^2 of the surface water. This shortage in water reflects the dramatic evaporation of the surface water in Tushka as an arid region. In this year the surface water is mainly restricted to one lake with filling only the lowest parts of the other lakes, forming swamps that filled by vegetation. The supervised classification revealed that the vegetated areas and swamps have been covered about 612 Km^2. Eight years later (In Dec 2019), although, the lower lake in the southeastern corner have been recharged again from the Nile, the surface water have been covered about 120 Km^2, with decreasing about 162 Km^2. In this year, water filled only the lowest parts of the main lake and the stored water was decreased, roughly ~ 50 % of the surface water dried up than in 2011. The swamps/vegetated areas also decreased from 612 to 523 Km^2 with decreasing about 88 Km^2 as a result of water evaporation.

Noteworthy, the surface water that have been covered Tushka lakes dramatically depleted and dried up from 2002 to 2019 due to fracture systems, porous rocks and extra-evaporation process in one of the driest region in the world. Dry up of these lakes may impact the biota, wet lands and agricultural activities.

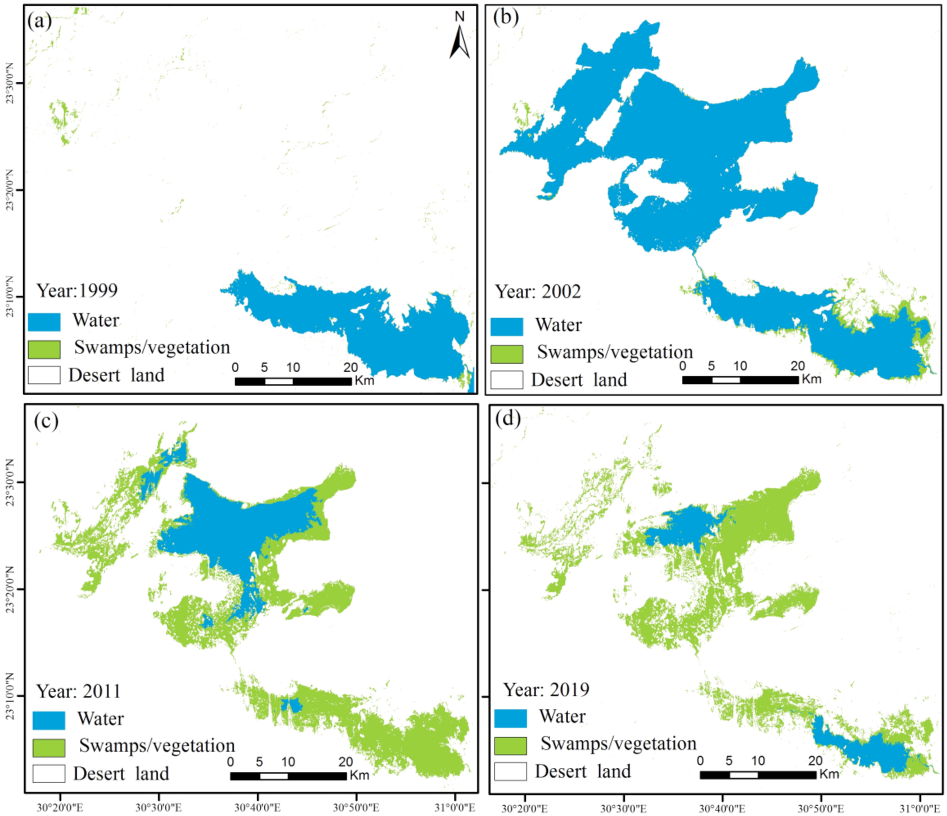

Figure 2. Monitoring surface water resources using Landsat data; (a) arid Tushka lakes in November 1999; (b) maximum fill in Tushka lakes in March 2002; (c) lowering the level of water in Tushka lakes in July 2011; (d) decreasing water level in Dec 2019

3.2 Dynamics of sand dunes

About 6 percent of the total world's land cover represents by aeolian sand which cover 97 % of the arid lands (Pye and Tsoar, 2008). Monitoring sand dunes dynamics is significant in revealing significant information for future development and settlement (Gaber et al., 2018), because the dynamics of sand dunes causing disturbances in infrastructures, agricultural, and economic activities. Satellite high resolution images clearly display the sand dunes in arid lands (Fig. 3a). The coherence change detection (CCD) technique is utilized to quantify the dynamics of sand dunes between two images of Sentinel-1 (VV polarization) that they are acquired on June 3, 2017 and January 12, 2019 in Saudi Arabia. The results revealed that the coherence (ɣ) ranges from zero to 0.98, zero indicates high dynamics in sand dunes that characterized by brown color (Fig. 3 b). Areas of relatively stable (0.98) sand dunes revealed in blue. Areas of green color are more dynamic than the blue and less than the brown based on intensity of the sand dunes dynamics. The information of intensity and phase of the single look complex (SLC) SAR type were analyzed to form the CCD output image that revealed sand dunes dynamics in spatio-temporal scales.

In the present study, comparing two scenes of Nov 30, 2012 and Feb 21, 2016 of high resolution images of Google Earth revealed that the migration of sand dunes have high negative impact on the infrastructures (Fig. 3c, d) as the movement of sand by wind have the capacity to cover desert roads (Fig. 3 d), farms and areas of human settlements.

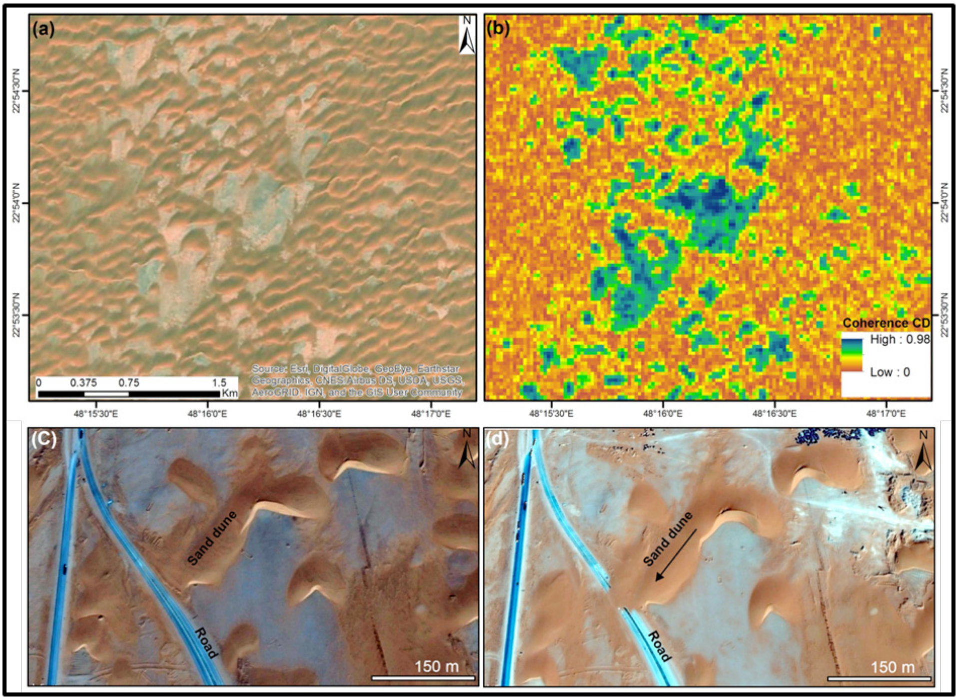

Figure 3. Sand dunes in Saudi Arabia; (a) high resolution image revealing sand dunes; (b) CCD of sand dunes dynamics of the same area in "a"; (c) image of sand dunes in Nov 30, 2012; (d) sand dunes in Feb 21, 2016. The center of image c and d is at Lat 24°12'52.96"N and Long 48° 6'27.52"E

3.3 Volcano monitoring

Volcanic activities are remarkable but extremely risky events to monitor on-site during eruption. Volcanoes are perhaps the one of the highly important environmental/geological feature where remote sensing technology is most effective. Continuous monitoring of lively volcanoes in active areas around the world is important as remote sensing provide information even in extreme dangerous conditions. For example, Etna volcano has exploded in Sept 3, 2013 and continuing in June 2020 (Fig. 4). Satellite data can yield an improved understanding of volcanic processes and volcanic hazards simply by providing more frequent observations at a wide variety of wavelengths.

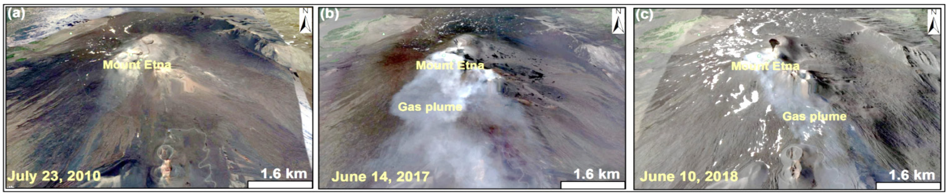

Figure 4. Monitoring the activities of Etna volcano's gas plume: (a) July 23, 2010 before eruption; (b) June 14, 2017. (Note: Etna volcano in Italy has exploded in Sept 3, 2013 and continuing in June 2020)

4. Conclusions

Remotely-sensed technique revealed several phenomena in different spatial, temporal and spectral resolutions. This chapter summarized some functions of remote sensing and GIS towards knowing and monitoring environments. Imaging the Earth using satellites allows the collection and analysis of several digital images that revealing surface and near-surface features of our planet. Remotely-sensed techniques have presented valuable information on observing and monitoring environmental phenomena in spatio-temporal scales. Remote sensing technologies offered observing tools to monitor extreme dangerous events such as volcanoes. Furthermore, it has the capability of observing the changes of land use/cover including agricultural, residential, water resources and, infrastructures. Moreover, observing the dynamics of sand dunes, the lowering/rising of water levels of the rivers, seas and lakes. These findings revealed the importance of utilizing remote sensing techniques in any climatic and environmental conditions. In addition to, the remote sensing technique afford the continuous monitoring of climatic conditions in space and time that allowed providing information on any changes in climate through time.

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