ΣΤΟΙΧΕΙΑ ΚΩΔΙΚΟΠΟΙΗΣΗΣ ΠΑΡΑΔΟΤΕΟΥ

4.3.1 Μελέτη Χαρτογράφησης Επικινδυνότητας

Συγχρηματοδοτείται από την Ευρωπαϊκή Ένωση (ΕΤΠΑ) και από Εθνικούς πόρους της Ελλάδας και της Κύπρου

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Contracting Authority: CYPRUS CIVIL DEFENCE

TENDERER/Coordinator: Cyprus University of Technology (CUT)

22/12/2018

Summary

This document comprise the Final Report on the National Risk Assessment (NRA) of Cyprus. The contracting authority of this study is the Cyprus Civil Defence and the consortium team prepared this report is coordinated by the Cyprus University of Technology. The report includes general information on Cyprus and the context of the completed NRA study. The risk assessment methodology used in the study is described along with its application on seven predefined hazards, namely: Earthquake and Tsunami, Floods, Water scarcity, Large-scale technological accidents, Fires in forests and rural areas, Sea level rise and Coastal Erosion and Marine Pollution. The risk assessment carried-out on each hazard is described in separate chapters. The data obtained for each hazard are used to develop an integrated risk matrix, illustrating the risk level exerted from these hazards. The methodology for the development of the risk matrix is based on impact analysis, which is used for the formation of singular risk matrices for the impact categories involved in the study. It should be noted that the selection of the hazard scenarios for the formulation of the risk matrix was conducted by the corresponding experts to represent moderate likelihood. Further scenarios can be implemented using the adopted methodology to provide results for rarer events.

Furthermore, in this report two independent studies, prepared for the Ministry of Agriculture, Rural Development and Environment of Cyprus are included as appendices in this report. The studies referred to the effect of climate change on health and land desertification.

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Geological Survey Department

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ABBREVIATIONS

NRA	National Risk Assessment
DLS	Department of Land and Surveys
PIO	Press and Information Office
UCPM	Union Civil Protection Mechanism
EU	European Union
EC	European Commission
UNISDR	United Nations Office for Disaster Risk Reduction

1. Introduction- Context of the NRA-CY

In the SENDAI framework of the United Nations, with a timeframe of 2015-2030, the European Union has developed a strategy for achieving the objectives of the Framework. In particular, with the decision of the Council of the European Union and the European Parliament, 1313 / 2013EU on a *Union Civil Protection Mechanism* (**UCPM**), Member States were required to submit a summary of national risk assessments to the Commission. Based on Article 6 of the UCPM decision, Participating States submitted summaries of NRAs by 22 December 2015, and will do so every three years thereafter. Cyprus fulfilled its institutional obligation before December 22, 2015, as provided for in the decision, with a preliminary report. In December 2016, Cyprus completed its national risk assessment and informed the Commission of this by sending its final report. The next date for the submission of the 3rd national risk assessments is 22 December 2018.

Consequently, **the main objective of the current contract** is the preparation of the 3rd national risk assessment for the Republic of Cyprus, which contains the probability of occurrence, potential consequences, Cyprus's exposure analysis and vulnerability analysis for the following predefined hazards:

- Earthquake and tsunami.
- Floods.
- Water scarcity.
- Large-scale technological accidents.
- Fires in forests and rural areas.
- Sea level rise and coastal erosion.
- Marine pollution.
- Hazards synergy.

Furthermore, as part of the UCPM legislation mentioned above, Member States provided the European Commission with summaries of the main elements of their National Risk Assessments (NRAs). According to the produced report[1], "*contributions received were of varying levels of details, and reflected varying levels of progress and completeness in the production of NRAs. Certain summaries demonstrated a high level of advancement in undertaking a national assessment of disaster risks and using this exercise to contribute directly to emergency planning. In a relatively high number of cases, however,* ***information on the range of disaster risks and their assessment at a national level remains limited or is not yet finalised***".

Cyprus is one of these cases that provided limited information especially on the main risk analysis factors, i.e. the impact/consequences and the probability/likelihood of occurrence.
Therefore, this project has a twofold target:

1. Produce a NRA that complies with EU guidelines so that it allows for comparison with the NRAs of the other Member States. Based on the NRA, Cyprus will establish a risk mitigation strategy for disasters.
2. Provide the missing information on risk assessment to the European Commission (EC), in order to improve, through this contribution of knowledge, the support of the EC when needed.

[1] COMMISSION STAFF WORKING DOCUMENT: Overview of Natural and Man-made Disaster Risks the European Union may face

Sendai Framework

The ***Sendai Framework for Disaster Risk Reduction 2015-2030*** (Sendai Framework) is the successor instrument to the ***Hyogo Framework for Action (HFA) 2005-2015***: *Building the Resilience of Nations and Communities to Disasters*.

The Sendai Framework is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action [UNISDR[2]].

The Seven Global Targets →

(a) Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015.
(b) Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020 -2030 compared to the period 2005-2015.
(c) Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.
(d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.
(e) Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.
(f) Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.
(g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

The Four Priorities for Action

Priority 1. Understanding disaster risk

Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness and response.

Priority 2. Strengthening disaster risk governance to manage disaster risk

Disaster risk governance at the national, regional and global levels is very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

Priority 3. Investing in disaster risk reduction for resilience

Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.

Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

The growth of disaster risk means there is a need to strengthen disaster preparedness for response, take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity

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[2] https://www.unisdr.org/

to build back better, including through integrating disaster risk reduction into development measures.

Sendai- Risk Assessment Guidelines

To support the implementation of priority 1, in 2016 the United Nations Office for Disaster Risk Reduction (UNISDR) commissioned the development of guidelines on national disaster risk assessment (NDRA) as part of a series of thematic guidelines under its "Words into Action" initiative to support national implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030.

These Guidelines are the result of the collaboration between over 100 leading experts from national authorities, international organizations, non-governmental organizations, academia, think tanks and private-sector entities. They focus on Sendai Framework's first Priority for Action: Understanding Disaster Risk, which is the basis for all measures on disaster risk reduction and is closely linked to the other three Priorities for Action.

The first part of the Guidelines presents 10 enabling elements for designing and implementing an assessment, clustered in three stages. The elements are interlinked through many common topics for attention and feedback loops.

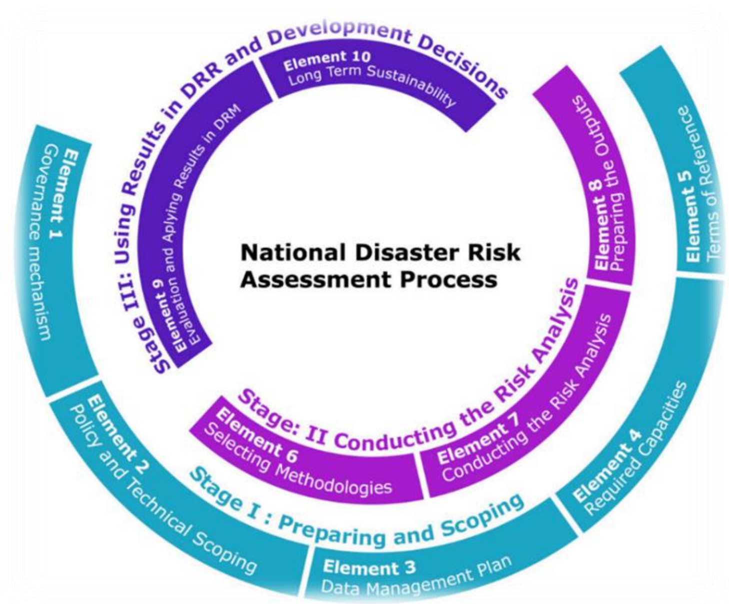

Figure 1: Ten enabling elements in three stages of the NDRA process, interlinked through overlapping areas of concern and feedback loops

The NDRA guidelines are in-line with the risk assessment process flow outlined in the international standards on risk management (ISO 31000:2009) and on risk assessment (31010:2009). It starts with setting the context and then consists of three steps: risk identification, risk analysis and risk evaluation. This relationship is depicted in the Table 1 below.

Table 1. Mapping of ISO steps to the elements of the NDRA guidelines[3]

ISO steps	Guideline elements	
Establishing context	Element 1	Establishing NDRA governance mechanism
	Element 2	Defining the policy scope and technical scope of NDRA
Risk identification	Element 2	Defining the policy scope and technical scope of NDRA
	Element 6	Selecting risk analysis methodologies
Risk analysis	Element 6	Selecting risk analysis methodologies
	Element 7	Conducting risk analysis
Risk evaluation	Element 8	Preparing the outputs of risk analysis for communication with stakeholders
	Element 9	Facilitating the process for applying results in DRM decisions and solutions

[3] Words into Action Guidelines-National Disaster Risk Assessment, UNISDR 2017

2. General information about Cyprus: socio-economical scenario, population projection

General description (PIO, 2018)

Location: Cyprus is the third largest island in the Mediterranean, after Sicily and Sardinia, with an area of 9,251 sq. km (3,572 sq. miles),extending 240 km (149 miles) from east to west and 100 km (62 miles) from north to south. It is strategically situated at the north-eastern corner of the Mediterranean, at the crossroads of Europe, Africa and Asia: at a distance of 300 km north of Egypt, 105 km west of Syria, and 75 km south of Turkey; Greece lies 380 km to the north-west (Rhodes – Karpathos).

Topography: Cyprus has two mountain ranges: the Pentadaktylos range, which runs along almost the entire northern coast, and the Troodos massif in the central and south-western parts of the island which culminates in the peak of Mount Olympus, 1.953 m above sea level. Cyprus' coastal line is indented and rocky in the north with long sandy beaches in the south. Between the two ranges lies the fertile plain of Messaoria. Forests cover approximately 19% of the total area of the island. Furthermore, in Cyprus there are two salt lakes. Cyprus's topography is depicted in Figure 2.1.

Figure 2.1 Cyprus topography (DLS, 2018)

Climate: Cyprus has a Mediterranean climate: hot dry summers from June to September and mild, wet winters from November to March, which are separated by short Autumn and Spring seasons of rapid change in weather patterns in October, April and May. Sunshine is abundant during the whole year, particularly from April to September when the daily average exceeds eleven hours.

Population: according to official statistics, the population of Cyprus is 947.000 (December 2016) with the following distribution: - 74,6% (706.800) Greek Cypriots - 9,8% (92.200) Turkish Cypriots [estimate] - 15,6% (148.000) foreign residents and workers.

Greek and Turkish are the official **languages**. English is widely spoken.

Religion: Greek Cypriots are predominantly Christian and adhere to the Autocephalous Greek Orthodox Church of Cyprus. Turkish Cypriots are predominantly Sunni Muslims, while Maronites belong to the Maronite Catholic Church, Armenians predominantly to the Armenian Apostolic Orthodox Church and Latins to the Latin Catholic Church.

Political Status: Cyprus gained its independence from British colonial rule in 1960. In 1974 Turkey invaded Cyprus and occupied 36,2% of its sovereign territory. A ceasefire line still runs across the island and cuts through the heart of the capital, Lefkosia (Nicosia), dividing the city and the country. Although its northern part is under foreign occupation, the Republic of Cyprus is internationally recognised as the sole legitimate state on the island with sovereignty over its entire territory, including the areas occupied by Turkey (PIO, 2018).

Government: Cyprus is an independent sovereign Republic with a presidential system of government. The constitution provides for separate executive, legislative and judicial branches of government with independent powers. The President is both Head of State and Government. The executive power is exercised by the President through an appointed Council of Ministers. The Council of Ministers exercises executive power in all matters. Each Minister is the head of his or her Ministry and exercises executive power on all matters within that Ministry's domain. Legislative authority is exercised by a unicameral House of Representatives. The House consists of 56 members, which are elected for a five-year term.

Cyprus and EU: On 1 May 2004 the Republic of Cyprus became a full member of the EU. Accession to the EU was a natural choice for Cyprus, dictated by its culture, civilisation, history, its European outlook and adherence to the ideals of democracy, freedom and justice.

Socio-economical scenario

One of the main targets in the EU is to reduce poverty by lifting at least 20 million people out of the risk of poverty or social exclusion by 2020. this situation means that people at risk of poverty or social exclusion were in at least one of the following situations (eurostat, 2018):

1. at risk of poverty after social transfers (income poverty).
2. severely materially deprived.
3. living in households with very low work intensity.

Furthermore, according to eurostat (2018) in 2016 the following facts characterise this issue:

- 118.0 million people in the EU lived in households at risk of poverty or social exclusion; 23.5 % of the population.
- 17.3 % of the population in the EU were at risk of poverty.
- 10.5 % of the population aged 0-59 years in the EU lived in households with very low work intensity.
- 7.5 % of the population in the EU were severely materially deprived.

The statistical comparison on this issue between the EU and Cyprus is shown in Table 2.1. the table provides information on different age groups. For 2017, the situation is relatively the same among the age groups in Cyprus but is higher than the overall EU risk. Among these age groups, the elderly in Cyprus have comparatively higher risk of poverty or social exclusion than their EU counterpart.

Table 2.1. People at risk of poverty or social exclusion, by age group (% of specified population)

Year	Total		Aged 0-17 years		Aged 18-64 years		65 years and over	
	EU	Cyprus	**EU**	Cyprus	**EU**	Cyprus	**EU**	Cyprus
2006	25,3	25,4	27,5	21,3	24,8	21,4	24,7	55,6
2009	23,3	23,5	26,5	20,2	22,8	19,9	21,7	48,6
2012	24,7	27,1	28	27,5	25,3	25,8	19,3	33,4
2013	24,6	27,8	27,9	27,7	25,5	28,2	18,2	26,1
2014	24,4	27,4	27,8	24,7	25,4	28,3	17,8	27,2
2015	23,8	28,9	27,1	28,9	24,7	30,5	17,4	20,8
2016	23,5	27,7	26,4	29,6	24,2	28,1	18,2	22,9
2017	22,5	25,2	24,5	25,5	23,2	25,3	18,1	24,6

Population projection

The projection of Cyprus population showing the changes between 2015 to 2080 is shown in Figure 2.2 using data obtained from eurostat (2018). The graph contains information on the following scenarios:

- Higher, lower , and no migration.
- Lower fertility.
- Lower mortality.

The biggest variation is caused by the higher migration scenario, followed by the lower mortality and the greatest decline is caused considering no migration.

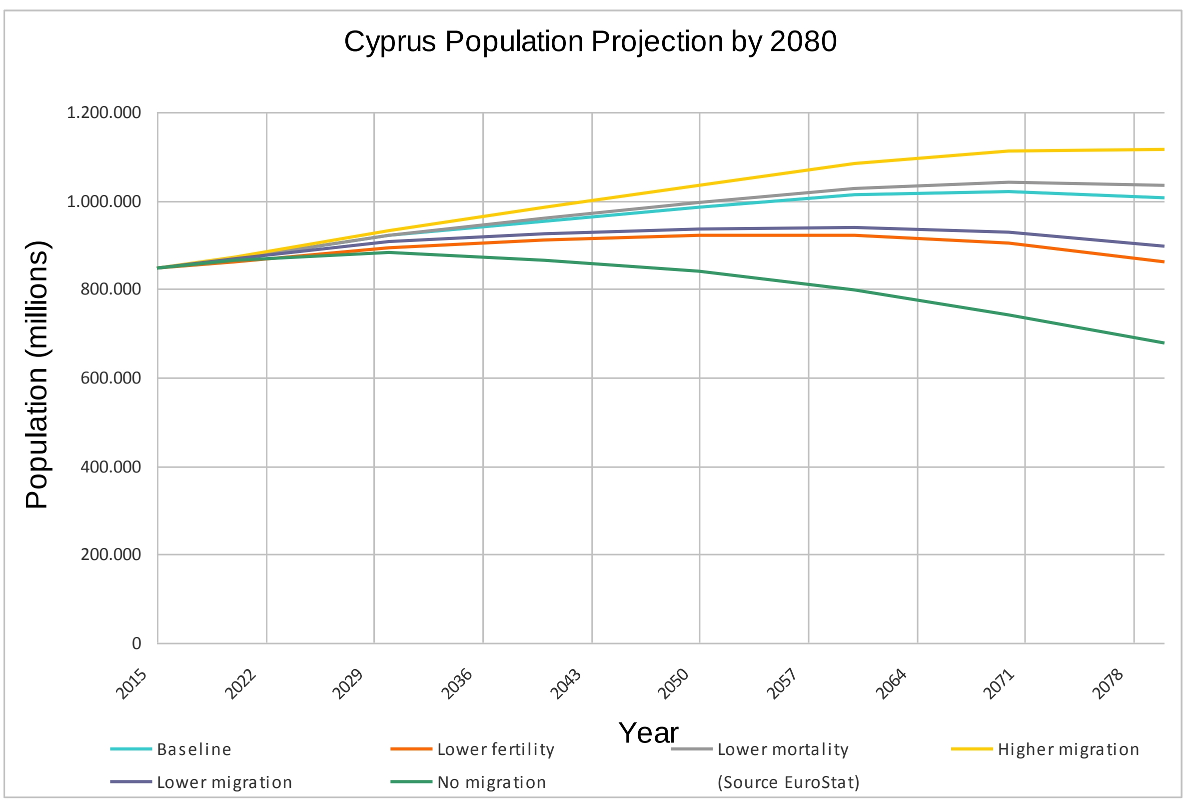

Figure 2.2 Cyprus population projection by 2080 (eurostat, 2018)

The following tables list information according to demographic reports and data released by the statistical service of the Republic of Cyprus. In listed period, 2000-2017, the proportion of population under 15 decreased and the over 65 has increased. Also the life expectancy has increased and the birth rate has decreased.

Table 2.2. General demographic indicators of Cyprus

Population (thousands)	2000	2010	2014	2015	2016	2017
Total	697,5	839,8	847,0	848,3	854,8	864,2
Males	342,7	408,8	411,8	412,7	416,7	421,5
Females	354,8	431,0	435,2	435,6	438,1	442,7
Population distribution by age (%)	2000	2010	2014	2015	2016	2017
0-14 years	22,3	16,8	16,4	16,4	16,3	16,2
15-64 years	66,4	70,5	68,9	68,5	68,1	67,9
65+	11,3	12,7	14,6	15,1	15,6	15,9
Life expectancy at birth (years)	2000	2010	2014	2015	2016	2017
Men	----	79	80,2	79,8	80,3	80,0
Women	----	83,7	84,2	83,5	84,7	84,1
Population change	2000	2010	2014	2015	2016	2017
Annual growth rate at mid-year (%)	1,0	2,6	-1,0	-1,2	0,8	1,2
Natural increase rate (per 1000 residents)	4,5	5,6	4,5	4,0	4,7	3,7
Net migration (number)	+3.960	+15.913	-14.826	-2.000	+2.499	+6.201
Fertility	2000	2010	2014	2015	2016	2017
Live births (number)	8.447	9.801	9.258	9.170	9.455	9.229
Crude birth rate (per 1000 residents)	12,2	11,8	10,9	10,9	11,1	10,7
Total fertility rate	1,64	1,44	1,31	1,32	1,37	1,32
Mortality	2000	2010	2014	2015	2016	2017
Deaths (number)	5.355	5.103	5.424	5.859	5.471	5.996
Crude death rate (per 1000 residents)	7,7	6,2	6,4	6,9	6,4	7,0
Infant mortality rate (per 1000 live births)	5,6	3,2	2,1	2,7	2,6	1,3

Table 2.3 lists the population distribution in districts (urban and rural areas). The data show that the majority of the population lives in urban areas with a higher tendency that rural areas.

Table 2.3. Population per district (in thousands)

District-Total	2000	2010	2014	2015	2016	2017
Total	697,5	839,8	847,0	848,3	854,8	864,2
Nicosia	277,9	328,0	329,5	330,0	332,2	335,9
Famagusta	37,8	46,3	46,8	46,9	47,0	47,5
Larnaca	116,2	142,3	144,0	144,2	144,9	146,5
Limassol	199,5	235,5	236,6	237,0	239,4	242,0
Paphos	66,1	87,7	90,1	90,2	91,3	92,3
District-Urban areas	2000	2010	2014	2015	2016	2017
Total	480,1	567,2	569,3	570,2	576,9	577.574
Nicosia	204,1	240,2	241,0	241,4	244,2	244.500
Famagusta	----	----	----	----	----	----
Larnaca	71,1	84,3	84,8	84,9	85,7	85.874
Limassol	159,2	181,1	180,0	180,3	182,6	183.658
Paphos	45,7	61,6	63,5	63,6	64,4	63.542
District-Rural areas	2000	2010	2014	2015	2016	2017
Total	217,4	272,6	277,7	278,1	277,9	279.386
Nicosia	73,8	87,8	88,5	88,6	88,0	89.620
Famagusta	37,8	46,3	46,8	46,9	47,0	47.338
Larnaca	45,1	58,0	59,2	59,3	59,2	59.491
Limassol	40,3	54,4	56,6	56,7	56,8	56.184
Paphos	20,4	26,1	26,6	26,6	26,9	26.753

References

P.I.O. (2018), Press and Information Office, Republic of Cyprus, N.83/2018
DLS (2018), Department of land and Surveys Portal
Eurostat (2018), Statistics explained, https://ec.europa.eu/eurostat/statistics-explained/index.php/Main_Page

3. Risk assessment methodology

The methodology to implement the objectives on the Cyprus NRA is based on the:

- Sendai Framework and NDRA Guidelines
- EU risk assessment guidelines[4] and,
- Requirements of the International Standards ISO 31000[5] and ISO 31010[6].

In addition, some elements/guidelines, e.g. for the formation of scenarios, the development of the risk matrix, presentation and visualisation of data, have been adapted from NRA of other EU countries, namely:

- UK-*National Risk Register of civil emergencies* (public version of the classified NRA).
- Netherlands- *National Risk Assessment No.6* and *Working with scenarios, risk assessment and capabilities.*
- Germany- *Method of Risk Analysis for Civil Protection.*

3.1 General process for risk assessment

As depicted in figure 3.1, **risk assessment** is the overall process of risk identification, risk analysis and risk evaluation.

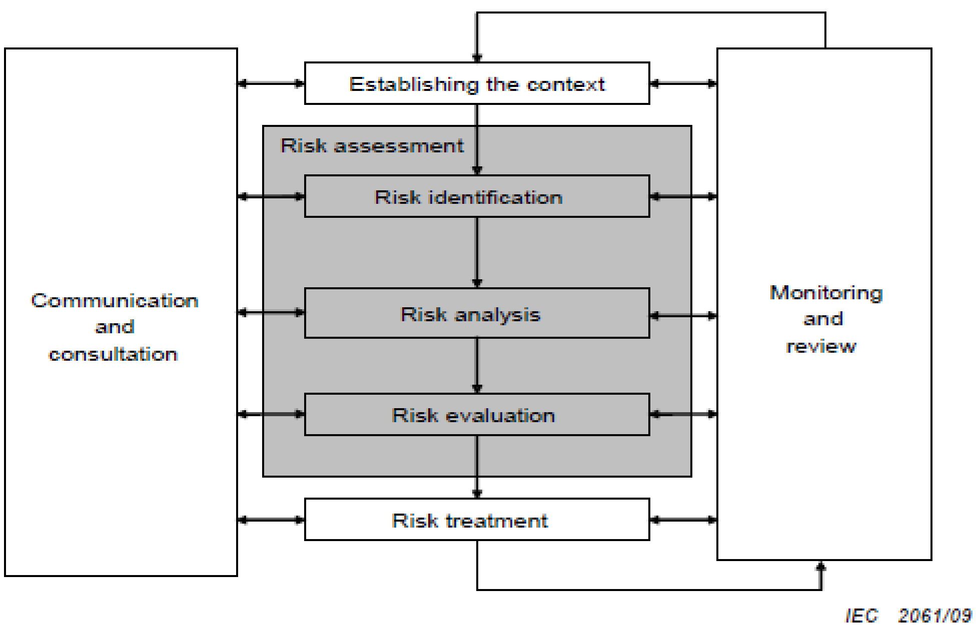

Figure 3.1. Contribution of risk assessment to the risk management process (ISO31010)

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[4] COMMISSION STAFF WORKING PAPER: Risk Assessment and Mapping Guidelines for Disaster Management

[5] IEC/ISO 31000:2009, Risk management – Guidelines

[6] IEC/ISO 31010:2009: Risk management — Risk assessment techniques

The **risk identification** process includes identifying the causes and source of the risk i.e. hazard, events, situations or circumstances, which could have a major influence upon objectives and the nature of that impact. For this project, whereas the hazards have already been identified by the contracting authority (CA), the pending task regards the development of hazard scenarios. This will be followed by the risk analysis and evaluation.

Risk analysis consists of determining the consequences and their probabilities for identified risk events, taking into account the presence (or not) and the effectiveness of any existing controls. The consequences and their probabilities are then combined to determine a level of risk. All three items, namely consequences, probabilities and existing control measures will be considered in this study. Furthermore, consequences analysis will be considered in terms of human, economic & environmental and political/social impacts, which each impact will be analysed in terms of vulnerability and exposure. The risk will be estimated considering the probability of hazard's occurrence, vulnerability and exposure.

For the proposed study, both single-risk analysis and multi-risk assessments will be performed as per EU guidelines[1] on the subject. To determine the singular risk from a pre-defined hazard in isolation (independent) from the other hazards a single-risk assessment is necessary and it will be followed. On the other hand, multi-risk assessment determines the total risk considering the interaction and interdependency between several hazards in terms of possibility and vulnerability, e.g. follow-on hazardous events such as earthquake and tsunami. Therefore this approach will be used to determine the risk due to the hazards synergy through identified multi-risk scenarios considering the interdependent hazards and also for the development of the risk matrix and mapping for all the hazards analysed.

Risk evaluation involves comparing estimated levels of risk with risk criteria defined when the context was established, in order to determine the significance of the level and type of risk. Risk evaluation uses the understanding of risk obtained during risk analysis to make decisions about future actions on issues like whether a risk needs treatment, priorities for treatment, whether an activity should be undertaken and which of a number of paths should be followed. In the context of this study, risk based criteria will be established to enable for risk evaluation. These base criteria will be defined regarding their magnitude of acceptability and tolerance, which will be the benchmark of assessing and calibrating the severity of each type of risk.

3.2 Methodology for NRA-CY

The designed methodology to implement the NRA-CY has adapted the sequence described above, i.e. risk identification→risk analysis → risk evaluation. To satisfy the objectives set in this project, there is a need to summarise and compare the risks estimated from the predefined hazards. Therefore, by examining the provisions and techniques/tools described in ISO 31010, the ***technique of scenario analysis*** is chosen for the risk assessment and it will be applied to identify the hazard scenarios and execute the impact analysis using **risk indices** and a **scoring approach**. Additionally, for the risk analysis of specific applications (e.g. WP6-Large scale technological accidents) other techniques such as the ***fault tree analysis*** and ***event tree analysis*** will be also employed. Such approach is supported by ISO31010, which states that "*more than one technique may be required for complex applications*".

The comparison of the hazard's risk level will be carried out using the ***risk matrix (consequence/probability matrix) method***, which will utilise the results of the impact analysis. The designed methodology, ***risk matrix based on the impact analysis in the scenario based approach***, described herein is depicted in figure 3.2: the produced hazard scenarios will be assessed through an impact analysis, which will provide data to be used in the risk matrix.

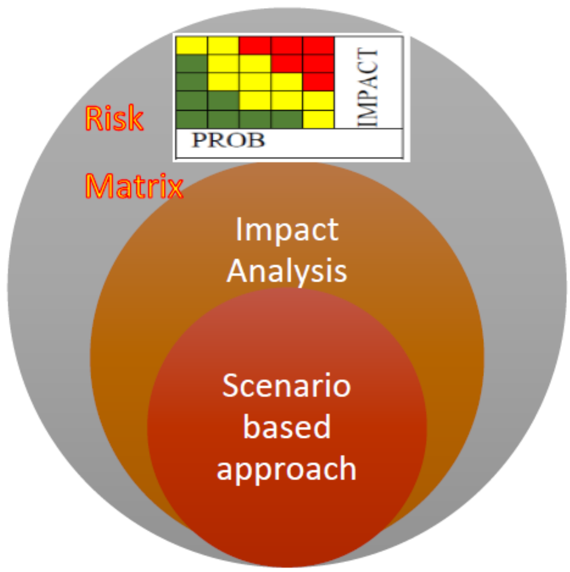


Figure 3.2. The NRA implementation methodology

3.3 Implementation steps

The NRA implementation methodology will be executed in four distinctive, interconnected, sequential steps, herein tasks 1-4. The chapters 4 to 10 that describe the risk assessment of the predefined hazards will have similar format and will consist of the following four distinctive steps/tasks:

Task 1: Hazard scenario identification

To develop each scenario, inputs are obtained from historic data and reports from governmental departments, scientific reports published for case studies in Cyprus, research reports prepared by local (public and private) universities. Further to data based in past experience, scenarios have been developed considering events and impacts which have so far not occurred but are plausible in the future. Assumptions have been used where necessary for relationships that there is lack of data. For every developed scenario the information leading to its definition are described in the relevant chapter.

The issue in this step was, which scenarios to choose or develop, as many situations in most cases can be transformed to scenarios. Therefore, general criteria used for the scenario building for each hazard include:

- Level of impact.

- Hazard scenario probability.
- Level of consequences.
- Other guidelines specified in EU guidelines for specific hazards.

The time period covering the development of scenarios will be adjusted and justified will be determined according to the hazard type. No time horizon has been set that is being applied for all hazards.

For every hazard, three (3) scenarios are identified and selected (from the range of possible scenarios) having different limits /types for the comparison to be meaningful (some scenario can co-exist, i.e. the expected scenario can represent either worst or better scenario, or even both):

- ❖ Worst scenario-Plausible with upper risk limit/level.
- ❖ Expected scenario-the scenario to be considered (to be prepared for). This scenario for every hazard is presented in the risk matrices of chapter 12.
- ❖ Best case/mild scenario-Plausible with lower risk limit

Task 2: Exposure and vulnerability of socioeconomical parameters

In risk analysis the **impact on human, economics & environment and political/society**, is analysed in terms of vulnerability and exposure. Therefore in this stage using a semi-quantitative approach when possible, for every hazard the exposure and vulnerability in these three categories is determined using numerical indicators (rating scales).

Task 3: Probabilistic scenarios analysis/ consequences and impact assessment

At this step, the probability of occurrence of each hazard scenario will be determined along with the associated consequences. Therefore, (taking into account all three categories of impacts) the risk is estimated as a function of the probability of hazard's occurrence (p), vulnerability (V) and exposure (E) as shown below,

$$Risk=R=f\,(p*E*V)$$

Task 4: Quantification of existing treatment measures and suggestions for adaptation and mitigation measures

In this final step, existing treatment measures are examined in order to determine whether the risk and/ or its magnitude is acceptable or tolerable and whether a risk will be accepted or treated as part of the national level risk assessment. Accordingly, suggestion for mitigation measures are specified where necessary.

3.4 Chapters design

Considering the aforementioned approach, a chapter (Ch4-10) is dedicated for each hazard. The content of each chapter is described below; there are also two appendices in this report, which have been prepared by other governmental departments and are included in order to complete the risk hazard map for Cyprus.

Chapter 4-Earthquake and Tsunami: This chapter will examine seismic scenarios based on both historic data and possible future events including those triggering the formation of tsunami.

Chapter 5-Floods: This chapter will examine the flood hazards in Cyprus including flash floods and urban floods and will identify the most vulnerable flood areas from developed flood model scenarios.

Chapter 6-Water scarcity: In this chapter, the elements leading to water scarcity will be first identified and then used to prepare hazard scenarios. The effect of climate change will be also incorporate in the scenario building.

Chapter 7-Large scale technological accidents: The risk assessment of all installations in Cyprus, handling toxic or flammable substances which are either lower or upper tier according to the SEVESO III directive will be carried-out in chapter 7.

Chapter 8-Fires in forests and rural areas: The work in this chapter includes forest and rural vegetation classification, which will allow the identification and mapping of fire hazard potential across the country and thus will lead to the preparation of hazard scenarios.

Chapter 9-Sea level rise and coastal erosion: In this chapter, the current sea level status and conditions will be described and classified followed by development of impact maps and estimation of the vulnerability of the exposed areas.

Chapter 10-Marine pollution: This chapter will assess the risk of marine pollution with emphasis in oil-spills originating either from the marine environment of Cyprus or from neighbouring areas.

Chapter 11-Hazards synergy: This chapter aims to study the risk resulting from several hazards, i.e. hazards synergy, under various interacting conditions and identify possible hazard scenarios.

Chapter 12-Risk matrix: The risk assessment's results from the examined hazards will be combined and analysed in this chapter, in order to estimate the overall risk. The results will be presented in a global risk matrix containing the hazard scenarios and their associated impact. Furthermore, risk mapping will provide additional visual aid of the obtained results.

Appendix I: This appendix contains the study for "*climate change risk assessment for the Health sector*", prepared for the department of environment of the Ministry of agriculture of Cyprus. The name of the authors of the study are mentioned at the beginning of the text and are not members of the consortium that has undertaken this National Risk Assessment study for Cyprus (NRA_CY). The study was prepared under a different contract and was provided by the Cyprus Civil Defence Athority to include in the NRA-CY report.

Appendix II: This appendix contains the study for "*land desertification"*, which was prepared for the department of environment of the Ministry of agriculture of Cyprus. The name of the authors of the study are mentioned at the beginning of the text and are not members of the consortium that has undertaken this National Risk Assessment study for Cyprus (NRA_CY). The study was prepared under a different contract and was provided by the Cyprus Civil Defence Athority to include in the NRA-CY report.

4. Earthquake and Tsunami

Introduction

Cyprus is located at the boundary between the Eurasian, Arabian and African plates within a complex tectonic setting. Studies (e.g. Papazachos and Papaioiannou, 1999) have demonstrated that the Anatolian subplate, to which Cyprus belongs, is forced to move westward by the collision of the African plate, which moves north north-eastward relative to the Eurasian one, and the Arabian plate, which moves northwards in a faster rate. The North Anatolian Fault and the East Anatolian fault (Figure 4.1), the two major strike-slip faults, enable this western movement of the Anatolian Subplate.

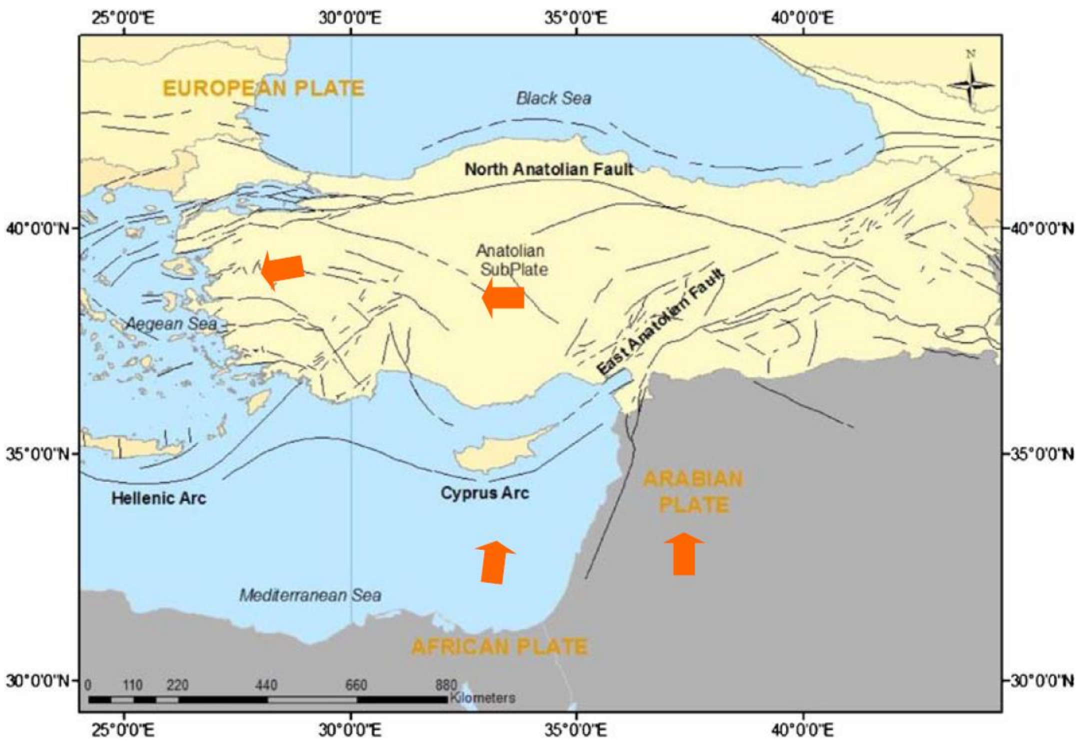


Figure 4.1. Principal tectonic elements of the Northeastern Mediterranean Region where Cyprus belongs (Barka et al., 1997)

The Cyprus Arc, being the boundary accommodating the movement between the African and Anatolian subplate, is relatively less active than the neighboring Hellenic Arc, Dead Sea and East Anatolian faults, being though the origin of several shallow earthquakes. According to historical records (Ambraseys, 1965; Galanopoulos and Delibasis, 1965; Kalogeras et al., 1999), Cyprus has suffered from at least 16 destructive earthquakes the past 2000 years and numerous smaller earthquakes (Figure 4.2). It is worth-noticed that modern instrumentation began in the island only after 1997 and thus, the seismic catalogue until then is composed by empirical relationships and various international sources. The largest earthquakes mostly occurred at the southern part of the island, causing damage in Paphos, Limassol, and Famagusta (e.g. the earthquakes of 342 with estimated magnitude of Mw=7.4, 1222 with Mw=6.8, 1577 with Mw=6.7, 1785 with Mw=7.1, 1940 with Mw=6.7 (Cagnan and Tanircan, 2010).

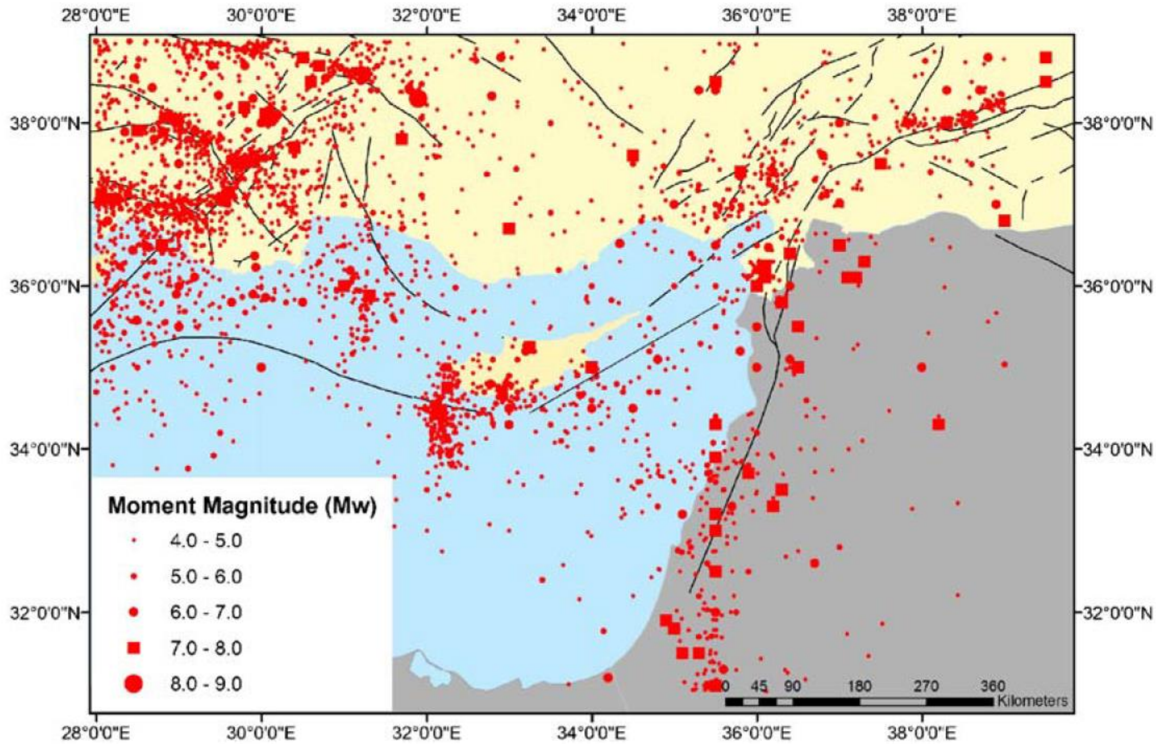


Figure 4.2. Distribution of shallow earthquake epicenters in the northeastern mediterranean region from 2150 B.C. to 2006 A.D. The soild lines are mapped and inferred faults. Map and Data from Cagnan and Tanircan (2009), Geological Survey department of Cyprus (1995), Barka et al. (1997) and USGS (1999).

Hence, the first large event in the region for which seismic data from digital network was available, was in 1996, of Mw=6.8 and shallow depth. Its epicentre was in the offshore to the southwest but a violent shock was felt almost throughout the island. Although building damage was limited, 20 people were slightly injured and 2 were the reported fatalities from indirect causes. Similarly, in 1999 an earthquake of Mw=5.6 with epicentre close to Limassol tremored the island with as many as 40 injuries mainly due to panic (Cyprus-mail, 2015). In 2015, a Mw=5.8 earthquake violently shocked the districts of Paphos up to Limassol mainly with contents damage. Finally, the latest deadliest earthquake that hit the island was in 1953 (Mw=6.1) and caused 40 fatalities, 100 injuries and extensive damage to 158 villages and the city of Paphos (Ambraseys, 1992).

All of the abovementioned make evident the need for thorough and continuously up-to-date study of the seismic hazard and risk of the island of Cyprus. Currently, the seismic zonation map of Figure 4.3 is used as part of the National Annex of Eurocode 8 (EN 1998-1:2004) after revision of the first zonation map as composed by the Geological Survey Department for the national seismic code (Cyprus Civil Engineers and Architects Association, 1992) based on historical macroseismic data. Several other studies have been performed following probabilistic more refined approaches

(Erdik et al., 1997; GSHAP Program, Giardini et al., 1999; SESAME Project, Jimenez et al, 2001; EMME Project, Erdik et al, 2012; SHARE Project, Giardini et al, 2013).

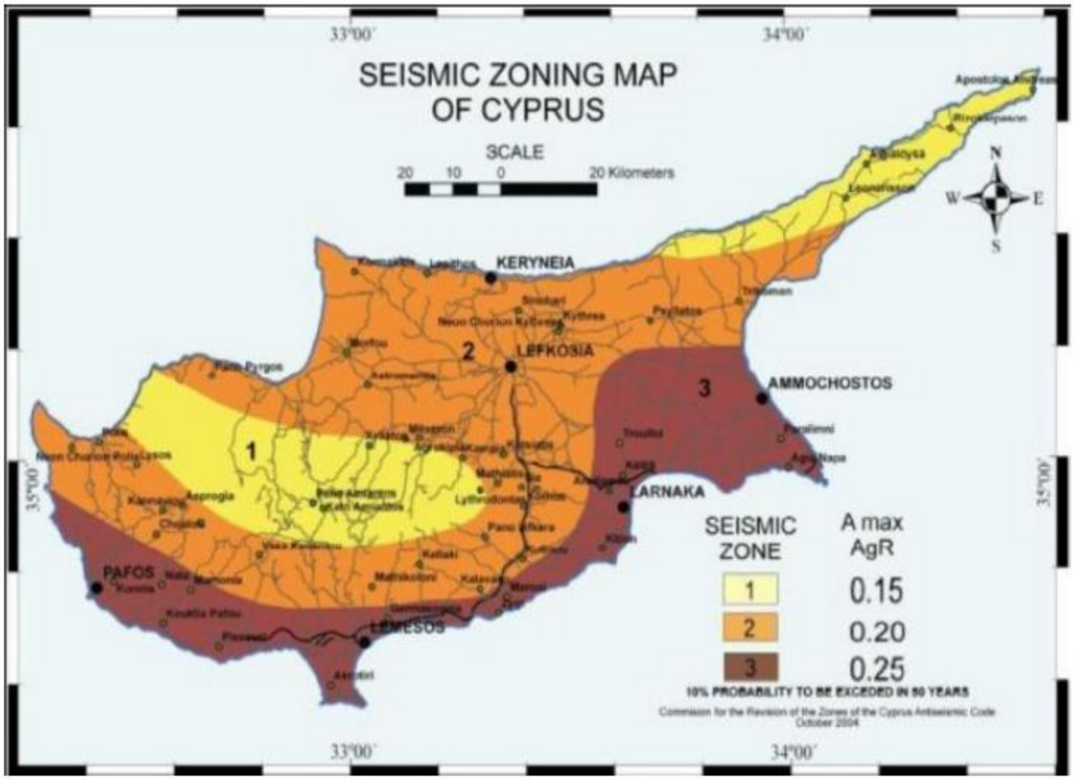


Figure 4.3. Seismic zonation map of Cyprus (EN 1998-1:2004)

Limited work has been done, however, to the risk assessment at urban or national level for Cyprus (Gountromichou et al., 2017a within PACES Project; Chrysostomou et al., 2014 within EMME Project, Erdik et al., 2012), although the outcome of the seismic risk assessment is more comprehensive and exploitable by the stakeholders and community. Hence, the seismic risk will be assessed in the current study based on existing hazard models (SHARE project, Giardini et al., 2014), exposure and vulnerability models that have been composed by previous works (Chrysostomou et al., 2014; Kyriakides et al., 2015) and the outcome will be given in monetary, building damage and affected population terms. Both probabilistic and deterministic analyses have been performed to provide results (aggregated and spatially distributed figures), at annual and probability-related basis, and for selected seismic scenarios.

For the performance of seismic hazard and risk analysis, the OpenQuake platform (Silva et al., 2013), developed within the Global Earthquake Model Foundation (GEM, 2018), has been applied. The engine is open-source, open-code and has the possibility to perform both probabilistic hazard and risk assessment and scenario damage and risk computation. Tailor-made hazard, exposure and vulnerability models have been uploaded together with customized logic trees to account for epistemic uncertainties. The open-source QGIS software has been used for the mapping of the results.

For the seismic risk assessment at national level, probabilistic seismic hazard and risk analysis has been initially performed. The risk outcome is in terms of monetary loss and is provided at aggregated level for the island and the four major cities and spatially distributed with gridded maps. Moreover, the risk analysis of two seismic scenarios with 10% and 2% probability of occurrence was performed. Monetary and human loss (casualties, injuries, displaced population) was estimated as well as damage distribution among the main structural typologies. Reference is made to the importance of a future social vulnerability and integrated risk analysis.

SEISMIC HAZARD ASSESSMENT

In order to assess the risk that a structure faces to sustain a certain level of damage from given earthquake shaking, it is necessary first to calculate the probability of exceedance of the level of ground shaking for a range of intensity levels. Hence, Probabilistic seismic Hazard Analysis will be first performed, able to provide the requested intensity measures (Peak Ground Acceleration, spectral amplitude, seismic intensity, etc) in function to recurrence rate. Following to this analysis, risk analysis (combining the exposure and vulnerability model) for all the generated ground motion fields (potential ground shaking scenarios) will lead to the probability-related loss estimation.

Probabilistic Seismic Hazard Analysis

Input hazard models

For the implementation of Probabilistic Seismic Hazard analysis, the classical integration procedure as proposed by Cornell (1968) and formulated by Field et al. (2003) has been incorporated into OpenQuake software and performed in the study herein for investigation time of 50 years. The input files are the *Seismic source model*, that is a collection of seismic sources describing the seismic activity (geometry and activity rate of each source) in a region of interest, and the *Ground motion model*, that associates Ground Motion Prediction Equations (GMPEs) and distribution weights to each tectonic region, given the occurrence of an earthquake rupture.

For the analysis, herein, the following three *seismic source models* (ESHM13) developed for SHARE project (Giardini et al., 2013) in the OpenQuake format (Pagani et al., 2014) have been used. Each of the models uses different assumptions to estimate earthquake activity rates in the European region.

1. Classic Area Source model: Contains the area source model (Figure 4.4a,b). Parametrization includes: magnitude-frequency distribution, temporal occurrence model, magnitude-area scaling relationship, definition of nodal planes, centroids and constrains of rupture planes.

2. Fault-Source and Background model (FSBG): a model that combines activity rates based on fully parameterised faults imbedded in large background seismicity zones (Figure 4.4c).

Contains fault source and the background seismicity model. Parametrization includes: magnitude-frequency distribution, temporal occurrence model, magnitude-area scaling relationship, definition of fault surface and faulting style.

3. SEIFA model: a kernel-smoothed model that generates earthquake rate forecasts based on fault slip and smoothed seismicity. The following information is contained: Location, Geometry, Incremental annual rate in 0.1 magnitude bins stating from Mw=4.5, cumulative annual rate, log1(cumulative annual rate).

It is noted that due to computational resource limitations, the crust (active and stable shallow) tectonic zone has been removed from the model.

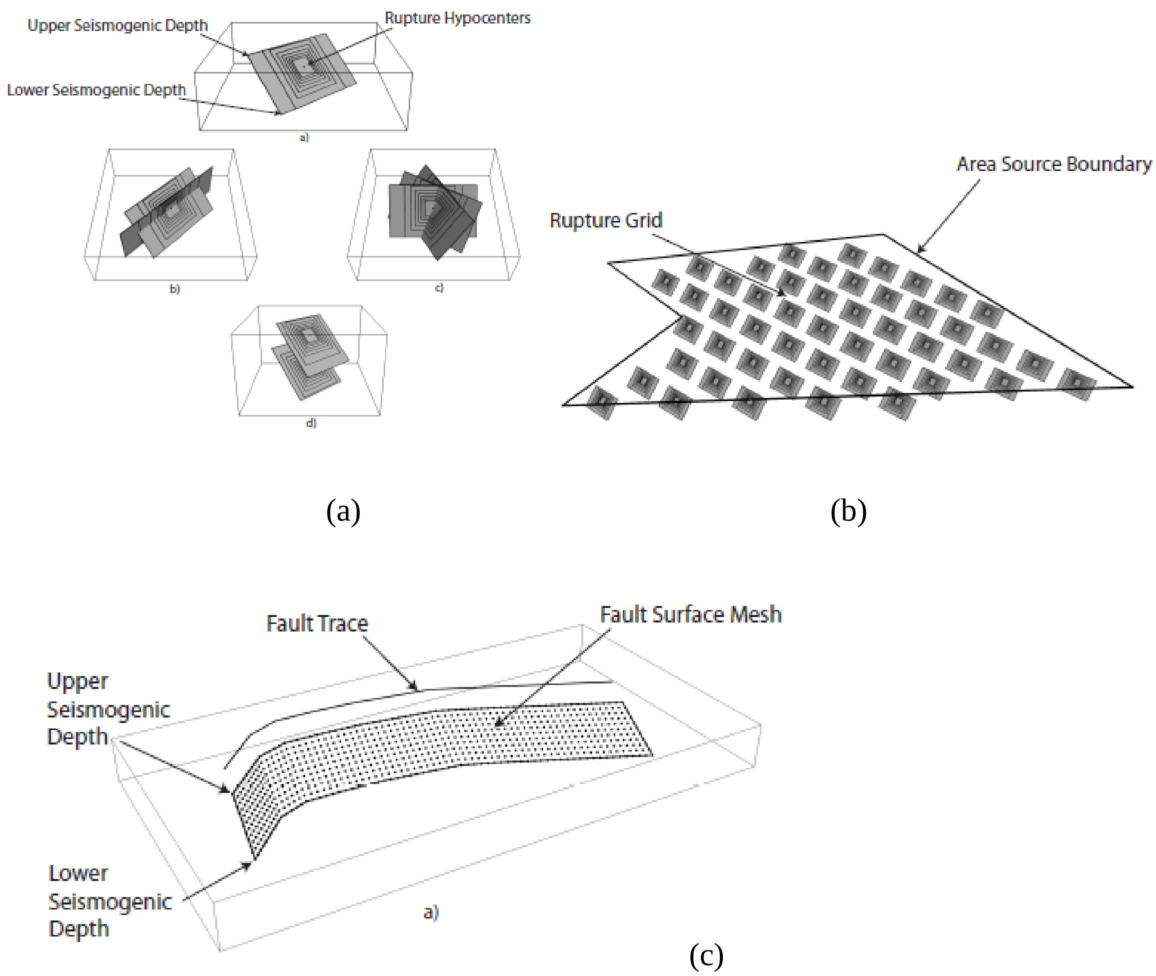


Figure 4.4. Graphical representation of earthquake ruptures (a) as generated by point sources for different input parameters ; (b) as generated by an area source, mainly originated by point sources uniformly distributed along an area ; (c) as a portion of a fault surface mesh, simulated in OpenQuake engine (Pagani et al., 2014).

In Figure 4.5 the fault top traces and planes of composite seismogenic sources (in grey) and the subduction traces (in color) of the Cyprus and Hellenic Arc, as compiled for the European Database of Seismogenic Faults (EDSF) within SHARE project, are illustrated for Cyprus. EDSF includes only faults that are capable of generating earthquakes of magnitude equal to or larger than Mw5.5

and aims at ensuring a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area (Basili et al., 2013). These have been incorporated into the abovementioned source models. Moreover, data from the two SHARE European Earthquake (SHEEC) sub-catalogues 1000-1899, 1900-2006 (Grünthal et al., 2013, Grünthal and Wahlström, 2012 and Stucchi et al., 2012) has been used for the generation of abovementioned the source models, as a basis for computation.

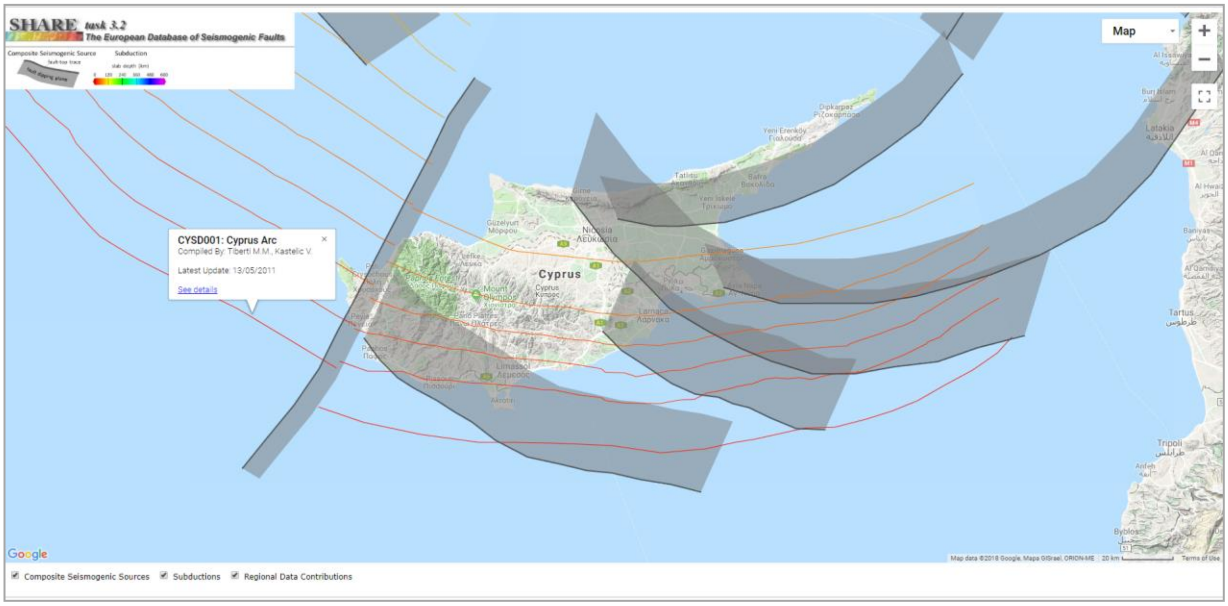


Figure 4.5. Extract of the European Database of Seismogenic Faults From Basili et al. (2013)

The *Seismic Source model logic tree* is essential integral component of PSH Analysis and describes the epistemic uncertainties associated with the construction of seismic source models used for different tectonic regions. The tailored logic tree proposed by SHARE project, used herein, is relatively simple with higher weight attributed to the Area Source model.

On the other hand, a more complex *Ground Motion model logic tree* defines the Ground Motion model which comprises different Ground Motion Prediction Equations, per tectonic setting, with their respective defined uncertainty. The Ground Motion Prediction Equations are empirically derived equations that correlate the source (and its parameters) with the propagation path and the site of interest (e.g. magnitude, distance and Vs30) leading to the computation of a ground motion parameter. The GMPE logic tree of SHARE Project (Figure 4.6) has been incorporated and the equations for Peak Ground Acceleration (PGA) and Spectral acceleration (Sa) have been applied, according to the hazard calculator.

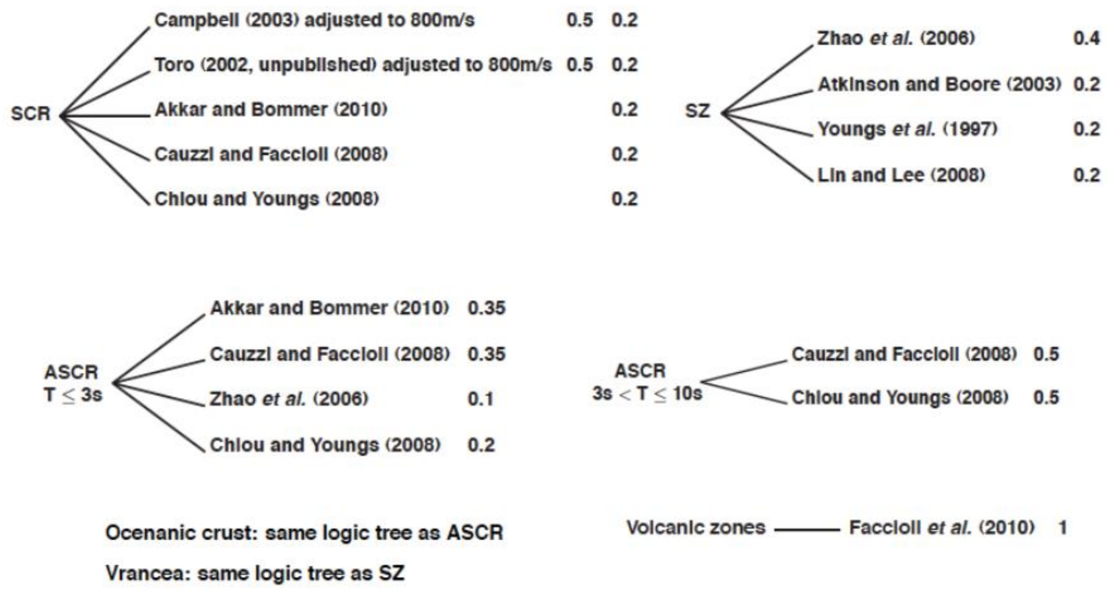


Figure 4.6. Ground motion prediction equation logic tree for SHARE (Woessner et al., 2013)

For the definition of the *site conditions*, a simplified model based on the Shear wave velocity (Vs30) map of USGS (Figure 4.7) has been used.

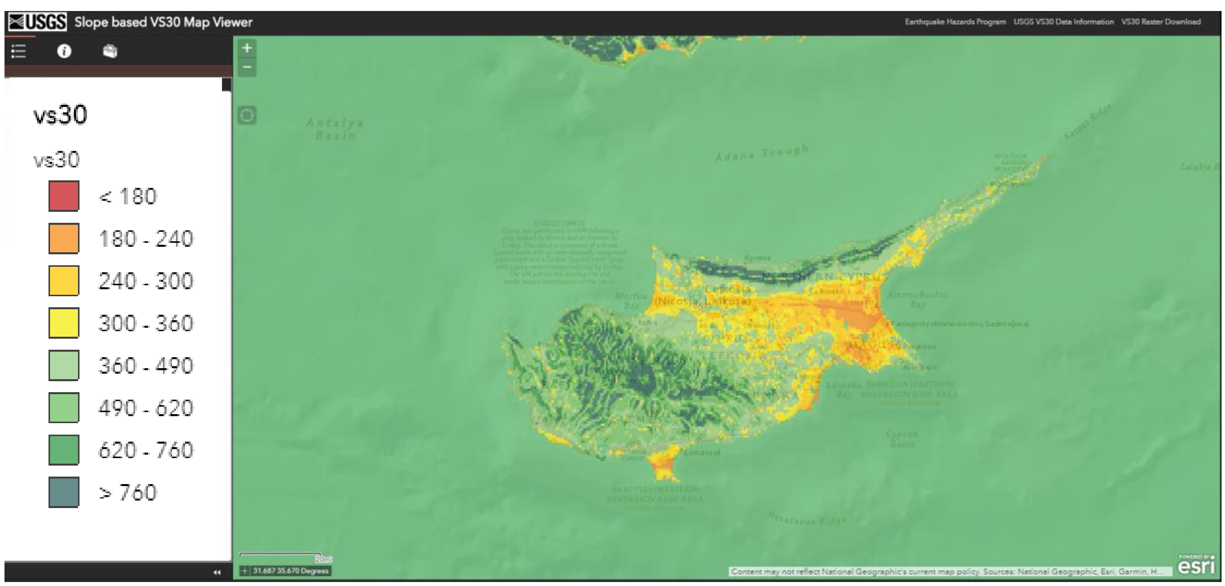


Figure 4.7. Shear wave velocity map of Cyprus (USGS, 2018)

Output – Seismic hazard curves

The information extracted from the probabilistic seismic hazard analysis is summarized in the *seismic hazard curve* which combines the rate (or probability) of exceedance of a range of intensity levels for different ground motion parameters at a given site. This curve is composed by consideration of exceedance of ground motion parameter levels by all possible earthquake ruptures included in the seismic source model within a given investigation time.

The curves below depict the Peak Ground Acceleration (PGA) (Figure 4.8) and the Spectral acceleration at T=0.3 s (Figure 4.9) with the corresponding probability of exceedance in 50 years. They have been plotted for the main cities of Cyprus for which PGA varies between 0.3 and 0.5g and Sa varies between 0.7 and 1.0g. It may be seen that the seismic hazard in Paphos and Limassol is the most elevated in the island, being in the vicinity of the shallow seismic subduction zones of the Cyprus and the Hellenic Arc (Figure 4.5). The elevated seismic hazard in the southwestern part of the island is also evident by the maps of Figure 4.10 to Figure 4.12).

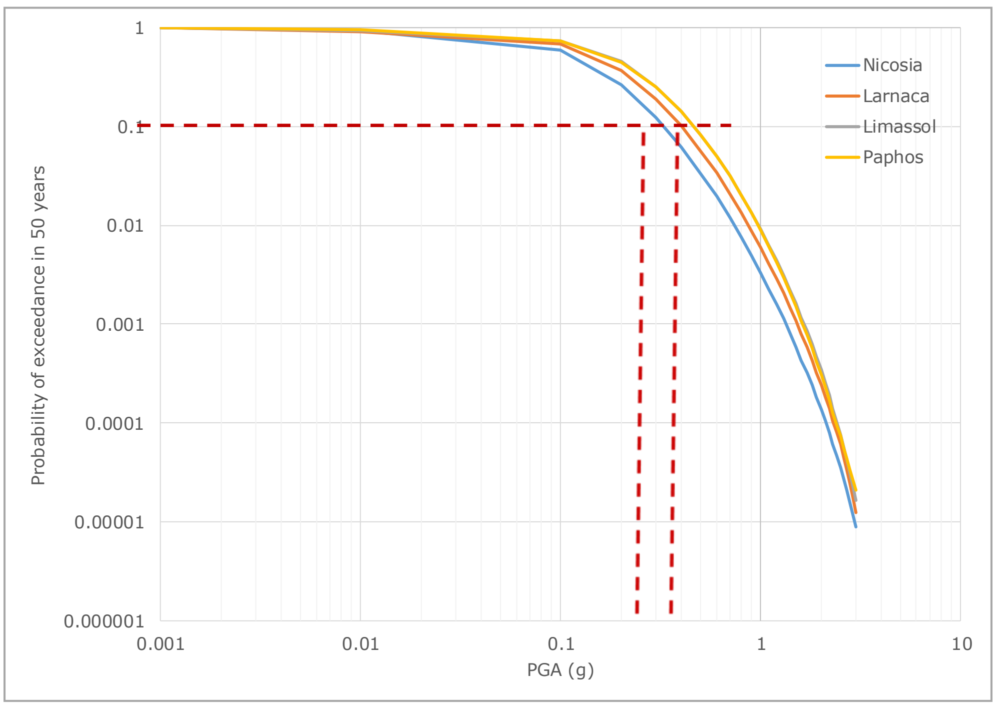


Figure 4.8. Hazard curves for the main cities of Cyprus in PGA extracted from PSHA

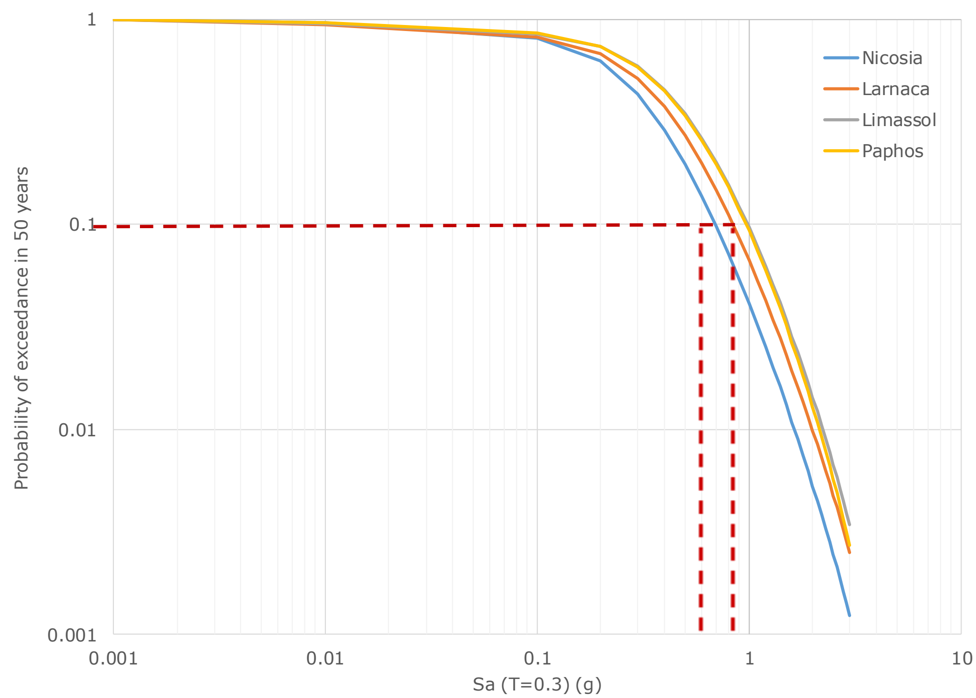


Figure 4.9. Hazard curves for the main cities of Cyprus in Spectral acceleration at T=0.3 s from PSHA

Output – Seismic hazard maps

The seismic hazard maps below express the distribution of the ground motion parameters under study for the given recurrence period (T). Figure 4.10 and Figure 4.11 illustrate the distribution of the Peak Ground Acceleration (PGA) for T=475 and T=2500 years, respectively. It is evident that the highest seismic hazard is concentrated in the southwestern part of Cyprus. More precisely, along the southwestern shore of the island, where Lemessos and Paphos are located, PGA exceeds 0.45g (for T=475years) and 0.8g (for T=2500 years. Interesting is the comparison with the current seismic design map (Figure 4.3) which anticipates max design PGA, in the same regions, equal to 0.25g (for T=475 years).

Figure 4.12 and Figure 4.13 illustrated the distribution throughout the island of spectral acceleration at fundamental period of 0.3 s with T=475 and T=2500 years, respectively. Values vary between 0.4 and 1.10g for T=475 years while for T=2500 design spectral acceleration n at 0.3 s varies between 0.9g (at the northern part of the island) to 2.0g. in the south-western.

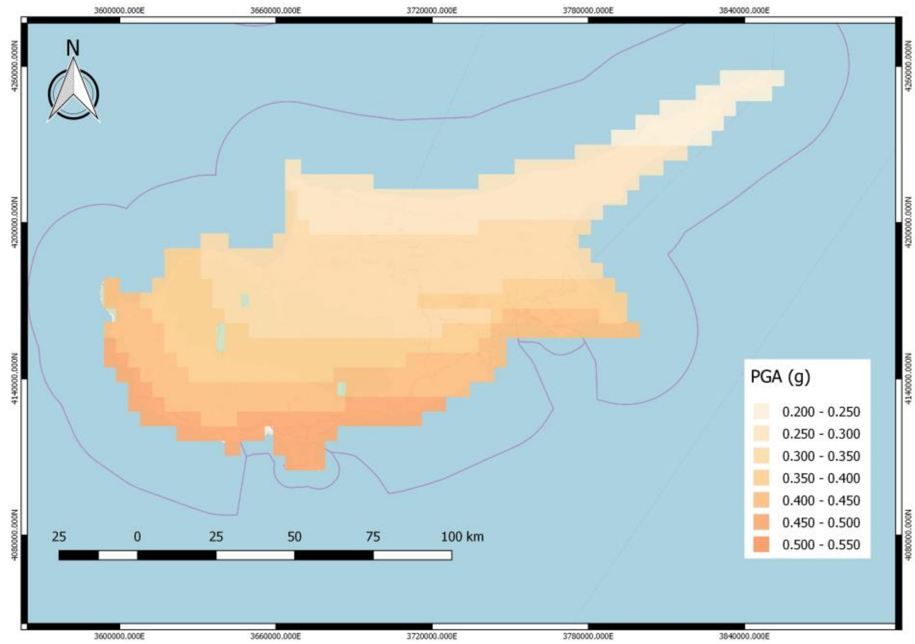


Figure 4.10. Mean seismic Hazard map in PGA for probability of exceedance 10% in 50 years (T=475 years)

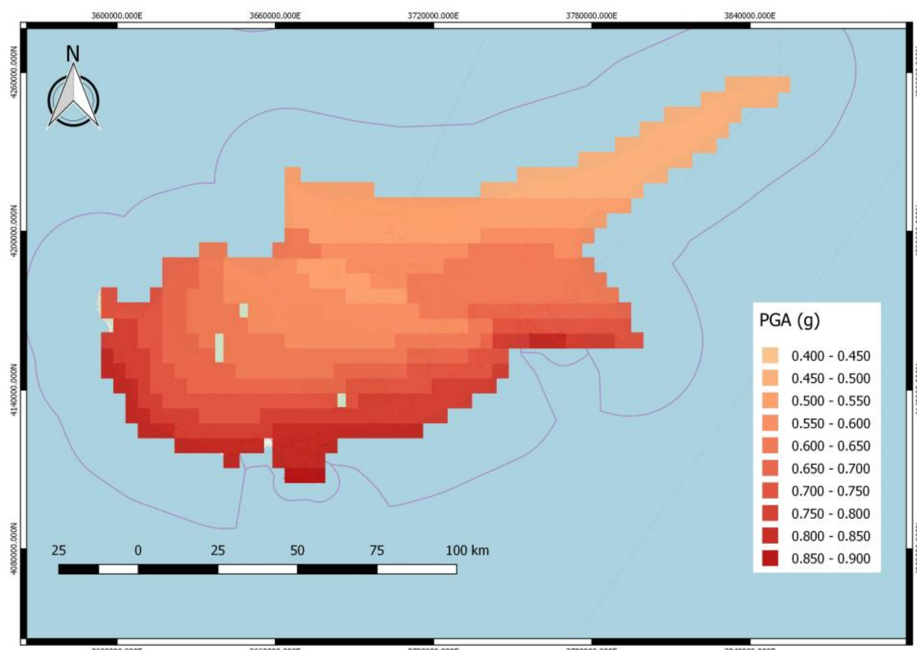


Figure 4.11. Mean seismic Hazard map in PGA for probability of exceedance 2% in 50 years (T=2500 years)

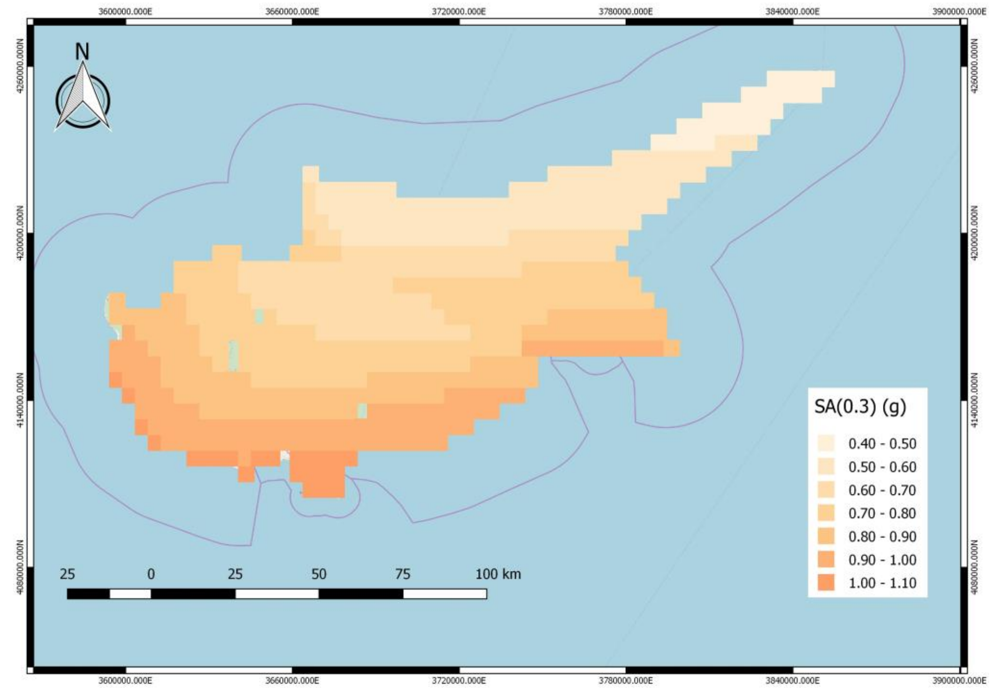


Figure 4.12. Mean seismic Hazard map in Spectral acceleration at T=0.3 s for probability of exceedance 10% in 50 years (T=475 years)

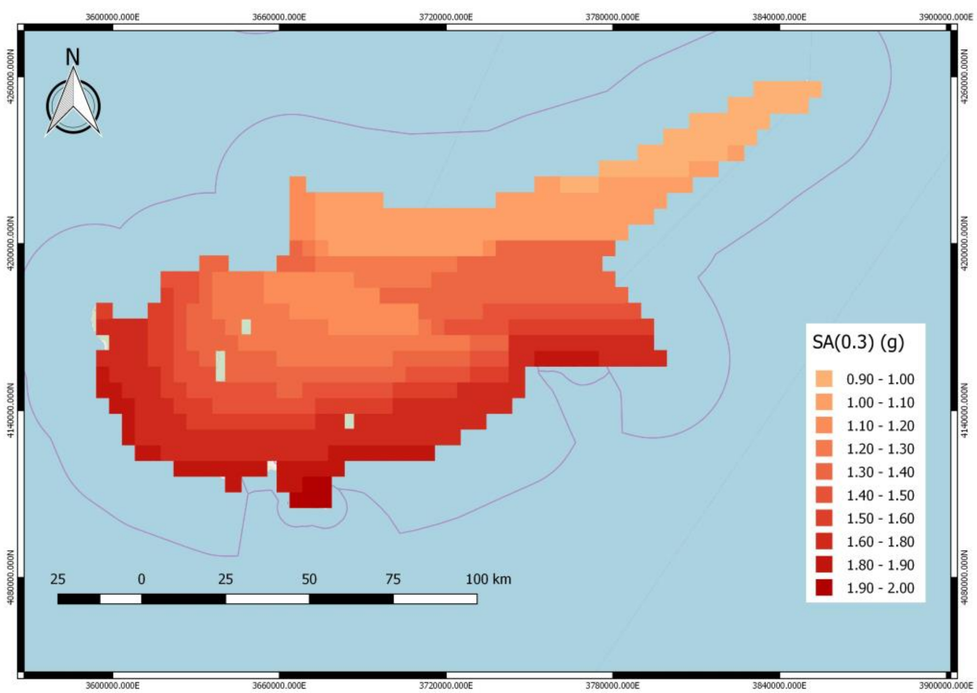


Figure 4.13. Mean seismic Hazard map in Spectral acceleration at T=0.3 s for probability of exceedance 2% in 50 years (T=2500 years)

EXPOSURE MODEL AND STRUCTURAL VULNERABILITY

Exposure model

The exposure model for Cyprus refers to the building stock and the permanent population. Main source of both databases is the 2011 Population Census of Cyprus and the GIS based building database of the Department of Lands and Surveys. All data was collected by to the local representatives of EMME project (Giardini et al., 2016), as reported in Chrysostomou et al. (2014) and was kindly provided by the authors of the latter work for the purposes of the current study. Within EMME project, a 1x1km^2 grid was generated for the entire island and a number of buildings, per building typology, and population is given per grid.

The classification of buildings per typology has taken place following the European Building Taxonomy Classification, as defined during the RiskUE project (2003). The criteria of the classification are the material, the construction period, as far as the seismic design codes are concerned and the building height. Hence the following typologies are available, according to Chrysostomou et al. (2014): bearing masonry, reinforced concrete (RC) frames for low- to mid-rise and high-rise buildings and further distinction of RC structures for low ductility (or with no Earthquake Design Code-ERD) and moderate ductility (with ERD). It is noted that, given that no detailed information is given with respect to the typology of masonry, no distinction was made between adobe and simple stone material. It has been also observed that all masonry buildings are built before 1975. The low- to mid-rise buildings have been grouped together, based on the availability of fragility curves (Par. 0). As explained by Kyriakides et al. (2015), fragility curves for low-rise buildings (for average height of 2 stories) have been generated due to their multitude, as well as fragility curves for high-rise buildings (for average height of 7 stories) due to their observed vulnerability. Mid-rise building of 3-5 stories height have not thoroughly examined due to low damage recording from previous earthquakes and limited resources. Design with seismic codes was enforced in 1992.

Figure 4.14 demonstrates the typological distribution of buildings throughout the island with ratios and absolute numbers. The total number of buildings, as registered in the Censuses is 326820. It is evident that low to mid-rise RC buildings with no seismic design codes (ERD) is the predominant typology (57% of the building stock) with its counterpart with ERD being the following one in multitude (27%). 17% of the registered building stock is made of bearing masonry, being mainly encountered in the Northern part of the island (Figure 4.17), if not accounting for the major cities. High-rise buildings correspond to around the 3% of the island's building stock. It should be noted that a number of high-rise buildings have been erected in the main cities in the period from 2011 but, considering that these are individual structures following the most modern seismic design provisions, their exclusion from the exposure model is not considered to significantly affect the overall risk outcome.

Figure 4.15 to Figure 4.19 illustrate the spatial distribution of buildings throughout the island. As expected, there is a high concentration (>3000 buildings per grid) in the big cities (Nicosia, Paphos, Limassol, Larnaca). Comparing Figure 4.18 and Figure 4.19, it is interesting to comment upon the fact that buildings designed with ERD codes, hence erected after 1992, are allocated also out of the big cities. Finally, in Figure 4.20 the population distribution per grid has been illustrated, indicating the expected correlation between population and number of buildings distribution.

The replacement value considered per structural typology is part of the exposure module of a risk study. Based on empirical data and for simplification reasons, the **average area per floor** has been decided for all typologies between **80 and 100m^2**. The **replacement cost** only for structural works ranges between **600 and 800 euro/m^2**. The **total structural replacement value** of the exposed assets is estimated around **32 billion euro**. No differentiation of the buildings per occupancy has been assumed.

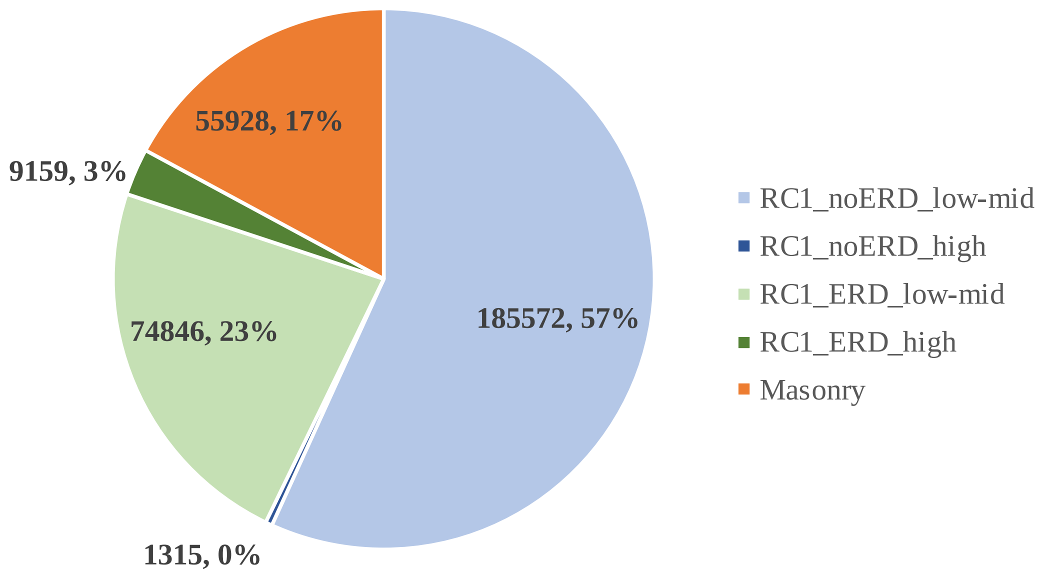


Figure 4.14. Distribution of building typologies for the island of Cyprus

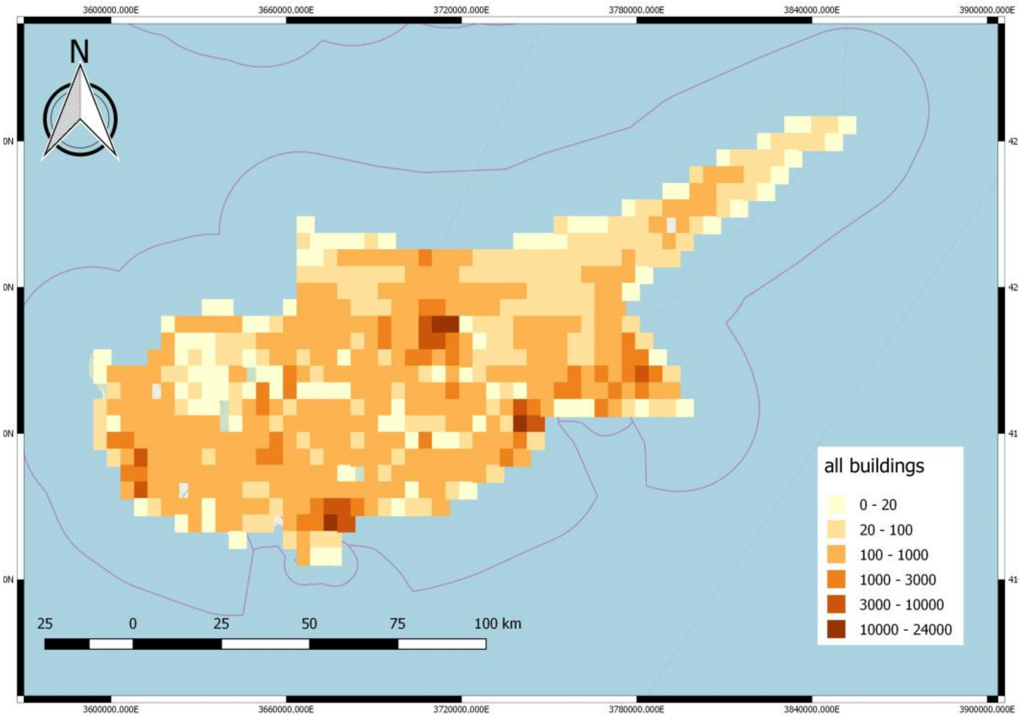


Figure 4.15. Distribution of number of buildings

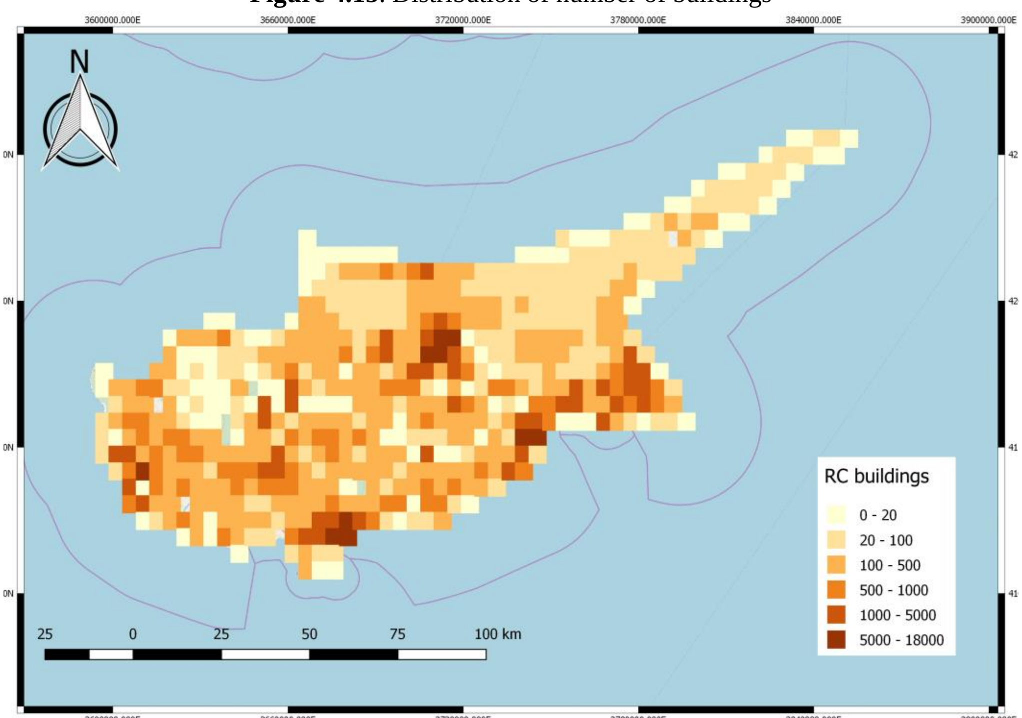


Figure 4.16. Distribution of number of RC buildings

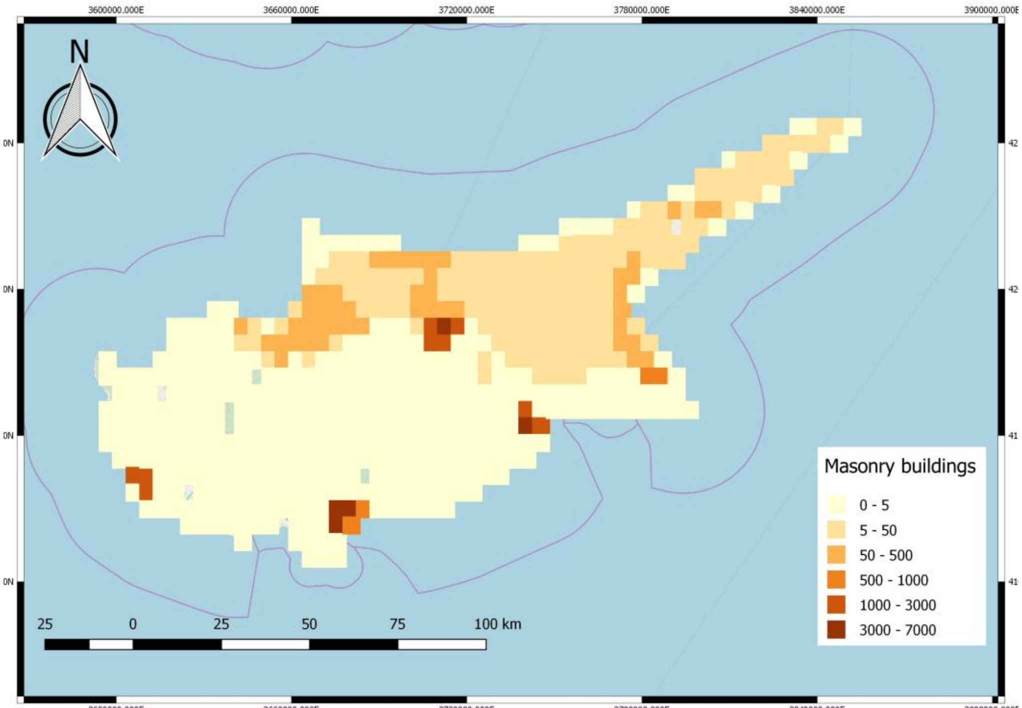


Figure 4.17. Distribution of number of masonry buildings

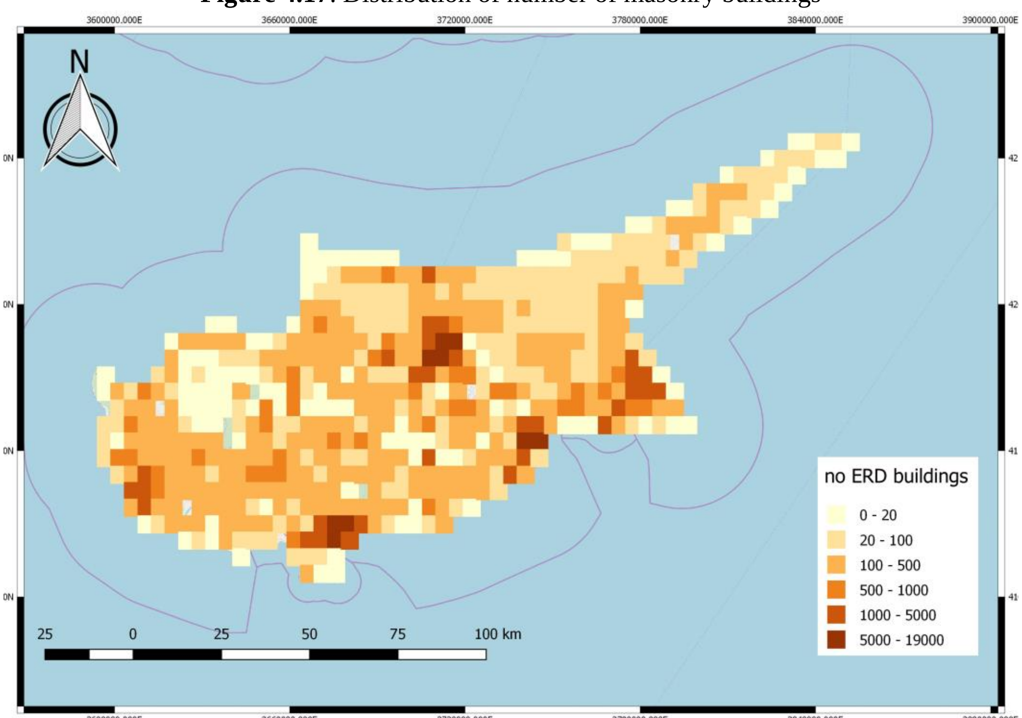


Figure 4.18. Distribution of buildings without ERD codes

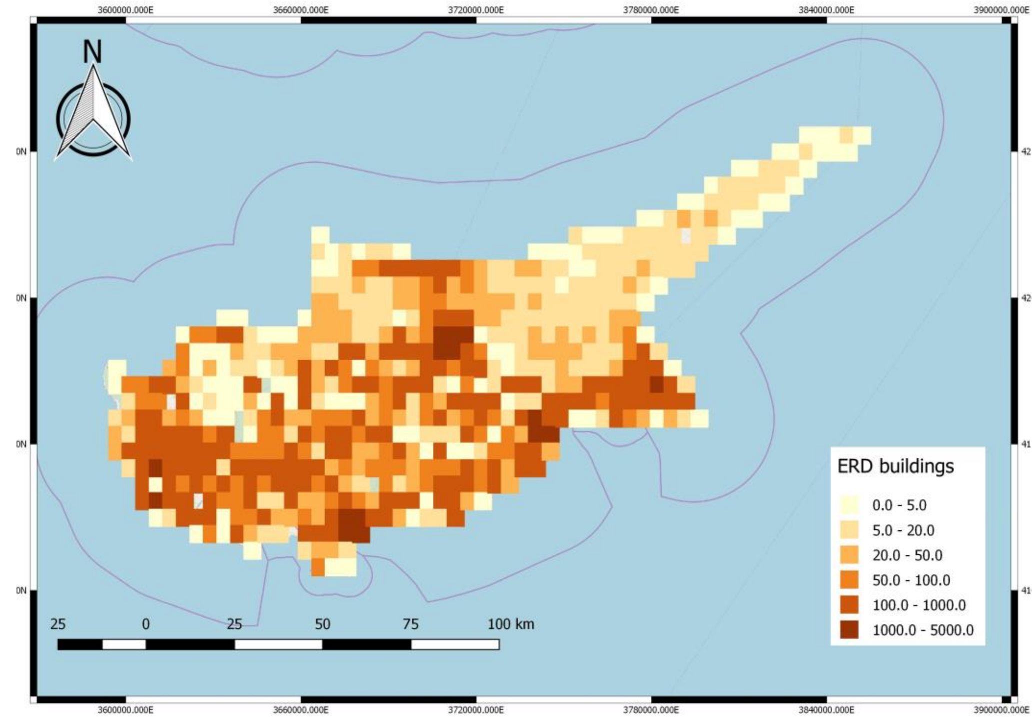


Figure 4.19. Distribution of buildings with ERD codes

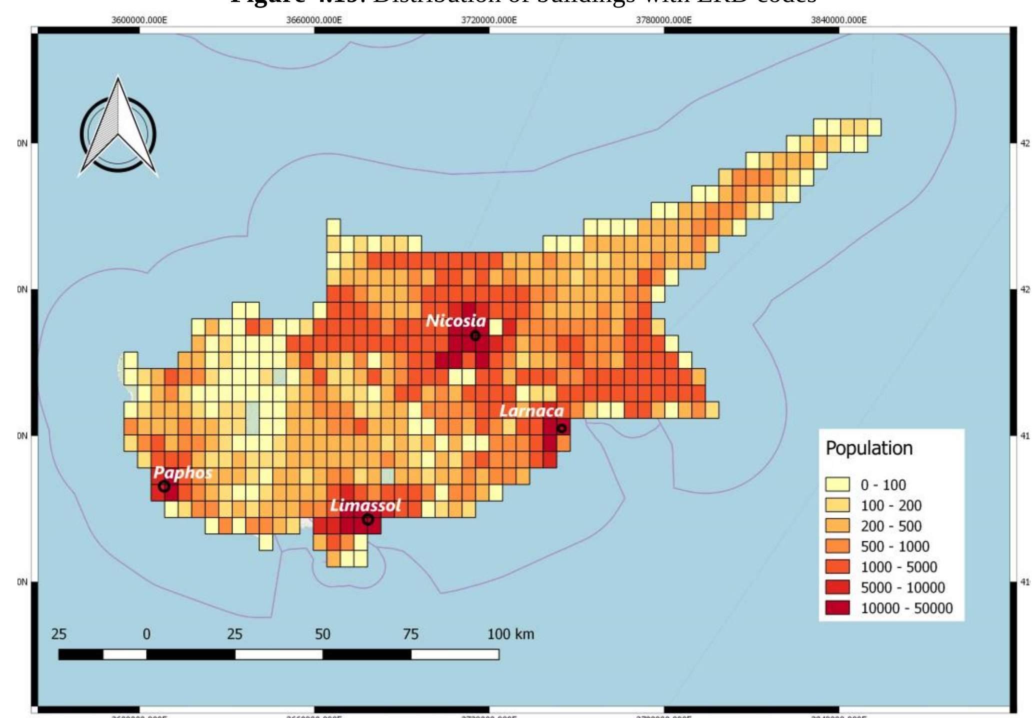


Figure 4.20. Distribution of permanent population

Physical (structural) vulnerability model

The structural vulnerability, being defined as the expected resistance of a structure or a structural typology when exposed to the seismic hazard. It is intrinsic parameter of the structure and depends on its structural, mechanical and geometric characteristics. For the performance of a reliable seismic risk study with probabilistic distribution of loss estimates, it is fundamental to apply a representative vulnerability model. This is expressed by fragility curves or functions (i.e. *continuous relationships expressing the conditional probability that different damage states will be exceeded at specified ground motion levels*), developed in analytical way, as explained below. For the convergence of a set of fragility curves, per structural typology, to a vulnerability curve, consequence functions are employed. The latter, as described below, are composed by damage ratios per damage state, which describe the ratio of cost of repair to cost of replacement, based on empirical data.

Structural fragility functions

For the reinforced concrete buildings, which represent the 83% of the Cypriot building stock, fragility curves analytically derived after the study of Kyriakides et al. (2015) for Limassol buildings, have been employed. These have been developed for low-rise (average height of 2 stories) and high-rise (average height of 7 stories) buildings, with ERD (Eurocodes) and no seismic design. For accounting for building variability within each structural typology, structural characteristics (material strength and detailing) were treated probabilistically using the Latin Hypercube Technique. In total, 60 building models have been simulated and 420 time-history analyses were performed for 7 sets of real acceleration records matched to the acceleration spectra of the 2 seismic zones of Limassol, after the Microzonation study of CGCD (2000).

Initially, fragility curves were first developed in terms of spectral displacement (Sd), by recording the top storey displacement at each damage level, and have been converted to PGA by means of the Limassol spectra (CGCD), considering that their combination with hazard studies in terms of PGA is more common. Hence, and for reasons of their validation with other studies of the same region's literature (Kappos et al., 2003) the latter have been implemented, as listed in Table 4.1. The fragility curves were derived by fitting the mean and standard deviation values of PGA to the lognormal distribution. The Damage States adopted are the following with the described damage thresholds (per Eurocodes) reached during the non-linear analyses. For reasons of compatibility with OpenQuake the wording used herein for the 4 levels of damage has been also marked below.

- **Damage Limitation (DL)** with columns yield rotational capacity (θy) – **Slight (S)**
- **Significant Damage (SD)** with ¾ of column's ultimate rotational capacity (θu) – **Moderate (M)**
- **Near Collapse (NC)** with column's ultimate rotational capacity and shear capacity – **Extensive (E)**

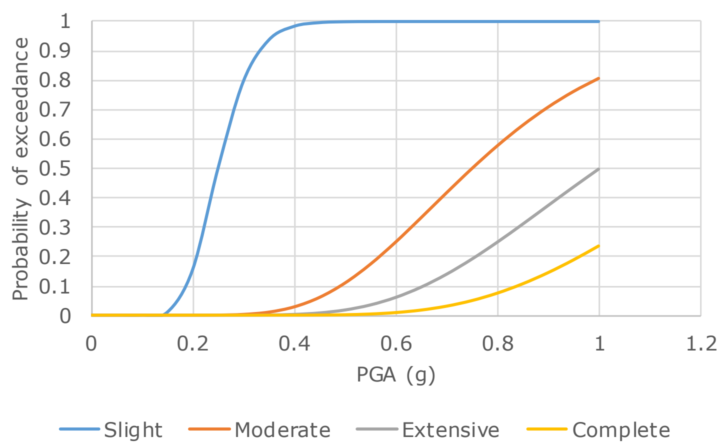
- **Building Collapse (FAIL)** with all columns of a floor reach NC limit or a max inter-storey drift of 4% is reached – **Collapse (C)**

As far as bearing masonry buildings are concerned, in the absence of local studies, it has been decided to make use of curves referenced in literature of the same region, for which engineering expertise demonstrates the existence of similar typology as in Cyprus. Hence, from the GEM/OpenQuake Physical risk Dataset, the analytical fragility curves developed by Ahmad et al. (2010) for the Euro-mediterranean masonry low to mid-rise masonry buildings have been selected. The curves are derived after non-linear static analyses (pushover) of prototype 2D buildings and seismic hazard obtained from 10 natural US accelerograms and IBS-2006 rock acceleration spectra. Uncertainties in lateral stiffness, strength and damage limit states are taken into account through Monte Carlo simulations. They have been derived for 5 damage states, in terms of spectral displacement (Sd) and PGA and for the purposes of their implementation in OpenQuake with the 4-Damage State approach, some transformations have been adopted.

The selected fragility functions have been uploaded to OpenQuake platform after having been included into the GEM/OpenQuake Physical Risk Datasets for Cyprus.

Table 4.1. Mean and standard deviation of fragility curves of all structural typologies implemented in the current study

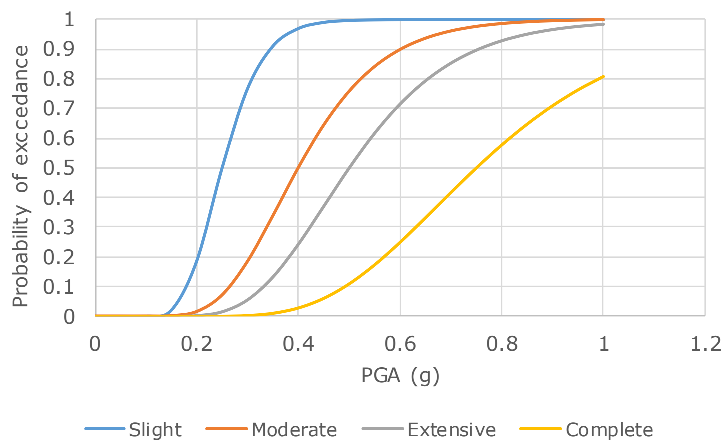
<table>
<tr><th>Typology</th><th></th><th></th></tr>
<tr><td>RC with ERD

Low-mid-rise (Kyriakides et al., 2015)</td><td><table><tr><th></th><th>μ</th><th>σ</th></tr><tr><td>S</td><td>0.25</td><td>0.22</td></tr><tr><td>M</td><td>0.75</td><td>0.33</td></tr><tr><td>E</td><td>1.0</td><td>0.33</td></tr><tr><td>C</td><td>1.25</td><td>0.31</td></tr></table></td><td>
</td></tr>
</table>

RC with ERD

High-rise (Kyriakides et al., 2015)

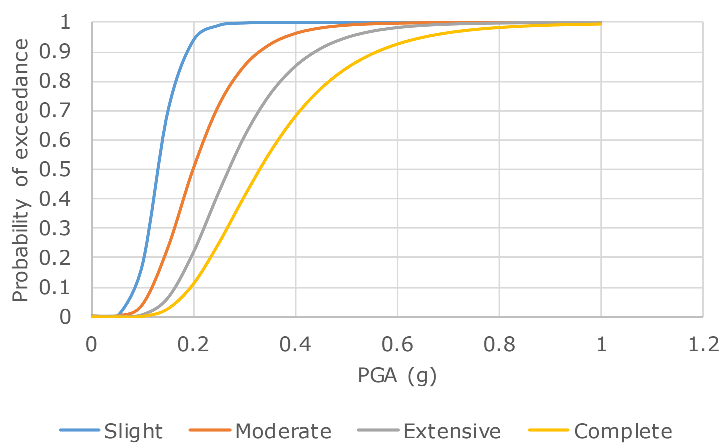
	μ	σ
S	0.25	0.25
M	0.40	0.32
E	0.50	0.32
C	0.75	0.33



RC without ERD

Low-mid-rise (Kyriakides et al., 2015)

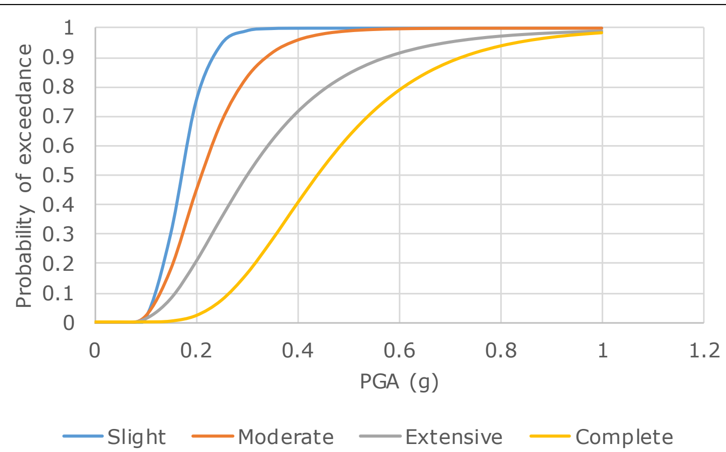
	μ	σ
S	0.13	0.28
M	0.20	0.39
E	0.27	0.38
C	0.33	0.41



RC without ERD

High-rise (Kyriakides et al., 2015)

	μ	σ
S	0.17	0.24
M	0.21	0.37
E	0.30	0.50
C	0.44	0.39



<table>
<tr>
<td>Masonry without ERD

low rise (Ahmad et al., 2010)</td>
<td>
<table>
<tr><td></td><td>μ</td><td>σ</td></tr>
<tr><td>S</td><td>0.25</td><td>0.22</td></tr>
<tr><td>M</td><td>0.75</td><td>0.33</td></tr>
<tr><td>E</td><td>1.00</td><td>0.33</td></tr>
<tr><td>C</td><td>1.25</td><td>0.31</td></tr>
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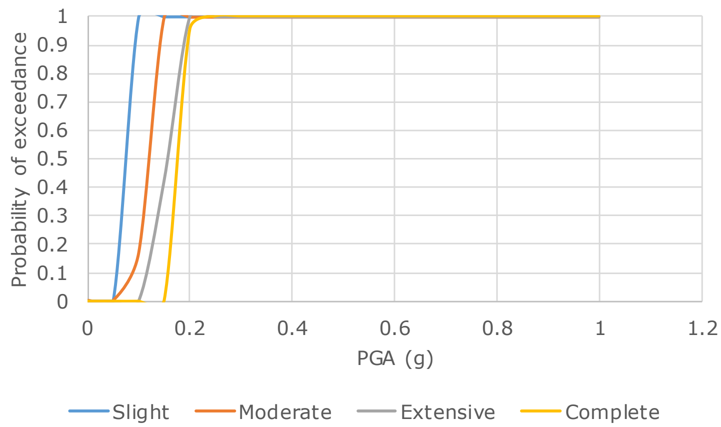
<td>
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Structural vulnerability functions

For the final derivation of vulnerability curves, functions that describe a total loss ratio for each level of intensity measure (here PGA is used), the adoption of a consequence (or damage ratio) model is necessary. The latter expresses the ratio of cost of repair with respect to the cost of replacement for each damage state. This is usually constructed based on damage information claimed by householders in financial terms following a damaging earthquake when requesting financial aid. This data was not easily available at this phase for Cyprus and thus published models by Kappos et al. (2006), based on the Greek reality, have been adopted considering no major discrepancies due to their similarities with the structural typologies (

Table 4.2). The multiplication of the set of fragility curves per structural typology with the damage ratios at each intensity (PGA) level leads to a unique continuous function of loss ratio per intensity measure level per structural typology (Figure 4.21). No coefficient of variation has been assumed.

It is interesting to observe that the no ERD structures present similar response for both low to mid-rise and high-rise buildings while the ERD buildings, with significantly more favourable seismic performance, present discrepancies according to their height. In particular, the high-rise buildings are observed to be more vulnerable due to higher displacement demands. On the other hand, for interpretation of the no ERD structures response, it may be noted that high-rise buildings have construction detailing and dimensions which, as opposed to low-to-mid-rise buildings, enhance their ductile performance and allow for redistribution of the seismic loading.

Table 4.2 RC and masonry damage ratios from Kappos et al. (2006)

	Slight	**Moderate**	**Extensive**	**Complete**
RC	0.05	0.2	0.45	0.8
Masonry	0.12	0.3	0.55	0.85

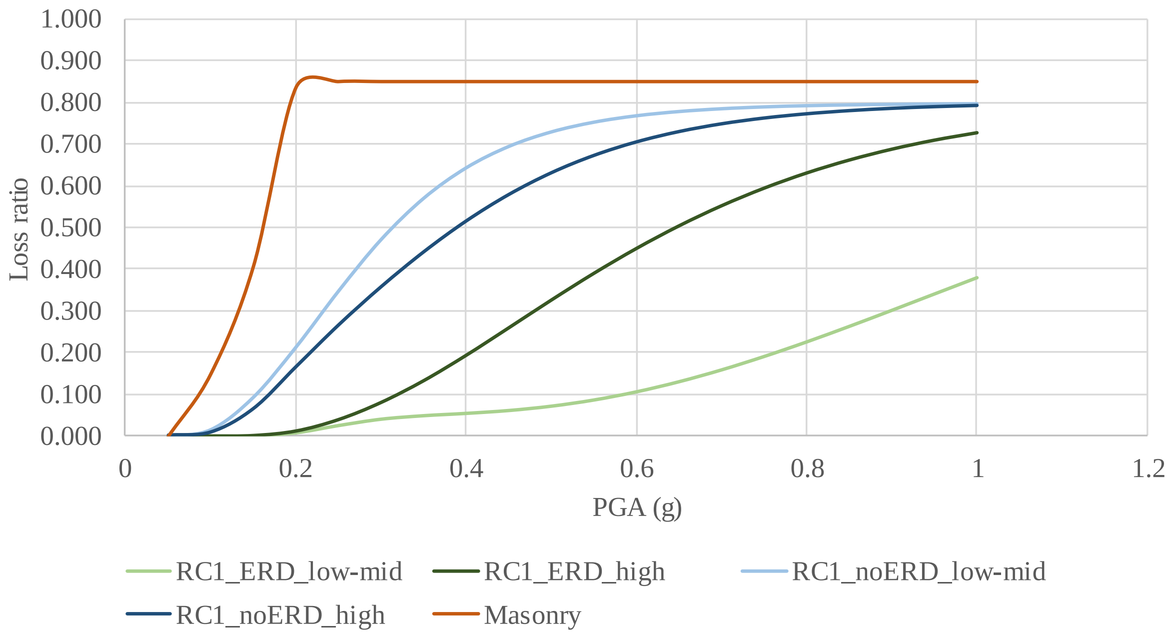

Figure 4.21. Loss functions for all structural typologies

SEISMIC RISK ASSESSMENT

Following the probabilistic hazard analysis that allow us to obtain the seismic hazard outputs, OpenQuake platform gives us the opportunity to perform a variation of probabilistic analysis, the so-called Stochastic event-based analysis. During this, the seismicity of a region is simulated according to the source models by generating *stochastic event sets* (or synthetic catalogue) for a given time span. Simulations are generated with the Monte Carlo (i.e. random) sampling procedure and a stochastic event set comprises a sample of the full population of ruptures. The number of the latter (ruptures generated by a source) depends on the probability distribution sampled by the Monte Carlo simulation or, in other words, the number of occurrences of each one in a time span.

From the stochastic event sets and the associated ground motion fields ("objects describing geographic distribution around a rupture of a ground motion intensity measure"), probabilistic seismic risk analysis takes place and leads to the calculation of loss distribution for individual assets, as well as aggregated loss distribution for all the assets of the exposure model, within a specified time period. For each ground motion field, the intensity measure level at a given site is combined with the predefined vulnerability functions per structural typology, randomly sampling loss ratios for the exposure model. Hence, monetary loss for the structural damage is estimated at asset level (which contains a number of buildings of specific structural typology) and for the entire portfolio for realizations with given probabilities of exceedance. The final loss estimate is deduced after multiplication of the loss ratio with the asset's replacement value.

From the above-mentioned loss output, it is possible to identify the realization and the corresponding earthquake rupture that has the requested probability of exceedance in order to determine seismic scenarios for further study.

Probabilistic loss estimates

Loss exceedance curves (aggregated losses)

Loss exceedance curves represent a list of losses and respective probabilities of exceedance, or the equivalent return periods. The loss exceedance curve is a comprehensive outcome of a probabilistic risk assessment and widely used, as it may provide a loss estimate for any probability of interest (Figure 4.22). In order to obtain a realistic approach for loss estimates within 10000 years, it was deemed necessary to perform stochastic event -based risk analysis for 50,000 years or investigation time of 50 years for 1000 stochastic event sets per logic tree path.

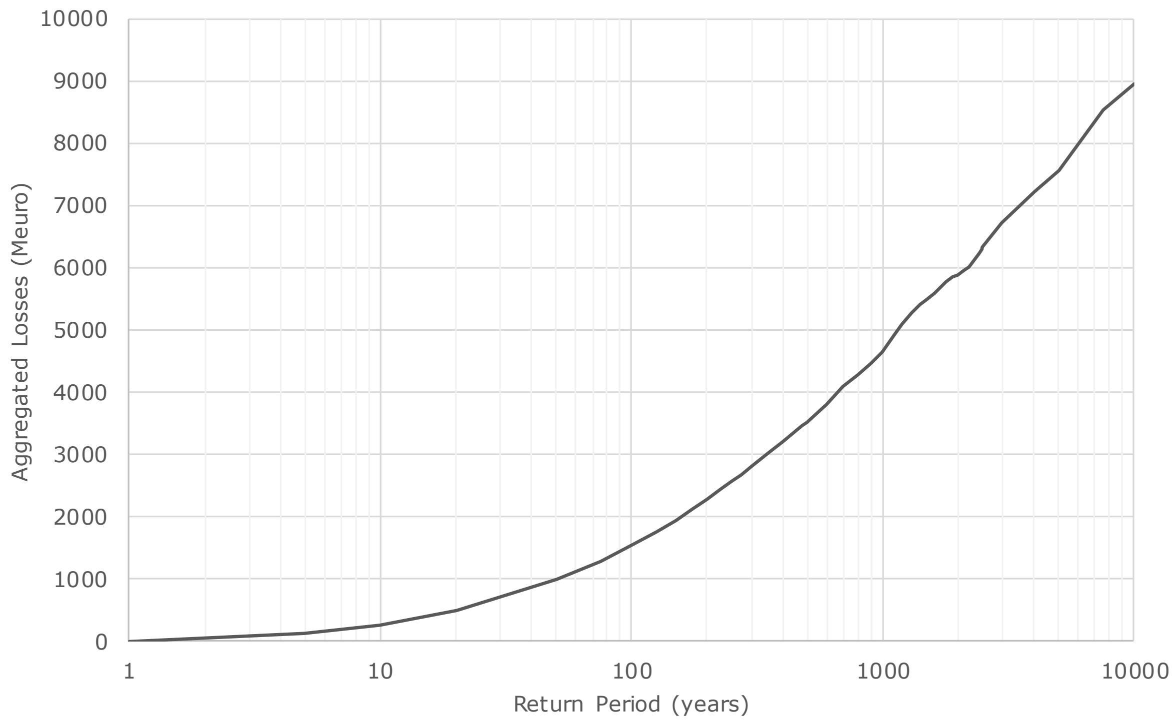

Figure 4.22 Loss exceedance curves

The *loss table* of Table 4.3 below has a list of the expected mean aggregated loss with annual frequency distribution and probability of exceedance within a 50 years time-span. Moreover, for a more comprehensive provision of the results, the return periods are calculated as a result of the Poisson probability model over 50 years. The results for the most interesting probabilities have been highlighted.

It is, therefore, noted that for the design earthquake with **T=475 years** (or 10% probability of exceedance), the expected aggregated mean loss is **3.46 billion euro,** what corresponds to the **14.5% of Cyprus island GDP** (Gross Domestic Product). For **T=2500 years** (or 2% probability of exceedance) the expected aggregated mean loss is **6.3 billion euro**, what corresponds to **26.6% of Cyprus island GDP**.

The mean loss ratio is calculated with normalization of the aggregated loss over the total replacement value of the entire building portfolio (~32 billion euro).

Table 4.3. Aggregated loss table for various return periods

Annual frequency of exceedance	Return period (years)	Probability of exceedance in 50 years	Mean loss (in million euro)	Mean loss ratio
1.00000	1	1.000	0	0.000
0.20000	5	1.000	114	0.004
0.10000	10	0.993	262	0.008
0.05000	20	0.918	497	0.016
0.02000	50	0.632	992	0.031
0.01000	100	0.393	1540	0.048
0.00500	200	0.221	2290	0.072
0.00333	300	0.154	2810	0.088
0.00211	475	0.100	3460	0.108
0.00100	1000	0.049	4660	0.146
0.00050	2000	0.025	5890	0.184
0.00040	2500	0.020	6330	0.198
0.00020	5000	0.010	7570	0.237
0.00013	7500	0.007	8550	0.268
0.00010	10000	0.005	8960	0.281

Average annual loss

By integration of the loss exceedance curves over the risk investigation time (t=50 years), estimation of the average annual loss takes place. This is equal to **116 million** euro, what corresponds to the **0.50% of the island's GDP**.

Moreover, the *average annual loss ratio (AALR)* is computed as the quotient between the abovementioned total loss and total replacement value for the entire portfolio and is estimated equal to **0.36%**. **Table 4.4** lists the aggregated average annual loss for the entire island and for the major cities (the assumption of two grid cells for all cities was adopted for compatibility). Limassol presents the highest expected annual loss due to both its increased seismic hazard and exposed buildings value. Moreover, the population exposed to the corresponding seismic risk (here structural loss) is also listed. It is interesting that Nicosia's exposed population is almost as high as Nicosia's for significantly lower average annual loss, what is explained by the high population density of Cyprus capital.

Table 4.4. Average annual loss (in euro) and corresponding exposed population

	Total	**Nicosia**	**Larnaca**	**Limassol**	**Paphos**
AAL	116,176,893	6,677,008	8,709,120	12,328,240	8,672,600
Population	1,022,406	50,072	37,232	54,248	33,643

Figure 4.23 illustrates the disaggregation of the total average annual loss per structural typology and Figure 4.24 the disaggregation of average annual loss ratio per structural typology. The latter has been computed over the total replacement value assumed per typology. From both Figures, it is evident that masonry and no ERD low to mid-rise buildings contribute the most to the total average annual loss being the most vulnerable typologies. This is even more evident from Figure 4.24. The latter typology corresponds also to the largest building population what places it on top of the overall loss contribution ranking (Figure 4.23). No observation of spatial correlation of specific typologies with increased seismic hazard can be made.

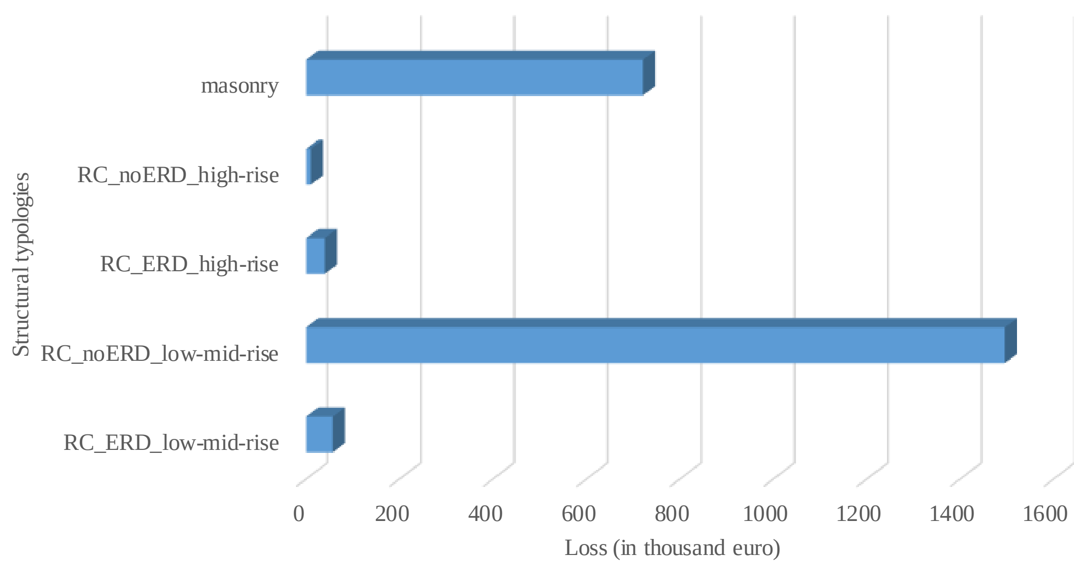

Figure 4.23. Disaggregation of average annual loss per structural typology

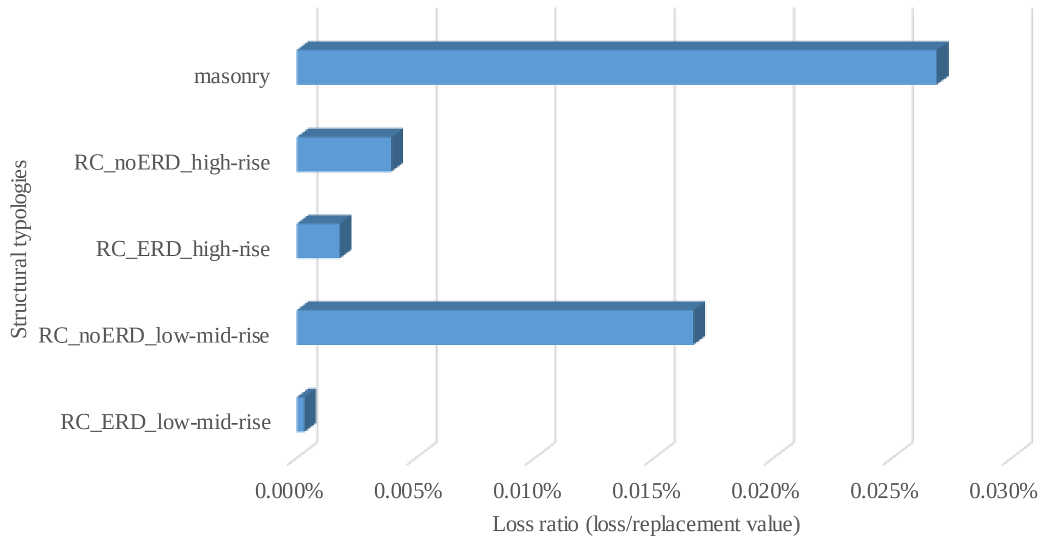

Figure 4.24. Disaggregation of average annual loss ratio per structural typology

Loss maps (Distributed losses)

The probabilistic loss maps below (Figure 4.25, Figure 4.26) contain the aggregated average losses per grid that have a specific probability of exceedance within a 50 years time-span throughout the region of interest. As expected, the spatial loss distribution does not change for the two return periods and highest loss is concentrated at the big cities, although the hazard is not equally distributed. It is noted that Limassol presents the highest expected loss while the affected area of Nicosia is more expanded as opposed to Paphos and Larnaca.

The graphs of Figure 4.27 and **Figure 4.28** demonstrate the disaggregation of total average loss and loss ratio per structural typology for the two return periods. Results are compatible to what discussed about the average annual loss and the highest contribution of loss is attributed to the no ERD low to mid-rise buildings (for total loss) and masonry (for loss ratio). It is characteristic that for both return periods the loss ratio for masonry buildings exceeds 50%, what, in a simplified way, means that for the potential seismic event with 10% probability of occurrence in 50 years, the expected damage to the masonry building stock could lead to the loss of more than 50% of its total structural value.

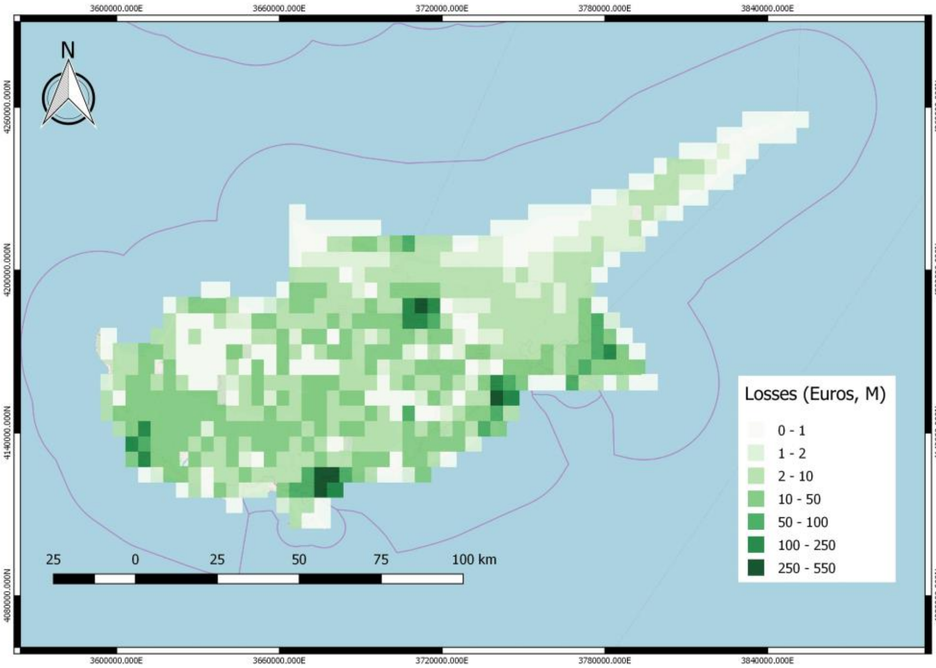

Figure 4.25. Loss map (in million euro) for 10% probability of exceedance in 50 years (T=475 years)

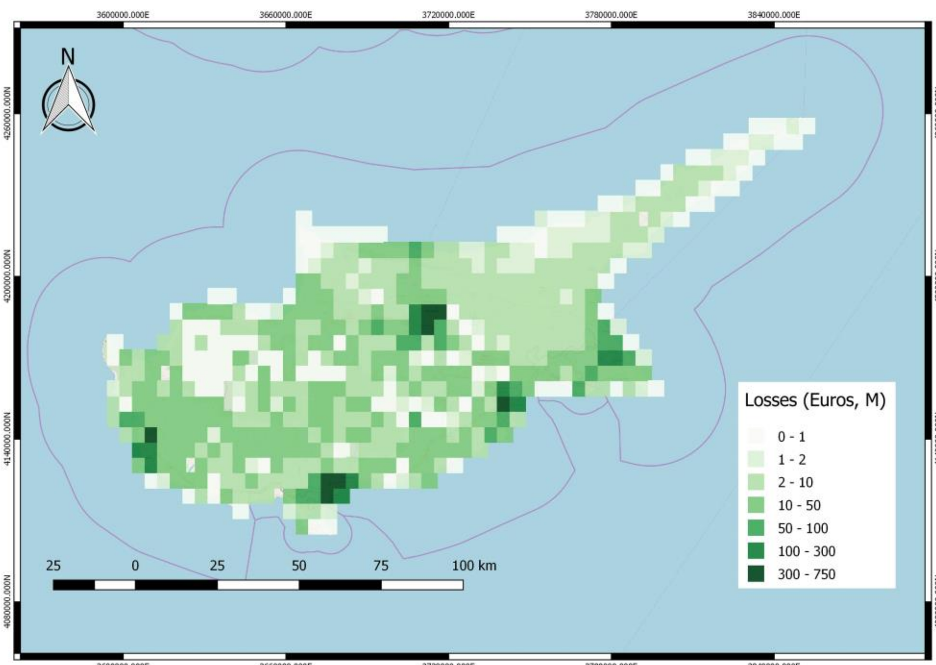

Figure 4.26. Loss map (in million euro) for 2% probability of exceedance in 50 years (T=475 years)

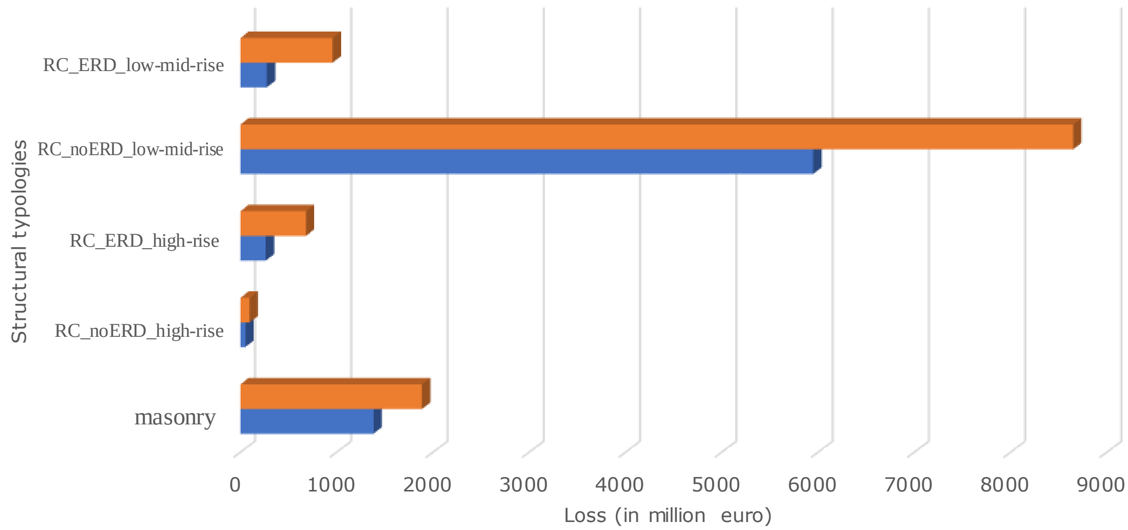

Figure 4.27. Loss per structural typology with 10% and 2% probability of exceedance in 50 years (T=475 and 2500 years)

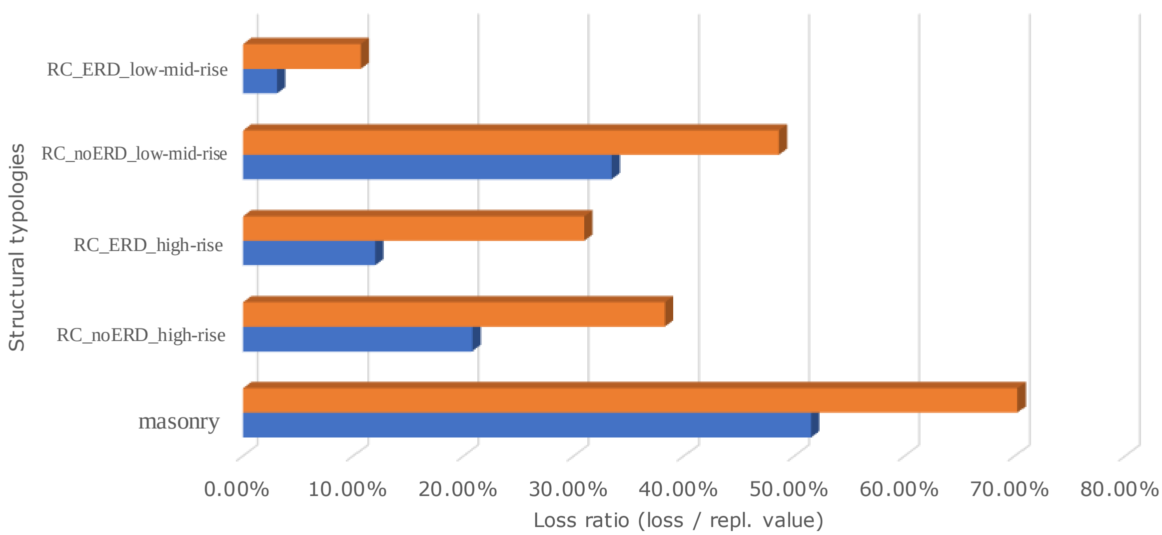

Figure 4.28. Loss ratio per structural typology with 10% and 2% probability of exceedance in 50 years (T=475 and 2500 years)

SCENARIO-BASED RISK ANALYSIS

Two seismic scenarios have been analysed. The first has probability of occurrence 10% in 50 years (or return period of 475 years), leading to aggregated loss with 10% probability of exceedance. The second one has 2% probability of occurrence (or return period of 2500 years) with loss with respective probability of exceedance. The selection of the earthquake ruptures has been randomly made among all the different realizations (15) of the stochastic catalogue. The GMPE that was decided to be implemented was that of Akkar and Bommer (2010) following the recommendation of Cagnan and Tanircan (2010). Each scenario was performed for a number of 1000 ground motion fields (for different ruptures within the fault).

In **Figure 4.29**, the geometry of the simulated faults and the hypocenter of the rupture, with the given probability of occurrence, are projected on the earth's surface on the island of Cyprus. The fault geometry and characteristics and the rupture magnitude of the selected events are summarized in **Table 4.5**.

Figure 4.29. Projected geometry of faults of seismic scenarios on the island of Cyprus (green line depicts top edge of the fault plane, red line bottom edge)

Table 4.5 Characteristics of earthquake ruptures for seismic scenarios

Return period	**Fault geometry**	**Fault characteristics**	**Rupture magnitude**
T = 475 years	<topLeft lon="33.3458862"	Strike: 294.757 deg Dip: 32.353 deg	Mw = 6.9

	lat="34.6093445" depth="6.5558157"/> <topRight lon="33.0992165" lat="34.7026100" depth="6.5558157"/> <bottomLeft lon="33.4420662" lat="34.7806168" depth="19.8441849"/> <bottomRight lon="33.1949921" lat="34.8740730" depth="19.8441849"/> Length: 50km Hypocenter Lat: 34.741734 Lon: 33.270561 Depth: 13.2km	Rake: 0 deg	
T = 2500 years	<topLeft lon="32.6790581" lat="34.6694412" depth="0"/> <topRight lon="32.2133713" lat="35.1708832" depth="0"/> <bottomLeft lon="32.9856491" lat="34.8597031" depth="30"/>	Strike: 322.444 deg Dip: 40.522 deg Rake: 0 deg	Mw = 7.7

	<bottomRight lon="32.5207596" lat="35.3623161" depth="30"/> Length: 140 km Hypocenter Lat: 35.004456 Lon: 32.581825 Depth: 13.2km		

Monetary loss outcome

The total average aggregated loss for the T=475 years scenario is **7.71 billion euro** and for the T=2500 years scenario is **9.37 billion euro**.

Figure 4.30 depicts distribution of the aggregated loss per grid for the T=475 years scenario. Considering the vicinity of the fault to Limassol (Figure 4.29) and the high exposure value, Limassol and its surroundings is the most heavily affected area.

Figure 4.31 illustrates the spatial distribution of the number of buildings that has reached the damage state Collapse for the selected seismic event with 10% probability of occurrence in 50 yeras. It is interesting that although the monetary loss is mainly concentrated in the big cities, heavily damaged building ("Collapsed") are encountered throughout the southwestern Cypriot territory as well as in the surroundings of Nicosia. As previously discussed, old masonry and RC buildings are present throughout the island, they are vulnerable, yet with low individual contribution to the total loss due to their small area and height and low replacement value compared to the newer structures.

As far as the "bigger" scenario is concerned with 2% probability of occurrence in 50 years, **Figure 4.32** and **Figure 4.33** illustrate the corresponding spatial distribution of loss and collapsed buildings. It may be noticed that the affected areas are shifted to the western part of the island, compatible to the faults trace location. Although the maximum absolute number of collapsed buildings is lower, they are encountered in much wider zones than in the previous scenario. Moreover, although the number of collapsed buildings may not change significantly, more important levels of damage are observed to a larger amount of structures. Hence, high losses cover a wider part of the grid, especially towards the West, where Paphos is located.

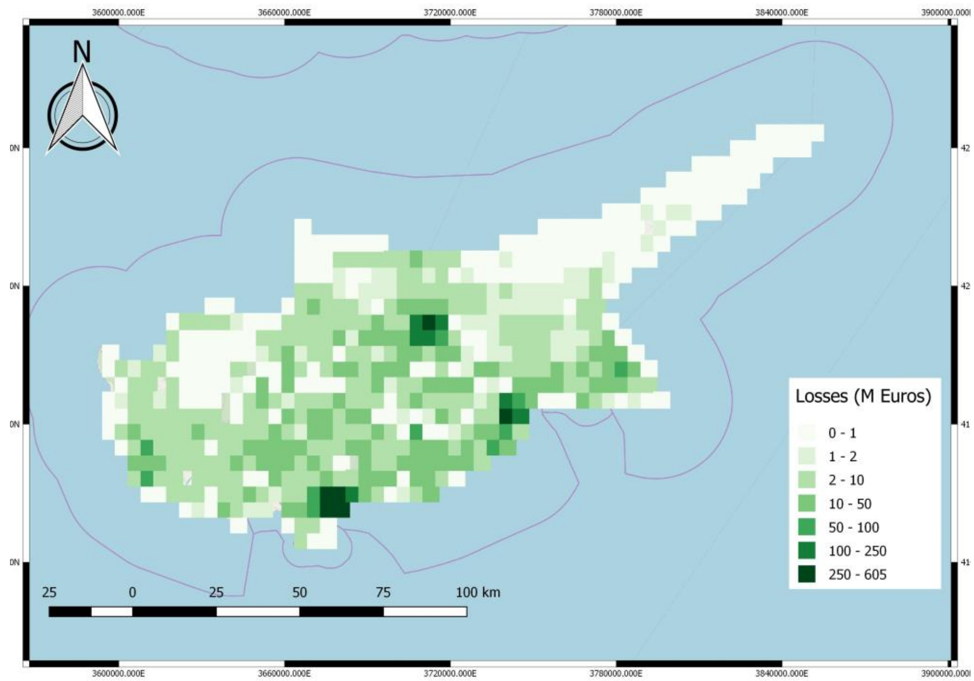

Figure 4.30. Loss map (in million euro) for seismic scenario with 10% probability of occurrence in 50 years (T=475 years)

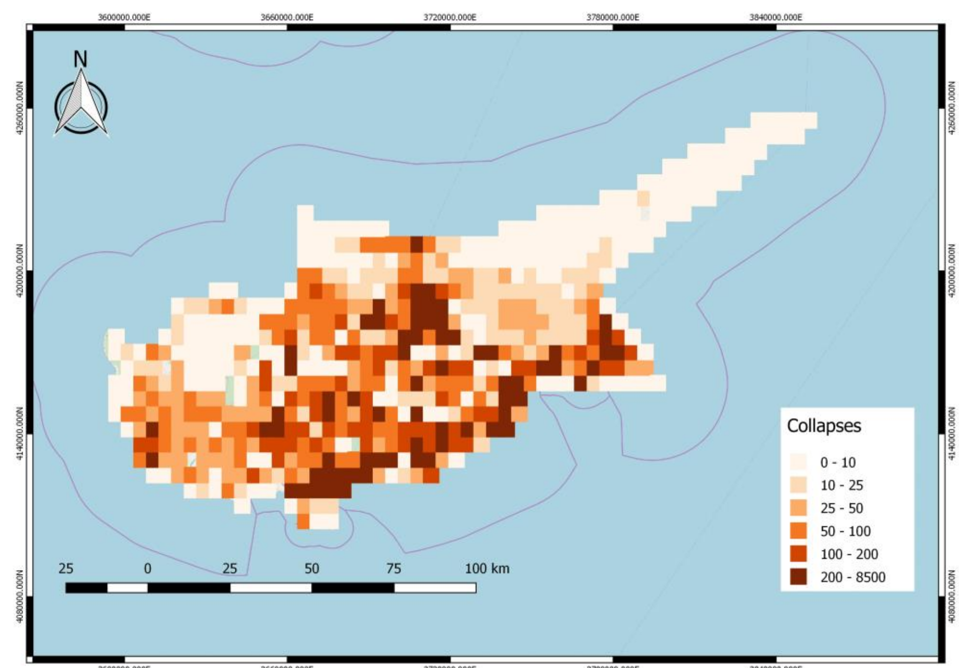

Figure 4.31. Collapse map (in number of buildings) as a result of damage assessment for a seismic scenario with 10% probability of occurrence in 50 years (T=475 years)

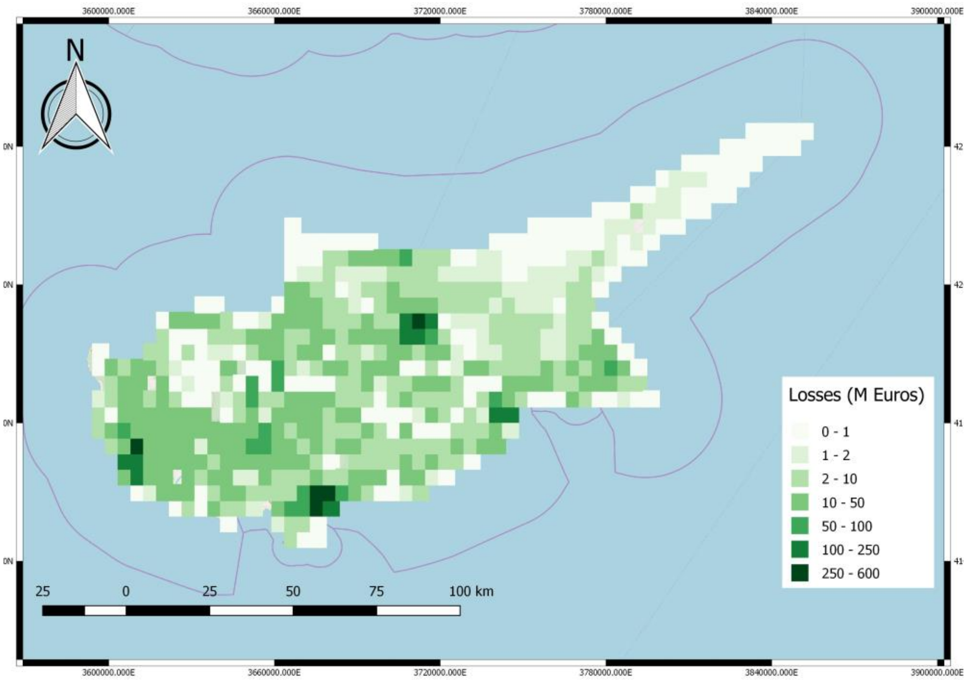

Figure 4.32. Loss map (in million euro) for seismic scenario with 2% probability of occurrence in 50 years (T=2500 years)

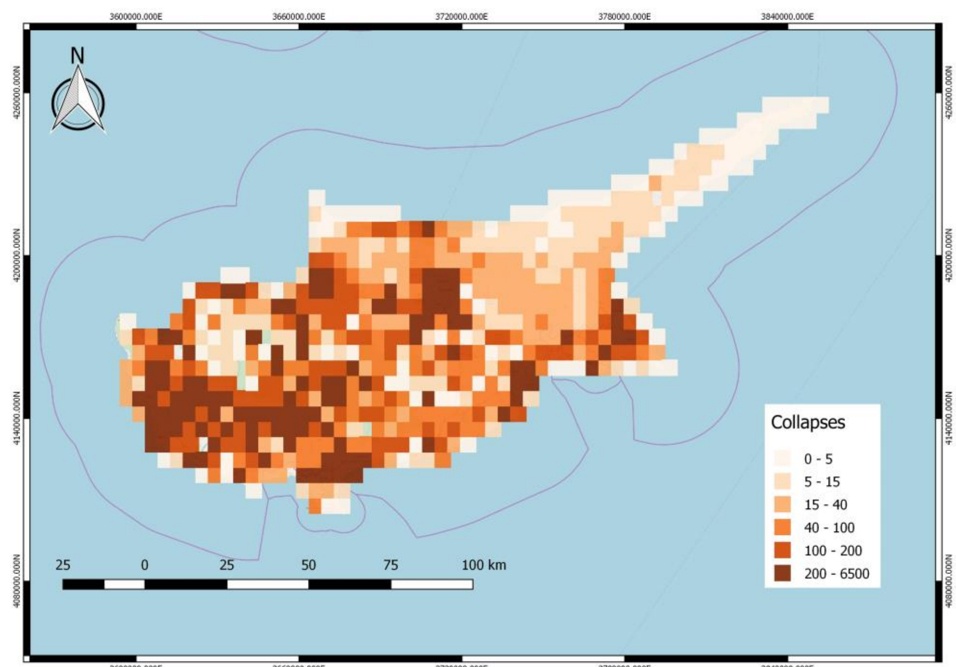

Figure 4.33. Collapse map (in number of buildings) as a result of damage assessment for a seismic scenario with 2% probability of occurrence in 50 years (T=2500 years)

Figure 4.34 and Table 4.6 demonstrate the number of buildings that suffer from different damage states for the two analysed seismic scenarios. In addition, **Table 4.6** marks also the ratio of buildings over the total building stock. It is interesting to notice that the 25.64% and the 32.37% of the total building stock for the T=475 and the T=2500 years scenario, is expected to reach the "Collapse" damage state, respectively. Moreover, the 40.07% and 32.19% is expected to present no damage.

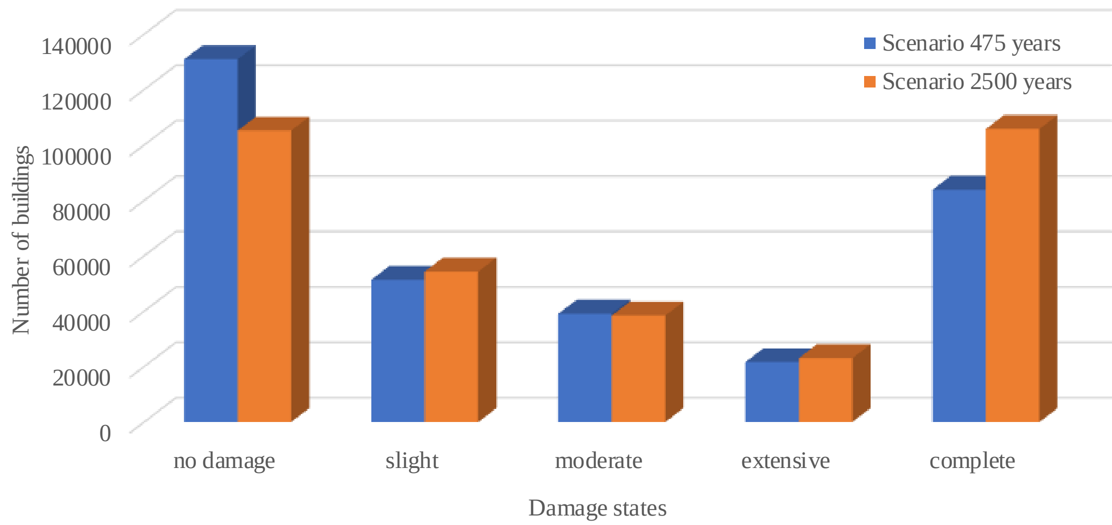

Figure 4.34. Distribution of number of buildings per damage state for the two studied scenarios

Table 4.6 Number and ratio of buildings per damage state for the two studied scenarios

	T = 475 years		**T = 2500 years**	
	Number of buildings	**Ratio**	**Number of buildings**	**Ratio**
no damage	130,954	40.07%	105,193	32.19%
slight	513,45	15.71%	54,317	16.62%
moderate	39,099	11.96%	38,450	11.76%
extensive	21,621	6.62%	23,069	7.06%
complete	83,812	25.64%	105,801	32.37%

The disaggregation of the damage outcome per structural typology (Figure 4.35, Figure 4.36) provides observations for further analysis and indications for potential targeted interventions. Hence, for both scenarios, the majority of "collapsed" buildings are encountered in the masonry and no ERD low-to-mid-rise typology, and especially to the latter one which has the highest building population. This is even clearer with the graph of **Figure 4.37** which depicts the ratio of collapsed buildings per structural typology. It is evident, therefore, that for both scenarios for the masonry and the no ERD low-to-mid-rise typologies, more than 30% of their stock is expected to present damage at the level of collapse.

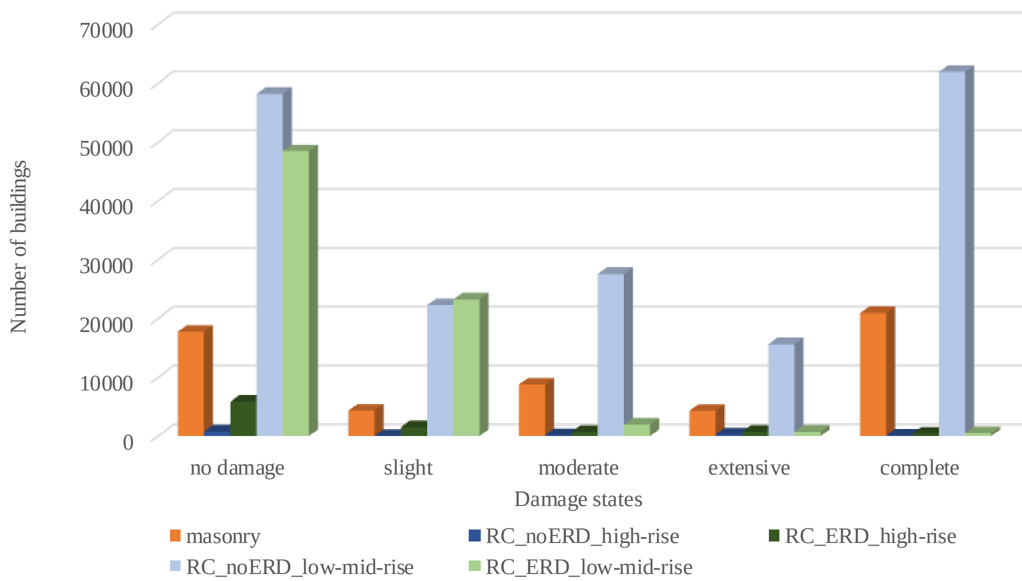

Figure 4.35. Disaggregation of damaged buildings per damage state and structural typology for seismic scenario with T=475 years

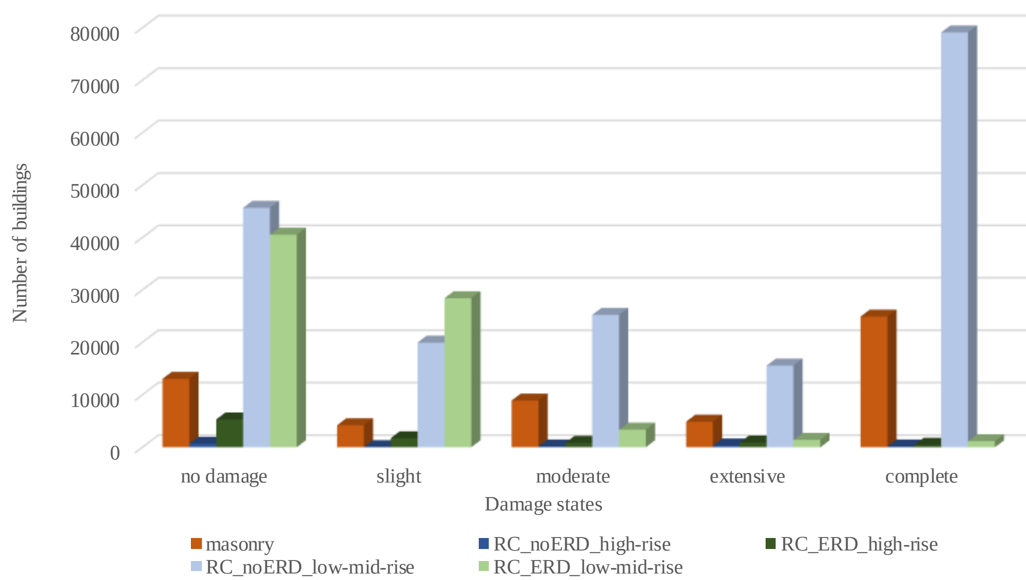

Figure 4.36. Disaggregation of damaged buildings per damage state and structural typology for seismic scenario with T=2500 years

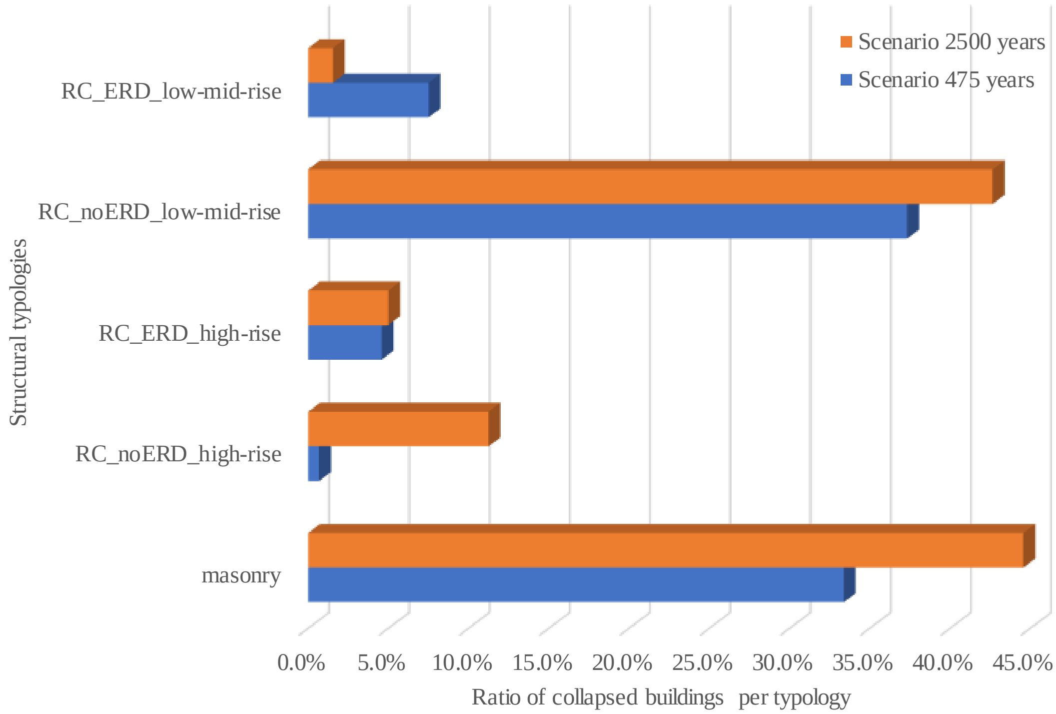

Figure 4.37. Ratio of collapsed buildings over total number of buildings per typology for the two studied scenarios

The presentation of results with the ratio of damaged buildings per the total stock per structural typology provides more representative results of the typological performance for each scenario. For the T=475 years and T=2500 years scenarios of **Figure 4.38** and Figure 4.39, it is evident that more than 30% and 40%, respectively, of masonry and no ERD low-to-mid-rise buildings are expected to reach the “Collapse” state, while a significant ratio of more than 20% of no ERD high-rise buildings presents extensive damage at the 2500 years scenario. It is interesting, moreover, that around 20% of ERD low-to-mid-rise buildings and 10% of ERD high-rise buildings are estimated to suffer from moderate and extensive damage according to the 475 and 2500 years scenario, respectively. This variation may be attributed to the spatial distribution of the building typologies since the main impact zone of the two seismic events varies.

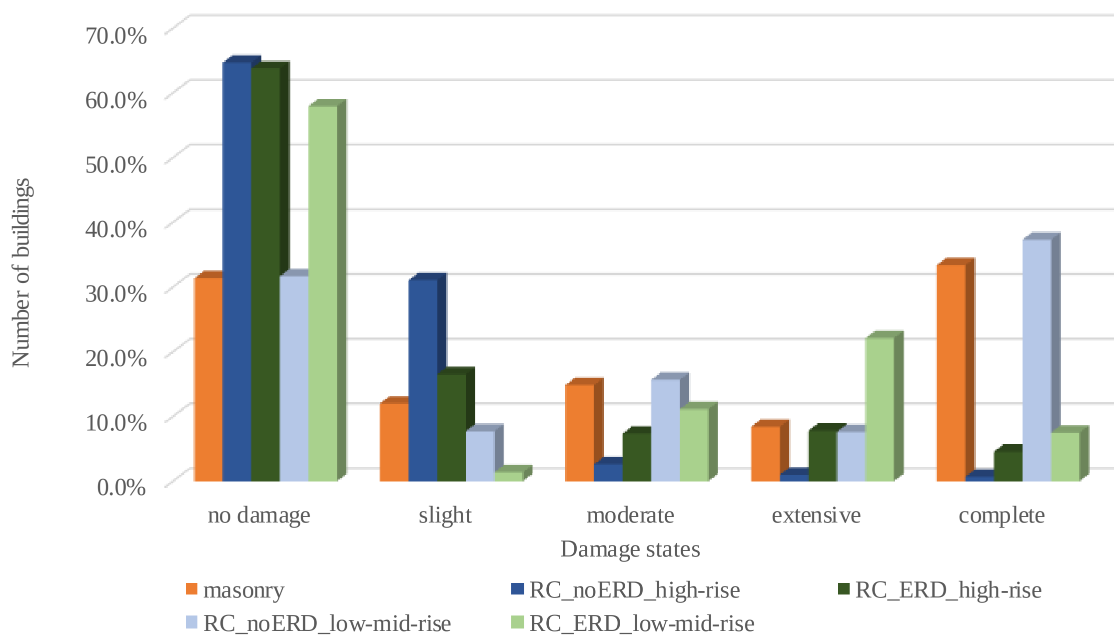

Figure 4.38. Disaggregation of ratio of damaged buildings per damaged state and structural typology for seismic scenario with T=475 years

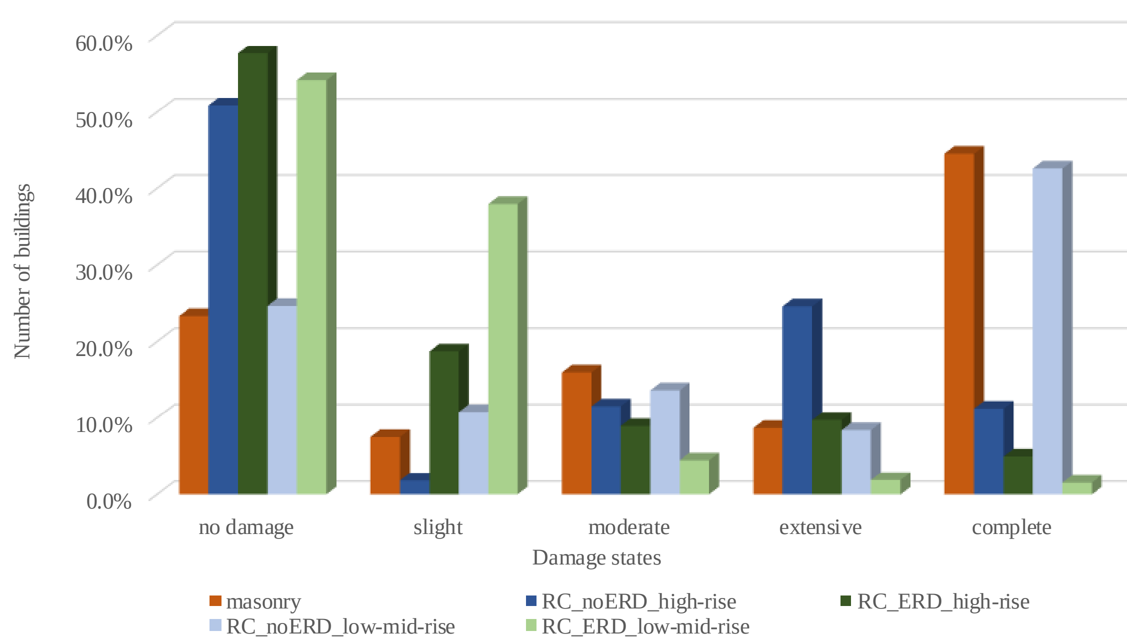

Figure 4.39. Disaggregation of ratio of damaged buildings per damaged state and structural typology for seismic scenario with T=2500 years

Human loss outcome

For the seismic scenarios, risk in terms of human loss has been also estimated in order to obtain a number of affected population to be elaborated as order of magnitude for disaster management purposes. This estimate is valuable for preparedness of the Civil Defence and municipalities for healthcare capacities, short and long-term accommodation, emergency response and relevant budget allocation.

Casualties (fatalities)

For the human casualty modelling (fatalities) the model of Coburn and Spence (2002) has been adopted with the values for the parameters as proposed by Spence for Thessaloniki case study (Greece) within LESSLOS project (Spence, 2007). This model enables the straight correlation of casualties with the vulnerability of the buildings, other than their use. Given the predominant presence of RC building, the coefficients corresponding to this typology have been adopted for all building blocks. The casualties (fatalities) have been separately estimated for day and night time, considering 80% of residential buildings and 20% of non-residential. An equivalent casualty model has been computed from which, in combination with "Complete" fragility curves, new fatality-related vulnerability curves were derived for each typology and uploaded to OpenQuake software. The base model is:

$$K_S = [M_1 \cdot M_2 \cdot M_3 \cdot (M_4 + M_5 \cdot (1 - M_4))]$$

Where:

M_1: the occupancy rate per building block (number of people / m^2 of building area). Here it is adopted equal to 0.025, mean proposed value for Thessaloniki (thus 40 m^2 per inhabitant, for simplification equal for all typologies.

M_2: a coefficient that depends on the use of the building at the time the earthquake strikes.

It is taken equal to 0.49 for day time and 0.70 at night time, assuming 80% residential buildings and 20% non-residential. Occupancy rates of 40% for residential building in day time and 75% for non-residential is assumed. Similarly, 75% for residential and 40% for non-residential buildings is assumed for night-time. Further investigation could be made based on actual statistical data, what has been though out of the scope of the present study.

M_3: ratio of inhabitants trapped in the building due to collapse, given "Collapse" state. This parameter is based on empirical data and an average value of 0.18 is adopted for the 475 years scenario and 0.26 for the 2500 years scenario.

M_4: the coefficient that correlates collapse with fatalities (dead or unsavable), taken for RC buildings equal to 0.4 and for masonry equal to 0.1, based on empirical casualty data and building collapse mechanisms

M_5: stands for the mortality due to collapses, taken as 0.7 for RC buildings and 0.45 for masonry buildings, again based on empirical statistical data.

Casualties (injuries)

The scope of this module is to provide an estimation of non-fatal casualties, or injuries in need of a greater degree of medical care and in need of transition to healthcare facilities. The availability of health-care structures in case of a strong seismic event can be, thus, studied so as to be guaranteed. The model adopted herein is the one proposed by HAZUS (1999) for indoor casualties and it has been applied only for Injury Severity 2. Hence, the casualty event tree described by HAZUS (1999) has been trimmed for estimation of Severity 2 injuries, to which all the branching probabilities (all four fragility curves) contribute:

$$P_{Sev.2} = [P(ds_{\_S})*P_{Sev,2\_S} + P(ds_{\_M})*P_{Sev,2\_M} + P(ds_{\_E})* P_{Sev,2\_E} + P(ds_{\_C})*P_{Sev,2\_C}] * M_2$$

The casualty rates ($P_{Sev,2\_i}$) for each damage state (i) is given in Table 4.7 and P(ds_i) refers to the fragility function per damage state. The M2 coefficient, to account for occupancy rates at residential and non-residential buildings, differentiating day and night-time, has been equally adopted after engineering judgment which allowed the variation of the initial model.

Table 4.7 Casualty rates per severity level and damage state (DG)

	Slight (%)	Moderate (%)	Extensive (%)	Collapse (%)
Reinforced Concrete	0.0	0.03	0.10	1.0
Masonry	0.0	0.10	0.20	2.0

The expected number of occupants injured per Severity 2 or in fatal state ($EN_{occupants}$) is a product of the number of occupants per asset at the time of earthquake (day-time, night-time) ($N_{occupants}$) and their probability of being injured ($P_{Sev,2}$) computed as vulnerability curves in loss human ratio terms. The population included in the input file refers to the total registered population per asset, as given by the 2011 Census and elaborated by Chrysostomou et al. (2014).

$$EN_{occupants\_Sev,i} = N_{occupants} * P_{Sev,2}$$

Displaced population

Earthquakes can cause loss of function or habitability of buildings, as described by the damage grades classification. The estimation of the affected number of population that would need to be displaced provides useful figures (order of magnitude) to stakeholders for anticipation of post-disaster provisions and/or evacuation planning. The households in need of housing are distinguished in those seeking for short-term public shelter at the immediate post-disaster phase and the long-term displaced ones, due to loss of habitability of their homes (red and yellow-tagged buildings). In the current study, the shelter model of HAZUS (1999) has been applied with proper engineering judgment and omission of American-based coefficients only for the long-term displaced population. This refers to the estimated number of inhabitants that would seek for accommodation for a period of several months since their residents are in need of major repairing or rebuilt, due to extensive damage.

The estimated amount of people expected to remain displaced "long-term", due to severe damage or collapse of their residences, is computed from the probabilities of reaching damage states Extensive and Collapse (fragility curves). The population of the exposure model refers to the permanent population per the 2011 Census, irrespectively of the occupancy, occupancy rate and time of the day.

$$\#DP_L = \{p[ds_{\_\mathrm{E}}] + p[ds_{\mathrm{C}}]\} \cdot Population$$

HAZUS (1999) suggests reduction coefficients to be applied upon the above-estimated numbers, with weight factors based mainly on US reality (ethnic, income, ownership, age considerations). In the current study, these weight coefficients have been omitted but, reference is made to the contribution of social vulnerability to the final estimate.

Based on past experience registered in Gountromichou et al. (2017b) as part of PACES Project, the estimated ratio of the affected population that would seek for long-term public accommodation strongly depends on the economic, age and cultural background of the homeowners. For example, in Emilia Romagna (Regione Emilia Romagna, 2012) only 40% of the evacuated population were housed in tent camps as a large amount of the displaced people has arranged their alternative housing by themselves. Moreover, alternative accommodating structures are often offered (hotels, ships or trains). Finally, the final number will reduce throughout the time, in function to the seasonal weather, age and culture of affected population, geographical location and economic background. It is characteristic that 2 months after Emilia's earthquake, only 30% of the initial hosts remained in tent camps and only 19% were still in need of housing after 5 months.

Considering the above-mentioned, the Cypriot mentality and family bonds, the possibility of ships to be used as floating residents and the large amount of touristic lodges, the 50% of the estimated displaced population is expected to be in need of public sheltering in tents or other portable structures.

In **Table 4.8**, the numbers of fatalities, injuries (severity 2) and long-term displaced population have been listed for the major cities, as emergency and post-disaster management primarily takes place at municipality level. Again, it is underlined that the figures should be taken into account for disaster management purposes as per order of magnitude. For the interpretation of the results, the loss maps of **Figure 4.30** and **Figure 4.32**, being the most comprehensive outcome of structural risk assessment, should be combined with the population distribution map of Figure 4.20 and map of Figure 4.29 which depicts the trace location of the causative faults for the two scenarios.

As far as the 475 years scenario is concerned, triggered by the activation of a WNW-ESE fault, dipping NNE, in the vicinity of Limassol, leads to about 40 fatalities, for day or night scenario, few hundreds of injuries and around 12,000 potentially long-term displaced residents, in Limassol city and its surroundings. The 2500 years scenario, with a 140m long NW-SE fault dipping NE, located towards the western part of the island, affects less Limassol, yet high numbers are also encountered in this area due to the population and buildings density. Paphos, is the most affected city for this scenario, being in the vicinity of the causative fault, with 30 to 45 fatalities, several dozens of injuries and around 9,000 of displaced people. Nicosia, also, presents a significant number of displaced population for both scenarios, ranging between 3,000 and 4,000, due to its population density, while the injuries, ranging between 30 and 60 people, are considerable numbers. Finally, Larnaca seems to be more affected by the 475 years scenario with 7-10 fatalities, 25-60 injuries and around 3,400 potentially displaced population.

It is noted, that due to the dimensions of the grid cells (1x1km^2) and the intention to keep a compatible approach for all cities, two grid cells per city have been considered, including the city center and some surroundings. Hence, any differences from reported cities population are justified.

Table 4.9 presents also the ratios of the affected population with respect to the exposed population in the same cell grids. Although the absolute numbers are more useful for disaster management and preparedness purposes, these relative figures provide a more representative picture of the extent each city is affected by each seismic event.

In **Table 4.8**, the total affected population of the island is also marked. It may be, thus, commented that, given the high numbers for all scenarios, exceeding by far the summation of the major cities, it is evident that casualties and displaced population is well dispersed throughout the island. These aggregated numbers are useful for centralized administration of the prevention and response of the national seismic risk strategy.

Table 4.8 Affected population for the two seismic scenarios

Cities	**Fatalities**				**Injuries**				**Displaced**	
	475 years		2500 years		475 years		2500 years		475 years	2500 years
	Day	Night	Day	Night	Day	Night	Day	Night		
Nicosia	6	8	12	17	22	51	30	68	3,003	3,996
Larnaca	7	10	4	5	26	60	10	25	3,412	1,404

Limassol	34	48	29	41	110	219	69	146	12,973	8,456
Paphos	1	1	31	45	3	10	78	176	498	8,973
Total	217	313	381	545	736	1493	878	1778	93,276	110,415

Table 4.9 Ratio of Affected population for the two seismic scenarios

Cities	**Fatalities ratio (%)**				**Injuries ratio (%)**				**Displaced ratio (%)**	
	475 years		**2500 years**		**475 years**		**2500 years**		**475 years**	**2500 years**
	Day	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**		
Nicosia	0.01	0.02	0.02	0.03	0.04	0.10	0.06	0.14	6.00	7.98
Larnaca	0.02	0.03	0.01	0.01	0.07	0.16	0.03	0.07	9.16	3.77
Limassol	0.06	0.09	0.05	0.08	0.20	0.40	0.13	0.27	23.91	15.59
Paphos	0.00	0.00	0.09	0.13	0.01	0.03	0.23	0.52	1.48	26.67
Total	0.02	0.03	0.04	0.05	0.07	0.15	0.09	0.17	9.12	10.80

SOCIAL VULNERABILITY AND INTEGRATED RISK ANALYSIS

An integrated strategic planning of prevention and management of natural hazards in countries of any living standard should take seriously into account both physical and social vulnerability. This innovative approach applies to the needs for less technocratic and more anthropocentric adaptation of the concept of vulnerability as the safety of human life doesn't depend only on the severity of the natural hazards and the quality of the built environment but also is related with the socioeconomic and political structures of the community and society.

Social vulnerability is a complex and multidimensional concept, a dynamic and ever-changing situation which, though, for measurement proposes is considered as static. The social vulnerability is a concept that assists to identify those characteristics and experiences of population that enable them to respond and recover from natural hazards (Cutter et al., 2003). Practically, it obtains a (comparative) measure through the variations of variables such as age, gender, education, occupation, economic status and quality of building stock. Socio-economic data that may alternate impacts of seismic hazard on population are generally extracted from National Population and Household Censuses.

The integration and implementation of Social Indices in the vulnerability analysis can contribute to the decrease of seismic risk as it implies that less casualties, injuries and economic losses involved in public health are anticipated. Therefore, in addition to the study on the seismic hazard and its impact on the built environment, it is possible to construct the social exposure model of the area of study, including spatial distribution of the socioeconomic characteristics of the population, such as age, gender, access to resources and education, distribution of income, institutional capacities, religion and other parameters (Cutter et al., 2003). Combination of variations of the above-mentioned socio-economic variables yields to the estimation of the Social Vulnerability Index (SoVI), which consists of a comparative measure of social vulnerability. Combination of SoVIs leads then into a composite indicator, summarizing the distribution of vulnerable population in respect to the damage within the affected area, setting social priorities as respond, preparedness and recovery link to population characteristics. The composite indicator summarizes the complex reality of social vulnerability and is implemented in the vulnerability analysis as modification factor of the final physical risk impacts, as part of the so-called Integrated Risk analysis (Burton et al., 2014)

An integrated risk model combining physical and social risk modules is elaborated by utilizing part of OpenQuake tools. The integration and implementation of Social Indices (SoVIs) into OpenQuake contributes to the decrease or aggravation of physical risk impacts (in loss or human terms), that are calculated either by stochastic event-based or scenario-based risk analyses. This is achieved by the Integrated Risk Modelling Toolkit (IRMT) of Global Earthquake Model Foundation, an open-source GIS-implemented tool that allows the risk analyst to draw conclusions on exposure, casualties prediction, and property loss, due to physical seismic vulnerability of the assets and seismic hazard, and to combine these with socio-economic vulnerability models (Burton et al., 2014). To derive the integrated risk model, a total risk index is constructed by the convolution of the SoVI with the estimates of the average annual loss. The latter is extracted in both aggregated results and in a mapped visualisation of the final risk outcome.

CONCLUSIONS

The seismic risk at national level has been calculated by implementation of probabilistic hazard and risk analysis in the OpenQuake risk platform of Global Earthquake Model (GEM) Foundation. The input seismic hazard model is the available European one, developed within SHARE (Giardini et al., 2013) project. From probabilistic hazard analysis, maps with Peak Ground Acceleration (PGA) distributions with 10% and 2% probability of exceedance and respective Spectral Acceleration distributions, have been generated. Moreover, hazard curves, combining the probability of exceedance of a range of intensity levels in terms of PGA, have been incised for the four major cities.

The exposure and vulnerability models have been provided by local studies (Chrysostomou et al., 2014; Kyriakides et al., 2015). The stochastic event-based risk analysis yielded aggregated loss estimates for several return periods, from which the loss exceedance curve for the island has been constructed. The aggregated mean loss and mean loss ratio has been also listed for numerous return periods, up to 10,000 years. The average annual loss and loss ratio were also estimated for the island, equal to 116M euro and 0.36% respectively, and for the four major cities, together with the respective exposed population. Limassol presents the highest impact in monetary terms due to its increased hazard and building stock. Disaggregation of the average annual loss and the average total loss, with 10% and 2% probability of exceedance, per structural typology, allowed for extracting observations with respect to the seismic vulnerability of the different typologies. The distribution of loss for 10% and 2% probability of exceedance has been also mapped on the input exposure grid.

Two seismic scenarios have been selected, based on the outcome of the probabilistic risk analysis. Hence, the first scenario is one among those of the stochastic catalogue that have probability of occurrence 10% in 50 years and the second one with probability of occurrence 2% in 50 years. Loss maps and maps with distribution of the collapsed buildings are produced for both scenarios. The extent of impact is compatible to the location of the fault of each scenario. The number and ratio of buildings that reach each damage state have been also registered, as well in function to the structural typologies, for better understanding of their performance and impact to the overall exposure. For the two scenarios, casualty modelling was also implemented, according to which the number of expected casualties and injuries were given for the day and night scenario for the four major cities and the entire island. Finally, based on literature models and expert's judgment, an approach of the potential population in need of long-term displacement was given. Again, Limassol seems to be the most heavily affected for both seismic scenarios, considering its vicinity to the faults and the high exposed building and human population.

Concluding, it is widely recognised that seismic risk management needs to be supported by scientific estimates of the impact of seismic risk. All the results provide realistic indications of what future seismic scenarios may result and are indispensable for the prevention and preparedness phases of the disaster management cycle. Hence, budget allocation, insurance premiums and institutional resources can be anticipated, as well as designation of evacuation routes or locations of shelters and coordination centers. An insight of social vulnerability and integrated risk assessment is also given in order to promote the further integration of the human aspect into an updated future version of the present risk assessment study.

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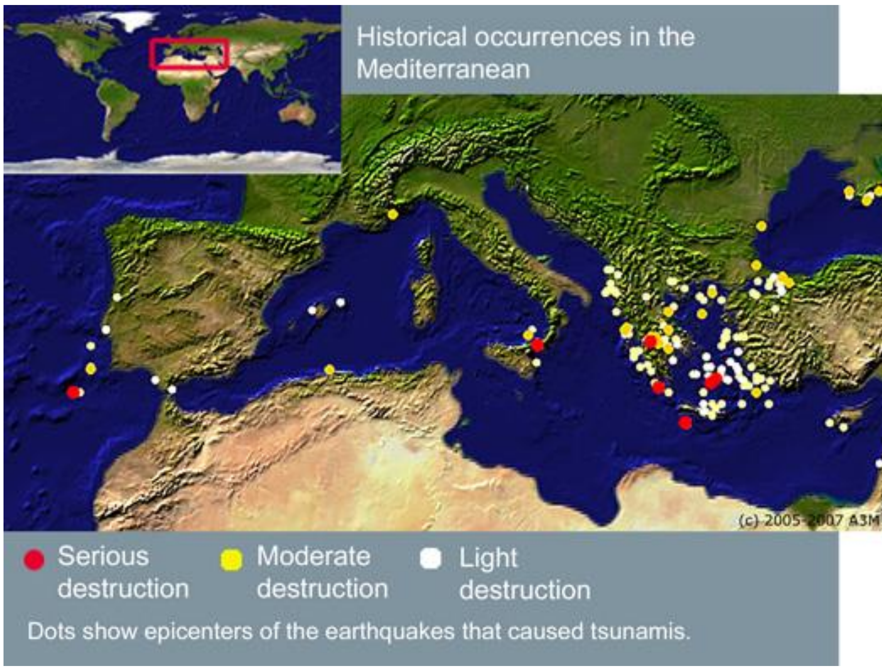
Tsunami

Tsunami hazard in the Mediterranean Sea is low compared to the Pacific Ocean, but it is significant.

Within the Mediterranean Sea (experiencing 10% of global tsunami activity), the tsunami hazard of Greece and Italy is the highest. The Cyprus-Levantine region is classified at the lowest level (Fokaefs & Papadopoulos, 2007). Within this area, the Levantine coast is at much higher risk than Cyprus.



However, for Cyprus an association between tsunami events and earthquakes has been documented through history by

(a) Direct Observations,
(b) Archaeological Evidence &
(c) Geomorphological Evidence.

The destructiveness of some historical events at local scale and the threat caused by regional events signify the need to evaluate tsunami risk by all available means.

The most catastrophic and well documented tsunamis in the Mediterranean are:

May 2003: After a quake near the coast of Algeria a tsunami was generated which destroyed over 100 boats on Mallorca and flooded Palmas Paseo Maritimo.

August 1999: A large destructive earthquake struck north-west Turkey and generated a local tsunami within the enclosed Sea of Marmara. It occurred along the Northern Anatolian Fault zone. Its epicentre was in the Gulf of Izmit. Official estimates indicated that about 17 000 people lost their lives and thousands more were injured.

October 1963: Tsunamis can develop not only in oceans: In Italy, near the town of Longarone, the entire northern slope of Mount Toc slid into the Vaiont dam. The water spilled over the dam and destroyed a number of villages with a wave of 140 metres. 4 000 people lost their lives.

July 1956: The best documented and most recent tsunamigenic earthquake in the Aegean Sea between Greece and Turkey is the one that occurred near the south-west coast of the island of Amorgos, killing 53 people, injuring 100 and destroying hundreds of houses. The waves were particularly high on the south coast of Amorgos and on the north coast of the island of Astypalaea. At these two places, the reported heights of the tsunami were 25 and 20 m, respectively.

December 1908: Due to an earthquake and the ensuing tsunami, the city of Messina in Italy was almost completely destroyed. More than 75,000 people were killed.

November 1755: The Portuguese capital of Lisbon and its inhabitants were particularly badly hit by an earthquake that occurred in the eastern Atlantic Ocean. Two thirds of the city was destroyed from resulting fires. The people seeking refuge from the flames on the banks of the Tejo River were surprised by huge flood waves produced by the earthquake. Some 60,000 people lost their lives. The waves were even observed in Ireland and on the other side of the Atlantic on the Lesser Antilles. On the coastline of the Madeira Islands the waves still had a height of 15 metres.

1672: The Cyclade islands, especially Santorini, were shaken by an earthquake The island Kos, in the east, was completely swallowed by the ensuing tsunami.

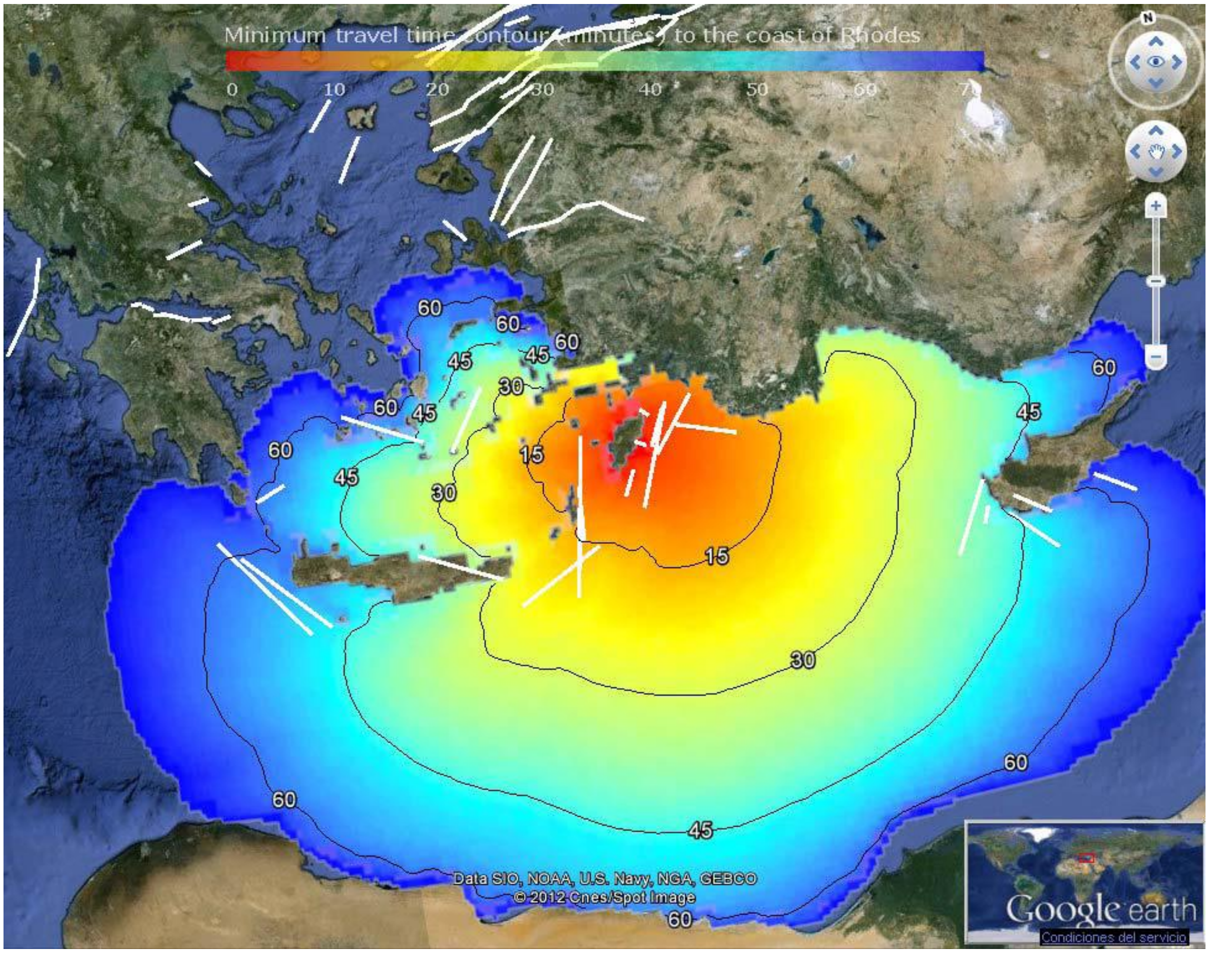
1650: A destructive earthquake was accompanied by a submarine explosion from the Colombo Volcano, which crater lies in the sea to the northeast of the island of Santorini. There was a devastating tsunami observed on the island of Ios, north of Santorini, and waves of up to 16 m were reported.

1303 AD: The quake with an estimated strength of 8 destroyed the island Rhodos and the eastern part of Crete. It caused a tsunami which reached the Egyptian coast.

365 AD: The quake of 8 to 8.5 in the year 365 caused heavy destruction on the whole of Crete. The tsunami that developed because of the quake destroyed complete coastal regions as far as Egypt and eastern Sicily. Records indicate that 50,000 people lost their lives in Alexandria.

1628 BC: The coasts of the entire eastern Mediterranean were submerged by flood waves of up to 60m high. The wave, caused by a volcanic eruption on Santorini, a Greek island in the Aegean Sea, and is believed to be responsible for the destruction of the Minoan culture.

Due to the small extent of the Mediterranean Sea, tsunami travel times are small, from seconds up to about one hour in the eastern Mediterranean (see map below).


Minimum travel time contour (minutes) to the coast of Rhodes
0
10
20
30
40
50
60
70
60
60
60
45
45
30
60
45
15
60
45
30
15
30
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45
60
60
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image
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TSUNAMIGENIC AREAS THAT MAY AFFECT CYPRUS

The eastern part of the Mediterranean Sea is seismo-tectonically dominated by possible subduction along the Cyprus Arc and the strike-slip Dead Sea Fault System.

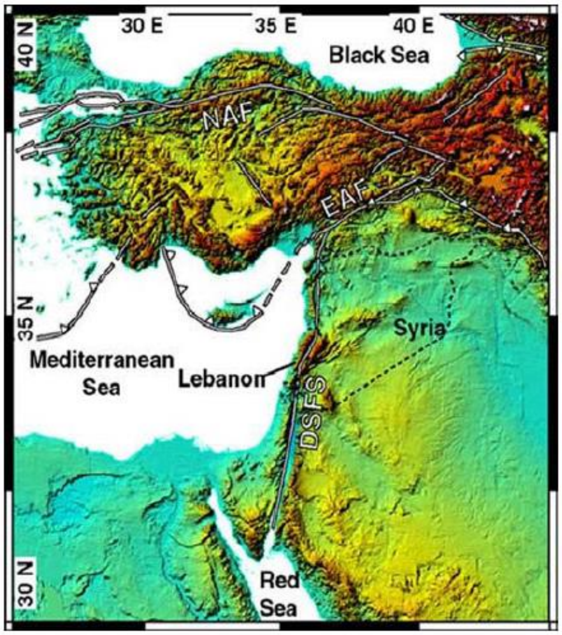


Figure 1: Tectonic setting of the Eastern Mediterranean (after Fokaefs & Papadopoulos, 2007).

There are two main mechanisms of tsunami generation, both of which are relevant to the east Mediterranean. These are:

(1) Shallow, high-magnitude, submarine earthquakes with cause significant vertical displacement of the ocean bottom.

(2) Earthquake-induced submarine landsliding.

The tsunamigenic areas that are expected to affect Cyprus are the Cyprus Arc, the eastern part of the Hellenic Arc and the Dead Sea Fault System. Tsunamis from these areas can originate by:

(a) Local, shallow and strong earthquakes originating along the Cyprus Arc, especially in the west and south-west of Pafos where the seismic activity is considerably higher than the other parts of the arc (e.g. the 1222 and 1953 earthquakes).

(b) Submarine landsliding near the coast of the Levantine Sea which is currently believed to be induced by earthquakes along the Dead Sea Fault System (e.g. the 1202 earthquake).

(c) Regional, shallow and strong earthquakes originating in the eastern segment of the Hellenic Arc, especially between Crete and Rhodes (e.g. the 1303 earthquake).

REPORTED TSUNAMIS ON THE COAST OF CYPRUS

Whereas the Levantine coast has been struck at least 20 times (Salamos *et al.*, 2007) by tsunamis induced by earthquakes of the Dead Sea Fault System, the Cyprus and Hellenic Arcs, there is reliable evidence for **2 occasions that Cyprus was struck by a destructive tsunami (1202, 1222)** and 2 occasions that a non-destructive tsunami was seen in the area (Ambraseys & Melville, 1988, Fokaefs & Papadopoulos, 2007, Yolsal *et al.*, 2007). These are:

Date	Source of tsunami	Area affected by the tsunami	Description
1202	Possibly landslide near the Levantine coast due to a strong earthquake in the area of Israel, Syria and Cyprus.	Levantine coast and Cyprus.	The sea between Cyprus and the Levantine coast parted and mountainous waves piled up throwing ships up onto the land. Eastern parts of the island were flooded.
1222	Strong submarine earthquake south of Pafos.	Cyprus.	One of the most destructive events reported in historical catalogues. Earthquake destruction and destructive tsunami flooding in Pafos and Lemesos. The castle of Pafos collapsed and the harbour was left without water.
1303	Strong earthquake in Hellenic Arc between Crete and Rhodes.	From Crete to Levantine coasts.	One of the largest and best documented seismic events in the history of the Mediterranean area. Destructive tsunami in Crete. Damaging sea-wave in Rhodes. Tsunami reported to be seen at SW Turkey, Egypt, Cyprus and Palestine.
1953	Strong double earthquake south-west of Cyprus.	Cyprus.	Small tsunami along the coast of Pafos which caused no damage.

It should be noted that Yolsal *et al.*, 2007, have performed simulations of the 1222 and 1303 events calculating wave heights and their distribution functions in the east Mediterranean.

There is additionally geomorphological evidence for strong tsunami action on the coasts of Cyprus (Kelletat D. & Schellmann, 2001, Whelan F. & Kelletat D., 2002, Noller *et al*., 2005, 2011), summarized in Figs 2 and 3.

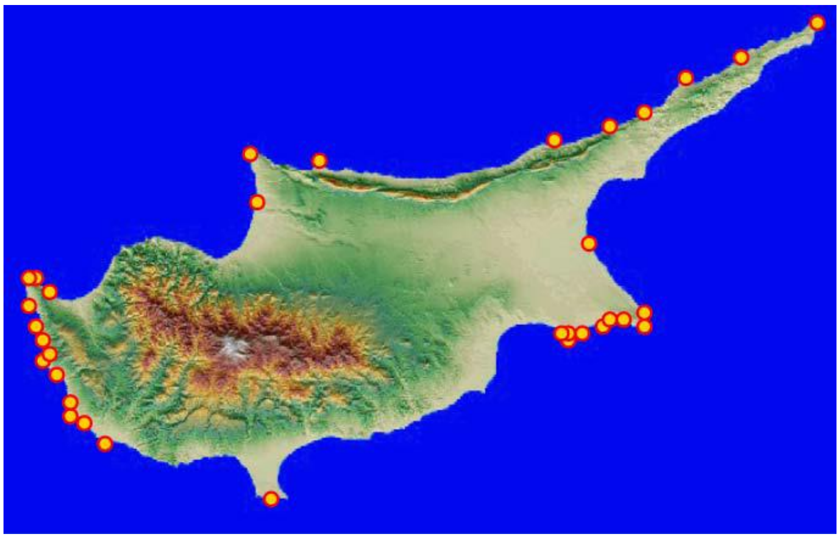


Figure 2: Distribution of geomorphological features indicating or suggesting origin by tsunami process (after Noller et al., 2005, 2011).

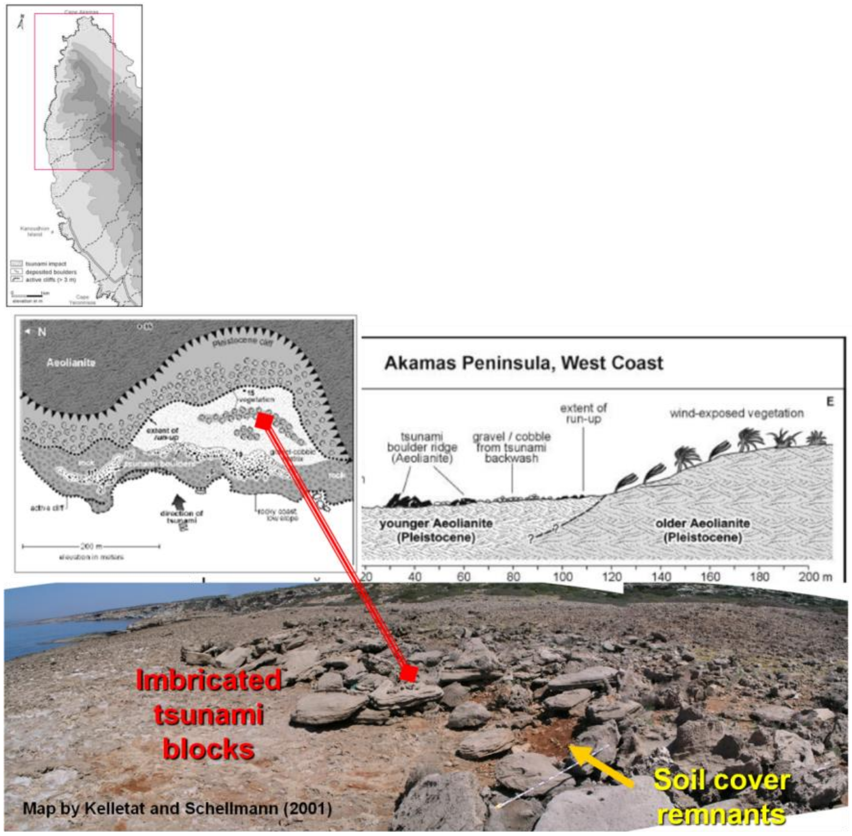


Figure 1: *Tsunami deposits in western Akamas area (after Kelletat & Shellmann).*

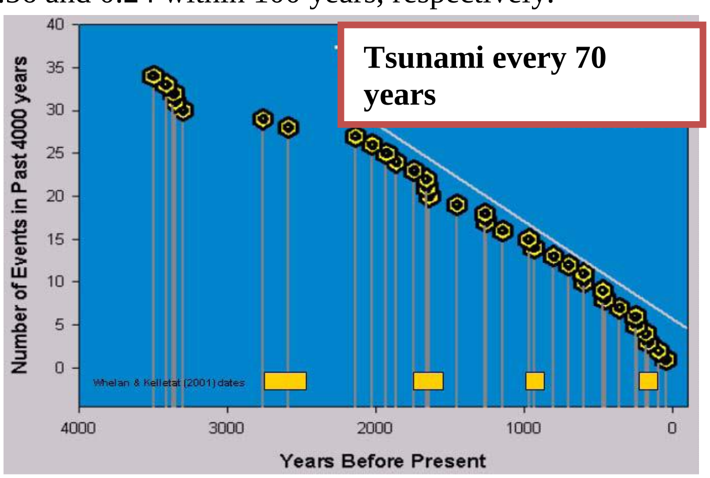
STATISTICAL EVALUATION OF TSUNAMI HAZARD IN THE CYPRUS-LEVANTINE AREA

The following tables summarize the results of Fokaefs & Papadopoulos, 2007 for the tsunami hazard of the Eastern Mediterranean area of Cyprus-Levantine:

Tsuna	Wave height (m)
I – V	<1.0
VI	2.0
VII – VIII	4.0
IX – X	8.0
XI	16.0
XII	32.0

Time Duration	Probab. Intensity >III	Probab. Intensity >V	Probab. Intensity >VIII
1	0.28	0.01	0.0001
50	0.81	0.34	0.13
100	0.96	0.56	0.24

The average tsunami recurrence in the Cyprus-Levantine Sea region is roughly estimated to be around **30 years, 120 years and 375 years for moderate (Intensity > III), strong (Intensity > V) and very strong (Intensity > VIII) events**, respectively. The rate of tsunami occurrence equals 0.033, 8.3 · 10–3 and 2.7 · 10–3 events/year for Intensity > III, V and VIII respectively. For a Poisson (random) process the probabilities of observing at least one moderate, strong or very strong tsunami are 0.28, 0.01 and 3 · 10–3 within 1 year, 0.81, 0.34 and 0.13 within 50 years and 0.96, 0.56 and 0.24 within 100 years, respectively.



However, preliminary results (Noller et al., 2005, 2011) combining geomorphic tsunami evidence and relative and absolute dating for Cyprus show that a tsunami affects the Cyprus coasts every 70 years.

CONCLUSION

Although the tsunami potential in the Cyprus region is relatively low compared to other tsunamigenic areas of the Mediterranean Sea, destructive local events, such as that of 1222, or threatening remote events of the Hellenic Arc, such as those of 1303, 1481 and numerous others, as well as the strong geomorphological evidence for tsunami activity on the Cyprus coasts, signify the need to evaluate tsunami risk by all available means.

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5. FLOODS- FAST AND URBAN FLOODS

5.1 Identification of the most vulnerable, to flooding, areas in Cyprus

The purpose of this task is to give information about the significant historic floods that took place up to year 2011 and identify the most vulnerable, to flooding, areas in Cyprus. The methodology used to identify these areas is described below. Also detailed description is given for each area that is vulnerable to flooding. All the information given in this task were taken from the Water Development Department (WDD). According to the aforementioned report, "Significant floods" are floods that have occurred in the past and have had significant effects and consequences on human health, the environment, cultural heritage and economic activities, and for which the possibility of such future events continues to exist, and major floods that have occurred in the past, which could potentially have a significant negative impact on similar phenomena in the future.

5.1.1 Significant historic floods

The information and description of significant floods that have occurred in the past is an essential part of Article 5 of the Act as a basis for identifying areas where there is potential of serious flood risks. These floods are events given by the Water Development Department (WDD) in a report that identifies areas for which have or may significantly have the potential of flood risks for the period of 1859 to 2011.

In Table 2, major floods are described using basic information (flood date, area code and comments), the geographical location of the affected areas and the name of the river. This table refers to 468 flood events covering the period from 1859 to 2011, as recorded by local newspapers, by the Department of Meteorology, the Water Development Department and other texts (theses / investigations).

5.1.2 Methodology

The methodology for identifying areas with significant potential flood risks was developed by the Water Development Department (WDD) and implemented by a consultant company. Evaluation of the methodology and suggestions for improvement were taken place prior the implementation of the methodology.

The size of a river basin seemed be a useful indicator of the volume and speed of flood flow. These elements also determine the consequences of a flood. Due to the lack of other data, it has been suggested, by the WDD, to use this indicator as a criterion for the preliminary selection of watercourses that can cause significant flood problems. From an analysis performed, concerning the historical floods of watercourses that caused deaths in Cyprus, the smallest of them had a catchment area of 8 km^2 while the average catchment area was 91 km^2. For these reasons, it was decided to use the 10 km^2 basin size as the minimum catchment area. This was taken a basis in the selection of the most vulnerable areas in terms of the flood risk. The main steps of the methodology used are:

1. Identification of the river sections with a catchment area greater than 10 km^2. During this step, GIS tools were used to identify these sections.
2. a. Classification of the following categories:
    i. Development Zones, prevailing the use of housing and the accumulation of new Public areas, with the main objective to be the protection of human health.
    ii. Industrial, Commercial, Craft and Tourist Zones, with the main objectives to be the protection of the economy, human health and the environment.

   b. Identification of historical and cultural heritage sites (based on available data).

   c. Identification of structured areas.
3. Identification of rivers that affect the areas of Step 2.
4. a. Relate all the above steps with historical floods, with reference to the victims and life losses but also to serious flood events without human casualties.

   b. Selection of some river sections used in Step 3 that were related to historical floods with victims and loss of life and / or other major floods.
5. a. Improvements/adjustments in the procedure followed in Step 4 (area selection) for areas with artificial flood protection infrastructures that minimize the likelihood of a recurring of historical flood or its impact.

   b. Possible discarding of areas where the river is surrounded by a Protection Zone that covers a large part of the flood plain and mitigates the flood risk.

   c. Possible increase of severity / flood risk because of climate change scenarios.
6. a. Possible addition of new areas where the evaluation of historic or non-recorded floods in connection with the current developments indicates a potential flood risk.

   b. Possible addition of new areas after increasing severity / risk because of climate change scenarios.
7. Locating areas with significant historical floods with a river basin size of less than 10 km^2 or another type of flood. Additional areas of significant flood risk, beyond the selection above based on historical data, were included. With the evaluation of the historical flood data, some other areas were added in the group of areas that have potentially significant flood risks. These were not recognized in the previous steps since for example they did not satisfy some prerequisites i.e. areas with a catchment area less than 10 km^2. This step was performed on the basis of historical data and current circumstances where the risk is considered to be significant and should be evaluated.
8. Evaluation of the flood risk recurrence and the significance of future impacts in the areas identified in step 7.

The Figure 5.1 below is showing schematically the 8 steps of the described methodology.

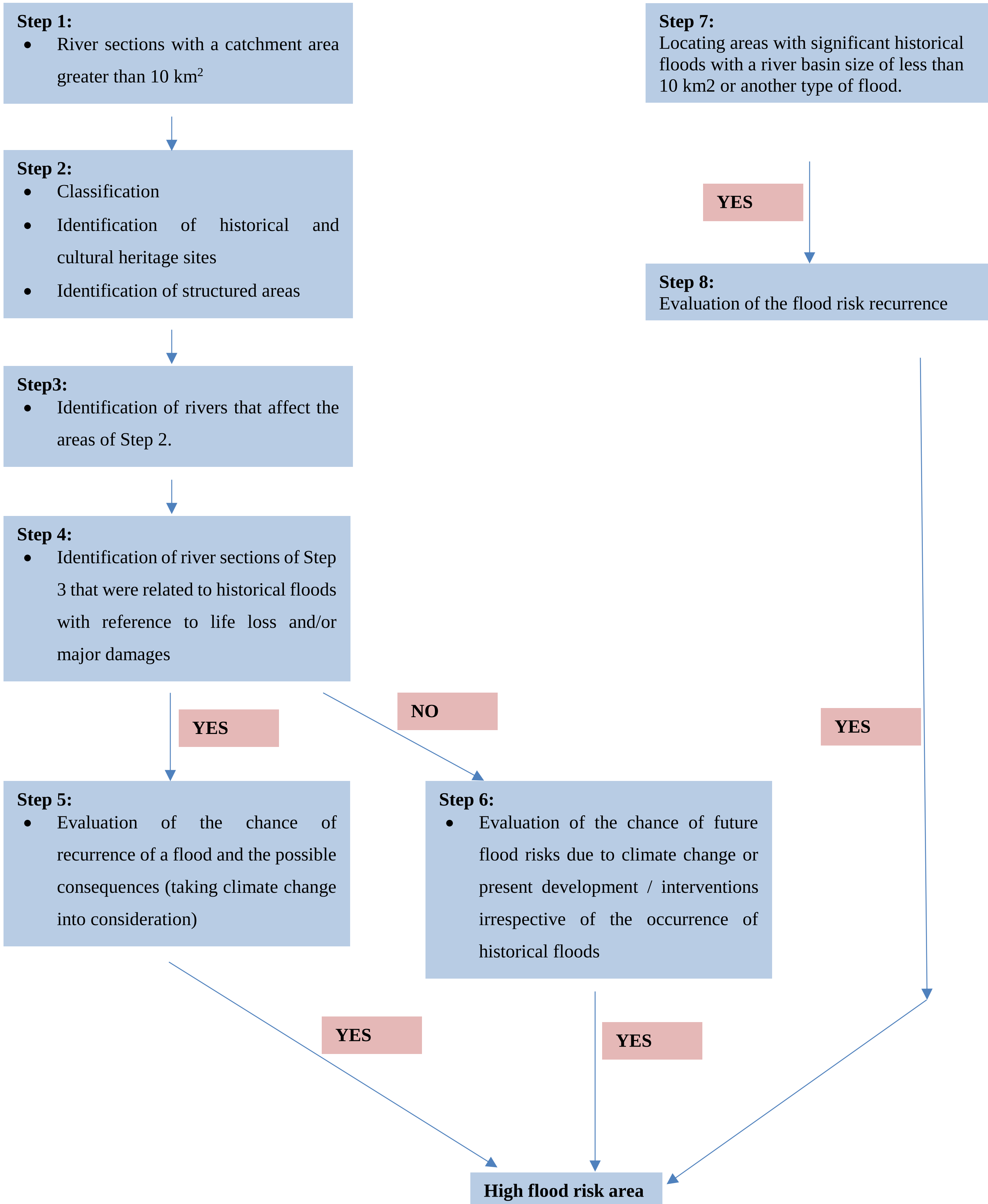


Figure 5.40:Methodology for identifying areas with significant potential flood risks

5.1.3 Areas vulnerable to flooding in Cyprus

The areas in Cyprus, that come up, by applying the above methodology, that are having a significant flood risk are listed in this chapter. The following Table 5.shows the 19 identified areas of potential flooding in Cyprus (Table 5.10). Cyprus has many rivers, shown in Figure 5. 41 while their sections that have a catchment area of more than 10 km^2 are shown in Figure 5. 42. The end result of the above described methodology is given in Figure 5. 43 where all 19 areas of potential flooding in Cyprus are mapped.

Table 5.10: Areas of potential flooding in Cyprus

A/A	Area Code	Name of River / Stream	Length of river (m)
1	CY-APSFR01	Pediaios	25 310
2	CY-APSFR02	Klimos	5 740
3	CY-APSFR03	Merikas (tributary)	3 250
4	CY-APSFR04	Kalogeros	5 630
5	CY-APSFR05	Merikas	5 690
6	CY-APSFR06	Almiyros-Alikos	7 750
7	CY-APSFR07	Paralimni	3 290
8	CY-APSFR08	Gialias	5 810
9	CY-APSFR09	Ormidia	4 960
10	CY-APSFR10	Archangelos	11 300
11	CY-APSFR11	Kamares	6 640
12	CY-APSFR12	Kosinas	8 770
13	CY-APSFR13	Limnarka	3 380
14	CY-APSFR14	Germasogeia	6 070
15	CY-APSFR15	Vathias	7 700
16	CY-APSFR16	Garyllis	13 730
17	CY-APSFR17	Marketou	3 760
18	CY-APSFR18	Komitis	3 600

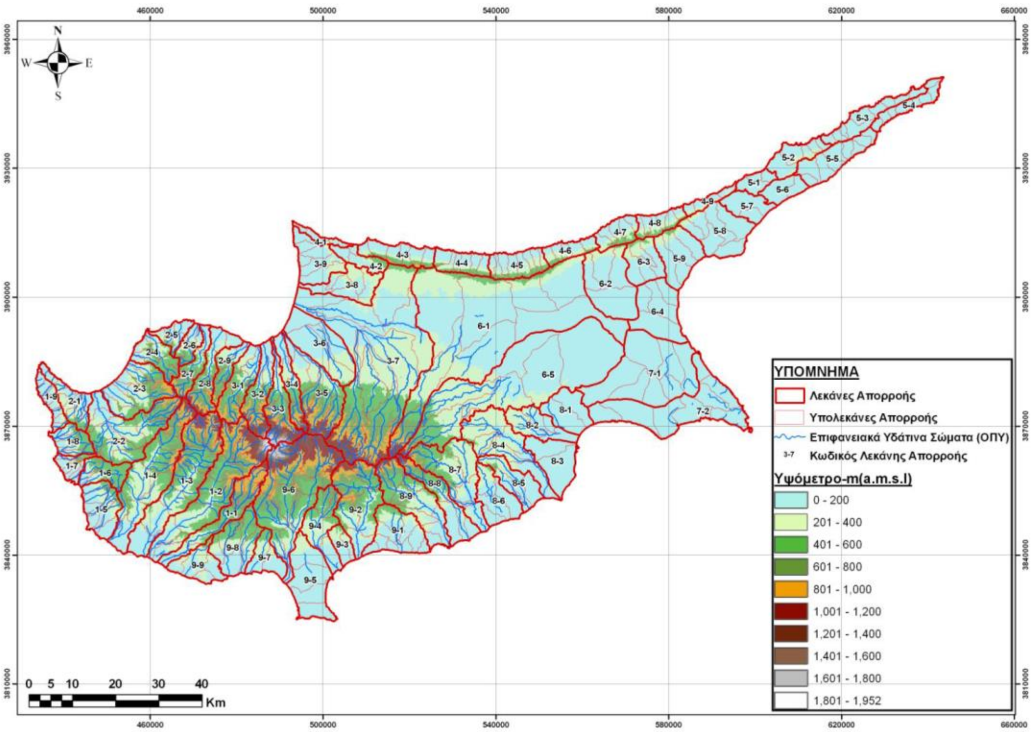


Figure 5. 41: Rivers in Cyprus with their basins, terrains and surface waterbodies (Source: WDD)

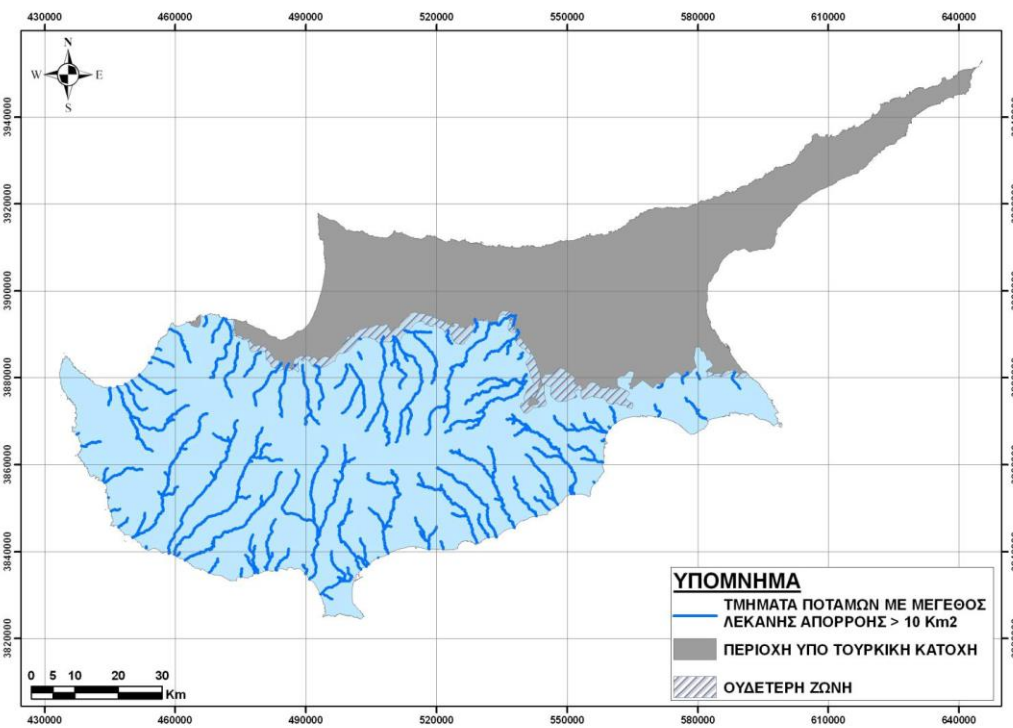


Figure 5. 42: River sections with a catchment area greater than 10 km^2 (Source: WDD)

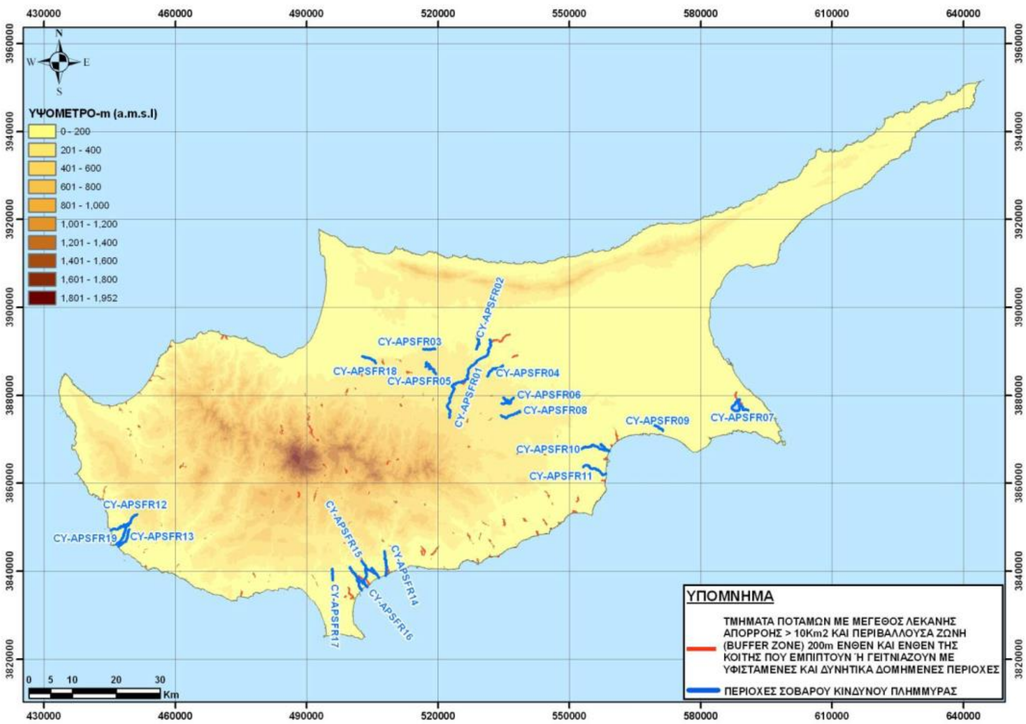


Figure 5. 43: Areas of potential flooding in Cyprus

The detailed description of the path and the affected sections of each area of potential flooding in Cyprus are described below.

5.1.3.1 Pediaios River

The section of the river affected by floods is from Politiko village to the Municipality of Nicosia and covers a distance of 25.3 km. This river is vulnerable to flash-flooding.

Part of Pediaios River passes through the Residential Communities / Municipalities of Politikou, Pera, Episkopeio, Ergates, Psimolofou, Aidayia, Devtera, Lakatameia, Engomi, Strovolos and Nicosia. The banks of the river are under increasing urbanization and population growth, while areas of the flood plain are used as sports grounds, stadiums, parks, etc. A large number of bridges benefit the transportation but not all of them were constructed with a complete Hydrologic / Hydraulic study. Also, many of these bridges are in the form of Irish Bridges that pose risks.

Over the past 150 years many floods were recorded of low to very high severity. 26 floods were of very low severity (T ~ 6 years), 10 floods were of low severity (T ~ 15 years), 4 floods were of moderate severity (T ~ 38 years) and 4 floods were of very high severity (T ~ 38 years). Some of them also caused deaths. Throughout the river, the riverbed is in the Z3 or Δα1 Protection Zone, varying in width from 20 to 200 m, (mainly this width is 100 to 120 m). The existence of this Zone reduces the risks of serious flood events and their impact. It is also noted that an enrichment dam has recently been built in the Tamasos area which, through correct operation, may allow a form of large flow management.

5.1.3.2 Klimos River

The section of the river affected by floods is in the areas of Egkomi and Agios Dometios and covers a distance of 3.3 km. This river is vulnerable to flash-flooding in combination with urban-flooding.

Part of the River Klimos passes through a fully urbanized area with Commercial, Industrial and Residential Areas, the Cyprus State Fair and sports grounds (Makarios and closed grounds). In many cases the riverbed is shape formed. There is no Protection Zone on most of the river. Historically there is a frequent presence of floods of very low (T ~ 10-20 years), low (T ~ 17-25 years) and moderate (T ~ 35-50 years) severity. From the entire length of the river section, the 1.9 km is covered (Residential Area of Makedonitissa up to Grigori Afxentiou street), while downstream Afxentiou street, the area is less inhabited, and the 1 km is uncovered.

5.1.3.3 Tributary of Merika River

The section of the river affected by floods is in the area of Kokkinotrimithia and covers 2.9 km. This river is vulnerable to flash-flooding.

Part of the tributary of the Merika River crosses the Residential Area (H2 and H3 Urban Areas) of Kokkinotrimithia. It is noted that the riverbed is not located in any Protection Zone, thus there is an increased risk of serious flood events. Although there is no evidence of a historic flood, the area is included in areas of severe danger due to its intensive urbanization over the last few years.

5.1.3.4 Kalogeros River

The section of the river affected by floods is from Strovolos to the Latsia Industrial Area and covers 5.5 km. This river is vulnerable to flash-flooding.

Part of the Kalogeros River passes through the boundaries of the Municipality of Strovolos and ends up in the Industrial Area of Latsia. Important elements are the proximity to the river of the GSP Sports Centre, the Nicosia-Limassol motorway and the Commercial and Industrial Zone that the river passes before it enters the Athalassa Park and ends up in the Athalassa dam. Throughout its length the riverbed is in a Δα1 Protection Zone of varying widths of 7 to 80 m with a prevailed size of 8-10 m. This zone is adjacent locally with Κα8 and Κα6 Residential Zones, with Commercial Industrial Zones Βδ2, Βα3, Εβ4 and Βδκ as well as the Αα1 Public Use Zone. Historically, at least one flood of very low severity and 2 low severity were recorded.

5.1.3.5 Merika River with Koutis and Katouris tributaries

The section of the river affected by floods is in the area of Paliometocho and Agioi Trimithias and covers 6.1 km. This river is vulnerable to flash-flooding.

Part of the Merika River passes through the Residential Areas of the communities of Agioi Trimithias and Paliometocho. In the Paliometocho area, the river has inflow from the Kouti and Katouris tributaries, which historically exhibited flash-floods of at least one very low, one low and one moderate severity flood (T~100 years). Throughout the length of the river, its riverbed is in a

Z3 Protection Zone with a mean width of 50 m which is adjacent to Residential Zones H1, H2 and H3. Shape formation projects of the river or its tributaries that pass through Paliometocho may increase the flood severity. The sections of the 2 tributaries passing through the flow point within the Residential Area should be examined together with the Merika River section.

5.1.3.6 Almyros – Alikos River

The section of the river affected by floods is in the Industrial Area of Dali and covers 6.6 km. This river is vulnerable to flash-flooding.
The segments and the junction of the Almyros and Alikos rivers are within the important Industrial Area of Dali. These segments were extended up to 500 m upstream of the Nicosia-Limassol motorway. The entire length of the riverbed is in a Z3 Protection Zone with a mean width of 20m. Dali Industrial Area is fully developed with significant industries and large number of employees. Over the past 10 years, 2 very low and 1 moderate severity floods have been recorded. The flood that occurred on 2/12/2003 caused the death of a driver who was drifted with his car. Older floods were not recorded probably because there was no human activity in the area.

5.1.3.7 Paralimni Lake and its Inlet River

The section of the river affected by floods is in the area of Paralimni covers 2.8 km. This river is vulnerable to flash-flooding.
The part of the river that flows into Paralimni's Lake and crosses Residential Urban Areas is considered as a flood risk area. The part of the river is not in a Protection Zone and houses are very close to its riverbed. In the same area, the Tasos Markos Stadium is a place of frequent use by many people. The severity of the impacts increases due to the low slope of the river itself (~ 0.2%) and the riparian area that is not more than 1-2%. The area has historically encountered at least 2 floods of low and 1 moderate severity.
The presence of the lake downstream is expected to act as a retention and flow control area in the downstream section of the river. Taking into account the intense pressures of plot and housing separation in the areas around the Lake, as well as the environmental status of the Lake as a Natura 2000 area, it is estimated that flood risk maps should also cover the Lake itself.

5.1.3.8 Yialias River

The section of the river affected by floods is in the Areas of Nisou, Pera Chorio and Dali and covers 5.5 km. This river is vulnerable to flash-flooding.
The area has an increased rate of urbanization, while public areas (stadiums, etc.), near the riverbed, are increasing. The Nicosia-Limassol motorway passes through the upstream part of the river and for this reason the study section of the river was extended by 500 m. Another important element in the area, that increases the severity of floods, is the presence and creation of sinks due to the presence of gypsum rocks that makes the location of some houses unsafe. This phenomenon is enhanced in the presence of floods. The presence of a Z3 Protection Zone, with an average width of 100 – 150 m across the entire length of the river section, reduces to some extent the potential impact of major floods. Also, the construction of an enrichment dam, upstream the river, is under

study, while its integration into flood management will be helpful. Historically, 6 - 7 floods of very low (T ~ 15-20 years), 1 of low, 1 of moderate and 1 of high severity (T ~ 100+ years) have been recorded.

5.1.3.9 Ormidia River

The section of the river affected by floods is in the area of Ormidia and covers 3.6 km. This river is vulnerable to flash-flooding.

The riverbed of the Northeaster tributary of the Ormidia river, which passes through the residential area, has been shape formed for 1 km with an open structure made of concrete with a width of about 6 - 7 m and a height of 1 m. The Northwest tributary that passes the "Vattenas" area has not been subjected to any intervention. According to the community's president an area of 0.3 km^2, located in the western and lower area of "Vattenas", is often affected by floods. The historical floods reported in 1983 and 2010 flooded the area at a height of 0.5 - 1 m. The historic flood file of the Contracting Authority does not report floods in this area. However, the recent costly concrete structure of shape forming the riverbed, as mentioned above, is indicative of a problem in the area. This construction achieved a significant reduction in flood risks, however, it is expected that the risks from the Northwester part of the river should be studied. Also, the existing concrete structure of the riverbed has to be examined and evaluated as to be consistent with the hydrology of the area. It should be noted that Ormidia is within the British Authority areas and is not covered by the Urban Planning Policy Statement. Also, there does not seem to be a Protection Zone for the riverbed.

5.1.3.10 Archangelos, Kamitsis River and their tributary

The section of the river affected by floods is in the Aradippou-Livadia area and covers 9.95 km. This river is vulnerable to flash-flooding.

A section of the Kamitsi River after the Archangelos River in the Rizoelia region flows for 2300m following the Northernmost boundary of the Residential Area and the Urban Planning Zones of the Municipality of Aradippou. The Agricultural Zone is located North of the riverbed. The riverbed is in a Δα2 Protection Zone with an average width of 40 - 50 m. The river then flows for 2500 m in the Agricultural Zone until it enters the Livadia Residential Area, from where, after 2700 m, it reaches the sea. There is no riverbed Protection Zone in the Livadia area. A tributary, from the Northeast, also crosses the Livadia Residential Area and joins the Kammitsi River at a distance of 500 m from the sea. In the Livadia area, the river passes through the K6 and K8 Residential Zones, the Eβ6 Commercial Zone, and the Bε1 Economic Activities Zone. The areas of Aradippou and Livadia, that face serious flood risks, are treated in the same way because the same rivers pass through both areas. According to the record of historical floods, Aradippou and Livadia areas have suffered at least 5 floods of very low (T ~ 20 years), 1 flood of low and 1 flood of moderate severity (T ~ 100+ years). An important fact in Livadia area is the very low slope of the terrain that prevents the rapid flood discharge to the sea, while in Aradippou the proximity of the residential area to the riverbed creates serious dangers. The Protection Zone in Aradippou area offers some reduction in flood risks. It should be noted that in Livadia area there have already been some projects for the shape formation of the existing riverbed, while some flood prodection strucures (dams) are under study for both Archangelos and Kamitsis rivers, upstream of the Aradippou community.

5.1.3.11 Kamares River

The section of the river affected by floods is in the Kamares area and covers 6.7 km. This river is vulnerable to flash-flooding and urban-flooding.
A section of the Kamares river passes through the “Kamares” Residential Area and then passes near the waste treatment plant of the area (possibly inactive), the main road of Larnaca-Limassol and the Kamares Monument and ends up flowing towards the sea through a riverbed parallel to the border of the Aliki in Larnaca area. The whole area, mainly the area of the main road near the Kamares monument, has a low terrain. From a point, 460 m upstream to downstream, the riverbed has been shape formed, underground, for the flow of the water. The Hydrological / Hydraulic sufficiency of this structure should be examined. The historical record of floods shows that over the last 30 years the area has suffered floods of very low (T ~ 8 years), low (T ~ 10 years) and moderate severity (T ~ 30 years). The existing riverbed that passes the inhabited area is not in a Protection Zone.

5.1.3.12 Kosinas River

The section of the river affected by floods is in the areas of Mesogi, Paphos city and Chlorakas and covers 9.4 km. This river is vulnerable to flash-flooding and urban-flooding.
Kosinas River flows from Mesogi (high altitudes) and reaches the sea (7 km downstream) with a relatively steep slope (5-6%). It runs through Residential Areas, which are rapidly being developed, while the Coastal Zone has been developed with hotels and tourist accommodation. The riverbed is locally covered by a Protection Zone of an average width of 30 - 40 m. The severity of the floods in the area is constantly increasing in line with residential development within the flood plain of the river and the rush of the stream flow, due to its natural inclination. Concluding, this river should be studied to obtain the necessary provisions for a smooth flood management. In the very recent past there have been floods of very low severity (T ~ 5 years).

5.1.3.13 Limnarka River

The section of the river affected by floods is in the area of Paphos city and covers 5.4 km. This river is vulnerable to flash-flooding and urban-flooding.
The river of Limnarka stems from Mesa Chorio and Armu areas, and mainly passes through the eastern boundaries of the city of Paphos, through areas that have recently developed intense urbanization. The section of the river of interest, starts at 450 m upstream of the important traffic junction on the Limassol-Paphos motorway and flows into a Protection Zone with an average

width of 60 – 70 m but in some cases up to 20m, at a distance up to 1700m downstream, where the Paphiakos Athletic stadium is. From this point and for 3 km up to the sea, it passes through Residential and Tourist Zones without the existence of a Protection Zone. Between the traffic junction and the stadium there are several commercial and industrial developments within the potential floodplain of the river. During the last 10 years in the area, through which the river flows, there are flood problems at the motorway junction, the junction the Paphiakos stadium and the coastal Poseidonos Avenue. Very Low severity floods with a 3-year return period and moderate severity floods with a 5-year return period have been recorded. Also, a high severity flood has been recorded. Flows are expected to increase with continued urbanization and possible integration of the river as a recipient of urban rainwater.

5.1.3.14 Germasogeia River

The section of the river affected by floods is in the area of Germasogeia and covers 6.1 km. This river is vulnerable to flash-flooding.

The section of the Germasogeia River downstream the Germasogeia dam (with capacity of 13.6 million m^3) has inflows from small tributaries and local rainfall. During its course to the sea (6 km), it is in a Δα2 Protection Zone with an average width of 375 m, up to 800 m from the beach where the Tourist, Residential and Commercial Zones are. The aquifer in the flooded area of the river is artificially enriched with discharges from the dam and the South Pipeline, and water is used for water supplies for the area of Germasogeia - Amathountas and Limassol. In recent years, there was an increase of urbanization of the river area and pressure has been put on to use public land within the Protection Zone (eg stadiums, parking areas, etc.). The dam acts as a flood inhibitor, but there is a serious risk of flooding when the dam is full or almost full.

5.1.3.15 Vathias River and its tributary

The section of the river affected by floods is in the areas of Mesa Geitonia, Agios Athnasios and East most region of Limassol and covers 11.8 km. This river is vulnerable to flash-flooding and urban-flooding.

Vathias River flows from the hills of Fasoula and Spitali (Limassol) to about 8 - 10 km from the city centre of Limassol. At a point, 450 m above the Limassol-Pafos motorway, the river is divided into 2 sections that enter the Limassol district and end up in the sea. The western part of the Vathias river does not seem to have a riverbed. Most of it has been covered with buildings and residences. The area is at low topographical level and accumulates a large stream of rainwater. From the point 500 m downstream of the former Athenaidion High School, the river connects with the old riverbed of the Garyllis River and ends up in the sea by the old harbor. The eastern part of the river is in a less developed Residential Area, following a route up to the Macedonia Avenue. At 650 m downstream of this point, it joins a tributary that originates from the area of Agios Athanasios and together follow a course parallel to the Griva Digeni street, expelling near the hotel “Crowne Plaza”. The entire length of the riverbed is not covered by a Protection Zone. It passes through Residential, Commercial and Tourist Areas. Despite the existence of hydraulic facilities in the area, flash-floods of high flows with a return period of more than 20 years cause problems and pose risks. The flow of this river has increased and is expected to increase even more with the ongoing urbanization and the building up of new areas. Typical urban rain drainage projects do not cover the existing size of the flash-floods presented by this river. It is very likely and reasonable that the drainage plan of the areas through which this river passes to integrate it as a natural recipient.

5.1.3.16 Garyllis River

The section of the river affected by floods is in the areas of Polemidia, Agios Antonios and Karnagio (Limassol) and covers 10 km. This river is vulnerable to flash-flooding and urban-flooding.

The section of the Garyllis River, 1300m downstream of the Polemidia Dam, passes through a residential area, without the riverbed being into a Protection Zone. From the point of Macedonia Avenue, the river has been diverted to a new riverbed leading to Limassol's "Karnagio". The old riverbed passes through the area of 4 "Fanaria" and the church of Agios Antonios reaching the sea. The old riverbed is also flowing from the western part of the Vathias River at a point 500 m downstream of the former Athenaidion High School. Historical reports of floods refer to huge damages and casualties (1880 AC and older), which led to the deflection of Garyllis River. With the construction of the Polemidia Dam (with capacity of 3,4 million m^3) and the deflection of Garyllis River, the significant risks have been reduced except in the case of overflowing the dam. The current riverbeds remain as recipients of rainwater and are expected to be included, wherever possible, in local rainwater drainage plans. Due to the route of the sections through residential and commercial industries and the absence of protection zones, and the creation (under construction) of new public areas (Linear Park, playgrounds etc.), ensuring proper flood management of low and moderate severity is considered necessary. In the past, floods of very low severity (T ~ 20 years) and low severity (T ~ 50 years) have been recorded.

5.1.3.17 "Argaki of Marketou" River

The section of the river affected by floods is in the area of Ipsonas and covers 2.7 km. This river is vulnerable to flash-flooding.

Part of "Argaki of Marketou" river flows next to the Industrial Area of Ipsonas and passes through the western part of its Residential Area. The riverbed up to a distance of 1200 m from the Industrial Area is covered by a Protection Zone with an average width of 30 – 40 m. The historical record of floods refers to flood events but does not accurately determine the affected areas, although the damage may seem to be in the areas downstream of Ipsonas village. The flow of the river ends up to the west of the Port where, along with flows from other watercourses, the floods occur in the area of Zakaki.

5.1.3.18 Comitis River

The section of the river affected by floods is in the area of Astromeritis and covers 3.8 km. This river is vulnerable to flash-flooding.

Part of the river Comitis passes through the Residential Area of Astromeritis (H1, H2 and H3 Residential Zones). In this section, the riverbed is not in a Protection Zone. The artificial formation of the riverbed is likely to increase the severity of the impact of floods. In the recent past, at least one moderate severity flood has been recorded (18/1/2010).

5.1.3.19 Vasilikos Stream

The section of the river affected by floods is in the Paphos city and covers 7.4 km. This river is vulnerable to flash-flooding and urban-flooding.

Vasilikos stream in Paphos springs from the area of Mesogi and passes through the Residential Area of Paphos before reaching the sea (6500 m). Beyond the width of the natural riverbed, there is no further Protection Zone, resulting in having houses and Public infrastructures very close to or within the riverbed (e.g. Paphos Swimming Pool Centre). Although the stream has a catchment area of less than 10 km^2, it is considered essential to be considered as an area with severe floods due to its slope and its route coming from a Residential Area and Tourist and Commercial Zones. It should be noted that the area nearby the Paphos Swimming Pool Centre, is a place of frequent use with too many users. It has been hit by floods at least 2 times in the last 20 years with serious damages. Due to the ongoing intense urbanization, it is expected that flood events will be more frequent with serious economic consequences and potential impacts on human health. The stream has a riverbed up to 1.8 km from the sea. Specifically, there is a riverbed up to the "Andreas Omirou" and "Sotiraki Makrides" intersection. From this point it enters an area of reeds (0.4 km) while the existence of a riverbed or drainage is uncertain. Downstream this point towards the tourist area of Kato Paphos, the stream does not seem in having a riverbed.

5.1.3.20 Some other possible areas vulnerable to flooding

Tremithos River

The section of the river affected by floods is in the Kiti-Pervolia region and covers 4.2 km. This river is vulnerable to flash-flooding.

The part of the Tremithos river, passing downstream the Kiti dam (with capacity of 1.6 million m3), passes through the Kiti Residential Area for 1500 m, then enters the Z1 Protection Zone for 2000 m and ends up at the coastal Tourist Zone for 700 m. The riverbed located in the Z3 Protection Zone with an average width of 30 – 40 m in the Residential and Tourist area, and 80 – 100 m in the Z1 area. There is a relatively rapid urbanization in the Kiti area and in the Tourist Zone. In the land consolidation area there is also an increased tendency for the building up of individual houses / villas. Along the river there are several mounds and soil dams for the artificial enrichment of the aquifer, often using high water quantities from the dam to flow downstream for enrichment purposes at the request of the Local Irrigation Authorities. The residential development and the enriching nature of the river with its water works should be studied to a better level to manage the serious floods in the area. Note that both the enrichment dam and the presence of a Protection Zone across the river reduce serious flood risks. Flooding events of very low, low and moderate severity of sparse frequency have been recorded.

Ammos River

The section of the river affected by floods is in the area of Alambra and covers 3.2 km. This river is vulnerable to flash-flooding.

The Alambra community faces a serious problem on the drainage of the rainwater flowing from the torrent of Ammos due to the topography and especially due to the Nicosia-Limassol motorway, which essentially bridges the area. Flash-floods cannot be drained down the motorway, resulting in serious problems for the community and the motorway. The sections of the torrents passing through the Residential Area are not covered by a Protection Zone and in many cases the riverbed is unclear due to human interventions. Over the last decade (i.e. after the construction of the motorway) there was 1 flood of very low (2000) and 1 flood of moderate (2009) severity.

Urban-flooding in Larnaca

The area of the Larnaca City, surrounded by Spyros Kyprianou Avenue, Petrakis Kyprianou-Patron-Anagenisis, G. Kranidiotis, G. Digeni, Artemidos and Kotza Tepe of a total area of approximately 3 - 3.5 km^2 encounters, very often, the problem of urban flooding which has economic impacts and also potential impacts on human health. Particularly, the mainly affected areas are: Agios Lazaros, Mitropolis and Chrysopolitissa. The proper drain of rainwater in the area is difficult due to the terrain and the absence of any natural recipient. There are plans for the construction of pumping stations, specifically on Patron Street, which will pump the rainwater into the drainage system of Spyros Kyprianou Avenue and from there they will end up in the sea. Historical floods (23 events) of very low (T ~ 7 years), low (T ~ 17 years) and moderate (T ~ 30 years) severity have been recorded.

District of Larnaca

The district administration of Larnaca gave some information in 2018 about the vulnerable to flooding areas in Larnaca district. These areas are: Kamares, the city of Larnaca, Aradippou, Livadia, Pila and Ormidia. Hydrological studies took place of the areas of: Livadia, Xilotimpou, Kamares, Pila, Verki, Aradippou and Ormidia. The district administration of Larnaca, as far as the flood hazard concerns, need to have more hydrological studies for the areas of: Xilofagou, Agglisides, Kiti and Oroklini. The budget for flood protection/control works foe year 2018 was € 350 000 for the district of Larnaca (Disstrict Administration of Larnaca, 2018).

Municipality of Larnaca

Flood problems within the Larnaca Municipal Limits are presented by the water drainage (a) from rainwater basins from northwestern areas outside municipal boundaries and (b) at local level, from the non-existence or non-completion of rainfall collection systems in the city.

Management of rainfall coming from the catchment area northwest of the city:

1. Kalo Chorio river basins (Kamares).

The Kamares area, suffered from extreme weather conditions in December 2014. There is a lot of information gathered at the District officer's Office through the study prepared by a consortium of private companies, for the design of Flood Protection Projects for the protection of Residential Zones of the Larnaca and Aradippou Municipalities located within the catchment area of the Kalo Chorio River.

2. Aradippou rainfall catchment areas (El Greco - Timaya Canal).
   The rainwaters coming through the areas of Aradippou end up in the channel of Stratigos Timayas Avenue. According to a study, made by the Department of Public Works, a closed drainage system was constructed, which starts from the Aradippou Municipality (Australia Avenue) and passes via Larnaca area (El Greco, Stymfalidon, Ptolemaidos, Edessis, Al. Ragavi, Penelope Delta) ending up in the big channel of Stratigou Timaya Avenue. Despite the completion of the project, floods often occur at the end of Al. Ragavis street near the Stadium of Nea Salamina and at the George Papandreou street. The Municipality of Larnaca, recently, took some flood preventing measures by strengthening the collection shafts and elevating the sidewalks in front of the G. Papandreou utility road, to prevent overflowing of the concentrated waters. These measures do not effectively solve the problems, and the existing system in the region needs further study.
3. Rainwater catchment areas of Aradippou - Livadia - Larnaca (Ximpouli Channel).
   These areas collect rainwater through existing culverts, embankment and closed channels leading to the open lined channel Ximpouli.
   For this area there was an earlier hydrological study by the Department of Public Works and at a meeting held with all the departments and services involved they finalized the proposed design of the core network which is gradually implemented through the licensing of plot separation. Since the end up of the entire system is not connected to the constructed channel of Ximpouli, the area bordered by the Municipal Limits of Livadia is often flooded.

Local flood problems in the city:
Within the city limits, rainwater collection systems are operated by three public bodies. The Municipality of Larnaca maintains the oldest network of the city, the Larnaca Sewerage Council constructs and maintains new networks in the sewerage sites and the Department of Public Works maintains rainwater collection systems built with central road projects.
At various points in the city, due to a poor system of rainwater collection or non-completion of sewerage projects, flood problems are encountered, which are addressed by temporary solutions.
The planned construction of two large pumping stations by the Larnaca Sewerage Council in Katharis area, of € 10 million budget, will resolve serious flood problems in the Mitropolis - Katharis area. Small maintenance works, such as the strengthening of wells catchment or the expansion of existing networks are some of the flood protection measures taken by the Municipality of Larnaca. The municipality budget includes an annual amount of about € 40.000 for this purpose.

(Municipality of Larnaca, 2018)

Municipality of Athienou

Reference to the topography and characteristics of the area:
The southern and eastern areas of the Municipality are characterized as hilly, while the west and north as lowlands with slight slopes of about 1-2%. The residential area is situated on the edge of the hilly area with slight slopes towards the north. Due to the topography of the area, the rainwater flows from the south to the north with a superficial flow to the existing slopes and / or floods.
Historic flood events:
The lack of satisfactory infrastructure works combined with the residential development of the area have limited the reception of rainwater reception areas (surface or underground) resulting in floods in vulnerable areas. Due to the topography of the area, the rainwater flows from the south to the north with a surface flow to the existing slopes and / or floods protection works. The lack of adequate infrastructure works combined with the residential development of the area have limited the reception of rainwater by the reception areas (surface or underground) resulting in floods in vulnerable areas.
Both in the wider area of the municipality and in the residential area there are no historical data / facts about serious floods. There have always been floods occurring periodically every year, flooding the streets and sometimes damaging premises. The most recent case that could be described as a flood had occurred on 10.12.2010. During that evening, after heavy rainfall on the borders of the residential area, a large amount of water passed from the residential area, resulting in several roads becoming impassable, flooded houses and estates and caused material damage fortunately without risking human lives. In the years following 2010, heavy rainfall occurred, resulting in floods but without significant material damage.
Vulnerable areas (in relation to floods):
Two vulnerable areas, within the residential area can be identified in the Athienou Municipality (**Figure 5.** ***44***). The rainwaters from the southern agricultural area end up in these areas, due to the altitude of the roads and the topography of the area. Vulnerable areas, after a heavy rainfall, collect large amounts of rainwater, resulting in high water levels in the streets, with the risk of flooding houses and homes. Due to the lack of adequate infrastructure of flood protection works, the problem is increased.
Existing hydrological studies and areas to be studied:
Until the flood of December 2010, there was no hydrological study in the municipality. Subsequently, on the occasion of the preparation of the study for the perimeter roads and other smaller works, hydrological studies were prepared that covered specific parts of the residential area. Recently, through a bidding process, a designer was selected to prepare a hydrological study for the residential area of the Municipality. The preparation of the hydrological study is in the early stages and is estimated to be completed in about 10 months.

Figure 5. 44: Vulnerable to flooding areas (blue highlight)

Flood protection measures:

In the municipality, on some problematic streets, there is a rainwater drainage system which, in order to be effective and work properly, should be kept clean. Every year, usually in the autumn, workers of the Municipality take care of the cleaning of rainwater drains both internally and externally at the inflow points.

Available budget for flood protection projects:

In recent years, the budget of the Municipality covered the estimated costs of maintenance and cleaning of the manholes. For the current year and for the next two years, there is provision in the budget of the Municipality with a sum of €50.000 for the execution of flood prodection development projects.

Construction / infrastructures / human lives affected by floods:

Vulnerable areas are flooded, and problems have been observed that affect construction / infrastructure but not human lives.

Due to climate change, observed in recent years, there has been an increase in rainfall intensity, resulting in more frequent floods.

(Municipality of Athienou, 2018)

Municipality of Aradippou

The construction of the rainwater drainage network in the Municipality of Aradippou is based on a study / plans conducted, for the Municipality of Aradippou, by the Department of Public Works. These plans constitute the General Drainage Drainage Plan of the Municipality of Aradippou.
As far as the rainwater runoff affecting the Aradippou municipal boundaries is concerned, the following catchment areas are mentioned:

a. Areas ending in the Kamares and Aliki channel, including runoffs:

- From the area of Kalo Chorio.
- From Rizoelia Forest Area, Industrial Zone / Area, Ellados Avenue, Klimis and Laxias of Rios.

  In the aforementioned areas, as in the area of Kamaron, where the waters end up, floods have occurred in the past, in cases of extreme rainfall.

b. Area of which the rainfall ends at the channel of Stratigos Timayas Avenue, in Larnaca, which includes runoffs:

- From Laxia area, to which the highway runs and rivers from the Rizoelias area north of the Forest, a residential area between Eleftherias Avenue and Kyriakou Matsis and the area north of GSZ stadium.

Individual cases of floods have been observed in this area, mainly due to the non-completion of the sewer network. It is noted that the development in Laxias was limited to the present stage, due to the fact that it is an area with underground faults.
This changed after the most recent studies and the area already is being developed, with the need for sewer network. There are practical difficulties (altitudes existing roads and culverts, etc.) for its construction.
The Laxia area, like all the rest of said area, needs hydrological survey and constructions, as determined by individual studies done to develop additional culverts in the already built area. At the moment the general rainwater drainage plan is applied here.

c. Area where its rainwater ends in Livadia and then in Larnaca in the channel of the Ximpoulis area, which includes drains:

- From Aradippou area, the Monarka area then the Konnos area ending through the area of the Municipality of Livadia to Larnaca on the channel of the Ximpoulis area.

In the Centre of Aradippou, floods have occurred several times in the past and there is still a great risk of future floods. To solve the flood problem, a hydrological Study has been developed. The flood prevention project provided the above study has not been promoted for economic reasons.
The Municipality of Aradippou contacted a Hydrological Study for the region of Monarka. It applies to developments within the thresholds for purposes of construction of the sewerage network, taking into account the contacted hydrological studies and the overall rainwater drainage plan of the municipality prepared by Public Works.

However, it is noted that the rainwater drainage pipelines proposed by the Aradippou sewerage plans are much larger than those that exist within the Municipal Limits of the Livadia and Larnaca Municipalities.

A relevant study for the areas of Aradippou, Livadia to the Ximpoulis Channel has been prepared by the Municipality of Larnaca and is available by the Technical Service of the Municipality of Larnaka. This study demonstrates the inadequacy of existing culverts in Livadia region and before the Ximpoulis channel.

d. The Archangelos river area, whose rainwaters end up in the flood protection channel of Livadia.

The Archangelos River has overflowed several times in the past and the risk is high for future events. To solve this issue, the Municipality of Aradippou has developed a Hydrological Study of the Archangelos River Bridges.

Until now, the flood protection projects provided for in this study have not been promoted. The WDD is designing for flood protection purposes, a dam on the Archangelos River.

(Municipality of Aradippou, 2018)

District of Paphos

In general, it should be noted that the District of Paphos does not face flood problems. The only flood that has occurred in recent years was in the Latsi area of the Municipality of Polis Chrysochous on 07/01/2012. The reason for this incident was the overflow of a stream due to the clogging of a bridge from various materials and mostly debris. In that event, there was no risk of loss of life, but there was damage on vehicles, electromechanical equipment and shops/apartments furniture. According to the relative estimation made by the Technical Services of the Paphos District Administration and the Department of Electromechanical Services, the cost of repairing the losses amounted to approximately € 55.000. In this case, the bridge was rebuilt in a way that prevents the repetition of a similar incident in the future.

In 2012 there were extensive damages to the road network of the District of Paphos, due to intense / severe rainfall combined with the local problematic / unsTable 5.geological conditions. The cost of repairing the damages following, according to the Technical Services of the Paphos District Administration amounted to € 250.000. Due to the geological instability and landslide problems generally presented in the District of Paphos, the Geological Survey Department, after field investigations, proposed concrete measures to support and stabilize all cases.

In the same year, small floods occurred on agriculture land along the riverbed of the Chrysochous River, due to the overflow of the Evretou Dam. The resulted damages to various plantations in the area, was found to be due to the human factor and the illegal interventions in the riverbed.

The most serious incident happened in Paphos District in the recent past occurred on 30/10/2006 and resulted in the loss of two people's lives. Specifically, after a heavy rainfall, water overflew a bridge in the main road between the communities of Lembas - Kissonerga, which is the responsibility of the Department of Public Works. The two persons were dragged by the rushing waters of the strem in their attempt to cross the bridge by car. After this incident, the Ministry of the Interior instructed the Technical Committee of the Cyprus Technical Chamber of Cyprus to identify the technical problems that arose from this 2006 weather event in Paphos, to investigate the possible causes and submit suggestions for prevention or dealing with similar situations in the future. Generally, the reports stated that the main causes of the incident were the human intervention in the natural environment, the urban development is processed before the construction of the needed infrastructure and, finally, the volume of rainwater as a result of building development, without requiring or having hydrological studies providing measures to address these phenomena.

The Pafos District Administration, acting in accordance with the "Prevention Principle", in cooperation with the Local Authorities, proceeds with the construction of appropriate rainwater projects in the communities of the District of Paphos and in combination with the reduction of human carelessness, an effort is made to reduce the occurrence of such phenomena as the above-mentioned incidents.

Every year, various flood protection projects such as bridge construction, road maintenance, construction of concrete trenches, construction of culverts, etc. are being carried out through the Communities Development Budgets. Specifically, for 2018 it is expected that the cost of flood protection works in various communities in the District of Paphos will amount to € 1.212.000, while it should be noted that a hydrological study is contacted when required.

Furthermore, in the context of preventive measures for flood protection, Paphos District Administration is in continuous contact with the Local Authorities during the winter season, while there is cooperation with the other services involved, such as the Fire Brigade, the Police, the Civil Defense and the Department of Public Works, for the coordination of the required actions. During extreme weather, administrative and technical staff are on alert for the early tackle of any problems arise.

(Disstrict Administration of Paphos, 2018).

Table 5.11: Significant Historic floods (1859-2011) (Source: Water Development Department)

/A	Date	Region Name	River Name	Type of flood	Severity of flooding
1	29/10/1859	Πόλη της Λευκωσίας	Πεδιαίος	Π	Very High
2	30/10/1887	Πόλη της Λεμεσού		Π	Very Low
3	11/12/1887	Καλαβασός		Π	Medium
4	11/12/1887	Πραστειό Μόρφου		Τ	Medium
5	11/12/1887	Νικήτας		Τ	Low
6	11/12/1887	Κάτω Ζώδια		Τ	High
7	28/12/1887	Επαρχία Μόρφου		Τ	Low
8	03/06/1888	Λακατάμεια	Πεδιαίος	Π	Low
9	03/06/1888	Στρόβολος	Πεδιαίος	Π	Low
10	03/06/1888	Αθηαίνου		Τ	Low
11	11/06/1888	Στύλλοι		Π	Very Low
12	20/10/1897	Κώμη Αγίου Ηλία	Γεροπόταμος	Τ	Medium
13	06/02/1901	Δάλι		Τ	Low
14	06/02/1901	Πόλη Λευκωσίας		Τ	Low
15	05/11/1901	Πόλη της Λευκωσίας	Πεδιαίος	Τ	Low
16	05/11/1901	Έγκωμη		Τ	Low
17	05/11/1901	Καιμακλί		Τ	Low
18	05/11/1901	Π. Λεύκαρα		Τ	Very Low
19	11/01/1903	Κυθραία	Πεδιαίος,	Τ	Very Low
20	11/01/1903	Λάρνακα	Γιαλιάς	Τ	Very Low
21	15/02/1903	Έγκωμη,	Πεδιαίος	Τ	Very Low
22	15/02/1903	Μόρφου		Τ	Very Low
23	15/02/1903	Επηχώ		Τ	Medium
24	12/08/1906	Παγκύπρια,		Π	Medium
25	12/08/1906	Καλοψίδα		Π	Medium
26	12/08/1906	Γέναγρα		Π	Medium
27	12/08/1906	Πραστειό Πάφου		Π	Medium
28	11/10/1906	Αγίοι Βαβατσινιάς		Τ	Low
29	11/10/1906	Οδού		Τ	Low
30	11/10/1906	Μελίνη		Τ	Low
31	11/10/1906	Επταγώνια		Τ	Low
32	11/10/1906	Βίκλα		Τ	Low
33	11/10/1906	Ακαπνού		Τ	Low
34	11/10/1906	Ορά		Τ	Low
35	11/10/1906	Κελλάκι		Τ	Low
36	11/10/1906	Κλωνάρι		Τ	Low
37	18/09/1909	Γούρρη		Τ	Low
38	18/09/1909	Φικάρδου		Τ	Low
39	18/09/1909	Λαζανιά		Τ	Low
40	18/09/1909	Καλό Χωριό		Τ	Low
41	16/05/1914	Παγκύπρια		Τ	Very Low
42	11/12/1918	Παγκύπρια		Τ	Medium
43	21/12/1918	Πόλη της Λευκωσίας	Πεδιαίος	Π	High
44	21/12/1918	Π. Δευτερά		Π	Very High
45	21/12/1918	Λακατάμια		Π	High
46	21/12/1918	Στρόβολος		Π	High
47	21/12/1918	Μόρφου	Οβκός, Σερράχης	Π	Medium
48	21/12/1918	Συριανοχώρι		Π	Medium
49	21/12/1918	Πυργά Μεσαορίας		Τ	Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
53	08/06/1921	Πέτρα	Κλαύδιος, Πετρασίτης, Ελιώτης, Ξεροπόταμος	Π	Medium
54	08/06/1921	Πεντάγεια		Π	Medium
55	04/07/1926	Λευκόνοικο		Τ	Medium
56	04/07/1926	Κνώδαρα		Τ	Very Low
57	13/01/1934	Μια Μηλιά		Τ	Low
58	1936	Αχέλεια	Ποταμός της "Αχέλειας"	Π	Medium
59	1936	Καλαβασός,	Ποταμός της Καλαβασού	Π	Medium
60	1936	Περιστερώνα Λευκωσίας	Ποταμός της Περιστερώνας	Π	Low
61	1936	Επαρχία Λεμεσού		Τ	Medium
62	1936	Κάτω Αμίαντος		Τ	Medium
63	1936	Πάνω Αμίαντος		Τ	Medium
64	1936	Πέρα Πεδί		Τ	Medium
65	1936	Λιμνάτης		Τ	Medium
66	1937	Πόλη της Λευκωσίας	Πεδιαίος	Τ	Very Low
67	1937	Ακάκι	Σερράχης	Π	Very Low
68	1945	Συλίκου		Τ	Very Low
69	21/12/1952	Πόλη Λευκωσίας		Α	Very Low
70	05/11/1955	Πόλη Αμμοχώστου		Α	Very Low
71	1957	Συλίκου		Τ	Very Low
72	26/11/1960	Αμμόχωστος		ΑΚ	Low
73	15/05/1964	Πόλη Λευκωσίας	Πεδιαίος	Τ	Very Low
74	16/05/1964	Παλλουριώτισσα		Α	Low
75	16/05/1964	Άγιο Δομέτιος		Α	Low
76	16/05/1964	Άγιο Παύλος		Α	Low
77	16/05/1964	Έγκωμη		Α	Low
78	16/05/1964	Άγιοι Ομολογητές		Α	Low
79	15/12/1964	Σαλαμίνα	Πεδιαίος, Γιαλιάς	Τ	Very Low
80	05/10/1965	Πόλη Λεμεσού		Α	Very
81	05/10/1965	Παγκύπρια		Α	Very Low
82	05/10/1965	Πόλη Λευκωσίας		Α	Low
83	05/10/1965	Άγιος Δομέτιος		Α	Low
84	05/10/1965	Άγιος Παύλος,		Α	Low
85	05/10/1965	Παλλουριώτισσα,		Α	Low
86	05/10/1965	Και'μακλί		Α	Low
87	13/10/1965	Μόρφου		Κ	Very Low
88	23/10/1965	Παλλουριώτισσα		Α	Very Low
89	18/10/1967	Φυλλιά	Οβγός	Τ	Very Low
90	18/10/1967	Μόρφου		Τ	Very Low
91	18/10/1967	Πόλη Λάρνακας		Α	Very Low
92	18/10/1967	Πόλη Λευκωσία	Πεδιαίος	Τ	Low
93	18/10/1967	Στρόβολος		Τ	Low
94	18/10/1967	Γερόλακκος		Τ	Low
95	18/10/1967	Μύρτου		Τ	Low
96	18/10/1967	Άγιος Δομέτιος		Κ	Medium

50	21/12/1918	Δάλι,	Γιαλιάς, Τρέμιθος, Βασιλοπόταμος.	Π	Low
51	21/12/1918	Νήσου		Π	Low
52	21/12/1918	Μια Μηλιά		Π	Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
100	01/11/1967	Αβδελλερό,		K	Very Low
101	01/11/1967	Αθηαίνου		K	Very Low
102	01/11/1967	Κόσιη		K	Very Low
103	25/12/1968	Κούκλια	Χα-Ποτάμί	Π	High
104	25/12/1968	Ακάκι	Σερράχης, Κλάριος, Κούρρης	Π	High
105	25/12/1968	Κατωκοπιά		Π	High
106	25/12/1968	Επισκοπειό		Π	High
107	25/12/1968	Περιστερώνα		Π	High
108	25/12/1968	Κάτω Μονή		Π	High
109	25/12/1968	Φαρμακάς		Π	High
110	25/12/1968	Άσσια		Π	High
111	25/12/1968	Μόρφου		Π	High
112	25/12/1968	Καλλιάνα		Π	High
113	25/12/1968	Παλαιχώρι		Π	High
114	25/12/1968	Συριανοχώρι		Π	High
115	13/01/1969	Πόλη Λεμεσού,	Γαρύλλης,	Π	Very Low
116	13/01/1969	Γερμασόγεια,	Ποταμός Γερμασόγειας	Π	Very Low
117	13/01/1969	Καζιβερά	Σερράχης	Τ	Very Low
118	08/01/1969	Πόλη Λευκωσίας		Α	Low
119	08/01/1969	Καιμακλί		Α	Low
120	08/01/1969	Άγιος Κασσιανός		Α	Low
121	18/01/1969	Πόλη Λεμεσού		K	Very Low
122	21/01/1969	Κοντέα		K	Very Low
123	21/01/1969	Καντού		K	Very Low
124	21/01/1969	Τρίκωμο		K	Very Low
125	21/01/1969	Ερημη	Κούρης	Π	Very Low
126	19/03/1969	Μόρφου	Σερράρης	Π	Low
127	19/03/1969	Μάσσαρι		Π	Low
128	05/08/1971	Πόλη Λευκωσίας		Α	Medium
129	05/08/1971	Παλλουριώτισσα		Α	Low
130	05/08/1971	Καιμακλί		Α	Low
131	05/08/1971	Τ ράρωνας		Α	Low
132	08/02/1973	Πόλη Αμμορώστου		Α	Very Low
133	12/06/1973	Λεμεσός		Α	Low
134	12/06/1973	Τσέρι		Α	Very
135	08-11/10/1973	Αμμόρωστος		Α	Very Low
136	12/10/1973	Πόλη Λεμεσού		Α	Very Low
137	30-31/10/1973	Αμμόρωστος		Α	Very Low
138	23/09/1975	Πόλη Λευκωσίας		Α	Very Low
139	23/09/1975	Άγιοι Ομολογητές		Α	Very Low
140	08/12/1977	Πόλη Λεμεσού		Α	Very Low
141	11/12/1978	Πόλη Λευκωσίας		Α	Very Low
142	11/12/1978	Πόλη Λάρνακας,		Α	Very Low
143	11/12/1978	Άχνα		Α	Very Low
144	11/12/1978	Πόλη Λεμεσού		Α	Very Low

97	18/10/1967	Άγιος Παύλος		K	Medium
98	18/10/1967	Έγκωμη		K	Medium
99	01/11/1967	Αραδίππου		K	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
150	04/10/1979	Άγιος Δομέτιος		Α	Low
151	04/10/1979	Στρόβολος,		Α	Low
152	04/10/1979	Ανθούπολη,		Α	Low
153	04/10/1979	Παλλουριώτισσα,		Α	Low
154	04/10/1979	Καιμακλί		Α	Low
155	29/01/1981	Ύ ψωνας		ΑΚ	Low
156	29/01/1981	Φασούρι-Τσερκέζοι,		ΑΚ	Low
157	29/01/1981	Τ ραχώνι		ΑΚ	Low
158	29/01/1981	Πόλη Λάρνακας		ΑΚ	Low
159	25-26/3/1981	Παλαιομέτοχο	Ποταμός Κατούρης	Τ	Medium
160	25-26/3/1981	Παλλουριώτισσα		Α	Medium
161	25-26/3/1981	Καιμακλί		Α	Medium
162	15/06/1981	Αγία Άννα,	Τρέμιθος	Π	Low
163	15/06/1981	Αραδίππου	Ποταμοί Αρχάγγελος, Καμμίτσης	Π	Low
164	15/06/1981	Λειβάδια	Ποταμοί Αρχάγγελος, Καμμίτσης	Π	Low
165	15/06/1981	Δεκέλεια-Λά ρνακα		Π	Low
166	15/06/1981	Κοφίνου		Π	Low
167	15/06/1981	Μοσφιλωτή		Π	Low
168	15/06/1981	Κλαυδιά		Π	Low
169	27/11/1981	Σωτήρα		K	Low
170	27/11/1981	Δασάκι της Άχνας		K	Low
171	27/11/1981	Λιοπέτρι		K	Low
172	27/11/1981	Φρέναρος		K	Low
173	10/06/1983	Λύμπια		K	Very Low
174	10/06/1983	Λειβάδια		K	Very Low
175	1-2/11/1984	Αραδίππου	Ποταμός Αρχάγγελος	Τ	Medium
176	1-2/11/1984	Λειβάδια		Τ	Medium
177	1-2/11/1984	Πόλη Λάρνακας		Α	Medium
178	04/11/1984	Πόλη Λάρνακας		Α	Medium
179	04/11/1984	Λειβάδια	Ποταμός Αρχάγγελος	Π	Medium
180	04/11/1984	Πύλα		Τ	Medium
181	04/11/1984	Ορόκλινη		Τ	Medium
182	04/11/1984	Στρόβολος		ΚΤ	Low
183	23/12/1984	Λάρνακα		Α	Very Low
184	1984	Συλίκου		Τ	Very Low
185	06/03/1987	Πόλη Λεμεσού		Α	Very Low
186	06/03/1987	Πόλη Λάρνακας		Α	Very Low
187	15/02/1988	Σωτήρα		K	Low
188	15/02/1988	Λιοπέτρι		K	Low
189	15/02/1988	Παραλίμνι		K	Low
190	15/02/1988	Δερύνεια		K	Low

145	07/02/1979	Πόλη Λευκωσίας		A	Very Low
146	30/10/1979	Αγίοι Ομολογητές,		A	Very Low
147	30/10/1979	Παλλουριώτισσα		A	Very Low
148	02/10/1979	Πόλη Λευκωσίας		A	Very Low
149	04/10/1979	Έγκωμη		A	Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
195	16/06/1992	Στρόβολος		A	Low
196	16/06/1992	Παλλουριώτισσα		A	Low
197	16/06/1992	Άγιος Δομέτιος		A	Low
198	16/06/1992	Μακεδονίτισσα-Έγκωμη		A	Low
199	16/06/1992	Καιμακλί		A	Low
200	16/06/1992	Άγιος Παύλος		A	Low
201	16/06/1992	Αρχάγγελος		A	Low
202	03/11/1994	Πόλη Λευκωσίας		A	Low
203	03/11/1994	Λεμεσός (Άγιος Αθανάσιος)		A	Very Low
204	03/11/1994	Τσέρι		AK	Low
205	03/11/1994	Γέρι		AK	Low
206	03/11/1994	Λατσιά		AK	Low
207	03/11/1994	Παλουριώτισσα		AK	Low
208	03/11/1994	Λακατάμεια		AK	Low
209	21/11/1994	Τσέρι	Πεδιαίος, Βασιλικός	A	Very Low
210	21/11/1994	Λατσιά		A	Very Low
211	21/11/1994	Λακατάμεια		Π	Very Low
212	21/11/1994	Μακεδονίτισσα-Έγκωμη		Π	Very Low
213	21/11/1994	Ανθούπολης		A	Very Low
214	21/11/1994	Πόλη Λάρνακας		A	Very Low
215	21/11/1994	Μοσφιλωτή		Π	Very Low
216	21/11/1994	Αθηένου		A	Very Low
217	21/11/1994	Καλαβασός		Π	Very Low
218	21/11/1994	Πόλη Λεμεσού		A	Very Low
219	21/11/1994	Γερμασόγεια		A	Very Low
220	21/11/1994	Πόλη Πάφου		A	Very Low
221	04/04/1995	Λατσιά		T	Very Low
222	09/07/1995	Αγ. Δομέτιος	Ποταμός Κλήμος	A	Low
223	09/07/1995	Αγ. Παύλος		A	Low
224	09/07/1995	Αγλαντζιά		A	Low
225	09/07/1995	Παλουριώτισσα		A	Low
226	03/01/1996	Πόλη Λευκωσίας	Πεδιαίος	AT	Very Low
227	03/01/1996	Πόλη Λάρνακας		AT	Very Low
228	03/01/1996	Πόλη Λεμεσού		AT	Very Low
229	10/10/1996	Πάφος		K	Very Low
230	10/10/1996	Λεμεσός		K	Very Low
231	20/11/1996	Πόλη Λεμεσού		A	Low
232	26/11/1996	Άγιος Παύλος		A	Very Low
233	26/11/1996	Άγιος Δομέτιος		A	Very Low
234	26/11/1996	Έγκωμη	Πεδιαίος	A	Very Low
235	18-22/10/97	Τρούλλοι	Ποταμός Ορόκλινης	Π	High

191	15/02/1988	Φρέναρος		K	Low
192	28/10/1988	Πόλη Λάρνακα		A	Low
193	01/12/1991	Πόλη Λάρνακα		A	Very Low
194	08/12/1991	Αραδίππου		K	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
241	28/09/2000	Αραδίππου,		K	Very Low
242	28/09/2000	Κόσιη,		K	Very Low
243	28/09/2000	Αθηαίνου,		K	Very Low
244	28/09/2000	Άγιος Θεόδωρος		K	Very Low
245	28/09/2000	Λειβάδια		K	Very Low
246	09/10/2000	Αλάμπρα		T	Very Low
247	09/10/2000	Δάλι		T	Very Low
248	22/11/2000	Πόλη Λάρνακας		AT	Very Low
249	22/11/2000	Λειβάδια	Ποταμός Αρχάγγελος	AT	Very Low
250	22/11/2000	Αραδίππου		AT	Very Low
251	28/11/2000	Μανδριά		T	Very Low
252	28/11/2000	Τίμη		T	Very Low
253	28/11/2000	Αχέλεια		T	Very Low
254	28/11/2000	Νικόκλεια		T	Very Low
255	28/11/2000	Λακατάμεια		K	Low
256	28/11/2000	Αρχάγγελος		K	Low
257	28/11/2000	Λατσιά		K	Low
258	28/11/2000	Ψημολόφου		K	Low
259	28/11/2000	Γέρι		K	Low
260	28/11/2000	Πόλη Λεμεσού		K	Low
261	13/03/2001	Στρόβολος		A	Low
262	13/03/2001	Έγκωμη-Μακεδονίτισσα		A	Low
263	13/03/2001	Άγιος Δομέτιος		A	Low
264	13/03/2001	Αρχάγγελος		A	Low
265	13/03/2001	Κάτω Μονή		T	Low
266	13/03/2001	Μένοικο		T	Low
267	19/03/2001	Έγκωμη-Μακεδονίτισσα		A	Very Low
268	14/05/2001	Έγκωμη-Μακεδονίτισσα	Πεδιαίος	A	Medium
269	14/05/2001	Στρόβολος		A	Medium
270	14/05/2001	Άγιος Δομέτιος		A	Medium
271	14/05/2001	Άγιος Παύλος		A	Medium
272	14/05/2001	Λακατάμεια		A	Medium
273	14/05/2001	Τσέρι		A	Medium
274	14/05/2001	Αρχάγγελος		A	Medium
275	02/12/2001	Πάφος		AT	Very Low
276	02/12/2001	Χλώρακα		T	Very Low
277	02/12/2001	Έμπα		T	Very Low
278	02/12/2001	Μεσόγη		T	Very Low
279	02/12/2001	Πόλη Λάρνακας		A	Low
280	03/12/2001	Αραδίππου		A	Very Low
281	03/12/2001	Λειβάδια		A	Very Low
282	08/12/2001	Ποταμιά	Γιαλιάς	Π	Very Low
283	08/12/2001	Πέρα Χωριό		K	Very Low
284	08/12/2001	Λύμπια		K	Very Low

236	04/09/1998	Δάλι	Γιαλιάς, Αλμυρός	Τ	Very Low
237	10/11/1998	Ζακάκι		Α	Very Low
238	27/09/2000	Έγκωμη-Μακεδονίτισσα,		Α	Very Low
239	27/09/2000	Παλλουριώτισσα,		Α	Very Low
240	27/09/2000	Άγιος Παύλος		Α	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
290	14/05/2002	Έγκωμη-Μακεδονίτισσα,		Α	Very Low
291	14/05/2002	Στρόβολος		Α	Very Low
292	14/05/2002	Άγιος Δομέτιος		Α	Very Low
293	14/05/2002	Άγιος Παύλος		Α	Very Low
294	14/05/2002	Αγλαντζιά		Α	Very Low
295	14/05/2002	Άγιος Ανδρέας		Α	Very Low
296	14/05/2002	Άγιοι Ομολογητές		Α	Very Low
297	14/05/2002	Λατσιά		Α	Very Low
298	03/12/2002	Πόλη Λευκωσίας		Α	Very Low
299	03/12/2002	Άγιος Δομέτιος		Α	Very Low
300	03/12/2002	Ανθούπολη		Α	Very Low
301	03/12/2002	Στρόβολος	Πεδιαίος	Π	Very Low
302	08/12/2002	Αθηαίνου		ΚΤ	Very Low
303	19/12/2002	Πόλη Λάρνακας		Α	Low
304	12-13/2/2003	Στρόβολος,	Πεδιαίος	Π	Very Low
305	12-13/2/2003	Αρχάγγελος,		Π	Very Low
306	12-13/2/2003	Παλαιομέτορο	Ποταμός Κουτής	Τ	Low
307	12-13/2/2003	Αγίοι Τριμιθιάς		Τ	Low
308	12-13/2/2003	Δάλι		Π	Low
309	12-13/2/2003	Πέρα Χωρίο Νήσου	Γιαλιάς	Π	High
310	12-13/2/2003	Πόλη Λάρνακας		Α	Medium
311	12-13/2/2003	Πυργά		Α	Medium
312	12-13/2/2003	Ζακάκι		Α	Medium
313	12-13/2/2003	Πολεμίδια		Α	Medium
314	12-13/2/2003	Πόλη Πάφου		Α	Medium
315	31/05/2003	Αγλαντζιά		Α	Very Low
316	31/05/2003	Αγίοι Ομολογητές		Α	Very Low
317	31/05/2003	Στρόβολος		Κ	Very Low
318	31/05/2003	Πέρα Χωριό Νήσου		Κ	Very Low
319	01/10/2003	Π. Λεύκαρα		Κ	Very Low
320	02/10/2003	Ζακάκι		Κ	Very Low
321	02/10/2003	Τ ραχώνι		Κ	Very Low

285	08/12/2001	Δάλι		Κ	Very Low
286	08/12/2001	Πόλη Λευκωσίας		Α	Very Low
287	08/12/2001	Λακατάμεια		Α	Very Low
288	08/12/2001	Στρόβολος	Πεδιαίος	Π	Very Low
289	08/12/2001	Αγλαντζιά		Α	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
329	3-4/12/2003	Καλό Χωριό		Α	Very Low
330	3-4/12/2003	Αραδίππου		Α	Very Low
331	04/12/2003	Πόλη Πάφου		Α	Very Low
332	04/12/2003	Έμπα		Α	Very Low
333	04/12/2003	Μεσόγη		Α	Very Low
334	04/12/2003	Πόλη Λευκωσίας		Α	Very Low
335	04/12/2003	Λατσιά		Α	Very Low
336	04/12/2003	Γέρι		Α	Very Low
337	04/12/2003	Άγιος Αντώνιος		Α	Very Low
338	15/12/2003	Πόλη Λάρνακας		Α	Low
339	11/01/2004	Λεμεσός		ΑΚ	Low
340	11/01/2004	Ζακάκι		ΑΚ	Low
341	11/01/2004	Άγιος Ιωάννης,		ΑΚ	Low
342	11/01/2004	Κάτω Πολεμίδια		ΑΚ	Low
343	11/01/2004	Πόλη Λάρνακας		Α	Very Low
344	11/01/2004	Κάτω Μονή		ΑΤ	Very Low
345	11/01/2004	Αγία Μαρίνα Ξυλιάτου		ΑΤ	Very Low
346	12/01/2004	Κάτω Πολεμίδια		ΑΚ	Medium
347	12/01/2004	Ζακάκι		ΑΚ	Medium
348	12/01/2004	Άγιος Ιωάννης		ΑΚ	Medium
349	12/01/2004	Άγιος Γεώργιος		ΑΚ	Medium
350	12/01/2004	Ύψωνας		ΑΚ	Medium
351	12/01/2004	Τ ραχώνι		ΑΚ	Medium
352	12/01/2004	Κοτσιάτης	Γιαλιάς	Τ	Very Low
353	12/01/2004	Αγία Βαρβάρα		Τ	Very Low
354	12/01/2004	Πέρα Χωρίο Νήσου		Τ	Very Low
355	12/01/2004	Πόλη Λάρνακας,		Α	Medium
356	12/01/2004	Κοφίνου		Α	Medium
357	12/01/2004	Αραδίππου		Α	Medium
358	12/01/2004	Ορόκλινη		Α	Medium
359	12/01/2004	Αλεθρικό	Τρέμιθος	Α	Medium
360	12/01/2004	Ξυλοφάγου		Κ	Low
361	12/01/2004	Δερύνεια		Κ	Low
362	12/01/2004	Αυγόρου,		Κ	Low
363	12/01/2004	Λιοπέτρι		Κ	Low
364	12/01/2004	Σωτήρα		Κ	Low
365	12/01/2004	Παραλίμνι		Κ	Low
366	12/01/2004	Πόλη Πάφου,		Τ	Very Low
367	12/01/2004	Πόλις Χρυσοχούς		Τ	Very Low
368	12/01/2004	Τίμη		Τ	Very Low
369	12/01/2004	Μανδριά		Τ	Very Low
370	12/01/2004	Στρόβολος	Πεδιαίος	ΑΤ	Low
371	12/01/2004	Παλαιχώρι	Μαρούλλενα	ΑΤ	Low
372	31/5-1/6/2005	Αγίοι Τριμιθιάς		Τ	Very Low

322	02/12/2003	Δάλι	Ποταμός Αλμυρός, (Γιαλιάς)	Τ	Medium
323	02/12/2003	Νήσου	Γιαλιάς	Τ	Very Low
324	02/12/2003	Δάλι		Τ	Very Low
325	02/12/2003	Στρόβολος,	Πεδιαίος	Τ	Very Low
326	02/12/2003	Λακατάμια,	Πεδιαίος	Τ	Very Low
327	02/12/2003	Ψημολόφου		Τ	Very Low
328	3-4/12/2003	Πόλη Λάρνακα		Α	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
376	31/5-1/6/2005	Αγλαντζιά	Πεδιαίος	ΑΤ	Medium
377	31/5-1/6/2005	Λακατάμια		ΑΤ	Medium
378	31/5-1/6/2005	Στρόβολος		ΑΤ	Medium
379	31/5-1/6/2005	Έγκωμη		ΑΤ	Medium
380	31/5-1/6/2005	Εργάτες		ΑΤ	Medium
381	31/5-1/6/2005	Καμπιά		ΑΤ	Medium
382	31/5-1/6/2005	Ψημολόφου		ΑΤ	Medium
383	31/5-1/6/2005	Δευτερά		ΑΤ	Medium
384	31/5-1/6/2005	Πέρα Ορεινής		ΑΤ	Medium
385	31/5-1/6/2005	Αρεδιού		ΑΤ	Medium
386	31/5-1/6/2005	Τσέρι		ΑΤ	Medium
387	18/11/2005	Ζακάκι		Α	Medium
388	18/11/2005	Ομόνοια		Α	Medium
389	18/11/2005	Άγιος Αθανάσιος		Α	Medium
390	18/11/2005	Ύψωνας		Α	Medium
391	11/01/2006	Αγία Νάπα		Κ	Medium
392	11/01/2006	Παραλίμνι		Κ	Medium
393	11/01/2006	Λιοπέτρι		Κ	Medium
394	11/01/2006	Αυγόρου		Κ	Medium
395	11/01/2006	Άχνα		Κ	Medium
396	11/01/2006	Σωτήρα		Κ	Medium
397	11/01/2006	Ξυλοφάγου		Κ	Medium
398	27/03/2006	Έγκωμη-Μακεδονίτισσα,		Α	Low
399	27/03/2006	Στρόβολος,		Α	Low
400	27/03/2006	Αγλαντζιά		Α	Low
401	27/03/2006	Άγιοι Ομολογητές		Α	Low
402	27/03/2006	Αρχάγγελος		Α	Low
403	05/07/2006	Στρόβολος,		Α	Very Low
404	05/07/2006	Λακατάμεια		Α	Very Low
405	05/07/2006	Παλλουριώτισσα		Α	Very Low
406	05/07/2006	Καιμακλί		Α	Very Low
407	13/10/2006	Πόλη Πάφου		Α	Medium
408	30/10/2006	Πόλη Πάφου		ΚΤ	High
409	30/10/2006	Κισσόνεργα		ΚΤ	High
410	30/10/2006	Έμπα		ΚΤ	High
411	30/10/2006	Τάλα		ΚΤ	High
412	30/10/2006	Χλώρακα		ΚΤ	Low
413	30/10/2006	Πέγεια		ΚΤ	Low
414	31/10/2006	Κίτι	Τρέμιθος	Τ	Very Low
415	31/10/2006	Λειβάδια	Αρχάγγελος	Τ	Very Low
416	3-5/2/2007	Πόλη Λάρνακας		Α	Very Low

373	31/5-1/6/2005	Παλαιομέτοχο		Τ	Very Low
374	31/5-1/6/2005	Πόλη Λάρνακας		ΑΚ	Very Low
375	31/5-1/6/2005	Ορόκλινη		ΑΚ	Very Low

A/A	Date	Region Name	River Name	Type of flood	Severity of flooding
428	22/12/2008	Μανδριά		Α	Low
429	30/01/2009	Πέγεια	Άσπρος	Τ	Very Low
430	30/01/2009	Πόλις της Χρυσοχούς		Τ	Very Low
431	30/01/2009	Κελοκέδαρα		Τ	Very Low
432	26/02/2009	Κοράκου	Κλάριος	Π	Very Low
433	26/02/2009	Πόλη Πάφου,	Εζούσας	ΑΚ	Low
434	26/02/2009	Γεροσκήπου,		ΑΚ	Low
435	26/02/2009	Επισκοπή		ΑΚ	Low
436	27/10/2009	Αλάμπρα	Γιαλιάς, Γέρος	Π	Medium
437	27/10/2009	Αγία Βαρβάρα,		Π	Medium
438	27/10/2009	Πέρα Χωρίο Νήσου		Π	Medium
439	27/10/2009	Λύμπια		Π	Medium
440	27/10/2009	Δάλι		Π	Medium
441	27/10/2009	Μοσφηλωτή		Π	Medium
442	28/10/2009	Έγκωμη-Μακεδονίτισσα		Α	Very Low
443	28/10/2009	Άγιος Δομέτιος		Α	Very Low
444	28/10/2009	Άγιος Παύλος		Α	Very Low
445	28/10/2009	Άγιος Ανδρέας		Α	Very Low
446	02/11/2009	Πόλη Πάφου		Α	Very Low
447	02/11/2009	Τίμη		Α	Very Low
448	02/11/2009	Μανδριά		Α	Very Low
449	18/01/2010	Λεμεσός		Α	Very Low
450	18/01/2010	Ζακάκι		Α	Very Low
451	18/01/2010	Νατά		Π	Very Low
452	18/01/2010	Χολέτρια		Π	Very Low
453	18/01/2010	Πόλη Λευκωσίας		ΑΤ	Medium
454	18/01/2010	Έγκωμη-Μακεδονίτισα		ΑΤ	Medium
455	18/01/2010	Ακάκι,		ΑΤ	Medium
456	18/01/2010	Λακατάμεια		ΑΤ	Medium
457	18/01/2010	Αστρομερίτης	Κομίτης	ΑΤ	Medium
458	18/01/2010	Περιστερώνα	Κομίτης	ΑΤ	Medium
459	18/01/2010	Ορούντα		ΑΤ	Medium
460	18/01/2010	Στρόβολος	Πεδιαίος	ΑΤ	Medium
461	18/01/2010	Πέρα Χωρίο Νήσου		ΑΤ	Medium
462	18/01/2010	Αρχάγγελος,		ΑΤ	Medium
463	18/01/2010	Φλάσου,	Κλάριος, Κομήτης	ΑΤ	Medium
464	18/01/2010	Δάλι		ΑΤ	Medium
465	18/01/2010	Κοράκου	Κλάριος, Κομήτης	ΑΤ	Medium
466	22/04/2010	Πόλη Λεμεσού		ΑΚ	Medium
467	22/04/2010	Άγιος Αθανάσιος		ΑΚ	Medium

417	3-5/2/2007	Ευρύχου	Ποταμός Κλάριος	Π	Very Low
418	3-5/2/2007	Κοράκου		Π	Very Low
419	22/10/2008	Πόλη Λευκωσίας		Α	Very Low
420	22/10/2008	Αγλαντζιά		Α	Very Low
421	22/10/2008	Αρχάγγελος,		Α	Very Low
422	22/10/2008	Στρόβολος		Α	Very Low
423	22/12/2008	Ζακάκι		Α	Low
424	22/12/2008	Αναρίτα		Α	Low
425	22/12/2008	Ορόκλινη		Α	Low
426	22/12/2008	Ασώματος		Α	Low
427	22/12/2008	Κούκλια		Α	Low

468	03/01/2011	Πόλη Λάρνακας		Α	Low

*Sources of the historic flood events	**Type of flood
1. Systematic check of newspaper archive	Θ = coastal flooding
2. Published in Newspaper: «Κυπριακός Φύλαξ» (1934 - 1936)	T= rapid response
3. Published in the weekly Newspaper ΕΝΩΣΙΣ	Π = river flood
4. Published in the weekly Newspaper ΑΛΗΘΕΙΑ	A = urban flood
5. Published in the Newspaper ΦΩΝΗ ΤΗΣ ΚΥΠΡΟΥ	K = deluge flooding
6. Published in the weekly Newspaper ΣΑΛΠΙΞ	Y = Flood of underground water
7. Published in the weekly Newspaper ΕΥΑΓΟΡΑΣ	
8. Published in the Newspaper ΚΥΠΡΟΣ	
9. Published in the Newspaper ΕΛΕΥΘΕΡΙΑ	
10. Annual reports WDD	
11. Published in the Newspaper «Ο Φιλελεύθερος»	
12. Meteorological Department	
13. Fire Department	
14. Theses E. Χρίστου 1995	
15. Photo archive of hydrology department	
16. Archive of hydrology department	
17. Published in the Newspaper «Η Σημερινή»	
18. Published in the Newspaper «Ο Αγών»	
19. Published in the Newspaper «Πολίτης»	
20. Letter from the president of Sylikou 3/11/2010	
21. Published in the Newspaper «Νέος Κυπριακός Φύλαξ»	

5.2 Analysis of flood models

Two of the main steps in accomplishing the obligations towards the European Union with regard to the implementation of the European Directive 2007/60/EC on the assessment and management of flood risks and the relevant law of Cyprus Law N. 70 (i)/2010 which provides for the evaluation, management and treatment of flood risks, are the hydrologic and hydraulic models of the most vulnerable to flooding areas in Cyprus. This modeling helps in the creation of the flood hazard and risk maps.

This report contains information taken by projects from private companies worked on the modelling of flood risks in Cyprus under the instructions of Water Development Department who sponsored of the projects.

5.2.1 Hydrological rainfall – runoff models

The development of hydrological models was performed by using the HEC-HMS software and the HEC-GeoHMS as an additional toolbar in the ESRI products ArcGIS.

The model parameters were divided into two categories. Those which are directly measurable and those that are estimated according to the characteristics of the area. The former includes:

- the extent of the basin
- the mean slope of the basin
- length of watercourses

The parameters belonging in the second category are the indirect ones:

- The CN (Curve Number) number which was determined though ArcMAP using the available geographic data (soil characteristics and land use)
- The initial humidity
- The cross section of the river at sites that were considered to be natural streams or arranged with a non-lined cross section was considered trapezoidal. In positions where there were arrangements with open or close lined section, the corresponding cross section was considered (usually rectangular).
- The dimensions of the stream
- The Manning roughness coefficient
- The slope of the stream

Examples of the sub-basin and stream parameters used are given in the following tables.

Table 5.12: Example of the parameters used for the sub-basins of the Kalogeros river **(**Source: Water Development Department)

A/A	**Name**	**Area**	**Average slope**	**CN Number**	**Initial Losses**	**24hr Rainfall 2Yrs**	**Inflow time**	**Lag time**
		(km2)	**(%)**		**(mm)**	**(in)**	**(hr)**	**(hr)**
1	W240	0.354	6.75	85.2	8.83	1.457	0.29	0.17
2	W250	0.987	5.73	89.5	5.96	1.457	0.79	0.48
3	W260	0.612	6.79	88.8	6.39	1.457	0.68	0.41
4	W280	0.619	6.18	82.2	11.01	1.457	0.89	0.53
5	W290	0.255	6.50	84.5	9.29	1.457	0.29	0.17
6	W310	1.940	4.37	85.8	8.40	1.483	0.93	0.56
7	W320	1.901	5.59	79.0	13.46	1.648	1.04	0.62
8	W330	1.099	7.64	78.9	13.60	1.675	0.85	0.51
9	W360	0.832	4.53	88.7	6.46	1.457	0.70	0.42
10	W380	2.751	4.96	79.7	12.95	1.586	0.98	0.59
11	W410	3.803	15.77	67.3	24.70	1.700	1.10	0.66
12	W420	1.059	10.81	75.0	16.90	1.700	0.80	0.48
13	W440	2.646	17.45	67.6	24.34	1.700	1.23	0.74
14	W490	3.046	14.24	70.5	21.31	1.673	1.34	0.80
15	W530	3.099	7.23	74.7	17.17	1.700	1.48	0.89
16	W540	1.305	8.51	85.5	8.64	1.700	0.32	0.19
17	W580	0.033	4.44	74.2	17.69	1.457	0.12	0.07
18	W630	0.450	7.33	84.1	9.61	1.510	0.47	0.28
19	W640	2.464	4.46	83.9	9.75	1.679	1.23	0.74
						Area (Km2) =		29.26
						Inflow time (hrs) Tc=		4.32
						Area Reduction Factor =		**0.98**

Table 5.13: Example of the parameters used for the streams of the Kalogeros river (Source: Water Development Department)

A/A	Name	Length	Upstream elevation	Downstream elevation	Slope	Cross section	Width	Lateral slope	Manning Coefficient	Time of Tavel
		(m)			(m/m)		(m)	(h:v)		(hrs)
1	R20	330.52	158.89	158.89	0.004000	Trapezoid	6.0	1.5	0.050	0.14
2	R30	644.41	161.63	158.89	0.004260	Trapezoid	6.0	1.5	0.040	0.21
3	R60	1199.33	169.48	161.63	0.006546	Trapezoid	6.0	1.5	0.070	0.55
4	R50	323.85	171.60	169.48	0.006549	Trapezoid	6.0	1.5	0.040	0.08
5	R70	763.41	175.39	171.60	0.004952	Trapezoid	6.0	1.5	0.070	0.40
6	R150	2649.78	196.61	175.39	0.008008	Trapezoid	10.0	1.5	0.040	0.64
7	R110	845.27	170.28	161.63	0.010230	Trapezoid	3.0	1.5	0.070	0.30
8	R160	1590.89	184.56	170.28	0.008975	Trapezoid	3.0	1.5	0.025	0.22
9	R140	164.50	197.59	196.61	0.005960	Trapezoid	10.0	1.5	0.030	0.03
10	R230	3979.10	243.22	197.59	0.011469	Trapezoid	5.0	1.5	0.035	0.68
11	R550	1608.09	266.85	243.22	0.014691	Trapezoid	3.0	1.5	0.035	0.24
12	R90	331.78	182.26	175.39	0.020716	Trapezoid	2.0	1.5	0.030	0.04
13	R610	708.55	187.06	182.26	0.006781	Trapezoid	2.0	1.5	0.030	0.13

5.2.1.1 Design storms

Rainfall (IDF) curves produced by the Cyprus Meteorological Service were used for the formation of the design storms. For each station that affects the particular basin, three hyetographs (graphical representation of rainfall over time) were constructed (one for each return period T=20 years, T=100 years and T=500 years).

The rainfall heights of the hyetographs were such that they ensure that the resulting tensions for selected durations (e.g. 5min, 10min, 1min, 30min, 1hr, 2hr, 6 hr, 24 hr) will be equal to those of the corresponding rainfall for each of the return periods. The method proposed to be used is the Alternating Block method as described in the relevant bibliography (Applied Hydrology, 1988, V.T. Chow, D.R. Maidment and L.W. Mays).

As an example, the following tables were used for the formation of design storms in the case of the Kalogeros River.

Table 5.14: Influence of the weather stations on each sub-basin of the Kalogeros River (Source: Water Development Department)

Watershed (basin)	**Weather Station**	**Area of influence (km2)**	**Weight**
W240	666	0.438	0.999
W250	666	1.174	0.999
W260	666	0.612	0.999
W280	666	0.619	0.999
W290	666	0.255	0.999
W310	583	0.133	0.068
W310	640	0.670	0.344
W310	666	1.146	0.588
W320	583	1.498	0.788
W320	666	0.402	0.212
W330	583	0.987	0.898
W330	666	0.111	0.102
W360	666	0.831	0.999
W380	583	1.462	0.532
W380	666	1.288	0.468
W410	583	3.800	0.999
W420	583	1.058	0.999
W440	583	2.644	0.999
W490	580	0.341	0.112
W490	583	2.661	0.873
W490	597	0.043	0.014
W530	583	3.165	0.999
W540	583	1.304	0.999
W580	666	0.033	0.999
W630	583	0.086	0.191
W630	640	0.102	0.227
W630	666	0.261	0.582

Watershed (basin)	**Weather Station**	**Area of influence (km2)**	**Weight**
W640	583	2.178	0.902
W640	640	0.236	0.098
W640	666	0.000	0.000

Table 5.15: Example of calculation of the watersheds' time of travel for the Kalogeros River (Source: Water Development Department)

Watershed Name	W240	W250	W260	W280	W290	W580	W310	W320	W330	W360
Watershed ID	24	25	26	28	29	58	31	32	33	36
Sheet Flow Characteristics										
Manning's Roughness Coefficient	0.011	0.011	0.011	0.06	0.011	0.06	0.011	0.06	0.06	0.011
Flow Length (ft)	100	100	100	100	100	99.9999	99.9999	99.9998	100	100.0001
Two-Year 24-hour Rainfall (in)	1.457	1.457	1.457	1.457	1.457	1.457	1.483	1.648	1.675	1.457
Land Slope (ft/ft)	0.0453	0.016	0.0752	0.0175	0.0058	0.0815	0.1069	0.1802	0.0177	0.0131
Sheet Flow Tt (hr)	0.02	0.03	0.02	0.12	0.05	0.07	0.02	0.05	0.11	0.04
Shallow Concentrated Flow Characteristics										
Surface Description (1 - unpaved, 2 - paved)	2	2	2	1	2	1	2	1	1	2
Flow Length (ft)	3092	7021	4705	4902	2899	196.4087	7593.813	6477.444	1269.676	4673.506
Watercourse Slope (ft/ft)	0.0332	0.0187	0.0191	0.0126	0.0331	0.0337	0.018	0.0323	0.0458	0.0174
Average Velocity - computed (ft/s)	3.70	2.78	2.81	1.81	3.70	2.96	2.73	2.90	3.45	2.68
Shallow Concentrated Flow Tt (hr)	0.23	0.70	0.47	0.75	0.22	0.02	0.77	0.62	0.10	0.48
Channel Flow Characterisitics										
Cross-sectional Flow Area (ft2)	22.02	18.02	22.02	22.02	22.02	18.02	22.02	18.02	26.02	19.02
Wetted Perimeter (ft)	17.78	13.78	17.78	17.78	17.78	13.78	17.78	13.78	21.78	14.78
Hydraulic Radius - computed (ft)	1.24	1.31	1.24	1.24	1.24	1.31	1.24	1.31	1.19	1.29
Channel Slope (ft/ft)	0.006	0.0067	0.0036	0.0118	0.004	0.0156	0.0177	0.0116	0.0078	0.0121
Manning's Roughness Coefficient	0.05	0.025	0.04	0.07	0.04	0.025	0.07	0.05	0.04	0.07
Average Velocity - computed (ft/s)	2.66	5.83	2.58	2.67	2.72	8.90	3.27	3.84	3.70	2.77
Flow Length (ft)	348	1251	1803	151	197	1024.33	1680.256	5124.672	8470.322	1816.877
Channel Flow Tt (hr)	0.04	0.06	0.19	0.02	0.02	0.03	0.14	0.37	0.64	0.18
Watershed Time of travel (hr)	0.29	0.79	0.68	0.89	0.29	0.12	0.93	1.04	0.85	0.70

5.2.1.2 Rainfall losses

The loss model used is the Curve Number model (CN) of SCS (SCS National Engineering Handbook, Section 4, 1985) which is used empirically in hydrology for the prediction of direct runoff or infiltration due to rainfall (United States Department of Agriculture (1986). Urban hydrology for small watersheds. Technical Release 55 (TR-55) (Second ed.). Natural Resources Conservation Service, Conservation Engineering Division). The existing Corine 2006 map was used to determine the combination of territorial coverage and processing. The matching of the SCS tables was based on the closest resemblance to the descriptions of the Corine map and the SCS TR-55 tables. A relevant work in southern Italy was also taken into account.

5.2.1.3 Basin response-Rainfall Runoff relationships

The model used is the SCS (Soil Conservation Service) unit model, which is an event model, a single, empirical, parameterized identifier that is assessed by the properties of the watershed. It is fully consistent with the available data and the type of rainfall in Cyprus (generally individual events).
The data required for the construction of the SCS model result from the characteristics of the basin such as:

- The area of the basin and
- The concentration time, which is the time required to reach the farthest hydraulic drop in the basin output position. This time can be allocated to the following components:
    - The time needed in the slopes of the basin
    - The route time as shallow flow and
    - The time of travel in the main stream

5.2.1.4 Routing of hydrographs through pipelines

Routing of the flow is the process of determining the hydrography at a point of the water stream from a known or hypothetical hydrograph to one or more upstream points.
The basic data required for the implementation of Routing models are:

- The description of the water stream, is either in indirect ways or in usual terms of bottom width, cross section etc.
- The parameters of energy loss models e.g. Manning roughness coefficient
- The initial conditions of the basin
- Limit conditions. The marginal conditions are the upstream influx, the lateral inputs, input hydrographs of the confluences etc.

The model that has been used is the Muskingum-Cunge model.

5.2.1.5 Reservoirs

Reservoirs in Cyprus do not, always, work to cover the needs of flood protection. The modelling of the existing reservoirs was made considering that at the beginning of the rainfall their level is not below the maximum normal level.
Storage - water level relationships in the reservoir and water level – flow supply from Spillway were taken from the Water Development Department.

5.2.1.6 Calibration of hydrological models

In the 7 out of the 19 regions there are flow data. These areas are the Pediaios river with 2 stations, the Kalogeros river with 1 station, the inflow River of Paralimni Lake with 1 station, the Gialias river with 2 stations, the Archangelos – Kammitsis river with 3 stations, the Germasogeia river with 2 stations and the Garyllis river with 1 station. After calibration, the parameters of the models were adjusted in order to represent (model) satisfactorily two recent historical floods and to satisfactorily approach the expected value of the runoff for each of the 3 recovery periods.

5.2.2 Hydraulic models

Hydraulic models were developed using the HEC-RAS software for scalar unsteady flow analysis conditions. The purpose of the hydraulic models is to calculate the depth and flow velocities that will be used in the of hazard maps. For each hydraulic model there were three simulations – one for each return period of 20, 100 and 500 years for which the corresponding hazard maps were produced as well.

5.2.2.1 Model Geometry Configuration

The model geometry was created using the tools of HEC-GeoRAS in an ArcGIS environment and then minor corrections were made within the HEC-RAS software.

The information used in the hydraulic model is as follows:

- The ground model resulting from the LIDAR footprint made along the river
- Aerial photos taken during LIDAR capture
- A 5-meter digital Raster Dem model
- Photographic material from on-site study visits across the river to estimate linear friction loss coefficients
- Sketches of measurements of the dimensions of the structures (bridges, drains and ditches)

5.2.2.2 Integrating hydraulic structures into the model

The construction data from the topographical surveys were recorded by checking the information using the ground model.

Below is a Table 5.with the structures taken into account in the hydraulic model of Kalogeros River. It is noted that types of construction may differ from reality for simulation needs, e.g. a small-sized bridge can be modelled as a culvert, or a blocked culvert can be simulated as a small embankment.

Table 5.16: Structures affecting the river flow for the Kalogeros River (Source: Water Development Department)

A/A	River Code	Section Code	Model Position	Structure type	Structure overcoming		
					T=20	T=100	T=500
1	c04	c04_01	0+157	Bridge / Culvert	NO	NO	NO
2	c04	c04_01	0+724	Bridge / Culvert	NO	YES	YES
3	c04	c04_01	2+387	Bridge / Culvert	YES	YES	YES
4	c04	c04_01	2+544	Bridge / Culvert	NO	NO	NO
5	c04	c04_01	3+375	Bridge / Culvert	NO	YES	YES
6	c04	c04_01	5+448	Bridge / Culvert	YES	YES	YES
7	c04	c04_01	5+756	Bridge / Culvert	YES	YES	YES
8	c04	c04_01	5+886	Bridge / Culvert	YES	YES	YES

5.2.2.3 Estimation of the coefficients of linear local friction losses

The estimation of the coefficients of linear losses was done by calculating the Manning coefficient using the Cowan method, as described in Open Channel Hydraulics, Ven Te Chow, Reprint of the 1959 Edition, pp. 106-109. For each section where the value of the coefficient n was estimated, there is a corresponding photographic documentation from the site visit.

The following Table 5.shows the calculation of the linear loss coefficients using the above method. In the Table 5.there are references to photos taken during the study.

Table 5.17: Estimation of the Manning coefficient for Kalogeros River (Source: Water Development Department)

Main Channel																									Left Overbank			Right Overbank		
Photo	Station	Table	Cowan method																						Station	Table	n	Station	Table	n
			Material involved (n_0)			Degree of irregularity (n_1)			Variations of Channel cross sections (n_2)			Relative effect of obstructions (n_3)			Vegetation (n_4)			Degree of meandering (m_5)						Value n						
			id	condition	value	id	condition	value	id	condition	value	id	condition	value	id	condition	value	id	L	D.M.	id	condition	value							
	0																								0			0		
DSC01380	160	D1a8	1	Earth	0.020	1	Smooth	0.000	2	Alternating occasionally	0.005	1	Negligible	0.000	4	Very high	0.075	1	155	1.03	1	Minor	1.000	0.100	160	D2d1	0.110	160	D2d1	0.110
DSC01386	700	Ce2	1	Earth	0.020	1	Smooth	0.000	2	Alternating occasionally	0.005	1	Negligible	0.000	2	Medium	0.018	1	500	1.08	1	Minor	1.000	0.043	400	D2a2	0.035	250	build	0.025
DSC01403	1000	D1a3	1	Earth	0.020	1	Smooth	0.000	1	Gradual	0.000	1	Negligible	0.000	2	Medium	0.018	2	240	1.25	2	Appriciable	1.150	0.044	600	build	0.025	420	D2d4	0.100
DSC01418	1900	D1a7	1	Earth	0.020	3	Moderate	0.010	2	Alternating occasionally	0.005	1	Negligible	0.000	2	Medium	0.018	2	760	1.18	1	Appriciable	1.150	0.061	3,000	D2a1	0.030	600	D2d4	0.100
DSC01439	2240	D1a3	1	Earth	0.020	2	Minor	0.005	1	Gradual	0.000	1	Negligible	0.000	1	Low	0.008	2	250	1.36	2	Appriciable	1.150	0.038	3,400	build	0.025	720	D2c1	0.050
DSC01448	2850	D1a7	1	Earth	0.020	3	Moderate	0.010	2	Alternating occasionally	0.005	1	Negligible	0.000	1	Low	0.008	2	500	1.22	2	Appriciable	1.150	0.049	3,425	park	0.016	1,250	build	0.025
DSC01476	3100	B2c2		Open channel																				0.016	5,960	D2a1	0.030	1,800	D2a1	0.030
DSC01492	4900	D1a7	1	Earth	0.020	3	Moderate	0.010	2	Alternating occasionally	0.005	1	Negligible	0.000	2	Medium	0.018	2	1450	1.24	2	Appriciable	1.150	0.061				2,260	build	0.025
DSC01534	5300	D1a3	1	Earth	0.020	2	Minor	0.005	2	Alternating occasionally	0.005	1	Negligible	0.000	1	Low	0.008	1	400	1.00	1	Minor	1.000	0.038				3,125	Park	0.016
DSC01555	5400	D1a7	1	Earth	0.020	3	Moderate	0.010	2	Alternating occasionally	0.005	1	Negligible	0.000	2	Medium	0.018	1	90	1.11	1	Minor	1.000	0.053				5,960	D2a1	0.030
DSC01556	5500	B2c2		Open channel																				0.018						
DSC01564	5700	Cb2	1	Earth	0.020	1	Smooth	0.000	1	Gradual	0.000	1	Negligible	0.000	1	Low	0.008	1	170	1.18	1	Minor	1.000	0.028						
DSC01567	5750	B2c2		Open channel																				0.016						
DSC01570	5960	Cb2	1	Earth	0.020	1	Smooth	0.000	1	Gradual	0.000	1	Negligible	0.000	1	Low	0.008	1	170	1.24	2	Minor	1.000	0.028						

5.2.2.4 Estimation of the local loss coefficient

The local loss coefficients at the entrances of the culverts were based on the tables in the HEC-RAS manual and the Hydraulic Design of Highway Culverts (FHWA, 1985) as can be seen in tables below.

Table 5.18: Entrance loss coefficient for Pipe Culverts (FHWA, 1985)

Type of Structure and Design of Entrance	Coefficient, k_{en}
Concrete Pipe Projecting from Fill (no headwall):	
Socket end of pipe	0.2
Square cut end of pipe	0.5
Concrete Pipe with Headwall or Headwall and Wingwalls:	
Socket end of pipe (grooved end)	0.2
Square cut end of pipe	0.5
Rounded entrance, with rounding radius = 1/12 of diameter	0.2
Concrete Pipe:	
Mitered to conform to fill slope	0.7
End section conformed to fill slope	0.5
Beveled edges, 33.7 or 45 degree bevels	0.2
Side slope tapered inlet	0.2
Corrugated Metal Pipe or Pipe-Arch:	
Projected from fill (no headwall)	0.9
Headwall or headwall and wingwalls square edge	0.5
Mitered to conform to fill slope	0.7
End section conformed to fill slope	0.5
Beveled edges, 33.7 or 45 degree bevels	0.2
Side slope tapered inlet	0.2

Table 5.19: Entrance loss coefficient for reinforced concrete box culverts (FHWA, 1985)

Type of Structure and Design of Entrance	Coefficient, k_{en}
Headwall Parallel to Embankment (no wingwalls):	
Square-edged on three edges	0.5
Three edges rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 30 to 75 degrees to Barrel:	
Square-edge at crown	0.4
Top corner rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 10 to 25 degrees to Barrel:	
Square-edge at crown	0.5
Wingwalls parallel (extension of sides):	
Square-edge at crown	0.7
Side or slope tapered inlet	0.2

Table 5.20: Entrance loss coefficients for ConSpan culverts (FHWA, 1985)

Type of Entrance	Coefficient, k_{en}
Extended wingwalls 0 degrees	0.5
45 degree wingwalls	0.3
Straight Headwall	0.4

5.2.2.5 Positioning of ineffective flow areas

Ineffective flow areas are flooded areas that are not characterized by significant speeds in the direction of the flow. Such areas have been set upstream and downstream from bridge embankments and culverts and into riparian areas where water is stagnated.

5.2.2.6 Calibration of hydraulic Models

From the 7 areas for which hydrological models were calibrated only the 4 had measuring stations in the part of the stream that developed hydraulic model. A calibration of the hydraulic model was attempted, but no significant changes were made to the parameters of the model (coefficient Manning) originally selected.

5.2.2.7 Simulations

The simulations were performed for three return periods, in the same geometric file of HEC-RAS. The simulation scenarios have been introduced as boundary conditions of the model. The start and end time of the entry floodgraphs coincides with the corresponding times of the hydrological model.

5.3 Consequences and impact assessment

In 2014, Water Development Department (WDD), created hazard and risk maps the most vulnerable, to flooding, areas in Cyprus given in Task 4.1 of this project. The purpose of this deliverable is to specify the methodology followed by the WDD to produce the flood hazard maps as well as the flood risk maps. The hazard maps produced, show the impact of the flood, including the area covered by the overflow as well as the water depth, while, on the other hand, the risk maps produced depict the potential negative effects of the floods. The information was taken from both procedures shoed in Tasks 4.1 and 4.2. The creation of such maps helped in fulfilling Cyprus's obligations towards the European Union regarding the implementation of the European Directive 2007/60/EC on the assessment and management of flood risks and the relevant Law of Cyprus Law N. 70 (I) / 2010.
This report contains information taken by projects from private companies worked on the modelling of flood risks in Cyprus under the instructions of Water Development Department who sponsored of the projects.

5.3.1 Areas vulnerable to flooding in Cyprus

The following Table 5.determines the 19 areas vulnerable to flooding in Cyprus, presented in Task 4.1.

Table 5.21: Areas of potential flooding in Cyprus (Source: WDD)

A/A	Area Code	Name of River / Stream	Length of river (m)
1	CY-APSFR01	Pediaios	25 310
2	CY-APSFR02	Klimos	5 740
3	CY-APSFR03	Merikas (tributary)	3 250
4	CY-APSFR04	Kalogeros	5 630
5	CY-APSFR05	Merikas	5 690
6	CY-APSFR06	Almiyros-Alikos	7 750
7	CY-APSFR07	Paralimni	3 290
8	CY-APSFR08	Gialias	5 810
9	CY-APSFR09	Ormidia	4 960
10	CY-APSFR10	Archangelos	11 300
11	CY-APSFR11	Kamares	6 640
12	CY-APSFR12	Kosinas	8 770
13	CY-APSFR13	Limnarka	3 380
14	CY-APSFR14	Germasogeia	6 070
15	CY-APSFR15	Vathias	7 700
16	CY-APSFR16	Garyllis	13 730
17	CY-APSFR17	Marketou	3 760
18	CY-APSFR18	Komitis	3 600
19	CY-APSFR19	Vasilikos	7 790

5.3.2 Data used

The following data was used during the map production:

- Aerial photographs 2008 provided by the Department of Lands and Surveys.
- Satellite images available from ArcGIS Online for areas not covered by the 2008 backgrounds.
- Bare Earth Digital Terrain Model in Triangular Irregular Network (TIN) format resulting from LIDAR data.
- A geospatial file with the land uses in the areas under consideration and a Table 5.with building and coverage factors per use given by WDD.
- A geospatial database with site locations that may cause accidental pollution in the event of a flood.
- The population density values (area per person).
- The results of the hydraulic modelling solutions for each area.

5.3.3 Flood Hazard and Risk Maps produced

Table 5.22 summarises all the hazard and risk maps produced for all of the areas of consideration.

Table 5.22: Total hazard and risk maps produced

A/A	**Name of River / Stream**	**Hazard maps**					**Risk maps**				**Totals**
		Summary	**Flood possibility**			**Total**	**Flood possibility**			**Total**	
			Low	**Medium**	**High**		**Low**	**Medium**	**High**		
1	Pediaios	8	8	8	8	**32**	8	8	8	**24**	**56**
2	Klimos	2	2	2	2	**8**	2	2	2	**6**	**14**
3	Merikas (tributary)	1	1	1	1	**4**	1	1	1	**3**	**7**
4	Kalogeros	2	2	2	2	**8**	2	2	2	**6**	**14**
5	Merikas	2	2	2	2	**8**	2	2	2	**6**	**14**
6	Almiyros-Alikos	1	1	1	1	**4**	1	1	1	**3**	**7**
7	Paralimni	1	1	1	1	**4**	1	1	1	**3**	**7**
8	Gialias	2	2	2	2	**8**	2	2	2	**6**	**14**
9	Ormidia	2	2	2	2	**8**	2	2	2	**6**	**14**
10	Archangelos	2	2	2	2	**8**	2	2	2	**6**	**14**

11	Kamares	2	2	2	2	**8**	2	2	2	**6**	**14**
12	Kosinas	2	2	2	2	**8**	2	2	2	**6**	**14**
13	Limnarka	1	1	1	1	**4**	1	1	1	**3**	**7**
14	Germasogeia	3	3	3	3	**12**	3	3	3	**9**	**21**
15	Vathias	2	2	2	2	**8**	2	2	2	**6**	**14**
16	Garyllis	3	3	3	3	**12**	3	3	3	**9**	**21**
17	Marketou	2	2	2	2	**8**	2	2	2	**6**	**14**
18	Komitis	1	1	1	1	**4**	1	1	1	**3**	**7**
19	Vasilikos	3	3	3	3	**12**	3	3	3	**9**	**21**
Totals		**42**	**42**	**42**	**42**	**168**	**42**	**42**	**42**	**126**	**294**

In cases of river basins that could not be showed by a single sheet of paper, more than one sheets were numbered appropriately.

5.3.4 Creation of flood hazard maps

1. Extraction of the maximum water level using HEC-RAS

Only the maximum water level section (MaxWS) results were extracted from HEC-RAS per cross section. Hydraulic model resolutions were made for non-steady flow conditions with a five (5) minutes step and a fifteen (15) minutes output.

2. Conversion of the file into XML formatting

In order to import digital data into a GIS environment, the file extracted from HEC-RAS (SDF formatting) has to be converted to XML. The conversion is performed through HEC-GEORAS tools.

3. Import of the XML file into GIS

The above file is imported into a GIS environment using HEC-GEORAS tools. In more detail, a File Geodatabase is created where the vector data is imported as a minimum: a) the XS Cut Lines of the hydraulic model and b) the polygon in which the flooding will be shown, (Bounding Polygon) is depicted. During this phase, the digital model (TIN) of the bare ground is also converted to a mosaic file (dtmgrid). The pixel size has been set at two (2) meters for all models. The size is small since highly analysed data is available due to the LIDAR flood area. This size also determines the pixel size of the flow-rate file to be generated in the next steps.

4. Editing of the vector data

The processing of the above mainly consists from the expansion of the polygon flood imaging to cross sections in the positions wherein set levees point in hydraulic model and in small areas which are flooded but are not described by the cross sections. In the cross sections of the levees, the polygon produced is limited to these positions which affect the extent of the flooding in the cross sections before and after these positions.

5. Production of a triangular digital model of maximum water level

Using a HEC-GEORAS tool (Water Surface Generation) and based on the maximum water level contained in the hydraulic model cross sections already introduced into the GIS, the triangular model of maximum water level (t Max WS) is produced.

6. Production of a mosaic file of depths flow and flood boundaries

The triangular water surface model created in step e. is firstly converted to a mosaic file with a pixel size defined when the data is entering the GIS database (see step 3). The depth flow-rate mosaic is then produced by subtracting for each pixel the value of the terrain altitude from the value the maximum water level. Finally, the flood boundary is generated as the outline of the above depths flow mosaic file.

7. Editing of the flood limit

Then the flood limit is edited in a GIS environment. Normalization of points that were not consistent with the overall picture of the terrain.

8. Editing of the flood mosaic file

For the filling of small soil islets within the flood limits, applied automated methods in Arc GIS Toolbox (Nibble) were used.

9. Cut off a segment of a depth flow file within the processed flood limit

Finally, with the ArcGIS Toolbox (Raster Clip) tools, the processed mosaic depth flow file was cut off within the processed flood limit.

10. Creation of Hazard maps

A geodatabase and a map file (mxd) for each study area and each return period were created. The background of the depth flow record, the flood limit, the cross sections and the cross-sectional boundary were inserted on each map. Then the cross sections whose elements will be visualized are selected. It is noted that due to the high cross-sectional density required in the hydraulic models for solving under non-steady flow conditions, it was not possible to visualize all the cross-sections.

5.3.5 Creation of flood risk maps

Risk maps illustrate the potential negative effects of low, medium and high possibility floods. They include:

- The maximum number of inhabitants likely to be affected by the full development of urban areas in each zone. The estimation of the population potentially affected by the flood is calculated by the combination of satellite imaging where the growth rate of the zones is shown, and the total population of the zone indicated.
- The land use and the type of economic activity based on urban areas in areas likely to be affected. The type of economic activity is distinguished on maps with different colour gradations.
- The “Sensitive” infrastructure (drinking water pumping stations and sewage treatment plants)
- The protected areas of (archaeological sites and Natura 2000 sites).
- The structures that may cause accidental pollution in the event of a flood. (power stations, hazardous waste facilities, slaughterhouses, landfill sites, mineral products industries, large livestock farms, etc.).

For the production of flood risk maps, the following steps were taken per region and per return period:

1. A geographic intersection of the polygonal flood boundary level of the hazard maps was made with the polygonal level of the Urban Areas.
2. The multi-polygonal plane entries resulting from the intersection and consisted of multiple polygons were split into individual polygons with ArcGIS Toolbox tools (Multipart to Singlepart).
3. These polygons were generalized by incorporating small-area polygons (sliver polygons) into their adjacent polygons. The Inclusion was first done automatically for polygons with a minimum criterion of ten m^2 and minimum area / perimeter ratio the numeric value 0.3. The above polygons were integrated into the respective adjacent polygons with the maximum common boundary length. Then, after a visual inspection, the remaining polygons were merged manually.
4. For the above thematic level of flood-affected areas, the population was calculated as the maximum population affected by the full development of the zone by multiplying the building factor and the area of each polygon and dividing by the squared meters corresponding to each resident.
5. Finally, the above polygonal thematic level was transformed into feature point (feature to point) and the maximum potential population affected by the flood was represented (with the size of the point). This information of the fully developed population of the flood area in conjunction with the satellite image from which the rate of development can be estimated gives an estimation of the affected population.

For the compilation of risk maps, a geodatabase was created, per study area, where all geographic data was input for all three return periods. For each return period a separate ESRI ArcMap file (mxd file) was created. The representation of the development zones likely to be affected by flooding was done with different color gradations depending on the type of zone. To aid in the presentation process, an additional field was created in the Table 5.of characteristics of urban areas called "Label_Group" grouping the zones into categories. The residential zones (Group 1) are colored with red gradients, public-use zones (group 2) with blue graduations, the industry / crafts and trade zones (group 3) with yellow scales, and the protection zones and agricultural zones (group 4) with green gradients. Areas labelled as "Non-Zone" (Group 0) were stained with grayscale.

5.3.6 Flood scenarios in Cyprus

The three scenarios that were created to show the flooding events are the ones that are shown on Table 5.22, i.e. low flood possibility (return period of 500 years), medium flood possibility (return period of 100 years) and high flood possibility (return period of 20 years) scenarios. The following maps (**Error! Reference source not found.-Error! Reference source not found.**) represent the 3 scenarios for Pediaios river. Each scenario is separated into hazard and risk maps. There are 8 flood hazard maps showing all three return periods and 24 flood risk maps (8 flood risk maps * 3 return periods - T). The population affected by the flooding of each one of the 19 vulnerable to flooding areas is shown in the next two Figure 5.s.

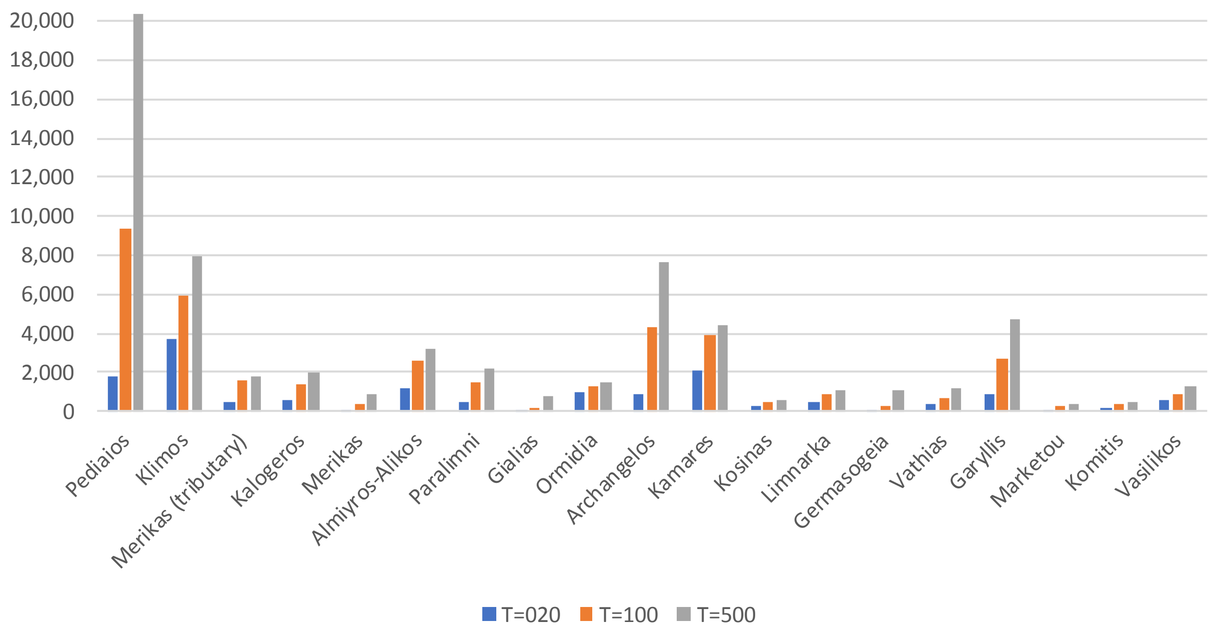


Figure 5. 45: Estimated population affected by flooding in full development of the river area (WDD)

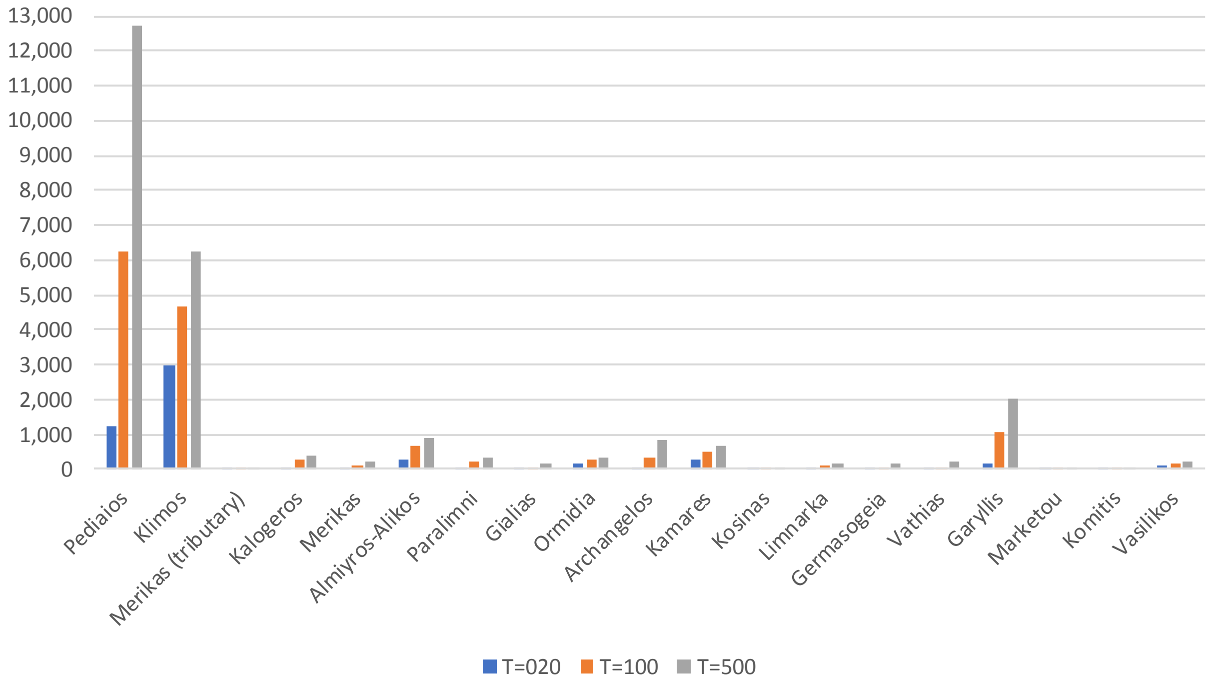


Figure 5. 46: Estimated population (in river area) affected by flooding in 2014 (WDD)

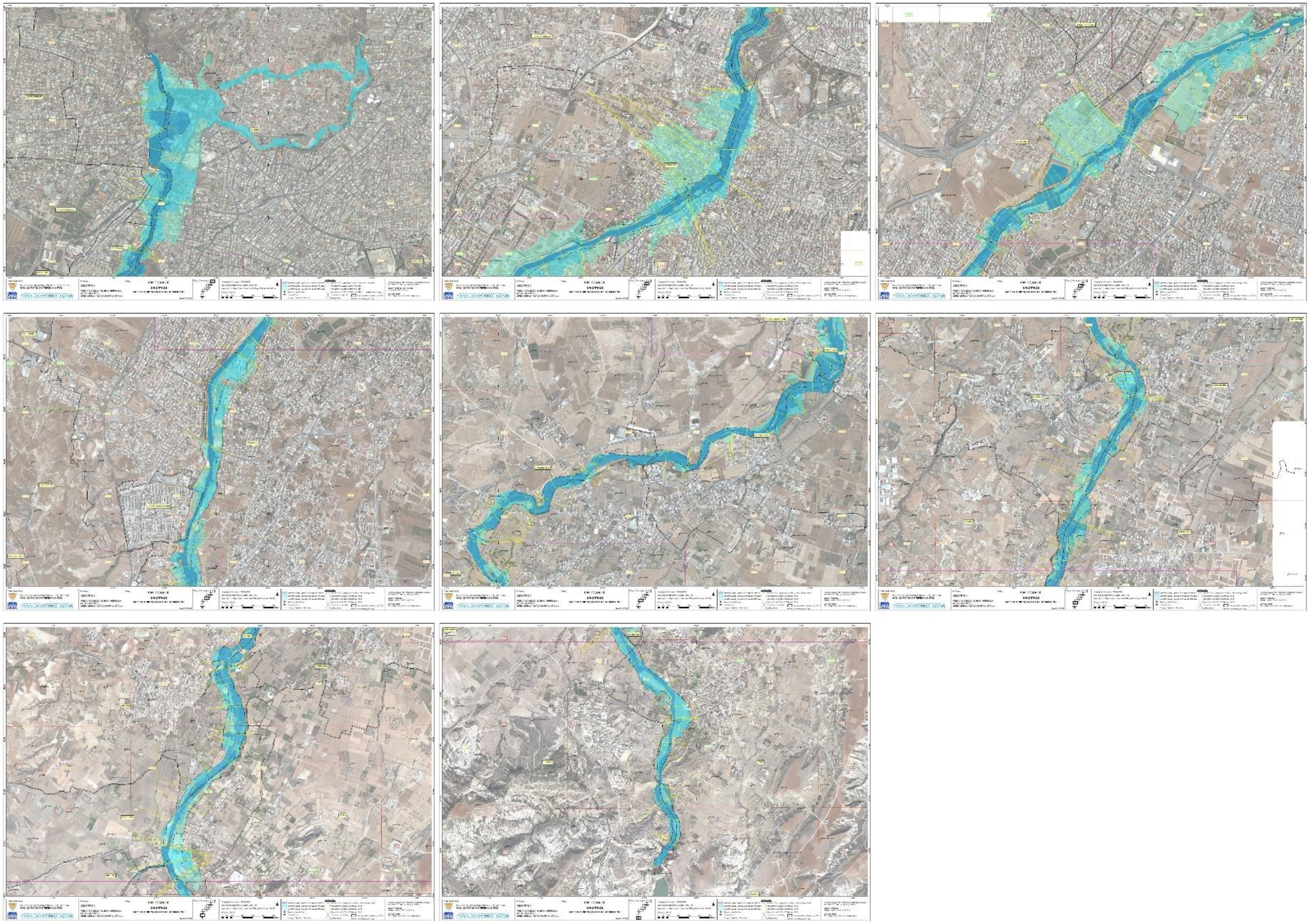


Figure 5.8-5.47: Flood Hazard map of Pediaios river - 20, 100 and 500 restoration periods – 1-8 (WDD)

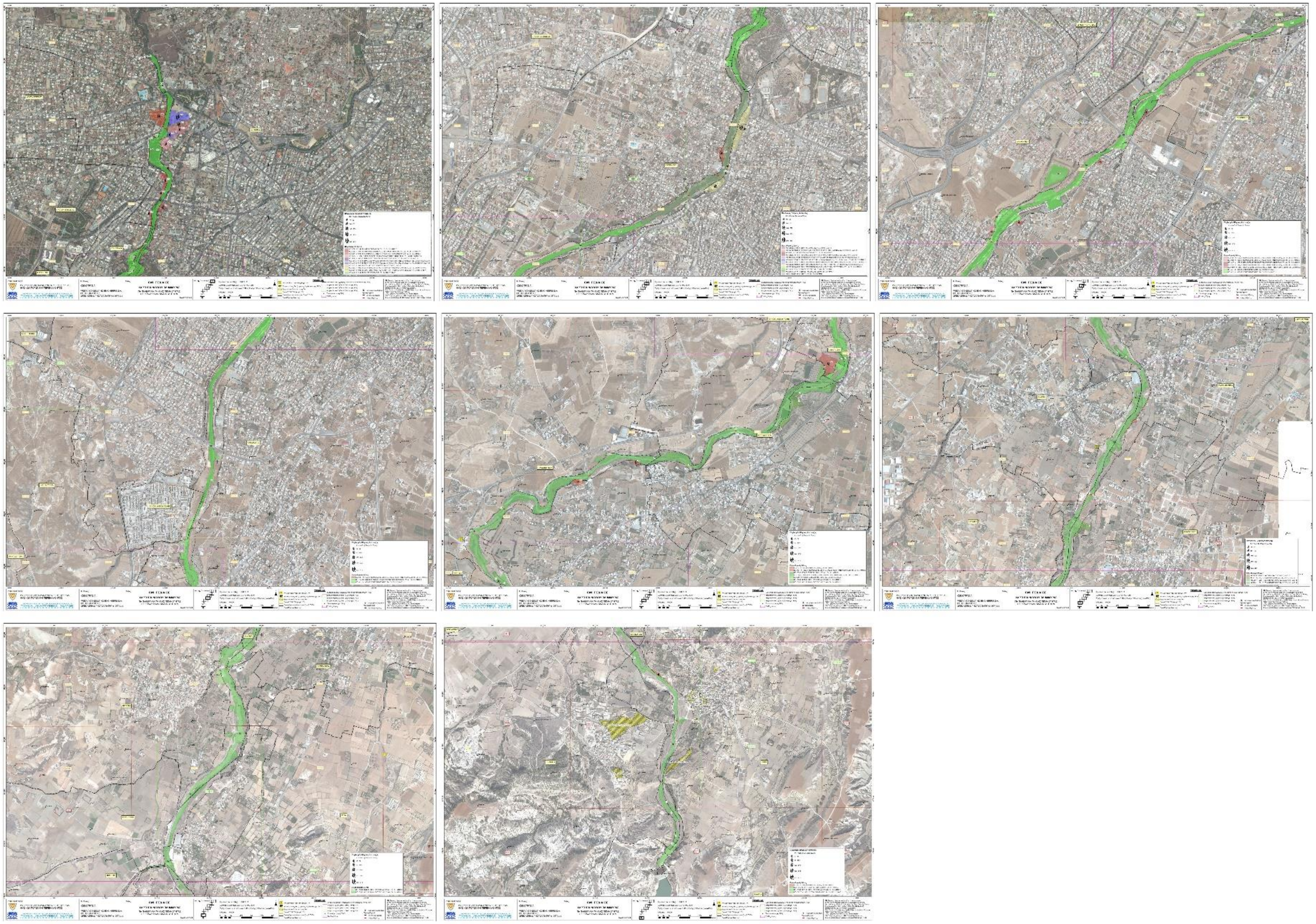


Figure 5.16-5.48: Flood Risk map of Pediaios river - 20 years restoration period ,1-8 (WDD)

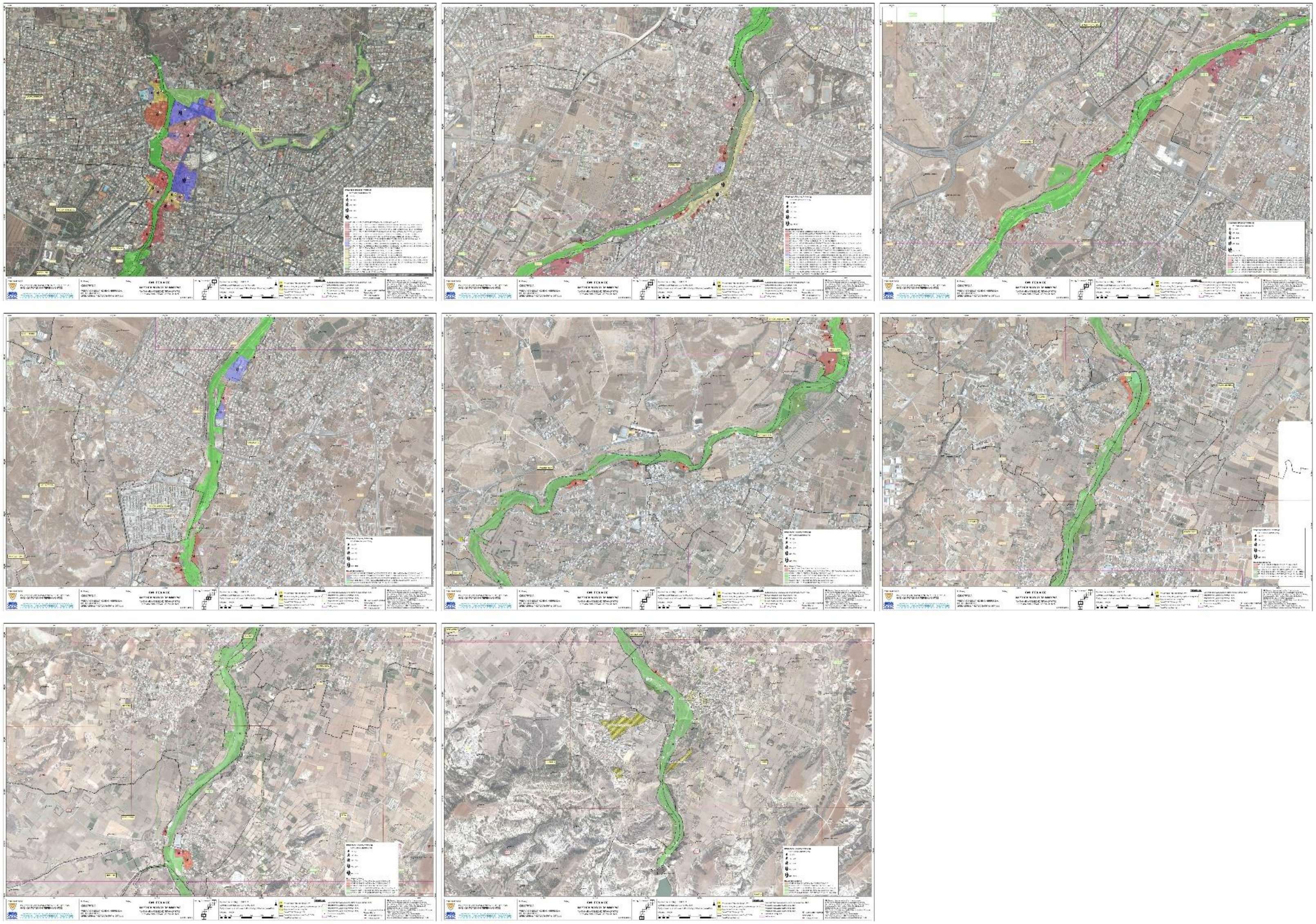


Figure 5.24-5.31: Flood Risk map of Pediaios river - 100 years restoration period ,1-8 (WDD)

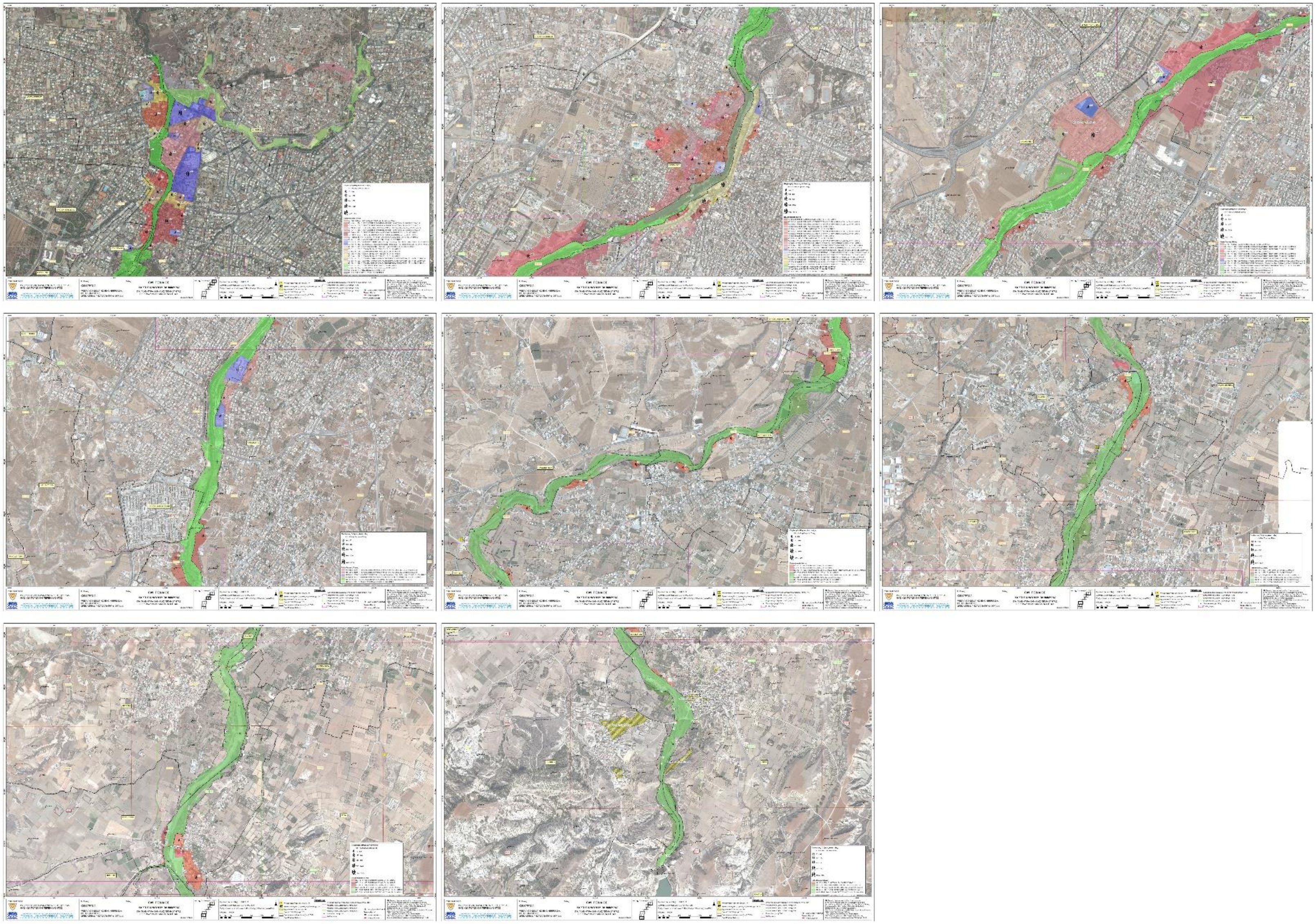


Figure 5.32-5.49: Flood Risk map of Pediaios river - 500 years restoration period – 8/8 (WDD)

5.3 Early warning system for floods in Cyprus

The aim of this task is to describe an Early warning tool produced by an EU funded project that supports decision makers in the prediction of flood events according to the flood models created in Task 4.3. This tool is connected to a geodatabase created in a Geographic Information System (GIS) environment and through interpolation according to the intensity of precipitation. It is a tool, which links the maximum intensity precipitation to areas which can lead to potentials floods.

The Early Warning tool was produced during a project that received funding from the European Union's Directorate-General humanitarian aid and civil protection (DG-ECHO) under Grant Agreement ECHO/SUB/2015/713788/PREP02. The name of the project was "Use of SDSS and MCDA to prepare for disasters Or Plan for multiple hazards" while "DECATASTROPHIZE" was its acronym. The information of this task was taken from the DECATASTROPHIZE project.

The Decision Support System (DSS) Tool

This tool is a platform for the dissemination of geospatial data and information about hazards, including floods, for emergency management purposes. The basic features of the tool are:

- Basic GIS visualization. The tool performs in a GIS environment i.e. it displays vector and raster data which overlay over high resolutions background, it displays layers legends, there is scale control and mouse lat/long coordinates, maps printing and measuring tools are applicable.
- Geospatial data integration. Different GIS tools can be used by different authorized personnel in monitoring the same or different hazard/event
- Web GIS editing tools to harmonize feedback. The user can to annotate a map in order to describe the current status of an area where a disaster is recently happened.
- Visualization of time-dependent layers. The tool can provide time-dependent visualization on the map.
- Integration of existing Hazard Models. The tool can work, after integration and adaptation, with different existing hazard models. This can be performed either by full model integration or using precomputed scenarios or using manual execution of external models or by having loose platform integration.

It consists of three different sections, that are interconnected to each other to form a recursive workflow stopping at the end of an emergency. These three different sections support the main phases of the emergency management: Early Warning, Impact Assessment and Mitigation of Impact plus a few modules that provide generic supports needed by the three phases. The DSS with its modules and processes are described in the following Figure 5..

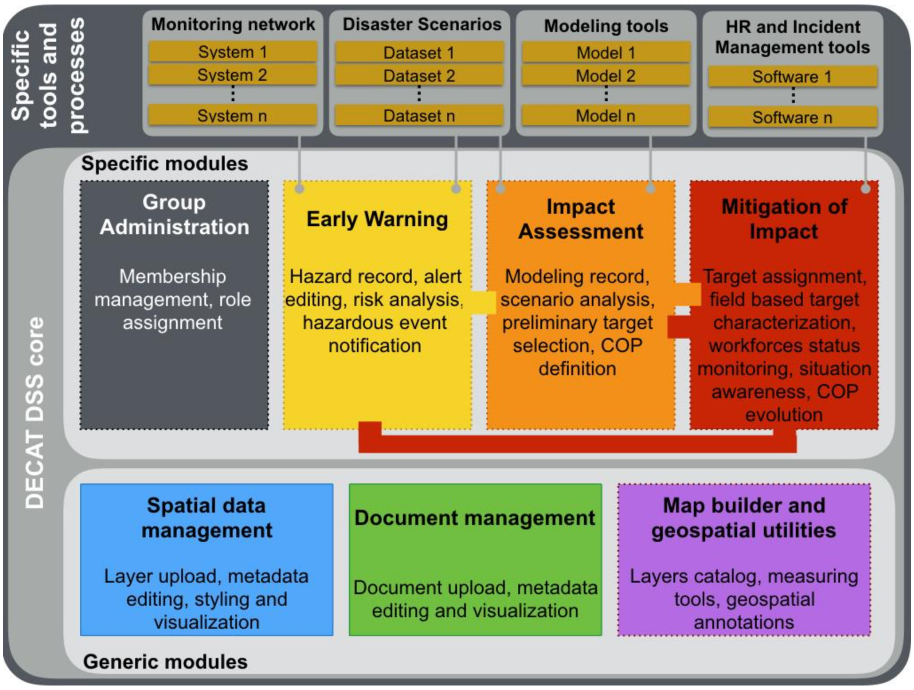


Figure 5. 50: Functional decomposition of the DSS platform (Damalas et al. 2018)

The Early Warning phase, aimed to collect the hazardous event occurring in a certain area to provide early warnings to the disaster management team. It provides the operator with wizards helping in editing and updating events (ex. flooding events) occurring inside the area of interest. in these wizards, the operator can edit point features and record ancillary information for the characterization of a hazardous event, i.e. the level of the hazard. As Figure 5. 51 shows, the event is firstly promoted to the DSS platform, and then the other phases are enabled enableing the impact and manage of the emergeny.

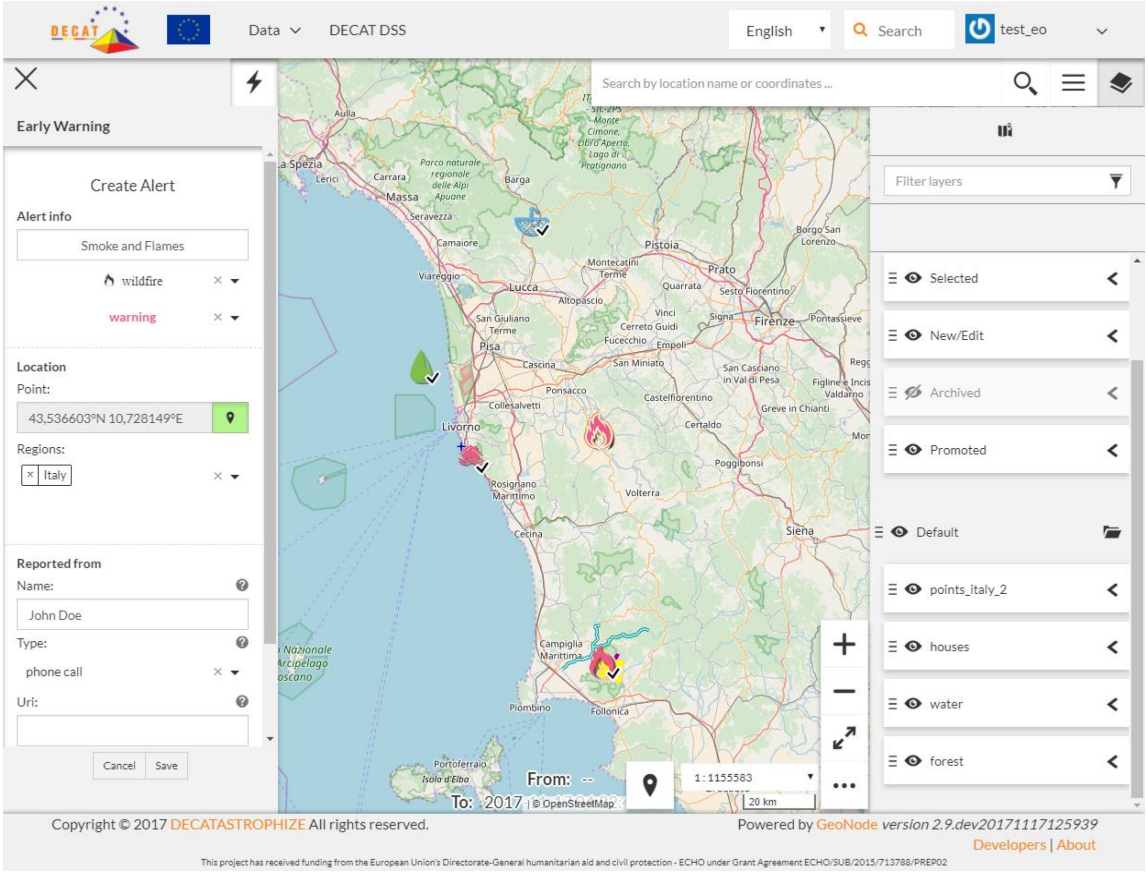


Figure 5. 51: User Interface for Event Operator (Damalas et al. 2018)

The impact assessment phase is where all context data in the area of interest and the hazardous event are analyzed by modeling or pre-formulated scenario analyses, additional spatial information, reports and documents useful to properly identify and locate specific needs of rescue and recovery interventions. The aim of the phase is to evaluate at an early stage the distribution and magnitude of potential losses due to a disaster. It is designed to permit the creation and update of the Common Operating Picture (COP) for the emergency managers. The COP can be the reference map created by the impact assessor which can be used to show multi-hazard modeling together with geospatial information related to emergency plan implementation like hospital locations and targets needing urgent intervention. **Figure 5.** ***52*** shows some symbols (for fire hazard) that were used to visualize the hazard. These symbols can be changed accordingly for many hazards, including floods. The COP can then be frozen and shared with the emergency managers, responsible to assign rescue or recovery targets to work-force teams.

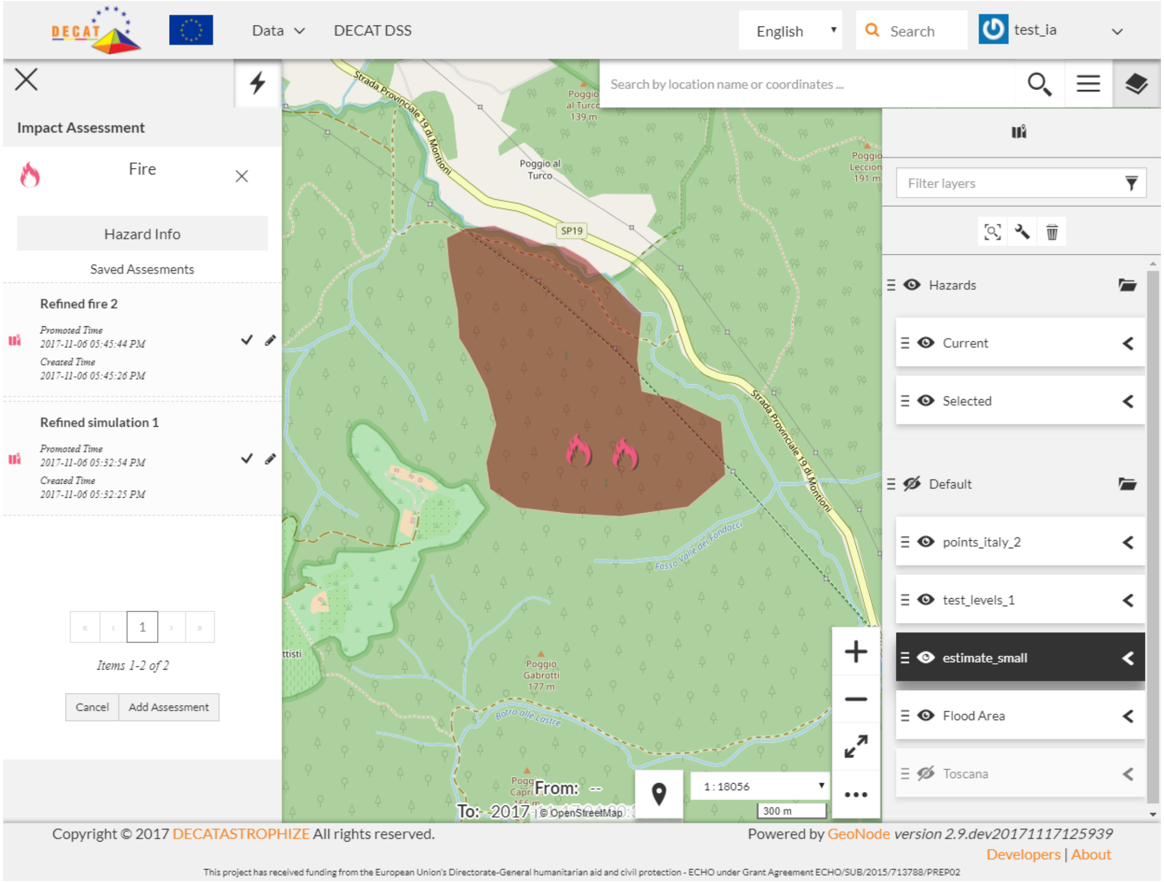


Figure 5. 52: User Interface for Impact Assessor (Damalas et al. 2018)

The mitigation of the impact phase assists the tactical level by: a) prioritizing the mitigation actions and rescue operations in the area of interest, b) recording the allocation of relief workforces and incident management evolution and c) using feedbacks from the field to update the assessment or to notify unexpected events, occurred in the crises area, significantly influencing the disaster evolution. It provides to the emergency managers the ability to work together and manage online the COP. This is performed by allocating the working teams by means of the workforce they belong. **Figure 5.** *53* shows the mitigation of the impact phase where the geospatial features can be updated in real-time to capture the status of the resources engaged in rescuing operation on field.

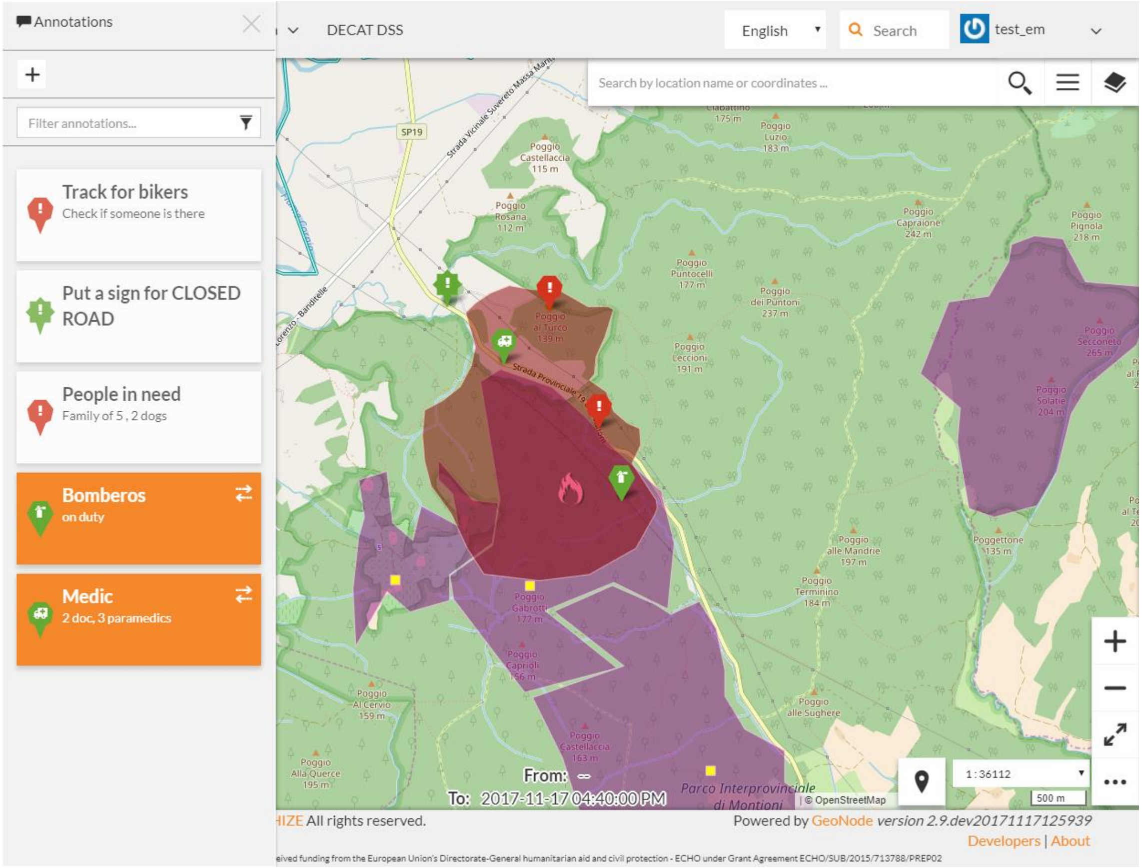


Figure 5. 53: User interface of the Emergency Manager – mitigation of the impact (Damalas et al. 2018)

The management of hazards on DSS tool, is managed as a workflow. Different types of Operators, with different expertise, capabilities and responsibilities, are involved on the different phases of the management of the impact event and its mitigation. The main objective is to provide to the users involved only the tool and information they really need, helping them to take action quickly and in an intuitive way. **Figure 5.** ***54*** shows the three phases and the roles of each phase user.

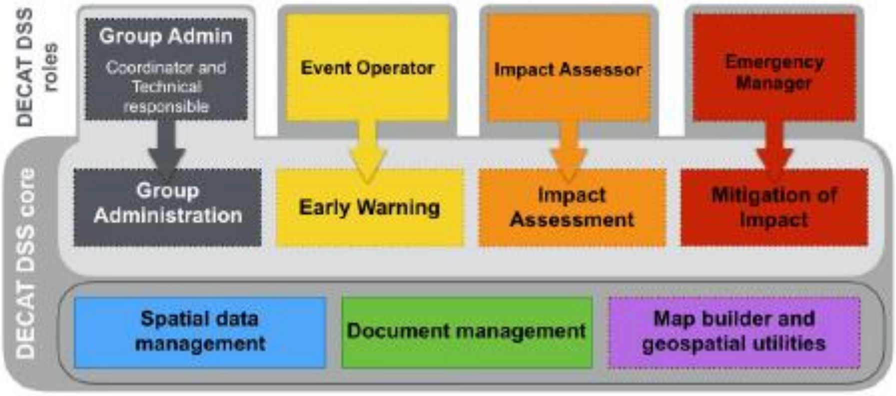


Figure 5. 54: Roles of the operators of each phase

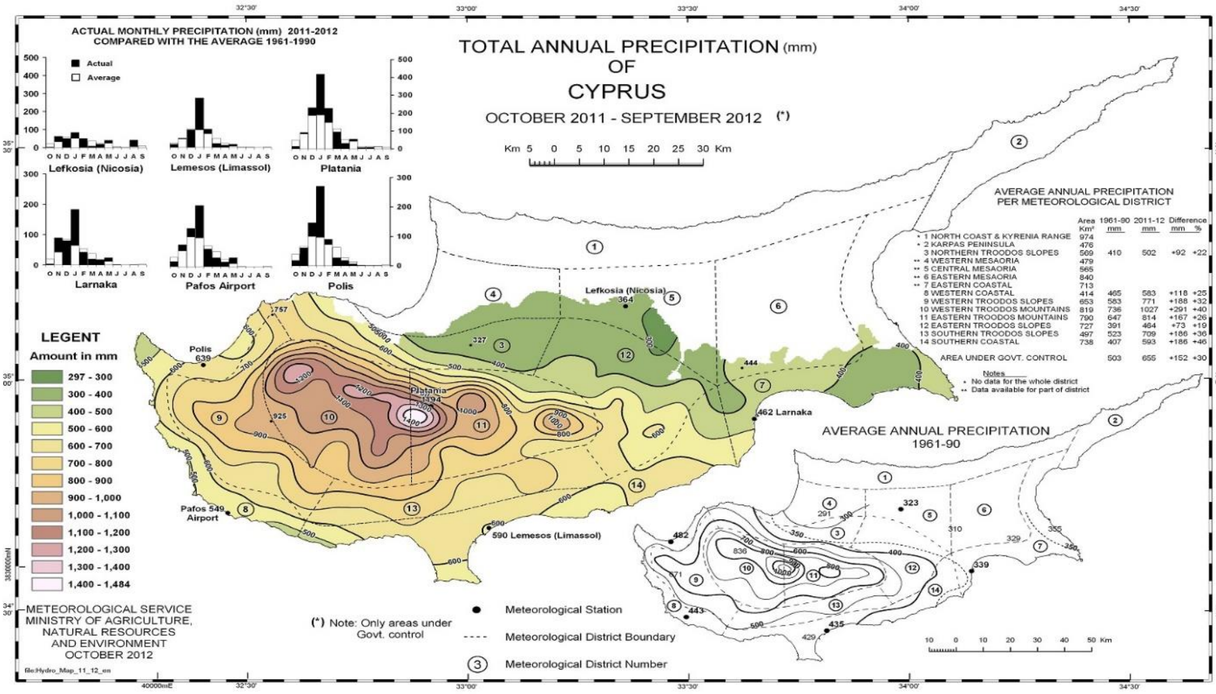
In other words, the whole tool is designed in a way to make procedures simple and speed up the sharing of the geospatial information. Also, it disseminates the geospatial representation of the COP progression by supporting a workflow of repeated communication among Early Warning updates, Impact Assessment re-evaluations and Emergency management evolution. Tools like the one described in this task, can help managers and event operators to prepare and prevent from the flood hazard, but also in the event of a multi-hazard scenario.

6. Water Scarcity

This section describes the observed trends in water resources, water use and water scarcity in Cyprus up to 2018. Water scarcity scenarios have been developed and assessed, and the associated impacts have been determined.

6.1 Water Resources

Cyprus is in the Eastern Mediterranean, a semi-arid region with a Mediterranean climate. An island with no borders with other neighbouring countries, Cyprus depends predominantly on rainfall for its natural water resources, with rainfall following the seasonal variations of a typical Mediterranean climate i.e. rain (and snow in the Troodos massif) during the winter months (December – February) and intense heat and drought during the summer months.
Average annual precipitation over the whole island is 460 mm, with variations in rainfall across latitude and altitude as shown by Figure 6.1.



(Period 2) (Rossel, 2001).

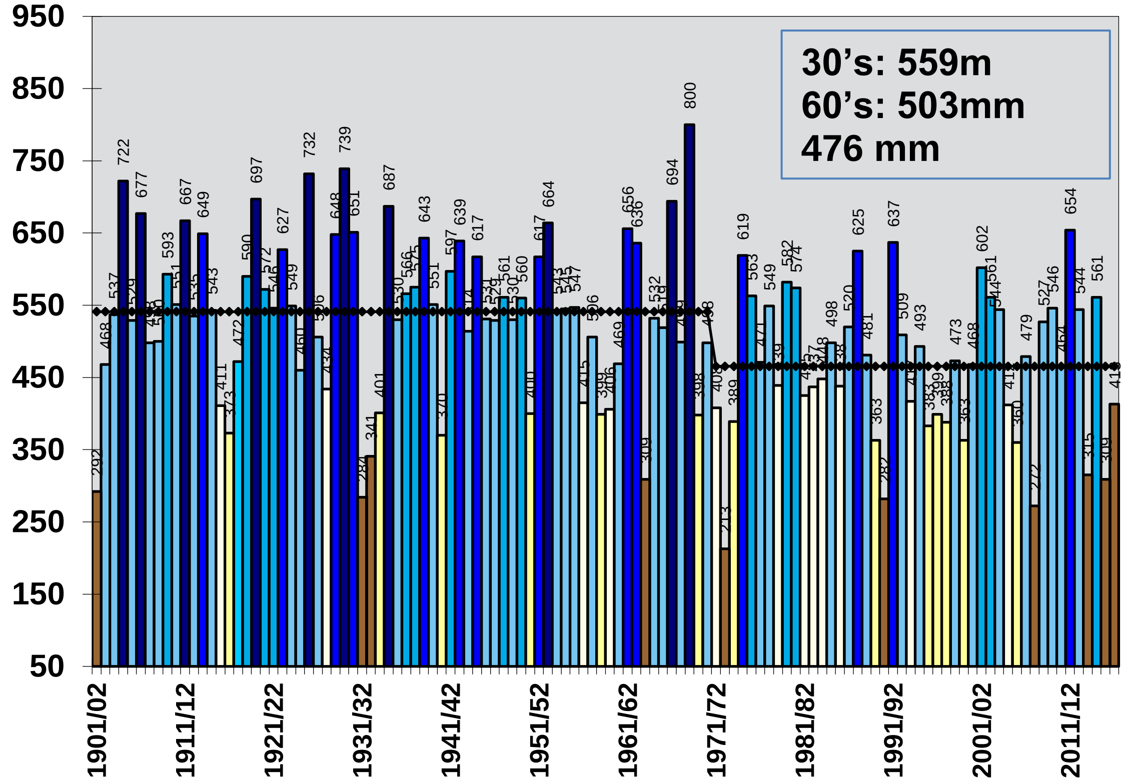


Figure 6.2: Annual average precipitation in Cyprus (Source: WDD,2018)

Cyprus suffers from long and often severe droughts during summer, with the island classified (along with Malta) as the EU country with the most acute water shortage. This is supported by data from the European Drought Observatory which further indicate that droughts have been accompanying this decrease in rainfall (Figure 6.3). The three-month Standardised Precipitation Index (SPI-3) for Cyprus for the period 1981 to 2018, shows clearly the incidence of drought, whereby negative SPI values represent rainfall deficit7.

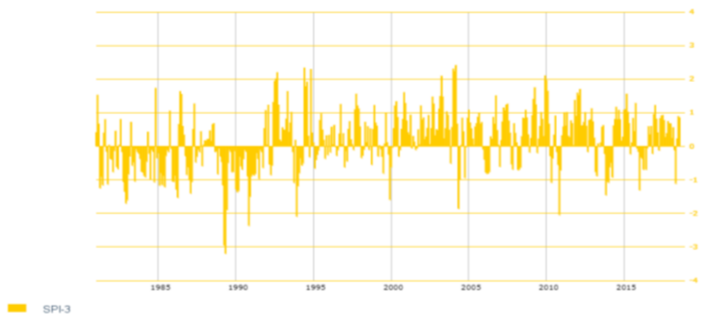


Figure 6.3: SPI-3 indicators for Cyprus *(Source*: European Drought Observatory)

Over the last 50 years, water scarcity has become one of the most pressing and growing problems facing the country, due to the declining rainfall, which is accompanied by population growth (locals and immigrants), growth in the tourism industry, the varying seasonal demand for water, the improvement in living standards, and the increase in water demand for irrigation after the construction of the large Governmental water projects (WDD, 2018). In fact, in 2008 Cyprus experienced its most intense and prolonged period of drought, which resulted in 100% water cuts to agriculture, restriction of domestic water supply to 36 hours per week and water imports from Greece.

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7 The intensity of a drought event is classified according to the magnitude of the negative SPI values such that the larger the negative SPI values are, the more serious the drought is.

Such trends have impacted water resources (Section 6.2) and have led the Government to build extensive water related infrastructure (Section 6.3) to manage the decrease in rainfall and the subsequent incidences of drought.

6.2 Description of water bodies in Cyprus

Due to its relatively small size (9251 km^2), the island is regarded as one single River Basin District (RBD), subdivided into nine hydrological units consisting of 70 watersheds (Figure 6.4). However, the area under control of the Government of the Republic of Cyprus (5800 Km^2) encompasses 47 watersheds, which will be the focus of this report.

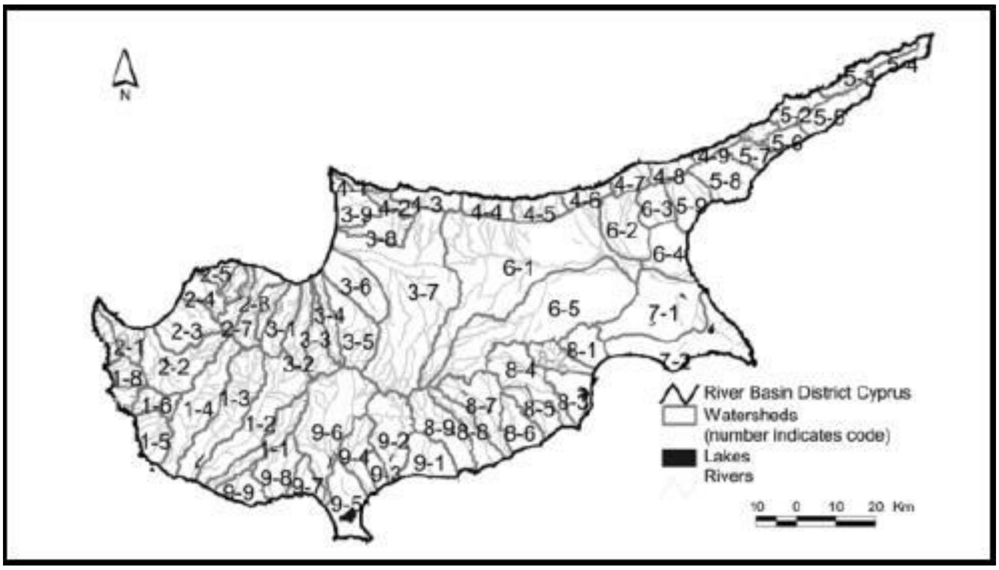


Figure 6.4: Nine hydrological units of Cyprus's River Basin District

The island has 177 river bodies (174 are found in the government-controlled areas), 8 lakes, 22 coastal water bodies (12 are found in the government-controlled areas), and 22 groundwater bodies. Of these water bodies, 56 have been identified as heavily modified (2nd River Basin Management Plan for Cyprus, 2016).

Most rivers originate in Troodos and only flow 3 to 4 months a year; i.e. they are dry for the rest of the year. This pattern follows the Mediterranean climate and the seasonal distribution of precipitation, with a minimum precipitation in the summer months and a maximum precipitation during the winter months. As a result, there are no rivers with *perennial flow along their entire length*. Specifically in the government controlled areas, 33 river bodies have been designated as type 'perennial mountain streams'; 71 river bodies have been designated as type 'intermittent streams'; 59 river bodies have been identified as type 'harsh intermittent streams' and 11 water bodies have been designated as type 'ephemeral and episodic streams'(2nd River Basin Management Plan for Cyprus, 2016).

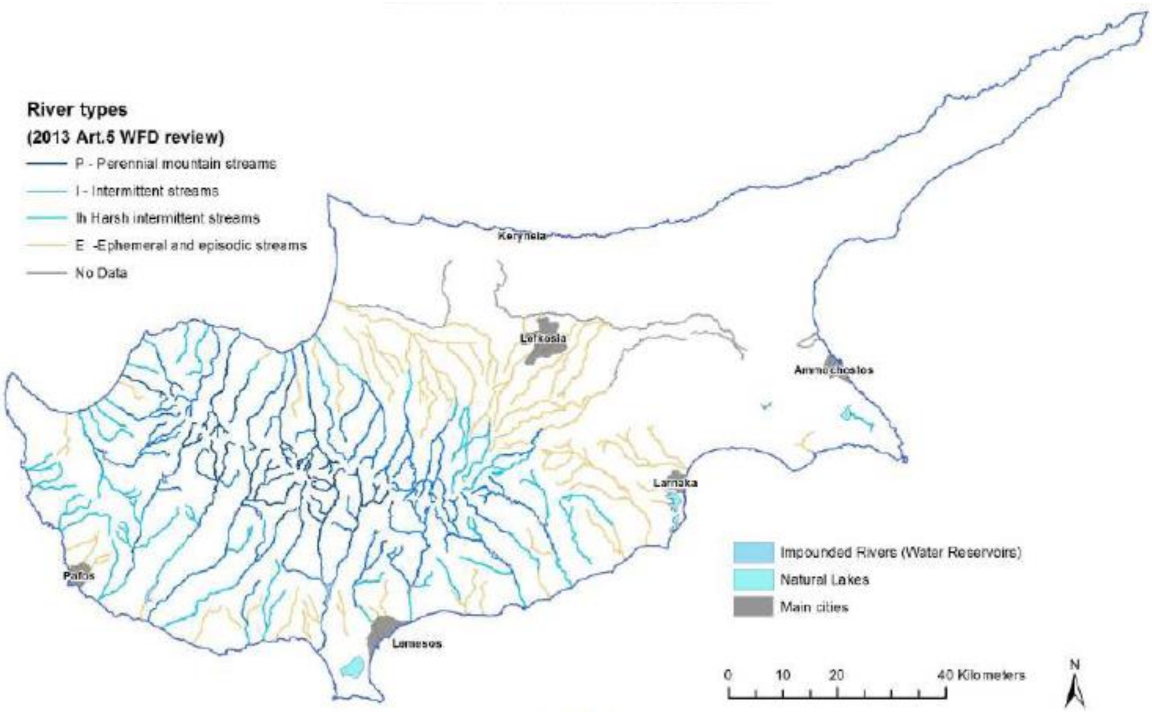


Figure 6.5: River bodies in Cyprus (*Source*: 2nd River Basin Management Plan for Cyprus, 2016)

Cyprus has no natural freshwater lakes; the island has seven natural lakes which are of salt or brackish water and one storage basin, which is designated as an Artificial Water Body (Report on the Review & Update of Article 5 (Water Reservoirs), 2014). The natural salt and brackish lakes are dynamic systems and dry up regularly according to rainfall and evaporation, whilst the water level of the storage basin depends on both rainfall and use. The storage basin often receives inflow in the winter months, but in the summer months the water quantities decline as water is consumed, resulting in variability in its water levels (Report on the Review & Update of Article 5 (Water Reservoirs), 2014).

There are 66 aquifers, the majority of which are phreatic. These have been grouped into 22 groundwater bodies, 21 of which are within the areas under Government control (Figure 6.6). These groundwater bodies are either contained within the Troodos Mountain, or directly supplied by runoff coming from this mountain range. An exception is the groundwater body of Kokkinochoria in the Famagusta district. However, this also, but to a lesser extent, is fed by the river Gialias which originates in the Troodos mountain (CCD, 2016).

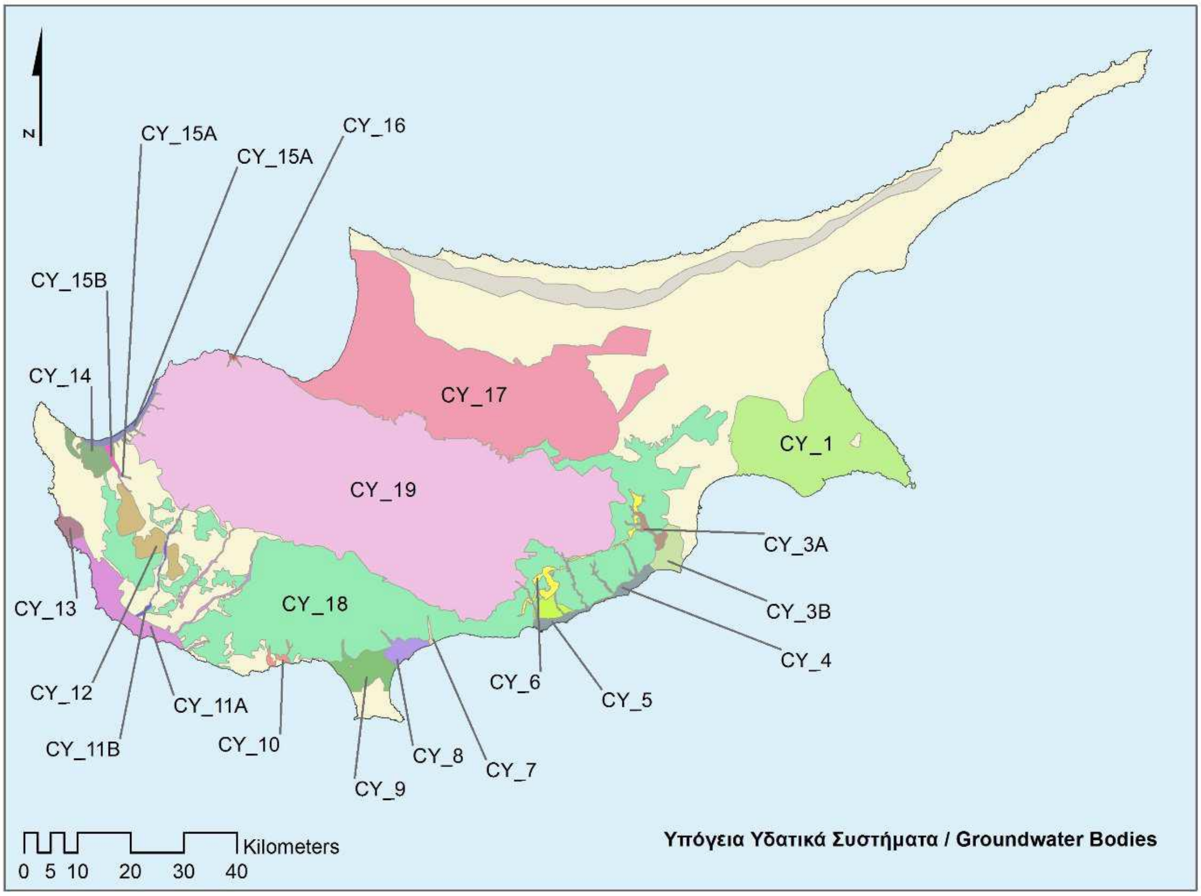


Figure 6.6: Groundwater Bodies in Cyprus (*Source*: 2nd River Basin Management Plan for Cyprus, 2016)

The Cyprus Water Development Department (WDD) reports that a reduction in rainfall has negatively impacted the quantitative status of some of the groundwater bodies (particularly the groundwater bodies that are replenished by rainwater) (WDD, 2015; WDD, 2016; WDD, 2017, WDD, 2018).

Statistical analysis of the precipitation records available over the period of the hydrological years 1916/17-1999/00 shows a step change around 1969/70, dividing the time series into two separate stationary periods. The mean precipitation of the 1970/71-1999/00 period is lower than the mean precipitation of the 1916/17-1969/70 period in the order of 5-25%, a fact that has resulted in a significant reduction in the water available on the island (Rossel, 2001). As a result, there has been a reduction in the recharge of the island's aquifers, which, in combination with overabstraction, has negatively impacted the quantitative status of the island's groundwater bodies.

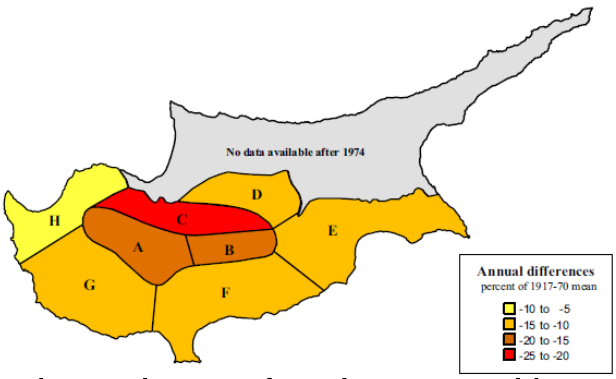


Figure 6.7: Differences between the means of annual precipitation of the Period 1970/71-1999/00 and the Period 1916/17-1969/70 (Difference = (Mean Period$_{1970/71-1999/00}$ – Mean Period$_{1916/17-1969/70}$) * 100 / Mean Period$_{1916/17-1969/70}$). Source: (Rossel, 2001)

Fifty-two per cent of the groundwater bodies are currently in poor quantitative status, as indicated by Table 6.1. The main pressures resulting in the poor quantitative status of groundwater bodies include saltwater intrusion, a reduction in rainfall, and overabstraction (Zal et al., 2017). About half of the groundwater is abstracted to meet the country's water needs (Zal et al., 2017), including:

1. public water needs,

2. agriculture needs (5,368 m3 /ha were used for irrigation purposes, or up to 60% of the total irrigation use), and

3. Industry needs.

As indicated by the table below, in total 11 groundwater bodies were in a poor quantitative status in 2016 (for which the latest data is available).

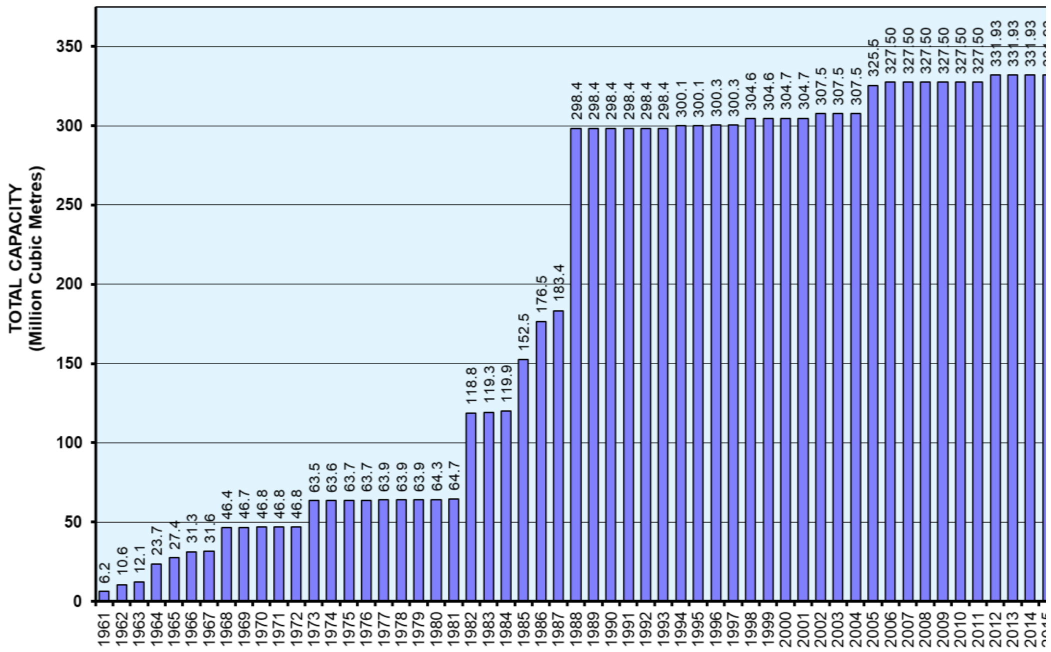
Table 6.1: Overview of the Quantitative Status of groundwater bodies in Cyprus from 2008-2016. (Source: WDD, 2018)

Groundwater body	Quantitative Status 2008-2013	Quantitative Status 2014	Quantitative Status 2015	Quantitative Status 2016
CY_1 Kokkinochoria	Poor	Poor	Poor	Poor
CY_3A Kiti - Treminthou	No data	Poor	Good	Poor
CY_3B Kiti - Pervolia	Poor	Poor	Poor	Poor
CY_4 Softades - Zygi	Poor	Poor	Poor	Poor
CY_5 Maroni	Poor	Poor	Good	Good
CY_6 Mari - Kalo Chorio	Poor	Poor	Poor	Poor
CY_7 Germasogeia	Good	Good	Good	Good
CY_8 Lemesos	Poor	Poor	Good	Poor
CY_9 Akrotiri	Poor	Poor	Poor	Poor
CY_10 Paramali - Avdimou	Poor	Poor	Good	Good
CY_11A Pafos	Good	Good	Good	Good
CY_11B Koitis Ezousas	Poor	Good	Good	Good
CY_12 Letymvou - Giolou	Poor	Good	Good	Good
CY_13 Pegeia	Poor	Poor	Poor	Poor
CY_14 Androlikou	Good	Poor	Poor	Poor
CY_15A Chrysochou - Gialia	Poor	Poor	Good	Good
CY_15B Koitis Chrysochous	Poor	Poor	Good	Good

CY_16 Pyrgos	Poor	Poor	Good	No reliable data/measurements
CY_17 Central and Western Mesaoria	Poor	Poor	Poor	Poor
CY_18 Lefkara - Pachna	Poor	Poor	Poor	Poor
CY_19 Troodos	Poor	Good	Good	Good
CY_20 Pentadaktylos	-	-	-	No measurements
Total in poor quantitative status:	17	16	9	11

6.3 Water related Infrastructure

Until 1997 the main source of water in Cyprus was rainfall. Whilst the quantity of water falling over the total surface area of the free part of Cyprus is estimated at 2.750 million cubic meters (mcm), only 10% or 275 mcm is available for exploitation, since the remaining 90% returns to the atmosphere through evapotranspiration. This available average annual net rainfall of 275 mcm is distributed between surface and groundwater storage with a ratio 1:3 respectively which is furthermore unevenly distributed geographically, with the highest in the two mountain ranges and the lowest in the eastern lowlands and coastal areas. From the underground storage approximately 1/3 flows into the sea (WDD, 2018). Additionally, there is great variation of rainfall with frequent droughts spanning two to four years. All this has necessitated the development of significant water-related infrastructure and Cyprus has constructed dams on almost all watercourses as well as conveyors and other related infrastructure (water treatment plants, pumping stations, distribution networks). The total dam capacity of Cyprus is 331.93 million cubic metres (Figure 6.8). Cyprus has a high dam density with 60 dams per 10, 000 km^2.



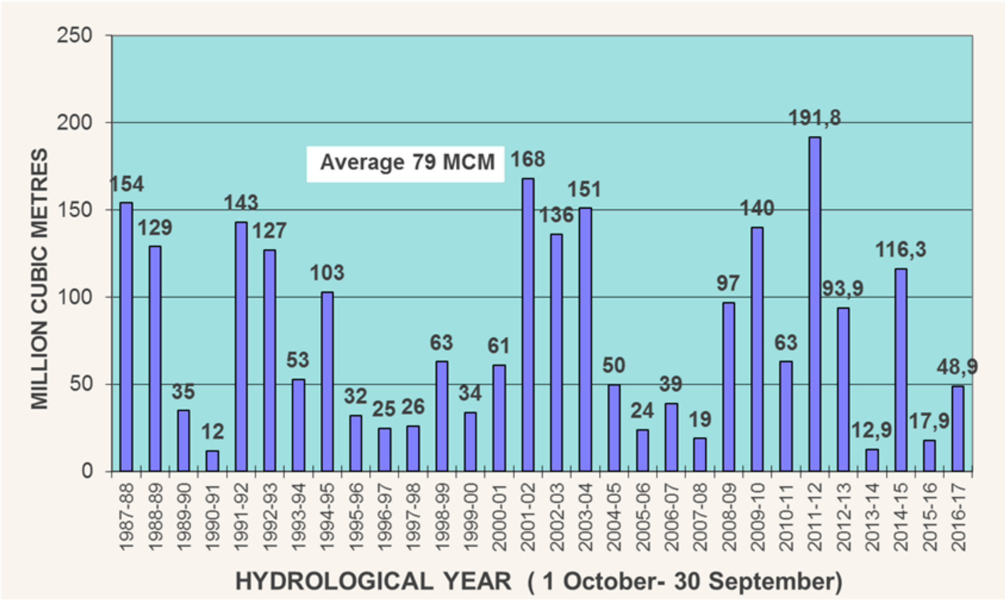


Figure 6.9: Inflow of water to Dams (WDD, 2018)

Cyprus has invested greatly in water development and water works. Government owned water works (GWW) include the:

- Southern Conveyor Project, the largest development project in Cyprus.
- GWW of Yermasoyia-Polemidhia (connected to the SCP)
- GWWof Vasilikos-Pentaschinos (connected to the SCP)
- GWW of Paphos
- GWW of Chrysochous
- Nicosia irrigation projects

The Southern Conveyor Project (SCP) collects surface water from the southern part of Cyprus and delivers it to central and eastern areas, including the main four population areas of Nicosia, Lemesos, Larnaca and Ammochostos and their surrounding villages. The SCP is connected to the GWW of Yermasoyia and Vasilikos-Pentaschinos, constituting the Unified SCP.

The Unified SCP includes a number of large dams (the biggest of which is Kouris dam with a capacity of 110 MCM), a 110km conveyor that conveys water from Kouris to the western part of the island and also all the relevant infrastructure which serve the irrigation and domestic water needs of the areas of Nicosia, Lemesos, Larnaca and Ammochostos (long pipelines, pumping stations, water treatment plants, irrigation networks etc.).The Kouris dam collects the water from four rivers: the Kouris, Limnatis, Diarizos and Kryos.

SOUTHERN CONVEYOR PROJECT

The Paphos GWW, the second large water project in Cyprus, consists of three dams, the biggest of which is the Asprokremmos dam (capacity of 52.38 MCM) and all the related water infrastructure, including 24 boreholes in the river bed of Asprokremmos (capacity 10 MCM) and boreholes in the coastal plain of Paphos (capacity 4 MCM).

Despite development of the GWW, water scarcity conditions in Cyprus have become acute over the years and the natural water resources have not been enough to satisfy basic needs. As a result, Cyprus introduced the use of non-conventional water resources; desalination in 1997 and recycled water (tertiary treated wastewater) in 2000.

Cyprus currently has 4 desalination plants, which serve the domestic water needs of the GWW area with a total production yield of 200.000 m^3/day:

Desalination Plant	**cubic meters/day**
Larnaca	60.000
Dekeleia	20.000
Episkopi	60.000
Vasilikos	60.000

A further desalination plant with a capacity of 15,000m^3/day is expected to become operational in Paphos, by the end of 2020, and will serve the needs of the district of Paphos. Until then, a mobile desalination plant is at the stage of tendering.

The water from the desalination plants are allocated through the GWW for the bulk supply of domestic water to Local Water Authorities. As shown in Figure 6.11, desalination has become an increasingly important contribution to the islands' water supply, and a tool to manage shortages related to droughts.

At present, the GWW satisfy 85% - 90% of the total domestic water supply and up to 40% of irrigation use (this varies according to each year but it is rarely satisfied).

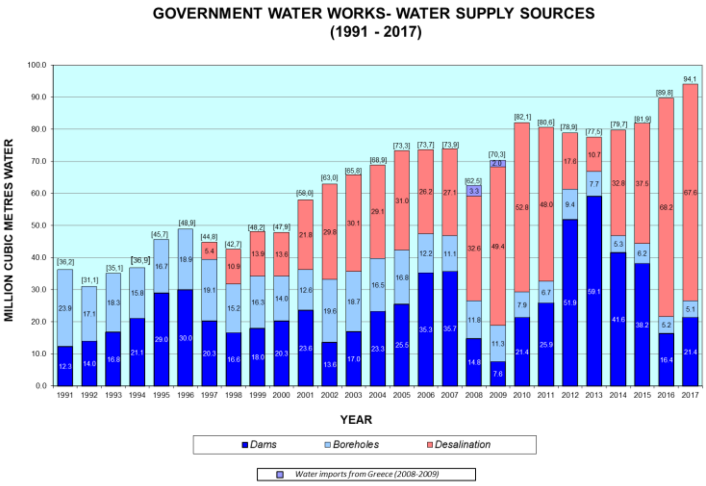


Figure 6.11: Sources of Domestic Water Supply (*Source*: WDD, 2018)

Recycled water is produced from the tertiary treatment of sewage effluent and is used for agricultural crops, green/recreational areas and for recharge of groundwater aquifers. The production and use of recycled water is regulated by legislation, whilst the code of good agricultural practice sets the rules for the use of recycled water in irrigation. e.g. which crops can be irrigated, safety precautions, irrigation practices and methods. Urban Sewage Boards are responsible for collection and treatment of sewage effluent, with the WDD responsible for the management and distribution of the recycled water. As shown by Figure 6.12 use of recycled water has been increasing over the last decade, with the production of tertiary treated water reaching 21.9 MCM in 2016. It should be also noted that significant quantities of tertiary treated wastewater effluent are used for the recharge of aquifers in the Pafos and Akrotiri coastal areas. Water is then pumped and used for irrigation.

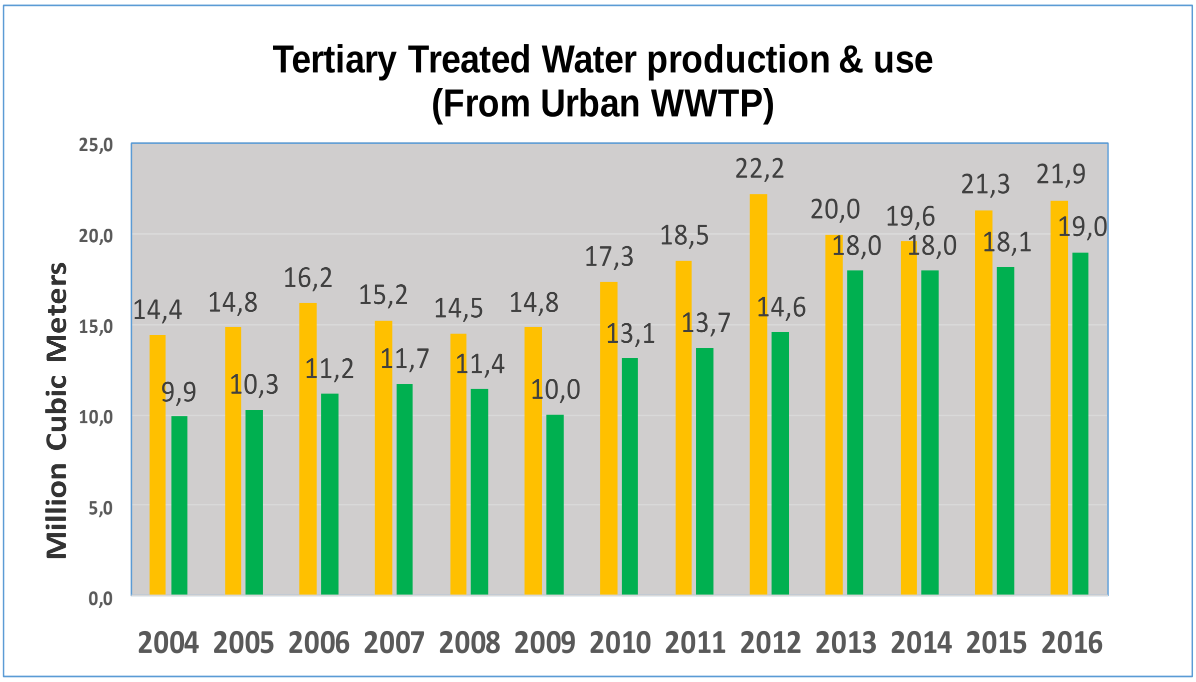
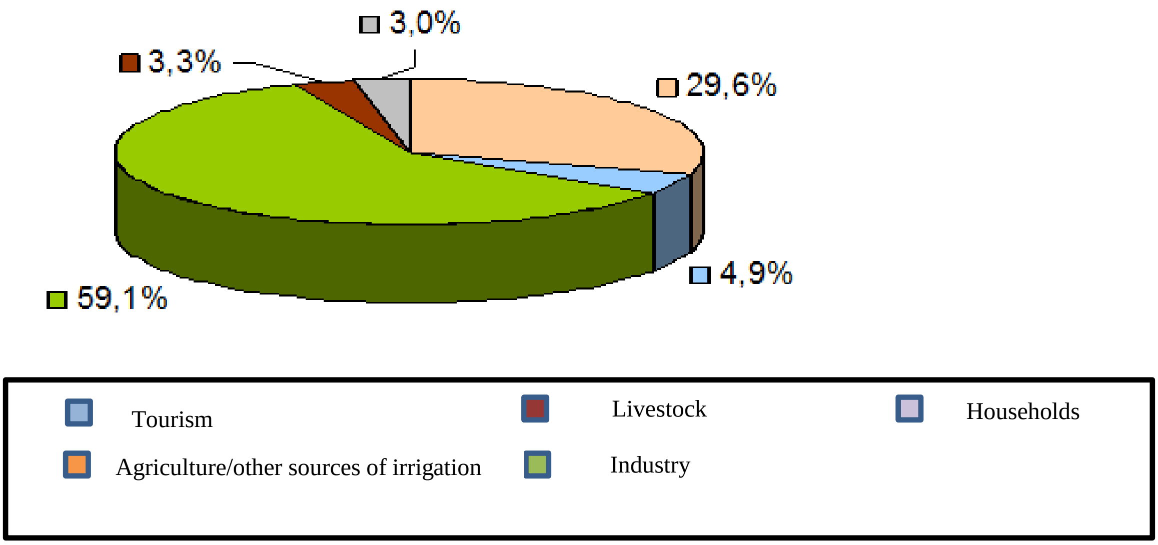


Figure 6.12: Increased use of recycled water (*Source*: WDD, 2018)

6.3 Water consumption

The main source of demand for water in Cyprus is from the agriculture sector for irrigation purposes, which accounts for 59.1% of water consumption. Households consume 29.6% of water, whilst tourism, livestock and industry consume significantly less amounts of waters, amounting to 4.9%, 3.3% and 3% of water consumption respectively (Figures 6.13 and 6.14).



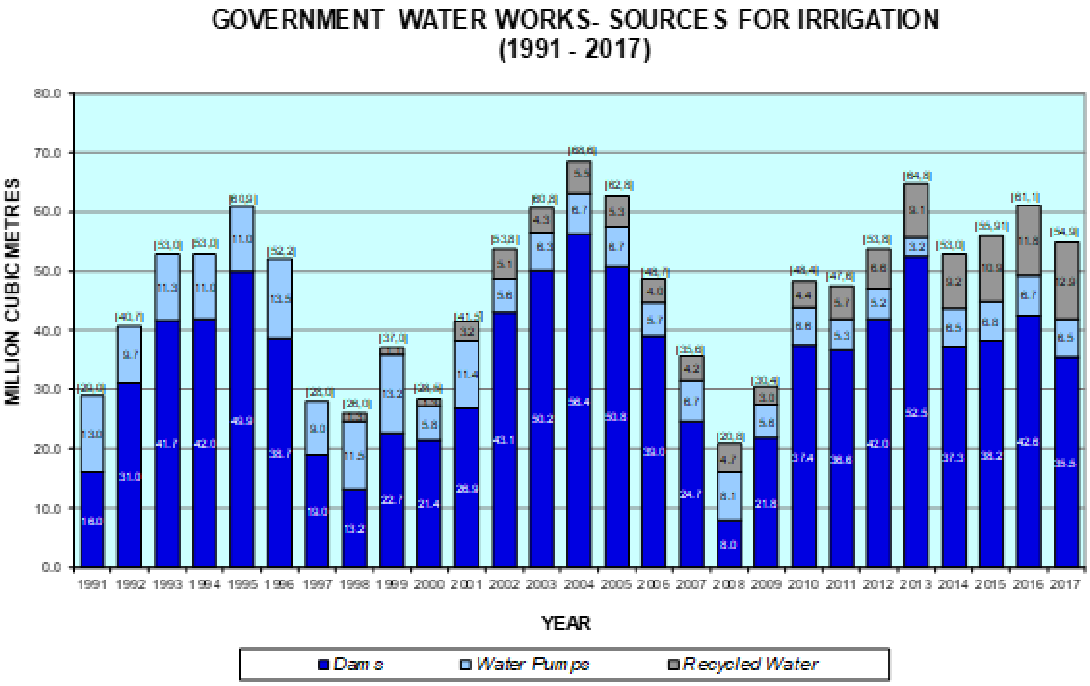


Figure 6.14: Use of water for Irrigation in Cyprus per source (Eurostat, 2018)

As stated in Section 6.2, due to the annual variability in rainfall, the GWW cannot satisfy the actual total demand for water for irrigation. The GWW (fresh water from dams and recycled water from the urban areas) theoretically provide around 50% of total annual irrigation water demand under "normal" hydrological conditions, but in recent years were only able to cover approximately 25% of irrigation water needs.

Farmers of irrigated land that falls outside of the GWW use groundwater which is legally abstracted by Water User´s Associations (WUA), called Irrigation Divisions/Associations, which hold formal water use rights on their own sources of water and by private boreholes outside the GWW that hold abstraction licenses (ARI, 2016).

Whilst groundwater abstractions (inside or outside the GWW) are mostly done from legal boreholes and wells, illegal boreholes are also in use. Due to limited monitoring of groundwater abstractions in the past, there is a lack of reliable data on how many illegal boreholes are currently in use as well as their geographic spread (Hadjipanteli, 2018). As a result, it has been observed that the groundwater bodies of Cyprus face severe over-abstraction problems, (see section 3.2 above). In addition, over the last decades Irrigation Divisions which encompass licenses to operate wells, or abstraction permits for surface waters (mostly streams); have experienced a decline both in rainfall and runoff (due to the construction of the large GWW drying-out many streams) (Hadjipanteli, 2011). As the production of the Irrigation Divisions decreases as well as the production of boreholes (legal and illegal) decreases due to overabstraction or, in the case of coastal regions, due to saltwater intrusion the demand for water from government supplies will likely increase. As the amounts used by boreholes have not been reliably registered, it is difficult to predict with certainty how much demand will increase.

6.4 Water Balance and Water Scarcity

The average Water Exploitation Index (WEI) for Cyprus is 73.1 % for the years 2009-2013, indicating freshwater sources that are highly stressed. The WEI measures the annual total fresh water abstraction in a country as a percentage of its long-term annual average available water (LTAA) from renewable fresh water resources (groundwater and surface water). Total fresh water abstraction includes water removed from any fresh water source, either permanently or temporarily. Severe scarcity occurs where the WEI exceeds 40%, indicating clearly that Cyprus suffers from severe water scarcity.

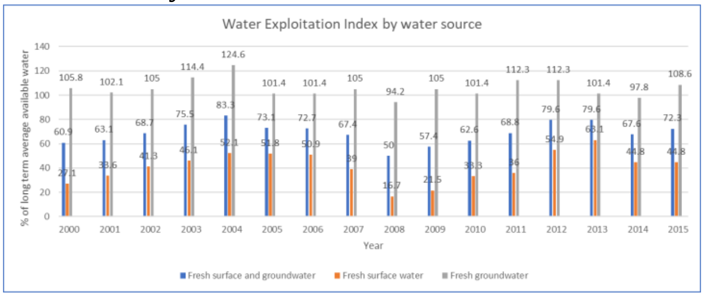


Figure 6.15: Water Exploitation Index Cyprus (*Source:* Eurostat, 2016)

The severity of the island's water scarcity can be further illustrated by Table 6.2 in which the water balance in Cyprus is negative for the years 2013, 2014 and 2017, despite enhancement of the water balance by non-conventional sources such as water recycling, indicating that the consumption of water exceeds the water that is available.

Table 6.2: Water Balance (*Source*: WDD, 2018)

Year	Water Demand (MCM)	Water Availability from Conventional Sources				Enhancement of water balance from Non-Conventional Sources		Total available water capacity (MCM) [(from precipitation) + desalinated + recycled]	Water balance (MCM) [=Total available water capacity – Water demand]	Volume of water used for irrigation (MCM)
		Rainfall (mm)	Volume of rain (MCM)	Available water capacity from precipitation (MCM) *[Note: About 90% of rainfall is lost due to evapotranspiration and about 0.02% from runoff to sea]*	Water Balance (MCM) [=Available water capacity from precipitation - Water Demand]	Volume of desalinated water (MCM)	Volume of recycled water (MCM)			
2010	257	429	2570	197	-60	53	12	262	5	82
2011	258	558	3348	265	7	49	14	328	70	81
2012	259	790	4737	404	145	18	17	438	179	80
2013	260	295	1770	117	-143	11	17	145	**-115**	78
2014	261	393	2358	173	-88	33	17	222	**-39**	80
2015	262	484	2904	228	-34	38	18	285	23	82
2016	**263**	430	2580	198	-65	69	19	285	22	90
2017	264	326	1956	136	-128	69	20	224	**-40**	94

6.5 Scenarios for Risk Assessment

Considering the existing water scarcity in Cyprus described in the sections above, which makes the island along with Malta one of the two "water poorest" countries in the EU, two scenarios have been identified and assessed indicative of persisting water stress particularly in years of excessive drought. The scenarios reflect the challenges of water scarcity which are inherently associated with water supplies, quality of water storage, transport and distribution infrastructure and water demand of highly seasonal variability.

Two scenarios for water scarcity have been developed that describe the trigger event(s) and its consequences, as identified in D2.1 and D2.2 Commencement and Approach report, and which are mainly based on official ministerial reports, previous experience, technical reports and expert opinion. The analysis of the scenarios includes:

1. A description of the phenomenon impacting the country;
2. the (underlying) causes and processes, and the trigger which "activates" the hazard;
3. the context of the events;
4. the impacts of the hazard together with response and control measures.

It is assumed that the two scenarios are plausible although they may have different likelihoods, as they originate from historic events taking into consideration developments and measures for water resource management and are affected by climate change or population variability throughout the year. The expected scenario will be assessed in the development of the risk matrix in chapter 11. The second scenario with climate change impact it will be a worst-case scenario that overwhelms national capacity to respond, as identified in EC guidelines, the Netherlands NRA and the ECORYS reports.

6.5.1 Scenario selection rationale

Within the purpose of this study and taking into consideration the outcomes of discussions with WDD and using existing data submitted by WDD to EUROSTAT8, two main scenarios have been established. The first one, termed "expected" scenario is based on extrapolation of historic conditions of the water resources and water management in Cyprus. It is a realistic scenario, primarily based on changing rainfall/water resource data, where related data and water management statistics have been obtained from official statistical data of various Governmental Departments and considers the implementation of the Integrated water management framework that includes:

5. Water Protection and Management Law (N. 13/2004) (Water Framework Directive 2000/60/EC transposition);
6. Integrated Water Management Law (N. 79/2010);
7. Pollution Control Law (N. 106/2002); and
8. Drought management plan.

The second scenario – the climate change scenario- is based upon climate change projections for Cyprus and subsequent analysis as introduced by European Environment Agency documents9. According to the report, under the RCP 2.5 scenario, rainfall may decrease by 20-30% whereas this decrease may be doubled under RCP4.5. Droughts across the Mediterranean may lead to increasing water scarcity, declining crop yields and desertification, in addition to increasing water demand for agriculture, and potential issues related to drinking water quality.

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8 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en

9 EEA Report No 2/2009, Water resources across Europe — confronting water scarcity and drought, ISSN 1725-9177

The second scenario considers a period up to 2030 and includes several considerations (sub-scenarios) for – population and demographic changes, - variability in precipitation patterns due to climate change, - changes in agricultural land and irrigation profiles, - expansion of government water works, - tourism patterns and changes in water consumption behaviour.

6.5.2 Context – scenario development

The developed scenarios have been split in four main parts following the OECD – EUROSTAT questionnaire on inland waters10 and the risk matrix approach presented in chapter 11.

Part – I Freshwater Resources.

Part I of both scenarios provides an overview of expected renewable freshwater resources and their availability in Cyprus. The main components used for the assessment of freshwater resources are indicated in Figure 6.16. Surface and groundwater resources are replenished by precipitation falling over the territory of the country and ends up as runoff to rivers and recharge to aquifers (internal flow), and surface waters (inflow). This part of the assessment methodology also includes an estimate of the outflow of surface and groundwaters to the sea. The data used for the assessment of freshwater resources for each scenario are historical hydrological/meteorological monitoring data and future climate modelling data.

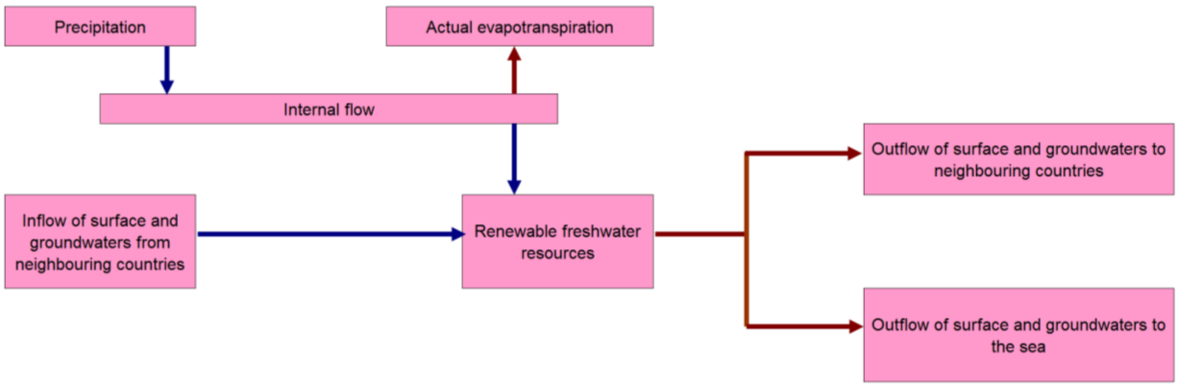

Figure 6.16: Assessment of freshwater resources (*Source*: United Nations Statistics Division, 2018)

Part II Freshwater Abstraction and Use

Part II of both scenarios describes the abstraction of freshwater from surface waters (rivers, lakes etc.) and from groundwaters (through wells or springs), based on its various uses. Water is abstracted by the public or private bodies whose main function is to provide water to the general public (the water supply industry). It can also be directly abstracted by industries, farmers, households and others. Part-II covers the amount of water made available for use by abstraction, desalination, reuse and net imports.

10 https://ec.europa.eu/eurostat/statistics-explained/index.php/Water_statistics

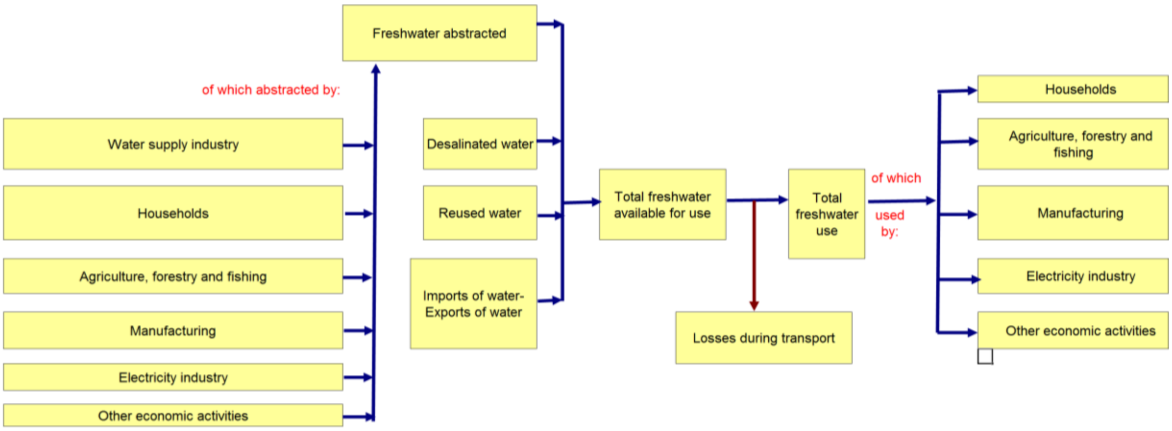

Figure 6.17: Assessment of freshwater abstraction and use (*Source*: United Nations Statistics Division, 2018)

Part III – Government Waterworks

Part III focuses on the WDD infrastructures and activities, i.e., the provision of water to the general public and customers, broken down by the main economic activity. It also considers information on the population served and its profiling.

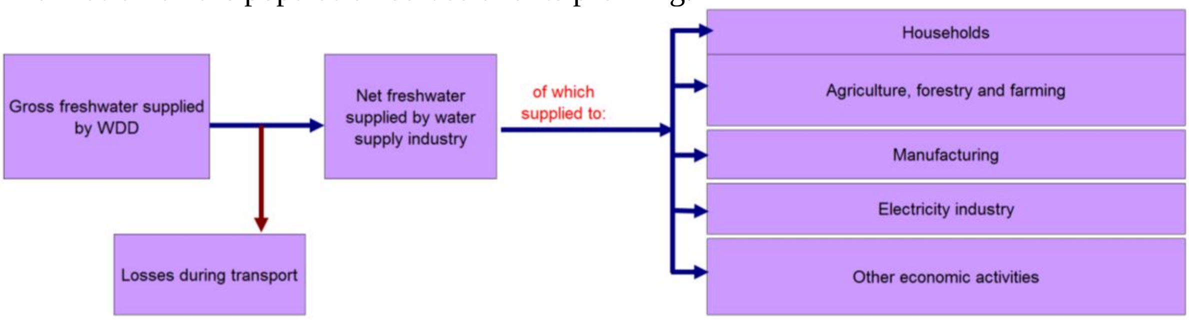

Figure 6.18: Assessment of government waterworks (*Source*: United Nations Statistics Division, 2018)

Part IV – Risk Matrix

Part IV introduces the implementation of the risk matrix approach on the worst case scenario. Following the Cyprus National Risk Assessment implementation methodology and taking into consideration the data as described in the previous sections, likelihood and impact categories have been identified for each scenario. As water scarcity / drought is a multi-annual event, the risk table needs to be modified to account for future climate projections.

6.5.3 Climate change scenario

Scenario properties

Part I - Freshwater Resources

Future precipitation estimates for Cyprus have been collated from existing literature as highlighted in the following section. Overall, a reduction in precipitation and prolonged droughts will likely be a most significant impact of climate change in Cyprus (Paxian et al., 2015, Kitoh and Endo, 2016), with changes in extremes of rainfall also expected.

According to LIFE-CYADAPT project Deliverable 3.2, different climate models provide different estimations for future annual precipitation changes for the near future (2021-2050). The PRECIS model estimates less annual precipitation in the Northern coasts, whereas for the rest of the areas minor decreases (less than 5%) or no changes at all are projected. The area around Orites Forest, east of Paphos is the only area with an increase in total annual precipitation, which is minor however (up to 5mm). The ENSEMBLE model mean presents a decrease in annual total precipitation all over Cyprus, with the highest one (about 100-

120mm) located in the central part of Troodos. Both models report similar trends during the autumn / winter period which is the island's wettest period. Concerning future changes of annual maximum total rainfall over 1 day, PRECIS show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions, whereas ENSEMBLE model mean projections show no change in those areas. Camera et al (2017) assess future precipitation projections for 2020–2050 reporting a 1.5–12 % decrease in the mean annual rainfall over Cyprus for 2020–2050 and a reduction of 10% on average on the number of extreme events (>50 mm/day).

Hadjinicolaou et al (2011) report projected rainfall to decrease by 2-8% during mid-century, but do not consider this change as statistically significant. The precipitation frequency is projected to decrease in inland Nicosia and in coastal Limassol, while the mountainous Saittas could experience more frequent 5-15mm/day rainfall. The annual number of consecutive dry days shows a statistically significant increase (of 9 days) in Limassol. Results also indicate a shift of the mean climate to a warmer state, with a relatively strong increase in the warm extremes. Peleg et al, report that according to modeling studies, future rainfalls in the region will become less frequent, with a reduction of 1.2–3.4% in 6-h intervals classified as wet synoptic systems and a 10–22% reduction in wet events. They further predicted that the maximum wet event duration in the mid-21st century would become shorter relative to the current climate, implying that extremely long wet systems will become less frequent.

Zittis et al stress the difficulty in making reliable projections in the far future due to the difficulties in modeling convective phenomena, which are linked to extreme precipitation events. In their work, Panagos et all, assessed soil erosivity due to climate change and introduced the data in the Rainfall Erosivity Database at European Scale (REDES) database. They report an island averaged increase of 41.3% on the R-factor when comparing mid-century to present day assessments.

Climate Scenario Generation

In order to account for the water scarcity risk in Cyprus for a period up to 2030, climate simulations from the CORDEX database were abstracted and used. The data introduced in Figure 6.20 below, indicate that for the long term averaged values up to 2030, the annual amount of rainfall on Cyprus will likely remain at present day levels although the number of days with extreme precipitation (Rain > 50 mm) will likely decrease. The data indicate that for the near future, there will be an evident decrease of annual rainfall in the order of 20%, which will be compensated by more rainy years as we are approaching the 2030's. This scenario is collectively termed as Climate Scenario 1 (CS1).

However, in order to capture the large uncertainties in the climate change projections, a second more adverse climate change scenario has been proposed in the lower limits of the projections. This has been named as Climate Scenario 2 (CS2) and anticipates a larger decrease of rainfall values in the order of 20%. Furthermore, according to climate projections, the precipitation will most likely be concentrated into isolated intense events with a very specific geographical focus depending on local micro-climatic conditions. This could potentially result in a reduced amount of water reaching the dams and groundwater aquifers.

Due to the anticipated increase of annual temperature, the amount of water lost due to evapotranspiration will be higher overall by about 1%.

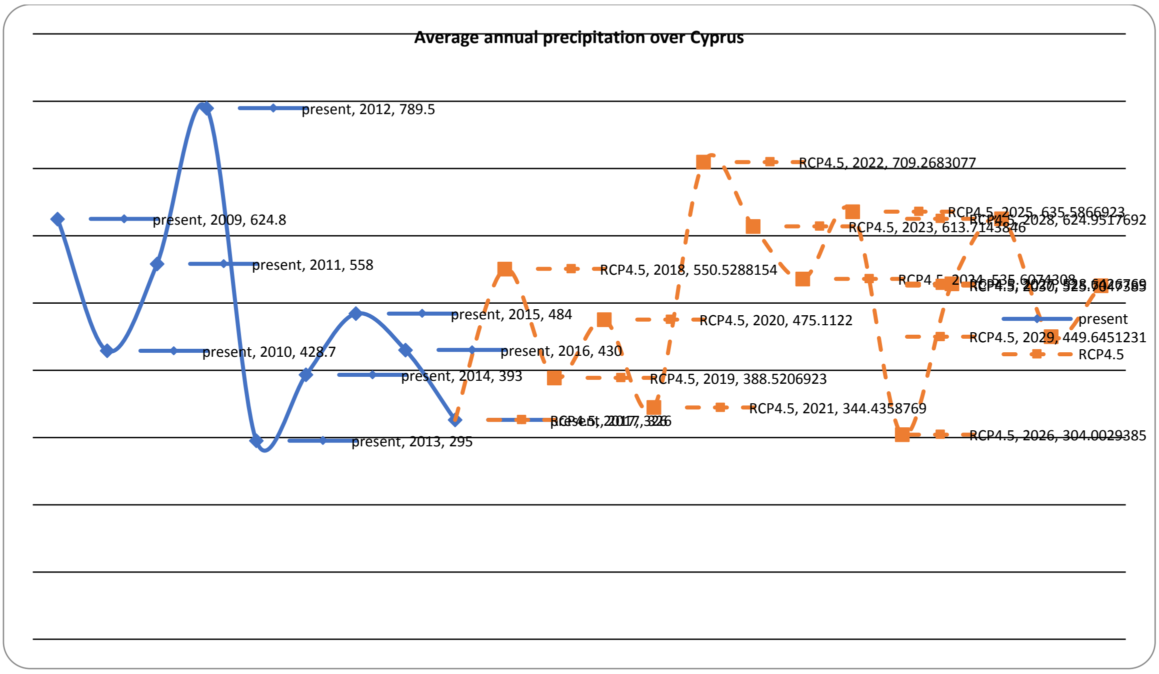

Figure 6.20: Average Annual precipitation over Cyprus (actual and predicted under RCP 4.5 scenario)

Part II - Freshwater Abstraction and Use

Concerning the amount of water that is abstracted the following assumptions have been made. The total number of people in Cyprus will vary between 920,000 – according to Eurostat Statistics on demographic changes [11] and 880,000 people – according to the Cyprus Statistical office[12]. Based on these estimates the demand for drinking water will vary between 69,000 and 71,6000k m^3/year. Concerning tourism there is an estimate between 11,000 and 13000k m^3/year of water demand from the sector[8] , taking into consideration the uncertainty of WDD estimations.

Concerning industrial consumption of water, no major changes are anticipated. For the farming, forestry and fishing sectors, according to EU study "Trends in the EU Agricultural Land Within 2015-2030" [13], it is anticipated that Cyprus will experience the largest decrease in vineyards in the entire EU and will also see the largest relative growth in fruit trees in the EU, more than 30%. Likewise, as the overall EU picture, Cyprus is expecting no drastic changes in agricultural land with a slight increase in the order of 5%.

For future climate change two sub-scenarios are considered, one sub-scenario where groundwater availability is not improved due to many aquifers suffering from salt water intrusion, and one where water policy and mitigation measures are implemented leading to an improvement in groundwater quality. Following the spatial projections of rainfall distribution, boreholes at the coastal areas of the island are more exposed to droughts and thus salt water intrusion. Thus, in the climate change scenario water abstraction from boreholes will not increase but is projected to stabilize due to non-replenishment of groundwater resources.

Concerning the climate change scenario, issues like a) population growth linked to urban sprawl, b) increase of tourists to the island, and c) changes of agricultural land are expected to slightly modify the above distribution and also increase the total demand. Another important issue considered is the high seasonal variability between water demand and rainfall, which

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[11] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=People_in_the_EU_-_statistics_on_demographic_changes

[12] http://www.mof.gov.cy/mof/cystat/statistics.nsf/populationcondition_21main_en

[13] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/trends-eu-agricultural-land-within-2015-2030

could be a potential pressure point. Furthermore, a similar water pricing policy is assumed, that is not expected to change the water demand patterns.

Part III - Government Waterworks

With respect to non-conventional sources of water production, the volume of desalinated water and that of recycled water will be increased. The Paphos desalination plant is expected to enter into service around the 2nd half of 2020 with an annual production of 20MCM of drinking water, whereas upgrades of the Vasiliko and/or Lemesos desalination plant will further enrich the water balance with 40k m^3/day. Concerning the waste water treatment plants, new planned plants at Anthoupoli and Tersephanous will increase the amount of recycled water that will be given mainly for irrigation purposes. Furthermore, the south conveyor project will be fully operational in this period.

Part IV – Risk Matrix

Scenario CS1

In the 2030's Cyprus will be faced with a persisting water scarcity issue although there are significant projects that have been implemented and will be implemented that will help manage the risk. Using the averaged projections CORDEX database, model EC-EARTH/RCA 4, for the rainfall in Cyprus as the primary driver, the following scenario has been implemented:

- ✓ CS1 – precipitation exhibits a small averaged decrease (**Category = *LIKELY***),

Identified impacts

For human activities, similarly to the baseline scenario, no fatalities and/or injuries are expected. No major relocations are expected, but it is possible that farmers / people living in rural areas will face increased difficulties in having access to water for farming purposes.

H1: Fatalities and injuries = LIMITED

H2: People Relocation/evacuation = LIMITED

Economy: the impacts of water scarcity are multidimensional and extend over the entire period under consideration. Following the categorization of D2.1, the following impacts are expected:

1. Property damage. Minimal damages to properties are expected ***EC1 (property damage) = LIMITED***
2. Cultural heritage. ***No impact***
3. Infrastructure. More water infrastructures will be operated under this scenario (desalination and waste water treatment plants). ***EC1 (infrastructure) = CONSIDERABLE***
4. Economic activity. Under the ES1 climate change scenario, the tourism sector will be given priority for access to drinking water and thus no economic impact is anticipated. Agriculture is expected to increase without too much water stressing. ***EC1 (economic activity) = LIMITED***
5. Other economic. No major changes from the baseline scenarios are foreseen and so the impacts are the same as for the baseline scenario. ***EC1 (other economic activity) = CONSIDERABLE***

Water scarcity is expected to have multi-dimensional environmental impacts on the flora and fauna of the island. Local species that rely on water and good water quality will be under stress and with an increased danger of extinction. Furthermore, prolonged droughts and water scarcity will likely affect the incidence and management of wildfires of the island, both in terms of changing frequency and also in terms of higher impacts. Finally, urban green areas will be under increased pressures as no water will be available for irrigation during hot and dry periods. The environmental footprint of the entire island will be impacted, for a period of at least a year, whereas (partial) restoration costs could reach in the order of millions of euros.

EN1: Environment = CATASTROPHIC

Concerning the socio-political impacts of the water scarcity, the following categories **have been considered:**

6. Interruption and/or shutdown of critical infrastructures, which in this case is related to GWW. ***SP1 (damage of CI) = LIMITED***

7. The water scarcity will impact the everyday life/needs and disrupt the smooth societal functionality, with respect to people's access to water. The amount of people disrupted (staying without service) could be an important percentage of the population, although this would not last for several weeks. ***SP2 (everyday life) = CONSIDERABLE***

8. Finally, and following recent events on water shortages there is significant psychological implications and anxiety in case of water scarcity, especially for severely exposed population groups such as famers and the tourism industry. ***SP3 (social impact) = SERIOUS***

Impact category	Criterion	A	B	C	D	E
HUMAN→numbers	**H1**: Fatalities and injuries	X				
	H2: People Relocation/evacuation	X				
ECONOMY→ **EC1**: Assets costs (€) for the following indicators:	→ **EC1**: Assets costs (€) Indicators:			x		
	a) Property damage: repairs/restoration for buildings/coast/environment etc; materials	x				
	b) Cultural heritage					
	c)Infrastructure: roads, bridges, energy/technology plants etc.		x			
	d)Disruption of economic activity: tourism		x			
	e) Other specific cost (secondary cost to economy)		x			
ENVIRONMENTAL →polluted area (sq km) and event duration, for each	**EN1**: Environmental damage					x
SOCIAL-POLITICAL→number and duration (use 2-entry matrix), when possible, eg. For	**SP1**: damage (interruption/shutdown) of critical infrastructures	x				
	SP2: everyday life/needs disruption-societal functionality: traffic flow; normal activities (school, work)		x			

infrastructures and functions	**SP3**: social impact= public order and safety; psychological implications; anxiety			x		

Climate Scenario 2 – CS2

As explained previously, a more adverse climate change scenario is also used to assess the Upper Level Impact and Hazard properties. This compound scenario considers that a lower amount of rainfall will drop to the island by about 20%, and also the highest scenarios for population growth and tourist demand will appear.

- ✓ CS2 - takes into consideration a larger decrease intro the average precipitation by about 20% (**Category = *UNLIKELY***).

Identified impacts for CS2

For human activities, similarly to the baseline scenario, no fatalities and/or injuries are expected. No major relocations are expected, but it is possible that farmers / people living in rural areas will face increased difficulties in having access to water for farming purposes.

H1: Fatalities and injuries = LIMITED

H2: People Relocation/evacuation = LIMITED

Economy: the impacts of water scarcity are multidimensional and extend over the entire period under consideration. Following the categorization of D2.1, the following impacts are expected:

1. Property damage. Minimal damages to properties are expected ***EC1 (property damage) = LIMITED***
2. Cultural heritage. ***No impact***
3. Infrastructure. More water infrastructures will be operated under this scenario (desalination and waste water treatment plants, south conveyor) but due to demand driven stress these will be more susceptible to damages / degradation of service quality. ***EC1 (infrastructure) = CONSIDERABLE***
4. Economic activity. For the CS2 the combination of nonlinear tourism growth and limited available water resources will have a serious impact on the island's economy. Additionally, the agriculture sector will be particularly stressed as the irrigated crops areas will be on the increase and this could be seen as having a compound impact. ***EC1 (economic activity) = SERIOUS***
5. Other economic. Owing to the increased economic impact on the previous categories, second order effects as identified previously in the baseline scenario are expected to be higher, ***EC1 (other economic activity) = SERIOUS***

Water scarcity is expected to have multi-dimensional environmental impacts on the flora and fauna of the island. Local species that rely on water and good water quality will be under stress and with an increased danger of extinction. Furthermore, prolonged droughts and water scarcity will likely affect the incidence and management of wildfires of the island, both in terms of changing frequency and also in terms of higher impacts. Finally, urban green areas will be under increased pressures as no water will be available for irrigation during hot and dry periods. The environmental footprint of the entire island will be impacted, for a period of at least a year, whereas (partial) restoration costs could reach in the order of millions of euros.

EN1: Environmental = CATASTROPHIC

Concerning the socio-political impacts of the water scarcity, the following categories **have been considered:**

6. As in all scenarios. ***SP1 (damage of CI) = LIMITED***

7. The water scarcity will impact the everyday life/needs and disrupt the smooth societal functionality, with respect to people's and economic sectors access to water. As this is the most adverse scenario examined, people disrupted (staying without service) could be an important percentage of the population and this could last for several weeks during the period. ***SP2 (everyday life) = CONSIDERABLE***

8. Finally, and given probability on water shortages, there is significant psychological implications and anxiety, especially for severely exposed population groups such as famers and the tourism industry. ***SP3 (social impact) = VERY SERIOUS***

Impact category	Criterion	A	B	C	D	E
HUMAN→numbers	**H1**: Fatalities and injuries	X				
	H2: People Relocation/evacuation	X				
ECONOMY→ **EC1**: Assets costs (€) for the following indicators:	→ **EC1**: Assets costs (€) Indicators:			x		
	b) Property damage: repairs/restoration for buildings/coast/environment etc; materials	x				
	b) Cultural heritage					
	c)Infrastructure: roads, bridges, energy/technology plants etc.		x			
	d)Disruption of economic activity: tourism		x			
	e) Other specific cost (secondary cost to economy)		x			
ENVIRONMENTAL →polluted area (sq km) and event duration, for each	**EN1**: Environmental damage					x
SOCIAL-POLITICAL→number and duration (use 2-entry matrix), when possible, eg. For infrastructures and functions	**SP1**: damage (interruption/shutdown) of critical infrastructures	x				
	SP2: everyday life/needs disruption-societal functionality: traffic flow; normal activities (school, work)			x		
	SP3: social impact= public order and safety; psychological implications; anxiety				x	

6.6 Treatment measures and suggestions for adaptation and mitigation measures

The WDD has developed a Roadmap for the quantitative management of surface waters and a second Roadmap for the gradual reduction of water abstraction from groundwater for irrigation as part of its 2nd River Basin Management Plan (WDD, 2016). Each Roadmap is made up of four actions, with an implementation time horizon of 2027.

Table 6.3 Roadmap for the quantitative management of surface waters

Action 1	Recording of the amounts abstracted. This action entails recording and updating of the relevant Registry.
Action 2	Research into alternative methods for saving water, particularly for irrigation uses. This is made up of a series of smaller actions: • Implementation of water pricing policy. • Crop restructuring, including substitution of water intensive crops • Use of improved irrigation systems and irrigation technology • Increased use of desalination including through increasing the capacity of existing desalination plants and possibly building new plants • Increased use of recycled water for irrigation
Action 3	Creation of a Plan for Managing the Quantity of Water, which will include: • Integration of water supply and water infrastructure projects and their monitoring into one unified system • Monthly or bimonthly water balance studies for each autonomous GWW • Updating current and future water needs for water supply, irrigation and environmental/ecological requirements • Updating of the hydrological study to the determine the hydrological conditions in average hydrological years, drought and wet years
Action 4	Adaptation of the Water Policy Management taking into account the findings of Action 3 in order to determine the quantities of water for domestic water supply and irrigation

Table 6.4 Roadmap for the gradual reduction of water abstraction from groundwater for irrigation

Action 1	Identification of private boreholes and the quantity of water abstracted (this action was begun under the 1st River Basin Management Plan)
Action 2	Determination of the quantities of water that can be abstracted from groundwater sources annually. This will require specialized hydrogeological studies.
Action 3	Identification and implementation of water saving actions
Action 4	Development of an incentive and implementation mechanism as well as an inspection mechanism. Incentives could be in the form of water pricing policies whilst inspection of boreholes and the amounts abstracted could be achieved through integration of such requirements in the inspection duties of other government departments.

The WDD has also produced an updated Drought Management Plan (2016) with three actions related to managing water resources during dry periods:

- **Action 1**: Adherence to the abstraction allowances for the SCP and Paphos GWWs (Tables 6.5 and6.6 below). The updated Drought Management Plan recommends that the abstraction allowances should be determined based on the **total** volume available in **all** dams at the end of the hydrological year (1st of April) and as such abstraction allowances should be revised regularly. Currently they are:

Table 6.5: Annual Abstraction Allowances for South Conveyor Project			
Volume in 1st of April *V* (hm^3)	**Category**	**Annual Allowances (hm^3)**	**Action**
V>120	Adequate	55	No cuts
120>V>100	Mild deficit	44	Minor cuts
100>V>80	Moderate deficit	35	Moderate cuts
80>V>50	Serious deficit	25	Large cuts
V<50	Extreme deficit	14	Very large cuts

Table 6.6: Annual Abstraction Allowances for Paphos Government Waterworks			
Volume in 1st of April *V* (hm^3)	**Category**	**Annual Allowances (hm^3)**	**Action**
V>400	Adequate	17	No cuts
40>V>25	Mild deficit	14	Minor cuts
25>V>15	Moderate deficit	10	Moderate cuts
15>V>10	Serious deficit	7	Large cuts
V<10	Extreme deficit	4	Very large cuts

- **Action 2**: Update of the appropriate mechanism for monitoring and managing drought using indicators that monitor the intensity and duration of drought.
- **Action 3**: Use of desalination plants in times of drought, with desalination plants operating at full capacity in times of serious deficit and at maximum capacity in times of extreme deficit. The construction and operation of the Paphos desalination plant is considered imperative for achieving the amounts of desalinated water that will allow adequate management of drought periods.

To manage the impacts of water scarcity, the actions described in the 2nd River Basin Management Plan and the updated Drought Management Plan must be strictly implemented. Some actions in the 1st River Basin Management Plan and the first Drought Management Plan were only partially implemented, with the primary reason being the economic recession. Significantly, the evaluation of the implementation of the first Drought Management Plan, observed that the series of actions related to minimizing the quantities of water abstracted during dry periods were not strictly adhered to for all GWWs (e.g. the SCP for 2013-14, see the updated Drought Management Plan, 2016). It is imperative that in the implementation of the updated Drought Management Plan the actions related to annual allowances in water abstracted during dry years are implemented as described for each GWW in the tables above. It is important that the annual allowances are revised regularly, and that these are adhered to even in average or wet hydrological years to ensure adequate water resources in periods of drought.

Further development of GWWs including the Paphos desalination plant (annual production of 20MCM of drinking water), planned upgrades to the Vasiliko and Lemesos desalination plants (with a total increase in capacity if 40k m3/day) and planned development of infrastructure for

the use of recycled water from waste water treatment plants in Anthoupoli and Tersephanous (which will increase the amount of recycled water for irrigation purposes) will be vital in managing the water scarcity of the island.
The use of non-conventional water resources (e.g. desalination and recycled water) are expected to increase; it is recommended that the WDD undertake specialized studies on the impacts to the economy of the use of such non-conventional water resources as well as the impact that the use of energy-intensive desalination plants will have on the energy balance of the island and its greenhouse gas emissions reduction commitments.

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7. Large scale technological accidents

7.1 Description of SEVESO installations in Cyprus

The risk assessment of all installations in Cyprus, handling toxic or flammable substances which are either lower or upper tier according to the SEVESO III directive will be carried-out in this chapter.

7.1.1 The SEVESO Directive

Major accidents involving dangerous chemicals pose a significant threat to humans, the environment and the economy. However, the use of large amounts of dangerous chemicals is unavoidable in some industry sectors. To minimise the associated risk and prevent major accidents, measures should be in place to ensure appropriate preparedness and response.

The catastrophic accident in the Italian town of Seveso in 1976 prompted the adoption of legislation on the prevention and control of such major accidents. The so-called Seveso-Directive (Directive 82/501/EEC) was later amended from lessons learned by other accidents such as Bhopal, Toulouse or Enschede resulting into Seveso-II (Directive 96/82/EC). Moreover, in 2012 Seveso-III (Directive 2012/18/EU) was adopted taking into account the changes on the classification of chemicals and increased rights for citizens to access information.

Seveso-III (Directive 2012/18/EU) applies to more than 12000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel wholesale and storage (LPG, LNG) sectors.

7.1.2 SEVESO installations in Cyprus

In Cyprus there are 12 major hazards installations handing flammable substances in large quantities and are obliged to submit safety reports according to the SEVESO III Directive. These are the so called upper tier SEVESO installations and they have large amounts of LPG and fuel oils, as presented in Table 7.1. In addition there exist four upper tier SEVESO installations under construction. In Cyprus 18 hazards installations are located handing smaller amounts of toxic, flammable and explosive substances, obliged to submit relatively simple safety reports according to the SEVESO III Directive, for lower tier SEVESO installations and are presented in Table 7.2. The lower tier installations handle fuels, LPG, explosives and only one installation handles chlorine. Hazardous installations are located in the Southern part of Cyprus in the following areas: a) Larnaca (Road Larnaca- Dekelias), Mari-Vasilikou, and b) Limassol as presented in Figure 7.1.

Table 7.1 Upper tier SEVESO installations

No	Installation	Area	Hazardous Substances/ Quantities of hazardous substances: https://espirs.jrc.ec.europa.eu/en/espirs /public/publicsearch [1]
1	Petrolina Holdings Public Ltd (Petrolina Oils)	Larnaca	• Fuel Storage (UNL95 RON, UNL98 RON,Diesel,AGO, HGO, GGO,MGO, Kerosine) 26392 tonnes
2	Petrolina Holdings Public Ltd (Petrolina Gas)	Larnaca	• LPG 1263 tonnes
3	Petrolina Holdings Public Ltd (Euro Gas)	Larnaca - Livadia	• LPG 270 tonnes
4	Intergaz	Larnaca - Dekelia	• LPG 1273 tonnes
5	Synergas	Larnaca - Dekelia	• LPG 910 tonnes
6	Exxon Mobil Cyprus Ltd	Larnaca - Dekelia	• Petroleum Products (UNL95,UNL98,Heating Diesel,Diesel (LSB7 & LSB0),Marked Diesel,Kerosine) 25000 tonnes
7	Hellenic Petroleum	Larnaca - Dekelia	• Petroleum products (Diesel 50ppm, Diesel 50ppm, Unleaded 98,Diesel 50ppm, Unleaded 100, Agri diesel Slops Tanks, Kerosine,Jet A-1,Diesel Marine, Unleaded 95,Diesel 0.2%,HFO,LFO) 44000 tonnes • LPG 925 tonnes
8	Petrolina Holdings Public Ltd (Centragaz Installations)	Larnaca - Dekelia	• LPG 446 tonnes
9	Electricity Authority of Cyprus	Mari - Vasiliko	• Petroleum products (HFO 90000 tonnes, DFO 99000 tonnes) • Hydrazine 2 tonnes
10	Electricity Authority of Cyprus	Larnaca - Dekelia	• Petroleum Products (Fuel oil, Diesel) 1040000 tonnes • Hydrazine 1.9 tonnes
11	VTTV Vasiliko Ltd	Mari - Vasiliko	• Petroleum Products (UNL 95 RON,UNL 98 RON,MTBE,ULSD Ultra-Low Sulphur Diesel 10ppm,Gasoil – 0,1%S,Gasoil,JET-a1,FAME 100) 434000 tonnes
12	Petrolina Holdings Public Ltd (Vasiliko)	Mari - Vasiliko	• Fuel storage (JET-A1, UNL 95 RON, UNL 98 RON, ADO, HDO, MGO,HFO/LFO) 30000 tonnes
13	Hellenic Petroleum (Vasiliko)	Mari - Vasiliko	Under construction
14	Cyprus Organisation for Storage and management of oil stocks	Mari - Vasiliko	Under construction
15	Blue Circle Engineering Ltd	Mari - Vasiliko	Under construction
16	EUROGATE Container Terminal Limassol Ltd	Limassol port	Pending Safety Report

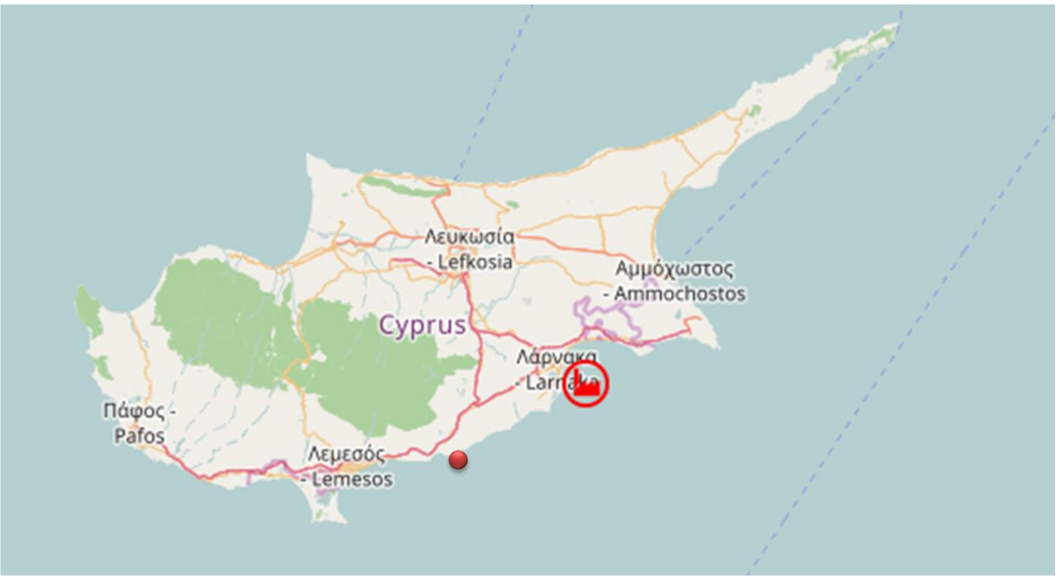

Figure 7.1: Siting of Upper tier SEVESO installations in Cyprus

Table 7. 2- Lower tier SEVESO installations

No	Installation	Area	Substances/ Quantities of hazardous substances: https://espirs.jrc.ec.europa.eu/en/espirs/public/publicsearch [1}
1	Petrolina Holdings Public Ltd (Lina)	Larnaca – Dekelia	liquid petroleum products 7211 tonnes
2	Electricity Authority of Cyprus	Moni	liquid petroleum products 10000 tonnes
3	Explomin Imports/ exports Ltd	Latomia Sias	Explosives: P1a 42 tonnes, Ammonium nitrate 275 tonnes
4	Hellenic Copper Mines Ltd	Solea	Explosives (P1a 36 tonnes, P1b 0.007 tonnes) Ammonium nitrate 54 tonnes
5	K. Kythreotis Holdings Ltd	Kellaki	Explosives P1.a 32 tonnes, Ammonium nitrate 30 tonnes
6	G&L Calibers Ltd	Ergates	Explosives (P1a 40 tonnes, P1b 13 tonnes)
7	Procopis G. Gavriilides Ltd	Larnaca	Explosives (P1a 30 tonnes, P1b 8.1 tonnes)
8	Linde Hadzikyriakos Gas Ltd	Strovolos	Oxygen 174 tonnes, nitrous oxide 22 tonnes, acetylene 2.5 tonnes
9	Panaska Trading Co Ltd	Geri	Explosives, oxidizing and dangerous for the environment chemical substances 149 tonnes Flammable liquids P5a 4 tonnes, P5b 240 tonnes E1 174 tonnes E2 50 tonnes
10	A.P. Georgiades Ltd	Geri -Dali	Chlorine 14 tonnes oxidizing and dangerous for the environment chemical substances 68 tonnes
11	Thermogaz Ltd	Akaki	LPG 80 tonnes
12	E. Emmanouel & Sons Ltd	Tseri	LPG 138 tonnes
13	Blue Circle Engineering Ltd	Strovolos	LPG
14	Larnaca Aviation Fuelling System (LAFS)	Dromolaxia – Meneou	liquid petroleum products 5200 tonnes
15	P&S LPG GAS LTD	Paphos	LPG 93 tonnes
16	T&E ARESTI LTD	Larnaca	LPG 65 tonnes
17	LANITIS GAS LTD	Ipsonas	LPG 80 tonnes
18	K. MICHAILAS & SIA LTD	Aradippou	LPG 75 tonnes

7.1.3 Accidents/ Incidents of SEVESO installations in Cyprus

No major hazard accidents of SEVESO installations have been reported in Cyprus. An accident with severe consequences both fatalities and injuries occurred on 11 July 2011 at the Evangelos Florakis Naval Base near Zygi. A large amount of ammunition and military explosives that had been stored outdoors for over two years at the Naval Base self-detonated, killing 13 people and injuring 62. The explosion severely damaged hundreds of buildings in Zygi and the nearby Vasilikos power station, Cyprus' largest one, causing widespread disruption in the supply of power to the island [2].

7.2 RISK ASSESSMENT METHODOLOGY FOR MAJOR TECHNOLOGICAL HAZARDS

The methodology and procedures to be followed for the qualification of the risk from installations handling toxic or flammable substances can be distinguished into three major phases [3]:

- I) Assessment of Plant Damage States and their Frequency of occurrence.
- II) Assessment of Consequences of Toxic or Flammable Substances Release.
- III) Risk Integration.

7.2.1 Assessment of Plant-Damage States and their Frequency of Occurrence

The first phase of a quantified risk assessment consist in analyzing the installation to identify potential accident initiators, assess the response of the plant and establish potential and damage states of the plant with the potential of releasing a dangerous substance in the environment.

This phase can be distinguished in the following major procedural steps :

Hazard source identification

The main sources of potential hazardous-substance releases are identified and the initiating events that can cause such releases are determined.

Accident Sequence Determination

A logic model for the installation is developed in this step. The model includes each and every initiator of potential accidents and the response to the installation to these initiators. Specific accident sequences are defined (in models called event trees) which consist of an initiating event, specific system failures or successes and their timing, and human responses. Accident sequences result in plant damage states which involve release of the hazardous substance. System failures are in turn modelled (in models called fault trees) in terms of basic component failures and human errors to identify their basic causes and to allow for the quantification of the system failure probabilities and accident sequence frequencies.

Plant Damage State Definition

A plant damage state uniquely characterizes the conditions of release of the hazardous substance. Accident sequences resulting into the same conditions of release are grouped into groups each corresponding to a particular plant damage state.

Data and Parameter Assessment

Parameters which must be estimated include the frequencies of the initiating events, component unavailability and probabilities of human actions. Whenever sufficient data from the past history of the installation's operation exist plant-specific estimation of these parameters are possible. Otherwise, generic values are used.

Accident Sequence and Plant Damage State Quantifications

This step quantifies the accident sequences and the plant damage states, that is calculates their frequency of occurrence. Accident sequences to be quantified in the event trees are specified and manipulated according to the laws of Boolean algebra in order to be put in a form suitable for quantification. The results of this step is the calculation of the frequency of occurrence of each accident sequence and consequently of each plant damage state.

7.2.2 Consequence Assessment of Flammable Substance Releases.

The second phase of the quantified risk assessment aim at the establishment of the consequences of the released hazardous substances. In this section the major steps for the assessment of the consequences of released flammable substances will be presented.

Determination of Release categories of Flammable Material

A release category for a flammable material uniquely determines the type of the physical phenomenon that could result in fatalities or injuries. For example, in the case of the LPG, it is established whether a BLEVE will take place or whether an explosion or deflagration will result following atmospheric dispersion of the gas. The type of fire that might result from other flammable materials is another example.

Estimation of Heat Radiation and Peak Overpressure.

In this step, a model for simulating the heat radiation or the peak overpressure resulting from the released flammable material and the associated physical phenomenon is established.

Dose Assessment

The integrated, over time, exposure of an individual to the extreme phenomenon generated by the flammable material is calculated. This defines the "dose" an individual receives.

Consequence Assessment

Appropriate dose/response models receiving as input the dose of heat radiation or overpressure calculate the probability of fatality or injury of the individual receiving the dose.

7.2.3 Risk Integration

Integration of the results obtained so far, that is combining the frequencies of the various accidents with the corresponding consequences results in the quantification of risk. Two risk measures are usually used to quantify risk, namely a) Individual risk at a location and b) Group risk in a given area

Individual Risk

Individual fatality risk is defined as the frequency (probability per unit of time) that an individual at a specific location (x, y) relative to the installation(s) will die as a result of an accident in the installation. Usually individual risk is expressed in terms of isorisk curves, that is the loci of points with the same level of individual risk.

Group Risk

Group fatality risk proceeds one step further than individual risk by taking into consideration the population size and distribution around the site of the installation. Group risk is expressed in terms of the so called (F, N) curves and gives the frequency for the number of fatalities which exceed the number N.

7.2.4 Release Categories for Flammable Materials

A release category refers to that set of conditions which uniquely define the resulting heat flux or overpressure at each point around the site of the release and at each time following the release. The release categories of the following plant damage states will be described:

1. Break of a tank or pipe with flammable liquid
2. BLEVE
3. Break of a tank or pipe with liquefied gas
4. Break of a tank or pipe with pressurized gas

Break of a tank or pipe with flammable material

If there is a release of a flammable liquid either from a pipe or a tank a.nd it is possible to have an ignition then the liquid will burn forming a pool fire. The conditions and parameters determining the heat flux of the pool fire are: the radius of the pool fire R, the ambient temperature T, the total mass in the pool and the type of flammable liquid

BLEVE

A Boiling Liquid Expanding Vapor Explosion (BLEVE) occurs when there is a sudden loss of containment of a pressure vessel containing a superheated liquid or a liquefied gas. The primary cause is usually an external flame impinging on the shell of a vessel above the liquid level, weakening the container and leading to sudden shell rupture allowing a superheated liquid to flash, typically increasing its volume over 200 times. The best known type of BLEVE involves LPG. A number of such incidents have occurred including San Carlos (1978), Cresent City, Illinois(1970), Mexico City, Mexico(1984).

The modeling philosophy is primary empirically based and all models use a power correlation to relate BLEVE diameter and duration to mass. The radiation received by a target is a function of transmissivity, surface emitted flux and the view factor. The input required for the calculation of radiation are the material properties the mass of material and the atmospheric humidity.

Break of a tank or pipe with liquefied gas

If there is a break of a tank or pipe with liquefied gas the gas will disperse and, if it encounters an ignition source the mixture of gas and air may either explode and cause damage to the surrounding owing to the shock wave, or burn as a flash fire in a very short period.

Flash fire

When a large amount of volatile flammable material is rapidly dispersed to the atmosphere a vapour cloud is formed and dispersed. If this cloud is ignited before the cloud is diluted below its LFL a (Unconfined vapour cloud explosion) UVCE or flash fire will occur. Early ignition might result in a flash fire. In this case, the flammable material is burned in a short period of time.

Deflagration

An ignition of a combustible mixture of a flammable gas and air may result in an explosion causing damage to the surroundings. The damage is mainly due to the shock wave that will be produced by such an unconfined vapour cloud explosion. Only the part of the cloud with concentrations between the lower flammability limit and upper flammability limit participate in the explosion. The explosion models predict peak overpressure with distance.

Break of a tank or pipe with pressurized gas

If a break occurs in a tank or pipe with pressurized gas a jet fire may occur if the dimensions of the break are small. Otherwise a fireball may occur. Jet fire modelling incorporates many mechanisms similar to those considered for pool fires. Burning rate, flame height, flame tilt, surface emitted power, atmospheric transmissivity are all empirical but well established factors. Some simplified approaches give a power law correlation for jet hazard zones.

Table 7.3 presents the scenarios which have been analysed for the Upper tier SEVESO installations.

7.2.5 Dose assessment

The objective of this task is the estimation of the effects of toxic material dispersion, the effects of thermal radiation, and the explosion effects. For toxic substances this is done on the basis of concentrations calculated by the dispersion model and the exposure of an individual to these concentrations. For substances causing high levels of thermal radiation, effects are

Table 7.3: Major Hazards Scenarios for SEVESO Plants

A: Flammables (Fuels, Petroleum products)
Tank failure and Pool fire (either inside the bund, or outside the bund)
Roof pool fire
Pipe failure, Jet fire and immediate ignition
Pipe failure, Jet fire and delayed flash fire
Pipe failure, Jet fire and delayed Vapour Cloud Explosion
Truck failure leading to pool fire
B : LPG
BLEVE of catastrophic failure of LPG tanks
Jet fire, owing to small tank rupture or pipe break of LPG pipelines
Dispersion of LPG and delayed flash fire
Dispersion of LPG and delayed Vapour Cloud Explosion

C: Toxics
Dispersion of SO2, produced during large pool fire
Dispersion of ammonia
Dispersion of Chlorine

calculated on the basis of thermal fluxes while in the case of explosions in terms of the overpressure.

Health effects are estimated in terms of the dose of the adverse effect an individual, exposed for a period of time (T) to the phenomenon, receives. The exposure time (T) of each individual to these effects is assumed constant and equal for all points (x,y) of the grid. Dose is calculated in terms of an equation of the type

$$d(x,y)=\int_0^T f[c(x,y,t)]dt$$

(1)

where c(x,y,t) is the intensity of extreme phenomenon (concentration, heat flux, overpressure) at time t and at point (x,y). Function {f} depends on the phenomenon and on the particular substance involved.

For thermal radiation the dose function is the following :

$$d(x,y)=[q(r)]^{4/3}x10^{-4}, r=\left(x^2+y^2\right)^{1/2} \qquad (2)$$

where q(r) is the thermal flux at distance r from the center of the fire (W/m2) [4,5,6].

For overpressure, the dose function is :

$$d(x,y)=\frac{0.0738}{P_s}+\frac{1.3x10^9}{P_s I_s} \qquad (3)$$

where *Ps* is the overpressure and Is is the impulse of the shock wave [4,5,6.]

7.2.6 Fatality Probability Assessment

The probability that an individual will die as a result of its exposure the extreme phenomenon is estimated in terms of dose-response models receiving as input the dose calculated by the dose module. Dose-response models are based on a “probit” function for the substance and/or phenomenon [4,5,6].

The probit model can be described as follows. It is assumed that each individual into a population exhibits a different “strength” in coping with a dose, d, of an adverse effect. Furthermore, the model assumes that this strength, S, is normally distributed with mean value 5 and standard deviation 1. It is also stipulated that a dose “d” generates a “stress” P_0 on each individual that is a function of the dose and of the substance. In particular

P_0 = Probit = A+B * ln {d} (4)

where A, B are substance (or phenomenon) dependent constants.

The model assumes that a person dies if its strength, S, is lower or equal than the dose induced stress P_0; that is, the probability of an individual dying, p_d , as a result of a dose (d) is given by:

$$p_d = P_r\{S \le P_0\} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{P_0} \exp\left[-\frac{(u-5)^2}{2}\right] du$$

or

$$p_d = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{P_0 - 5} \exp\left[-\frac{(u-5)^2}{2}\right] du \qquad (5)$$

It is noteworthy that p_d, implies that if N people receive dose d, then the expected number of fatalities is $(p_d \cdot N)$.

7.2.7 Risk Integration.

Integration of the results obtained so far, that is combining the frequencies of the various accidents with the corresponding consequences, results in the quantification of risk. Individual risk is calculated as follows:

Let:

r be an index spanning the space of the possible release categories of a toxic or flammable substance. It is reminded that the space of release categories includes all possible combinations of installation - related, weather, and any other parameters that determine the intensity of the adverse effect. (concentration, thermal radiation e.t.c.) ($r = 1, \ldots, R$)

f_r : be the frequency of the rth release category

$c_r(x,y,t)$ be the intensity of the adverse effect (e.g. concentration of toxic material, heat radiation, overpressure) at point (x,y) and instant of time t given that release category r has occurred.

$d_r(x,y)$ be the level of adverse exposure that is, the integrated over time exposure to the adverse effect. This quantity is commonly referred to as “dose.

It follows that the quantity pr (x,y), the conditional probability of fatality for an individual at location (x,y) given release category r, can be calculated form the doses as follows:

$$\text{release category } r \xrightarrow{BLEVE/\,fire/\,eplosion} c_r(x,y,t) \xrightarrow{Dose} d_r(x,y) \xrightarrow{\text{Probit}} p_r(x,y) \qquad (6)$$

If R(x,y) is the frequency of fatality for an individual at location *(x,y)* (individual risk) it follows that :

$$R(x,y)=\sum_{r=1}^{R} p_r(x,y) f_r \tag{7}$$

7.3 EXPOSURE AND VULNERABILITY OF SOCIOECONOMICAL PARAMETERS

In this section, the impact on human, economics & environment and political/society, will be analysed in terms of vulnerability and exposure. In this stage a semi-quantitative approach will be followed, and impact criteria will be assessed for three hazards scenarios namely a worst case scenario, an expected scenario and a mild scenario. The impacts for three categories, economy, environmental and social/political, will be determined using scales A - E.

Major accidents involving dangerous chemicals pose a significant threat to humans and the environment. Furthermore, such accidents cause human lives, huge economic losses, social-political issues and disrupt sustainable growth. The use of large amounts of dangerous chemicals is unavoidable in some industry sectors which are vital for a modern industrialised society. For the purpose of this study Seveso Directives have been followed as well. The Seveso Directives are the main EU legislation dealing specifically with the control of on-shore major accident hazards involving dangerous substances. The Seveso III Directive came into force on 1 June 2015, replacing the Seveso II Directive. The Directive focuses mainly at the prevention of major accidents, which involve dangerous substances, and secondly on the limitation of the consequences on people and the environment in case of a major-accident, based on the following guidelines:

• The identification of establishments, which include major-accident hazards, is based on the type and quantity of dangerous substances.

• The prevention of major-accidents, as well as the response to it, is based on the planning and implementation of the appropriate safety management systems and land use planning and the identification of potential risks and hazards.

• The registration of data and the communication and exchange of information between all the involved parts at all levels (operators, authorities, public, member states, European Commission) is established, so that significant data, valuable experiences and lessons learned can assist in preventing future accidents.

All upper tier SEVESO installations are obliged to submit a SEVEO report, where all accidental scenarios are identified and their consequences estimated. In all SEVESO report four consequence zones have been calculated which are the following: a) Domino zone, b) protection zone for the emergency responders (ZONE I), c) protection zone of the population, owing to severe effects (ZONE II) and d) protection zone of the population owing to medium effects (ZONE III). Table 7.4 presents the characteristics of each zone, which are the level of thermal radiation, toxicity or overpressure encountered in each zone.

Table 7.4: Consequence Zones for Upper – tier SEVESO installations

ZONE	*Description*	*Thermal Radiation*	*Toxicity*	*Overpressure (mbar)*
Domino	Domino effect	37.5 kW/m2		700
I	Protection of first responders	15 kW/m2, 1500TDU	LC50	350
II	Protection of population from severe effects	6 kW/m2, 4500TDU	LC1	140
III	Protection of the population from medium effects	3, 170TDU	IDLH	50

Table 7.5 presents the distances where these four zones are encountered, areas with considerable or severe consequences in case of major technological accidents, based on the SEVESO safety reports of installations in Cyprus.

Three accidental scenarios have been selected in order to assess the impact to the population, environment and society. The impact to the population was estimated by considering the area of zones I and II and the population distribution around the Seveso industrial installations. These scenarios are the following and the impacts are presented in Tables (6-8):

A. BLEVE and total failure of LPG tank 625 t (ELPE)
The installation of Hellenic Petroleum is based in Larnaca region (near Livadia area).

B. Pool fire in bund area (ELPE)
The installation of Hellenic Petroleum is based in Larnaca region (near Livadia area).

C. Jet fire 4" pipebreak (Intergaz) (based in Larnaca region, near Oroklini area.

The impact of Fatalities to the population is measured in a scale A-E which is equivalent to the following fatalities and serious injuries:

NUMBER OF FATALITIES AND SERIOUS INJURIES				
A	**B**	**C**	**D**	**E**
1-5	5-20	20-50	50-100	>100

Table 7.5: Accidental major hazard scenarios, SEVESO plants in Cyprus

Scenarios	**DOMINO ZONE (m)**	**ZONE I (m)**	**ZONE II (m)**	**ZONE III (m)**
ELPE				
BLEVE and total failure of LPG tank 625t	257	682	1190	1700
Jet fire 6" (σφαιρικής δεξαμενής)		135	181	225
Flash fire LPG tank 625t (D5)		174		
UVCE LPG tanks 625t		151	335	840
pool fire from failure of LPG tank 625t	47	93	145	192
roof pool fire		22	22	48
Pool fire in bund area	45	91	134	174
VCE in bund area		34	76	186
truck failure and pool fire 40t	45	91	134	174
jet fire (25kg/s)		77		
pipe break and flash fire		49		
pipe break and VCE		35	76	186
Dispersion of SO2, from cloud of fire		51	237	800
VTT VASILIKO				
Roof Pool Fire	24.7	41	41	85.6
Bund fire of Tank T8 (JET-A1)	62	111	154	194
Pool fire in bund with tanks TK 401-403	75	130	187	242
Flash fire (D5- F2)		57-140		
UVCE in tank area (F2)	17	30	52	120
Pool fire outside bund area - filling aea	45	91	134	174
pipe break 20" (246kg/s) jet fire		56	121	137
pipe break 18" FBR jetty jet fire		312	396	486
pipe break and flash fire in truck area		67-179		
pipe break and VCE in truck area	26	43	79	184
Dispersion of SO2, from cloud of fire		42-62	53-145	76-858
Synergas				
BLEVE tank 392t	201	599	1028	1469
jet fire - partial tank failure (392t) or bullet tank failure (115t)	59	96	141	187
flashfire - tank failure (392t) F2 -LFL		995		
VCE - tank failure (392t)			190	544
Pool fire -LPG tank 392 total failure	406	132	184	232
Petrolina Vasiliko				
Roof Pool Fire	18	38	53	66
Bund fire of Tank T8 (JET-A1)	62	111	154	194
Flash fire in tank area		65	146	361
UVCE in tank area		62	138	342
pool fire- pumping area	38	66	98	111
Scenarios	**DOMINO ZONE (m)**	**ZONE I (m)**	**ZONE II (m)**	**ZONE III (m)**
pool fire filling area	45	79	107	134
pipe break 12" jet fire	18	27	31	35
truck failure and VCE (F2)		21	47	115
pipe break 14" VCE (F2)		48	108	267
Dispersion of SO2, from cloud of pool fire F2		456	844	3184
Petrolina Gas				
BLEVE and total failure of LPG tank 1042t	270	848	1442	2058

jet fire (6in LPG pipeline)	370	86	135	214
jet fire 6"	179	57	91	134
pipeline failure 6"	159	50	81	120
LPG tank failure and flash fire (1024t)- F2		1524		
LPG tank failure and VCE (1024t)			256	735
pool fire -LPG tank failure 1042t	429	155	244	338
Petrolina Oils				
Roof Pool Fire	22	38	48	65
Flash fire in tank area (F2- LFL)		78		
UVCE in tank area		38	84	208
pool fire- outside bund	50	85	119	150
pipe break 4" jet fire	47	60	88	117
Flash fire uitside bund, 12" pipebreak (F2- LFL)		88		
VCE outside bund, 12" pipebreak (F2- LFL)		42	92	229
Intergaz (LPG)				
BLEVE and total failure of LPG tank 110t	135	407	699	998
Jet fire 4"	135	42	70	101
Flash fire LPG tank 110t (F2)		529		
UVCE LPG tank 110t			121	348
pool fire from failure of LPG tank 110t	61	102	143	180
Exxon Gas				
Roof Pool Fire	9	19	19	35
Bund fire of Tank T8 (JET-A1)	27.5	57	86	113
pipe break and flash fire F2		49		
pipe break and VCE		34	76	186
pool fire- outside bund	45	91	134	174
Jet fire outside bund		77		
pipe break outside bund and flash fire F2		49		
pipe break outside bund and VCE F2		34	76	186
Dispersion of SO2, from cloud of fire		51	237	800
Scenarios	**DOMINO ZONE (m)**	**ZONE I (m)**	**ZONE II (m)**	**ZONE III (m)**
Eurogas				
BLEVE and total failure of LPG tank 55t	105	299	518	743
Jet fire 4" (from tank)	49	62	92	123
Flash fire LPG tank 55t (F2 LEL)		383		
UVCE LPG tanks 55t	50		97	278
pool fire from failure of LPG tank 55t		68	95	119
Centragaz				
BLEVE and total failure of LPG tank 110t	140	338	553	798
jet fire (6in LPG pipeline)	370	86	135	214
LPG tank failure and flash fire (110t)- F2		648		
LPG tank failure and VCE (110t)	115	171	305	633
pool fire -LPG tank failure 110t	93	147	233	329
AHK DEKELEIAS				
Roof Pool Fire	28	47	60	80
Pool fire in Bund	107	165	224	281
Pool fire outside bund	28	46	62	77
Dispersion of ammonia, from cloud of fire F2		119	266	1467

AHK VASILIKO				
Pool fire outside bund	178	309	480	661
Dispersion of ammonia, from cloud of fire F2		302	526	1400
Dispersion of Hydrazin F2		179	289	518
Dispersion of HCL F2		136	189	957
Dispersion of Chlorine F2		453	1200	3300

7.4 PROBABILISTIC SCENARIOS ANALYSIS/ CONSEQUENCES AND IMPACT ASSESSMENT

At this step, the probability of occurrence of each hazard scenario will be determined along with the associated consequences. Therefore, (taking into account all three categories of impacts) the risk will be estimated as a function of the probability of hazard's occurrence (p), vulnerability (V) and exposure (E) as already described in paragraph 7.2.

Expected scenario – Analysis – Risk Matrix

According to the scientific literature the frequency of a BLEVE is 10^{-6}/year, the frequency of a pool fire 10^{-3}/year and the frequency of a jet fire 10^{-3}/year. Table 7.9 presents the likelihood and consequences for the population in case of the three accidental scenarios.

Table 7.9 Likelihood and consequences of the three accidental scenarios

SCENARIOS	**LIKELIHOOD**	**CONSEQUENCES**
#A BLEVE and total failure of LPG tank 625t (ELPE)	1	5
#B Pool fire in bund area (ELPE)	4	2
#C Jet fire 4" (Intergaz)	4	1

LIKELIHOOD: Frequency of Accident / yr				
1	**2**	**3**	**4**	**5**
1.00E-06	1.00E-05	1.00E-04	1.00E-03	1.00E-02
CONSEQUENCES: NUMBER OF FATALITIES AND SERIOUS INJURIES				
1	**2**	**3**	**4**	**5**
1-5	5-20	20-50	50-100	>100

7.5 QUANTIFICATION OF EXISTING TREATMENT MEASURES AND SUGGESTIONS FOR ADAPTATION AND MITIGATION MEASURES

According to the SEVESO III directive upper Tier Seveso installations draw up an internal emergency plan for the measures to be taken inside the establishment and supply the necessary information to the competent authority, to enable the latter to draw up external emergency plans (Article 12 and Annex IV of SEVESO III). Internal emergency plans contain disaster fighting processes and measures so as to minimise the effects, and to limit damage to human health, the environment and property. Internal emergency plans foresee training and exercises to personnel, public crisis communication, multi-disciplinary exercises with societal organisations (media) and authorities and exchange of information between companies and authorities.

The authorities draw up an external emergency plan for the measures to be taken outside the establishment in case of a major accident, according to article 13, of the SEVESO III directive. The general strategic plan in Cyprus for crisis management is called “Zinon” and has four alarm levels: a) level 1, which is the usual level consisting of training personnel and inspecting storage of dangerous substances. In this step incidents may occur within the installations but do not require external help from Fire Brigade, the Policy or from Ambulances b) level 2, in case of an incident which requires the assistance of the Fire Brigade c) level 3, in case an incident has occurred and the Fire Brigade, Policy or Ambulances are required, there are either fatalities or injuries, or the traffic has to be suspended and areas have to be evacuated. The national centre for crisis management ha to operate in this level d) level 4, in case repair of damage and recovery are required

The authorities have a Land Use Planning policy so as to: a) maintain appropriate safety distances between establishments covered by this Directive and residential areas, buildings and areas of public use, recreational areas, and, as far as possible, major transport routes; b) protect areas of particular natural sensitivity or interest in the vicinity of establishments, through appropriate safety distances or other relevant measures; and c) to take additional technical measures so as not to increase the risks to human health and the environment, in the case of existing establishments.

In addition, competent authorities organise a system of inspections of SEVESO plants and these plants are covered by an inspection plan which is regularly reviewed and, where appropriate, updated, according to Article 20 of the SEVESO III directive.

Natural hazards can cause multiple and simultaneous releases of hazardous materials over extended areas, damage or destroy safety barriers and systems, and disrupt lifelines often needed for accident prevention and mitigation. These are also the ingredients for cascading disasters. Successfully controlling a Natech accident has often turned out to be a major challenge, if not impossible, where no prior preparedness planning has taken place. Seveso III directive also mandates the member states to consider the probability of natural disasters in the risk assessment of major accident scenarios when preparing safety reports (Article 10), with an explicit mention of floods and earthquakes in the Annex II.

Unfortunately, experience has shown that disaster risk reduction frameworks do not fully address the issue of Natech hazards. Also, chemical-accident prevention and preparedness programs often overlook the specific aspects of Natech risk. This is compounded by the likely increase of future Natech risk due to worldwide industrialization, climate change, population growth, and community encroachment in areas subject to these kinds of hazards.

Prevention measures [8] in case of earthquakes so as to maintain structural integrity and position of tanks and pipelines, and containment of material are the following: a) seismic design for equipment and following appropriate codes and standards (e.g. API 650) for welded steel oil storage tanks, b) anchoring of above-ground storage tanks, c) use of resistant pipe materials and novel techniques for the strengthening of joints so as to better resist seismic loading, d) adjusting the orientation of pipe–line with respect to fault direction e) using low-density backfill material at the trench f) operator actions so as to reduce the flow in the pipeline or shut down and g) installation of strong-motion detectors on pipelines in seismic areas.

Prevention measures [8] in case of floods or tsunamis are the following: a) anchoring storage tanks with bolts or other types of restraining systems, b) filling up empty tanks in preparation of a flood c) creating barriers that steer the floodwaters away from the industrial plant d) perform a detailed flood risk assessment during the design of the pipeline to ensure that the maximum flood- hazard risks have been considered during the lifecycle of the pipeline and e) waterproofing vulnerable equipment so as to protect safety critical systems.

Finally, mitigation measures to reduce the impact of hazardous materials releases concurrent with natural disasters include walls/dikes around storage tanks, oil spill detectors, emergency shutoff valves, foam stocks, water curtains, water sprinkler systems and fire walls. The seismic design should be applied to containment dikes/walls and critical active and safety barriers. In case of natural disasters backup power generators are important since they may be required not only to maintain lighting but also the operation of critical equipment and plant operations.

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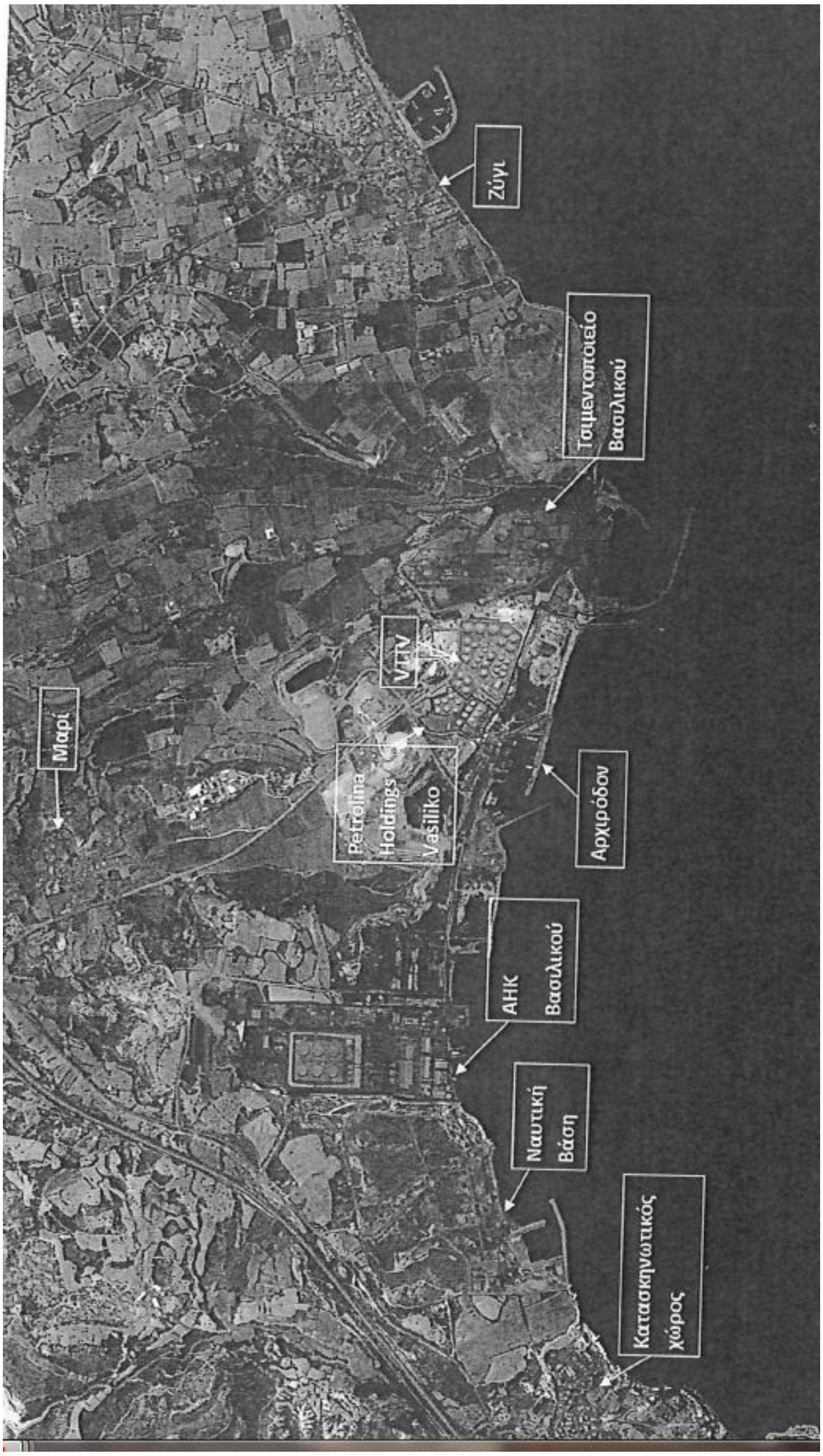
Appendix 7.1. Map showing siting of SEVESO plants (Larnaca area)

Appendix 7.2. Map showing siting of SEVESO plants (Vassiliko area)



8. Fires in forests and rural areas

8.1: Hazard scenario identification

Forest and rural vegetation classification, based on elaboration and analysis of satellite imagery, grey literature data and field visits will allowing for the identification and mapping fire hazard potential across the country. Forest (vegetation) fuel characterization and relative mapping will be implemented for assessing the respective component of the geographic distribution of hazard. Meteorological patterns and relevant regimes (wind) during the fire season will be studied in particular in statistically high-risk areas. Climate change projections over the next decade will be further used to identify intensity and frequency patterns and support mid-term fire prevention policy decisions and eventual fire management investments. Basic and extreme hazard scenarios will be prepared and analyzed based on relevant vegetation and climate patterns.

1. Introduction

Forest fires (also including megafies, WUI, etc) have been considered a major hazard in the EU domain[i]. On an annual basis half a million hectares of forest and natural lands is burned on average. The spatial characteristics and recurrence period of forest fires heavily depends on local meteorological conditions and dead biomass burning/accumulation, which is exacerbated by changing climate patterns.

The likelihood and characteristics of forest fires vary depending on the types of forest, topography, climatic conditions and preparedness to respond and contain early-on localised sources of fire. In fact, a large majority of forest fires are initiated by malicious or unintended human action. Forest fires can have major disruptive impacts on the environment, human lives health, cultural heritage and the economy, considering the particularly significant environmental, financial and well-being value of forests in Europe. When combined with extreme climate conditions and non-optimal emergency response, forest fires result to deaths (e.g. 49 in Portugal 2017, 99 in Greece 2018) and injuries, environmental and ecosystem degradation, extensive property damage, disruption to critical infrastructure services (electricity, transportation, water, telecoms), businesses and private assets. Secondary effects are also of importance due to high concentration of air pollutants (PM2.5, PM10, dioxins, CO, etc…) that could cause adverse health effects and contribute to global warming.

It should be noted that, WP7 relies on data that will be provided by the Department of Forestry and the Department of Meteorology. At the moment the research team anticipates delivery of data from the Department of Forestry. There is a fee for the Meteorological data provided by the Department of Meteorology, and we are in the process of finding a solution.

2. Description of Forest (vegetation) fuel characterization and relative mapping in Cyprus

According to the FAO, 18.7% or about 173,000 ha in Cyprus are covered by forests. In the period between 1990 and 2010, Cyprus lost an average of 600 ha or 0.37% per year. In total, between 1990 and 2010, Cyprus gained 7.5% of its forest cover or around 12,000 ha (Cyprus Forest Information and Data). Forests in Cyprus are classified in two groups (a) forests and (b) other wooded land. These two major forest types account for about 42% of the total land area[ii]. About 40% of this land is of state ownership. High forests account for 45% of the total forest area and lower vegetation for the rest 55% (Fig. 8.1). Plantations account only for 2.3% and were mainly planted in the past for fuelwood production, sand dune stabilisation and swamp drainage.

Forest ecosystems are established across the Troodos and Pentadaktylos ranges as well as along the coastal belt. It should be noted that there is no forest in the central Mesaoria plain, which is in general characterised as a climatic semi-arid zone with a prolonged drought period. Over the last decades there has been observed a small increase in forest cover due to afforestation of state land and abandonment of private land. Forest ownership status plays an important role in the quality of forest management. State forests are managed by the Department of Forests (DoF) and are under a systematic management and protection status, with almost 80% of this land use type registered in the Natura 2000 network**.** Private forest are usually fragmented small parts of land with an average size of 2-4 ha, growing at the borders of state forests.

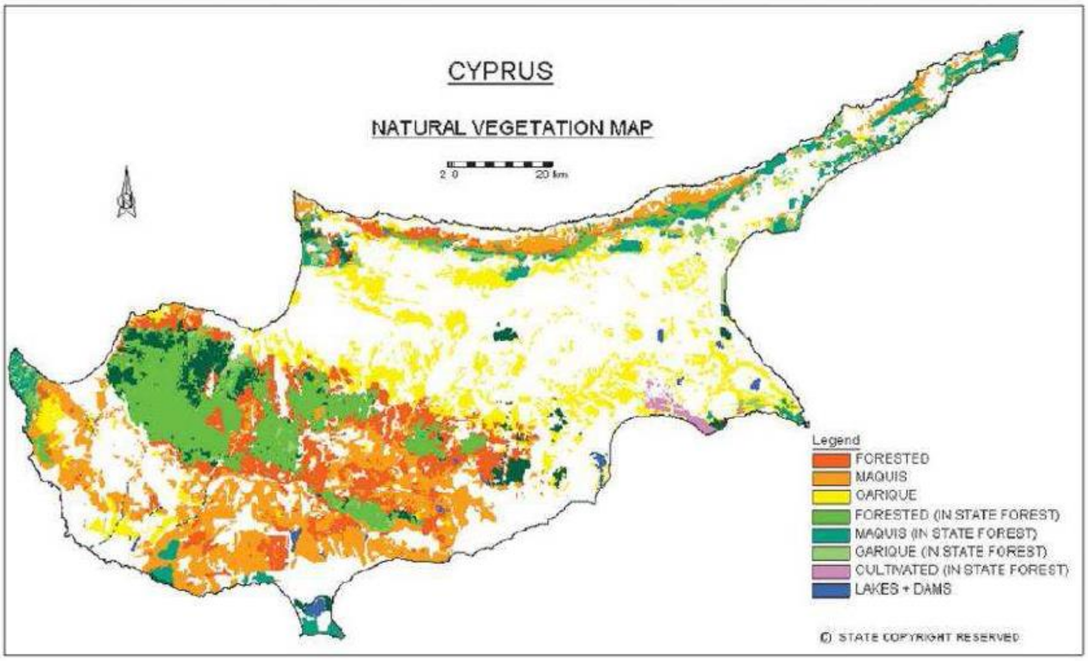


Figure 8.1 Natural Vegetation Map of Cyprus (Source: ECHOES Cost Action 2009)

The main state forests occupy the two mountainous ranges of south Troodos and northern Pentadactylos. Conifers and broadleaved tree species such as pines, cedars, cypress and oaks are the dominant elements of vegetation. The most common species is *Pinus*, which is the most productive species found up to 1400m above sea level (asl). *Pinus nigra* subsp. *pallasiana* dominates the higher elevations of the Troodos mountain up to 1950m asl. *Cedrus brevifolia* (endemic), *Juniperus foetidissima, Juniperus oxycedrus* and *Juniperus excelsa* are also found at higher elevations. The endemic *Quercus alnifolia* is usually found at the understory of conifer stands or in pure stands above 700m asl across the Troodos mountain range. Lowland forests (8% of total forested area) are dominated by *Juniperus phoenicea, Olea europaea, Ceratonia siliqua, Pistacia lentiscus, Pistacia terebinthus* and scattered *Pinus brutia.* **Table 8.1** provides information of the area covered by the most dominant tree species Cyprus. Sclerophyllus species such as *Quercus alnifolia, Crataegus azarolus, Pistacia lentiscus, Pistacia terebinthus, Olea europaea, Ceratonia siliqua, Sarcopoterium* *spinosum, Thymus capitatus and Ziziphus* lotus dominate the maqui and phryganic ecosystems that cover a large area in Cyprus (213.000 ha).

Pinus brutia is the only commercial species in Cyprus. The total area covered by *P. brutia* is around 138.000 ha, with only 30% characterised as productive. Due to the low growth rate and the existence of under stocked areas, the annual cut covers only 2% of the local demand for wood. Thus, forestry contribution to the economy of Cyprus is negligible.

Cypriot forests are an important resource that provides non-wood forest products and services (NWFPs). These services include soil and water protection and regulation, support of biological diversity, carbon sinks and mitigation of global warming and various recreational and touristic activities. **Table 8.2** provides a summary of some key ecosystem services provided by the common forest species in Cyprus. These services accounted for in management and climate change adaptation policies. In terms of biodiversity conservation, **Table 8.3** presents a list of the endemic trees and shrubs found in Cyprus. These species are of particular ecological value, which should be taken into account in management and climate change adaptation policies.

Table 8.1 Area Covered by the dominant forest species in Cyprus (Source DoF 2006)

Community	State	Private	Total
Pinus brutia	88.790	48.954	137.744
Juniperus phoenicia	5.350	2.940	8.290
Cupressus sempervirens		7.270	7.270
Pinus brutia- Quercus alnifolia	5.870		5.870
Ceratonia siliqua - Olea europaea		5.720	5.720
Pinus nigra	2.640		2.640
Pinus brutia - Pinus nigra	2.330		2.330
Platanus - Alnus spp	430	610	1.040
Eucalyptus spp	137	260	397
Cedrus brevifolia	130		130
Cedrus brevifolia - Pinus brutia	120		120
Quercus infectoria subsp. *veneris*		60	60

Table 8.2 Ecosystem services provided by common forest species (DoF 2011)

Species	Soil and Water Conservation	Biodiversity Conservation	Cultural Values	Aesthetic Values
Pinus brutia	X	X		X
Pinus nigra	X	X	X	X
Cedrus brevifolia	X	X	X	X
Juniperus foetidissima	X	X		X

Species	Soil and Water Conservation	Biodiversity Conservation	Cultural Values	Aesthetic Values
Juniperus excelsa	X	X		X
Juniperus phoenicea	X	X		X
Cupressus sempervirens	X	X	X	X
Quercus infectoria subsp. *veneris*	X	X	X	X
Quercus alnifolia	X	X		X
Platanus orientalis	X	X	X	X
Alnus orientalis	X	X		X
Eucalyptus spp.	X	X		X

Table 8.3 Endemic forest & woody species in Cyprus (DoF 2011)

Forest Trees and Other Woody Species Which Are Endemic In Cyprus			
1	*Acinos troodi*	27	*Onosma caespitosa*
2	*Alyssum akamasicum*	28	*Onosma fruticosa*
3	*Alyssum chondrogynum*	29	*Onosma troodi*
4	*Alyssum troodi*	30	*Origanum cordifolium*
5	*Anthemis plutonia*	31	*Origanum majorana* var *tenuifolium*
6	*Anthemis tricolor*	32	*Origanums yriacum* ssp. *bevanii*
7	*Arabis cypria*	33	*Phlomis brevibracteata*
8	*Arabis purpurea*	34	*Phlomis cypria* var. *cypria*
9	*Asperula cypria*	35	*Phlomis cypria* var. *occidentalis*
10	*Astragalus echinus* ssp. *chionistrae*	36	*Pterocephalus multiflorus* ssp. *multiflorus*
11	*Astragalus macrocarpus* ssp. *lefkarensis*	37	*Pterocephalus multiflorus* ssp. *obtusifolius*
12	*Ballota integrifolia*	38	*Ptilostemon chamaepeuce* var. *cyprius*
13	*Bosea cypria*	39	*Quercus alnifolia*
14	*Carlina pygmaea*	40	*Rosa chionistrae*
15	*Cedrus brevifolia*	41	*Rubia laurae*
16	*Centaurea akamantis*	42	*Salvia willeana*
17	*Dianthus cyprius*	43	*Saponaria cypria*
18	*Dianthus strictus* var. *troodi*	44	*Scabiosa cyprica*
19	*Erysimum kykkoticum*	45	*Sideritis cypria*
20	*Genista sphacelata* ssp. *crudelis*	46	*Teucrium cyprium* ssp. *cyprium*
21	*Hedysarum cyprium*	47	*Teucrium cyprium* ssp. *kyreniae*

Forest Trees and Other Woody Species Which Are Endemic In Cyprus			
22	*Helianthemum obtusifolium*	48	*Teucrium divaricatum* ssp. *canescens*
23	*Micrimeria cypria*	49	*Teucriumm icropodioides*
24	*Micromeria chionistrae*	50	*Thlaspi cyprium*
25	*Nepeta troodi*	51	*Thymus integer*
26	*Odontites cypria*		

Major threats for forest ecosystems in Cyprus are briefly described below.

Forest Fires are the most catastrophic agent for both forests and other wooded lands in Cyprus. As in most Mediterranean biomes fire risk and hazard is greater during the summer period. Abandonment of agricultural land contributes to increase of fire hazard through the increase of flammable vegetation components. The mean number of fires for the period between 2002 and 2014 was 198 with the mean area burned around 2100 ha per year. The highest number of fire events was recorded in 2013 and was associated with an increased burned area.

Grazing and in particular **overgrazing** is an important problem in some of the state forests in Cyprus. Overgrazing leads to vegetation degradation and soil erosion.

Climate Change. Over the last century, a strong increase in the mean summer temperature was recorded for the Eastern part of the Mediterranean basin from the 1950s, followed by a cooling until the mid-1970s. Subsequently a strong warming was observed with 2003 being the hottest summer[iii]. A strong decline in precipitation, starting from the early 1960s is evident. These climate changes are associated with over 6000 ha of dieback and secondary insect infestations in Cyprus forests (DoF 2011).

Land use and Land use changes, mainly associated with unsustainable touristic development affect private forestland.

According to the CYSTAT data[iv] the gross output of forestry recorded a significant increase reaching to €3.4 million in 2011, while in 2012 recorded a decrease of 16.4% and dropped to €2.8 million. Timber production recorded a decrease from 6,177 cubic metres in 2011 to 5,572 cubic meters in 2012. In addition, charcoal production increased significantly to 1,217 tons in 2012 from 662 tons in 2011. The long-term patterns of timber and charcoal production are presented in **Fig. 8.2**. A rather stable rate is observed for the 2002-2014 period.

As far as other forest products are concerned, a decrease was observed in fuel wood production, which dropped to €241,100 in 2012. The value of production of plants, seeds, Christmas trees etc. increased significantly and reached from €263,392 in 2010 to €1,544,000 in 2011, while the same value of production decreased by 43% and dropped to €879,200 in 2012. Reforestation increased by 22.8% in 2012 compared to 2011.

The Value added of the forestry subsector to the agricultural sector[14] decreased from 0.6% in 2011 to 0.5% in 2012. Agricultural sector’s contribution to GDP was 2% in 2011 and 1.9% in 2012 and rose to 2.5 in 2013 (CYSTAT 2014, 2015a, 2015b).

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[14] includes crop, livestock, forestry, fishing and ancillary production

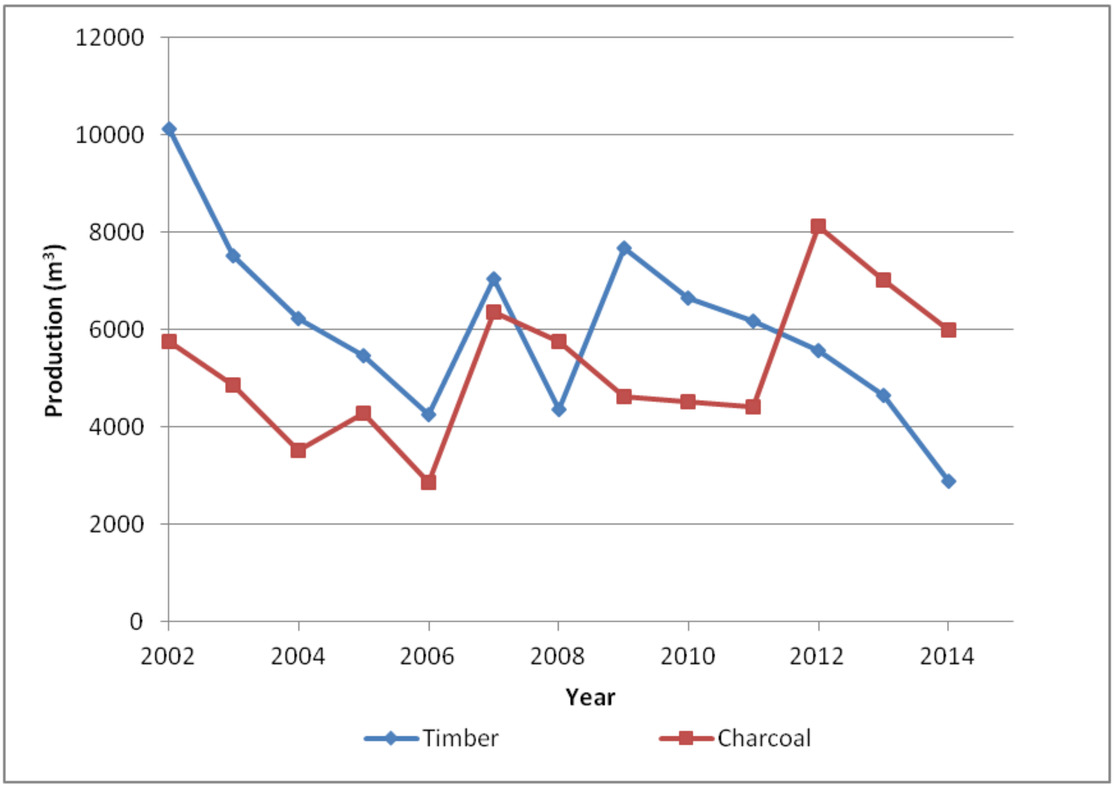

Figure 8.2 Timber and charcoal production during the 2002-2014 period (data source: DoF annual reports)

3. **Description of wind dynamic in Cyprus**

Over the eastern Mediterranean generally surface winds are mostly westerly or southwesterly in winter and northwesterly or northerly in summer. Usually of light or moderate strength, they rarely reach gale force.

Over the island of Cyprus, winds are quite variable in direction with orography and local heating effects playing a large part in determination of local wind direction and strength. Differences of temperature between sea and land, which are built up daily in predominant periods of clear skies in summer cause considerable sea and land breezes. Whilst these are most marked near the coasts they regularly penetrate inland in summer reaching the capital, Nicosia, often bringing a reduction of temperature and also an increase in humidity[v].

Gales are infrequent over Cyprus but may occur especially on exposed coasts with winter depressions. Small whirlwinds are common in summer appearing mostly near midday as "dust devils" on the hot dry central plain. Very rarely vortices, approaching a diameter of 100 metres or so and with the characteristics of water spouts at sea and of small tornadoes on land, occur in a thundery type of weather. Localized damage caused by these has been reported on a few occasions but in general Cyprus suffers relatively little wind damage.

Kleanthous et al[vi] provide an analysis of air pollution characteristics for Cyprus. Data from four monitoring stations of the network of the Air Quality Section of the Department of Labour Inspection[vii] had been used in this study. The stations are (a) the rural inland Agia Marina station (35.04N–33.06E, 532 m a.s.l.), (b) the rural-marine Inia (34.99N–32.40E, 672 m a.s.l.) to the east of Cyprus, (c) the lower altitude and more exposed to sea-breeze circulation rural Cavo Greco (35.02N–34.09E, 23 m a.s.l.) to the west of Cyprus, and (d) the rural-Stavrovouni (34.89N, 33.44E, 650 m a.s.l.). Agia Marina, is additionally part of the European Monitoring and Evaluation Programme[viii]. The Agia-Marina station started operation in 1997[ix].

The wind climatology shows a prevalence of north and north-westerly winds during the entire year, bringing continental air from Turkey and Eastern/Central Europe; their most frequent occurrence is observed during the dry period (May to September). Especially in summer, northerlies account for the largest fraction (80%) of the overall wind regime. Toward the wet season (October to April), their contribution is smaller mainly due to the enhancement of the southerlies (Africa) and westerlies (clean maritime air).

Station	**Data (units)**	**Period**	**Range**	**Average ± std**	**Median**	**Min**	**Max**
Agia Marina (EMEP)	Ozone (ppbv)	1997–2012	26.0–76.7	47.5 ± 8.2	47	26	76.7
	NO (ppbv)	2007–2012	0.0–1.4	0.2 ± 0.2	0.2	0	1.4
	NOy (ppbv)	2007–2012	0.4–9.7	1.8 ± 0.9	1.6	0.6	8.5
	CO (ppbv)	2011–2012	77.2–250.0	145.5 ± 27.6	142.2	77.2	250
	Temperature (°C)	1997–2012	1.3–35.7	18.9 ± 7.2	19	− 1.3	35.7
	Relative humidity (%)	2007–2012	12.8–91.6	55.0 ± 14.3	57.3	12.8	91.2
	Wind speed (m s− 1)	1997–2012	0.8–9.7	2.9 ± 1.0	2.6	0.8	9.7
	Solar radiation flux (W m− 2)	1997–2012	0.0–850.5	211.9 ± 99.5	209.4	0	387

Table 8.4. Basic statistics of observed daily mean chemical and meteorological parameters at the Agia Marina (EMEP) monitoring station including their minimum and maximum values.

Easternmost Mediterranean Sea; and especially maritime areas offshore of Middle East and Cyprus where the current 30 year mean wind speed value is below 6 m s1 revealing the lower wind power amounts (400 W m2), with negative future change at the middle and the near end of 21st century (100 to 200 W m2 , respectively). Additionally, almost all ensemble members agree that the wind power potential would decrease by more than 5%.

Parameters defining the framework (used to estimate probability, vulnerability and exposure)

Such parameters may be included to the general National Forest Fire Management system. Such parameters provide insight on the level of preparedness, that can play a critical role in defining the severity of an event as well as exposure and vulnerability of socioeconomical parameters.

Legislation

In Cyprus there are 2 laws concerning forest fires and their management:

(a) The Forest Law of 2012

(b) The Law for the Prevention and Control of Fires in Rural Areas of 1988.

Effective legislation actually defined the National Fire management Plan.

A number of Government agencies are involved in the extinguishment of fires, namely the Fire Service, the Forest Service and the Civil Defense Force. In case a fire breaks out in the areas falling under the British Sovereign Bases jurisdiction, the above are assisted by the relevant British authorities and in those cases that a fire incident occurs in the "green line" the UN authorities are getting involved. Each agency is involved according to the fire classification criteria as follows:

Forest Fires: The primary responsibility rests on the Department of Forest of the Ministry of Agriculture, Natural Resources and Environment.

Rural Fires: The Cyprus Fire Service which comes under the jurisdiction of the Ministry of Justice and Public Order through the Police is responsible to fight all rural fires which are up to the distance of 1km from forests boundaries. It is important to mention that the Civil Defense Force is acting in support of both in case of an emergency.

Prevention plans

The obligation for the preparation and implementation of fire prevention plans within the state forests and a zone of 2km from the state forest boundaries, lies on the Department of Forests. For other areas, the Department of Forests is involved only for the preparation of such plans. There are two major fire action plans: "Ifestos" and "Pyrsos". Effective prevention plans can affect the severity of an event and consequently the probability of having a major event.

Volunteers

A number of volunteers are involved in the forest fire management. They may contribute in fire detection (patrolling and observation) and in fire-fighting operations, as well as for the restoration of burnt areas. Training of volunteers may be an issue that can raise several concerns. The use of volunteers can increase the level of preparedness assist in dealing with an event, however, lack of adequate training can increase the probability of serious injuries and/or human losses (for them or for civilians).

Challenges of forest fire management due to geopolitical reasons (imported/exported fires, fires in the border)

Cyprus is an island, as such there are no imported or exported fires. Almost 40% of Cyprus is under occupation since the illegal invasion of Turkish troops in 1974. The Republic of Cyprus first response is in collaboration within and along the buffer zone, with the United Nations.

Firefighting Resources

The firefighting resources of the Department of Forests include:

(a) *Personnel:* 1.000 people (forest officers, fire fighters and fire watchers)

(b) *Ground and air means:* 2 firefighting airplanes, 83 fire engines of different types, 13 bulldozers, 4 trucks, 1 coordination vehicle and 185 personnel carrier vehicles.

(c) *Infrastructure:* 28 forest stations, 1 flight unit, 1 coordination center, 39 fire lookout stations, 215 watertanks, 38 helispots, 1 automatic fire detection system, network of forest roads and firebreaks.

Cooperation with other countries (Israel, Greece, ERCC)

The Republic of Cyprus enjoys the benefits of participating as a full member in the European Union since 2004. This fact provides the competent services of the Republic with directives, European instruments, joint committees, European authorities from which the Republic can draw a wealth of tools in terms of forest fires and disasters in general. The population of our country is 0.2% of the total EU population, area-wise Cyprus is 26^{th} out of the 28 EU Member States. The purpose of the above comparison is to highlight the fact that the Republic- due to size - is a special case in relation to the structure of its State Agencies.

The Republic has a functioning public service system. In the field of forest fires, the main "actors" are:

- Department of Forests
- Fire Service
- Civil defence
- Prosecutor
- Wildlife Fund
- National Guard
- Police

Financial data

Regarding the economic dimension, to date, of the cost of firefighting in the Republic of Cyprus, it should be mentioned the following:

- The Government spends approximately 0.02% of the State Budget on fire-related expenditure (i.e. wages and benefits, rental costs, maintenance), based on data from 2010 - today
- This figure is gradually decreasing to around 0.019% in the years of the economic crisis
- Based on Geneva Fire Statistics, there are countries that spend comparable rates of GDP (eg Singapore 0.02%, Romania 0.05%) but these are at the lower end of the spectrum
- Countries like Portugal or the United Kingdom spend about 0.2% of their GDP at similar costs and are at the top end

Livestock and grazing data information

Grazing within the State forest is prohibited, unless a license is granted, according to the Forest Law. However, in certain areas like Akamas, Pegeia, Oreites and Radhi forests and to a lesser extent in the Machera, Lythrodontas, Aetomoutti, Xylia and Kakorazia forests, illegal grazing is practiced. According to the Annual Report, during 2016 totally 9.078 ha of State forests were disturbed by grazing.

Boundaries and fire culture

The areas related to an increased probability of forest fires are those at the boundaries between forest and rural areas in which there are forms of human activities. Although illegal, the use of fire as a vegetation management tool is still practiced in Cyprus, mostly by farmers for agricultural land clearing and by shepherds for pasture regeneration purposes. Other uses of fire are engaged to recreational activity (setting barbecues and campfires), residential activities (cooking, heating, grass burning, etc) and garbage burning at illegal waste dumps.

Training of fire fighters and forest fire managers

Forest Officers attend training sessions in the fire management methods and techniques, which are performed by external experts. Forest fire fighters, throughout the fire season are trained in the firefighting techniques and in the use of firefighting equipment.

Forest fuel management programs

The Department of Forests designs and implements an annual forest fuel management program, aiming at reducing the risk of fire outbreaks as well as the spreading of forest fires. This program includes different silvicultural measures such as pruning, thinning and cleaning of the vegetation, mainly along forest and public roads and in places where there is a high risk of fire ignition (picnic and camping sites, garbage dumps, military training fields etc).

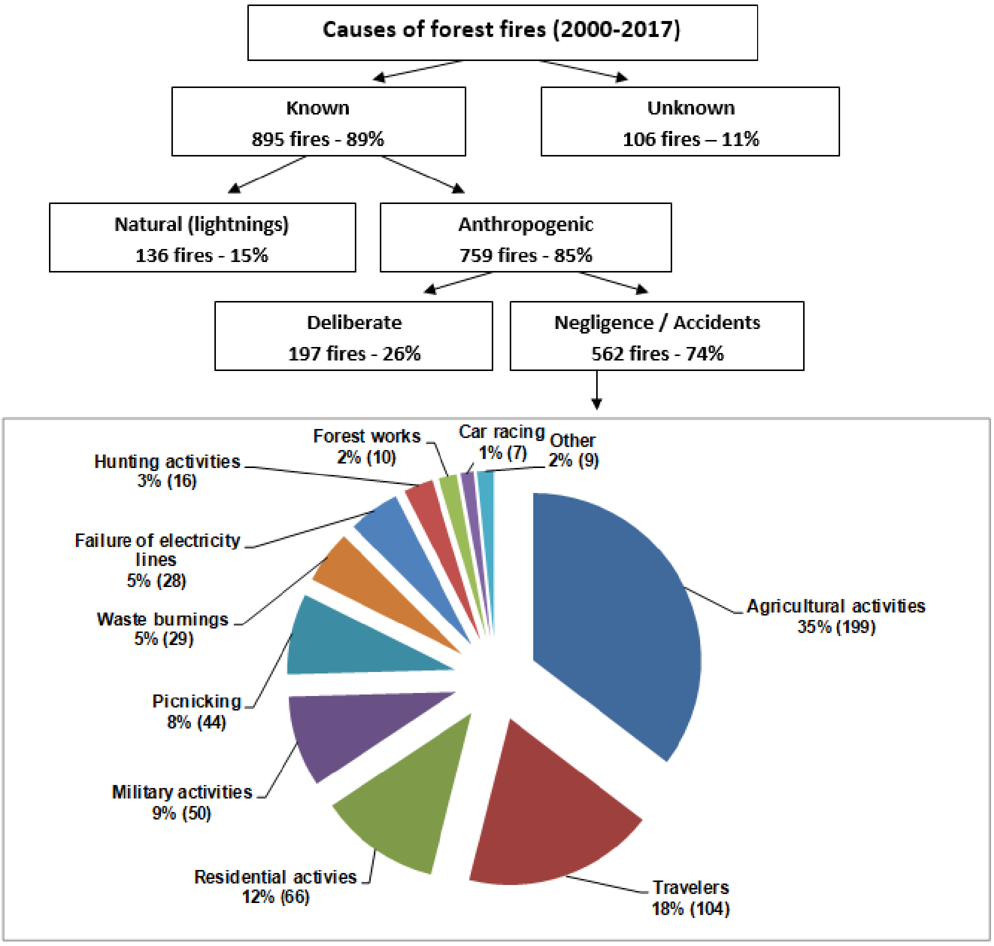

Figure 8.3: Causes of forest fires for the period 2000-2017

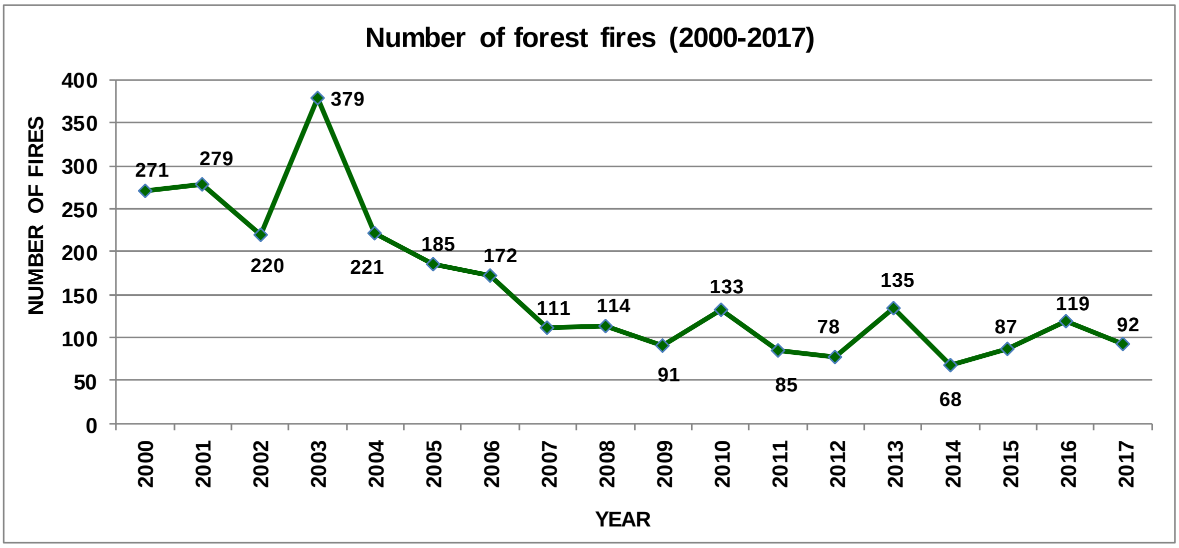

Figure 8.4: Annual number of forest fires in Cyprus for the period 2000-2017

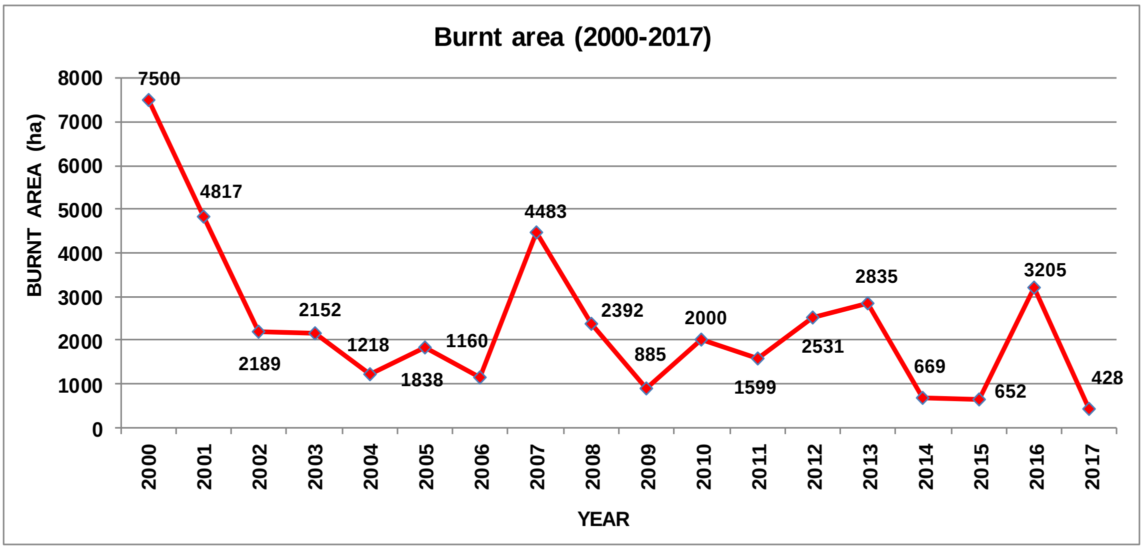

Figure 8.5: Annual burnt area in Cyprus for the period 2000-2017

Technological aspects

A number of available technologies are already used or are intended to be used in near future. Such technologies include:

- **GIS**
  Technology in use.
  Objective of the use: Burnt area mapping, rapid fire damage assessment, preparation of fire protection maps, etc.

- **UAV**
  Technology not in use at the moment but it will be used in the near future.

- **Remote sensing**

Technology in basic use.

- **Automatic fire detection systems**
  Technology in use.
  Objective of the use: Early fire detection.

- **Wireless sensors (including meteo stations)**
  Technology in use.
  Objective of the use: A network of automatic meteo stations exists, which is supporting the fire managers for the prevention and suppression of forest fires.

- **Modeling**
  Technology not in use.

- **Cellular phones**
- Technology in use.
  Objective of the use: Mobile phone apps are an efficient monitoring and decision support tool in fire management.

- **Fleet management**
  Technology in use.
  Objective of the use: A GPS based software was developed which is used for better management of the vehicle fleet of the Department of Forests and more specifically for increasing their performance during the fire suppression operations.

- **Social media**
  Technology in use.
  Objective of the use: Facebook software is used in order to facilitate the dissemination of information concerning forest fires and other forest management related issues.

Risk Communication

A fire danger rating system is applied in Cyprus by the forest service. Risk is mainly communicated through the media. There are five (5) fire danger classes in use: Low, Moderate, High, Very High and Extremely High.

Defining more parameters that will be used for calculating Risk and build scenarios

Fire season

For the case of Cyprus, the fire season starts in May and ends in October, but occasionally it starts in April and is extended up to November, according to the prevailing weather conditions. The most dangerous period of the fire season to start a fire is June to September.

Usual causes for fire start

Most frequent human activities that may cause a fire ignition are related to agriculture, residential activities, throw of burning cigarette butts or matches from travelers, camp fires, use of electrical machinery that produces sparks, military exercises, waste burnings, car racings, electric faults from powerlines, hunting activities, forest works etc.

Specific places

Forest fires in Cyprus usually starts along the state forest boundaries, mostly in regions with increased human activity.

Specific hours

The most critical hours for a forest fire to start is from 11:00am to 16:00pm

Meteorological conditions

The combination of prolonged drought period, high temperature, low relative humidity and strong wind, is the worst case scenario for a forest fire ignition.

Number of different fires that would start simultaneously

In many cases the Department of Forests had to deal with the suppression of multiple forest fires in a day. Not rarely, resources of the Department of Forests are involved in the suppression of 6-8 fire incidents in a single day.

8.2: Exposure and vulnerability of socioeconomical parameters

In this task, the **impact on human, economics & environment and political/society**, will be analysed in terms of vulnerability and exposure. Therefore, in this stage using a semi-quantitative approach when possible, for the hazard of fires in forest and rural areas, the exposure and vulnerability in these three categories will be determined using numerical rating scales.

Damages for the economy or the society suffered by forest fires the last decades in Cyprus

Every summer, year after year enormous blazes destroy thousands of acres of forests. The Mediterranean for a number of reasons is prone to such catastrophes. According to JRC[x] in the five Southern most affected European States (Greece, Italy, Spain, France, and Portugal) fires burned 323,896 hectares of land in 52,795 fires. According to the same publication between 1980 and 2009, 14,367,304 hectares were burnt in 1,501,409 fires, again in these five states.

Forest Fires have a lasting impact on *social*, *environmental* and *financial* level. In a social level the impacts of catastrophic fires are enormous. Human lives are lost, livelihoods and villages are destroyed, creating a lasting effect in a collective and individual level[xi].Forest fires, especially mega fires can cause psychopathologogical disturbances to survivors[xii]. Forest fires can cause psychopathological disturbances to fire fighters[xiii].

Novel techniques[xiv] used in environmental pollution analysis clearly show how the air quality is affected in the short term. In their paper Liu et al (2009) indicate a big increase in the number of particles in the atmosphere during the 2007 fires in Greece. Forest fires have long term environmental implications. Moreira et al argue that previously burned areas have an increased tendency to be burnt again creating, therefore, a vicious circle that intensifies the catastrophes. In addition to the above, forest fires increase the total carbon footprint. As early as 1994, Holeman[xv] (1994) based on Crutzen[xvi] (1990) and Andrae[xvii] (1990) quantified carbon emissions due to the various forms of wildland fire to 4.08×10^{15} tons of emitted carbon through biomass fuel burning. At that time and based on the same calculations, the overall carbon global emissions were estimated to be 13.28×10^{15} tons, therefore making biomass fuel burning 40% of the total.

In a financial level, wildland fires bear high costs. Prevention, suppression, costs to the medical system, additional costs to the pension system, insurance costs are only some of the measurable costs. Two critical factors though cannot be estimated: cost of human lives and loss in the added value for the country in general.

Tourism, especially in the Mediterranean is based upon an offer of sea, sun, culture, and nature. While sea and sun will continue existing even after a severe wildland fire catastrophe, cultural monuments and nature can suffer heavy losses. For instance, the tragic incident of the fires of 2007 in Peloponnese harmed the archaeological site of Olympia, the birthplace of the Olympic Games.

The large fire at Solea region in 2016, is responsible for the worst damages by forest fires in Cyprus during the last decades. This fire claimed the lives of two forest fire-fighters and caused the injury of 9 others, villages were seriously threatened and needed to be evacuated, private properties were destroyed, fire engines and other vehicles and equipment were damaged and 19 km^2 of pine forest was turned into ashes.

8.3: Probabilistic scenarios analysis / consequences and impact assessment

At this step, the probability of occurrence of each hazard scenario will be determined along with the associated consequences. Therefore, (taking into account all three categories of impacts) the risk will be estimated as a function of the probability of hazard's occurrence (p), vulnerability (V) and exposure (E) as shown below,

Risk=R=*f* (p*E*V)

8.4: Quantification of existing treatment measures and suggestions for adaptation and mitigation measures

In this final step, there will be a comparison of the results of the risk analysis with risk criteria to determine whether the risk and/ or its magnitude is acceptable or tolerable and whether a risk will be accepted or treated as part of the national level risk assessment. The risk for hazard will be evaluated against specified criteria that will be the terms of reference against which the significance of a risk will be analysed and evaluated. The risk criteria will include associated socioeconomic and environmental factors etc.

Criteria can be based on sources such as:

- agreed process objectives,
- criteria identified in specifications and national guidelines,
- research data from local universities and research institutions,
- Generally accepted industry criteria such as safety integrity levels.

Damages for the economy or the society suffered by forest fires the last decades in Cyprus
The large fire at Solea region in 2016, is responsible for the worst damages by forest fires in Cyprus during the last decades. This fire claimed the lives of two forest fire-fighters and caused the injury of 9 others, villages were seriously threatened and needed to be evacuated, private properties were destroyed, fire engines and other vehicles and equipment were damaged and 19 km^2 of pine forest was turned into ashes.

Scenarios

The definition of fire scenarios is a dynamic, spatial and integrative concept. The parameters that were described above, determining fire behavior (climatic, physiographic, biological, and social) may have different weighting. We can summarize the main components of forest fire scenarios as follows:

1. Fuels (ecosystems; plant communities):
2. Territorial dynamics and land-use changes:
3. Settlements
4. Fire history

The impact criteria will be assessed against three hazard scenarios that will be those scenarios were selected from the range of possible scenarios, having different limits /types for the comparison to be meaningful and fall into the following categories:

A. **Worst-case scenario.** Plausible with upper risk limit/level: assessed considering both impact and likelihood.

According to the worst-case scenario, during August, after a prolonged drought period, with high temperature, low relative humidity and strong wind there are two or more large scale forest fire outbreaks, close to a rural area at 16:00. Available means are not enough to face effectively limit the fires while due to the strong wind every minute counts and firefighting means from neighbouring countries will take some time to arrive. Thus, the fires would affect a large area, burning a significant area of forest, while evacuation plans may need revising for a significant number of citizens since fire could reach and probably burn villages from different directions, rural areas or even cities' borders. Power lines could be destroyed and critical infrastructures could be affected. Dangerous substances included in smoke and fumes would be released in the atmosphere. Psychological issues would arise for a large percentage of the population such as stress, insecurity, etc.

B. Best case/mild scenario-Plausible with lower risk limit

According to that scenario, during June, there is one large scale forest fire. Weather conditions are mild since there were some showers during the previous days. A number of available means is used to effectively limit the fire. No assistance is required from neighbouring countries. The fire would affect a limited forest area, while no evacuation plans are activated since fire is not close to rural areas.

Expected scenario – Analysis – Risk Matrix

According to historical data, there is one such fire every 8-10 years. Thus, the probability of considered to be high since such a scenario is likely to happen. In case that likelihood also consider the exposure and vulnerability of the potential target(s), it can be given a score of 4.

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9. Sea level rise and coastal erosion

9.1 INTRODUCTION - SEA LEVEL VARIATION INFLUENCE

The aim of this report is to examine the sea level conditions, as they form under the tidal influence. This when combined with the weather and geomorphology, are useful in defining vulnerable coastline regions during the time pass. Sea level variations were examined for selected offshore coastal sites around Cyprus, in order to reveal the influence of the tidal variations to the sea level (Figure 9.1).

Recent studies (Tsimplis et al., 2008, 2009) have shown that local sea level trends in the Eastern Mediterranean are not as large as the global average. Practically, what is happening is that the Eastern Mediterranean Sea is warming but also getting saltier, thus the expansion is compensated.

Figure 9.Error! No sequence specified.. Selected locations for sea level time series analysis

9.1.1 Description of tidal influence

Tide, is the periodic variation in sea level caused by the gravitational forces exerted by the changes in the relative positions of the Moon and the Sun. Tides may be regarded as forced waves. They are manifested by vertical movements of the sea surface (the height maximum and minimum are called high water [HW] and low water [LW]) and alternating horizontal movements of the water, the tidal currents. The words ebb and flow are used to designate the falling tide and the rising tide, respectively.

There are two high and two low tides per day at any given place, occurring at times that vary from day to day; the average interval between consecutive high tides is 12 hours 25 minutes. The tides of largest range or amplitude (spring tides) occur at new moon, when the moon and the sun are in the same direction, and at full moon, when they are in opposite directions; the tides of smallest range (neap tides) occur at intermediate phases of the moon. In some semi-enclosed seas, such as the Mediterranean, Black, and Baltic seas, the tidal range of sea level is only on the order of centimeters.

Tides are most easily observed—and of greatest practical importance—along seacoasts, where the amplitudes are exaggerated. When tidal motions run into the shallow waters of the continental shelf, their rate of advance is reduced, energy accumulates in a smaller volume, and the sea level rise and fall is amplified. The details of tidal motions in coastal waters, particularly in channels, gulfs, and estuaries, depend on the characteristics of coastal geometry and the water depth variation. Tidal amplitudes, the contrast between spring and neap tides, and the variation of times of high and low tide all vary widely from location to location.

9.1.2 Methodology

Tides are successfully predicted on the basis of accumulated observations of the tides at the place concerned. The analysis of the observations relies on the fact that any tidal pattern (in time) is a superposition of variations associated with periodicities in the motions of the moon and the sun relative to Earth. The periods involved are the same everywhere, ranging from about 12 hours to a year or more, but the relative sizes of their contributions are highly variable. Observations over a sufficient time make it possible to calculate which contributions are significant at a particular location and, thus, to forecast tidal times and heights. It is common that 40 components may be significant for practical calculations at one location. It should be noted that in order to achieve a complete description of the tidal components, more than 19.61 years of observations are required. This happens because of the celestial bodies orbits (the modulation of perihelion is disregarded as it is nearly constant over historical time, thus reducing the number of identifiable constituents) (Consoli et al.2014, Foreman et al., 1995). However, it is possible to deduce valid tidal status descriptions with smaller time intervals, preferably with one year samples.

For this report, six (6) locations (Table 9.1) were selected for analysis, covering the period from 01/01/2016 to 20/06/2018 and showing the relevant sea level variations. The analysis was applied to each point, over three separated periods with duration of one year (2016, 2017 and 2018). Data were obtained with the aid of OSU Tidal Inversion Software (Egbert et al.,1994, Egbert and Erofeeva, 2002), based on astronomical body forcing. Effects of other forcing are not included.

Location name	Longitude (East)	Latitude (North)	Area near
Station 1	34.060752^0	34.958992^0	Ayia Napa
Station 2	33.638100^0	34.843468^0	Larnaka
Station 3	33.112333^0	34.675582^0	Limassol
Station 4	32.381313^0	34.770695^0	Paphos
Station 5	32.330480^0	35.077979^0	Akamas
Station 6	32.681463^0	35.189902^0	Kato Pyrgos

Table 9.1. Location of the selected tidal observation stations.

The analysis of the sea level data was applied following the International Oceanographic Organization (IOC, 1985, 2006) methodology.

Since the tide generating forces are periodic with periods depended on the celestial movements of the earth-moon and earth-sun systems, the main species of tidal sets of constituents considered, are

• the semi-diurnals, containing frequencies close to two cycles per day,

• the diurnals, containing frequencies close to one cycle per day. These species appeared maximum amplitudes near latitudes 45° and zero at equator and poles.

• the mixed, containing frequencies close to two cycles per day, but with irregularities in heights(Figure 9.2).

The most common tidal constituents appear in Table 9.2.

***M2** - Principal lunar semidiurnal constituent (speed: 28.984 degrees per mean solar hour)
***S2** – Principal solar semidiurnal constituent (speed: 30.000 degrees per mean solar hour)
***N2** - Larger Lunar elliptic semidiurnal constituent (speed: 28.440 degrees per mean solar hour)
***K1** - Luni-solar declinational diurnal constituent (speed: 15.041 degrees per mean solar hour)
***K2** - Luni-solar declinational diurnal constituent (speed: 30.082 degrees per mean solar hour)
***O1** – Lunar declinational diurnal constituent (speed: 13.943 degrees per mean solar hour)
M4 – First overtide of M2 constituent (speed: 2 x M2 speed)
M6 – Second overtide of M2 constituent (speed: 3 x M2 speed)
S4 – First overtide of S2 constituent (speed: 2 x S2 speed)
MS4 – A compound tide of M2 and S2 (speed: M2 + S2 speed)
***P1** – Solar declinational diurnal constituent (speed: 14.9589 degrees per mean solar hour)

Table 9.2. Common tidal constituents. Stars (*) denote the main constituents that account the 83% of the total tide generating force (Doodson, 1941).

The ratio of the amplitude sum of O1 and K1, over the amplitude sum over M2 and S2 is used for tidal classification (Forrester, 1983, Foreman, 1977, Dietrich 1963). If the resulted numerical value (called the Form number) is less than 0.25 we have semidiurnal species, if the value is larger than 3.0 we have diurnal, and in all other cases mixed species.

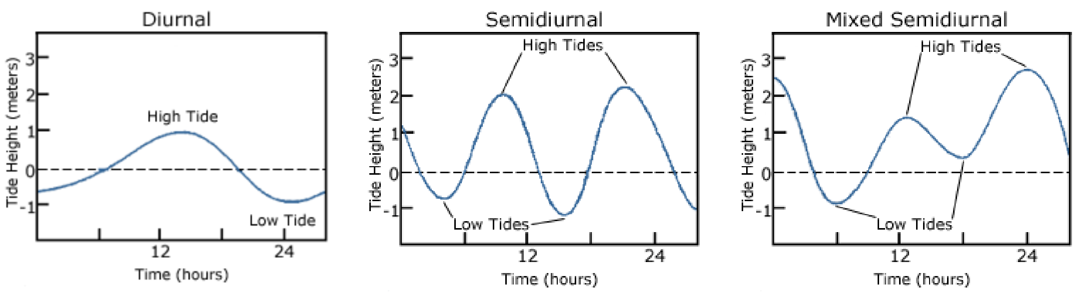


Figure 9.2.Tide classification, according their amplitudes. From left to right: Diurnal with one (1) high-low cycle, semidiurnal with two (2) high-low cycles and mixed semidiurnal with two (2) irregular cycles.

Over the last decades, many software tools have been developed for the relevant analysis (IOC, 2006) with reasonable success on the task. Among the most effectively used, are the programs created by Foreman (1977) and the MATLAB® t-tides (Pawlowicz, 2002). The "oce" software (Kelley, 2018) was developed recently, inside the "R" statistical software package, and this is the tool selected for the present analysis.

The harmonic analysis performed for m constituents is based on the function

$$h(t) = \sum_{j=1}^{m} f_j(t) A_j \cos[2\pi(V_j(t) + u_j t - g_j)]$$

where, Aj and gj are amplitude and the phase lag of constituent j, fj(t),uj(t) are the nodal modulation amplitude and the phase correction factors for constituent j and Vj(t) is the astronomical argument of constituent j.

The Rayleigh criterion, according to which two constituents of frequencies f1 and f2 cannot be resolved unless the time series spans a time interval of at least rc/(f1-f2), for the frequency selection is set to 1.0 (rc=1.0). Imposed Doodson (1921) tidal constituents, explain the super- and sub- harmonics as well as the seasonal variation.

9.2 HAZARD SCENARIO IDENTIFICATION

9.2.1 Environmental Damages & Restoration Due To Sea Level Variation Influence

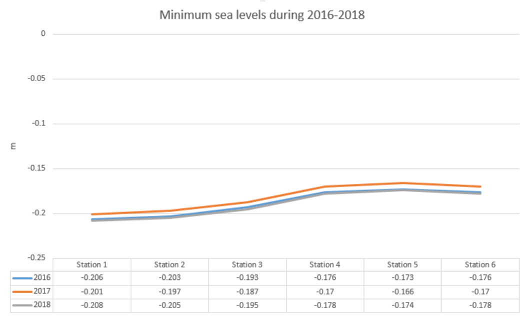
In all cases harmonic analysis revealed that the sea level variability is dominated by the S2 tidal constituent (principal solar semidiurnal constituent) followed by the M2 (principal lunar semidiurnal constituent), corresponding to mixed semidiurnal tidal species (Table 9.4). The exact numerical results along with their spectra is included in Appendixes 9.I for 2016, 9.II for 2017 and 9.III for 2018.

		Form number	Amplitudes (m)				
2016		(K1+O1)/(M2+S2)	K1	O1	M2	S2	Classification
	Station 1	0.2868	2.83E-02	1.89E-02	1.04E-01	6.06E-02	mixed semidiurnal
	Station 2	0.2849	2.77E-02	1.84E-02	1.02E-01	5.98E-02	mixed semidiurnal
	Station 3	0.2883	2.66E-02	1.76E-02	9.64E-02	5.69E-02	mixed semidiurnal
	Station 4	0.3008	2.53E-02	1.66E-02	8.74E-02	5.19E-02	mixed semidiurnal
	Station 5	0.3067	2.53E-02	1.66E-02	8.57E-02	5.09E-02	mixed semidiurnal
	Station 6	0.3090	2.61E-02	1.71E-02	8.79E-02	5.19E-02	mixed semidiurnal
2017							
	Station 1	0.2868	2.83E-02	1.89E-02	1.04E-01	6.06E-02	mixed semidiurnal
	Station 2	0.2849	2.77E-02	1.84E-02	1.02E-01	5.98E-02	mixed semidiurnal
	Station 3	0.2883	2.66E-02	1.76E-02	9.64E-02	5.69E-02	mixed semidiurnal
	Station 4	0.3008	2.53E-02	1.66E-02	8.74E-02	5.19E-02	mixed semidiurnal
	Station 5	0.3067	2.53E-02	1.66E-02	8.57E-02	5.09E-02	mixed semidiurnal
	Station 6	0.3083	2.60E-02	1.71E-02	8.79E-02	5.19E-02	mixed semidiurnal
2018							
	Station 1	0.2813	2.76E-02	1.91E-02	1.04E-01	6.20E-02	mixed semidiurnal
	Station 2	0.2794	2.70E-02	1.86E-02	1.02E-01	6.12E-02	mixed semidiurnal
	Station 3	0.2835	2.59E-02	1.79E-02	9.63E-02	5.82E-02	mixed semidiurnal
	Station 4	0.2956	2.46E-02	1.69E-02	8.73E-02	5.31E-02	mixed semidiurnal

	Station 5	0.3012	2.47E-02	1.68E-02	8.57E-02	5.21E-02	mixed semidiurnal
	Station 6	0.3028	2.54E-02	1.73E-02	8.79E-02	5.31E-02	mixed semidiurnal

Table 9.4. Tidal classification of the selected stations in response to corresponding amplitudes of the major tidal components during the last three (3) years (2016-2018).

Figure 9.3 shows the response to the sea level variation for each selected station.



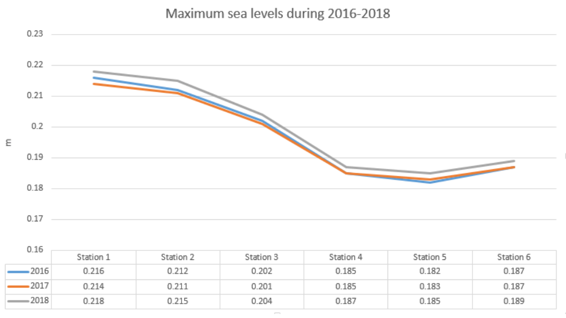


Figure 9.3: Minimum and maximum sea levels for each selected location during 2016-2018.

According to these results, the sea level variation influence can be classified as most significant near Ayia Napa (min. sea level -0.208m, max. sea level 0.218m) and less important near Akamas peninsula (min. sea level -0.174m, max. sea level 0.185m). Detail area influence classification is shown in Table 9.5.

It should be noted, that the harmonic analysis performed over the astronomical tidal components. This means that the corresponding results show only the gravitational and the geomorphological influence over the sea level. Weather condition influence (atmospheric pressure, strong winds, precipitation and evaporation) is certain to increase or decrease the expected sea level, at least to some locations. In order to achieve exact sea level data, it is required installation of specific oceanographic instruments known as sea level gauges and to retrieve data for about twenty years. However the astronomical tidal analysis is a valid guide for the general sea level variation overview, excluding extreme incidents.

Areas with higher tidal ranges, on the eastern side of Cyprus, can be expected to be more vulnerable to extreme incidents, because often risk increases dramatically after a threshold is reached, even if only briefly.

Response Influence	**Station name**	**Area near**
I – most significant	Station 1	Ayia Napa
II - significant	Station 2	Larnaka
III – less significant	Station 3	Limassol
IV - influenced	Station 6	Kato Pyrgos

V – low influence	Station 4	Paphos
VI - low influence	Station 5	Akamas

Table 9.5: Empirical sea level influence classification in response to the three years harmonic analysis.

9.2.2 Erosion vulnerability of Cyprus Coastal Area

Model predictions for the extent of sea-level increase in the Mediterranean for the 21st century range up to 61 cm (in a worst-case scenario) for the Eastern Mediterranean (Marcos and Tsimplis 2008). Satellite altimetry data on variations in the level of the Mediterranean Sea between January 1993 and June 2006 indicate that sea level will rise more in the Eastern Mediterranean than in the Western Mediterranean. Coastline stability is also affected by the increase in artificial structures, both within the drainage basin (especially reservoirs) and along the coastline (the proliferation of marinas and other urban and tourist-industry infrastructure, UNEP/MAP 2012).

Coastal erosion is caused by the movement of sediments from one area to another. The area in which the total volume of sediments decreases experiences erosion and the area in which it increases experiences accretion. Erosion is considered as both a benefit and a problem. Without erosion there would have been no sandy beaches and no sediments around. The loss of sediments from a natural beach is also a problem, as there is loss of precious land and risk to people’s safety.

Erosion constitutes a serious issue for the coasts of Cyprus.

A possible increase of the frequency of large storms in the coming centuries, can cause storm surges that may flood low-lying coastal areas, allowing destructive wave action to penetrate inland. The occurrence at the same time, of a sea-level rise, as presented in the previous section, would increase the area likely to be inundated by these coastal storms. Coastal erosion is affected by wave overtopping due to the

a) Increase of water depth and hence increase of breaking wave height at the same location. For example, a rock at a water depth of 3m will be impinged by a larger wave when the water depth increases to say 3.5m.

b) Change of wave height and direction due to climate change. If the wave direction changes or the wave height changes due to climate change then the coastal hydraulics change and the sediment movement changes.

Sea level may predicted from a combination of wave, hydrodynamical and tidal models, aided by a robust sea level monitoring network. Since no clear conclusions were derived on past trends of sea level change, in recent years there are serious efforts from Governmental Organizations and Universities of Cyprus for establishing a sea level station network that will collect, analyze and disseminate the information on sea level variations.

Activities have been identified (Loizidou, 2000) as the major causes of man-induced beach erosion in Cyprus are:

• construction of coastal works,

• beach mining,

• dam construction,

• urbanisation of coastal areas, which do not allow for adequate buffer zones.

Especially additional major causes of erosion due to man-made interventions have been identified (Theodosiou, 2018) to be

Extensive beach quarrying.

Construction of river dams

Rabid development of the coastal area.

Man-made coastal structures (for example illegal groynes and breakwaters).

Four (4) main types of beaches have been identified in Cyprus:

1. Sandy
2. Gravel
3. Mixed (sand and gravel)
4. Rocky

According to Theodosiou (2018), the first three types are classified as “soft” (total length of coast 184 km ie:53%) since they consist of movable material, possibly subjected to erosion. The rocky beaches are classified as “hard” (total length of coast 166 km ie:47%) and in the time scale of hundred years, are considered to be rather stable and difficult to be eroded.

9.3 GEOSTATISTICAL ANALYSIS/ VULNERABILITY PROBABILITIES

9.3.1 Environmental Damages & Restoration Due To Sea Level Variation Influence

Since there is no specific historical incidence of damages caused directly from the sea level variation, the impact estimations were based on rather intuitive, arbitrary criteria.

• The affected area has been estimated in response to the maximum sea level heights, varying from less than 1 to approximately 2 square kilometers.

• The incidence duration has been chosen to be no more than 4 days.

• The environmental restoration is the weaker estimate, since there exist many unknown factors that may occur during a catastrophic incidence. Here, we have assumed that the damaged areas had the ability and the potential to gradually return to their initial status. However, it is possible that at specific areas, like for example at the Akamas peninsula, if the sea turtles refuges are destroyed, the damage to be irreversible.

In response to the results shown in section 9.2.1 (Table 9.5), the possible environmental impacts are presented below for:

Station 1 case (near Ayia Napa)

Established criteria for impact category (most significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)					X	
Duration				X		

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days					
2<D<4 days			C	D	
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr					
1yr<D<5 yrs			0	+1	
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
				+1	

Station 2 case (near Larnaka)

Established criteria for impact category (significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)				X		
Duration				X		

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10

D<1 day					
1<D<2 days					
2<D<4 days		B	C		
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr					
1yr<D<5 yrs			0	+1	
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
				+1	

Station 3 case (near Limassol)
Established criteria for impact category (less significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)			X			
Duration			X			

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days		B			
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr		0			
1yr<D<5 yrs					

5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
p() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

Station 4 case (near Paphos)
Established criteria for impact category (low influence)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)		X				
Duration		X				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days	A				
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr		0			
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
p() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs

			0		

Station 5 case (near Akamas)

Established criteria for impact category (low influence)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)		X				
Duration		X				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days	A				
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr		0			
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
p() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

Station 6 case (near Kato Pyrgos)

Established criteria for impact category (influenced)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)		X				
Duration		X				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10

D<1 day					
1<D<2 days					
2<D<4 days	A				
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr		0			
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
p() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

9.3.2 Environmental Damages & Restoration Due To Coastal Erosion

During last decade, continuous studies of the Department of Land and Surveys of the Cyprus Ministry of Interior, with the cooperation of the Oceanography Center of the University of Cyprus, have shown that numerous beaches of the island, such as the coastline of Larnaka and Chrysochous Bay, have been suffering from severe erosion during the last 30 years (Figures 9.14, 9.15). However, the phenomenon of coastal erosion in Cyprus is mainly attributed to human interventions, which in some cases only are triggered by natural causes possibly associated with climate change.

Coastal retreating is another major problem presented by sea flooding when physical or anthropogenic barriers obstruct the process of landwards retreating. Given the significant proportion of the Cyprus coastline occupied by urban and tourist infrastructure, coastal retreating may constitute a serious issue for certain areas in the future.

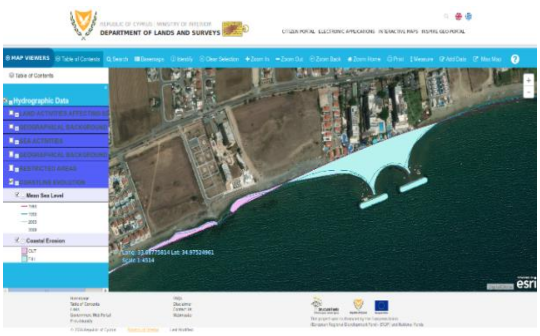


Figure 9.14: Coastal cut (pink) and fill (cyan) at a location of Larnaka bay. The total cut area shown is about 5 sq km^2, while the fill area is approximately 15 sq km^2. The shoreline change covers the period from 1963 to 2008. (Area 1)

(source:http://eservices.dls.moi.gov.cy/#/national/geoportalmapviewer)

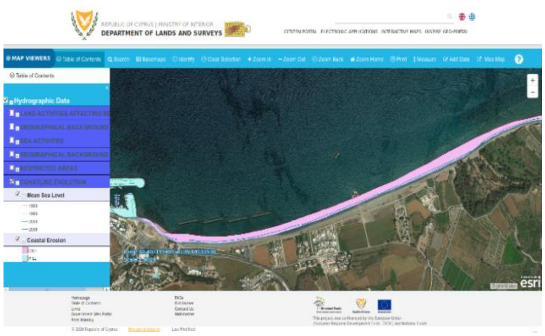


Figure 9.15: Coastal cut (pink) and fill (cyan) at a location of Chrysochous bay. The cut area shown is about 50 sq km^2, while the fill area is approximately 12 sq km^2. The shoreline change covers the period from 1963 to 2008. (Area 2)

(source:http://eservices.dls.moi.gov.cy/#/national/geoportalmapviewer)

Examination of the selected cases of the possible environmental impacts due to erosion of Cyprus Coastal Area, shown that for:

Area 1 case (Larnaka Bay)

Established criteria for impact category (most significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)						X
Duration					X	

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days					
2<D<4 days					
4-7 days					
>1 week			E		

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs				+1	
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
				+1	

Area 2 case (Chrysochous Bay)
Established criteria for impact category (significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)						X
Duration						X

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days					
2<D<4 days					
4-7 days					
>1 week					E

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					+1

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
					+1

9.4 SUGGESTIONS FOR HAZARD MITIGATION MEASURES CONSIDERING THE INFORMATION OF HAZARD AND VULNERABILITY-EXPOSURE

Sea level is expected to rise in the future. Some projections that have been performed as part of other studies have suggested that it may be expected that the Eastern Mediterranean will experience about 0,5m of increase by 2050 and 1 m by 2100 (UNEP/MAP 2012). These projections were considered as a pessimistic Climate Change scenario, since reports argue that vertical land movement is counteracting this potential effect and this phenomenon has not been taken into account in this study. It is noted that the coastline is already subject to erosion, as a result of human activities such as sand mining, dams, illegal breakwater construction and urbanization.

Climate change impacts are expected to deteriorate this erosion.

The set-up of a long- term Coastal Zone Management Programme and the formulation of Master Plans covering the whole coastline of Cyprus, could be a major step towards mitigating possible hazards.

The task for an Integrated Management of the coastal zone is to predict and find solutions for the present and future demands and problems through a sustainable balance between economic, welfare and environmental well-being.

It is known that the coastal zone is by definition, an area of conflict and is in fact, an area of continuous morphological changes, due to its dynamic behavior and its rapid response to any natural changes or human interventions. The implementation of Master Plans in coastal areas and the establishment of a Coastal Zone Monitoring System is important.

Moreover, further studies for the upgrading and improvement of the present legislative framework for an effective management, beneficial use, protection use and development of the coastal zone, can be proved beneficial, not only for disaster prevention and relevant measures, but for many other aspects of the human welfare activities and economic growth.

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10. Marine pollution

10.1 INTRODUCTION

In order to establish a view of the significance of the environmental impact due to marine pollution we are presenting distinct scenarios for three separate categories of marine pollution,

- oil spill pollution,
- plastic litter pollution,
- biological pollution.

For both plastic and oil-spill pollution, risk factors that posing the greatest threats for oil pollution are:

- Ship accidents, including collisions, groundings, explosion, structural failure and disintegration.
- Ship traffic.
- Transfer of oil during ship bunkering operations and STS.
- Transfer of oil from oil tankers to oil handling facilities and power plants.
- Trans-boundary oils movements in neighboring countries.

According to the definition given by Occhipinti-Ambrogi and Galil (2004), “Non-indigenous species, also known as alien species, are organisms that have entered ecosystems outside of their previously known ranges and that may survive and subsequently reproduce. They can be classified as unestablished, established, invasive (rapidly increasing numbers and range), or noxious (posing a risk).”

Benthic, or seabed-living, animals are the most plentiful non-indigenous species in the Mediterranean (UNEP/MAP 2009). More non-indigenous species are found in the Eastern Mediterranean than in the Western Mediterranean.

Non-indigenous species enter the Mediterranean through three broad avenues:

- Natural invasion through waterways such as the Suez Canal or Straits of Gibraltar;
- Transportation by ships through clinging or fouling on ship hulls, ballast water; and,
- Intentional and unintentional introduction by aquaculture activities, including commercial species, bait, and species for the aquarium trade (EEA and UNEP 1999).

Maritime transportation and aquaculture are the main ways non-indigenous species enter the Western Basin of the Mediterranean. Migration through the Suez Canal is responsible for most non-indigenous species in the Eastern Basin.

Ecological mostly impacts of invasive non-indigenous species, that have been documented (UNEP/MAP 2012; EEA and UNEP 2006) are

- Predation on native species affecting marine food chains,

• Invasive non-indigenous species of fish – parrotfish (Thalassoma pavo), yellowmouth barracuda (Sphyraena viridensis), and bluefish (Pomatomus saltator), for example – prey on commercial fish species.

- Competition with native species

• Invasive non-indigenous algae of the genus Caulerpa displaced native sea grass (Posidonia spp.) meadows.

• In Cyprus and Israel three native species – a starfish (Asterina gibosa), a prawn (Melicertus kerathurus), and a jellyfish (Rhizostoma pulmo) – decreased in abundance at the same time as three non-indigenous species – also a starfish (A. Burtoni), a prawn (Maruspenaues japonicas), and a jellyfish (Rhopilema pulma) – increased in abundance. The jellyfish Rhopilema nomadica has a negative impact on tourism, fisheries, and coastal installations in the eastern Mediterranean.

- Changes to native communities

• One invasive non-indigenous seaweed (Caulerpa taxifolia) can create dense mats that affect benthic communities and reduce spawning and feeding grounds for fish.
• Another, related non-indigenous species (C. racemosa) can grow over other species of seaweed and has been linked to a decrease in sponges.

10.2 HAZARD SCENARIO IDENTIFICATION

10.2.1 Oil Spill Incidents

Many environmental issues in the Mediterranean are connected to marine pollution, as it may occur due to the increasing commercial activities, the most important being the growth in oil transfer, exploration and production, pelagic fisheries, shipping, yachting and particularly coastal tourism.
The recommended procedure for responding to marine pollution incidents should include historical oil spill accidents that will provide information regarding areas that similar incidents occurred in the past that may assist in the identification of the behavior and movement of the harmful substances. The OC-UCY maintains an oil spill database that contains records of major oil spill incidents that have occurred in the Levantine basin from 2009, of which 99% is directly related to human activities (Figure 10.1).
It should be noted that the decrease of oil spill incidents after 2012, is a result of the observing system (satellite sources) information availability, that caused by various reasons (technical issues due to orbit changes, new satellite releases, and other similar issues) and should not misinterpreted as reduced oil spill rate. This material has been gathered and processed in Keyhole Markup language Zipped (KMZ) data files, which is a compressed version of a KML (Keyhole Markup Language), generally used for providing georeferenced information.
In order to further assist in the identification of higher risk areas, the historical incidents have been ordered on yearly basis. Figures 10.2 to 10.7 shown the oil spill accidents for each year.

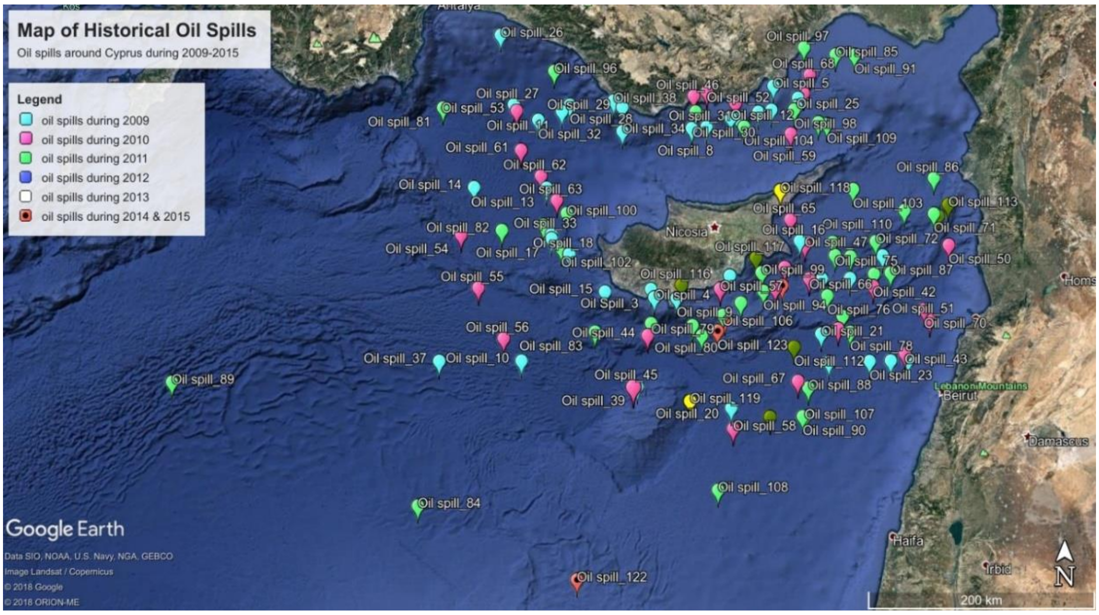

Figure 10.1: Locations of 123 oil spill incidents during 2009-2015.

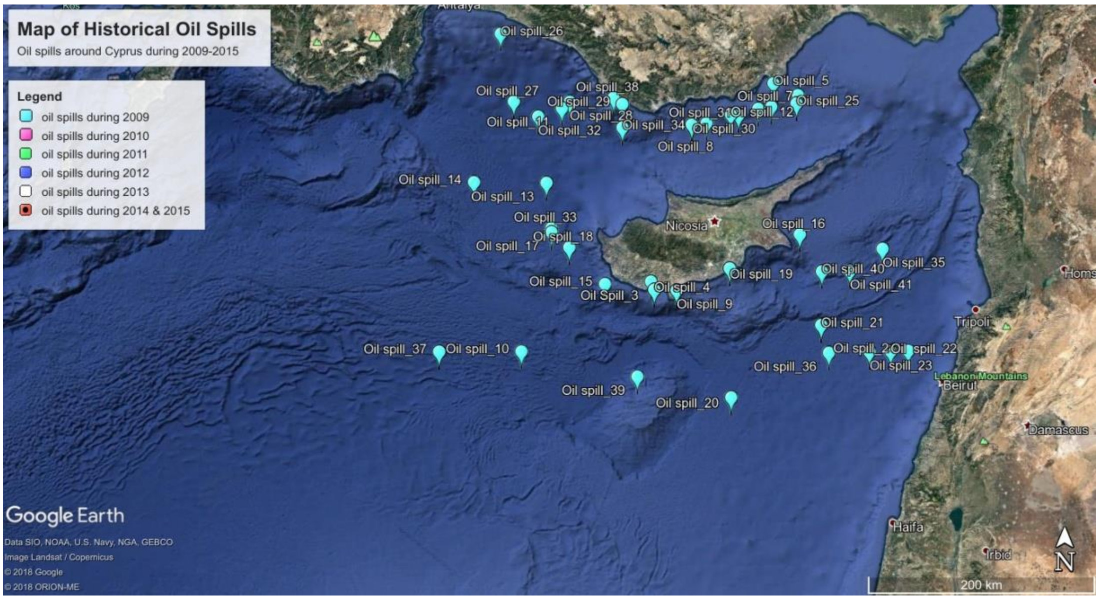

Figure 10.2: Oil spill incidents during 2009.

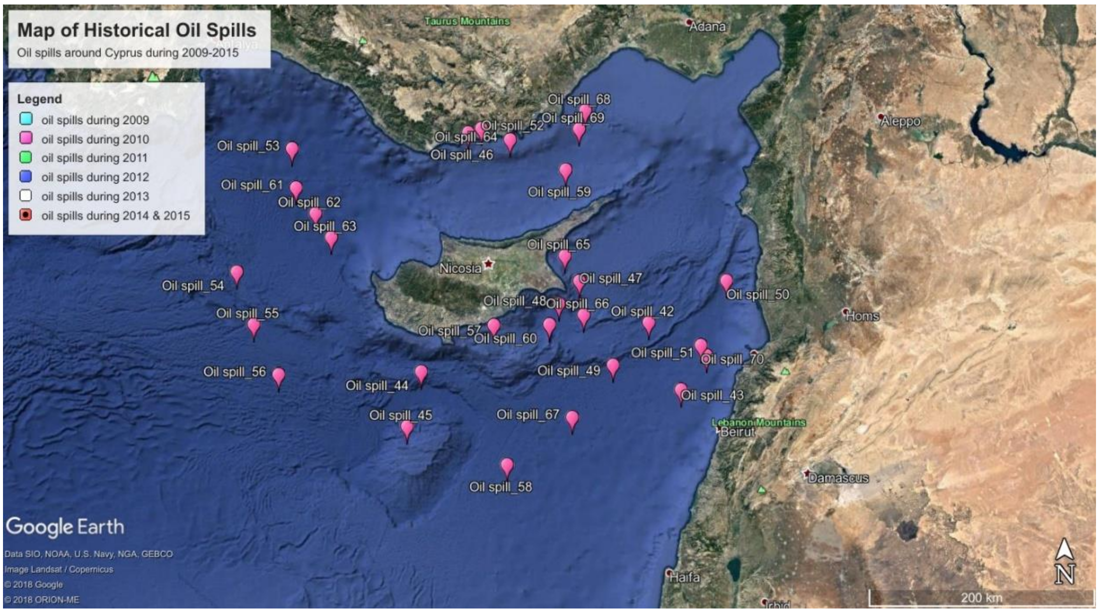

Figure 10.3: Oil spill incidents during 2010.

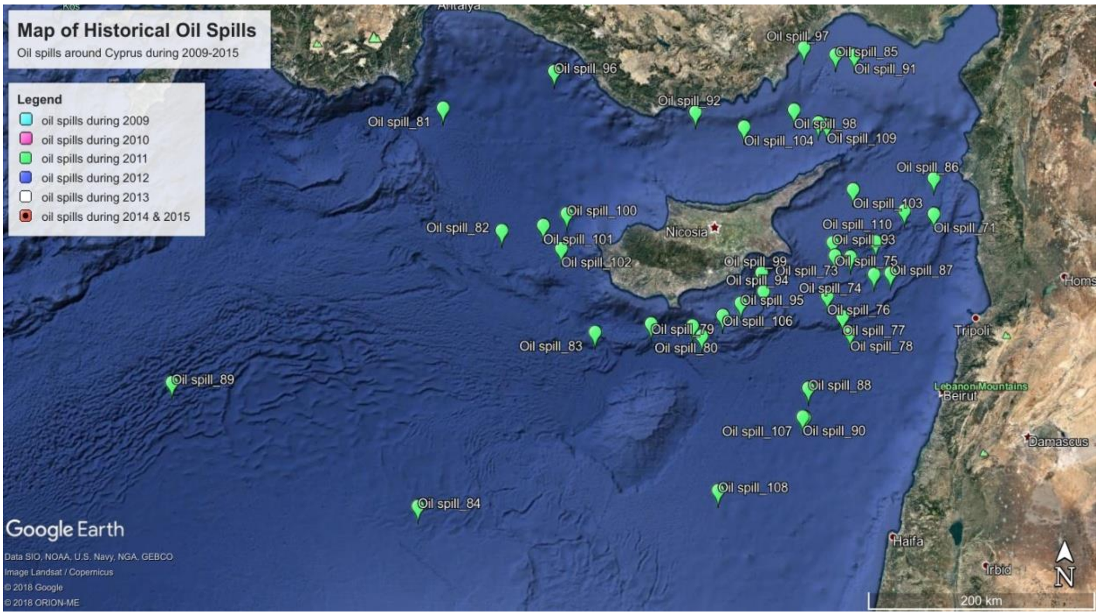

Figure 10.4: Oil spill incidents during 2011.

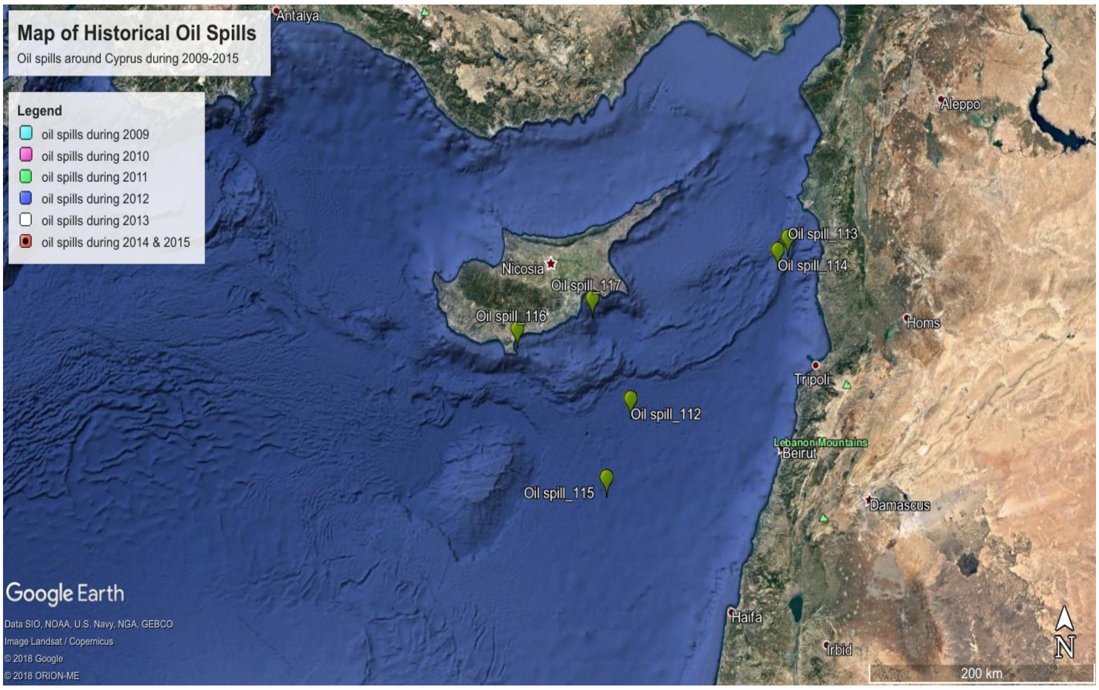

Figure 10.5: Oil spill incidents during 2012.

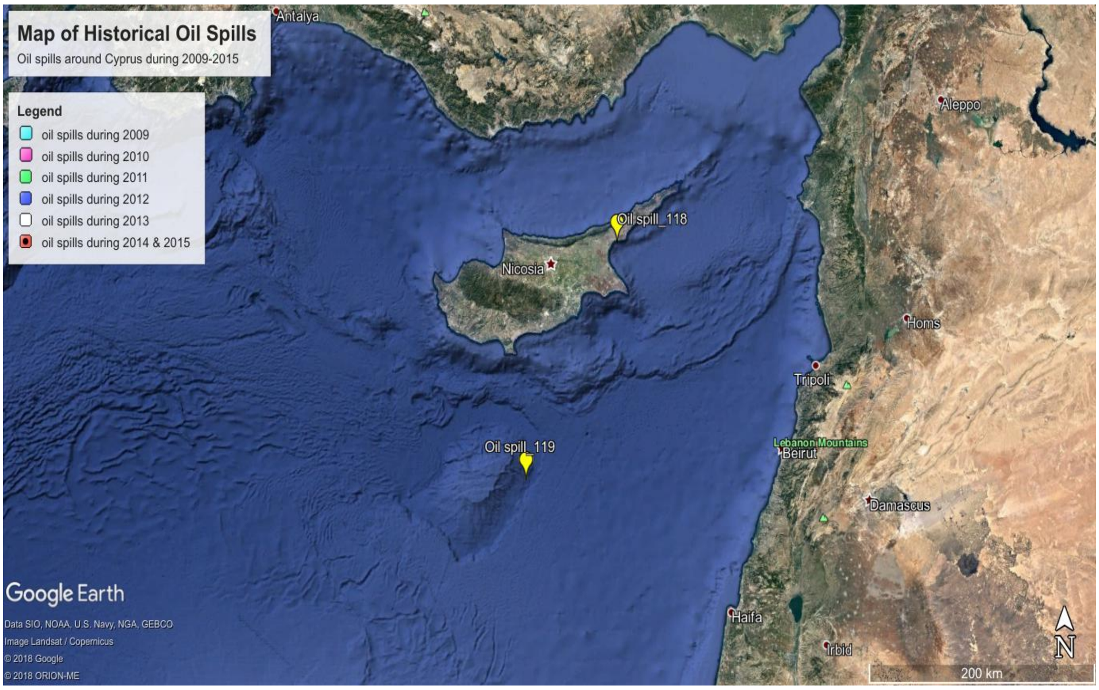

Figure 10.6: Oil spill incidents during 2013.

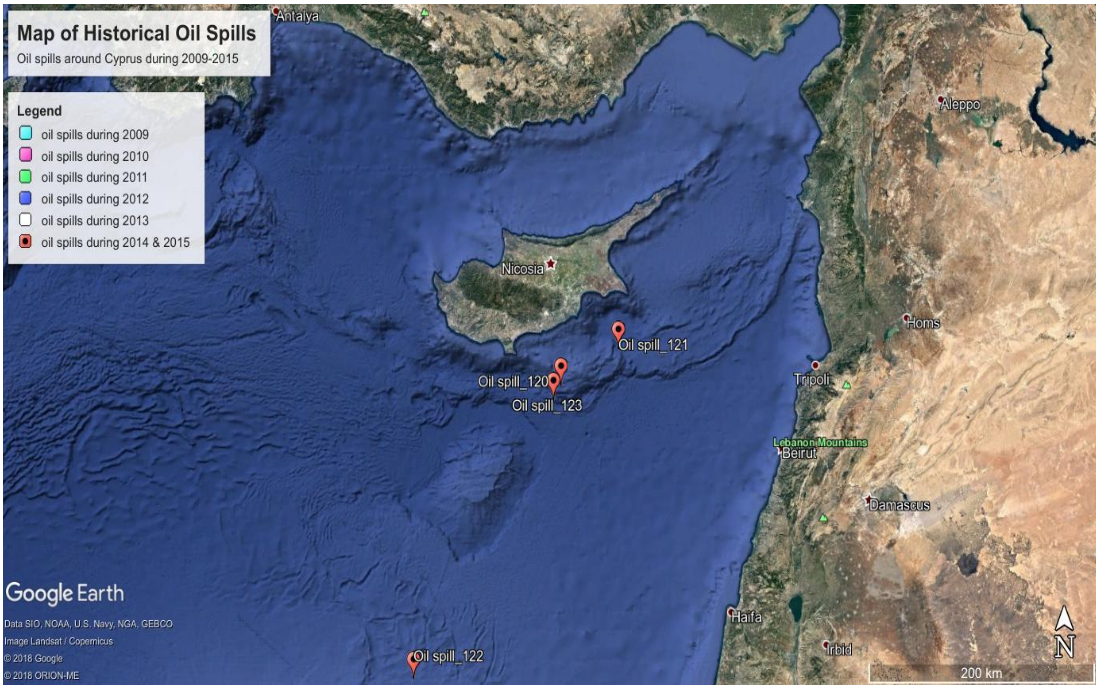

Figure 10.7: Oil spill incidents during 2014 & 2015.

For every point that is shown in the KMZ maps, the analogous information of the oil spill satellite image has been added (Figure 10.8)

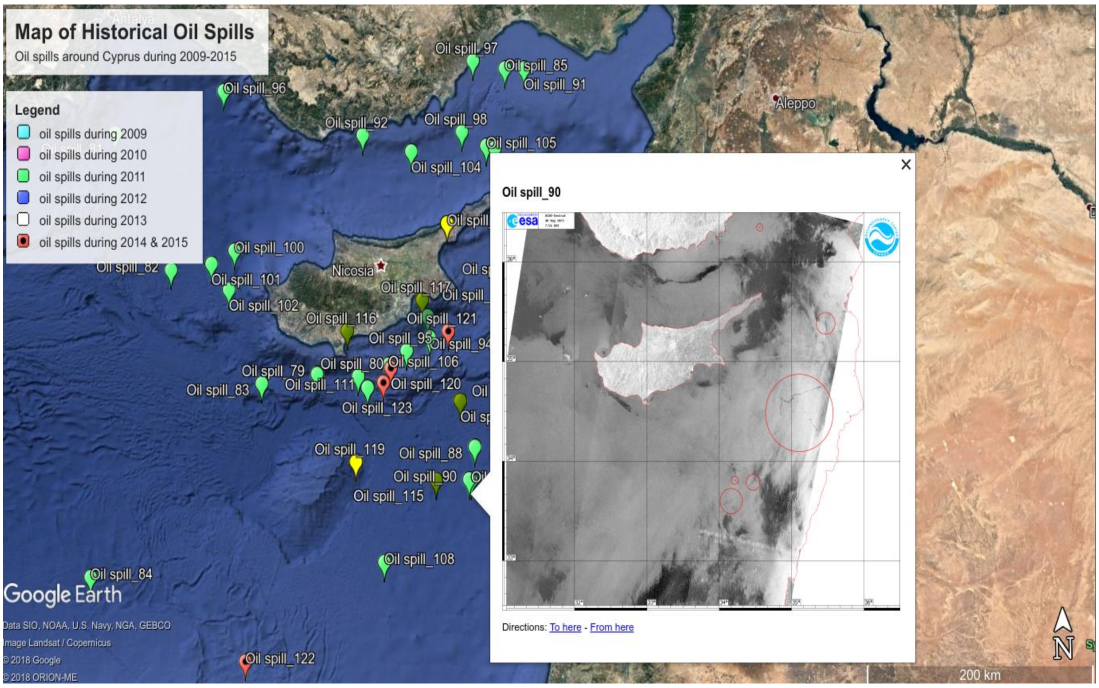

Figure 10.8: Processed satellite image showing the identified locations of oil spill accidents (red circles).

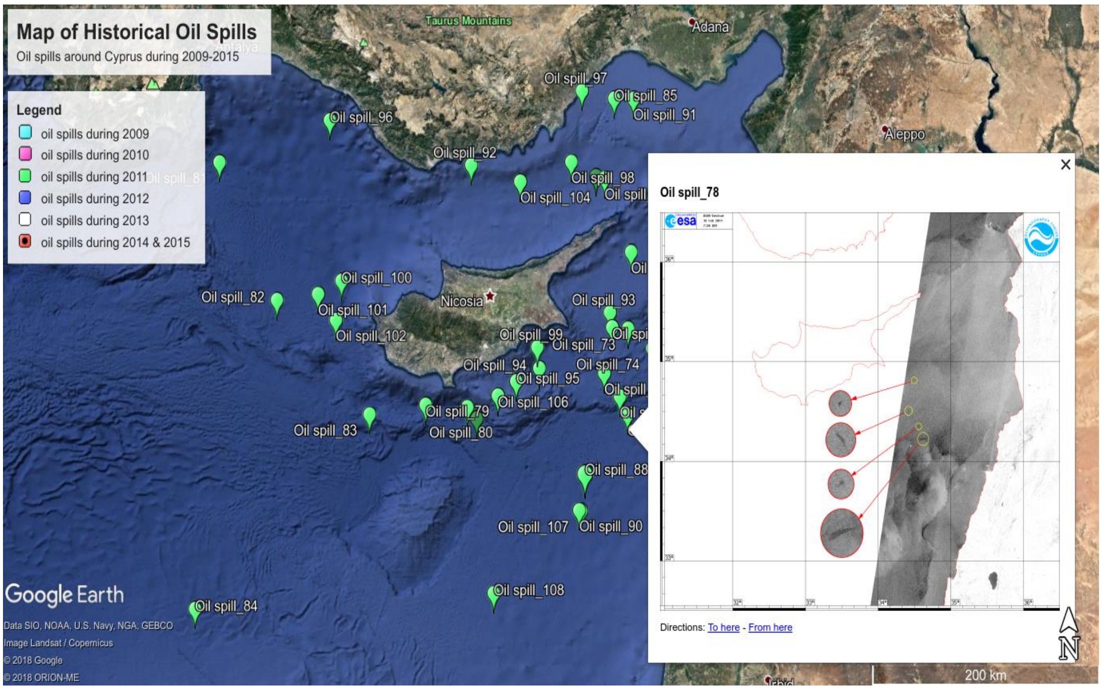

Figure 10.9: Processed satellite image showing identified locations of oil spill accidents. These incidents occurred during 2011, at the position designated by the number 78.

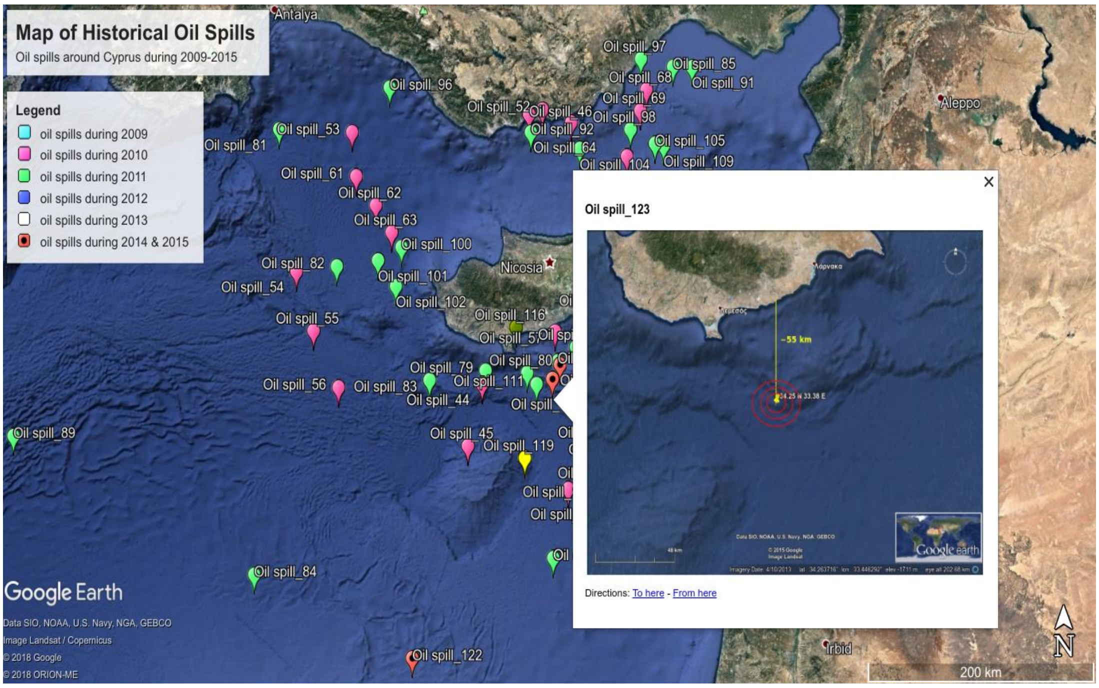

Figure 10.10: Along the historical oil spill incidents, some cases of Civil Defense exercises has been included, as the above.

10.2.2 Detailed Catalogue of Historical Oil Spills during 2009-2015

The database tracks the date and time, location and description of incident (Table 9.3).

No.	Latitude	Longitude	Date of oil spill	Time of oil spill	Description	Category (Accident / Physical disaster)
1	35° 54.6'	33° 47.8'	11/03/2009	7:51 GMT	EMSA oil slicks detection	Accident
2	35° 51.7'	33° 36.4'	11/03/2009	7:51 GMT	EMSA oil slicks detection	Accident
3	34° 34.1'	32° 45.7'	11/03/2009	7:51 GMT	EMSA oil slicks detection	Accident
4	34° 30.3'	32° 47.6'	11/03/2009	7:51 GMT	EMSA oil slicks detection	Accident
5	36° 6.6'	33° 56.9'	27/03/2009	7:48 GMT	EMSA oil slicks detection	Accident
6	36° 0.9'	34° 10.9'	27/03/2009	7:48 GMT	EMSA oil slicks detection	Accident
7	35° 55.5'	33° 55.4'	27/03/2009	7:48 GMT	EMSA oil slicks detection	Accident
8	35° 47.3'	33° 9.5'	27/03/2009	7:48 GMT	EMSA oil slicks detection	Accident
9	34° 30.0'	33° 0.1'	29/07/2009	7:51 UTC	EMSA oil slicks detection	Accident
10	34° 1.5'	31° 33.7'	29/07/2009	7:51 UTC	EMSA oil slicks detection	Accident
11	35° 55.0'	31° 55.5'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident

12	35° 52.0'	33° 32.0'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident
13	35° 20.0'	31° 47.0'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident
14	35° 20.0'	31° 6.0'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident
15	34° 33.0'	32° 20.0'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident
16	34° 55.5'	34° 10.0'	17/08/2009	7:54 UTC	EMSA oil slicks detection	Accident
17	34° 57.0'	31° 50.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
18	34° 50.0'	32° 00.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
19	34° 40.0'	33° 30.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
20	33° 40.0'	33° 30.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
21	34° 13.0'	34° 21.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
22	34° 0.0'	35° 0.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
23	34° 0.0'	34° 48.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
24	34° 0.0'	35° 10.0'	02/09/2009	7:51 UTC	EMSA oil slicks detection	Accident
25	35° 57.0'	34° 10.0'	21/09/2009	7:54 UTC	EMSA oil slicks detection	Accident
26	36° 30.0'	31° 20.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
27	35° 58.0'	31° 28.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
28	35° 58.0'	32° 0.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
29	35° 57.0'	32° 30.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
30	35° 48.0'	33° 10.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
31	35° 48.0'	33° 18.0'	29/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
32	35° 51.0'	31° 42.0'	07/10/2009	7:51 UTC	EMSA oil slicks detection	Accident
33	34° 59.0'	31° 50.0'	07/10/2009	7:51 UTC	EMSA oil slicks detection	Accident
34	35° 48.0'	32° 48.0'	07/10/2009	7:51 UTC	EMSA oil slicks detection	Accident
35	34° 48.0'	34° 57.0'	07/10/2009	7:51 UTC	EMSA oil slicks detection	Accident

36	34° 0.0'	34° 25.0'	07/10/2009	7:51 UTC	EMSA oil slicks detection	Accident
37	34° 0.9'	30° 48.0'	05/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
38	36° 0.0'	32° 25.0'	05/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
39	33° 50.0'	32° 38.0'	05/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
40	34° 38.0'	33° 22.0'	05/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
41	34° 38.0'	34° 38.0'	05/10/2009	3:52 UTC	EMSA oil slicks detection	Accident
42	34° 34.1'	34° 51.1'	21/05/2010	7:48 GMT	EMSA oil slicks detection	Accident
43	34° 3.1'	35° 8.1	21/05/2010	7:48 GMT	EMSA oil slicks detection	Accident
44	34° 13.2'	32° 43.8	21/05/2010	7:48 GMT	EMSA oil slicks detection	Accident
45	33° 48.3'	32° 35.8'	21/05/2010	7:48 GMT	EMSA oil slicks detection	Accident
46	36 2.2'	33° 10.9'	24/05/2010	7:54 GMT	EMSA oil slicks detection	Accident
47	34 53.6'	34° 12.8'	09/06/2010	7:51 GMT	EMSA oil slicks detection	Accident
48	34 43.5'	34° 1.1'	09/06/2010	7:51 GMT	EMSA oil slicks detection	Accident
49	34 15.1'	34° 30.6'	09/06/2010	7:51 GMT	EMSA oil slicks detection	Accident
50	34 52.1	35° 35.4'	09/06/2010	7:51 GMT	EMSA oil slicks detection	Accident
51	34 18.3'	35° 22.9'	09/06/2010	7:51 GMT	EMSA oil slicks detection	Accident
52	36 4.1'	33° 18.5'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
53	35 55.2'	31° 29.7'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
54	34 58.4'	30° 59.1'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
55	34 34.4'	31° 9.3'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
56	34° 11.6'	31° 23.7'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
57	34° 34.1'	33° 24.5'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
58	33° 30.6'	33° 31.0'	28/06/2010	7.54 GMT	EMSA oil slicks detection	Accident
59	35° 44.5'	34° 6.2'	02/08/2010	7.54 GMT	EMSA oil slicks detection	Accident

60	34° 34.1'	33° 55.6'	02/08/2010	7.54 GMT	EMSA oil slicks detection	Accident
61	35° 37.2'	31° 32.4'	02/08/2010	7.54 GMT	EMSA oil slicks detection	Accident
62	35° 25.5'	31° 43.8'	02/08/2010	7.54 GMT	EMSA oil slicks detection	Accident
63	35° 14.5'	31° 52.9'	02/08/2010	7.54 GMT	EMSA oil slicks detection	Accident
64	35° 58.7'	33° 34.8'	11/10/2010	7.54 GMT	EMSA oil slicks detection	Accident
65	35° 5.3'	34° 4.9'	11/10/2010	7.54 GMT	EMSA oil slicks detection	Accident
66	34° 38.2	34° 14.9'	11/10/2010	7.54 GMT	EMSA oil slicks detection	Accident
67	33° 51.7'	34° 7.4'	11/10/2010	7.54 GMT	EMSA oil slicks detection	Accident
68	36° 11.6'	34° 18.1'	22/12/2010	0:53 GMT	EMSA oil slicks detection	Accident
69	36° 3.1'	34° 14.3'	22/12/2010	0:53 GMT	EMSA oil slicks detection	Accident
70	34° 23.0'	35° 19.9'	22/12/2010	0:53 GMT	EMSA oil slicks detection	Accident
71	35° 6.6'	35° 27.4'	21/01/2011	19:33 GMT	ESA oil slicks detection	Accident
72	34° 54.6'	34° 53.3'	21/01/2011	19:33 GMT	ESA oil slicks detection	Accident
73	34° 47.9'	34° 38.6'	21/01/2011	19:33 GMT	ESA oil slicks detection	Accident
74	34° 39.7'	34° 51.8'	09/02/2011	19:38 GMT	ESA oil slicks detection	Accident
75	34° 48.6'	34° 29.8'	13/02/2011	7:38 GMT	ESA oil slicks detection	Accident
76	34° 30.3'	34° 24.9'	13/02/2011	7:38 GMT	ESA oil slicks detection	Accident
77	34° 20.8'	34° 33.3'	13/02/2011	7:38 GMT	ESA oil slicks detection	Accident
78	34° 13.5'	34° 37.4'	13/02/2011	7:38 GMT	ESA oil slicks detection	Accident
79	34° 18.6'	32° 45.7'	30/03/2011	19:42 GMT	ESA oil slicks detection	Accident
80	34° 17.6'	33° 8.8'	30/03/2011	19:42 GMT	ESA oil slicks detection	Accident
81	35° 56.2’	30° 47.6'	19/05/2011	7:59 GMT	ESA oil slicks detection	Accident
82	31° 22.0’	35° 0.6'	19/05/2011	7:59 GMT	ESA oil slicks detection	Accident
83	34° 14.8’	32° 14.5'	19/05/2011	7:59 GMT	ESA oil slicks detection	Accident

84	32° 55.00’	30° 37.5'	19/05/2011	7:59 GMT	ESA oil slicks detection	Accident
85	36° 20.8'	34° 33.6'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
86	35° 23.0'	35° 28.2'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
87	34° 40.1'	35° 1.3'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
88	33° 48.6'	34° 13.2'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
89	33° 47.0'	34° 28.3'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
90	33° 35.6'	34° 9.8'	30/05/2011	7:56 GMT	ESA oil slicks detection	Accident
91	36° 20.5'	34° 44.6'	10/06/2011	7:53 GMT	ESA oil slicks detection	Accident
92	35° 54.9'	33° 11.8'	10/06/2011	7:53 GMT	ESA oil slicks detection	Accident
93	34° 54.6'	34° 28.7’	10/06/2011	7:53 GMT	ESA oil slicks detection	Accident
94	34° 32.8'	33° 48.9’	20/06/2011	19:36 GMT	ESA oil slicks detection	Accident
95	34° 27.7'	33° 36.0’	20/06/2011	19:36 GMT	ESA oil slicks detection	Accident
96	36° 13.5'	31° 51.0'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
97	36° 24.3'	34° 15.3'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
98	35° 55.5'	34° 8.5'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
99	34° 41.3'	33° 48.0'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
100	35° 8.5'	31° 58.5'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
101	35° 3.1'	31° 45.3'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
102	34° 52.7'	31° 55.5'	29/07/2011	07:57 GMT	ESA oil slicks detection	Accident
103	35° 18.6’	34° 41.2’	08/09/2011	7:54 GMT	ESA oil slicks detection	Accident
104	35° 47.9'	33° 39.5'	26/09/2011	19:44 GMT	ESA oil slicks detection	Accident
105	35° 49.5'	34° 22.3'	26/09/2011	19:44 GMT	ESA oil slicks detection	Accident
106	34° 22.1'	33° 25.8'	26/09/2011	19:44 GMT	ESA oil slicks detection	Accident
107	33° 35.3'	34° 10.9'	26/09/2011	19:44 GMT	ESA oil slicks detection	Accident

108	33° 2.8’	33° 22.4’	26/09/2011	19:44 GMT	ESA oil slicks detection	Accident
109	35° 48.6’	34° 27.2’	27/09/2011	7:58 GMT	ESA oil slicks detection	Accident
110	35° 8.5’	35° 10.4’	07/11/2011	7:55 GMT	ESA oil slicks detection	Accident
111	34° 13.0’	33° 14.0’	04/10/2011	3:30 GMT	The tanker “MED EXERCISE CARRIER” suffered serious structural damage while being en route from the Suez Canal to the island of Cyprus at the position . The tanker was bound to call the oil unloading facility of Vassilikos Power Plant in Cyprus, carrying a cargo of 20.000 Tons of Heavy Fuel Oil 380. The tanker suffered serious cracking on its hull in way of tank no. 6 that contained approximately 1.800 Tons of oil. The release of Heavy FO began immediately. The master informed Cyprus Radio at channel 16 of the damage that created listing of the ship and a continuous oil flow into the sea. The position of the accident is approximately 22 nautical miles from the port and city of Limassol. **WEATHER CONDITIONS** Generally, the weather is brisk with moderate sea winds from the West. At sea, immediately after the accident, the weather conditions were fresh breeze of 10 m/s from the west with moderate seas.	Accident
112	34° 7.2’	34° 5.6’	05/03/2012	19:43 GMT	ESA oil slicks detection	Accident
113	35° 10.7'	35° 36.1'	05/04/2012	07:55 GMT	ESA oil slicks detection	Accident
114	35° 5.6'	35° 30.1'	05/04/2012	07:55 GMT	ESA oil slicks detection	Accident
115	33° 35.6'	33° 51.6	05/04/2012	07:55 GMT	ESA oil slicks detection	Accident
116	34° 35.96’	33° 2.83’	24/09/2012	23:00 GMT	Collision of an oil tanker and a bulk carrier in international waters 30 nautical miles southwest of Cyprus on Monday 24/9/2012. The oil tanker suffers serious hull damages which resulted into a discharge of approximately 2.000 M.T. of Heavy Fuel Oil (HFO 380). A large quantity of the oil reaches the maritime area off Limassol.	Accident
117	34° 48.00’	33° 45.00’	4/12/2012	09:00 GMT	An oil spill incident of very heavy oil type was reported offshore to the Larnaca Bay	Accident
118	35° 18.61’	33° 59.50’	16/07/2013	03:55 UTC	Information about an oil spill, approximately 100 tonnes HFO in an oil terminal located in Turkish. Type of oil: heavy, API 26	Accident

119	33° 43.3’	33° 07.2’	12/9/2013	7:20 UTC	Response to oil spill incident request Total volume of oil: 10 tons Type of oil: medium (API No 33)	Accident
120	34° 20.8’	33° 27.1	15/03/2014	14:30 UTC	Possible oil spill Total volume of oil: 5000 tons type of oil: heavy	Accident
121	34° 35.25’	33° 59.39’	07/04/2014	04:00 UTC	Possible oil spill	Accident
122	32° 22.20’	32° 04.97’	16/06/2014	07:00 UTC	A hypothetical blow out at the water depth of 1000 meter was reported from an offshore platform in the SE part of the Levantine. Flow rate of the oil released in the sea: 8000 m3/day of Belayim oil type, where this amount of oil is released as a continuous oil spill in the first 120 hours. (Based on a Civil Defense exercise scenario).	Accident
123	34° 15.00'	33° 22.80'	05/07/2015	05:02 UTC	An earth- (sea-) quake measuring 7.2 on the Richter-Scale occurred in the morning hours of Sunday, 5 July 2015 in the eastern Mediterranean Sea. As a secondary event to the earth- (sea-) quake, a tsunami-like tidal wave was generated at the epicenter and spread throughout the Eastern Mediterranean Sea. Waves with a maximum height of ca. six meters moved away concentrically from the epicenter at a speed of approx. 80 km / h. They hit the southern coast of Cyprus shortly before 08.30 hrs on Sunday. In some of the coastal plains, the tidal waves moved inland up to approximately 900 m adding to the destruction of the earthquake. (Based on a Civil Defense exercise scenario).	Physical disaster

Table 9.3. Records of major oil spill incidents from 2009 – 2015

10.3 VULNERABILITY PROBABILITIES

10.3.1 Oil-spill pollution

Using the Data Base prepared for this purpose, the following cases have been selected as representative of significant oil-spill incidents around the Cyprus sea.

Historical Case 1 - oil-spill due to ship damage 04/10/2011 03:30 GMT

The tanker “MED EXERCISE CARRIER” suffered serious structural damage while being en route from the Suez Canal to the island of Cyprus at the position 35° 8.5’ North Latitude and 35° 10.4’ East Longitude. The tanker was bound to call the oil unloading facility of Vassilikos Power Plant in Cyprus, carrying a cargo of 20.000 Tons of Heavy Fuel Oil 380. The tanker suffered serious cracking on its hull in way of tank no. 6 that contained approximately 1.800 Tons of oil. The release of Heavy FO began immediately. The master informed Cyprus Radio at channel 16 of the damage that created listing of the ship and a continuous oil flow into the sea. The position of the accident is approximately 22 nautical miles from the port and city of Limassol. (Figure 10.11).

Historical Case 2 – oil-spill due to vessel collision 24/09/2012 23:00 GMT

Collision of an oil tanker and a bulk carrier in international waters 30 nautical miles southwest of Cyprus on Monday 24/9/2012. The oil tanker suffers serious hull damages which resulted into a discharge of approximately 2.000 M.T. of Heavy Fuel Oil (HFO 380). A large quantity of the oil reaches the maritime area of Limassol. (Figure 10.12).

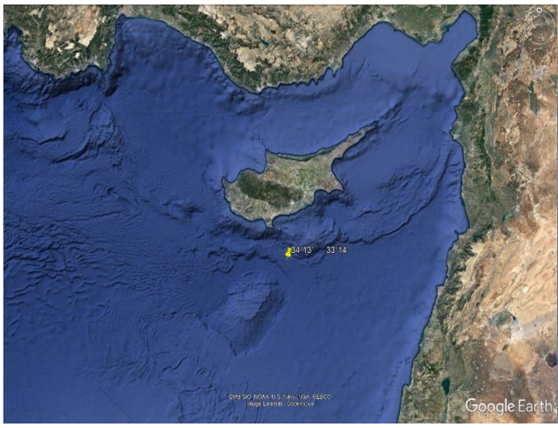

Figure 10.11: The tanker “MED EXERCISE CARRIER” carrying a cargo of 20.000 Tons of Heavy Fuel Oil suffered serious cracking on its hull, 22 nautical miles from the port of Limassol on 04/10/2011.

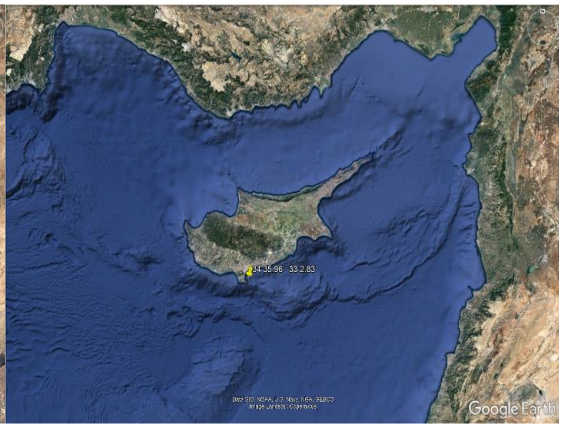

Figure 10.12: Collision of an oil tanker and a bulk carrier in international waters 30 nautical miles southwest of Cyprus on Monday 24/9/2012.

Historical case 1 (oil-spill due tanker damage)

Established criteria for impact category

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)			X			
Duration		X				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day		A			
1<D<2 days					
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths	0				
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

Historical case 2 (oil-spill due vessel collision)
Established criteria for impact category

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)			X			
Duration		X				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day		A			
1<D<2 days					
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths	0				
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

10.3.2 Plastic litter pollution

Marine litter is “any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment.” (Galgani et al., 2010) Source of marine litter is mainly the house-holds. Other major sources are tourist facilities, municipal dumps, ships and pleasure boats.

The marine environment is affected through deliberate disposal or unintentional discharge, either at sea or from land by way of rivers, drainage systems and wind.

Known effects include entanglement of marine animals in plastic and ingestion of plastic by marine organisms (EEA and UNEP 2006). There is growing evidence that microplastics can also have negative effects on marine organisms (GESAMP 2010). The additional challenge of microplastics is their small size, which makes them difficult to remove from the marine environment.

Scientific investigation is under development as the problem in the Mediterranean and elsewhere is continuously growing.

In order to simulate the problem, two scenarios of possible incidents are shown, with the assumption that the plastic litters behave similar to light oil-spill.

Case 1 - Description of GNOME model floating objects prediction results

A hypothetical incident of plastic bottles that goes from mountain to the sea in Cyprus, with the effect of sunlight and wave action rapidly breaks down in small pieces and enters the various levels of the marine foodchain.

Position: LAT: 35° 12.73'N ; LON: 32° 48.68'E on the 12 June 2018 at 18:00 UTC.

The analogue to plastic bottle flow rate of the oil released in the sea was simulated as 2,500 metric tons of gasoline oil (API: 32.5), with instantaneous particles during a period of 30 hours. (Figure 10.13). According the mathematical simulation the particles arrived to the coast after 25 hours.

Case 2 - Description of GNOME floating objects prediction results

A hypothetical incident of plastic bottles in Limassol, Cyprus.

Position: LAT: 34° 34.24'N ; LON: 33° 9.53'E on the 09 May 2018 at 00:00 UTC.

The analogue to plastic bottle flow rate of the oil released in the sea was simulated as 2,000 metric tons of gasoline oil (API: 32.5), with instantaneous particles during a period of 57 hours. (Figure 10.14). According to the mathematical simulation, the particles arrived to the coast after 57 hours.

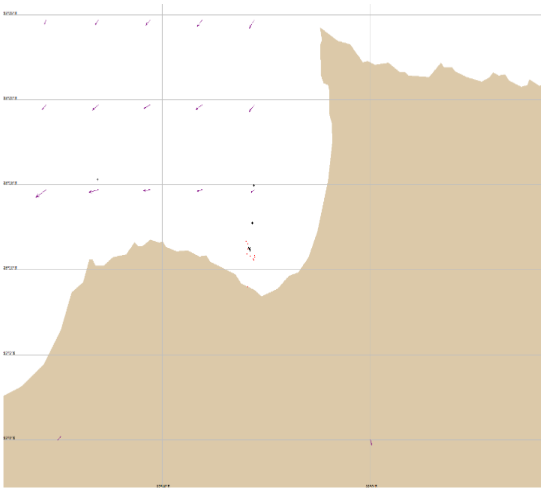

Figure 10.13: Oil spill after 25 hours (13/06/2018 19:00 UTC) .The sea surface currents are towards South-South-West. The wind West-South-West

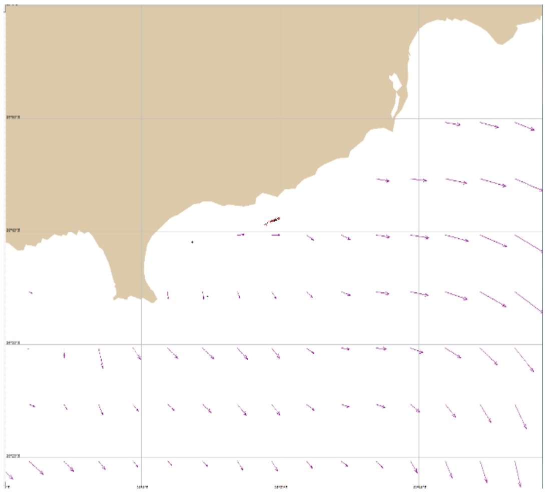

Figure 10.14: Oil spill after 19 hours (9/05/2018 19:00 UTC). The sea surface currents are towards

direction with an average speed 6 m/s. The particles arrived to the coast.

East. The wind South-West direction with an average speed 16 m/s.

Scenario case 1 (plastic bottles LAT: 35° 12.73'N ; LON: 32° 48.68'E)
Established criteria for impact category (most significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)		A				
Duration		A				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days	A				
2<D<4 days					
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths	0				
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
		0			

Scenario case 2 (plastic bottles near Limassol)
Established criteria for impact category (most significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)		A				
Duration		A				

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days					
2<D<4 days	A				
4-7 days					
>1 week					

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths	0				
6mths<D<1 yr					
1yr<D<5 yrs					
5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
			0		

10.3.3 Biological pollution

A very special case has been observed in the years after 2010. Jellyfish invasion, has shown a considerable increase in the recent years. That is the reason that the Oceanography Center of the University of Cyprus, developed a special web page, where individuals can send updates regarding the spotted jellyfish locations around the Cyprus waters (Figures 10.15,10.16).

Figure 10.15: Jellyfish invasion map, with species number indications. The "MEDUSA" site (http://www.oceanography.ucy.ac.cy/medusa/home.html) developed, to aid in the identification and information gathering on the specific biological hazard.

Figure 10.16: A simple guide to assist the public reporting jellyfish appearances.

Station 1 case (Ayia Napa Bay jellyfish invasion)

Established criteria for impact category (most significant)

Impact category	Criterion	A	B	C	D	E
ENVIRONMENTAL	EN1: Environmental damage					
Affected area (km^2)						X
Duration						X

EN1:Environmental Damage					
Area (km^2) Duration	<1	1-2	2-5	5-10	>10
D<1 day					
1<D<2 days					
2<D<4 days					
4-7 days					
>1 week			E		

EN1:Environmental restoration					
Cost Duration	<100k	1-300k	3-500k	2mil	>2mil
D<6 mths					
6mths<D<1 yr					
1yr<D<5 yrs			0		

5-10 yrs					
>10 yrs					

Likelihood of occurrence categories and values/scale:

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p()	Very low	Low	Medium	High	Very high
	1	2	3	4	5
P() per year,%	P<0.67	0.67-2	2-10	10-50	>50
Frequency of event	...in more than 100 yrs	...in 50 to 100 yrs	...in 10 to 50 yrs	… in 2 to 10 yrs	At least every 2 yrs
				+1	

10.4 SUGGESTIONS FOR HAZARD MITIGATION MEASURES CONSIDERING THE INFORMATION OF HAZARD AND VULNERABILITY-EXPOSURE

The level of success of a response to a catastrophic oil spill scenario depends mainly on the proper identification of the imminent risks. This is best done through regular risk assessment. In view of the growing offshore oil and gas activities in the Eastern Mediterranean high-risk zones should be identified and updated regularly and measures should be taken towards preparedness for response and mitigation, e.g. for oil spill confinement and clean-up measures. It should be noted that other geographical, economical and sensitivity parameters should be taken in account like

-Areas of high ecological value and in need of special environmental protection.

-Areas of important economic activity (tourism, public beaches, hotels, water desalination, intakes, fishing, fish farms, port and marinas) to be severely affected from an oil spill.

-Locations with dense ship traffic.

-Locations with dense oil transfer operations.

-Amount and properties of oils likely to be spilled.

-Areas with limited or difficult access.

-Fish farms and shell-fish farms.

-Aquatic habitats.

-Industrial sea water intakes.

-Sites of archaeological interest.

-Areas of particular natural beauty, Mediterranean Special Protected Areas and areas protected under National Fisheries Law.

-Shallow-water areas or sea areas with little hydrodynamic circulation, where the use of chemical oil dispersal must be avoided.

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11. Hazards synergy

The multi risk assessment process starts with the risk assessment for single hazards. Single-hazard risk examine exclusively on the impact of only one specific hazard although this hazard may raise the vulnerability.

Multi-risk assessments determine the total risk from several hazards/ the likelihood of occurrence of different hazards either occurring at the same time or shortly following each other, because they are dependent from one another or because they are caused by the same triggering event or hazard; or merely threatening the same elements at risk (vulnerable/ exposed elements) without chronological coincidence.
The use of multi-risk approaches are important in all geographic areas susceptible to several types of hazards, as is the case in many regions in the EU. In this situation, exclusively focussing on the impact of only one specific hazard could even result in raising the vulnerability in respect of another type of hazard. For example, if a building development on a flood plain is approved because its structure includes an elevated and stilted ground floor, this could result in the structure being particularly vulnerable to the effects of an earthquake's seismic waves
The challenge of multi-risk assessments is to adequately take account of possible cascading/follow-on effects (also: knock-on effects or domino effects) among hazards, i.e. the situation where one hazard causes one or more sequential hazards. For example, an earthquake may cause the explosion of a gas pipeline, or an industrial accident may cause a forest fire. Multi-risk assessments thus consider the interdependency of several hazards and risks.
In practice another challenge of multi-risk assessments lies in the co-ordination and interfacing between different specialised authorities and agencies, which each deal with specific hazards or risks without developing a complete overview of the knock-on, domino and cascading effects.66 Indeed, the manager of a gas pipeline may not be aware of the probability of a volcanic eruption causing a 10 cm ash layer leading to the structural failure of a bridge used for the gas pipeline. Likewise, the forest fire department may not be sufficiently knowledgeable about the probability of an industrial accident leading to a forest fire.

Through the review of the relevant guidelines and the pertinent research literature the following mechanisms of interaction are identified:
<u>Mechanisms of interactions</u>:

- **Cascading**/Domino/concatenated: one event triggering another
- **Coupled events (conjoint)** : different hazards triggered by the same triggering event (tropical storm triggers flash floods and/or debris flow)
- **Independent**: events occur independently but nearly simultaneously, but in close (short space) time or near space →close proximity. Triggering with some time-lag. This case affects vulnerability
- **Dynamic vulnerability**: Independent without chronological coincidence but threaten the same elements. This case also affects vulnerability.
- **Dynamic hazard**: Independent hazards without chronological coincidence but the occurrence of one hazard significantly influences the probability of other hazard occurring (earthquake, weaken slope soil and increase probability of landslide).

The identification of the hazard scenarios is carried-out using matrix to establish the presence of any of those mechanisms. Using the matrix, several cascading events are identified as well as events related with dynamic vulnerability and dynamic hazard. From these events, some will be selected to be included in the NRA.
Such scenarios under examination can include:

1. earthquake→tsunami (→coastal erosion)
2. industrial failure/explosion, e.g. Vasilikos → marine pollution
3. earthquake→floods (due to dam failure)
4. water scarcity →fires

HAZARDS	**Earth-quake**	**Tsunami**	**Floods**	**Water scarcity**	**Tech. accidents**	**Fires**	**SLR-Coastal erosion**	**Marine pollution**
Earthquake	Dynamic vulnerabil	Casca ding	casca ding	----	casca ding	---	---	casca ding
Tsunami	Caused by	---	---	----	casca ding	---	Cascadi ng	casca ding
Floods	Caused by, dam	----	----	---	----	----	----	casca ding
Water scarcity	---	---	---	---	---	Dyn. Haz.	---	---
Tech. accidents	---	---	---	---	---	---	---	casca ding
Fires	---	---	---	---	---	Dyn. Vuln	---	---
SLR-coastal erosion	---	---	---	---	---	---	---	---
Marine pollution	---	---	---	---	---	---	---	---

12. Risk Matrix

In this chapter, the data and information collected from previous chapters are processed in order to develop an integrated risk matrix including all hazards and their subsequent consequences for a selected hazard scenario. The consequences are estimated and quantified through an impact analysis based on defined criteria and indicators.

For risk assessments, the relevant EU guidelines state that "*always all three categories of impact should be considered*", namely the:

1. **Human Impacts** (Units: number of affected people).
2. **Economics and environmental impacts** (Units: Euro), expressed in monetary terms and includes all the hazard induced associated costs/expenses such as healthcare, buildings restoration, environmental costs etc.
3. **Political/social impacts**, (Units: expressed in semi-quantitative 5 stage-scale because it cannot be measured in single units), considers situations such as public outrage and unrest etc.

The impacts can be directly presented separately for each category or they can be combined to present all considered impacts in an integrated format. Consequently risk matrices can be available in a single integrated format or three singular (disaggregated) format; the latter approach is desired/ideal for the EU Commission as allow for comparison between the NRA of the Member States (MS).

The integrated risk matrix is combining the impacts of each hazard so that the developed scenarios are compared and evaluated against each other. Therefore the integrated risk matrix aims to provide a comparative representation of the identified scenarios caused by the different hazards.

To achieve this comparative representation, a procedure involving impact and likelihood categories is designed and applied for all hazards. Impact criteria are defined and every hazard scenario identified in the related chapter will be assessed against these criteria. For every hazard, three (3) scenarios are identified and selected (from the range of possible scenarios) having different limits /types for the comparison to be meaningful (some scenario can co-exist, i.e. the expected scenario can represent either worst or better scenario, or even both):

- ❖ Worst scenario-Plausible with upper risk limit/level: assessed considering both impact and likelihood, i.e. risk. If there are many scenarios select the one with highest risk
- ❖ Expected scenario-the scenario to be considered (to be prepared for)-
- ❖ Best case/mild scenario-Plausible with lower risk limit

The developed risk matrices for this study will represent the expected scenario.

12.1 Impact criteria

The criteria that will be used for the impact analysis in this NRA are listed in table 12.1. The criteria describe consequences in the Human (H), Economy (EC), Environmental (EN) and Social/Political (SP) categories. The criteria will quantify the impact using the indicators presented in Tables 12.2-12.9. Based on the values of the indicators the impact of each criterion is assigned a label, ranging from A to E. The associated description for each label is shown in Table 12.1 and characterise *limited* (A) to *catastrophic* (E) impacts. The Human related criteria are used to describe the number of fatalities and injuries (H1) and the number of people that must relocated or evacuated (H2) an area after the hazard scenario is occurring. The economy criterion (EC) expressed in euros, is the summation of individual costs for damage on properties, cultural heritage and infrastructure as well as cost for disruption of economy activity; any other costs (eg. Environmental cost that can be quantified in monetary terms is included here) are included in the "*other specific cost*" indicator. The impact on the environment (EN) is expressed in polluted area and duration of the polluting source. The Social/Political criteria considers damage to critical infrastructures (SP1) and disruption of everyday life needs (SP2) in terms of number and duration of interruption and the social impact (SP3) in qualitative terms.

Table 12.1 Established criteria for each impact category

Description	Limited	Considerable/ substantial	Serious	Very serious	Catastrophic
	A	B	C	D	E

Impact category	**Criterion**	A	B	C	D	E
HUMAN→Numbers	**H1**: Fatalities and injuries					
	H2: People Relocation/evacuation					
ECONOMY→ **EC1**: Summation of individual Assets costs (€) for the following indicators:	→ **EC**: Assets costs (€) Indicators:					
	a)Property damage: repairs/restoration for buildings/coast/environment etc; materials					
	b)Cultural heritage damage					
	c)Infrastructure damage: roads, bridges, energy/technology plants etc.					
	d)Disruption of economic activity: e.g. tourism					
	e)Other specific cost					
ENVIRONMENTAL →Polluted area (sq km) and event duration	**EN**: Environmental damage					
SOCIAL-POLITICAL→Number and duration of disrupted functions	**SP1**:damage (interruption/shutdown) of critical infrastructures					
	SP2: everyday life/needs disruption-societal functionality: traffic flow; normal activities (school, work)					
	SP3: social impact= public order and safety; psychological implications; anxiety					

12.2 Impact Indicators: values/scale

For every criterion listed in Table 12.1 specific indicators are defined, so that the impact is quantified. For the classification of indicators' categories, vulnerability and exposure is incorporated in the estimations. The values for the indicators' categories are representative for the standards of Cyprus and are based on existing data and experts opinion whereas necessary.

Impact category: HUMAN

The H1 criterion describes fatalities and two types of injured persons: light injured that are treated on site and released and serious injured that required immediate hospital care.

Table 12.2 Indicators for criterion H1

H1: Fatalities (F) and Injuries (I) [Light (LI) and Serious (SI)]					
Indicator-number	Zero F and SI, LI<5	Zero F, SI≤5 , LI 5-20	F≤2, SI 6-20, LI=21-50	F= 3-10, SI=20-50 and LI 51-100	F>10 SI>50 LI>100
	A	B	C	D	E

*seriously injured: immediate hospital care

For relocated/evacuated persons, two-entry matrix is used to account for the number of affected people and the duration of the relocation act.

Table 12.3 Indicators for criterion H2

H2: Relocation/Evacuation					
Number→ Duration ↓	<50	51<200	201<500	501<2000	>2000
Up to 1 week	A	A	B	B	C
Up to 1 month	A	B	B	C	D
1-6 month	B	B	C	D	E
>6 month	B	C	C	D	E

Impact category: ECONOMY

The economy criterion EC is assigned a label considering the summation of costs (∑xi) of individual categories (X1 to X5) as previously explained and shown also in Table 12.4.

Table 12.4 Indicators for criterion EC

EC: Assets costs (€)					
Indicator-Total Value (€)	cost<1m	cost<10m	cost<100m	cost<500m	Cost>500m
	A	B	C	D	E
∑xi					
	Property damage	Cult. heritage	Infrastructure	Economic activity	Other: e.g. environmental
Costs→	X1	X2	X3	X4	X5

Impact category: ENVIRONMENTAL

The environmental criterion EN considers the area that is polluted/damaged and the duration of the harmful event.

Table 12.5 Indicators for criterion EN

EN: Environmental Damage					
Area (sq km)→ Duration ↓	<1	1-2	2-5	5-10	>10
D<1 day	A	A	A	B	C
1<D<2 days	A	B	B	B	C
2<D<4 days	A	B	C	D	D
4-7 days	B	C	C	D	E
>1 week	B	C	D	E	E

To distinguish the severity of different events and quantify more realistically the occurred damage, Table 12.6 act as a supporting tool for the estimation made using the Table 12.5 above, e.g. a fire and a flood having the same duration are damaging the same area; the restoration of the burned area is different to that of the flooded area and should be considered. Using this table, for the zero (0) cells no action is required, for the +1 cells the label of Table 12.5 is increased by one (eg. B→C) and for the +2 cells the label is increased by 2 (eg. B→D).

Table 12.6 Indicators for criterion EN*

Supporting EN*: Environmental restoration					
Cost → Duration ↓	<100k	1-300k	3-500	2mil	>2 mil
D<6 mths	0	0	0	0	0
6mths<D<1 yr	0	0	0	0	0
1yr<D<5 yrs	0	0	0	+1	+1
5-10 yrs	0	0	0	+1	+2
>10 yrs	0	0	+1	+2	+2

Impact category: SOCIAL/POLITICAL

The Social/Political criteria represent the number of damaged critical infrastructures and the effect on societal functionality in quantitative terms. On the other hand, the social impact is expressed in qualitative terms.

Table 12.7 Indicators for criterion SP1

SP1: Damage to critical infrastructures					
Number→ Duration ↓	1	2	3	4	≥5
D<1 day	A	A	A	B	C
1<D<6 days	A	B	B	B	C
1-2 week	A	B	C	D	D
2 weeks-1 month	B	C	C	D	E
>month	B	C	D	E	E

*= +1 category if affects more than ½ of the country's territory

Table 12.8 Indicators for criterion SP2

SP2: Disruption to everyday needs (societal functionality)					
Number→ Duration ↓	1	2	3	4	≥5
D<1 day	A	A	A	B	C
1<D<6 days	A	B	B	B	C
1-2 week	A	B	C	D	D
2 weeks-1 month	B	C	C	D	E
>month	B	C	D	E	E

Table 12.9 Indicators for criterion SP3

SP3: Social impact					
Description	Very low	Low	Moderate	High	Very high
	A	B	C	D	E

12.3 Probability/Likelihood of occurrence: categories and values/scale

This section is dealing with the probability/likelihood of occurrence of the hazard scenarios and the breakdown into scales. These scales are based on historical data related with Cyprus as well as with values used in the NRA of other countries. The selected categories are ranging from very unlikely likelihood → very likely likelihood or similarly to very low probability → very high probability of low; medium; high; very high. For the predefined hazard, no time horizon has been set for occurrence. To attain a comparative nature to the different scenarios, the probability that any hazard scenario will occur within a year is used.

Table 12.10 Probability of occurrence scales

Likelihood	Very unlikely	unlikely	possible	likely	Very likely
Probability,p(NH)	Very low	Low	Medium	High	Very high
	1	**2**	**3**	**4**	**5**
p(NH) per year, %	P<0.67	0.67-2	2-10	10-50	>50
Frequency: 1 event…	… in more than 150 yrs	… in 50 to 150 yrs	…in 10 to 50 yrs	…in 2 to 10 yrs	At least every 2 yrs

The determination of the likelihood should also consider the exposure and vulnerability of the potential target(s) and for this reason the Table 12.11 is developed. Similarly as before, +1, means , one category up, from 3→4 and -1 one category down, 4→3.

Table 12.11 Supporting tool for probability of occurrence

Exposure→ vulnerability↓	Low	Medium	high
Low	-1	-1	0
Medium	-1	0	+1
high	0 (or +1)	+1	+1

12.4 Integrated Risk Matrix and Singular Risk Matrices

For the development of the risk matrices, the impact score and the probability of occurrence of every hazard scenario is needed. For the calculation of the impact score the following procedure is used:

Impact score calculation procedure:

1. Each hazard scenario is assessed against each of the seven criteria
2. An impact score is determined for every criterion using the relevant indicators
3. The individual scores are aggregated to produce an overall impact score for the examined hazard scenario. All impact categories are considered equally important and thus they have equal weighting in the aggregation. For the aggregation, a linear value function is used, e.g. the labels (A→E) are represented by numerical values, 1→5 respectively, e.g. label A is 1 etc.
4. For each scenario, the probability of occurrence is selected.

The hazard scenarios analysed and presented in this study are summarised in Table 12.12 and represent the *expected case* as this explained in the aforementioned sections.

Table 12.12. Summary of hazard scenarios

No	Hazard	Description
1	Earthquake	The earthquake with 50y return period
2	Floods	Pediaios river flooding in the district of Nicosia; 20 yrs return period
3	Water scarcity	This compound scenario considers that a lower amount of rainfall will drop to the island by about 20%, and also the highest scenarios for population growth and tourist demand will appear.
4	Large scale technological accidents	#B Pool fire in bund area (ELPE)
5	Fires in forest	According to historical data, there is one such fire every 8-10 years.
6	Coastal erosion	Coastal erosion on Larnaca Bay affected also by sea level rise
7	Marine pollution	Oil spill due to tanker damage

Data collection

The collected data used in the impact analysis are shown in the following tables for each hazard scenario developed. The data has been used to develop the risk matrix through processing and analysis of the impact and the probability of occurrence. Every table is accompanied by a graph, which depict the impact scores listed in the tables. The graph illustrates, which impact criterion influence more the impact of the hazard.

Table 12.13 Input data of Impact analysis for earthquake										
EARTHQUAKE - Probability of occurrence: 3										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number		C→3						
	H2: People Relocation/evacuation	number		B→2						5
ECONOMY	→ **EC1**: Assets costs (€)	Euro		C→3						3
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		A→1						1
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		C→3						
	SP2: everyday life/needs disruption	Number, duration		B→2						
	SP3: social impact	qualitative		B→2						7

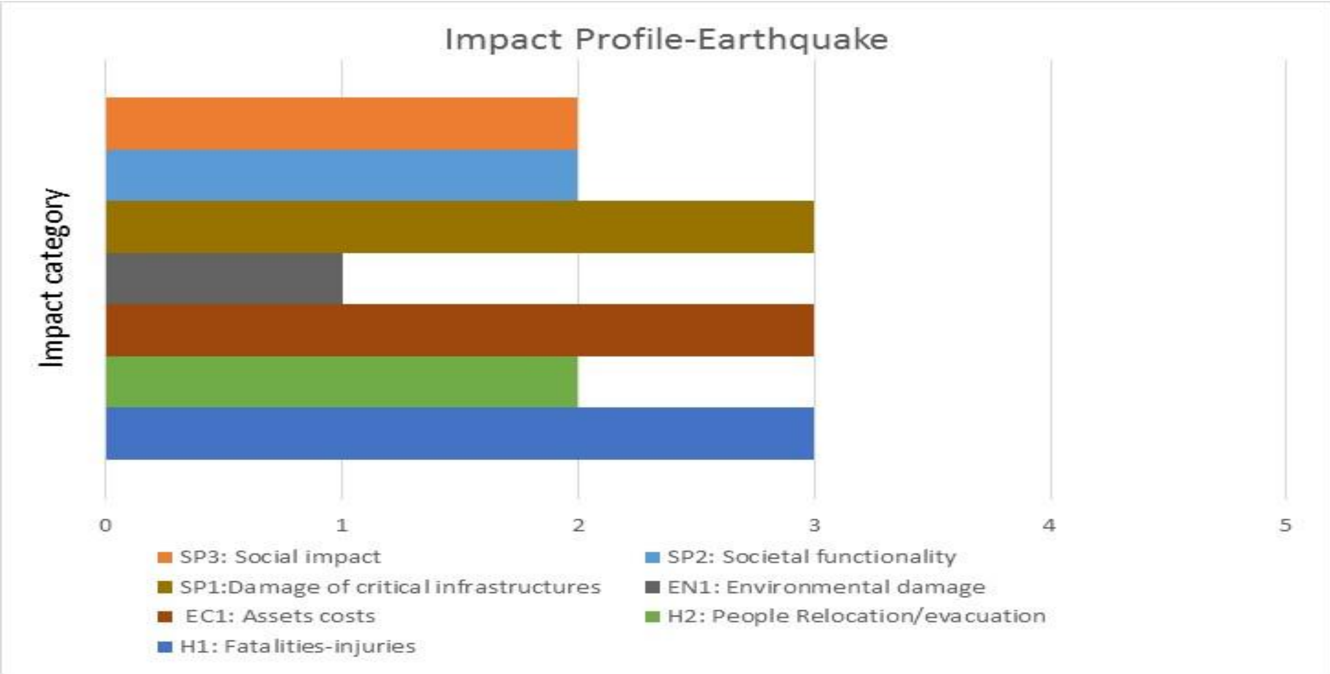

Impact Profile-Earthquake
Impact category
0
1
2
3
4
5
SP3: Social impact
SP2: Societal functionality
SP1:Damage of critical infrastructures
EN1: Environmental damage
EC1: Assets costs
H2: People Relocation/evacuation
H1: Fatalities-injuries

Table 12.14 Input data of Impact analysis for floods

FLOODS. -Probability of occurrence: 3										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number		D→3						
	H2: People Relocation/evacuation	number		B→2						5
ECONOMY	→ **EC1**: Assets costs (€)	Euro		B→2						2
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		B→2						2
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		B→2						
	SP2: everyday life/needs disruption	Number, duration		B→2						
	SP3: social impact	qualitative		B→2						6

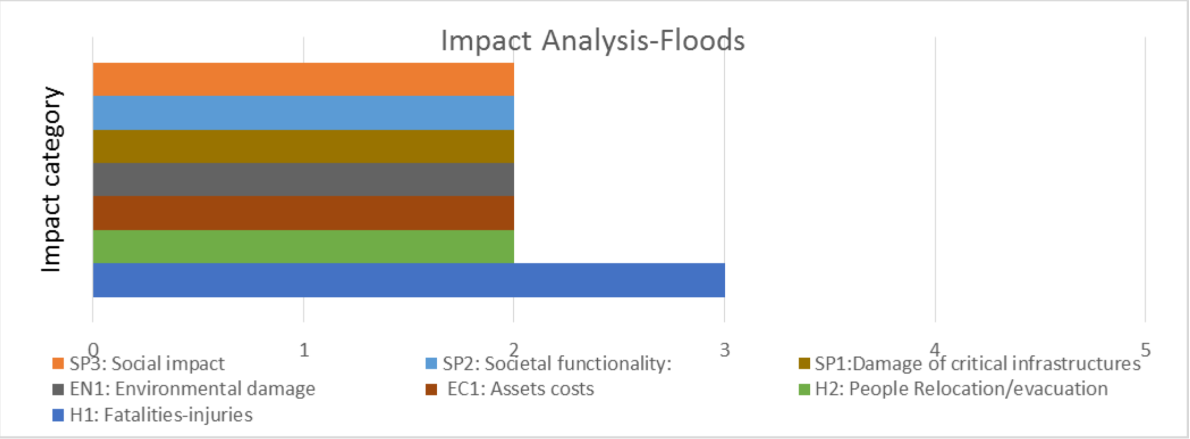


Table 12.15 Input data of Impact analysis for water scarcity

WATER SCARCITY. -Probability of occurrence: 2										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number	F=5	A→1						
	H2: People Relocation/evacuation	number		A→1						2
ECONOMY	→ **EC1**: Assets costs (€)	Euro		C→3						3
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		C→3						3
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		B→2						
	SP2: everyday life/needs disruption	Number, duration		C→3						
	SP3: social impact	qualitative		A→1						7

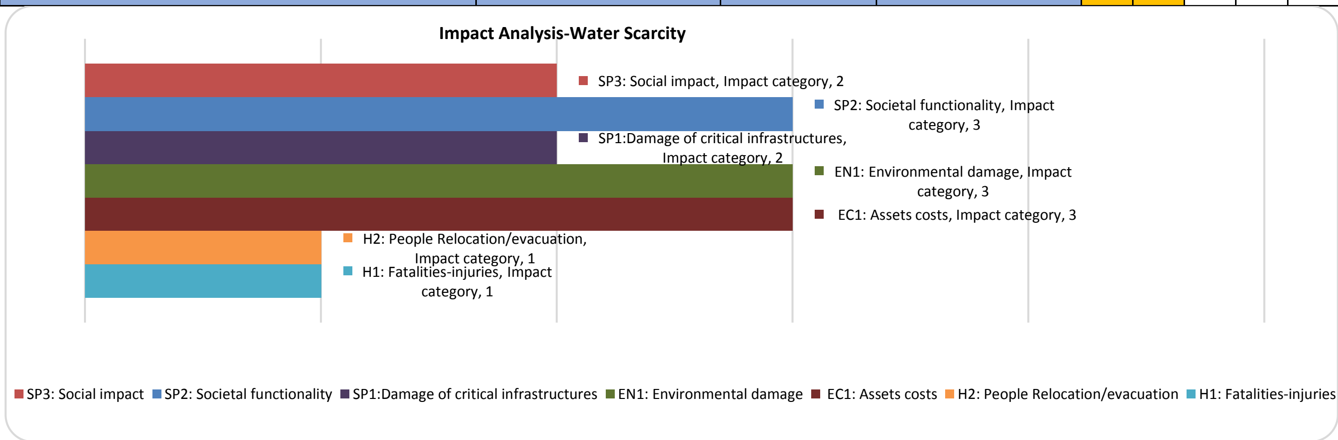


Table 12.16 Input data of Impact analysis for technological accidents

TECHNOLOGICAL ACCIDENTS. - Probability of occurrence: 1										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number	F=5	B→2						
	H2: People Relocation/evacuation	number		A→1						
ECONOMY	→ **EC1**: Assets costs (€)	Euro		C→3						
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		B→2						
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		B→2						
	SP2: everyday life/needs disruption	Number, duration		A→1						
	SP3: social impact	qualitative		A→1						

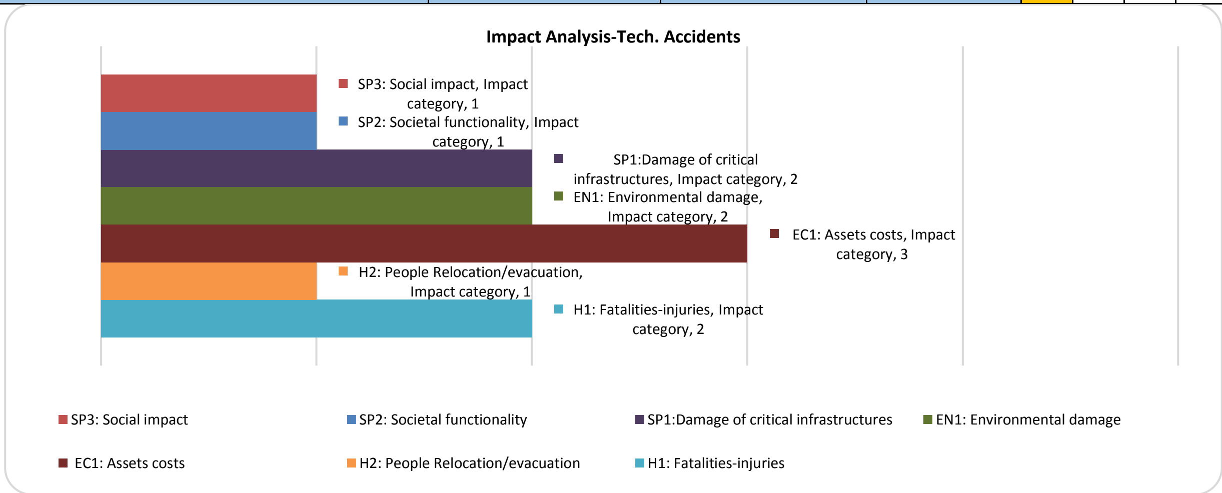


Table 12.17 Input data of Impact analysis for fires

FIRES. -Probability of occurrence: 4										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number	F=	B→2						
	H2: People Relocation/evacuation	number		B→2						4
ECONOMY	→ **EC1**: Assets costs (€)	Euro		C→3						3
	a)Property damage:	Euro		B→2						
	b)Cultural heritage	Euro		B→2						
	c)Infrastructure:	Euro		B→2						
	d)Disruption of economic activity	Euro		C→3						
	e)Other specific cost	Euro		B→2						
ENVIRONMENT	**EN1**: Environmental damage	sq km		D--4						4
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		B→2						
	SP2: everyday life/needs disruption	Number, duration		B→2						
	SP3: social impact	qualitative		B→2						6

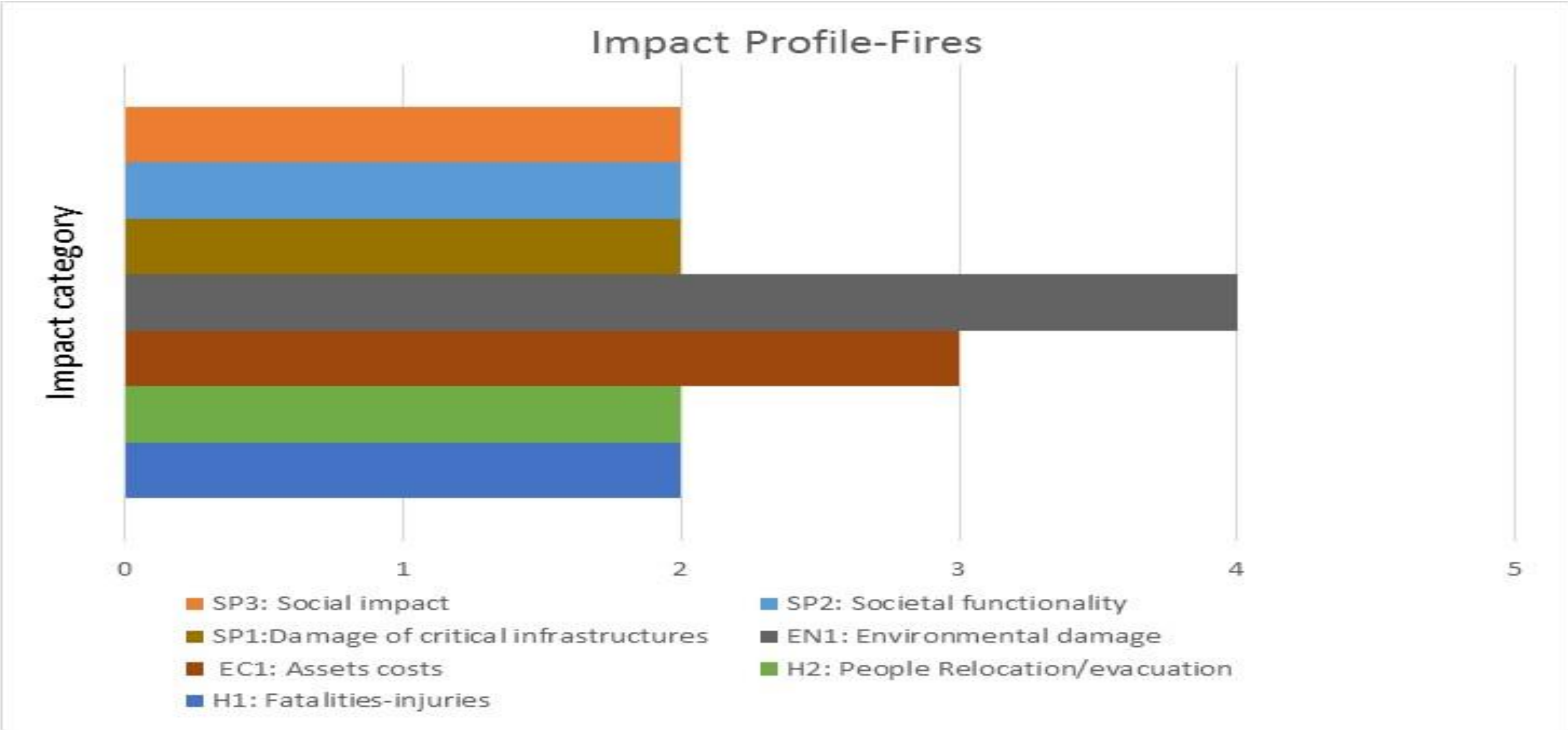

Impact Profile-Fires
Impact category
0
1
2
3
4
5
SP3: Social impact
SP2: Societal functionality
SP1:Damage of critical infrastructures
EN1: Environmental damage
EC1: Assets costs
H2: People Relocation/evacuation
H1: Fatalities-injuries

Table 12.18 Input data of Impact analysis for SLR and coastal erosion

SEA LEVEL RISE & COASTAL EROSION. -Probability of occurrence: 4										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number		A→1						
	H2: People Relocation/evacuation	number		A→1						2
ECONOMY	→ **EC1**: Assets costs (€)	Euro		A→1						1
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		E→5						5
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		A→1						
	SP2: everyday life/needs disruption	Number, duration		A→1						
	SP3: social impact	qualitative		A→1						3

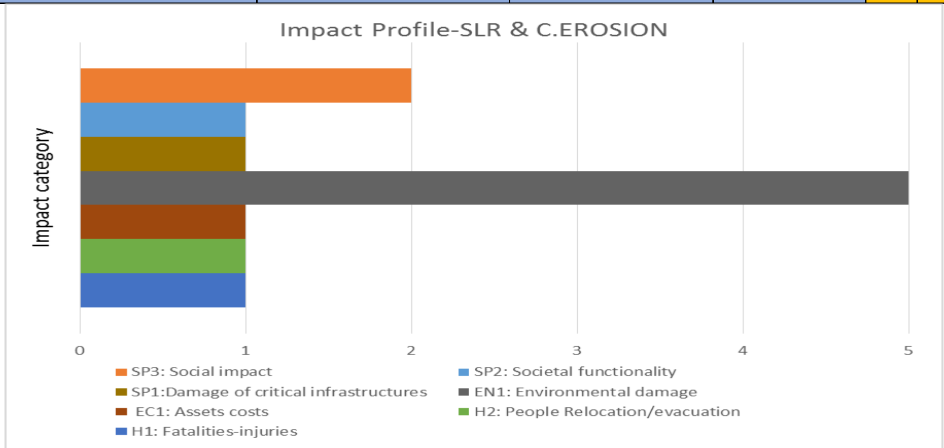
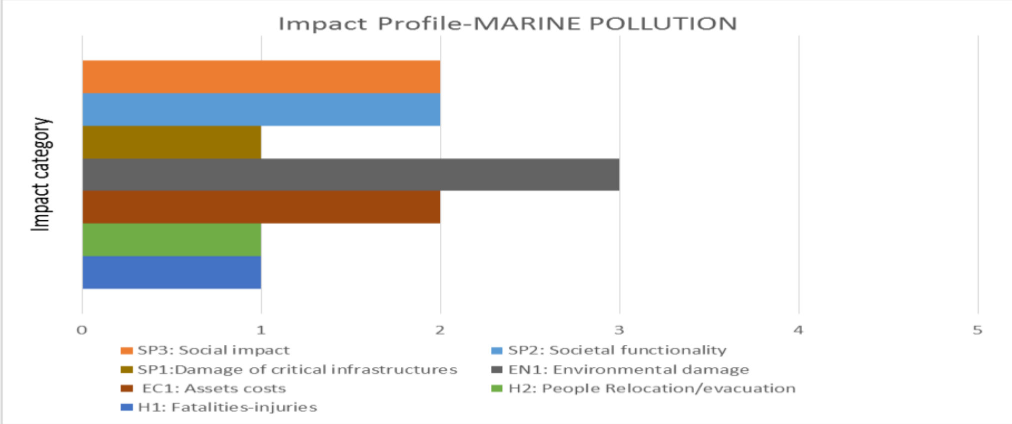


Table 12.19 Input data of Impact analysis for marine pollution

MARINE POLLUTION -Probability of occurrence: 3										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number		A→1						
	H2: People Relocation/evacuation	number		A→1						2
ECONOMY	→ **EC1**: Assets costs (€)	Euro		B→2						2
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		C→3						3
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		A→1						
	SP2: everyday life/needs disruption	Number, duration		B→2						
	SP3: social impact	qualitative		B→2						5



12.4.1 Integrated Risk Matrix

Using the overall impact value (**I**) and the probability of hazard occurrence (**p_h**) for each hazard scenario, the risk matrix is developed based on the risk level, which is calculated as **$r=I*p_h$**. Therefore the minimum risk level is 1 and the maximum risk level can be 25. The risk zones are defined as follow:

- $1<r\leq6$, Low risk (green colour in matrices)
- $6<r\leq15$, Medium risk (yellow colour in matrices)
- $15<r\leq25$, High risk (red colour in matrices)

The risk levels of the examined expected scenarios caused by the seven (7) hazards are listed and plotted in Figure 12.1 below. All hazard scenarios are characterised as medium to low risk: fires have the highest risk level, followed by earthquakes, SLR/coastal erosion and floods. The lowest risk is associated with technological accidents.

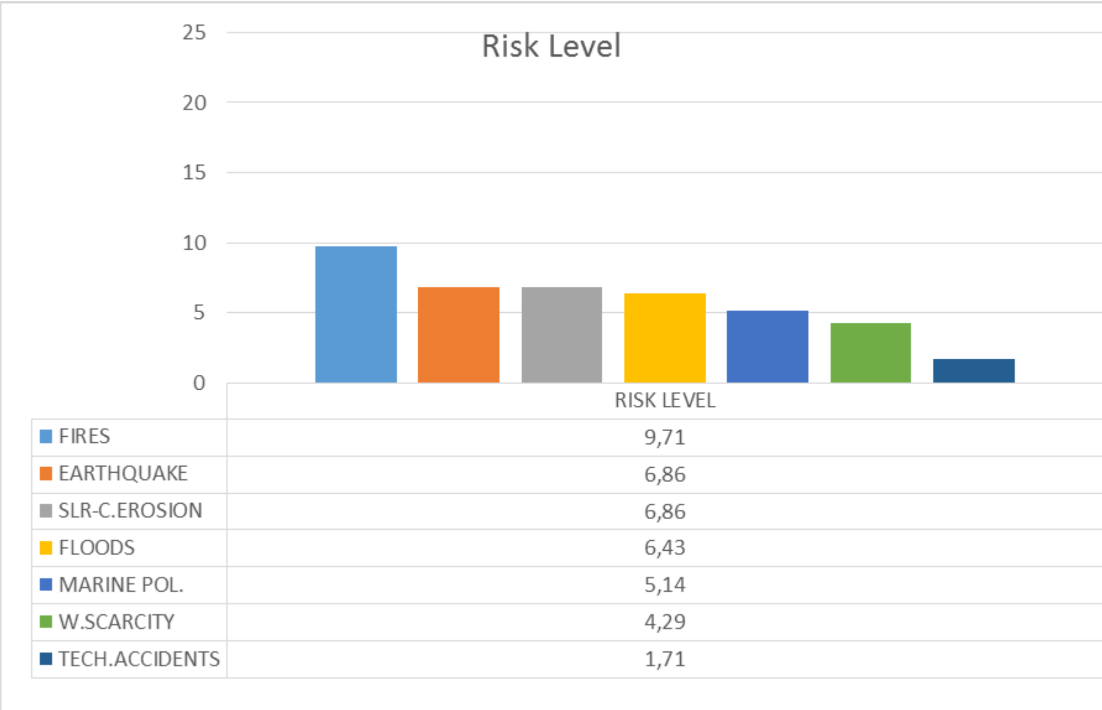


Figure 12.1 Risk levels

These results are used to develop the integrated risk matrix. The developed scenarios have medium to low risk considering the expected case scenarios. The scenarios with medium risk level lie in the yellow zone, whereas the green zone describe scenarios with lower risk levels.

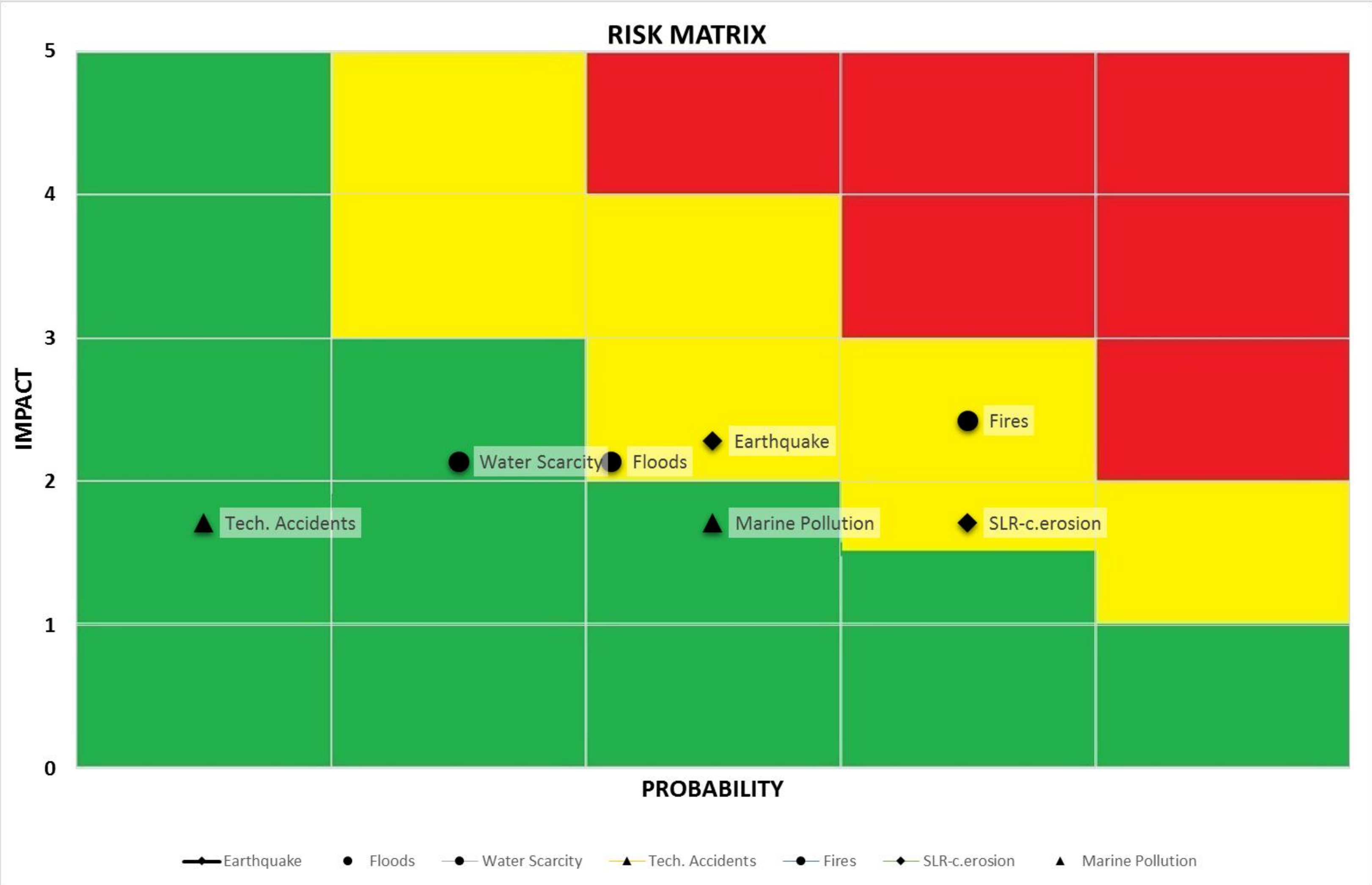


Figure 12.2 Integrated risk matrix for the expected case hazard scenarios

12.4.2 Singular Risk Matrices

In addition to the integrated risk matrix, singular matrices (disaggregated format) have been developed for 1) Human impact, 2) Economic impact, 3) Environmental impact and 4) Social/Political impact. These matrices are depicted in the subsequent graphs of Figures 12.3-12.6.

Risk Matrix for Human Impact

Considering only the human impact, the scenarios with the higher score are for fires, earthquakes and floods, i.e. it is expected that these scenarios will cause the greatest fatalities and injuries to the population.

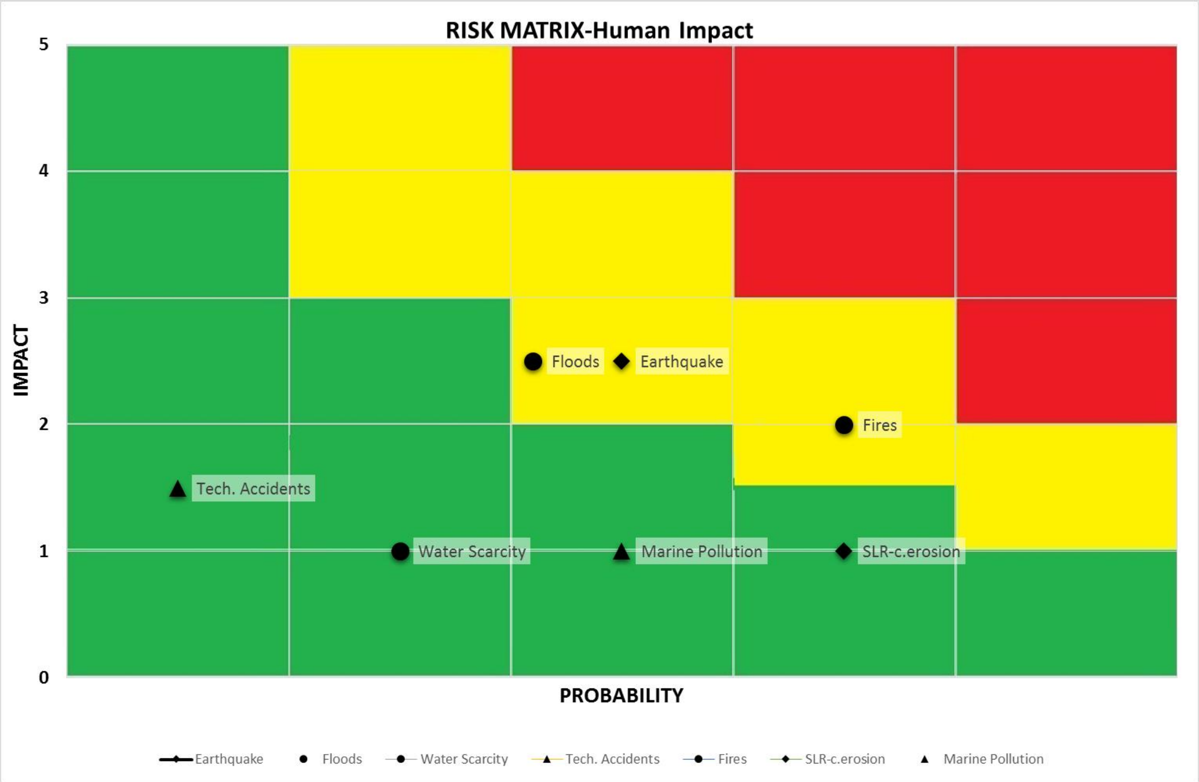


Figure 12.3 Risk matrix for Human Impact

Risk Matrix for Economic Impact

For the case whereas only the impact on economy is considered, the higher score is for the fire scenario, followed by earthquakes. Floods, water scarcity and marine pollution also reach medium level risk.

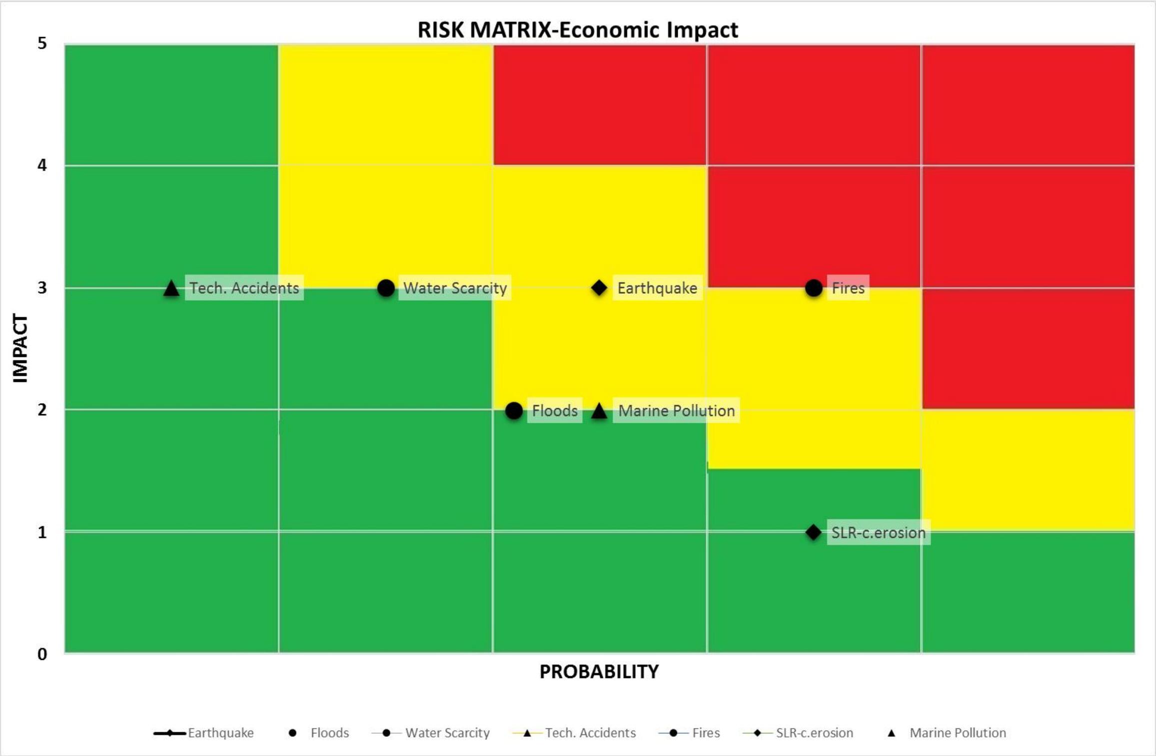


Figure 12.4 Risk matrix for Economic Impact

Risk Matrix for Environmental Impact

Considering only the environmental impact, it is the only case that some scenarios reach high risk level: the higher risk level is for sea-level-rise and coastal erosion followed by fires in the forest. Also medium risk level is reached for the scenario of marine pollution. It is obvious that scenarios related directly with the natural environment (sea and forests) are affected the most. Earthquakes although poses a significant threat in other impact categories, has a low risk level when the natural environment is addressed.

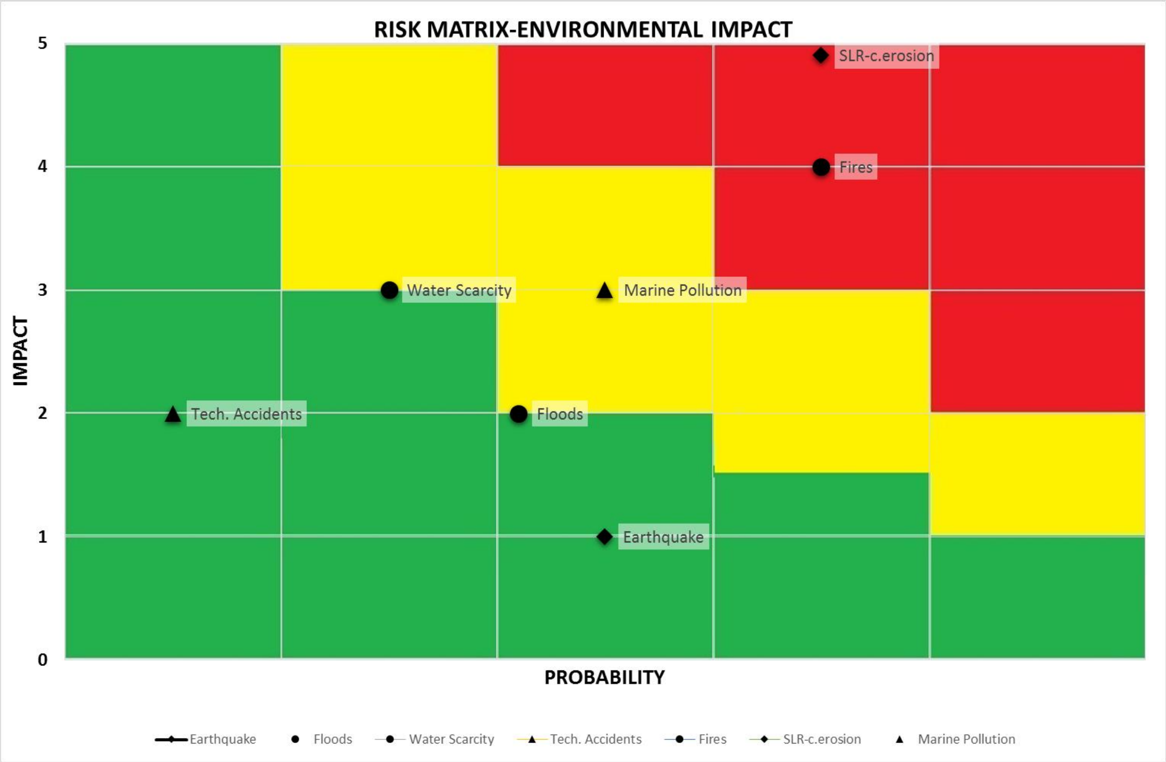


Figure 12.5 Risk matrix for Environmental Impact

Risk Matrix for Social/Political Impact

The results for social/political impact are shown in the figure below. The impact for this category has been qualitatively evaluated. The scenarios involving fires and earthquakes poses the higher risk level although belongs to the defined medium risk zones.

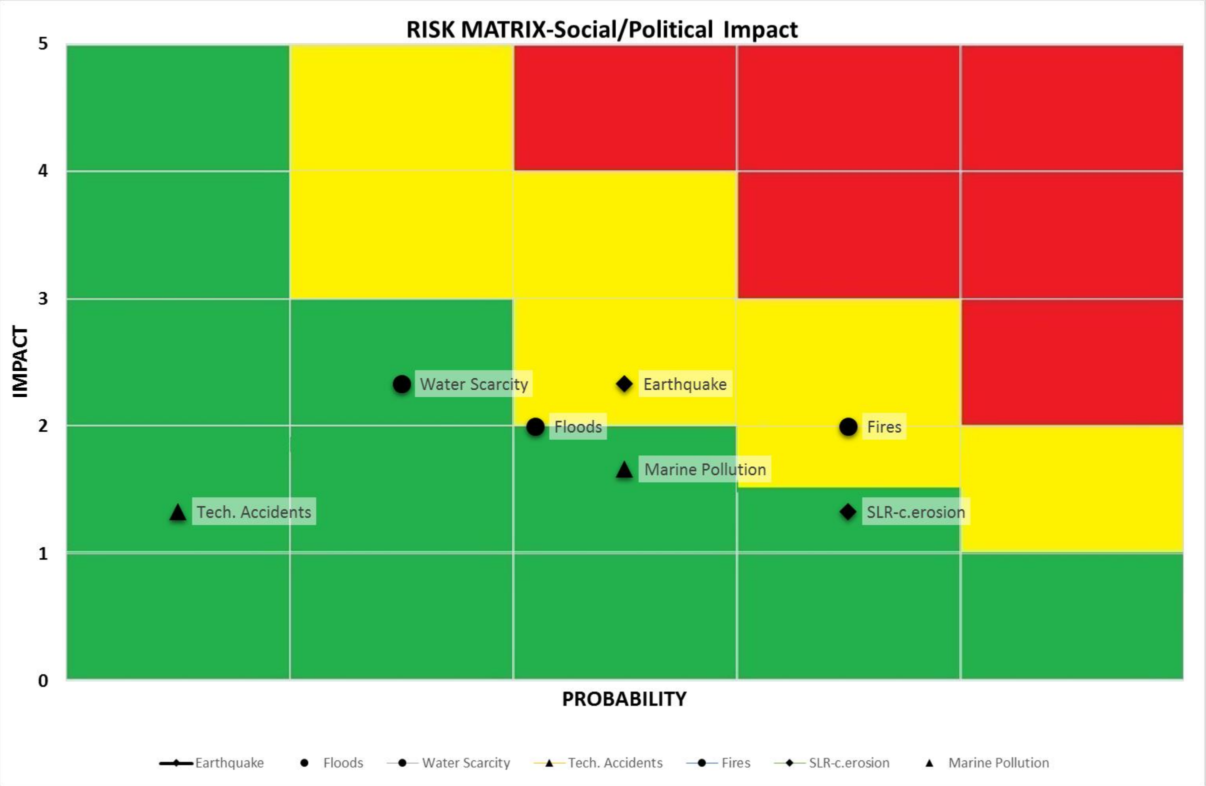


Figure 12.6 Risk matrix for Social/Political Impact

The result plotted in the singular risk matrices are also tabulated in Table 12.20. It can been seen that fires have overall the higher risk level considering all the categories followed by the earthquake, flood and SLR/coastal erosion scenarios. The lowest risk of the expected case scenarios is for the technological accidents.

Table 12.20 Risk levels summary for individual impacts

Human Risk level		**Economic Risk level**		**S/P Risk level**		**Environmental Risk level**	
Fires	8	Fires	12	Fires	8	SLR-C.Erosion	19,6
Earthquake	7,5	Earthquake	9	Earthquake	7	Fires	16
Floods	7,5	Floods	6	Floods	6	Marine pol.	9
SLR-C.Erosion	4	W.scarcity	6	SLR-C.Erosion	5	Floods	6
Marine pol.	3	Marine pol.	6	Marine pol.	5	W.scarcity	6
W.scarcity	2	SLR-C.Erosion	4	W.scarcity	4	Earthquake	3
Tech.Acci-dents	1,5	Tech.Acci-dents	3	Tech.Acci-dents	1,3	Tech.Accident s	2

12.4.3 Overall Impact Analysis

In this section the data from the impact analysis will be presented. The seven hazard scenarios have been assessed against seven impact criteria. Figure 12.7 shows the total impact exerted by each scenario (different colours show the contribution of each impact criterion in the total value). The greatest impact is caused by the fire scenario and secondly by the earthquake scenario. Considerable impacts are also caused by floods and water scarcity. In terms of total impact, marine pollution, SLR-coastal erosion and technological accidents have the same score although the individual criteria scores are different.

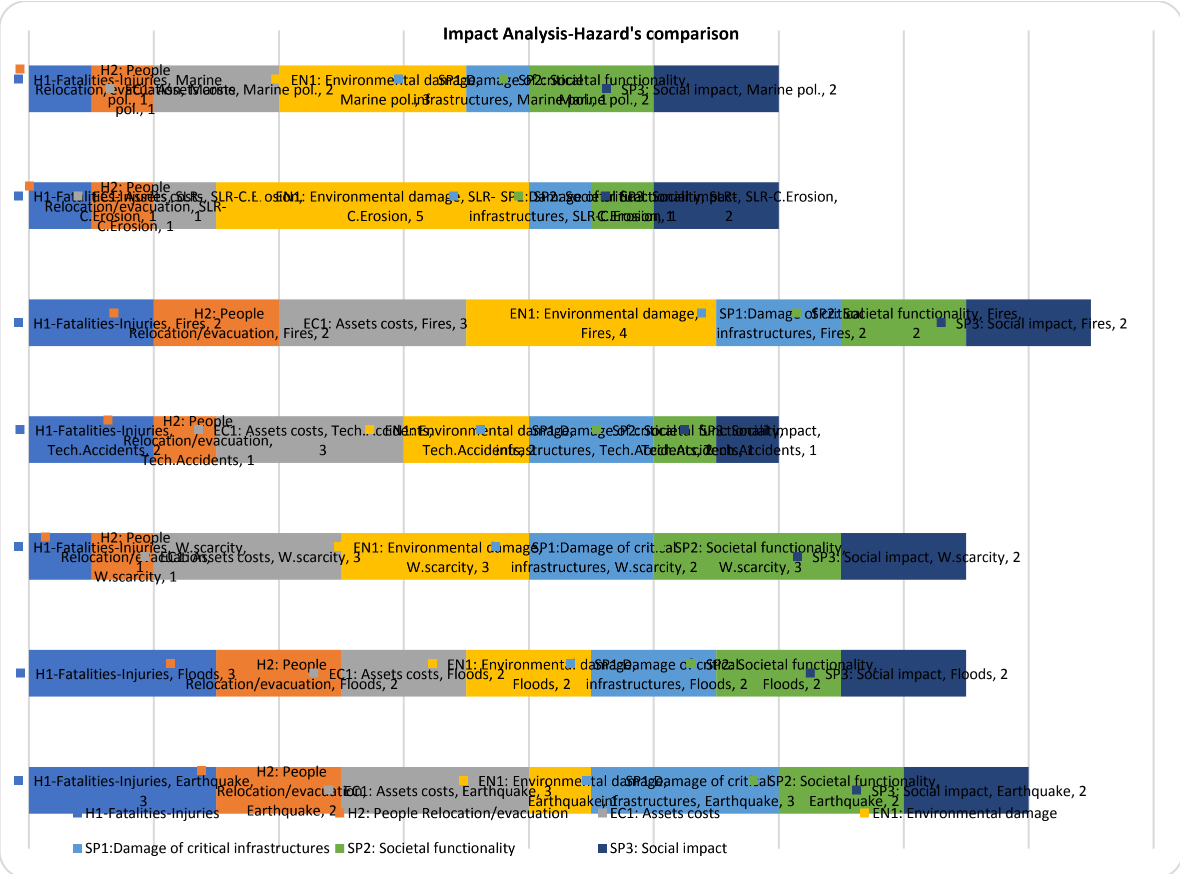


Figure 12.7 Overall Impact analysis

The total impact of each criterion, e.g. the sum of criterion H1 considering the seven hazard scenarios etc, is depicted in Figure 12.8. It can be seen that impacts on environment and economy are the leading impact receivers. Besides H2 (relocation/evacuation) the other criteria are having the same total impact. This trend is also illustrated in the enclosed target diagram. The criteria closer to the centre are receiving the greatest impact.

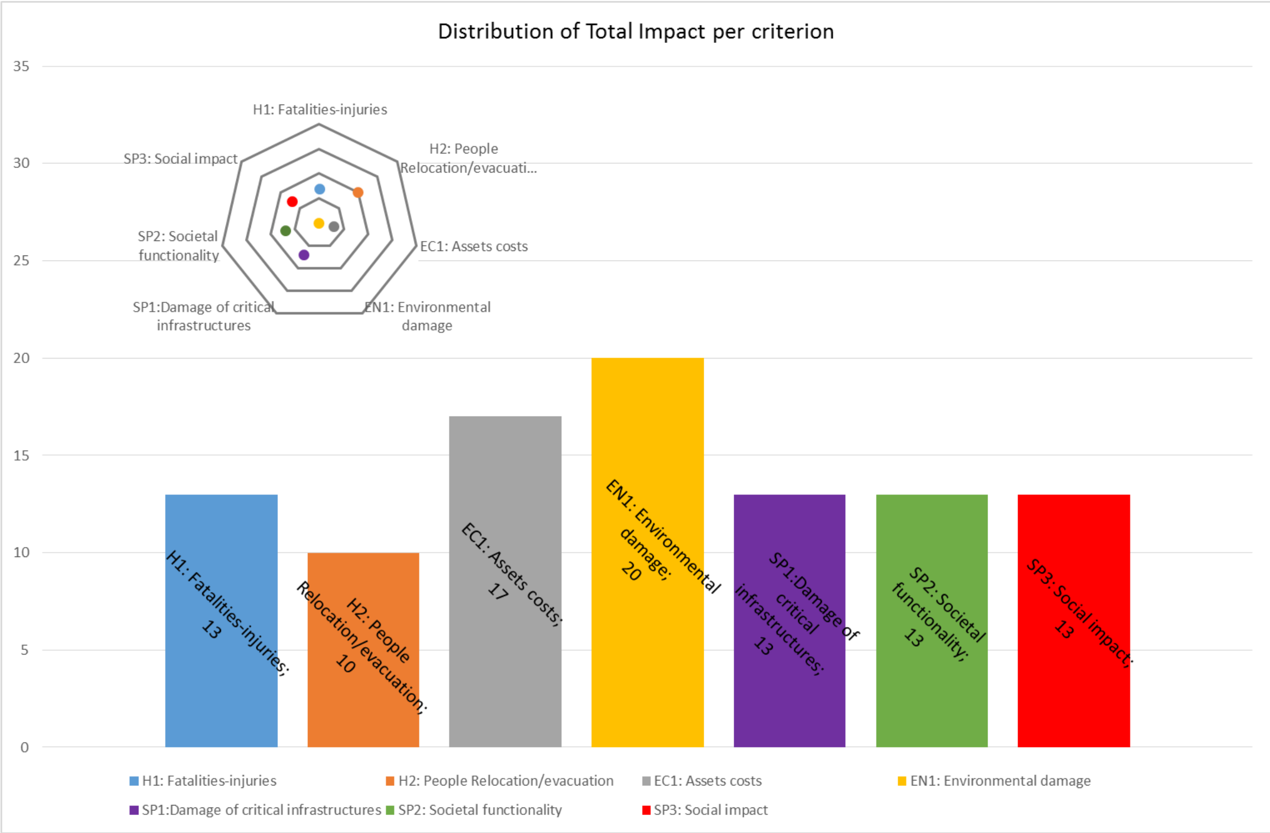


Figure 12.8 Distribution of Total Impact per criterion

Furthermore, the impact criterion having the maximum score in each scenario is identified and presented in Figure 12.9. The results show that earthquake and technological accidents affect mostly the economy, floods the humans, water scarcity affects equally economy and the environment and the remaining scenarios are affecting the environment.

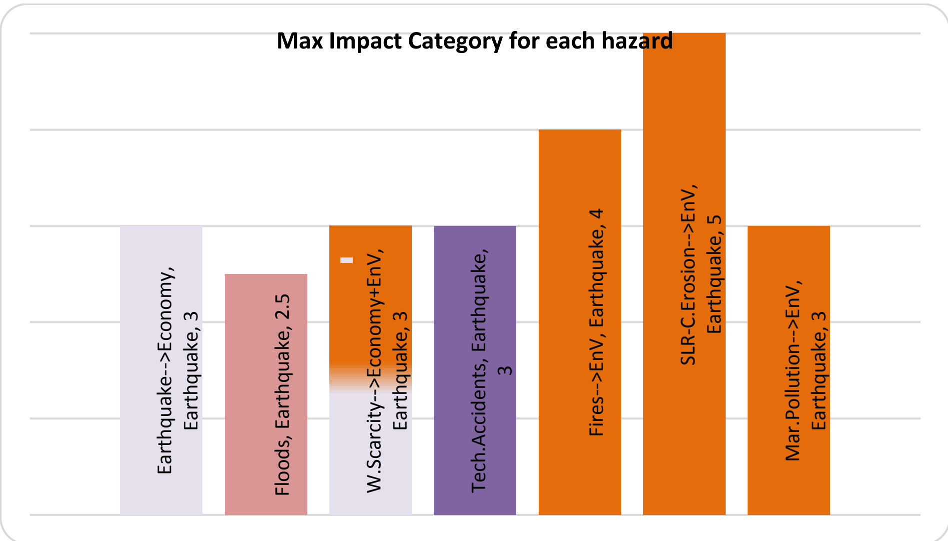


Figure 12.9 Maximum Impact criterion for each hazard

APPENDICES

Appendix 1: Climate Change Risk Assessment for the Health Sector
Appendix 2: Climate Change Risk Assessment for Land Desertification

CYPRUS GOVERNMENT
Ministry of Agriculture, Rural Development and Environment
Department of Environment
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Climate Change Risk Assessment

Contract No. 22/2014

Climate Change Risk Assessment for the Health Sector

Prepared by ADENS SA




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Revision Table

Version	Date	Comments
v.1	12.05.2016	Initial Version
v.2	27.07.2016	Correction in paragraphs 5.4, 6.2 & 7.3 (morbidity results)

Abbreviations

CC	Climate Change
CCRA	Climate Change Risk Assessment
CYSTAT	Statistical Service of Cyprus
EEA	European Environment Agency
EU	European Union
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
PM	Particulate Matter
YLL	Years of life lost

1. Introduction

• 1.1 Scope of this Report

The consultancy services scope, under the current Contract is to support the Ministry of Agriculture, Natural Resources and the Environment and in particular the Department of Environment, in order to implement successfully in the Republic of Cyprus, the decision of the Council of the EU and the Euro Parliament 1313/2013/EU and fulfil the obligation to publish the **1st Climate Change Risk Assessment (CCRA) in 2016 for Cyprus**.

The Department of Environment has a statutory role to advise Ministers on the preparation of the national CCRA. The Government will then produce the **revised National Adaptation Program** that will set out the policies and proposals to address the risks identified by the CCRA. The **Competent Administrations** will also set out their respective policies in response to the CCRA.

In order to ensure that the CCRA is able to consider how different risks act together in time and space, and how responses may mitigate different risks, an **Evidence Report** will be structured around chapters, based on particular economic, social and environmental systems where there are numerous interactions between the different risks considered, and/or similarities in the adaptation responses to the risks.

The CCRA will give an assessment of potential impacts (opportunities and threats) from climate change, focusing on how climate risks are likely to manifest themselves over the 21st century in the absence of action. For the 2016 **Evidence Report**, the Department of Environment will produce a focused report that will seek to address the following issues:

- Assess climate risks in the light of methods of assessment and knowledge of climate change impacts;

- A fuller assessment of how climate interacts with socio-economic factors and how these drivers of risk might change in the future, for example economic growth; population change; land-use change;
- How the effects of adaptation actions are likely to alter risk levels;
- Assess the magnitude of impact and the urgency of action needed for different threats and opportunities, as well as developing an understanding of the possible net effect of different risks acting together;
- Assess the uncertainties, limitations and confidence in the underlying evidence and analysis for different risks.

The **Evidence Report** will cover Cyprus and will be used to inform both the Cyprus Government and Competent Administrations on future priorities for adaptation policy.

This **Health Sector Report** is one of the twelve sector reports, which together form a key step in the process of developing the **Evidence Report**.

A list of climate change impacts in the Health sector was developed (the “Tier 1” list). There were too many impacts to be analysed within the time and resources available for the CCRA.

Hence, a selection of impacts for analysis was made (the 'Tier 2' list). This report covers the Tier 1 and Tier 2 lists, and the analysis undertaken to provide projections of the consequences of climate change. The analysis, based on the **UK CCRA methodology with minor adaptations**, included identification of risk metrics, development of response functions, an adaptive capacity assessment, competent authorities mapping and assessment of the magnitude of the risks. It required consultation with government departments to collect data and support the analysis [**1, 2**].

1.2 Background

According to the definitions given by the International Panel on Climate Change (IPCC), **Climate change** refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. The United Nations Framework Convention on Climate Change (UNFCCC) 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." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes [**3**].

IPCC defines **Risk** as the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. Thus, **Risk assessment** is the qualitative and/or quantitative scientific estimation of risks [**3**].

1.3 Overview of the Sector

According to the latest demographic report released from the statistical service of the Republic of Cyprus, the population of the Government controlled area was estimated at 847.000 at the end of 2014, compared to 858.000 at the end of 2013 recording a decrease of 1,3% [**4**]. The proportion of children below 15 decreased to 16,4% while the proportion of old-aged persons 65 and over increased to 14,6% in 2014, compared to 25,4% and 11,0% respectively in 1992 and 25,0% and 10,8% in 1982. There was a gradual increase in the proportion of old-aged persons and a decrease in the proportion of children demonstrating the ageing process. The proportion of persons aged 45-64 increased also, to 24,5% from 19,3% in 1992 and 17,6% in 1982 indicating an ageing of the working age population as well.

Given the fact that the percentage of the citizens above 65 years of age has increased from 12,7% in 2010 to 14,6% in 2013 and the crude birth rate has been reduced from 11,8 births per 1.000 population in 2010 to 10,9 births in 2014, Cyprus can be considered as a country with high aging population. This poses a serious challenge to the health and pension system of Cyprus (Table 1.1).

Table 1.1 General Demographic indicators of Cyprus [4]

Population at the end of the year (000's)	**2010**	**2011**	**2012**	**2013**	**2014**
Total	839,8	862,0	865,9	858,0	847,0
Males	408,8	419,0	421,0	417,5	411,8
Females	431,0	443,0	444,9	440,5	435,2
Population distribution by age (%)	**2010**	**2011**	**2012**	**2013**	**2014**
0-14 years	16,8	16,5	16,4	16,3	16,4
15-64 years	70,5	70,7	70,4	69,8	69,0
65+	12,7	12,8	13,2	13,9	14,6
Life expectancy at birth (years)	**2010**	**2011**	**2012**	**2013**	**2014**
Men	79,0	79,3	78,8	80,0	80,7

Women	83,7	83,0	83,2	84,8	84,5
Population change	**2010**	**2011**	**2012**	**2013**	**2014**
Annual growth rate (end year) %	2,5	2,6	0,5	-,0.9	1,3
Natural increase rate (per 1.000 population)	5,7	4,9	5,2	4,9	4,7
Net migration (number)	15.913	18.142	-629	-12.078	-15.000
Fertility	**2010**	**2011**	**2012**	**2013**	**2014**
Live births (number)	9.801	9.622	10.161	9.341	9.258
Crude birth rate (per 1.000 population)	11,8	11,3	11,8	10,8	10,9
Total fertility rate	1,44	1,35	1,39	1,30	1,31
Mortality	**2010**	**2011**	**2012**	**2013**	**2014**
Deaths (number)	5.103	5.504	5.665	5.141	5.250
Crude death rate (per 1.000 population)	6,2	6,5	6,6	6,0	6,2
Infant mortality rate (per 1.000 live births)	3,2	3,1	3,5	1,6	1,4

According to Eurostat, in 2014, 122,3 million people, or 24,4 % of the population in the European Union (28 countries) were at risk of poverty or social exclusion, compared with 24.5 % in 2013 [**5**]. This means that these people were at least in one of the following conditions:

- at-risk-of-poverty after social transfers (income poverty);
- severely materially deprived or
- living in households with very low work intensity.

In Cyprus, this number rose to 234.000 people or 27,4% of the population.

With a rate of 27,8 % in the EU-28, children were at greater risk of poverty or social exclusion in 2014 than the rest of the population in 20 of the 28 EU Member States. The situation was relatively better for children than adults in Cyprus (24,7%). The elderly faced a lower risk of poverty or social exclusion in 2014 than the overall population both at EU-28 level (17,8 % as opposed to 24,4 %) and in 23 out of the 28 EU Member States. The risk of poverty or social exclusion faced by people aged 65 or more in 2014 ranged from 6,4 % in Luxembourg to 47,8 % in Bulgaria. In Cyprus this risk rose to 27,2% (1,5 times the EU-28). These differences in the relative situation of the elderly, at the EU-28 level, depend on a number of factors including the features of the pension systems for current pensioners and the age and gender structure of the elderly population, since elderly women and the very old tend to face much higher risks in some countries [**5**]. In Cyprus, Andreou and Pashardes (2009) attribute this to the insufficient pension system of the private sector [**7**].

Table 1.2 People at risk of poverty or social exclusion by age and sex, % of total population [6]

Year	Total			Less than 18 years			From 18 to 64 years			65 years or over		
	EU-28	EU-27	Cyprus	EU-28	EU-27	Cyprus	EU-28	EU-27	Cyprus	EU-28	EU-27	Cyprus
2006	:	25,3	25,4	:	27,5	21,3	:	24,8	21,4	:	24,7	55,6
2007	:	24,4	25,2	:	26,4	20,8	:	23,8	21,1	:	24,4	55,6
2008	:	23,7	23,3	:	26,4	21,5	:	23,0	18,9	:	23,3	49,3
2009	:	23,3	23,5	:	26,5	20,2	:	22,8	19,9	:	21,7	48,6
2010	23,8	23,7	24,6	27,5	27,5	21,8	23,6	23,6	22,1	20,1	19,9	42,6
2011	24,3	24,2	24,6	27,2	27,2	23,4	24,4	24,4	22,1	20,4	20,3	39,8
2012	24,7	24,7	27,1	28,0	27,9	27,5	25,3	25,2	25,8	19,3	19,2	33,4
2013	24,6	24,5	27,8	27,7	27,7	27,7	25,4	25,4	28,2	18,2	18,1	26,1
2014	24,4	24,4	27,4	27,8	27,7	24,7	25,4	25,3	28,3	17,8	17,7	27,2

1.2 Overview of the healthcare system

The healthcare system of Cyprus consists of two parallel delivery systems: a public one and a private one.

The public system is exclusively financed by the state budget, with services provided through a network of hospitals and health centres directly controlled by the Ministry of Health. Public providers have the status of civil servants and are salaried employees. The private system is financed mostly by out-of-pocket payments and to some degree by Voluntary Health Insurance. Other minor health care delivery sub-systems include the Workers' Union schemes, which mostly provide primary care services, and the schemes offered by semi-state organizations such as the Cyprus Telecommunication Authority and the Electricity Authority of Cyprus. The first mostly have their own network of providers, while the second use private providers [**8**].

Health services in the public system are provided by **six (6) General hospitals** (Lefkosia General, Archb.Makarios III Lefkosia, Larnaka General Makarios III, General Ammochostos, Lemesos General and Pafos General), **four (4) specialist centres** (Thalassemia Centre, Cyprus Institute of Neurology and Genetics, Bank of Cyprus Oncology Centre and the Arodafnousa Palliative Care Centre), one (**1**) Mental Health Hospital (Athalassa Mental Health Hospital), **two (2)** small rural hospitals (Kyperounda and Polis), **38** health centres, as well as many sub-centres for primary services [**8, 9**].

The private sector is comprised of for-profit hospitals, polyclinics, clinics, diagnostic centres and independent practices. According to CYSTAT (2014 data) there are **73** private hospitals/clinics with 1.385 beds [**9**].

In 2014, hospital beds totalled 2.912. Of these 1.527 were operating in the public sector (of which 132 in Athalassa Mental Health Hospital) and 1.385 in the private sector [**9**].

The main actors in the health care system are the Ministry of Health, the Ministry of Finance, the Ministry of Labour, Welfare and Social Insurance and to a lesser degree the Ministries of Education and Culture, Defence, Energy, Commerce, Industry and Tourism, Agriculture, Rural Development and Environment. Professional associations also play an important role. These include the Cyprus Medical Association, the Cyprus Nurses and Midwives Association, the Union of Public Doctors and the Union of Public Nurses, the Pancyprian Association of Private Hospitals, the workers' union of Pancyprian Federation of Labour, Cyprus Workers' Confederation, and Democratic Labour Federation of Cyprus, and some voluntary organizations and NGOs. Some of these organizations are politically influential in the health care planning process [**8**].

As mentioned above, the public healthcare system in Cyprus consists of 6 general hospitals (Lefkosia General, Archb.Makarios III Lefkosia, Larnaka General Makarios III, General Ammochostos, Lemesos General and Pafos General) and 2 rural hospitals (Kyperounta and Polis).

During 2014, 78.573 patients were treated and discharged from the general hospitals, compared with 78.670 in 2013, recording a decrease of 0,1%. In addition 1.405 patients were treated and discharged from Kyperounta and Polis rural hospitals in 2014 compared to 1.499 in 2013, recording an decrease of 6,3% [**9**].

The number of patients that were treated and discharged from general hospitals increased from 2011 to 2012 (6,5% increase) and then decreased from 2012 to 2014 (2,1% decrease), whereas the corresponding number in rural hospitals increased every year from 2011 to 2014 (Table 1.3).

Table 1.3 Patients discharged by public hospitals, 2011-2013 [**9**]

Hospital	**2011**		**2012**		**2013**		**2014**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
General Hospitals	75.441	98,3	80.369	98,4	78.670	98,1	78.573	98,2
Rural Hospitals	1.315	1,7	1.341	1,6	1.449	1.9	1.405	1,8
Total	76.756		81.710		80.169		79.978	

In 2013, 58.250 patients were discharged by private clinics and hospitals (21.428 day cases), whilst in 2014 the number rose to 68.243 (21.085 day cases).

Table 1.4 shows the number of persons per doctor and hospital bed. The percentage of beds occupancy in general hospitals decreases over the years and they are higher than the bed occupancy in rural hospitals. Patients tend to stay longer in rural than in general hospitals; though, the length of stay decreases over the years. The total expenditures on health services lies between 6,4% and 6,8% of GDP over the years 2011 to 2014, which is lower than the corresponding percentage in all other EU countries.

Table 1.4 General health indicators of Cyprus [9]

	2011	**2012**	**2013**	**2014**
Persons per doctor	335	332	313	295
Persons per hospital bed	284	288	293	293
Bed occupancy in General Hospitals (%)	92,4	77,0	75,5	77,4

Average length of stay in General Hospitals (days)	5,3	4,7	4,7	4,8
Bed occupancy in Rural Hospitals (%)	66,6	47,5	50,8	47,1
Average length of stay in Rural Hospitals (days)	9,4	7,2	6,3	6,3
Total expenditures on health services (€mn) as % of GDP	6,8	6,6	6,7	6,4

The percentage of patients discharged from general or rural hospitals by disease category are presented in Figures 1.1 and 1.2. Number of cases with neoplasm in general hospital had a significant increase in 2014 (14% of all cases) compared to 2011 (5,4%) and 2012 (5,8%). Diseases with the greatest increases in rural hospitals are those of the circulatory (2011: 6,7%, 2012: 13,1%, 2013: 13,5%, 2014: 17,4%), respiratory (2011: 3,4%, 2012: 8,7%, 2013: 10,2%, 2014: 13%) and digestive system (2011: 4,9%, 2012: 8,3% , 2013: 9,3%, 2014: 10,7%).

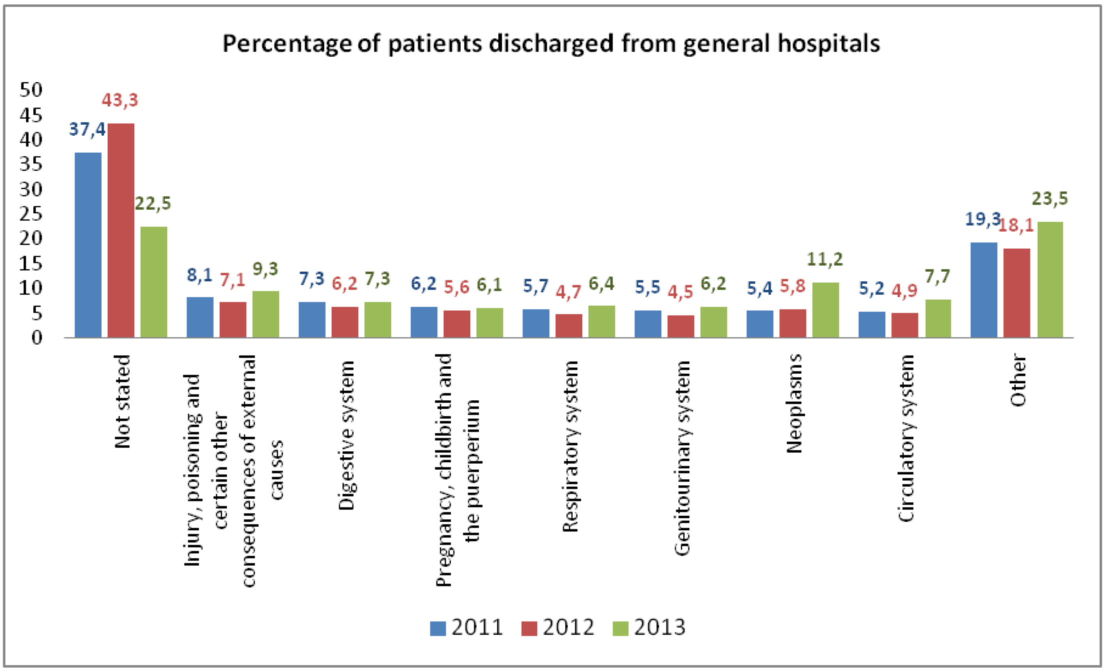


Figure 1.1 Percentage of cases discharged from general hospitals by disease category [9]

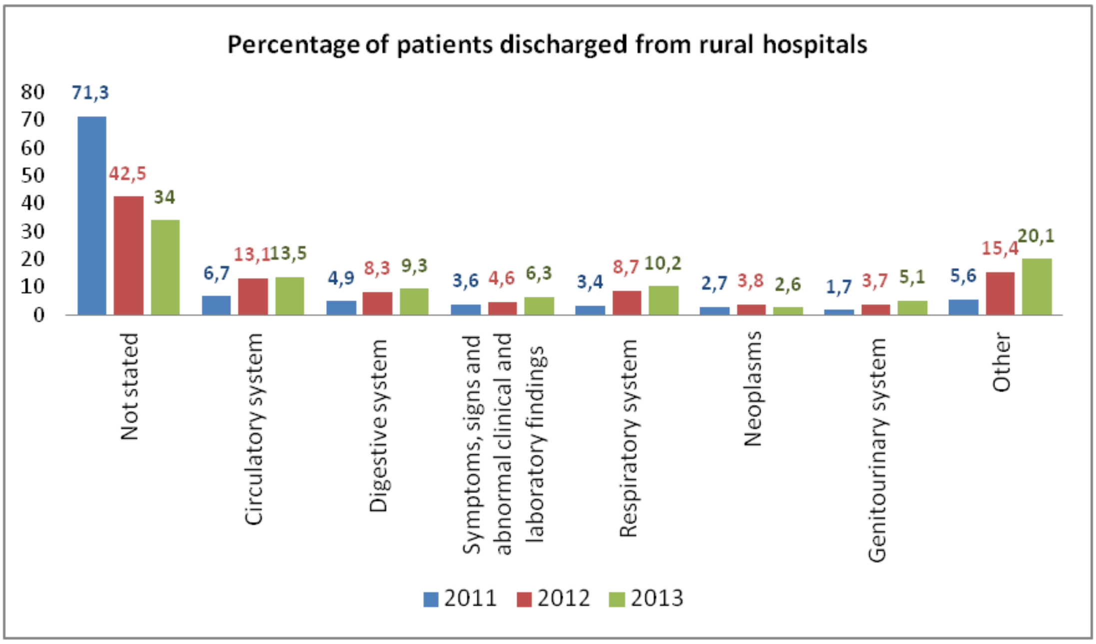
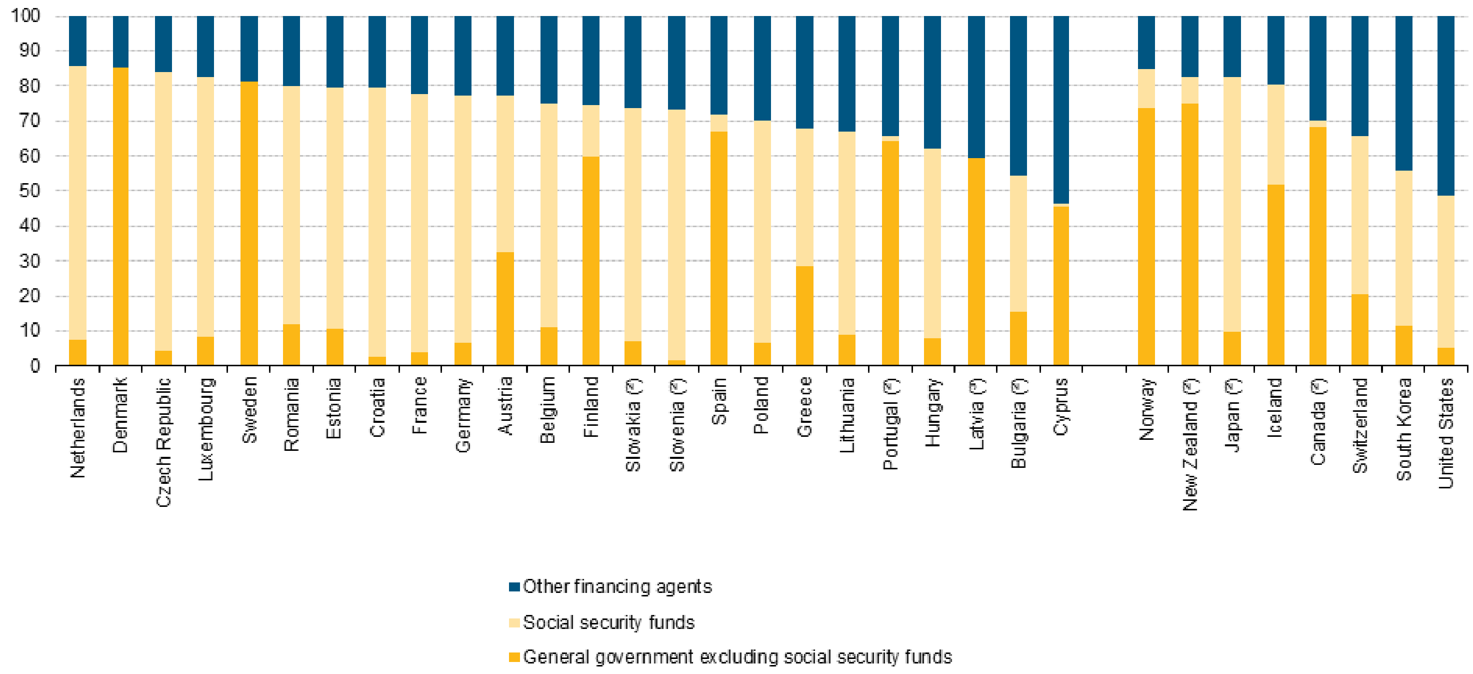


Figure 1.2 Percentage of cases discharged from rural hospitals by disease category [9]

Since 2003, total health expenditure in Cyprus as a percentage to GDP has increased by approximately 1%, despite the fact that it was one of the countries most severely hit by the recent economic crisis in the Eurozone. Nevertheless, the total health expenditure in Cyprus compared with the total health expenditure in EU 28 is about the half (see Figure 1.3).

In 2014, total expenditure on health services in Cyprus for the private sector was 658,9 million (664,3 million in 2013) and for the public sector was 448,1 (540,1 million in 2013) **[9]**. According to Eurostat, Cyprus is an exception among the EU members with respect to the fact that expenditures in the private health sector significantly exceed those of the public sector **[10]**. Cyprus has one of the lowest amounts of money spent in the EU countries for health (see Figure 1.4)



(1) Denmark, Cyprus, Portugal, Iceland, Norway and Switzerland: provisional. Ireland, Italy, Malta and the United Kingdom: not available.
(2) 2011.
(3) 2010.

Figure 1.3 Healthcare expenditure by financing agent, 2012 (% of current healthcare expenditure) [10]

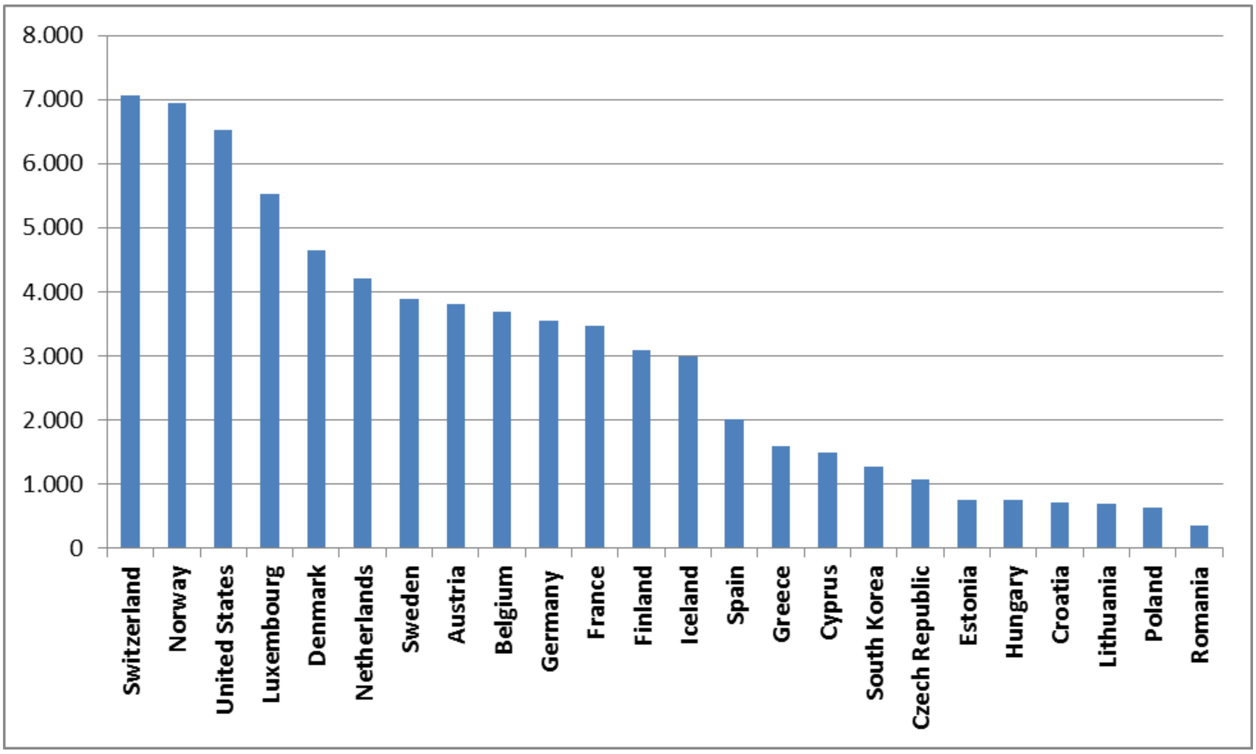


Figure 1.4 Health care expenditure by all financing agents in selected countries (euros per inhabitant, 2012) [11]

1.3 Causes of Death

There were 5.272 deaths recorded in Cyprus in 2013 compared to 5.225 in 2004, a rise of 0,9 % (Table 1.5). Between 2012 and 2013 the number of deaths decreased by 6,8% (5.659 deaths in 2012 vs 5.272 in 2013) recording the largest percentage decline in the past 10 years. The five leading causes of death for the period 2004-2013 were: Diseases of the circulatory system (38,2%, Neoplasms (21,5%), Endocrine, nutritional and metabolic diseases (7,5%), Diseases of the respiratory system (7,1%), External causes of injury and poisoning (5,9) [**12**].

In 2013, among the deaths due to diseases of the circulatory system (34,6% of all causes of death), 22,2% was due to ischaemic heart diseases, 6,9% due to cerebrovascular diseases and the remaining 5,4% was due to other of the circulatory system. Among neoplasms (24,6% of all causes of death), 23,7% was due to malignant neoplasms and the remaining 0,9% due to non-malignant neoplasms. Among the deaths due to endocrine, nutritional and metabolic diseases (8,4% of all causes of death), 7,1% was due to diabetes mellitus and the remaining 1,3% was due to other endocrine, nutritional and metabolic diseases. Among the deaths due to diseases of the respiratory system (8,0% of all causes of death), 2,9% was due to chronic lower respiratory diseases, 1,2% due to Pneumonia, 0,2% due to Influenza and the remaining 4% was due to other diseases of the respiratory system. Among the deaths due to external causes of morbidity and mortality (5,5 of all of all causes of death), 4,25% was due to accidents, 0,85% due to intentional self-harm, 0,2% due to assaults and the remaining 0,1% was due to other external causes [**12**].

As shown in Table 1.6, in 2012 higher standardized death rates were observed for the highly prevalent diseases of the circulatory system (402,17 deaths per 100.000 persons in Cyprus vs 394,18 deaths per 100.000 persons in EU 28), endocrine nutritional and metabolic diseases (84,72 deaths per 100.000 persons vs 29,98 deaths per 100.000 persons) and diseases of the genitourinary system (41,89 deaths per 100.000 persons vs 19,57 deaths per 100.000 persons).

Moreover, in 2012 Cyprus had a higher death rate compared with the EU 28 countries from infectious and parasitic diseases (16,89 deaths per 100.000 persons vs 15,97 deaths per 100.000 persons) and diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (8,36 deaths per 100.000 persons vs 2,98 deaths per 100.000 persons).

Higher death rates for several less usual causes were observed in 2012 like diseases of the skin and subcutaneous tissue (6,99 deaths per 100.000 persons vs 1,81 deaths per 100.000 persons), diseases of the musculoskeletal system and connective tissue (5,2 deaths per 100.000 persons vs 5,15 deaths per 100.000 persons), certain conditions originating in the perinatal period (2,85 deaths per 100.000 persons vs 2 deaths per 100.00 persons) and congenital malformations, deformations and chromosomal abnormalities (2,39 deaths per 100.000 persons vs 2,32 deaths per 100.000 persons).

Finally higher standardised death rates in 2012 were found for symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (52,94 deaths per 100.000 persons vs 37,52 deaths per 100.000 persons).

In 2013, Cyprus had a higher standardised death rate than the EU-28 for the following causes of death:

- Endocrine, nutritional and metabolic diseases (82,08 deaths per 100.000 persons vs 29,73 deaths per 100.000 persons)
- Diseases of the genitourinary system (36,23 deaths per 100.000 persons vs 19,33 deaths per 100.000 persons)
- Diseases of the skin and subcutaneous tissue (5,3 deaths per 100.000 persons vs 1,8 deaths per 100.000 persons)
- Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (6 deaths per 100.000 persons vs 2,98 deaths per 100.000 persons)
- Diseases of the respiratory system (84,32 deaths per 100.000 persons vs 82,5 deaths per 100.000 persons)
- Pregnancy, childbirth and the puerperium (0,09 deaths per 100.000 persons vs 0,05 deaths per 100.000 persons)

Table 1.5 Main causes of death [12]

Causes of death	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2004-2013
All causes of death	**5.224**	**5.425**	**5.125**	**5.380**	**5.194**	**5.182**	**5.093**	**5.393**	**5.659**	**5.272**	**52.947**
Diseases of the circulatory system	2.013	2.125	2.040	2.092	2.015	1.951	1.929	2.113	2.113	1.823	20.214
Neoplasms	1.005	1.012	1.017	1.109	1.139	1.177	1.154	1.193	1.278	1.297	11.381
Endocrine, nutritional and metabolic diseases	389	387	390	387	393	359	365	426	434	444	3.974
Diseases of the respiratory system	350	364	343	389	356	395	360	366	434	424	3.781
External causes of morbidity and mortality	319	410	294	330	314	313	293	277	293	289	3.132
Other	1.148	1.127	1.041	1.073	977	987	992	1.018	1.107	995	10.465

Table 1.6 Standardized death rate per 100.000 persons by cause in EU 28 and Cyprus [13]

Causes of death - Standardised death rate by residence	EU-28			Cyprus		
	2011	2012	2013	2011	2012	2013
All causes of death (A00-Y89) excluding S00-T98	**1.026,73**	**1.035,12**	**1.020,93**	**1.031,27**	**1.053,74**	**951,52**
Certain infectious and parasitic diseases (A00-B99)	15,43	15,97	15,95	16,28	16,89	15,71
Neoplasms	277,11	275,82	273,92	203,6	212,77	210,46
Malignant neoplasms (C00-C97)	*268,63*	*267,21*	*265,1*	*195,76*	*205,55*	*202,34*
Non-malignant neoplasms (benign and uncertain)	*8,48*	*8,61*	*8,82*	*7,83*	*7,22*	*8,12*
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	3	2,98	2,98	8,94	8,36	6
Endocrine, nutritional and metabolic diseases (E00-E90)	29,62	29,98	29,73	84,21	84,72	82,08
Mental and behavioural disorders (F00-F99)	31,1	34,17	36,4	18,5	19,79	18,78
Diseases of the nervous system and the sense organs (G00-H95)	35,33	38	38,14	29,39	36,3	30,85
Diseases of the circulatory system (I00-I99)	395,33	394,18	383,35	417,77	402,17	341,57
Ischaemic heart diseases	*139,26*	*136,87*	*131,87*	*127,68*	*115,85*	*104,18*
Other heart diseases	*90,27*	*91,49*	*89,47*	*142,29*	*133,36*	*107,67*
Cerebrovascular diseases	*94,11*	*92,48*	*88,68*	*85,66*	*82,42*	*71,86*

Causes of death - Standardised death rate by residence	EU-28			Cyprus		
	2011	**2012**	**2013**	**2011**	**2012**	**2013**
Other diseases of the circulatory system (remainder of I00-I99)	*71,7*	*73,34*	*73,33*	*62,14*	*70,55*	*57,86*
Diseases of the respiratory system (J00-J99)	80,53	83,71	82,5	79,83	89,55	84,32
Diseases of the digestive system (K00-K93)	45,83	45,25	44,1	38,59	29,92	35,3
Diseases of the skin and subcutaneous tissue (L00-L99)	1,74	1,81	1,8	7,74	6,99	5,3
Diseases of the musculoskeletal system and connective tissue (M00-M99)	4,97	5,15	5,03	4,17	5,2	5
Diseases of the genitourinary system (N00-N99)	19,17	19,57	19,33	35,45	41,89	36,23
Pregnancy, childbirth and the puerperium (O00-O99)	0,05	0,04	0,05		0,09	0,09
Certain conditions originating in the perinatal period (P00-P96)	2,01	2	1,94	1,73	2,85	0,62
Congenital malformations, deformations and chromosomal abnormalities (Q00-Q99)	2,34	2,32	2,32	2,96	2,39	1,16
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R00-R99)	36,02	37,52	37,42	43,47	52,94	34,66
External causes of morbidity and mortality (V01-Y89)	47,14	46,66	45,99	38,65	40,94	43,4

1.4 Environmental Health

Air quality in Cyprus is an issue of concern especially for Particulate Matter (PM). According to reports published by the European Environment Agency (EEA), 100% of the urban population in Cyprus was exposed to unhealthy levels of particulate matter (PM_{10}), above the EU reference value in 2009, 2010, 2011 and 2012 [**14, 15**]. The percentage of the total population exposed to ozone concentrations above the target value in the 2006 – 2010 period ranged from 0% in 2010 to 50,9% in 2009. The percentage of the total population exposed to PM_{10} concentrations above the day limit values in the 2006 – 2010 period exceeded 80%, reaching 99% in [**14**].

In 2012, according to an analysis of the EEA, the energy use and supply is responsible for 64% of NOx emissions, 17% of non-methane VOCs, 99% of sulphur dioxide (SO2) emissions and 29% of fine particulate matter ($PM_{2,5}$) [**15**].

According to data of the Department of Labour Inspection in the 2000 - 2014 period, there is a continuous decrease in the concentration of air pollutants (NO, NO_2, CO and SO_2) except ozone and particulate matter (PM). This reduction is mainly due to improved fuel quality, the introduction of new technology vehicles equipped with a catalytic converter, the periodic inspection of vehicles, etc. [**16**].

Ozone exceedances are mainly attributed to the climatic conditions prevailing in Cyprus, such as high temperatures and high solar radiation, as well as to transboundary pollution of Ozone and its precursors from the eastern Mediterranean and the neighbouring countries [**16**].

The main causes of Particulate Matter exceedances are [**16**]:

- emissions from vehicles, central heating and various industrial sources,
- airborne dust from agricultural areas, the Sahara and Asia
- resuspension from roads and uncovered urban areas during periods of drought and
- sea salts (marine aerosols).

The annual concentration at background stations, that are less influenced by anthropogenic pollution sources, is usually very close to the annual limit value [**16**].

In 2015, dust transport episodes were observed. The dust originated from the Sahara desert and regions of Northern Africa and Western Asia. Between the 7th and the 12th of September a significant dust transport episode from Syria was observed. During this period, the PM_{10} concentrations were extremely high and the mean daily concentration reached the 2600 mg/m^3 [**16**].

PM can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. It can also affect the central nervous system and the reproductive system, and can cause cancer. One outcome of exposure to PM can be premature death. Elevated levels of **ozone** can cause respiratory health problems, including decreased lung function, aggravation of asthma, and other lung diseases. It can also lead to premature mortality [**15**].

The European Environment Agency estimated that in Cyprus in 2012, **790** premature deaths were attributable to $PM_{2,5}$ (or 8.000 Years of life lost - YLL) and **40** (or 500 Years of life lost - YLL) to Ozone. [**17**]

• 1.5 Policy context – Competent Authorities

Through a highly centralized public administration system, the **Ministry of Health** is responsible for ensuring access to health services for all beneficiaries. Services are provided mainly by public hospitals and health centres, while priority setting, resource allocation, management, decision making, budgeting and the preparation of relevant legislation are exclusively the responsibility of the Ministry of Health. The ministry is also responsible for inspecting, regulating and licensing private hospitals and polyclinics. The Ministry of Health is organized into various departments including State General Laboratory, Pharmaceutical Services, Medical and Public Health Services, Mental Health Services, Dental Services and Nursing Services. The Anti-drug Council and the Health Insurance Organization are also under the supervision of the ministry [**8**].

Apart from the Ministry of Health, other ministries and agencies have roles and responsibilities in the broader health care and social protection sector. The Ministry of **Ministry of Labour, Welfare and Social Insurance** can be considered as the second pillar of the overall social protection system. It is responsible for the implementation of government policies for employment, social insurance, social welfare and industrial relations. It also provides social services at home to older and disabled people and is responsible for maternity allowances, sickness benefits, unemployment benefits, old-age pensions, invalidity pensions, widows' pensions, orphans' benefits, missing persons' allowances, marriage grants, maternity grants, funeral grants and benefits for employment accidents andoccupational diseases, including injury, disablement and death benefits [**8**].

The **Ministry of Finance** has a very important role as it prepares and controls the national budget and consequently decides on the amount of money allocated to the Ministry of Health; it has an indirect role in defining health policy and setting priorities for the broader health care sector. Additionally, the ministry is responsible for the administration of specific allowances and grants such as mobility allowances to disabled workers, financial assistance to persons with disabilities, child benefits and mothers' allowances [**8**].

The **Ministry of Education and Culture** is responsible for the education of health professionals, primarily within public and private universities in Cyprus, including the specialties of nursing, health care management and physiotherapy. Further, in cooperation with the Ministry of Health, the Ministry of Education and Culture provides health services as well as health promotion and educational programmes to all pupils in primary and secondary schools.

The **Ministry of Defence** operates one small military hospital and a network of physicians based in camps [**8**].

The **Ministry of Energy, Commerce, Industry and Tourism** is responsible for setting regulations regarding medical devices in collaboration with the Ministry of Health, while the Ministry of Agriculture, Rural Development and Environment.is responsible for setting regulations regarding waste disposal [**8**].

There are also a number of voluntary organizations and NGOs that play a significant role in providing health care services for specific segments of the population (e.g. the Anti-Cancer Association runs a special centre for palliative care for cancer patients). These organizations are funded mostly by donations, as well as by the Ministry of Health. Workers' unions also play a role in the healthcare system. Apart from their political influence, these three unions run their own parallel health systems that provide services to their members. Local authorities play only a minor role in planning, organization and provision of health care services, as they do not have enough power or economic resources to implement policies at a regional level. However, they are responsible for the maintenance of the public health centres located in their area and some of the larger municipalities operate welfare programmes. Nine municipalities have their own health inspectors, responsible for the control and monitoring of public swimming pools, restaurants and mini-markets and for drinking water in their region. Professional associations of doctors, dentists, pharmacists and nurses have their own role in the health system. Each group has its own Pancyprian Association, in which registration is mandatory for all health professionals. These associations are professional bodies that protect and promote the interests of their members and are responsible for Continuing Professional Development by organizing conferences and seminars. Most of them have enough power to influence political decisions regarding health care planning [**8**].

Finally, the role of patients' associations is very limited, since they typically advocate on behalf of very specific groups, such as those suffering from a particular disease. Further, they have no institutional role in health care planning and priority setting, although in some cases they may be asked to submit their own proposals [**8**].

Among the abovementioned institutions, those that govern climate change adaptation to the main risks of the Health Environment sector involve:

The **Public Health Services** of the Department of Medical and Public Health Services of the Ministry of Health have as mission the undertaking of all necessary measures for the safeguarding and promotion of environmental health. The **Public Health Services recommend** measures on the prevention of the effects of the emergence of high temperatures and heatwaves.

The Department of **Labour Inspection of the Ministry of Labour, Welfare and Social Insurance**, as the competent authority for the supervision of legislation on safety and health at work, prepares Codes of Practice for Thermal Stress of Workers containing guidelines in relation to the treatment of heat stress of workers in indoor or outdoor spaces. The Department is also responsible for the continuous monitoring of the air pollutants, the information of the public concerning the air quality of Cyprus and implementing measures to improve air quality to prevent negative effects on human health and the environment.

• 1.6 Structure of report

This report describes the methodological steps taken in the Health sector analysis.

Chapter 2 presents an overview of the general methodology applied used for impact selection and analysis in the CCRA. The methodology is described in detail in the Approach Report and is based on the UK CCRA methodology.

Chapter 3 gives an overview of the broad list of possible impacts referred to as the 'Tier 1' list (Section 3.1 and Appendix 1) and the identification of the most important impacts that were further analysed (the 'Tier 2' impacts). Chapter 3 also presents the 'risk metrics', which are measures for the impacts of climate change.

Chapter 4 presents the response functions, which show how the metric values are affected by climate change variables.

Chapter 5 presents the calculation of the impacts of climate change for the selected climate change scenarios.

Chapter 6 presents the results of the calculation of the impacts of climate change taking account of future socioeconomic change.

Chapter 7 presents the estimation of the economic costs of climate change.

Chapter 8 presents a summary of the adaptive capacity within the Sector.

Chapters 9 presents the findings of the Health sector analysis.

2 Methods

• 2.1 Introduction: CCRA Framework

The CCRA will give an assessment of potential impacts (opportunities and threats) from climate change, focusing on how climate risks are likely to manifest themselves over the 21st century in the absence of action. For the 2016 **Evidence Report**, the Department of Environment will produce a focused report that will seek to address the following issues:

- Assess climate risks in the light of methods of assessment and knowledge of climate change impacts;

- A fuller assessment of how climate interacts with socio-economic factors and how these drivers of risk might change in the future, for example economic growth; population change; land-use change;
- How the effects of adaptation actions are likely to alter risk levels;
- Assess the magnitude of impact and the urgency of action needed for different threats and opportunities, as well as developing an understanding of the possible net effect of different risks acting together;
- Assess the uncertainties, limitations and confidence in the underlying evidence and analysis for different risks.

Following the methodology applied in the 1st UK CCRA, the data gathering and analysis work for the CCRA was divided into sectors. The Cyprus CCRA focused on the following 12 sectors:

- Agriculture (Agronomy Subsector and Livestock Subsector)
- Biodiversity & Ecosystem Services
- Built Environment
- Business, Industry & Services
- Energy
- Forestry
- Floods & Coastal Erosion
- Health
- Marine & Fisheries
- Transport
- Soil
- Water

The Evidence report will draw together and interpret the evidence gathered by the CCRA conducted for each sector regarding current and future threats (and opportunities) posed by the impacts of climate change.

This Chapter outlines the steps undertaken to implement the CCRA per Sector. The methodology applied is an adaptation of the 1st UK CCRA [**1**].

The components of the CCRA sought to:

Identify and characterise the impacts of climate change. This was achieved by developing the Tier 1 list of impacts, which included impacts across the sectors as well as impacts not covered by the sectors and arising from cross-sector links.

Identify the main risks for closer analysis. This involved the selection of Tier 2 impacts for further analysis from the long list of impacts in Tier 1. Higher priority impacts were selected based on the social, environmental and economic magnitude of impacts and the urgency of taking action.

Assess current and future risk, using climate projections and considering socio-economic factors. The risk assessment was undertaken by developing 'response functions' that provide a relationship between changes in climate with specific consequences based on analysis of historic data, the use of models or expert elicitation. In some cases this was not possible, and a narrative approach was taken instead. The climate projections were then applied to assess future risks. The potential impact of changes in future society and the economy was also considered, to understand the combined effects for future scenarios.

Assess vulnerability. This involved:

- a review of Government policy on climate change in each sector
- an assessment of the social vulnerability to the climate change impacts
- an assessment of the adaptive capacity of each sector

Report on risks to inform action. The results for the other 12 sectors are presented in reports and the CCRA Evidence Report will draw together the main findings from the whole project, including consideration of cross-linkages between sectors, and outlines the risks to the Cyprus as a whole. According to the "Terms of Reference" the Evidence Report will have the following Chapters:

Chapter 1- Executive Summary/ Introduction

Chapter 2- Characterising the future (update on climate science, setting out socio-economic scenarios, approach to analysis and understanding risk)

Chapter 3- The rural economy and natural environment [risks associated with land use in rural areas- agriculture, forestry (forest fires) and semi-natural habitats including marine habitats (marine pollution)]

Chapter 4- Infrastructure (risks associated with the national infrastructure; transport, water/sea level rise, waste, ICT, energy/electricity)

Chapter 5- People and the built environment (risks directly affecting people and/or buildings, including through health impacts from heat and cold, pressure gradient winds, thunderstorms, droughts, dust in the lower atmosphere, earthquakes/tsunami, flood risk, water availability and quality, analysis of the effects of climate change on vulnerable groups, effects of climate change on wellbeing, risks/adaptation through blue and green infrastructure)

Chapter 6- Business and industry (risks to the private sector including finance, insurance, flood risk to businesses, supply chains)

Chapter 7- Global security (risks associated with food security, conflict, or migration that could affect Cyprus)

Chapter 8- Cross-cutting issues (chapter bringing together themes from across the report. This includes interdependencies, social vulnerability, and a focused look on the level of resilience to a small number of plausible extreme events with multiple knock-on impacts such as a major drought, earthquake/tsunami, flood, heatwave or cold snap).

Chapter 9- Conclusions

For each chapter, the following questions will be addressed:

1. Assess the magnitude of current climate related risks for that theme.
2. Consider how key drivers of change may alter in the future (climate and socio-economic changes)
3. Summarise for each chapter what the most significant threats or opportunities are now and in the future, and where additional research is most urgently needed.

From the structure of the Evidence Report that is presented above it is implied that the findings of each Sector will be grouped in the following **Themes**:

1) The rural economy and natural environment
2) Infrastructure
3) People and the built environment
4) Business and industry

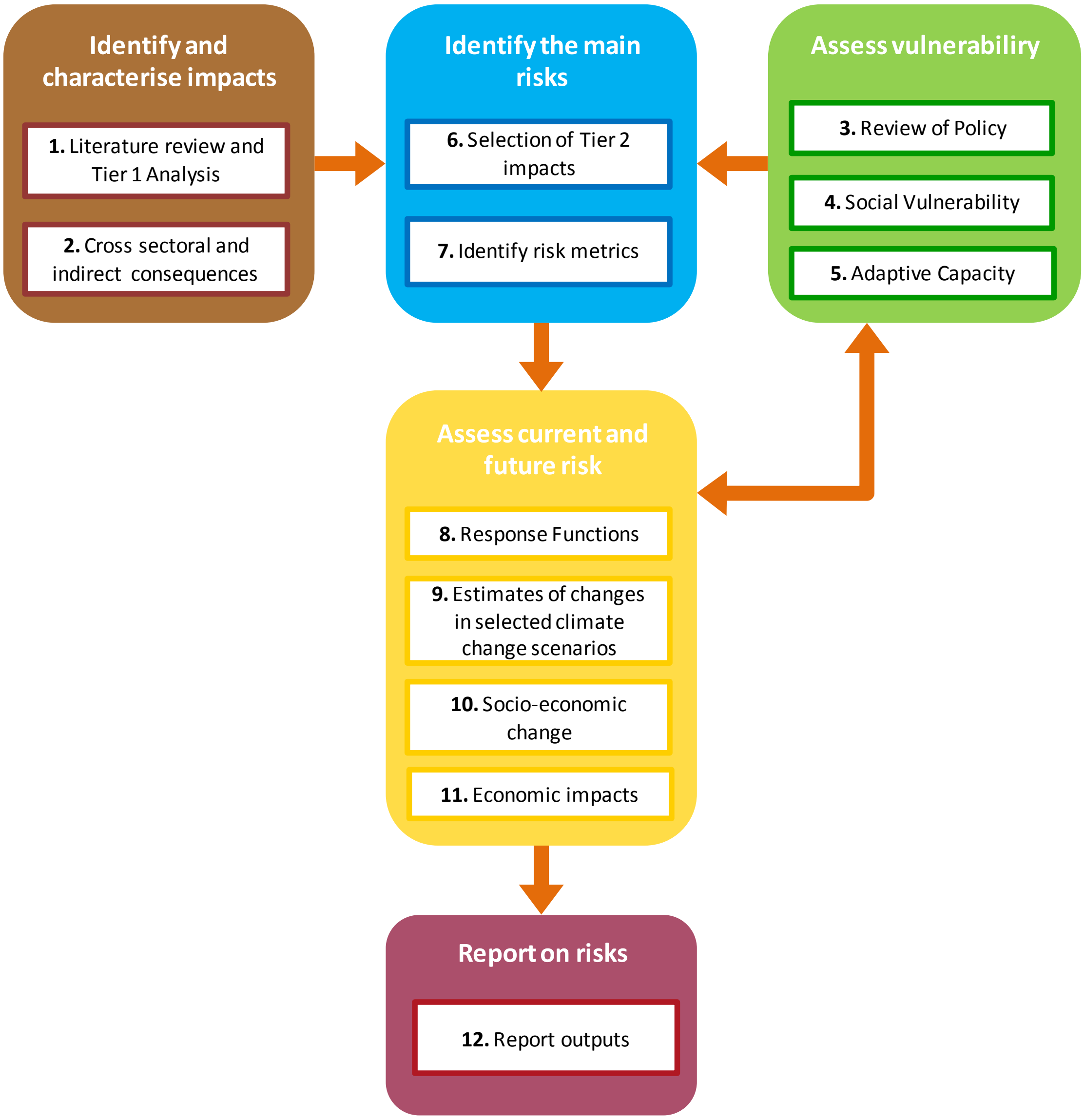


Figure 2.1 Steps of the CCRA

• 2.2 Outline of the method used to assess impacts, consequences and risks

• 2.2.1 Identify and characterise the impacts of climate change

Step 1 - Literature review and Tier 1 analysis

This step scopes the potential **impacts** and **consequences** of climate change on Cyprus based on existing evidence and collating the findings from literature reviews, stakeholders organizations and expert opinion. This work develops a Tier 1 list of impacts for each sector. Using the UK CCRA 11 Sector reports as a starting point, a preliminary list of impacts was collated. Impacts were also extracted from recent literature focussed in Cyprus or in the Mediterranean Basin, taking into account the existing and planned activities as well as the special characteristics of each sector.

Step 2 - Cross sectoral and indirect consequences

The Tier 1 lists of each sector in the CCRA were compared and developed further to include cross-sectoral and indirect impacts. The impacts that were identified in this step were added to the Tier 1 list of impacts.

• 2.2.2 Assess vulnerability

Step 3 - Review of Policy

Government policy on climate change develops and changes rapidly to keep pace with emerging science and understanding of how to respond through mitigation and adaptation. Each sector report includes an overview of selected relevant policy as this provides important context for understanding how the risks that are influenced by climate relate to existing policies.

This in turn provides an understanding of the urgency with which adaptation decisions would need to be taken (see Step 6).

Step 4 - Social Vulnerability

The vulnerability of different groups in society to the climate change risks for each sector is considered through a checklist of questions. This information is provided for context based on available data and informed judgement; it is not a detailed assessment of social vulnerability to specific risks.

This analysis however provides an understanding of the potential **magnitude of social impacts** and the **urgency** with which **adaptation** decisions would need to be taken (see Step 6) and where data is available also influences the selection of suitable risk metrics (see Step 7). Note that this step is different from Step 10, which considers how changes in society may affect the risks.

For the purposes of the CCRA, social vulnerability is recognised as a relevant factor in assessing the social consequences of climate change impacts. People who are likely to be most vulnerable to the social impacts of climate change are considered those:

- Living in places at risk
- Who are socially deprived
- Who are disempowered because of lack of awareness, adaptive capacity, support services and exclusion from decision-making.

Within each of these categories there is a number of social vulnerability characteristics, which are summarised in Table 2.1.

Table 2.1 Social vulnerability categories and characteristics

Social vulnerability category	Social vulnerability characteristics
People living in places at risk	• Location and place
People who are socially deprived	• Poor mental and physical health • Fewer financial resources • Living and working in poor quality homes or workplaces
People who are disempowered because of lack of awareness, adaptive capacity, support services and exclusion from decision-making	• Limited access to public and private transport • Limited or lack of awareness of risks • Lack of social networks • Little access to systems and support services (e.g. healthcare)

For **each Sector,** as part of the Social vulnerability analysis the above mentioned checklist was taken into account[15]. Similar or overlapping impacts were **grouped** together, where possible, and the following questions were asked of **each group** of impacts:

- Which locations are affected by these impacts?
- Is it spread evenly across regions or not?
- How will people with poor health (physical or mental) be affected by these impacts?
- How will people with fewer financial resources be affected?
- How will people living or working in poor quality homes or workplaces be affected?
- How will people who have limited access to public and private transport be affected?
- How will people with lack of awareness of risks be affected?
- How will people without social networks be affected?
- How will people with little access to systems and support services (e.g. health care) be affected?
- Are any other social vulnerability issues relevant?

[15] See Appendix 2

Step 5 - Adaptive Capacity

The adaptive capacity of a sector is the ability of the sector as a whole, including the organisations involved in working in the sector, to devise and implement effective adaptation strategies in response to information about potential future climate impacts.

The adaptive capacity assessment influences the risk assessment by improving the understanding of levels of **autonomous adaptation**, which is an important consideration when determining response functions (see Step 8). It also improves the understanding of decision-making within sectors and contributes to the development of the "**urgency**" criteria applied to the risk assessment results (see Step 12).

An overview of the adaptive capacity of each sector was carried out through literature review.

• 2.2.3 Identify the main risks

Step 6 - Selection of Tier 2 impacts

The Tier 1 list of impacts for each sector that resulted from Step 2 (see above) was consolidated to select the **higher priority impacts** for analysis in Tier 2. Firstly, similar or overlapping impacts were grouped where possible in a simple **cluster analysis**.

Secondly, the Tier 2 impacts were selected using a **simple multi-criteria assessment** based on the following criteria:

- **Magnitude** – the social, economic and environmental magnitude of consequences;
- **Likelihood** – the perceived likelihood of the impact (or its consequences) occurring;
- **Urgency** – the urgency with which adaptation decisions need to be taken.

These criteria are equally weighted (see Table 2.2) and scored following predefined guidelines as detailed in the following tables.

Table 2.2 Criteria scoring and weighting

Criteria	Score	Weight
Magnitude / economic	High = 3; Medium = 2; Low = 1	1/3 x 1/3 = 1/9
Magnitude / social	High = 3; Medium = 2; Low = 1	1/3 x 1/3 = 1/9
Magnitude / environmental	High = 3; Medium = 2; Low = 1	1/3 x 1/3 = 1/9
Likelihood	High = 3; Medium = 2; Low = 1	1/3
Urgency	High = 3; Medium = 2; Low = 1	1/3

The formula used to combine scores is the following:

$$100 * \left(\frac{Social + Environmental + Economic}{9}\right) * \left(\frac{Likelihood}{3}\right) * \left(\frac{Urgency}{3}\right)$$

This means that the lowest possible score is 3,7 and highest possible score is 100.

Magnitude

Table 2.3 Relative magnitude classification criteria

Class	Economic	Environmental	Social
High	**Major damage and Disruption**	**Major or widespread loss or decline in long-term quality of valued habitats**	**Potential for many fatalities or serious harm or major disruption**
	• Major and recurrent damage to property and infrastructure • Major consequence on regional and national economy • Major cross-sector consequences • Major disruption or loss of national or international transport links • Major loss/gain of employment opportunities	• Major loss or decline in long-term quality of valued species/habitat/landscape • Major or long-term decline in status/condition of sites of international/national significance • Widespread Failure of ecosystem function or services • Widespread decline in land/water/air quality • Major cross-sector consequences	• Potential for many fatalities or serious harm • Loss or major disruption to utilities (water/gas/electricity) • Major consequences on vulnerable groups • Increase in national health burden • Large reduction in community services • Major damage or loss of cultural assets/high symbolic value • Major role for emergency services • Major impacts on personal security e.g. increased crime
	~ €1 million for a single event or per year	***~ 100 ha lost/gained ~ 100 km river***	***~15.000 affected ~150 harmed ~10 fatalities***
Medium	**Moderate damage and disruption**	**Medium-term or moderate loss**	**Significant numbers affected**
	• Widespread damage to property and infrastructure • Influence on regional economy	• Important/medium-term consequences on species/habitat/landscape • Medium-term or moderate loss of quality/status of sites of national importance	• Significant numbers affected • Minor disruption to utilities (water/gas/electricity) • Increased inequality, e.g. through rising

Class	Economic	Environmental	Social
	• Consequences on operations & service provision initiating contingency plans • Minor disruption of national transport links • Moderate cross-sector consequences • Moderate loss/gain of employment opportunities	• Regional decline in land/water/air quality • Medium-term or Regional loss/decline in ecosystem services • Moderate cross-sector consequences	costs of service provision • Consequence on health burden • Moderate reduction in community services • Moderate increased role for emergency services • Minor impacts on personal security
	~ €100.000 per event or year	***~ 10 ha lost/gained ~ 10 km***	***~1.500 affected, ~30 harmed, ~1 fatality***
Low	**Minor damage and disruption**	**Short term/ reversible/local effects sites**	**Small numbers affected/within 'coping range'**
	• Minor or very local consequences • No consequence on national or regional economy • Localised disruption of transport	• Short-term/reversible effects on species/habitat/landscape or ecosystem services • Localised decline in land/water/air quality • Short-term loss/minor decline in quality/status of designated sites	• Small numbers affected • Small reduction in community services • Within 'coping range'
	~ €10.000 per event or year	***~ 1 ha of valued habitats damaged/improved ~ 1 km river quality affected***	***~150 affected ~15 harmed***

Likelihood

The criteria that apply for the classification of the **likelihood** are presented in Table 2.4. The following also apply:

- Likelihood of the consequence is occurring after **autonomous adaptation**.
- The final score should be based on both the **climate variable and the consequence** and **should be the lowest score of the two**. For example:

a) There is low confidence that there will be an increase in the frequency of intense storm events, but high confidence that there will be an increase in pluvial flooding, if there is an increase in the frequency of intense storm events. This therefore has a low degree of confidence.

b) There is high confidence that there will be an increase in seawater temperatures, but medium confidence that there will be shifts in populations of warm and colder water plankton, if there is an increase in seawater temperatures. This therefore has a medium degree of confidence.

- All emissions scenarios are considered collectively. This is **not a precise exercise at this stage** and requires expert judgement.

Table 2.4 Guidance on the classification of likelihood

Class	**Likelihood**
High	Likely that consequences will occur within the next century *(i) High confidence - about 7 out of 10 chance or greater*
Medium	About as likely or not to occur in the next century *(i) Medium confidence - between 3 and 6 out of 10 chance*
Low	Unlikely that consequences will occur within the next century *(i) Low confidence - less than 3 out of 10 chance*

Urgency

The urgency of decisions is a difficult concept given the uncertainties related to climate change. It aims to identify those decisions required before 2020 and areas with a shortfall in adaptive capacity. It also needs to deal with issues related to flexibility of decisions and potential adaptation pathways. The criteria are set out in summary and more detailed form below. By focusing on "urgent" decisions, the CCRA will help to avoid the risk of maladaptation to climate change. For the classification of the **urgency of decisions** the criteria that are presented in Table 2.5 will be followed. **Year 2020** is chosen as the '**high urgency**' threshold to cover the set of decisions that will be taken, or are likely to be initiated, prior to **the next CCRA**. Major decisions typically take three years or more from initiation to finalisation and are increasingly difficult to influence during this period. This means 2017 to 2020 decisions would be very hard to influence as a result of the next CCRA, which would be more likely to influence decisions taken between 2020 and 2025.

Table 2.5 Guidance on the classification of the "urgency of decisions"

Class	Urgency	Response
High	• Major policy, investment or other decisions required **before 2020** that will either undermine or strengthen the future resilience of infrastructure, investments, communities, biodiversity etc. • The objectives of these decisions may be undermined by the speed of climate consequences relative to the decision's payback period, whether measured in financial, environmental or social value. • Decisions have limited flexibility, e.g. development of 'long life' assets with 'lock in' to a specific adaptation pathway. • There is low understanding of the risks and / or of the options to adapt to them. • There is a significant shortfall in adaptive capacity with a likelihood of locked-in maladaptation unless action is taken to raise adaptive capacity very soon.	Act Now
Medium	• Major policy, investment or other decisions will be **taken before 2050** that will either undermine or strengthen the future resilience of infrastructure, investments, communities, biodiversity etc. • The objectives of these decisions may be undermined by the speed of climate consequences relative to the decision's payback period, whether measured in financial, environmental or social value. • There is medium understanding of the risks and / or of the options to adapt to them. • Decisions have some flexibility and there is some potential for incremental adaptation over the long term. • There is some shortfall in adaptive capacity with a limited risk of locked-in maladaptation unless action is taken to raise adaptive capacity	Watch Carefully
Low	• Major policy, investment or other decisions are **not required before 2050.** • There is high understanding of the risks and / or of the options to adapt to them. • Decisions have high flexibility with potential for incremental adaptation over time. • There is little or no shortfall in adaptive capacity with limited or no need to raise adaptive capacity to avoid maladaptation.	Wait and see

Scoring

The scoring for each impact or cluster of impacts was based on expert judgment and feedback from Contracting Authority and the stakeholder organisations. The project Manager supervised scoring carried out in each sector and ensured that a consistent approach was taken across all the sectors.

For the Biodiversity & Ecosystem Services sector a slight adjustment was made to the generic scoring approach set out above based upon the definition of environmental, social and economic criteria.

The first UK CCRA identified more than 700 impacts in the Tier 1 assessment for all sectors. With the time and resources available, it was considered impossible to undertake a detailed analysis of all of the Tier 1 risks, and so a selection process was carried out. The Tier 1 list of impacts resulting from Step 2 was scored in order to select the higher priority impacts for analysis, known as Tier 2 impacts. It was estimated early on that it was only going to be possible to analyse in detail around 100 impacts out of a total of around 700, which meant that the impacts that had a **combined score of around 30 or over were selected**. In this CCRA the same score threshold was applied.

Step 7 - Identifying risk metrics

Once the Tier 2 list of impacts was finalised, the next step was to determine whether the **impact can be measured and, if so, how**. For each impact in the Tier 2 list, one or more risk metrics will be identified. **Risk metrics provide a measure of the consequences of climate change**, related to specific climate variables or biophysical impacts. The risk metrics were developed to provide a spread of information about economic, environmental and social consequences.

• 2.2.4 Assess current and future risk

Current risks

An understanding of **current risks** will be the starting point for the assessment in each sector. This involves a literature review (e.g. CYPADAPT Project) and collecting the best information available on current risks from Government departments.

Future risks

Step 8 - Response functions

Step 8 established how each risk metric varies with one or more climate variables using available data or previous modelling work. This step is only possible where evidence exists to relate metrics to specific climate drivers, and it is highly likely that will not be possible for all of the Tier 2 impacts. This step will be carried out by developing a '**response function'**, which is a relationship to show how the risk metric varies with changes in climate variables. Some of the response functions will be qualitative, based on expert elicitation, whereas others will be quantitative.

It must be noted that the UK CCRA was based on a wide range of existing studies on the impacts of CC in UK. The data availability between UK and Cyprus is not quite comparable.

Given the time restrictions of the current contract and as the terms of reference state "This evidence report will be largely based on available evidence, rather than through commissioning significant new research. The approach to the analysis for each threat or opportunity considered was guided to a large extent by what is or was available during the study period.

Step 9 - Estimates of changes in selected climate change scenarios

The response functions were used to assess the magnitude of consequences due to climate change by making use of climate projections. The purpose of this step is to provide the estimates for the level of future risk (threat or opportunity), as measured by each risk metric.

We provided estimates of future risk under the two (2) most plausible Representative Concentration Pathway (RCPs) scenarios i.e. **RCP8.5** (the most **severe** scenario, featuring the highest emissions and 8,5 Wm^{-2} of global mean radiative forcing by 2100 relative to the pre-industrial times), and **RCP4.5** (a **medium** scenario, featuring 4,5 Wm^{-2} radiative forcing in 2100).

The results from these scenarios were analysed for two future time periods that are sufficiently distant from the present-day and therefore offer a higher possibility for statistically significant results. These periods were 2041-2060 (2050s) and 2071-2090 (2080s), to assess climate change in mid and late 21st century.

The baseline period against which the changes were computed is **1991-2010**. The 1961-1990 baseline often used in climate change science studies is avoided here, given that climate change has evolved over the past few decades, and therefore 1961-1990 is not representative of the 'present-day'. The choice of a 20 year length is a compromise between having enough data to give reasonable estimates for the key variables (both their means and extremes) and being relevant for the present-day (e.g. choosing a 30-year period would inevitably move the centre of the baseline period in the mid-1990s, which is too early as a present-day estimate). We avoid having 2015 as the centre of the present-day period, as that would inevitably require using data from 10 years of future simulations (2016-2025, in addition to 2006-2015), and that would diminish the value of any efforts to evaluate this simulation with observations from the recent past.

Step 10 - Socio-economic change

Many of the risk metrics in the CCRA are influenced by a wide range of drivers, not just by climate change. The way in which the social and economic future develops will influence the risk metrics. **Growth in population** is one of the major drivers in influencing risk metrics and may result in much larger changes than if the present day population is assumed. For some of the sectors where this driver is particularly important, future projections for change in population were considered to adjust the magnitude of the estimated risks derived in Step 9.

Step 11 - Economic impacts

Where possible, an attempt was made to express the magnitude of individual risks in monetary terms. The aim is to express the risk in terms of its effects on human welfare, as measured by the preferences of individuals in the affected population.

• 2.2.5 Report on risks

Step 12 Report on Risks

Report on risks has to take into account the cross sectoral issues. Moreover, some risks can be expressed in monetary terms but others are more difficult to quantify. In addition, when looking at risks some risks threaten particular groups at the same time as benefiting others. Report on risks in the Evidence Report will be implemented following the completion of the separate Sector Reports.

To allow comparison of these different risks, they are categorised as having either '**high'**, '**medium'** or '**low' magnitude** consequences and either a 'high', 'medium' or 'low' **confidence**.

Risks will be reported both on Onset Plot and Score Cards in the Evidence Report.

3. Impacts and Risk Metrics

• 3.1 Identifying impacts and consequences – The Tier 1 list

• 3.1.1 General

Worldwide climate change may alter significantly the health status and well-being of populations. Unfortunately, climate change effects on health are not given due attention, since most people believe that their personal health depends primarily on their lifestyle choices (e.g., dietary habits, physical activity etc.), heredity and access to health services. According to the Annual Report of WHO for 2002, climate change is responsible for 6% malaria cases and 2,4% of diarrhoea phenomena. Existing data associate the increase of global temperature of 1^{o}C with an expected increase of mortality by 1–4%.

Climate changes affect humans both directly and indirectly; direct impacts are caused by extreme weather events (such as heat waves, floods etc.) while indirect effects include mainly the consequences of environmental changes and ecological disturbances due to climate changes, such as diseases carried by insects, like malaria or West Nile virus, food contamination by the increase of temperature and/or relative humidity, food and water-borne diseases by groundwater contamination and/or air pollutants.

Rising temperatures and extreme heat may lead to injuries, effects on mental health, cardiovascular diseases, increase of the hospital emergency admissions and heat-related illnesses, increasing the morbidity/mortality rates, primarily to the elderly population and other vulnerable groups, such as infants and children [**18, 19, 20, 21**].

Anthropogenic GHGs, climate-active aerosol emissions and environmental degradation (land, coastal ecosystems, fisheries) caused by increased SO_2, NxO, CH_4 etc. may affect numerous upstream drivers of public health including indoor/outdoor air pollution, water security/quality and food security/quality. These parameters have been associated with forced migration, mental health disorders, cardiovascular diseases, asthma and other respiratory diseases and malnutrition [**22, 24, 23, 25**].

Food poisoning caused at high temperatures (over 30^{o}C) and/or high relative humidity (%RH), may lead to diarrheal diseases (such as salmonellosis) due to the growth of pathogen microbes (such as Salmonella spp.) and malnutrition [**26, 28, 27, 29**]. For instance, extreme weather events and sudden changes in the temperature and precipitation are able to damage crops and/or interrupt the transportation/delivery of foods. Furthermore, water-borne infections caused by pathogen microbes, biotoxins and toxic contaminants may lead to a wide variety of health effects, mainly related to gastrointestinal problems. The available data indicate outbreaks of water-borne diseases (such as cholera by the growth of Vibrio cholarae, diarrheal phenomena especially after Campylobacter spp. growth, leprospirosis, cryptosporiosis etc.) occurred after a severe precipitation event, such as rainfall or snowfall [**22, 27, 30, 31, 32**].

Air pollutants caused by ground-level ozone and particular air pollution/emissions may increase the prevalence of asthma, allergies, respiratory and cardiovascular diseases [**33, 34, 35, 36**].

More specifically, ozone at the ground level is identified as a main factor of large-scale damages including lung tissue damage (particularly among the elderly and children), sensitizing airways to other irritants and allergens, chest pain, nausea, pulmonary congestion etc. [**37,38,39**].

Changes in vector ecology may lead to malaria, West Nile virus, Rift Valley fever, encephalitis and other infection diseases. Increased temperatures combined with increased %RHs encourage the growth of both crop pests/weeds (leading to the increase of pesticides and fertilizers) and insects affecting public health (such as cockroaches carrying a wide variety of pathogens, Aedes albopictus causing West Nile virus, Anopheles mosquito species carrying the parasite of malaria etc.) [**40, 41,42, 43**].

Special attention for the effects of climate change in public health should be paid to the more vulnerable social groups, such as the elderly, infants and preschool children, persons with chronic health problems and/or a poor immune system, low income and unemployed nationals and immigrants with limited access to health care services.

3.1.2 CYPADAPT Findings

According to the CYPADAPT, the most dangerous factor for public health in Cyprus is the occurrence of heat waves and high temperatures, which are associated to increased mortality and morbidity, particularly during the summer months (see Table 2.1). As stated above, elderly people constitute a substantial part of the population and their health is more vulnerable to such phenomena.

Table 2.1 Overall vulnerability assessment of public health in Cyprus to climate changes [44]

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Deaths and health problems related to heat waves and high temperatures	High (5)	Moderate to High (4)	Limited to moderate (2)	Moderate (2,5)
Flood-related deaths and injuries	Limited to Moderate (2)	Moderate(3)	Moderate (3)	None (-0,6)
Landslide-related deaths and injuries	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1,6)
Fire-related deaths and injuries	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None (-0,6)
Vector-borne and rodent- borne diseases	Limited (1)	Limited to Moderate (2)	Moderate (3)	None (-1,6)
Water-borne and food-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate to High (4)	None (-2,6)
Climate-related effects upon nutrition	Limited to Moderate (2)	Limited (1)	High (5)	None (-3,6)
Air pollution-related diseases	Moderate (3)	Moderate (3)	Moderate (3)	None (0)

3.1.3 The Tier 1 List

A total of **46 impacts and consequences** for the Health sector were identified. These are listed in the in Appendix 1 and can be clustered as following:

- Temperature Morbidity (Summer)
- Temperature Mortality (Summer)
- Air Pollution (Ozone)
- Air pollution (Particulate Matter)
- Pollen and allergens
- Infrastructure Failure
- Food Supply
- Vector-Borne Diseases
- Water Quality and Water-Borne Diseases
- Demand for Emergency Medicine
- Food-Borne Diseases
- Outdoor Activities
- Sunlight/ UV Exposure
- Agricultural Contaminants
- Healthcare System Staff Performance
- Algal/Fungal Growth in Buildings
- Increased use of pesticides and herbicides in buildings
- Air Pollution (Winter)
- Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries
- Mental Health
- Social Disruption
- Temperature Morbidity (Winter)
- Medicine Efficacy
- Mobile Care and Support Services
- Patient Recovery Rates
- Traffic Accidents
- Healthcare System Property damage

3.2 Selection of Tier 2 impacts

Applying the methodology described in Chapter 2 on the aforementioned clusters of impacts, the following Tier 2 impacts were selected for analysis:

- Temperature Morbidity (Summer)
- Temperature Mortality (Summer)
- Air Pollution (Ozone)
- Air pollution (Particulate Matter)
- Pollen and allergens

In Appendix 2 the scoring of the Tier 1 list is presented.

3.3 Other impacts excluded from the risk metric analysis

3.3.1 Infrastructure Failure and Healthcare System Property damage

Transport, communications and power generation infrastructure may be compromised during extreme weather events such as floods, storms and heatwaves. Health care infrastructure could also be directly affected by floods, storms and heatwaves. For example, IT server overheating and disruption to communication may occur in health centres, hospitals, polyclinics, clinics, diagnostic centres and independent practitioners during heatwaves. Such incidents could seriously compromise access to healthcare services.

Heatwaves may also cause disruption to the health care sector if indoor temperatures in hospitals are not appropriately controlled.

Healthcare delivery will rely in part on the adaptive capacity of hospital infrastructure that is required to respond to the predicted physical and health-related impacts of climate change.

Regarding the vulnerability to floods, it is noted that no public hospitals or private clinics are within the floodplains defined by the Flood Risk Management Plant that was drafted within the framework of the Floods Directive

3.3.2 Water and Food Borne Diseases

Increased temperatures and changes in seasonal precipitation patterns is also likely to lead to more favourable conditions for the spread of certain water-borne, food-borne and vector-borne diseases in the future.

The European Centre for Disease Prevention and Control recently assessed the potential impacts of climate change on food and waterborne (FWB) diseases in Europe associated water temperature, seasonality, air temperature, heavy rainfall events, precipitation, and temperature changes with FWB pathogens.

Campylobacteriosis and salmonellosis were cited with the highest frequency in association with air temperature; campylobacteriosis and non-cholera vibrio infections were reported in association with water temperature; cryptosporidiosis followed by campylobacteriosis were related with highest frequency with precipitation; and cryptosporidiosis followed by non-cholera vibrio were found in association with precipitation events [**45**].

The most prevalent FWB disease in Europe is campylobacteriosis which exhibits strong seasonality and has been associated with a number of meteorological variables and specific weather events, which indicates that campylobacteriosis peaks may shift as a result of climate change in the future. Temperature has also a pronounced influence on salmonellosis and food poisoning notifications, which can be attributed to improper food storage and handling at the time of eating. Nonetheless, salmonellosis incidence has declined throughout Europe over the last ten years, in part due to public health measures. Therefore, carefully implemented health promotion and food safety policies should be able to counterbalance the probable negative impacts on public health. Erratic precipitation events are predicted to increase cryptosporidiosis outbreaks, even though the strength of the association might vary by climatic region [**45**].

Listeria sp. was not associated with temperature thresholds, extreme precipitation events, or temperature limits. Despite the lack of scientific data, it is not likely that climate change will directly influence listeriosis incidence, though it could result in more cases through indirect pathways. The association between climatic determinants and *Norovirus* is tenuous, in part due to the relative lack of published information. As such, no data are available on temperature extremes or thresholds, or on the after- effects of storms, droughts, or rain events. In contrast, there is documented evidence of a strong association between rising summer (water) temperatures, extended summer seasons and non-cholera *Vibrio* spp. infections. Nevertheless, any increase of the disease burden is projected to be modest due to low current incidence rates [**45**].

The European Centre for Disease Prevention and Control concluded that whether the potentially increased transmission of Cryptosporidium spp., non-cholera Vibrio spp., Salmonella spp. and Campylobacter spp. will manifest as a greater public health risk in the future depends not only on the accuracy of climate predictions but also on:

- the current and future state of disease prevention and control infrastructures;
- the baseline resilience and health status of exposed populations; and
- the extent to which climate change adaptation strategies specifically designed to address FWB diseases have been devised and implemented.

According to the analysis in the Water Sector Report, it seems unlikely that global warming will have a major impact on the risk of disease associated with mains water supplies in Cyprus. With the current available evidence and scenarios for climate change in Cyprus it would appear that the public health effects of climate change, at least as far as waterborne disease is concerned, are likely to be relatively negligible when compared to other public health concerns.

Although a potentially risk, the public and environmental health infrastructure is likely to prevent substantial changes in the prevalence of the FWB diseases.

3.3.3 Food Supply and nutrition

Under climate change, the frequency and intensity of extreme weather events such as droughts, floods and storms could increase, with an adverse impact on livelihoods and food security. Climate-related disasters have the potential to destroy crops, critical infrastructure, and key community assets therefore deteriorating livelihoods and exacerbating poverty [**46**].

Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity. Climate change could increase the prices of major crops in some regions. For the most vulnerable people, lower agricultural output would also mean lower income. Under these conditions, the poorest people — who already use most of their income on food — would have to sacrifice additional income to meet their nutritional requirements [**46**].

Climate-related risks affect calorie intake, particularly in areas where chronic food insecurity is already a significant problem. Changing climatic conditions could also create a vicious cycle of disease and hunger. Nutrition is also likely to be affected by climate change through related impacts on food security, care practices and health [**46**].

The risks of climate change are not just to the production capacity of food security – but also to the potential growth in incomes and ability to purchase food of poor people, the risk of market disruptions, effects on supply and storage systems, and effects on stability of agricultural and rural incomes as well as nutritional content. Studies point to changes in the nutritional quality of foods (reduced concentration in proteins and in some minerals like zinc and iron), due to elevated CO_2, particularly for flour from grain cereals [**47**].

• 3.3.4 Vector-Borne Diseases

Vector-borne diseases are infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, triatomine bugs, sandflies, and blackflies. Arthropod vectors are cold-blooded (ectothermic) and thus especially sensitive to climatic factors. Weather influences survival and reproduction rates of vectors, in turn influencing habitat suitability, distribution and abundance; intensity and temporal pattern of vector activity (particularly biting rates) throughout the year; and rates of development, survival and reproduction of pathogens within vectors. However, climate is only one of many factors influencing vector distribution, such as habitat destruction, land use, pesticide application, and host density [**48**].

West Nile fever is caused by the West Nile virus, a virus of the family Flaviviridae, which is part of the Japanese encephalitis antigenic group. West Nile fever mainly infects birds and infrequently human beings through the bite of an infected *Culex* mosquito [**48**].

During the last years, West Nile Fever cases in humans have increased in several Mediterranean countries. For example, in Israel, a severe upsurge occurred during the hot summer of 2000 and again in the extremely warm summer of 2010. A change in the seasonality of the disease was observed, as the outbreaks began earlier in the year. An outbreak first occurred in Central Macedonia in northern Greece in the summer of 2010. During the same period, cases in humans were also reported in other Mediterranean countries: Turkey, Italy and Spain (together with other locations, mainly in Eurasia). Additionally, it was detected in horses in Greece, Italy, Gibraltar and Morocco. A study by found that uncharacteristically elevated temperatures during the summer of 2010 correlated with the West Nile fever upsurge in humans. Since 2010, all subsequent years (2011–2014) have been characterized by the re-emergence of West Nile fever within the same countries. A recent research analysed the status of infection by West Nile fever in Europe and its neighbouring countries in relation to environmental and climatic risk parameters. The anomalous temperatures in July were identified as one of the main risk factors [**49**].

Dengue is the most important arboviral human disease, however, mainly due to nearly universal use of piped water the disease has disappeared from Europe. Dengue is frequently introduced into Europe by travelers returning from dengue-endemic countries but no local transmission has been reported since it would also depend on the reintroduction of its principal vector, the mosquito *Aede aegypti* (also the yellow fever mosquito) which is adapted to urban environments. However, over the last 15 years another competent vector *Ades albopictus* (Asian tiger mosquito) has been introduced into Europe and expanded into several countries, raising the possibility of dengue transmission [**48**].

Transmission of the dengue virus is sensitive to climate. Temperature, rainfall and humidity affect the breeding cycle, survival and biting rate of the mosquito vectors, while temperature in particular favours the rapid development of the vector (which is highly sensitive to climate conditions), increases the frequency of blood meals, and reduces the extrinsic incubation period. During the years 2008–2012, dengue fever cases were reported in several Mediterranean (and Adriatic) countries: Greece, Croatia, Italy, Malta, France, Spain and Portugal. Although most cases were probably imported, in 2010 local transmission of dengue was reported in both Croatia and France. Today, there is an apparent threat of dengue outbreaks in the Mediterranean European countries. According to the ECDC evaluations, future expansion of the vector could be further facilitated by climate change, as altered warming and precipitation patterns might increase the number of suitable niches [**49**].

Chikungunya fever is caused by a virus of the genus Alphavirus, in the family Togaviridae, which is transmitted to human beings by the bite of infected mosquitoes such as *A. aegypti*, and *A. albopictus* [**48**].

In 2007, first transmission in Mediterranean Europe was reported from north-eastern Italy. During the period between 2008 and 2012 imported cases were reported in several countries in the Mediterranean basin including Greece, Italy, France and Spain. If global climate change continues, *A. albopictus and A. aegypti* will disperse beyond their current geographic boundaries, since temperature plays a very significant role in the development (and mortality rates) of *A. albopictus*. As *A. albopictus* is currently present in the region, Chikungunya outbreaks may be caused in the north western Mediterranean under favourable climatic conditions [**49**].

Malaria is caused by one of four species of the *Plasmodium* parasite transmitted by female *Anopheles* spp. mosquitoes. Historically malaria was endemic in Europe, including Scandinavia, but it was eventually eliminated in 1975 through a number of factors related to socioeconomic development. The potential for malaria transmission is intricately connected to meteorological conditions such as temperature and precipitation [**48**].

The potential for malaria and other “tropical” diseases to invade southern Europe is commonly cited as an example of the territorial expansion of risk due to climate change (socioeconomic, building codes, land use, treatment, capacity of health-care system, etc.). While climatic factors may favour autochthonous transmission, increased vector density, and accelerated parasite development, other factors (socioeconomic, building codes, land use, treatment, etc.) limit the likelihood of climate-related re-emergence of malaria in Europe [**48**].

During the years 2008–2012, malaria cases were reported in several Mediterranean countries: Cyprus, Greece, Malta, Spain and Portugal. While most malaria cases were reported as imported, in 2012 twenty-two cases from Greece and one from France were reported as not imported. In 2012 in the eastern Mediterranean and North Africa, malaria cases were reported in Lebanon, Egypt, Libya, Tunisia and Morocco. According to the WHO, all cases were imported with no local transmission. Since dominant or potentially important malaria vectors exist in the area, global climate change creates the potential, albeit relatively small, for the reappearance of malaria in countries where it was previously eradicated [**49**].

Leishmaniasis is a protozoan parasitic infection caused by *Leishmania infantum* that is transmitted to human beings through the bite of an infected female sandfly. Temperature influences the biting activity rates of the vector, diapause, and maturation of the protozoan parasite in the vector. Sandfly distribution in Europe is south of latitude 45^{o}N and less than 800 m above sea level, although it has recently expanded as high as 49^{o}N [**48**].

During the period of 2003–2008, Leishmaniasis cases were reported from 16 Mediterranean countries, particularly in the eastern and southern sides of the basin. On average, 85.555 cases per year were reported for the Mediterranean basin, most of them in Algeria, Syria, Libya and Morocco. During the same period, Leishmaniasis cases were reported from 22 Mediterranean countries around the whole basin (on average, 875 reported cases per year for the entire region) [**49**].

Vector reproduction, parasite development and bite frequency generally rise with temperature. Therefore, malaria, tick-borne encephalitis, and dengue fever are very likely to become increasingly widespread in certain parts of the world (mainly in tropical and sub-tropical climates) due to projected rises in temperatures [**2**]. Climate is an important geographic determinant of vectors, but the data do not conclusively demonstrate that recent climatic changes have resulted in increased disease vector-borne disease incidence on a pan-European level. The risk of reintroduction of malaria into certain European countries is very low and determined by other variables rather than climate change. Introduction of dengue, West Nile fever, and chikungunya into new regions in Europe is a more immediate consequence of virus importation into competent vector habitats; climate change is one of many factors that influence vector habitat [**48**].

However, future outbreaks of certain vector borne diseases such as malaria, would still be expected to be rare and limited in number in Europe. It is important to note that the relevance of environmental change to patterns of disease depends on the susceptibility of local populations to the disease, the robustness of local food and water safety measures, vector control measures and communicable disease surveillance and control arrangements (e.g. vaccination programmes, legislation). It is likely that the public health infrastructure would prevent the indigenous spread of Vector borne diseases [**2**].

3.3.5 Demand for Emergency Medicine

Emergency medicine is very likely to experience a significant change in demand for its services over and above current annual levels as a result of climate change. This is likely to result in an increase in levels and variety of demand during extreme weather events, such as heatwaves.

3.3.6 Outdoor Activities

Working, exercising or playing outdoors during extreme weather events such as heatwaves, floods and windstorms will increase the health risks for those exposed. The main health impacts of this are likely to include respiratory and cardiovascular effects due to heat exhaustion, sunstroke and sunburn. However, there will also be a number of health benefits such as increased exposure affecting vitamin D levels. People most at risk of adverse health effects would be those exercising or working outdoors during high temperatures.

- ### 3.3.7 Sunlight/ UV Exposure

The most common diseases linked to ultraviolet radiation exposure are skin cancers and cataracts as well as other less common detrimental health effects including sunburn, photodermatoses, photoaggravation of inflammatory skin disorders and immunosuppressive effects on the skin. The most serious of these effects are skin cancers, which are either melanoma or non-melanoma skin cancers.

Health benefits of ultraviolet radiation exposure include the synthesis of vitamin D, and although ultraviolet exposure may exacerbate inflammatory skin conditions it also has some therapeutic effects. It has long been known that vitamin D is required to maintain a healthy skeleton through a process of calcium metabolism and the main source of vitamin D is through exposure to short wave ultraviolet radiation, with diet playing a minor role.

The amount of UV radiation which reaches the surface of the earth is dependent on a number of factors, the main one of which is the amount absorbed by the stratospheric ozone layer. The effect of climate change on UV radiation exposure is difficult to assess due to probable increased outdoor activity due to extended summer season and lower levels of clothing.

Cyprus has year-round sunshine and therefore ultraviolet radiation levels are on the high end. The population-weighted average daily ambient ultraviolet radiation R level for 1997–2003 was 3439 J m^{-2}, which was higher than other countries in the Mediterranean region. Despite the high ultraviolet radiation levels in Cyprus, skin cancer rates are relatively low; in 2008 the WASR of melanoma was 5,8 for men and 5,7 for women. Melanoma of the skin was the eighth most common cancer in both men and women in 2008. Whether the rate reflects better protection from ultraviolet radiation through human factors (use of sunscreen and protective clothing during exposure to the sun) or genetic factors (relating to skin colour etc.) is not known. Considering the geographic location of Cyprus and conquests it experienced by many different populations, such as Phoenicians, Egyptians, Romans, Venetians, Ottomans, British, and so on, the genetic make-up of the Cypriot population is most likely complex and reflected in the enormous skin colour variation of the people (going from very light complexions to very dark complexions). Even though the rate of skin cancer is relatively low, it has been rising over the years suggesting ultraviolet radiation is having a bigger impact on the population [**50**].

Both negative and positive effects of increased sunlight/ ultraviolet radiation radiation exposure are difficult to quantify. It should be noted that the risk of malignant skin tumours as a result of UV exposure is currently considered to be of a greater consequence

3.3.8 Agricultural Contaminants

Humans are potentially exposed to a number of agriculturally derived chemicals and pathogens in the environment (air, soil, water and sediment) by a number of different routes. This not only includes consumption of food (both crops and livestock) exposed to contaminants through the food chain, as well as via groundwater and surface waters used for drinking, but also from direct contact with water bodies or agricultural soils through for example, recreational use. A likely increase in the use of pesticides as crop diseases become more prevalent will increase levels of pesticide applied to food items. Changes in climate (e.g. warmer conditions and and drier summers), could result in the emergence of new pathogens, or the increased incidence of existing diseases. Although existing drinking water treatment and monitoring will likely prevent high human exposure levels, human exposure to pathogens in food items may increase, although the magnitude of this increase will be highly dependent on the contaminant type.

Although attributing health effects due to agricultural contaminants to the general population is often inconclusive, several studies have associated different health outcomes with exposure to chemicals from agriculture. These include Parkinson's disease, linked to exposure to pesticides and a number of medical disorders linked to chlorphenoxy herbicide exposure [**2**].

3.3.9 Healthcare System Staff Performance

Healthcare staff performance may be compromised during heatwaves, if indoor temperatures are not appropriately controlled. Floods may also affect negatively the ability to get to work. IT equipment and power failures due to extreme weather will also compromise staff performance.

- ### 3.3.10 Medicine Efficacy

Manufactured drugs are in general licensed for storage at temperatures up to 25°C. Exposure of medicines (or other medical and laboratory materials) to high temperatures during storage and transit could have consequences on their efficacy [**2**].

- ### 3.3.11 Patient Recovery Rates

Patient recovery may be compromised during extreme weather events, particularly during heatwaves, if indoor temperatures in hospitals are not appropriately controlled.

- ### 3.3.12 Algal/Fungal Growth in Buildings

Mould can have significant consequences for human health, most commonly allergic reactions to the spores, especially asthma. The main climate driver for condensation, damp and mould is increased winter precipitation and consequent higher humidity levels. More research is needed to determine the link between damp homes and respiratory conditions.

- ### 3.3.13 Increased use of pesticides and herbicides in buildings

With a progression to warmer summers, there is an increased likelihood of infestations occurring in properties. Increase in vector reproduction and parasite development could lead to increased use of pesticides and herbicides in homes. Exposure to pesticides has been associated with neurodevelopmental outcomes and leukemia, and acute pesticide poisoning in extreme exposures.

- ### 3.3.14 Air Pollution (Winter)

Winter air pollution episodes are likely to decline in frequency and intensity partly as a result of warmer temperatures. The likely decrease in winter air pollution episodes will be associated with a proportional decrease in mortality and morbidity. Apart from climatic effects, winter air pollution episodes are also likely to further decline due to projected reductions in atmospheric emissions (e.g. traffic-related) of particulate matter (PM_{10}), nitrogen oxides (NO_X) and Volatile Organic Compounds due to future tightening of both fuel and vehicle emission legislation. The effect of the projected changes in atmospheric emission on winter air pollution is likely to be much larger than any effects associated with changing climatic conditions [**2**].

- ### 3.3.15 Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries

Extreme weather events such as floods, storms can cause deaths and injuries, however there are no sufficient data to quantify the future risk.

• 3.3.16 Mental Health

Mental health impacts of storms and floods can arise as a result of the stress of evacuation, property damage, economic loss, and household disruption. However remains limited evidence regarding the long-term mental health impacts of these events [**3**]

• 3.3.17 Social Disruption

Extreme weather events can increase in social disruption, exacerbating inequalities in communities and raising tensions between different social groups e.g. between those who live in areas more likely to flood and those who do not or can afford to protect their properties. Mental stress, violent behaviour and suicides increase during hot weather. Ambient temperature and heat waves are strongly correlated with increases in violent crime and associated injuries. Increased night-time temperatures can also lead to heat stress and sleep deprivation, with a potential increase in social unrest. Although some research has been carried out into how social behaviour changes under different climate effects, further research is required in this area [**2**].

• 3.3.18 Temperature Morbidity (Winter)

Within winter months, as temperatures increase this will almost certainly result in a reduction in the number of hospital admissions due to cold related illnesses.

• 3.3.19 Mobile Care and Support Services

Mobile care and support services include ambulances, transportation of patients and organs, etc. Potential problems in the future will be mainly due to transport network and infrastructure problems and traffic accidents. Adverse weather conditions could also increase disruption to mobile support services and could endanger lives and limit the supply of medicines and the delivery of urgent health care to patients. Ambulance response times can be adversely affected by severe weather.

• 3.3.20 Traffic Accidents

A future changing climate is likely to have an effect on the number of traffic accidents as a result of a number of factors, the main ones of which are outlined below.

Warmer weather is likely to lead to more vehicle breakdowns due to overheating of engines with resultant disruption to travel and also to increased wear and tear of road surfaces

Wetter winters will increase the risk of landslide, with a subsequent increase in risk to transport links, as well as directly, traffic accidents. More intense rainfall levels in winter will lead to an increased risk of traffic accidents due to reduced visibility leading to more difficult driving conditions, as well as localised flood areas as a result of low areas and/or an overwhelmed drainage system.

3.4 Cross-sector impacts

There are a number of cross-sectoral impacts that have linkages to the health sector. The largest numbers of these are linked to four main impacts which were noted as:

- **Human illness or morbidity**

Includes a number of impacts linked to various diseases, pollution, contamination, air quality, mental health, etc.

- **Conflict**

Conflict caused by a number of issues including changes to supplies of water or food, flood risk etc.

- **Death or injury**

Change in the number of deaths or injuries due to changes in weather conditions as well as consequential effects such as changes to flood risks and traffic accidents etc.

- **A changed demand for health care services**

A change in the numbers and/or levels of illness, death, injury or morbidity will have a consequential impact on the demand for health care services.

In addition, there are a number of consequential impacts related to these impacts that impact across other sectors. The most obvious of these are within the Business, Industry, Services sector and Built Environment.

3.5 Risk metrics

Risk metrics provide a measure of the consequences of climate change. Metrics should satisfy a number of criteria, i.e. they should:

- Be sensitive to climate but also allow the disaggregation of climate and socio-economic effects.
- Provide a measure of changing probability or consequences relevant to a baseline, so historical data are required to establish the current situation.
- Be presented at the national and regional scales, based on high quality data that will be also available in the future, allowing the metrics to be repeatable in subsequent CCRA cycles.
- Reflect economic, environmental and social consequences of climate change; some metrics may be monetised but others may simply indicate the areas affected or consequences for vulnerable groups of society.

The selected metrics for the Health Sector are listed below.

HE1 - Temperature Mortality. As temperatures increase, mainly during summer months, this can have a subsequent effect on the number of premature deaths as a result of heat related illnesses (i.e. cardio-vascular and respiratory diseases). These deaths tend to increase above a set temperature threshold, with the threshold and rate of increase varying between regions. Temperature mortality (heat-related) has been addressed by assessing the change in mortality rate based on published exposure response functions, threshold temperatures and data on maximum daily temperature and daily death counts.

HE2 - Temperature Morbidity. As temperatures increase, mainly during summer months, this can have a subsequent effect on the number of hospital admissions as a result of heat related illnesses. Hospital admissions attributable to heat are more difficult to attribute than those under heat related deaths. For this metric, a proportional relationship has been assumed between patient days and heat related mortality based on the UK CCRA, and therefore results should be interpreted with caution.

HE3 – Air Pollution

Ground-level ozone can directly affect human health. Acute exposure to ozone may cause irritation to the eyes and nose and very high levels can cause damage to the airway lining. Mainly in spring and summer months increased sunlight and warm temperatures, there can be a noticeable increase in ground-level ozone. This can lead to increases in daily mortality and hospital admissions linked to respiratory diseases.

Particulate matter (PM_{10} and $PM_{2,5}$), has also been associated with daily mortality. PM_{10} is often used as an air pollution indicator when assessing a possible confounding effect on the temperature–mortality relationship.

HE4 - Pollen and allergens

Higher temperatures may cause an earlier and possibly longer pollen season. More days with high pollen concentrations would result in more people with hay fever and pollen asthma.

4 Response Functions

4.1 Summary

The purpose of this step is to understand the sensitivity (according to the available evidence) of the selected metrics to changing climate conditions. It was based on review and synthesis of existing research outputs and government analyses and included recording key assumptions and uncertainties related to the assessment. Given the varied and extensive form within the built environment, selected metrics were developed as a means of capturing key issues and enabling risk assessment.

For each metric, suitable datasets were sought from publicly available sources (either government analyses or wider published research); this will provide the basis for consistency in the delivery of future risk assessments.

The result is a response function that is used in conjunction with future climate projections, in Chapter 5, to assess future risks.

4.2 HE1 - Temperature Mortality

Climate change is likely to have a range of health effects in Europe. Studies have confirmed the effects of heat on mortality and morbidity in European populations and particularly in older people and those with chronic disease. With respect to sub-regional vulnerability, populations in Southern Europe appear to be most sensitive to hot weather, and also will experience the highest heat wave exposures [**3**].

The effect of increased temperatures on mortality has consistently been shown to be nonlinear, following a U-, V-, J-, or inverse J-shaped curve, where minimum mortality is found at a certain temperature or within a temperature range, at moderate temperatures, and mortality increases below and above the threshold, for heat-related effects, with higher mortality at temperature extremes. The aforementioned shapes of the relationship between mortality and weather indicators have been identified in many different geographic regions, including Europe, the United States and China. The temperature-mortality relationship varies geographically, with adverse effects of heat beginning at lower temperatures, thereby suggesting that the population adapt to their local climate. Studies from several European cities attributed a change of between 0,7% and 3,6% in all-cause mortality to a 1°C increase of temperature above a certain threshold. The "Prevention of Acute Health Effects of Weather conditions in Europe" project estimated an increase in mortality of 2% in northern cities and 3% in southern cities for every 1°C rise in apparent temperature above thresholds.

The strength of the relationship between daily outdoor temperature and health outcomes differs between countries, between cities and even in the same location from one year to the next [**51**]. Differences in heat sensitivity, coping capacity, and adaptation measures of different populations, as well as climatic differences across the globe, can influence the relationship of air temperature with mortality and cause it to be region specific. Lubczyńska et al. suggest that the relationship between air temperature and mortality, as reported for a certain region, cannot be directly extrapolated to other regions with, for example, different climatic zones, without introducing errors [**52**].

Various studies have indicated that temperature can not only affect deaths occurring on the same day, but on several subsequent days: deaths on each day depend on the effect of the same day's temperature as well as the lag effects of the previous days' temperatures [**53**].

Lubczyńska *et al*. using data from Cyrus found a relationship between high temperatures and cardiovascular mortality for cerebrovascular diseases, ischaemic and other heart diseases, with the highest risk associated with ischaemic heart diseases. The relationship is strongest on the actual day of the event and the relative risk remains significantly elevated for approximately one day following the event. The increase in risk is most evident on days with the highest temperatures. The highest relative risks are observed for the daily mean temperature time series, which suggests that consecutive high day- and night-time temperatures are the most hazardous [**52**].

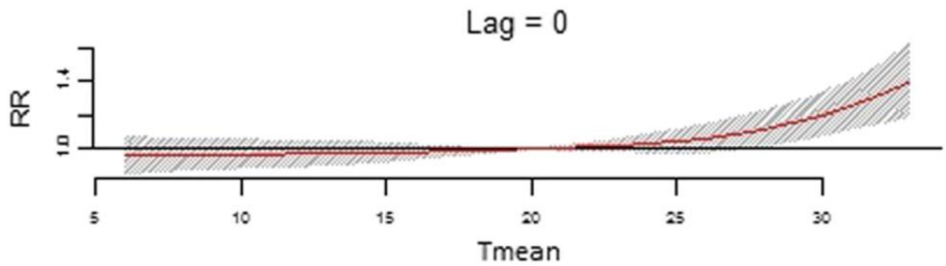


Figure 4.1 Relative cardiovascular mortality risk (Lag=0). The grey shadings represent the 95% confidence intervals[52]

Tsangari *et al*. examined the daily mortality data for the 2004-2009 period (all-cause mortality excluding external causes), daily values of maximum temperature and mean relative humidity. They found that temperature has a significant effect on all-cause mortality in Cyprus, independent of humidity and seasonality. The effect of temperature is non-linear and more specifically it is constant up to one point and follows a **V-shaped relation** where a hot threshold can be observed [**53**].

Specifically, the risk of mortality in Cyprus increases for temperatures above **33,7^{0}C**. Moreover, there is a significant increase at very high temperatures.. The effect of heat is much higher on the current day and within the next couple of days indicating a short-term effect.

Results and conclusions for the district of Nicosia are very similar to those found for Cyprus as a whole area. Heat had an immediate effect of on mortality within the first two days, and a lower effect in lags 2-10. However, the effect observed for Nicosia was less pronounced, much smaller and smoother and the threshold temperature was different, at **32,5^{0}C**.

Analysis of the heat-mortality relationship for the district of Limassol showed slightly different characteristics, with a higher threshold temperature of **38^{0}C**, above which the effect on health was very strong, especially for lags 0-1. The effect in lags 0-1 was much stronger in Limassol in comparison to Nicosia or Cyprus.

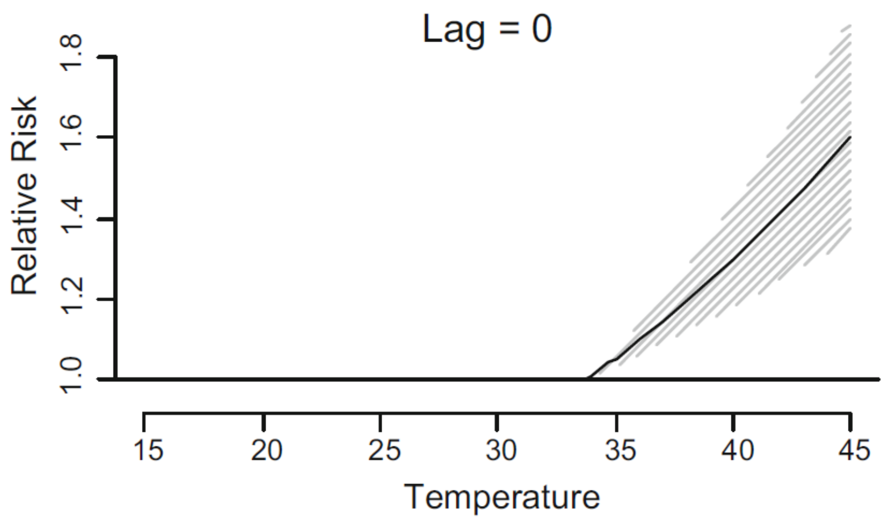


Figure 4.2 Relative all-cause mortality risk for Lag=0. Cyprus, 2007–2009 [53]

The calculation of temperature-related mortality has been based on a methodology applied in other studies [**2**, **54**] that requires knowledge of regional temperature thresholds and exposure-response coefficients for heat related effects on health, as well as baseline population and mortality data.

Excess mortality due to high temperature was calculated employing the following function.

$\Delta y = y_o \, [e^{\beta \Delta T} - 1] \times D$

Where:

- Δy is the expected number of excess deaths
- yo is the expected daily number of deaths (without climate change)
- β is coefficient of the relationship between mortality and high temperature (above threshold)
- ΔT is the temperature difference above the threshold
- D indicates number of exposed days above threshold

Relative Risk is defined as the ratio of deaths that occur under heat effect relative to a baseline mortality:

$RR = e^{\beta \Delta T}$

Where:

- β is coefficient of the relationship between mortality and high temperature (above threshold); according to the results of Tsangari *et al* [53] for Cyprus and for Lag=0

- ΔT is the difference between maximum daily temperature and the threshold of 33,7°C established by Tsangari *et al* [**53**]

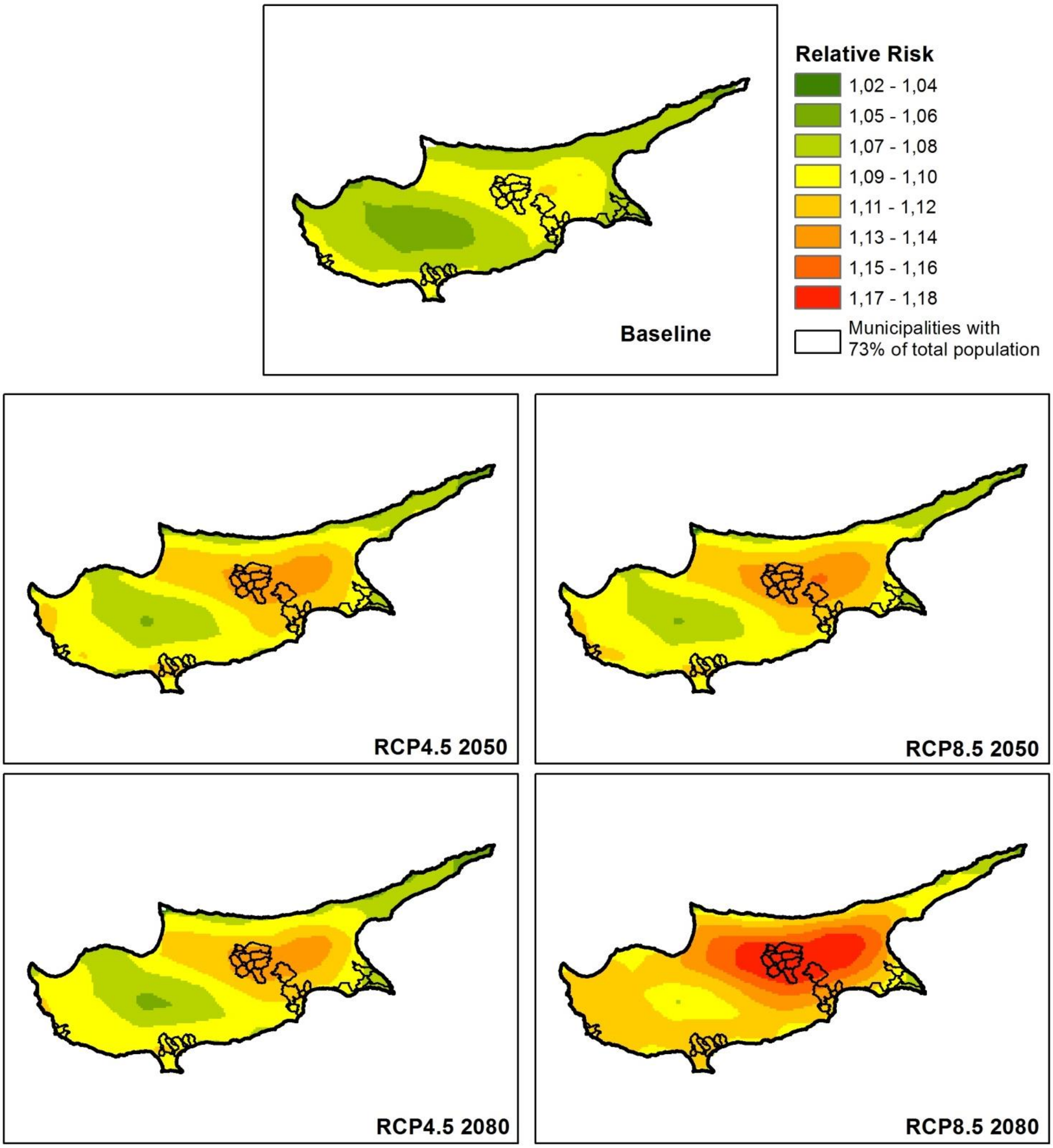


Figure 4.1 Modelled Relative all-cause mortality Risk

4.3 HE2 - Temperature Morbidity

Morbidity rises in hot weather, particularly for the elderly, very young and sick people. Elderly people are vulnerable to heat stress. Vulnerability to heat in old age is linked to intrinsic changes in the regulatory system or to the presence of drugs that interfere with normal homeostasis.

Heatwaves (i.e. continuous days of exceptional heat) in particular have been shown to increase respiratory and cardiovascular illnesses. Exposure to high temperatures during heatwaves may cause dehydration, heat cramps caused by fluid and electrolyte imbalances often caused by exertion, heat exhaustion, and heat stroke which can result in organ failure, brain damage or death. Heatwaves have also been linked to mental stress, violent behavior and suicides which increase during hot weather.

Heatwaves are associated with a series of health problems ranging from increased morbidity to excess death toll. Numerous studies have examined the harmful impact of heat waves on mortality with nearly consistent results. However, the number of studies on the heat wave-morbidity relationship is relatively small and their outcomes varied across regions. Knowledge gaps on the heat wave-morbidity association still exist [**55**].

Li *et al.* through an extensive literature review found that most of the existing literature identified the negative effect of heat waves on emergency medical care. They found inconsistent results among studies on hospital admissions. This inconsistency was attributed due to various social factors that can veil the modest environmental effect. For example, the number of available beds is often limited, so most patients will be treated in the ED and then sent home. Only a small number of patients are hospitalized in each study location during heat waves, which may reduce the statistical power. It might indeed be the case that the adverse effect of heat waves on hospital admission is a lot smaller than on emergency medical services use because ambulances and emergency departments are really at the front line of medical assistance, and thus are more sensitive to acute events [**55**].

Hames and Vardoulakis concluded that generally hotter climatic conditions and more frequent and intense heatwaves are likely to cause an increase in patient days per year in hospital in the UK due to heat-related illness (i.e. hospital admissions attributable to high temperatures but not necessarily diagnosed as hyperthermia, heat stroke, etc.) [**2**]. In the UK CCRA, Hames and Vardoulakis using an empirical relationship between heat-related deaths and hospital patient days per year in the UK obtained from the Donaldson *et al*. [**56**] estimated the heat related morbidity by multiplying the heat related mortality deaths by **102**.

This risk metric estimates the number of hospital admissions attributable to heat. It was assumed that a premature death is related with 102 patient-days in hospital per year.

- ## 4.4 HE3 - Air Pollution

Climate change will have complex and local effects on pollution chemistry ,transport, emissions, and deposition. Outdoor air pollutants have adverse effects on human health, biodiversity, crop yields, and cultural heritage. The main outcomes of concern are both the average (background) levels and peak events for tropospheric ozone, particulates, sulphur oxides (SO_x),and nitrogen oxides (NO_x). Future pollutant concentrations in Europe have been assessed using atmospheric chemistry models, principally for ozone. Reviews have concluded that climate change per se (assuming no change in future emissions or other factors) is likely to increase summer tropospheric ozone levels (range 1 to 10 ppb) by2050s in polluted areas (i.e., where concentrations of precursor nitrogen oxides are higher). The effect of future climate change alone on future concentrations of particulates, nitrogen oxides, and volatile organic compounds (VOCs) is much more uncertain [**3**].

The main characteristics associated with air quality in the Mediterranean region are the intense photochemistry and the mixture of anthropogenic and natural (Saharan dust, sea salt and pollen) particulate matter. There is strong link between air pollution and regional climate mainly through the surface energy portioning and water cycle. Desert dust is one of the crucial components that contribute to the air quality degradation of the Mediterranean region [**57**].

There are already high levels of air pollution in the Eastern Mediterranean and the Middle East region, both of natural and anthropogenic origin. The fine aerosol particles are mostly composed of sulphates and particulate organic matter, whereas the coarser particles are dominated by desert dust. The levels of fine aerosol particles in the Eastern Mediterranean and the Middle East region are expected to rise substantially during the mid-21st Century due to increasing emissions of sulphur dioxide and nitrogen oxides [**58**].

In summer the Eastern Mediterranean and the Middle East is largely cloud-free, and the relatively intense solar radiation promotes the formation of ozone. In the Mediterranean region, ozone levels often exceed air quality limits, particularly in summer, and the Mediterranean ozone levels are among the highest in the world. It is likely that ozone levels will continue to increase and that the Eastern Mediterranean and the Middle East will be a persisting air pollution 'hot spot' [**58**].

The effects of climate change on pollutant concentrations are rather uncertain. Overall, emission controls (or the lack thereof) are considered to have a stronger influence on air quality than climate and land-use changes. In future, the expected increases in warming and drying will be conducive for ozone formation, especially during heat spells, and this can have major consequences for air quality within the Eastern Mediterranean and the Middle East [**58**].

Air quality is expected to become poorer in the Eastern Mediterranean and the Middle East. Whereas human-induced emissions in most of Europe are decreasing, they are increasing in Turkey and the Middle East, which affect ozone and particulate air pollution, leading to excess morbidity and mortality. In the northern Eastern Mediterranean and the Middle East increasing dryness will likely be associated with fire activity and consequent pollution emissions [**59**].

Due to lack of available data it was not possible to produce response functions linking climatic variables and ozone or particulate matter concentration.

• 4.5 HE4 - Pollen and allergens

The impacts of climate change on allergenic plants and pollen distribution can be summarised as following [**60, 2**]:

- faster plant growth;
- changes in plant species distribution
- larger quantities of pollen produced by plants
- increased amounts of allergenic proteins contained in pollen,
- earlier plant growing season and therefore earlier and longer growing pollen seasons.

Increased exposure to aeroallergens (which would vary regionally) may increase the likelihood of developing allergic rhinitis or asthma in sensitized individuals and an aggravation in patients already symptomatic [**2**].

A longer pollen season, and changes to the distribution of plant species noted above may also result in changes to pollen related food allergies. Some food allergies (especially fruits) are linked to pollen allergy (either because of similarities between the proteins in the pollen and in the fruit or from the association between birch tree pollen allergy and some food allergies). If there are more, or more-prolonged periods, of pollen production, then there is a risk of more people developing related food allergies linked to plant-derived foods such as apples, stone fruits, celery, carrot, nuts and soybeans [**2**].

Current knowledge on the worldwide effects of climate change on respiratory allergic diseases is provided by epidemiological and experimental studies on the relationship between asthma and environmental factors, like meteorological variables, airborne allergens and air pollution. Pollen allergy is frequently used to study the interrelationship between air pollution and allergic respiratory diseases (rhinitis and asthma). Epidemiologic studies have demonstrated that urbanization, high levels of vehicle emissions and westernized lifestyle are correlated to an increase in the frequency of pollen-induced respiratory allergy prevalent in people who live in urban areas compared to those who live in rural areas. Meteorological factors (temperature, wind speed, humidity, thunderstorms etc.) along with their climatic regimes (warm or cold anomalies and dry or wet periods, etc.), can affect both biological and chemical components of this interaction. Climate changes might induce negative effects on respiratory allergic diseases favouring the increased length and severity of pollen season and the increasing frequency of urban air pollution episodes. Climatic factors (temperature, wind speed, humidity, etc.) can affect both components (biological and chemical) of this interaction [**60**]:

However, there is currently insufficient quantitative evidence for establishing the impact of climate change on aeroallergens including pollen and the associated risks for public health.

5 Estimated Consequences of Climate Change

5.1 Introduction

In order to estimate the consequences of CC, the climate projections were applied on the response functions.

The results presented in this section only consider climate change sensitivity. No change is made to the current socio-economic baseline. Social and economic drivers are only introduced in Chapter 6.

For each metric a scorecard is be given to indicate the confidence in the estimates given and the level of risk or opportunity.

Confidence is assessed as high (H), medium (M) or low (L).

Risks (Threats and opportunities) are scored either high (3) medium (2) or low (1) (shown to the right). These will be given for the lower (L) and upper (U) estimates for the 2050s and 2080s.

Metric Code	**Metric Name**	**Confidence**	**2050s**		**2080s**	
			L RCP4.5	**U** RCP8.5	**L** RCP4.5	**U** RCP8.5
			Risk/opportunity			
X	XXXX					

Classification of Confidence

Confidence Class	Definition
High (H)	Reliable analysis and methods, with a strong theoretical basis, subject to peer review and accepted within a sector as “fit for purpose”.
Medium (M)	Estimation of potential impacts or consequences, grounded in theory, using accepted methods and with some agreement across the sector

Low (L)	Expert view based on limited information, e.g. anecdotal evidence, or very simplistic estimation methods

Risks and opportunities are scored as the magnitude classes used for scoring impacts in the Tier 2 selection. For scoring purposes 3 = High, 2 = Medium and 1 = Low. For the scorecard, the risk/opportunity level relates to the most relevant of the economic/environmental/social criteria.

Level of risk or opportunity	
3	Positive - High consequences
2	Positive - Medium consequences
1	Positive - Low consequences
1	Negative -Low consequences
2	Negative - Medium consequences
3	Negative - High consequences
-	No data

5.2 Data used

Estimates of future risk are given under the two (2) most plausible Representative Concentration Pathway (RCPs) scenarios in compliance with the latest Assessment Report of the IPCC (AR5). The RCP8.5 is the most **severe** scenario, featuring the highest emissions and 8,5 Wm^{-2} of global mean radiative forcing by 2100 relative to the pre-industrial times. The RCP4.5 is a **medium** scenario, featuring 4,5 Wm^{-2} radiative forcing in 2100).

The results from these scenarios are analysed for two future time periods that are sufficiently distant from the present-day and therefore offer a higher possibility for statistically significant results. These periods are 2050s (2041-2060) and 2080s (2071-2090), to assess climate change in mid and late 21st century. We avoided the 2020 period as it is too close to the reference, present-day period, and therefore the noise is expected to dominate the results. To ensure a high signal-to-noise ratio, we averaged the output of 20 years centred around those two periods. Future changes were estimated as the difference from the 1991-2010 reference, present-day period.

The climate variables applied on the response functions, were generated from daily data of the SMHI-MPI (EURO-CORDEX) model.

5.3 HE1 - Temperature Mortality

Metric Code	Metric Name	Confidence	2050s		2080s	
			L RCP4.5	U RCP8.5	L RCP4.5	U RCP8.5
			Risk			
HE1	Temperature Mortality	**M**	3	3	3	3

We used daily maximum temperature data in order to calculate the temperature difference above the maximum daily threshold of 33,7°C as well as to calculate days with maximum temperature above the threshold values. Baseline non-accidental, all-cause daily mortality was calculated from data for the 2004-2013 period (see Table 1.5). The β coefficient of the relationship between mortality and high temperature (above threshold) was based on the results of Tsangari *et al* [53] for Cyprus and for Lag=0. The excess heat mortality results are presented in the following table and are population weighted.

Table 5.1 Annual excess Heat Mortality (Government controlled area of Cyprus)

Reference period	2050s		2080s	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5
50	97 (+94%)	113 (+126%)	102 (+104%)	184 (+268%)

5.4 HE2 - Temperature Morbidity

Metric Code	Metric Name	Confidence	2050s		2080s	
			L RCP4.5	U RCP8.5	L RCP4.5	U RCP8.5
			Risk			
HE2	Temperature Morbidity	**L**	3	3	3	3

This risk metric estimates the number of hospital admissions attributable to heat. These totals are estimated by multiplying the heat related mortality deaths by 102. These estimates are very uncertain.

Table 5.2 Annual Excess Heat Morbidity (Government controlled area of Cyprus) - patient-days in hospital per year

Reference period	2050s		2080s	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5
5.100	9.894	11.526	10.404	18.768

• 5.5 HE3 - Air Pollution

Metric Code	Metric Name	Confidence	2050s		2080s	
			L RCP4.5	U RCP8.5	L RCP4.5	U RCP8.5
			Risk			
HE3	Air Pollution	L				

Literature suggests that climate change is likely to increase the levels of some pollutants; however, there are no sufficient data to quantify the risk.

• 5.6 HE4 - Pollen and allergens

Metric Code	Metric Name	Confidence	2050s		2080s	
			L RCP4.5	U RCP8.5	L RCP4.5	U RCP8.5
			Risk			

HE4	Pollen and allergens	**L**				

There is insufficient quantitative evidence for establishing the impact of climate change on aeroallergens including pollen and the associated risks for public health.

6 Socio-economic Influence on the Projected Consequences

• 6.1 Population projections

Europop2013, the latest population projections released by Eurostat, provide a **main scenario** and **four variants** for population developments from 2013 to 2080 across 31 European countries. These projections were produced using data for 1 January 2013 as a starting point and therefore include any modifications made to demographic statistics resulting from the 2011 population census exercise.

Data on population, live births and deaths used as input data in EUROPOP2013 round are official statistics provided by the national statistical authorities to Eurostat in the frame of annual demographic data collection. Migration flows have been measured in terms of net migration (including statistical adjustment) and computed as residual from the annual demographic balance. The 'main input dataset' includes the 2013 base-population and the assumptions for fertility, mortality and international net migration (including statistical adjustment), and defines the frame of main scenario for producing the population projections. Four variants were obtained by modifying one of the assumptions' component while the other components of the 'main input dataset' were maintained constant.

Europop2013 projections result from the application of a set of assumptions on future developments for **fertility, mortality and net migration**. The projections should not be considered as forecasts, as they show what would happen to the resulting population structure if the set of assumptions are held constant over the entire time horizon under consideration; in other words, the projections are 'what-if' scenarios that track population developments under a set of assumptions. As these projections are made over a relatively long time horizon, statements about the likely future developments for the EU's population should be taken with caution, and interpreted as only one of a range of possible demographic developments.

The time horizon covered in Europop2013 is 2013 until **2080** for the **main scenario and zero migration variant**, and 2013 until **2060 for the higher life expectancy, reduced migration and lower fertility variants.**

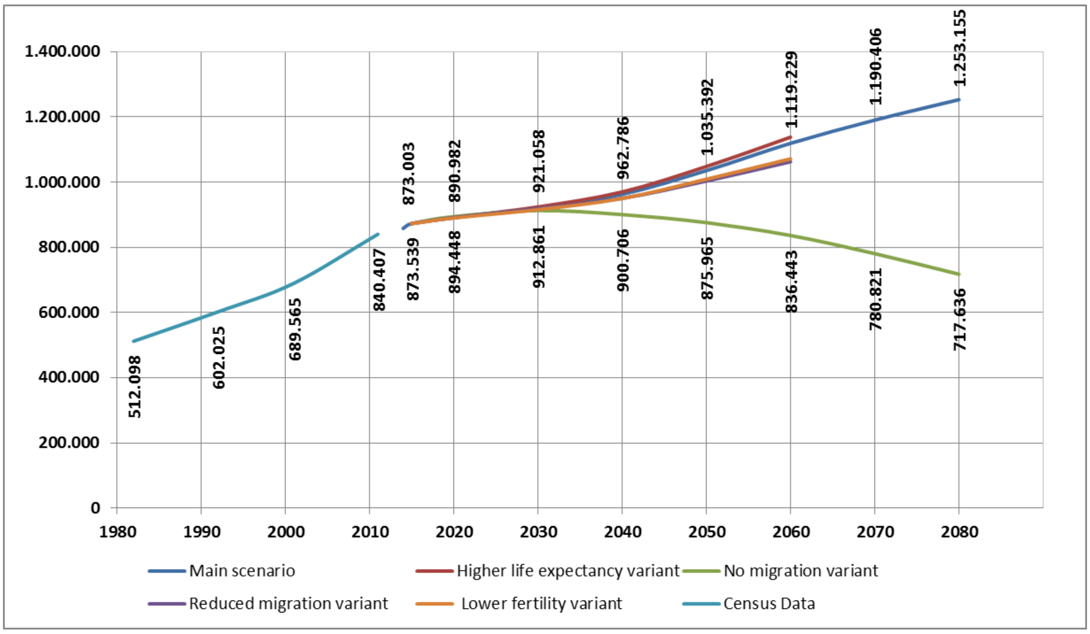


Figure 6.1 Europop2013 Cyprus population projections and Census Data

Figure 6.1 presents the projected changes to the population of Cyprus during the period 2014 to 2080. There is little variation between the Main scenario and the following 3 Scenarios: Higher life expectancy variant, Reduced migration variant and Lower fertility variant. According to the *main scenario*, the population of Cyprus is predicted to rise up to 20% by 2050 and 46,1% by 2080 (in comparison to 2014). The old-age dependency ratio is estimated 19,9% in 2014 and will rise to 42,3% by 2080. According to the *No migration variant Scenario population* is predicted to decline by -22% during the period 2015 to 2080.

According to the main scenario, the proportion of persons aged 65 or over will reach 25% in by 2050 and 2080. The population aged 80 or over will reach 8% in 2050 and 11% in 2080 (3,1% in 2015).

The average household size in Cyprus according to Census data was:

- 3,23 in 1992
- 3,06 in 2001 and
- 2,76 in 2011

Assuming that the average household size will not further decline, the estimated number of households for the "main" scenario for 2050 and 2080 is 375.142 and 454.042 respectively. For the "No migration variant" Scenario population scenario is 317.379 and 260.013.

• 6.2 Temperature mortality and morbidity

The aforementioned population projections were applied in the HE1 - Temperature Mortality metric. It was assumed that there will be no change in future population distribution and that the daily mortality rate will be proportional to the total populations regardless the changes in the age distribution (It is expected that autonomous and planned adaptation will compensate the negative effect of population aging on temperature related mortality). The heat-related mortality threshold and exposure-response coefficients have been assumed to remain unchanged in the future. This is of course a simplifying assumption since regional populations are likely to partially acclimatise to generally increasing temperatures through gradual physiological and planned adaptation (increased use of air conditioning, heat health warning systems, etc.).

Both RCP4.5 and RCP8.5 scenarios that don't take into account population change, predict a net increase in heat mortality that has a similar trend with the No migration variant Scenario of Europop2013. However, the combination of the RCP8.5 scenario and the Main population Scenario of Europop2013 shows drastic increase in excess heat mortality.

Table 6.1 Annual excess Heat Mortality (Government controlled area of Cyprus)

Scenario	Reference period	2050s		2080s	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Climate Change only	50	97 (+94%)	113 (+126%)	102 (+104%)	184 (+268%)
Climate change and population change – Main Scenario of Europop2013	50	119 (+139%	140 (+180%)	153 (+207%)	276 (+452%)
Climate change and population change – No migration variant Scenario of Europop2013	50	101 (+102%)	118 (+137%)	88 (+76%)	158 (+216%)

Table 6.2 Annual excess Heat Morbidity (Government controlled area of Cyprus)

Scenario	Reference period	2050s		2080s	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Climate Change only	5.100	9.894	11.526	10.404	18.768
Climate change and population change – Main Scenario of Europop2013	5.100	12.138	14.280	15.606	28.152

Climate change and population change – No migration variant Scenario of Europop2013	5.100	10.302	12.036	8.976	16.116

According to the main scenario of Europop2013, it is expected that the aged population will grow not only in relative but also in absolute terms. The number of persons aged 80 and over (oldest old) is expected to nearly triple, rising from 27.120 in 2015 to about 87.417 in 2050 and 135.039 in 2080. This impact will be more visible from 2025 onwards, due to the expected increase in life expectancy. As such, it is these social groups that would be most at risk of heat stress as a result of an increased frequency of elevated temperature events.

7 Economic Impacts

• 7.1 Introduction

A monetisation exercise allows an initial comparison of the relative importance of different risks within and between sectors. Since money is a metric with which people are familiar, it may also serve as an effective way of communicating the possible extent of climate change risks and help raise awareness.

A variety of methods are available to determine the costs. These methods can be categorised according to whether they are based on:

- Market prices (MP)
- Non-market values (NMV) or
- Informed judgement (IJ)

Informed judgement has been used where there is no quantitative evidence and was based on extrapolation and/or interpretation of existing data.

Notes:

1 - signifies a negative impact or loss; + signifies benefits or cost reduction

2 Impact Cost Ranking:

- Low (L) = €10.000 – 99.000 per annum;
- Medium (M) = €100.000 – 999.000 per annum;
- High (H) ≥ €1m per annum
- ? = not possible to assess

3 Confidence:

- High: Significant confidence in the data, models and assumptions used in monetisation and their applicability to the current assessment.
- Medium: There are some limitations regarding consistency and completeness of the data, models and assumptions used in monetisation.
- Low: The knowledge base used for monetisation is extremely limited.

• 7.2 Temperature Mortality

The European Commission 2009 Impact Assessment Guidelines discuss a number of methods of the evaluation of Mortality Risk on environment and health, presented in the following paragraphs [**61**]. In cases where values of impacts, such as on health or environment, are not directly revealed in market prices other techniques may have to be used. There are ways of calculating monetary costs and benefits of goods that do not have a direct market price. They either reflect the **"willingness to pay" (WTP)** for or the "willingness to accept" **(WTA)** a particular outcome and consist of stated preference (contingent valuation, conjoint analysis, choice experiments) and revealed preferences methods (travel cost method, hedonic pricing). Revealed preference methods are based on evidence from real market transactions such as correlations between noise disturbance and house prices. As such, they are based on real actions by people that are incurring real actual costs. Stated preference methods, on the other hand, involve the construction of hypothetical markets and asking people via questionnaires and interviews how they value a given outcome. These techniques have been used in a wide range of circumstances, and well-designed surveys are shown to provide robust estimates that are broadly similar to those from revealed preference methods. Notable uses include finding estimates for reductions in risk of premature deaths or non-fatal injuries, or to determine values for environmental outcomes, the use of public parks or historic buildings.

Several methods exist for quantitatively evaluating potential health impacts. A distinction can be made between **monetary and non-monetary methods**. Non-monetary approaches are potentially less controversial and may be more suitable in a cost effectiveness analysis, whereas monetary approaches are needed if the aim is to present a comprehensive cost benefit analysis. Non-monetary approaches can sometimes be monetised by placing monetary values on their results. The following paragraphs outline the most common nonmonetary approaches first, which is then followed by a brief introduction into the most standard monetary approaches.

Non-monetary approaches

- **Quality Adjusted Life Years (QALY)**

The QALY method uses available information on objective improvements in health / life quality and combines it with the duration of that improvement. A year of life in perfect health is counted as 1,0 whereas years spent in less than perfect health are given values of less than 1,0. Values are generally derived from surveys of patients and doctors (stated preferences) and represent an average among different social groups. QALYs allow aggregation over the number of individuals affected. One can use equal weights for each individual or adjust weights to reflect preferences for particular target groups. Future life years may be discounted using a common discount factor. Previous studies in the health sector have used values of 50.000 – 80.000 Euros for a QALY.

- **Disability Adjusted Life Years (DALY)**

A DALY is very similar to a QALY, effectively being its negative value. It measures the number of quality adjusted years lost in comparison to the benchmark scenario. In all other respects it is not conceptually different from QALY and should lead to the same assessment.

- **Healthy Life Years (HLY)**

The HLY approach measures the number of quality adjusted remaining life years per person. It is similar to QALY and life years in the future should be discounted and weights can be used when aggregating across individuals. HLY is technically a sum of QALYs, using the remaining life expectancy as the upper bound for summation. It is included in the set of indicators used in the Lisbon strategy. However, when done correctly, QALY and HLY should lead to the same conclusions.

Monetary approaches

Many decisions lead to a **reduction in risk** but not to its complete elimination. The aim of monetising health impacts is not to place a monetary figure on someone's life, but to compare the benefits of a reduction in risk against the costs. Any decision in this context means placing an implicit monetary value on health benefits. Decision-making will be easier and may be more consistent and transparent if we have a monetary estimate of the value of health benefits.

The following monetary approaches are standard methods for this purpose:

- **"Accounting style" approaches**

Cost of Illness (COI)

The Cost of Illness method is a rather simple measure comprising only the medical expenses related to the incidence of an illness. If an option lowers the rate of occurrence of an illness the saved medical expenses can be estimated and constitute a benefit. Conversely, if an option leads to an aggravation of a health situation, one can state the associated direct costs. However, the usefulness of this method is limited as it does not include other indirect costs to society such as loss of hours worked, or how people value their own health. Also, in some situations it leads to perverse results: for example, an action that kills somebody who otherwise would have spent time in hospital would be seen as a benefit using the COI approach.

Human Capital

The human capital method tries to measure the loss of future earnings in case of disability or premature death. It can also be interpreted as a measure of the loss to social welfare caused by death / disability / lower productivity. Potential criticism can be that this method leads to different values of lives depending on the projected future earnings, which could be seen as immoral, and places no value on people who are outside the workforce (such as the elderly). Average values could be used to lessen these concerns or if the individuals affected by an option cannot be identified precisely enough.

- **Preference Based approaches**

Another method to evaluate health impacts is to analyse individuals' stated or revealed preferences with respect to being exposed to a particular situation that involves a health risk. This can be measured by using the concepts of Willingness to Pay (WTP) for an improvement or Willingness To Accept (WTA) compensation for a worsening. Two concepts that make use of these methodologies are the Value of a Statistical Life (VOSL) and the Value of a Statistical Life Year (VOLY).

Value of Statistical Life (VoSL)

The VoSL is derived by investigating individuals' WTP for a lower risk of mortality, divided by that risk reduction. As such, the VOLSL method does not measure the value of a life per se, instead it puts a monetary value on the willingness to accept slightly higher or lower levels of risk. Of course, if taken to the extreme, everyone's life is priceless and cannot be monetised[16].

Value of Statistical Life Year (VOLY)

The VOLY measures more generally the WTP for an increase of one additional year of life expectancy. It should be noted that neither VOSL nor VOLY provides a measure of the quality of life. To do that one would have to combine them with the measures outlined above. The use of the above mentioned valuation concepts can lead to moral criticism. The idea of 'putting a value on someone's life' is seen as unethical. Indeed, we cannot – and do not seek to – place a monetary value on our own lives or on other individuals' lives. However, changes in risks are a different matter. While no one would trade their life for a sum of money, most people will be prepared to choose between safety equipment with different prices and offering different levels of safety, or between different ways of crossing a street compared to the saving of time. We can therefore identify the value individuals place on small changes in risk.[17]

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[16] To understand the VoSL concept, it may be useful to take an example. Suppose that in a city composed of 100,000 identical individuals, there is an investment project that will make the city's roads safer. It is known that on average 5 individuals die every year on these roads, and the project is expected to reduce from 5 to 2 the number of expected fatalities per year. Suppose now that each member of the city is willing to pay $150 annually to benefit from this reduction in mortality risk induced by the project. Then the corresponding VoSL would be $150×100, 000/3 =$5 million. Indeed $15 million could be collected in this city to save 3 statistical lives, and so the value of a statistical life could be established at $5 million. This example also illustrates why estimates about individuals' VoSL can be useful. Suppose indeed that one ignores the WTP of city members from this specific project; but one has some information about money/risk tradeoffs observed from the city members' choices (or from survey studies) concerning other mortality risks. Then it can be useful to compute an average implicit VoSL in this city based on these choice data, and use this VoSL to estimate the benefits of this specific risk-reduction road safety project that one wants to evaluate [**62**].

[17] Defra use VOLY to value 2-6 months loss in life expectancy for every death brought forward due to air pollution[**2, 65, 66**]

Research undertaken in the past has resulted in values of **1-2 million Euros for VoSL** and **50.000-100.000 Euros for VOLY** in Europe (2004).

In the current analysis the Value a Statistical Life was assumed 1 million Euros, according to the suggestions of the European Commission Guidelines.

Table 7.1 Valuation of premature heat fatalities per year (million Euros)

Scenario	2050s		2080s	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Climate Change only	97	113	102	184
Climate change and population change – Main Scenario of Europop2013	119	140	153	276
Climate change and population change – No migration variant Scenario of Europop2013	101	118	88	158

• 7.3 Temperature Morbidity

For morbidity, the estimates should include resource costs (e.g. healthcare costs) and dis-utility (opportunity costs, i.e. lost productivity, are considered in the sensitivity).

More recently, the World Health Organization in the framework of the CHOICE project, created a database with unit cost values for primary and secondary public health care services for its 191 member states. These estimates represent only the "hotel" component of hospital costs, i.e., excluding the cost of drugs and diagnostic tests but including costs such as personnel, capital and food costs. The outpatient unit costs present the estimated cost per outpatient visit, and include all cost components except drugs and diagnostics. The results for Cyprus are given in the following table.

The current analysis focused on the "hotel" component of hospital cost that is only a part of the hospitalisation cost. It was assumed an average cost of 300 € of bed day.

Table 7.2 Impatient and outpatient visit cost (2008 prices)

Cyprus	**Inpatient visit costs - Public facility costs**			
	Primary-level hospital	Secondary-level hospital	Teaching hospital	
Cost per bed day €	265,3	276,8	357,9	
	Outpatient visit costs - Public facility costs, urban area			
	Health Centre (no beds)	Health Centre (with beds)	Primary-level hospital	Secondary-level hospital
Cost per outpatient visit €	25,9	32,0	36,5	38,0

Table 7.3 Valuation of heat morbidity cost per year (million Euros)

Scenario	**Reference period**	**2050s**		**2080s**	
		RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Climate Change only	1,53	2,97	3,46	3,12	5,63
Climate change and population change – Main Scenario of Europop2013	1,53	3,64	4,28	4,68	8,45
Climate change and population change – No migration variant Scenario of Europop2013	1,53	3,09	3,61	2,69	4,83

7.4 Results

As climate change develops the size of the heat-related mortality risks increase significantly, so that the increased welfare cost in the 2080s is at least 3- times higher.

Table 7.4 Summary of monetization scoring

Risk Metric	2050	2080	Estimation Method	Confidence	Notes
HE1 - Temperature Mortality					
L, RCP4.5	-H	-H	Non-market values (NMV) / (IJ)	M	Assume no acclimatisation. Do not include urban heat island and heatwave impacts. No age structure changes included.
U, RCP8.5	-H	-H			
HE2 - Temperature Morbidity					
L, RCP4.5	-H	-H	Informed judgement/MP	L	Assume no acclimatisation. Do not include urban heat island and heatwave impacts. No age structure changes included.
U, RCP8.5	-H	-H			
HE3 - Air Pollution					
L, RCP4.5	?	?	-	-	
U, RCP8.5	?	?			
HE4 - Pollen and allergens					
L, RCP4.5	?	?	-	-	
U, RCP8.5	?	?			

8 Adaptive Capacity

The public health response of Cyprus in heat waves is based at forecasting heat waves, issuing warnings and providing advices for self-protection from heat waves, through the mass media (television, radio, newspapers, public websites). In addition, during severe heat waves in Cyprus (as in summer of 2003), the government in order to protect its citizens from adverse health effects, recommends a curfew between the high risk hours of the day. However, people frequently ignore curfews out of negligence, with all the adverse effects that may follow [**44**].

The majority of houses and indoor public areas as well as private trade facilities in Cyprus, are fully air-conditioned. Furthermore, there are communal centres fully air-conditioned to accommodate people with no access to an air-conditioned environment during days of elevated temperatures. However, the protection of the population from heat waves is not always possible. Due to the rapid nature of some heat-related health effects such as heat strokes, people do not make it to the hospital. [**44**].

There is evidence that population acclimatisation and adaptive capacity (e.g. increased use of air conditioning and gradual physiological adaptation) can influence the level of certain health risks associated with climate change. For example, people can become gradually acclimatised to higher temperatures and there are indications that European regions with hot summers do not have significantly higher annual heatrelated mortality rates than cold regions [**2**].

Public health protection measures such as warning systems, health alerts, public awareness campaigns and home-based prevention advice can help reduce the health risks of higher temperatures associated with climate change; providing these is a sign of capacity to adapt to short term climate risks. An example is given by the Heatwave Plan for England, which was initially launched in 2004 and is updated yearly. This contains guidance for the general public, and the health and social care sector on protecting vulnerable people from the effects of heat. Similar air pollution and ozone forecasts and alerts, including relevant health advice, are commonly issued by local authorities and other organisations [**2**].

Heat wave plans have been shown to reduce heat-related mortality in Italy, but evidence of effectiveness is still very limited. There is little information about how future changes in housing and infrastructure would reduce the regional or local future burden of heat-related mortality or morbidity [**3**].

Additional adaptation measures proposed by Shoukri and Zachariadis (2012) include [**67**]:

- Creation and protection of urban parks to reduce the urban heat island phenomenon and improve air quality
- Implement a coherent early warning system
- Establishment of a General Health Scheme and horizontal integration of the climate change adaptation priority in all sectors
- Development of contingency plans in health and social care systems to cope with increasing numbers of patients

- Preparation of an emergency plan in order to specify the responsibilities of various health and social service bodies
- Develop guidelines and proper training for medical doctors (private and public sector).

9 Conclusions

It is not straightforward to rank the Health Sector risks relative to one another. The following Table provides an indication of the relative ranking of the risks based on successive stages of the CCRA:

- the Tier 1 impacts scoring (Appendix 2),
- the severity of consequences obtained by applying climate change projections to the response functions (Chapter 5) and
- the monetisation of these consequences (Chapter 7).

Inevitably, there is a degree of subjectivity and uncertainty in all these approaches. In some cases, for example the Urban Heat Island and Subsidence, there is still significant uncertainty over the magnitude of the consequences.

Table 9.1 Ranking of Health sector risks

	Tier 1 impacts score	Consequences score ranges (2050s, 2080s)	Monetisation ranges (2050s, 2080s)
HE1 - Temperature Mortality	89	**-3**	-H
HE2 - Temperature Morbidity	89	**-3**	-H
HE3 - Air Pollution	40	Too uncertain	Not possible to assess
HE4 - Pollen and allergens	30	Too uncertain	Not possible to assess

Heat-related mortality and morbidity are the main challenges that the Sector will face due to climate change. Illness associated with exposure higher levels of air pollution (and potentially pollen) is also expected to increase but there are no sufficient data to quantify this risk.

Climate change presents complex socioeconomic challenges, which could act as risk magnifiers in the future, particularly for vulnerable populations.

The population groups that are most vulnerable to heat waves are the elderly, persons with pre-existing chronic diseases, people confined to bed, children, population groups with low socio-economic status, workers in outdoor environments. The occupations most at risk of heatstroke, include construction and agriculture/forestry/fishing work. Considering the fact that a high percentage of immigrants labourers, work in outdoor environments, the risk for the particular vulnerable group is high [**44**].

Senior citizens (>65 years) are mostly sensitive to direct climate change effects such as thermal stress during heat waves and health stress during other extreme weather events. The elderly population can face unequal access to healthcare, as they are often unable to travel long distances to the nearest health facility. Children (<14 years) is another high-risk group to heat waves because they do not have fully developed temperature regulation mechanisms and are unable to change their environments without help from adults. The very young are at higher risk of death while older children have more heat stress due to time spent in exercise – playing outdoors [**44**].

It is likely that certain risks are not going to be evenly distributed with urban populations (especially Nicosia) appearing to be more affected by heatwaves and heat-related mortality due to Urban Heat Island (see also Built Environment Sector). In the urban areas where the air pollution levels are elevated, heat waves are more frequent. Furthermore, the increases in temperatures would be higher in the interior than on the coast of Cyprus which leads to higher adverse health implications on the population living inland.

Most risks in the health sector are strongly correlated to social demographics. The elderly for example are typically more vulnerable to most health impacts, and a projected ageing population is likely to increase these risks.

Heat related deaths are a function of several factors, including the age distribution of the population, levels of deprivation, and social capital (i.e. social networks and contacts). However, the relationship between temperature related mortality, deprivation and social capital is very complex and not possible to characterise within this assessment. Baseline mortality rates, as well as temperature related mortality slopes and thresholds are assumed to remain unchanged in the future, and heat related mortality are therefore considered to be solely proportional to population sizes.

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Appendices

- ### Appendix 1 The 'Tier 1' list of impacts

- ### A. Analytical Tier 1 list

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
1	Temperature (gradual changes and extremes)	Increase in frequency of high or extreme temperature episodes (heatwaves)	Additional effects from extremes (heat-waves) - morbidity impacts	T	Impacts on workforce; increased care / hospital intake for vulnerable people; dehydration; heat cramps; heat stress/exhaustion and sun stroke; mental health
2	Temperature (gradual changes and extremes)	Increase in average temperature	Increased summer morbidity	T	Increased demands on health and adult care services
3	Changes in precipitation and temperature	Extreme weather events	Increased summer mortality (heatwaves)	T	Increased demands on health and adult care services
4	Temperature (gradual changes and extremes)	Increase in average temperature, heatwaves, UV, etc.	Changes in air quality and increase in frequency and intensity of air pollution episodes during warm seasons (mainly tropospheric, aka ground-level, ozone concentrations, some secondary particle species, biogenic emissions of VOCs and semi-volatiles etc.)	T	Increase in intensity and frequency of associated mortality and morbidity e.g. increase in respiratory disease and associated hospital admissions. Budgetary impact on health care sector
5	Temperature (gradual changes and extremes)	Increase in average summer temperature; heat waves	increased need for AC use => increases in energy needs => increases in combustion-related air pollution	T	All-cause, CVD, respiratory mortality and morbidity and in general air pollution associated short- and long-term adverse health

[18] T:Threat, O:Opportunity

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
6	Changes in annual, seasonal or daily precipitation	Droughts	Increases in wildfires	T	Property loss, accidental deaths, potentially increased anxiety levels among those affected. Respiratory and CVD morbidity due to increases in air pollution levels
7	Changes in annual, seasonal or daily precipitation	Droughts	Increase in frequency and intensity in Saharan dust days => increases in particle air pollution during those days, but now this includes bioaerosol carrying biological products of pathogenic vectors (e.g. endotoxin)	T	Air pollution-related adverse health, but now worsened by the presence of biological agents such as endotoxin
8	Temperature (gradual changes and extremes)	Increase in average temperature	Longer pollen season and more days with high pollen concentrations	T	Impact on health - more people with hay fever and pollen asthma; increased severity of symptoms. This then leads to higher costs and demands on for diagnosis and treatment of more complex allergies.
9	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume -increase in frequency of heavy winter rainfall events	Flooding leading to physical damage of Cyprus Health System infrastructure and buildings, and disruptions in transportation of patients, medical staff and supplies	T	Disruptions in hospital, clinics, general practice offices and care homes. Failure to deliver healthcare. Certain services may need to be relocated
10	Changes in precipitation and temperature	Extreme weather events	IT server overheating in hospitals (Heatwaves)	T	Disruption to communication in hospitals
11	Changes in precipitation and temperature	Extreme weather events	Buildings and other infrastructure may	T	May require certain wards to temporarily close

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
			not be resilient to these events (e.g. heatwaves and floods)		down as patients could not be treated in a safe environment; demand for cooling increases
12	Changes in annual, seasonal or daily precipitation	Droughts	increased aridity => decline in soil nutrients (e.g. nitrogen, organic carbon)	T	Decreased nutrient content in food => inadequate intake of certain nutrients such iron, calcium, vitamins, etc. => long term health impacts
13	Changes in precipitation and temperature	Extreme weather events	crop yield alterations, damage to crops, alterations in livestock productivity	T	Loss of nutritional benefits, increased dependence on imports, potential malnutrition-related impacts in poorer populations
14	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in vector reproduction, parasite development and bite frequency	T	Increase in prevalence of certain vector borne diseases (mainly ticks and lyme disease)
15	Changes in precipitation and temperature	Changes in temperature and precipitation	Cases of malaria may become more common (this is unlikely to become a serious public health concern)	T	Impact on health
16	Changes in precipitation and temperature	Changes in temperature and precipitation	New disease (or disease boundaries)	T	This will influence the training and requirements of the health workforce, the physical infrastructure of hospitals, care homes and other facilities, and emergency transportation of patients and equipment
17	Changes in annual, seasonal or daily precipitation	Increase in frequency of intense precipitation events	Deterioration in the quality of surface waters	T	Could adversely affect the health of those engaged in recreational water contact

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
18	Changes in precipitation and temperature	Increase in average temperature and frequency of heavy precipitation events	Flooding leading to negative impact on raw water quality; Reduced water quality (increases in contamination due to waterborne pathogens)	T	Private water and surface water supplies without filtration may be affected. Increased incidence of water borne diseases and diarrhoeal events
19	Sea level rise and extreme events (storm surge and high precipitation)	Sea level rise, storm surge, increase in rainfall	Flood risk, other e.g. spread of communicable diseases	T	Increase in self-reported illnesses, particularly relating to skin, respiratory and gastro-intestinal conditions
20	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in water-borne diseases (Cryptosporidiosis) in people using surface waters (inland and coastal) for recreational purposes	T	Impact on health
21	Changes in annual, seasonal or daily precipitation	Droughts, changes in precipitation patterns	Reduced water supply	T	Limited access to water; limited access to clean and safe water; increased dependence on desalinated water
22	Changes in precipitation and temperature	Higher occurrence of extreme weather events such as heatwaves and floods	A significant rise in demand for emergency medicine (including ambulatory emergency care)	T	Overwhelming public services
23	Temperature (gradual changes and extremes)	Increase in average summer temperature; heat waves	Multiplication of pathogenic micro-organisms	T	Increase in cases of food poisoning during the summer
24	Temperature (gradual changes and extremes)	Increase in average winter temperature	Increase in outdoor activities/ recreation leading to exercise and lifestyle benefits	O	Better health and wellbeing; contributions to the economy
25	Temperature (gradual changes and extremes)	Increase in average summer temperature	Decrease in outdoor activities/ recreation leading to exercise and lifestyle benefits	T	Worse health and wellbeing; impacts on the contributions to the economy

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
26	Changes in cloud cover	Increase in number of sunny days	Increase in cataracts	T	
27	Changes in cloud cover	Reduction in cloud cover; increase in sunny days; increase in average summer temperature	Delay in the rate of recovery of the stratospheric ozone layer	T	Increase in UV radiation exposure and sunburn and skin cancer incidence
28	Changes in cloud cover		Delay in the rate of recovery of the stratospheric ozone layer	T	UV radiation exposure affected
29	Changes in cloud cover	Increase in number of sunny days	People encouraged to spend more time in the sun	O	Increased sunlight exposure enhancing vitamin D levels and related health benefits
30	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in indirect human exposure to agricultural contaminants including certain pesticides, fertilizers, bacteria and viruses (magnitude of the increases highly dependent on contaminant type)	T	Health risks associated with many pathogens, particulate and particle-associated contaminants could increase significantly
31	Changes in precipitation and temperature	Extreme weather events	Health care staff performance compromised	T	
32	Changes in precipitation and temperature	Milder, wetter winters	Increased algal or fungal growth in existing buildings	T	Impact on respiratory conditions
33	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in vector reproduction, parasite development and bite frequency	T	Increase of in-home pesticide use to kill the parasites/ pests, neurotoxic effects (among others). Exposure to pesticides has been associated with neurodevelopmental outcomes and leukemia, and acute pesticide poisoning in extreme exposures. Increase

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
					in vector reproduction and parasite development could lead to increase of pesticides and herbicides in homes
34	Temperature (gradual changes and extremes)	Increase in average winter temperature	Decline in frequency and intensity of winter air pollution episodes	O	Proportional decrease in associated mortality and morbidity
35	Changes in precipitation and temperature	Extreme weather events	Extreme weather risk to elderly (over 75), especially those who are socially isolated or living on their own	T	
36	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume -increase in frequency of heavy winter rainfall events	Flood risk fatality/injury	T	Increased demands on health and adult care services
37	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume -increase in frequency of heavy winter rainfall events	Increased injuries and fatalities	T	Increased demands on health and adult care services
38	Sea level rise and extreme events (storm surge and high precipitation)	Sea level rise, storm surge, increase in rainfall	Flood risk psychological well-being and mental stress	T	Common mental disorders, including anxiety and depression, which may last for months and possibly even years after the flood event. Mental health, psychological support and counselling services may experience a rise in demand
39	Changes in precipitation and temperature	Extreme weather events (such as droughts and tornadoes)	Social disruption, injuries, deaths, disability	T	Exacerbate inequalities in communities; increasing tension e.g. between those who live in areas more likely to flood and those who do

No	Main climate driver	Climate effects	Climate change impact	T/O[18]	Consequences
					not or can afford to protect their properties affecting community cohesion
40	Temperature (gradual changes and extremes)	Increase in average temperature	Reduced winter morbidity	O	
41	Temperature (gradual changes and extremes)	Hot summers / heatwaves; increase in average temperatures	Exposure of medicines (or other medical and laboratory materials) to high temperatures during storage and transit (most licences specify storage below 25°C)	T	Reduction in medicine efficacy
42	Changes in precipitation and temperature	Increased volatility and severe weather	Increased strain on mobile care and support services	T	
43	Changes in precipitation and temperature	Extreme weather events	Patient recovery in hospitals may be compromised	T	
44	Changes in precipitation and temperature	Milder winters	Fewer traffic accidents	O	Smaller burden on emergency services during winter
45	Changes in annual, seasonal or daily precipitation	Extreme weather events	More traffic accidents	T	Greater burden on emergency services
46	Sea level rise and extreme events (storm surge and high precipitation)	Increase in rainfall (either as Increased long-term averages or more frequent and intense short-duration rainfall).	Flooding of property	T	Loss of medication

B. Clustered Tier 1 list and Cross Cutting Issues

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
1	Temperature (gradual changes and extremes)	Increase in frequency of high or extreme temperature episodes (heatwaves)	Additional effects from extremes (heat-waves) - morbidity impacts	Temperature Morbidity (Summer)	
2	Temperature (gradual changes and extremes)	Increase in average temperature	Increased summer morbidity	Temperature Morbidity (Summer)	
3	Changes in precipitation and temperature	Extreme weather events	Increased summer mortality (heatwaves)	Temperature Mortality (Summer)	
4	Temperature (gradual changes and extremes)	Increase in average temperature, heatwaves, UV, etc	Changes in air quality and increase in frequency and intensity of air pollution episodes during warm seasons (mainly tropospheric, aka ground-level, ozone concentrations, some secondary particle species, biogenic emissions of VOCs and semi-volatiles etc)	Air Pollution (Ozone)	
5	Temperature (gradual changes and extremes)	Increase in average summer temperature; heat waves	increased need for AC use => increases in energy needs => increases in combustion-related air pollution	Air pollution (Particulate Matter)	Energy Sector
6	Changes in annual, seasonal or daily precipitation	Droughts	Increases in wildfires	Air pollution (Particulate Matter)	Forestry Sector
7	Changes in annual, seasonal or daily precipitation	Droughts	Increase in frequency and intensity in Saharan dust days => increases in	Air pollution (Particulate Matter)	

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
			particle air pollution during those days, but now this includes bioaerosol carrying biological products of pathogenic vectors (eg endotoxin)		
8	Temperature (gradual changes and extremes)	Increase in average temperature	Longer pollen season and more days with high pollen concentrations	Pollen and allergens	
9	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume - increase in frequency of heavy winter rainfall events	Flooding leading to physical damage of Cyprus Health System infrastructure and buildings, and disruptions in transportation of patients, medical staff and supplies	Infrastructure Failure	Floods & Coastal Erosion Sector
10	Changes in precipitation and temperature	Extreme weather events	IT server overheating in hospitals (Heatwaves)	Infrastructure Failure	
11	Changes in precipitation and temperature	Extreme weather events	Buildings and other infrastructure may not be resilient to these events (e.g. heatwaves and floods)	Infrastructure Failure /Healthcare System Property Damage	Floods & Coastal Erosion Sector
12	Changes in annual, seasonal or daily precipitation	Droughts	increased aridity => decline in soil nutrients (eg nitrogen, organic carbon)	Food Supply	
13	Changes in precipitation and temperature	Extreme weather events	crop yield alterations, damage to crops, alterations in livestock productivity	Food Supply	Agriculture Sector
14	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in vector reproduction, parasite development and bite frequency	Vector-Borne Diseases	

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
15	Changes in precipitation and temperature	Changes in temperature and precipitation	Cases of malaria may become more common (this is unlikely to become a serious public health concern)	Vector-Borne Diseases	
16	Changes in precipitation and temperature	Changes in temperature and precipitation	New disease (or disease boundaries)	Vector-Borne Diseases	
17	Changes in annual, seasonal or daily precipitation	Increase in frequency of intense precipitation events	Deterioration in the quality of surface waters	Water Quality and Water-Borne Diseases	Water Sector
18	Changes in precipitation and temperature	Increase in average temperature and frequency of heavy precipitation events	Flooding leading to negative impact on raw water quality; Reduced water quality (increases in contamination due to waterborne pathogens)	Water Quality and Water-Borne Diseases	Water Sector
19	Sea level rise and extreme events (storm surge and high precipitation)	Sea level rise, storm surge, increase in rainfall	Flood risk, other e.g. spread of communicable diseases	Water Quality and Water-Borne Diseases	Water Sector
20	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in water-borne diseases (Cryptosporidiosis) in people using surface waters (inland and coastal) for recreational purposes	Water Quality and Water-Borne Diseases	Water Sector
21	Changes in annual, seasonal or daily precipitation	Droughts, changes in precipitation patterns	Reduced water supply	Water Quality and Water-Borne Diseases	Water Sector
22	Changes in precipitation and temperature	Higher occurrence of extreme weather events such as heatwaves and floods	A significant rise in demand for emergency medicine (including ambulatory emergency care)	Demand for Emergency Medicine	

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
23	Temperature (gradual changes and extremes)	Increase in average summer temperature; heat waves	Multiplication of pathogenic micro-organisms	Food-Borne Diseases	
24	Temperature (gradual changes and extremes)	Increase in average winter temperature	Increase in outdoor activities/ recreation leading to exercise and lifestyle benefits	Outdoor Activities	
25	Temperature (gradual changes and extremes)	Increase in average summer temperature	Decrease in outdoor activities/ recreation leading to exercise and lifestyle benefits	Outdoor Activities	
26	Changes in cloud cover	Increase in number of sunny days	Increase in cataracts	Sunlight/ UV Exposure	
27	Changes in cloud cover	Reduction in cloud cover; increase in sunny days; increase in average summer temperature	Delay in the rate of recovery of the stratospheric ozone layer	Sunlight/ UV Exposure	
28	Changes in cloud cover		Delay in the rate of recovery of the stratospheric ozone layer	Sunlight/ UV Exposure	
29	Changes in cloud cover	Increase in number of sunny days	People encouraged to spend more time in the sun	Sunlight/ UV Exposure	
30	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in indirect human exposure to agricultural contaminants including certain pesticides, fertilizers, bacteria and viruses (magnitude of the increases highly dependent on contaminant type)	Agricultural Contaminants	Agriculture Sector
31	Changes in precipitation and temperature	Extreme weather events	Health care staff performance compromised	Healthcare System Staff Performance	

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
32	Changes in precipitation and temperature	Milder, wetter winters	Increased algal or fungal growth in existing buildings	Algal/Fungal Growth in Buildings	Built Environment Sector
33	Temperature (gradual changes and extremes)	Increase in average temperature	Increase in vector reproduction, parasite development and bite frequency	Increased use of pesticides and herbicides in buildings	Built Environment Sector
34	Temperature (gradual changes and extremes)	Increase in average winter temperature	Decline in frequency and intensity of winter air pollution episodes	Air Pollution (Winter)	
35	Changes in precipitation and temperature	Extreme weather events	Extreme weather risk to elderly (over 75), especially those who are socially isolated or living on their own	Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries	Floods & Coastal Erosion Sector
36	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume - increase in frequency of heavy winter rainfall events	Flood risk fatality/injury	Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries	Floods & Coastal Erosion Sector
37	Changes in annual, seasonal or daily precipitation	Increase in rainfall intensity and volume - increase in frequency of heavy winter rainfall events	Increased injuries and fatalities	Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries	Floods & Coastal Erosion Sector
38	Sea level rise and extreme events (storm surge and high precipitation)	Sea level rise, storm surge, increase in rainfall	Flood risk psychological well-being and mental stress	Mental Health	Floods & Coastal Erosion Sector
39	Changes in precipitation and temperature	Extreme weather events (such as droughts and tornades)	Social disruption, injuries, deaths, disability	Social Disruption	

No	Main climate driver	Climate effects	Climate change impact	Clusters	Cross Cutting Issues
40	Temperature (gradual changes and extremes)	Increase in average temperature	Reduced winter morbidity	Temperature Morbidity (Winter)	
41	Temperature (gradual changes and extremes)	Hot summers / heatwaves; increase in average temperatures	Exposure of medicines (or other medical and laboratory materials) to high temperatures during storage and transit (most licences specify storage below 25°C)	Medicine Efficacy	
42	Changes in precipitation and temperature	Increased volatility and severe weather	Increased strain on mobile care and support services	Mobile Care and Support Services	
43	Changes in precipitation and temperature	Extreme weather events	Patient recovery in hospitals may be compromised	Patient Recovery Rates	
44	Changes in precipitation and temperature	Milder winters	Fewer traffic accidents	Traffic Accidents	Transport Sector
45	Changes in annual, seasonal or daily precipitation	Extreme weather events	More traffic accidents	Traffic Accidents	Transport Sector
46	Sea level rise and extreme events (storm surge and high precipitation)	Increase in rainfall (either as Increased longterm averages or more frequent and intense short-duration rainfall).	Flooding of property	Healthcare System Property damage	Floods & Coastal Erosion Sector

- Appendix 2 Scored Tier 1 Impacts
- A. Scores and social vulnerability assessment

Clusters	Vuln. Groups Y/N	Economic	Environmental	Social	Likelihood	Urgency	Score
Temperature Morbidity (Summer)	**Y (elderly, people with compromised health, etc.)**	**3**	**2**	**3**	**3**	**3**	**89**
Temperature Mortality (Summer)	**Y (elderly, people with compromised health, etc.)**	**3**	**2**	**3**	**3**	**3**	**89**
Air Pollution (Ozone)	**Y (asthmatics, people with compromised health, etc.)**	**2**	**3**	**3**	**2**	**2**	**40**
Air pollution (Particulate Matter)	**Y (elderly, people with compromised health, etc.)**	**2**	**3**	**3**	**2**	**2**	**40**
Pollen and allergens	**Y (asthmatics, people with compromised health, etc.)**	**2**	**1**	**3**	**2**	**2**	**30**
Infrastructure Failure	N	2	1	3	1	3	22
Infrastructure Failure /Healthcare System Property Damage	N	2	1	3	1	3	22
Food Supply	Yes (low income people)	2	1	3	2	1	15
Vector-Borne Diseases	N	2	1	3	2	1	15
Water Quality and Water-Borne Diseases	N	1	2	3	2	1	15

Clusters	Vuln. Groups Y/N	Economic	Environmental	Social	Likelihood	Urgency	Score
Demand for Emergency Medicine	Yes (low income people)	1	1	3	2	1	12
Food-Borne Diseases	N	1	1	3	2	1	12
Outdoor Activities	N	2	1	2	2	1	12
Sunlight/ UV Exposure	N	2	1	2	2	1	12
Agricultural Contaminants	N	1	2	1	2	1	10
Healthcare System Staff Performance	N	1	1	2	1	2	10
Algal/Fungal Growth in Buildings	Y (elderly, people with compromised health, etc.)	1	1	1	2	1	7
Increased use of pesticides and herbicides in buildings	Y (elderly, people with compromised health, etc.)	1	1	1	2	1	7
Air Pollution (Winter)	Y (elderly, people with compromised health, etc.)	1	1	3	1	1	6
Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries	Y (elderly, people with mobility/cognitive constraints, eta)	1	1	3	1	1	6

Clusters	Vuln. Groups Y/N	Economic	Environmental	Social	Likelihood	Urgency	Score
Mental Health	Y (elderly, socially isolated people, etc)	1	1	3	1	1	6
Social Disruption	Y (elderly, low income people, etc.)	1	1	3	1	1	6
Temperature Morbidity (Winter)	Y (elderly, people with compromised health, etc.)	1	1	3	1	1	6
Medicine Efficacy	Y (elderly, people with compromised health, etc.)	1	1	2	1	1	5
Mobile Care and Support Services	Y (elderly, people with compromised health, etc.)	1	1	2	1	1	5
Patient Recovery Rates	Y (people with compromised health)	1	1	2	1	1	5
Traffic Accidents	N	1	1	2	1	1	5
Healthcare System Property damage	N	1	1	1	1	1	4

- **B Justification**

Clusters	Economic	Environmental	Social	Likelihood
Temperature Morbidity (Summer)	Major consequence on regional and national economy	Medium.	Major consequences on vulnerable groups	High (CC:H, Cons:H)
Temperature Mortality (Summer)	Major consequence on regional and national economy	Medium. Increased energy consumption	Major consequences on vulnerable groups	High (CC:H, Cons:H)
Air Pollution (Ozone)	Consequences initiating contingency plans	Widespread decline in air quality	Large numbers affected	Medium (CC: H, Cons:M)
Air pollution (Particulate Matter)	Consequences initiating contingency plans	Widespread decline in air quality	Large numbers affected	Medium (CC:M, Cons:H)
Pollen and allergens	Moderate consequences on national or regional economy	Not relevant	Large numbers affected	Medium (CC: H, Cons:M)
Infrastructure Failure	Consequences on operations & service provision initiating contingency plans. Relevant facilities are not located in flood prone areas or near the coastline. Impacts due to building overheating are expected.	Low. Increase in energy consumption during heatwaves	Increase in national health burden	Low (CC: M, Cons:L)
Infrastructure Failure /Healthcare System Property Damage	Consequences on operations & service provision initiating contingency plans. Relevant facilities are not located in flood prone areas or near the coastline. Impacts due to building overheating are expected.	Low. Increase in energy consumption during heatwaves	Increase in national health burden	Low (CC: M, Cons:L)
Food Supply	Moderate consequence on national or regional economy	Low.	Large numbers affected	Medium (CC:M, Cons:M)

Clusters	Economic	Environmental	Social	Likelihood
Vector-Borne Diseases	Moderate consequence on national or regional economy	Not relevant	Large numbers affected	Medium, (CC: H, Cons:M)
Water Quality and Water-Borne Diseases	No consequence on national or regional economy	Regional decline in water quality	Large numbers affected	Medium, (CC: H, Cons:M)
Demand for Emergency Medicine	No consequence on national economy	Low. Increase in natural resources demand	Large numbers affected	Medium (CC:M, Cons:H)
Food-Borne Diseases	No consequence on national or regional economy	Low impacts	Large numbers affected	Medium (CC: H, Cons:M)
Outdoor Activities	Moderate consequence on national or regional economy	Not relevant	Significant numbers affected	Medium (CC: H, Cons:M)
Sunlight/ UV Exposure	Moderate consequence on national or regional economy	Not relevant	Significant numbers affected	Medium, (CC: H, Cons:M)
Agricultural Contaminants	No consequence on national or regional economy	Medium. Regional decline in land/water/air quality	Within 'coping range' public health issues	Medium (CC: H, Cons:M)
Healthcare System Staff Performance	No consequence on national or regional economy	Not relevant	Significant numbers affected	Low (CC: H, Cons:L)
Algal/Fungal Growth in Buildings	No consequence on national or regional economy	Low. Localised decline in air quality	Within 'coping range' public health issues	Medium (CC:M, Cons:M)
Increased use of pesticides and herbicides in buildings	No consequence on national or regional economy	Low. Localised decline in air quality	Within 'coping range' public health issues	Medium (CC: H, Cons:M)
Air Pollution (Winter)	No benefits for national or regional economy	Improvement of air quality	Large numbers affected	Low (CC:H, Cons:L)
Extreme Weather Event (flooding, storms, landslides) Mortality & Injuries	Minor or very local consequences	Low. Increase in natural resources demand	Large numbers affected	Low (CC:M, Cons:L)
Mental Health	Minor or very local consequences	Not relevant	Large numbers affected	Low (CC: m, Cons:L)
Social Disruption	No consequence on national economy	Not relevant	Significant numbers affected	Low (CC: M, Cons:L)
Temperature Morbidity (Winter)	Minor or very local consequences	Low. Decrease in natural resources demand	Large numbers affected	Low (CC: H, Cons:L)

Clusters	Economic	Environmental	Social	Likelihood
Medicine Efficacy	No consequence on national or regional economy	Low. Increase in natural resources demand	Significant numbers affected	Low (CC: H, Cons:L)
Mobile Care and Support Services	Localised disruption	Not relevant	Significant numbers affected	Low (CC: H, Cons:L)
Patient Recovery Rates	No consequence on national economy	Not relevant	Significant numbers affected	Low (CC: H, Cons:L)
Traffic Accidents	Localised disruption	Not relevant	Significant numbers affected	Low (CC: H, Cons:L)
Healthcare System Property damage	Relevant facilities are not located in flood prone areas or near the coastline	Not relevant	Small numbers affected	Low (CC:M, Cons:L)

CYPRUS GOVERNMENT
Ministry of Agriculture, Rural Development and Environment
Department of Environment
20-22 28th Oktovriou Ave, Engomi, 2414, Nicosia, Cyprus

Climate Change Risk Assessment

Contract No.

Land Desertification




Contractors:

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AGRICULTURAL UNIVERSITY OF ATHENS

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Revision Table

Version	Date	Comments
v.1	9.03.2016	Initial Version

2.2. Land desertification

Land desertification is one of the most serious environmental issues at global, national, regional and local scales. Desertification has been defined as “the land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities” (UNEP, 1994). The process of desertification is characterized by the reduction of available soil water to the growing plants resulting to critical low plant productivity. Land desertification is the consequence of a series of important degradation processes in semi-arid and arid regions, where water is the main limiting factor of land use performance on ecosystems. Desertification of an area will proceed if certain land components are degraded beyond specific thresholds, above which further change is irreversible. The following three major processes of land degradation can be distinguished: (a) the loss of nutrient-rich topsoil due to wind and water erosion, (b) the decrease in soil water content induced by various causes including unsustainable agricultural practices or overgrazing, and (c) the accumulation of salts or other toxic substances in the soil.

Soil erosion is a significant process of land degradation and, consequently, desertification in the island of Cyprus. The prevailing climatic conditions are characterized by high rainfall erosivity and long rainfall seasonality and aridity favouring soil erosion of sloping areas. Soil salinization is another main degradation and desertification process affecting mainly plain areas with poor drainage conditions and especially the coastal areas. Extensive forest fires occurring during the dry period and induced by man is a significant cause promoting desertification. In addition, Overgrazing is regarded as a serious pressure on natural environment and a well-known desertification driver in areas where morphology, climate, vegetation cover and soil are unsuitable for intensive use.

Among the physical environment characteristics climate, soil, and vegetation are important factors of desertification in Cyprus. Rainfall, amount and distribution, is a major factor affecting biomass production, and soil erosion rates on hilly lands. The prevailing semi-arid climatic conditions, which are expected to be worsen in the near future, are characterized by seasonal distribution of rainfall which makes the existing ecosystems vulnerable to land degradation and desertification. The uneven annual and inter-annual distribution of rainfall, and the occurrence of extreme events are the main climatic factors contributing to land degradation desertification. However, desertification will proceed, in a certain landscape, when the soil is not able to provide the plants with rooting space, water and nutrients. In the semi-arid zones, the land becomes irreversibly desertified when the rootable soil depth is not capable to sustain a certain minimum vegetation cover. There are cases that desertification proceeds even on deep soils, when their water balance is not capable of meeting the needs of plants. Extensive studies in the last decades supported by a plethora of applied EU commissioned research and projects have shown that the soil parameters greatly affecting desertification are parent material, soil depth, slope gradient, slope aspect, soil texture and amount of rock fragments on the soil surface. These parameters are related to water availability to the plants and to soil erosion resistance.

2.2.1 Methodology used

The following two threats due to climate change have been assessed (a) soil erosion, and (b) land desertification. Even though soil salinization risk is an important threat especially for the coastal areas, the assessment was not possible due to the lack of detailed soil maps of Cyprus.

Soil erosion assessment

Soil erosion risk has been assessed using the recently derived from the most recent state of the art methodology of the EU research project DESIRE (2010). The proposed methodology has been based on a series of indicators related to climate, soil, vegetation, fires, agriculture, cultivation, husbandry, land management, land use, water use, tourism, social, and institutional (Table 2.2.1). The following parameters-indicators are used for the estimation of soil erosion risk affecting desertification risk: annual rainfall, aridity index, rainfall seasonality, slope aspect, slope gradient, soil depth, soil textural class, organic matter of surface horizon, agricultural cover type, natural vegetation cover type, percentage of plant cover, parallel employment ,tillage operations, tillage depth, tillage direction, grazing control, grazing intensity, fire protection, sustainable farming, soil water conservation measures, land abandonment, land use intensity, period of existing land use, run-off water storage, tourism intensity, population density, subsidies, and policy implementation.

Table 2.2.1. Indicators with the corresponding weighing indices for the assessment of soil erosion risk in agricultural areas, pastures, and forests

Indicators	**Water erosion**		
	Agricultural areas	**Pastures and shrubs**	**Forests**
CLIMATE			
Rainfall	0.348		
Rainfall seasonality	0.245	0.654	0.41
Aridity index			0.225

Indicators	Water erosion		
	Agricultural areas	Pastures and shrubs	Forests
SOIL			
Slope aspect	0.191		
Slope gradient	0.359		
Soil depth	0.082	0.167	0.225
Soil texture		0.115	
Organic matter	0.17		
VEGETATION			
Vegetation cover type	0.089		0.369
Plant cover	0.089	0.305	0.169
FIRES			
Fire risk			-0.417
Burned area		-0.182	0.309
AGRICULTURE			
Parallel employment	-0.159		
CULTIVATION			
Tillage operations	0.158		

Indicators	Water erosion		
	Agricultural areas	Pastures and shrubs	Forests
Tillage depth		-0.24	
Tillage direction		0.124	
HUSBANDRY			
Grazing control		0.186	
Grazing intensity			-0.392
LAND MANAGEMENT			
Fire protection			0.247
Sustainable farming	0.196		
Soil water conservation		0.134	
Terracing (presence)	0.176		
LAND USE			
Land abandonment	-0.364		0.133
Land use intensity	0.205	0.175	
eriod of existing land use		0.112	
WATER USE			
Runoff water storage	-0.155	0.314	

Indicators	Water erosion		
	Agricultural areas	Pastures and shrubs	Forests
TOURISM			
Tourism intensity		0.127	
SOCIAL			
Population density			0.356
INSTITUTIONAL			
Farm subsidies	0.105	0.405	
Policy implementation	0.38	0.282	

The classes for each indicator used with the corresponding indices are given in Table 2.2.2 (Kairis *et al*., 2013; Kosmas *et al*., 2013). The climatic data used are those for rainfall and air temperature provided for the project for climate projections RCP4.5 and RCP8.5. Aridity index was calculated The aridity index has been estimated by the Bagnouls-Gaussen index (BGI) using the following equation:

$$\mathbf{BGI = \sum_{i=1}^{n} (2ti - Pi)*k}$$

Where: ti is the mean air temperature for month i in 0°C, Pi is the total precipitation for month i in mm; and k represents the proportion of month during which 2ti - Pi >0. Raifall seasonality (SI) calculated according to Walsh and Lawler (1981):

$$SIi = \frac{1}{Ri}\sum_{n=1}^{n=12}\left|Xin - \frac{Ri}{12}\right|$$

Where Ri is the total annual precipitation for the particular year under study and Xin is the actual monthly precipitation for month n. The general soil map of Cyprus was used for assessing the indicators soil depth, soil texture, and organic matter.

Slope gradient and slope aspect was defined using the existing topographic map of Cyprus. Vegetation cover was defined using CORINE 2000. Based on this map the indicators related to fire, agriculture, cultivation, husbandry, land use ware assessed. Data on climate, water use were identified from the existing provided reports. Data for the indicators related to tourism and social were found from the Cyprus statistical Service. Farm subsidies have been allocated according to existing EU regulation. Policy implementation was assessed based on the land use type. The area has been divided according to land cover type in: (a) agricultural areas, (b) pastures, and (c) forested areas. The algorithms with the corresponding beta values of the linear regression model used for each cover type are given in Table 2.2.1.

Table 2.2.2. Indicators with the distinct classes for each indicator and the related sensitivity (vulnerability) score

CLIMATE

Annual air Temperature (ºC)					

Annual rainfall (mm)				

BG aridity index	<50	50-75	75-100	100-125	125-150	>150
	1.0	*1.2*	*1.4*	*1.6*	*1.8*	*2.0*

Rain seasonality	<0.19	0.20-0.39	0.40-0.59	0.60-0.79	0.80-0.99	1.00-1.19	>1.20
	1.0	*1.2*	*1.4*	*1.6*	*1.8*	*1.9*	*2.0*

Rain erosivity (mm/h)	<60	60 -90	91-120	121-160	>160
	1.0	*1.2*	*1.5*	*1.8*	*2.0*

SOILS

Slope aspect	N, NW, NE	S, SW, SE	Plain
	1.0	*2.0*	*1.0*

Slope gradient (%)	<2	2 - 6	6-12	12-18	18-25	25-35	35-60	>60
	1.0	*1.2*	*1.4*	*1.6*	*1.7*	*1.8*	*1.9*	*2.0*

Soil depth (cm)	<15	15-30	30-60	60-100	100-1500	>150
	2.0	*1.8*	*1.6*	*1.4*	*1.2*	*1.0*

Soil textural class	Very coarse	Coarse	Medium	Moderate fine	Fine	Very fine
	2.0	*1.8*	*1.6*	*1.2*	*1.3*	*1.4*

Organic matter of surface horiz. (%)	High >6.0	Medium 2.1-6.0	Low 2.0-1.1	Very low <1.0
	1.0	*1.3*	*1.6*	*2.0*

VEGETATION

Agricultural cover type	Cereals	Olives	vines	almonds	oranges	vegetables	cotton	bare
	2.0	*1.0*	*1.4*	*1.3*	*1.6*	*1.8*	*1.5*	*2.0*

Natural vegetation cover type	Mixed Med. machia/ evergreen forest	Med. machia	Permanent grassland	Annual grassland	Deciduous Forest	Pine forest	Evergreen Forest	bare
	1.2	*1.4*	*1.5*	*1.8*	*1.6*	*1.4*	*1.0*	*2.0*

Plant cover (%)	<10	10-25	25-50	50-75	>75
	2.0	*1.8*	*1.5*	*1.3*	*1.0*

FIRES

Fire risk	Low	Moderate	High	Very high
	1.0	*1.4*	*1.7*	*2.0*

Burned area (ha burned/10 years/10 km^2 of territorial)	Low (<10 ha)	Moderate (10 -25 ha)	High (26 - 50 ha)	Very high (>50 ha)
	1.0	*1.3*	*1.7*	*2.0*

AGRICULTURE

Parallel employment	NO	industry	tourism	State	Municipality
	1.0	*2.0*	*1.4*	*1.7*	*1.5*

CULTIVATION

Tillage operations	NO	Plowing	Disking, harrowing	Cultivator
	1.0	*2.0*	*1.7*	*1.4*

Tillage depth (cm)	NO	<20	20-30	30-40	>40
	1.0	*1.1*	*1.3*	*1.7*	*2.0*

Tillage direction	Down-slope	Up-slope	Parallel to Contour up- slope furrow	Parallel to Contour down-slope furrow	Down-slope Oblique	Up-slope Oblique	Other (No tillage)
	2.0	1.4	1.2	1.5	1.8	1.3	1.0

HUSBANDRY

Grazing control	NO	Sustainable Number of animal	Fencing	Avoidance of soil compaction (very wet soil)	Fire Protection
	2.0	*1.0*	*1.2*	*1.4*	*1.3*

Grazing intensity	Low (SR<GC)	Moderate SR=GC to 1.5GC)	High (SR>1.5GC)
	1.0	*1.5*	*2.0*

LAND MANAGEMENT

Fire protection (Protected/total area %)	NO	Low <25%	Moderate 25-50%	High 50-75%	Very high >75%
	2.0	*1.8*	*1.6*	*1.3*	*1.0*

Sustainable farming	No Sustainable Farming	No tillage	Minimum Tillage	Inducing Plant cover	Up-slope tillage	Minimum plowing depth
	2.0	*1.0*	*1.3*	*1.1*	*1.4*	*1.5*

Soil water conservation measures	Weed control	Mulching	temporary storage of water runoff	inducing vapor adsorption	No
	1.0	*1.0*	*1.0*	*1.2*	*2.0*

Terracing (presence of) (area protected/total area, %)	NO	Low, <25%	Moderate, 25-50%	High, 50-75%	Very high, >75%
	2.0	*1.7*	*1.5*	*1.2*	*1.0*

LAND USE

Land abandonment **(ha/10 years/10 km^2**	Low (<10 ha)	Moderate (10 -25 ha)	High (26 - 50 ha)	Very high (>50 ha)
	1.0	*1.3*	*1.6*	*2.0*

Land use intensity	Low	medium	High
	1.0	*1.5*	*2.0*

(Period) of existing land use	<1 year	1-5 years	5-10 years	10-20 years	30-50 years	>50 years
	2.0	*1.8*	*1.6*	*1.4*	*1.2*	*1.0*

WATER USE

Runoff water storage	No	Low	moderate	adequate
	2.0	1.8	1.4	1.0

TOURISM

Tourism intensity (number of overnight stays /10 km^2 =R)	Low R<0.01	Moderate R=0.01-0.04	High R=0.04-0.08	Very high R>0.08
	1.0	*1.3*	*1.7*	*2.0*

SOCIAL

Population density (people / km^2)	Low <50	Moderate 50-100	High 100-300	Very high >300
	1.0	*1.3*	*1.7*	*2.0*

INSTITUTIONAL

Subsidies					

Policy implementation	Adequate >75% of the area	Moderate (25-75% of the area)	Low (<25% of the area)	No
	1.0	*1.4*	*1.7*	*2.0*

<u>Land desertification assessment</u>

The sensitivity (vulnerability) to desertification has been assessed based on the MEDALUS project definition of Environmentally Sensitive Areas (ESAs). Four types of ESAs have been distinguished based on the stage of land degradation (Kosmas *et al.*, 1999):

<u>Critical ESAs</u>: Areas already highly degraded through past misuse, presenting a threat to the environment of the surrounding areas, i.e. badly eroded areas subject to high run-off and sediment loss. This may cause appreciable flooding downstream and reservoir sedimentation.

<u>Fragile ESAs</u>: Areas in which any change in the delicate balance between natural and human activity is likely to bring about desertification. For example, a land use

change (a shift towards cereals cultivation) on sensitive soils might produce immediate increase in run-off and erosion, and perhaps pesticide and fertilizer pollution downstream.

Potential ESAs: Areas threatened by or prone to desertification under significant climate change, if a particular combination of land use is implemented or where offsite impacts will produce severe problems elsewhere, for example pesticide transfer to downslope or downstream areas under variable land use or socio-economic conditions.

Non Threatened ESAs: Areas with deep to very deep soils, nearly flat, well drained, coarse-textured or finer textured soils, under semi-arid or wetter climatic conditions, independently of vegetation, are considered as being non-threatened by desertification.

The various types of ESAs to desertification have been defined by using certain key indicators or parameters for assessing the land capability to withstand further degradation, or the land suitability for supporting specific types of land use. For the evaluation of the environmentally sensitive areas to desertification four physical environment qualities are considered: soil quality, climate quality, vegetation quality and management quality (Kosmas et al., 1999) and (Figure 2.2.1). The indicators used for the above compilation are: soil texture, parent material, rock fragments, slope gradient, soil depth, soil drainage, annual rainfall, aridity index, slope aspect, fire risk, erosion protection, drought resistance, percentage of plant cover, land use intensity, and land policy enforcement. The physical environment qualities (soil quality, climate quality, vegetation quality) and the management quality have been combined in the following equation for calculation of the environmentally sensitivity index (ESAI) for the definition of the various types of ESAs to desertification.

$$\mathbf{ESAI = (SQI * CQI * VQI * MQI)^{1/4}}$$

The ranges of ESAI for each of type of the ESAs including three subclasses in each type appear in Table 2.2.3. Each type of ESAs is defined on a three-point scale, ranging from 3 (high sensitivity) to 1 (lower sensitivity), in order that the boundaries of the successive classes of ESAs may be better integrated.

Table 2.2.3. Types of ESAs and corresponding ranges of indices

Type	Subtype	Range of ESAI
Critical	C3	>1.53
«	C2	1.42-1.53
«	C1	1.38-1.41
Fragile	F3	1.33-1.37
«	F2	1.27-1.32
«	F1	1.23-1.26

Potential	P	1.17-1.22
Non affected	N	<1.17

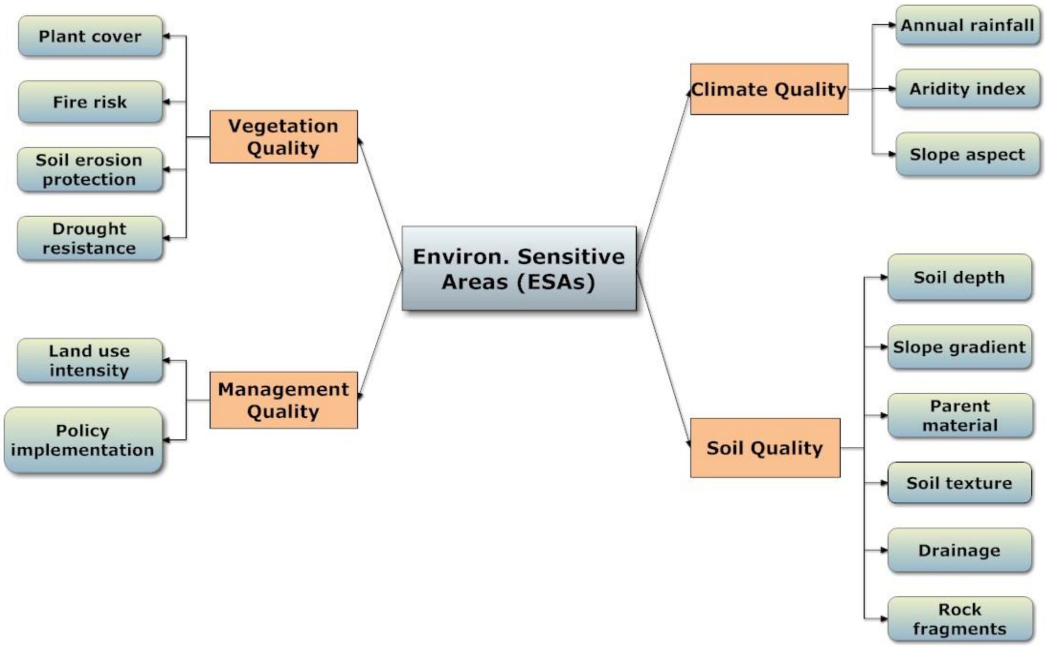


Figure 2.2.1. The indicators and qualities used for identification environmentally sensitive areas (ESAs) to desertification

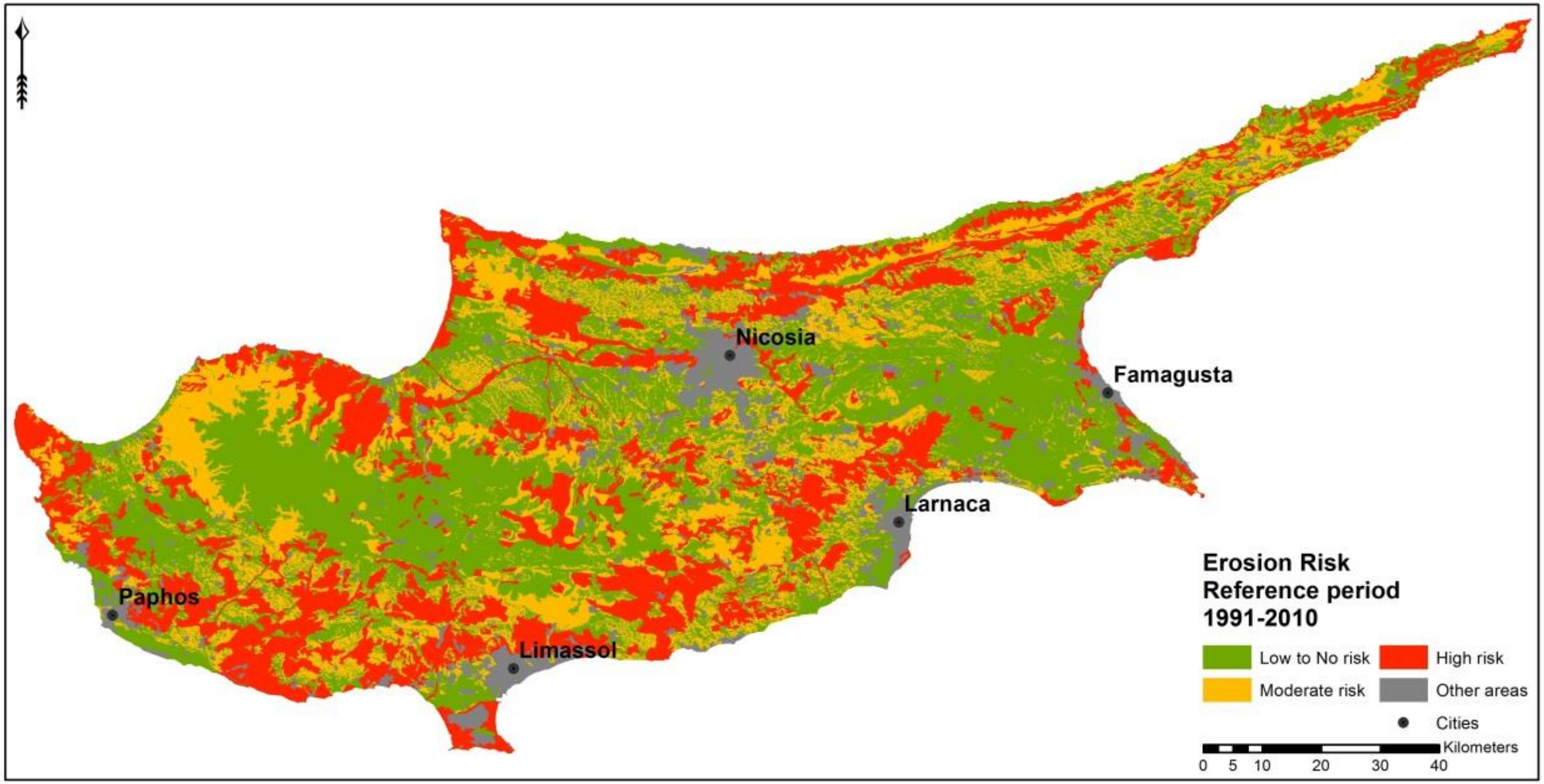
2.2.2. Analysis of land degradation and desertification

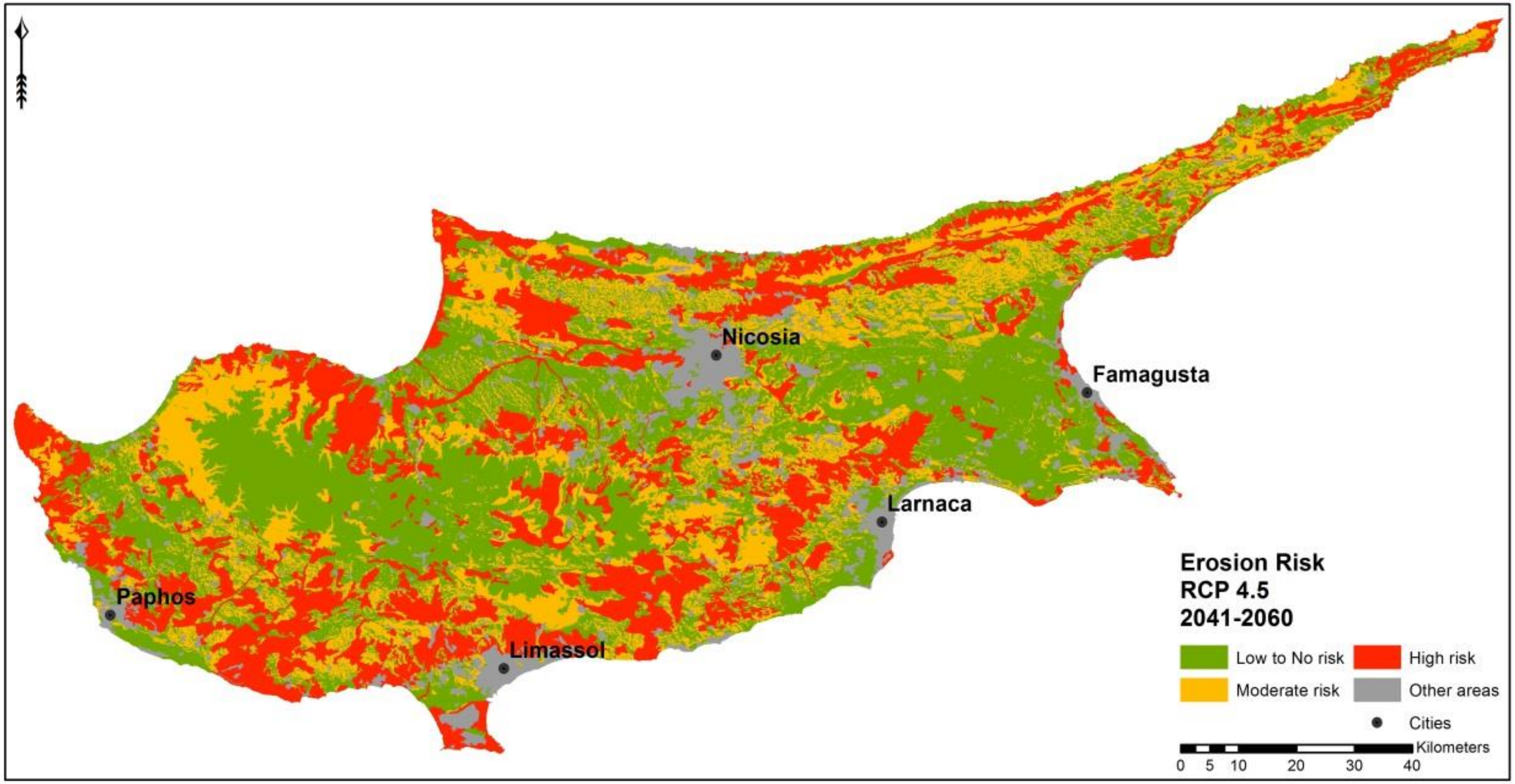
2.2.2.1. Soil erosion risk assessment

Climate projection RCP4.5

As Figure 2.2.2 shows the area of Cyprus is highly affected by soil erosion basically due to the sloping terrain. Based on the reference period climatic data, areas with high and moderate risk of soil erosion cover 26.6% and 23.5%, respectively (Table 2.2.4). However, a significant part of the island (43.3% of the total area) is characterized by low or no erosion risk. Soil erosion risk is expected to increase under the climate projection RCP4.5 for both periods (2041-2060, and 2071-2090). Areas with moderate erosion risk will increase from 23.5% to 24.2% in the period 2041-2060 to 26.4% in the period 2071-2090. Areas with low erosion risk are expected to decrease from 43.3% in the reference period to 41.5% in the period 2041-2060 and to 39.0% in the period 2071-2090. Areas characterized with high erosion risk are expected to remain unchanged.

The increase in erosion risk is expected due to the decrease in annual rainfall and the increase in air temperature adversely affecting rainfall seasonality and aridity index. The increase in aridity is expected to affect negatively plant cover and therefore surface rain water runoff and soil erosion will increase. The average aridity index, measured by Bagnouls-Gaussen index, is expected to change from 209.5 (reference period) to 248.7 in the period 2041-2060 to 269.2 in the period 2071-2090. The average rain seasonality index, derived by the Walsh and Lawler (1981) equation, is estimated to slightly increase from 0.78 (reference period) to 0.79 in 2041-2060 to 0.81 in 2071-2090.


Nicosia
Famagusta
Larnaca
Paphos
Limassol
Erosion Risk
Reference period
1991-2010
Low to No risk
High risk
Moderate risk
Other areas
Cities
Kilometers
0 5 10 20 30 40


Nicosia
Famagusta
Larnaca
Paphos
Limassol
Erosion Risk
RCP 4.5
2041-2060
Low to No risk
High risk
Moderate risk
Other areas
Cities
Kilometers
0 5 10 20 30 40

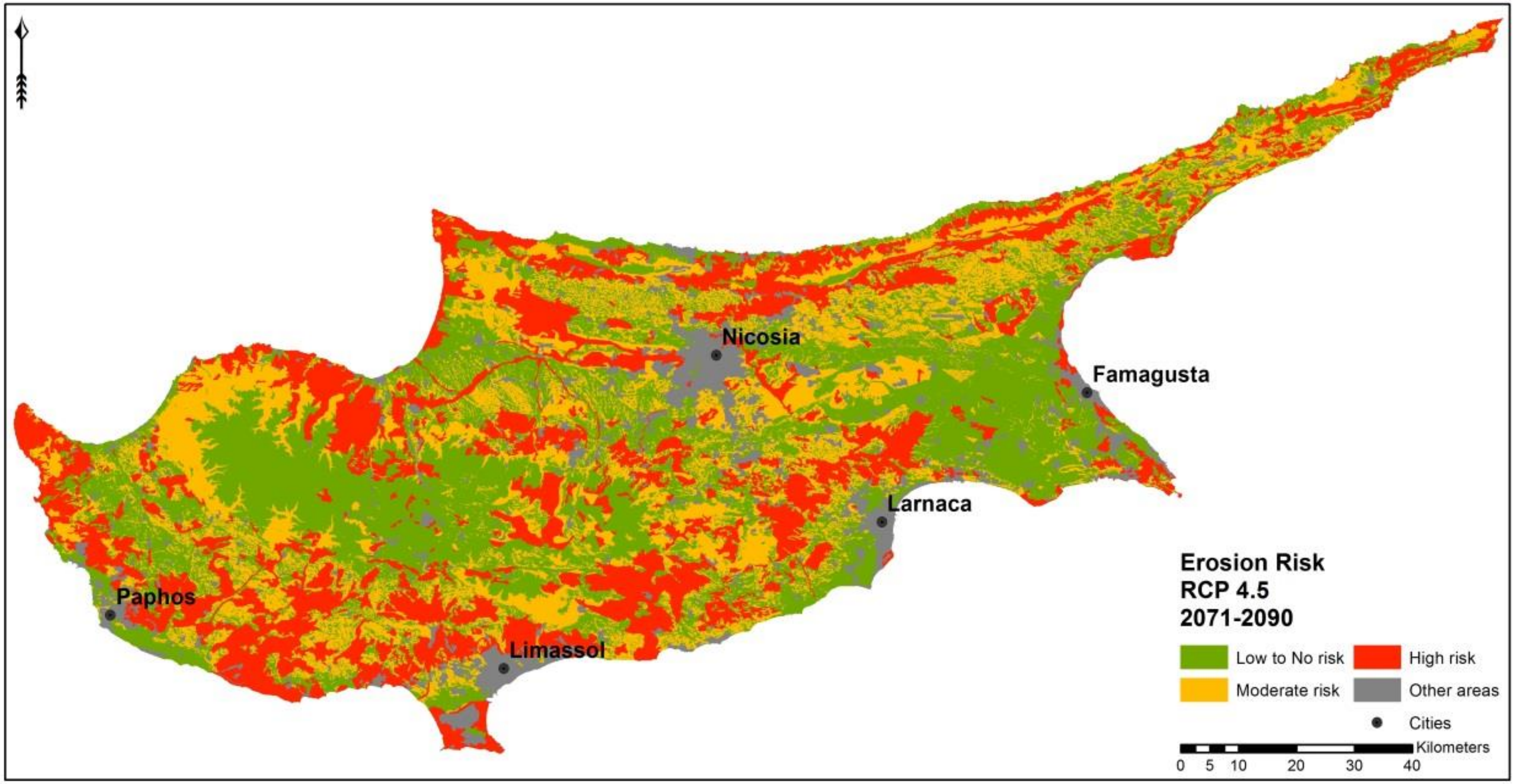


Figure 2.2.2. Assessment of soil erosion risk for (a) reference period (upper), (b) period 2041-2060 (middle), and (c) period 2071-2090 (lower) for the climate projection RCP4.5.

Table 2.2.4. Distribution of erosion risk for the reference period, period 2041-2060 and period 2071-2090 for theclimate projection RCP4.5

Erosion risk	Reference period		Climate projection RCP4.5 (period 2041-2060)		Climate projection RCP4.5 (period 2071-2090)	
	area (ha)	area (%)	area (ha)	area (%)	area (ha)	area (%)
High	244877,1	26,6	244318,4	26,5	246187,5	26,7
Moderate	216772,9	23,5	223136,4	24,2	243223,6	26,4
Low-no risk	399494,7	43,3	382450,7	41,5	359099,5	39,0
Other areas	72144,9	7,8	72144,9	7,8	72144,9	7,8
TOTAL	922050,5	100,0	922050,5	100,0	922050,5	100,0

Climate projection RCP8.5

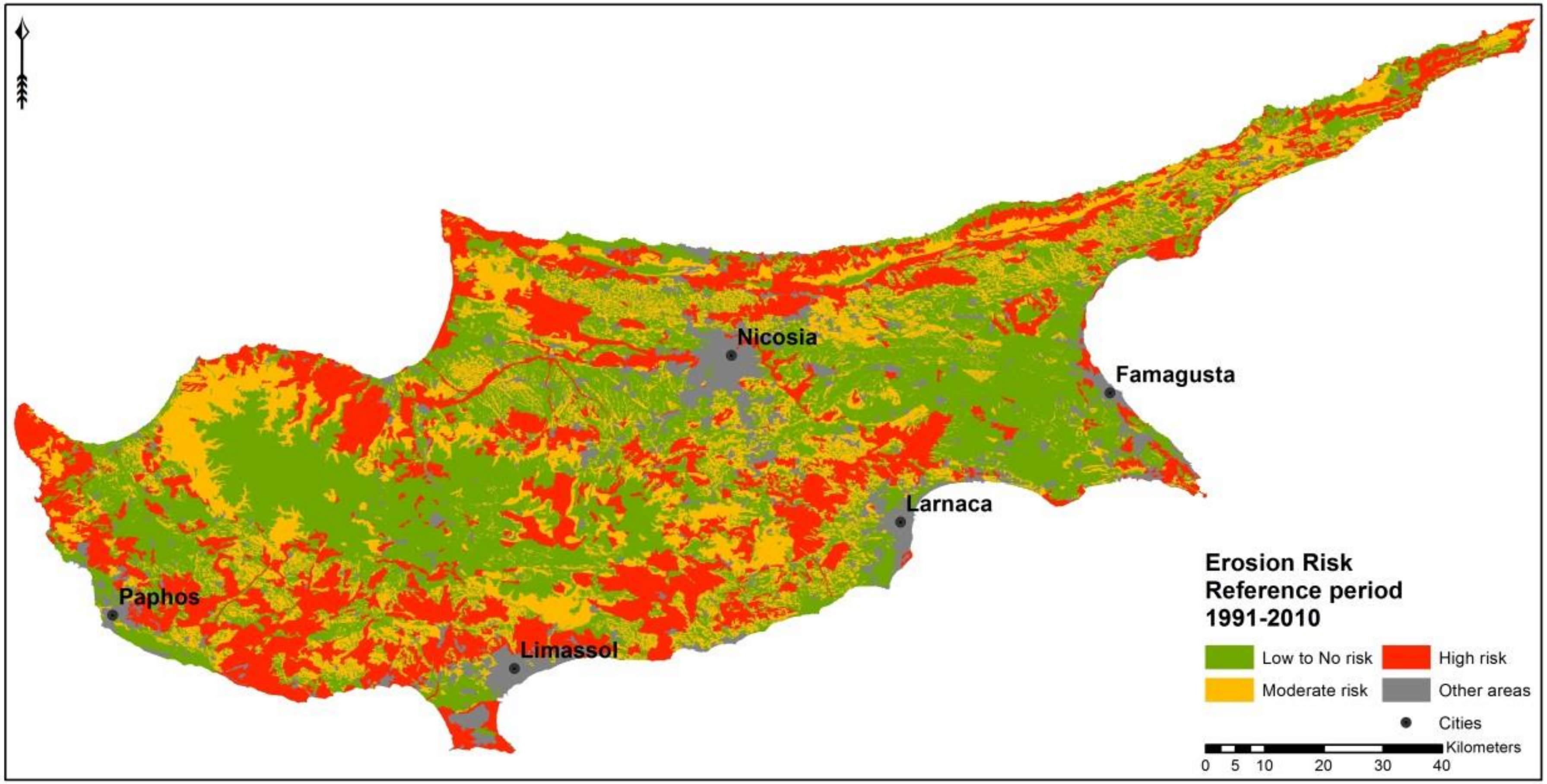
Similar trends with climate projection RCP4.5 have been assessed on soil erosion risk for the climate projection RCP8.5. The soil erosion risk is expected to be both higher compared to the reference period conditions and to climate projection RCP4.5 (Figure 2.2.3). As Table 2.2.5 shows, areas with low to no erosion risk will decrease from 43.3% in the reference period to 42.9% in the period 2041-2060 and to 37.4% in the period 2071-2090. Areas with high erosion risk will increase from 26.6% in the reference period to 27.0% in the period 2041-2090 and then is expected a slight decrease to 26,3% in the period 2071-2090. Areas characterized with moderate erosion risk will decrease from 23.5% in the reference period to 22.2% in the period 2041-2070 and then is expected a significant increase to 28.5% for the period 2071-2090.

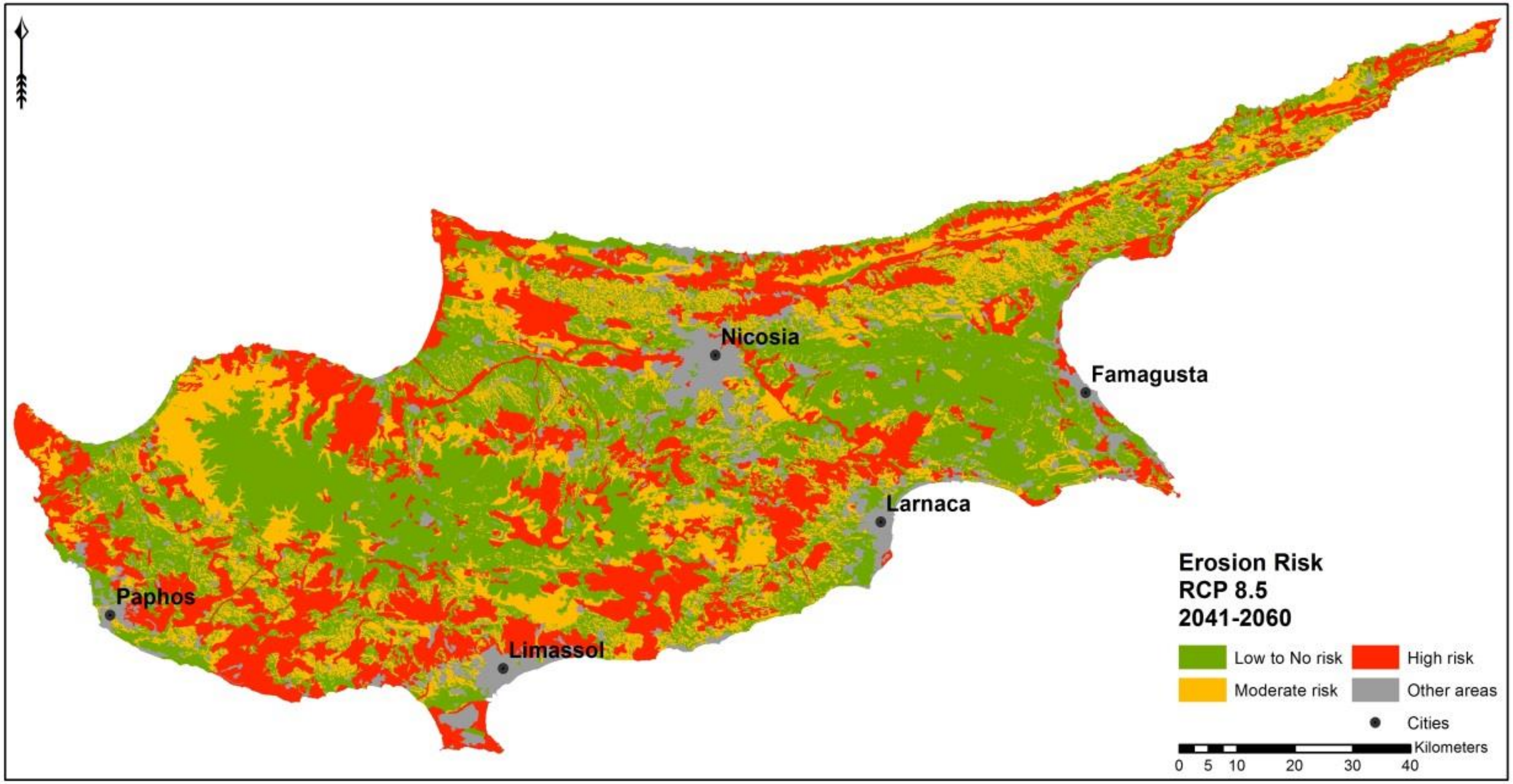
Regarding climate projection RCP4.5, the increase in erosion risk is expected due to the decrease in the annual rainfall and the increase in air temperature adversely affecting rainfall seasonality and aridity index. The average aridity index, measured by Bagnouls-Gaussen index, is expected to change from 209.5 (reference period) to 264.4 in the period 2041-2060 to 290.6 in the period 2071-2090. The rain seasonality index, derived by the Walsh and Lawler (1981) equation, is estimated to increase from 0.78 (reference period) to 0.84 in 2041-2060 and then to decrease to 0.75 in 2071-2090.

Table 2.2.5. Distribution of erosion risk for the reference period, period 2041-2060 and period 2071-2090 for the climate projection RCP8.5

Erosion risk	Reference period		Climate projection RCP8.5 (period 2041-2060)		Climate projection RCP8.5 (period 2071-2090)	
	area (ha)	area (%)	area (ha)	area (%)	area (ha)	area (%)

High	244877,1	26,6	248753,5	27,0	242699,2	26,3
Moderate	216772,9	23,5	204597,6	22,2	262659,7	28,5
Low-no risk	399494,7	43,3	395059,5	42,9	344546,7	37,4
Other areas	72144,9	7,8	72144,9	7,8	72144,9	7,8
TOTAL	922050,5	100,0	922050,5	100,0	922050,5	100,0


Nicosia
Famagusta
Larnaca
Paphos
Limassol
Erosion Risk
Reference period
1991-2010
Low to No risk
High risk
Moderate risk
Other areas
Cities
Kilometers
0 5 10 20 30 40


Nicosia
Famagusta
Larnaca
Paphos
Limassol
Erosion Risk
RCP 8.5
2041-2060
Low to No risk
High risk
Moderate risk
Other areas
Cities
Kilometers
0 5 10 20 30 40

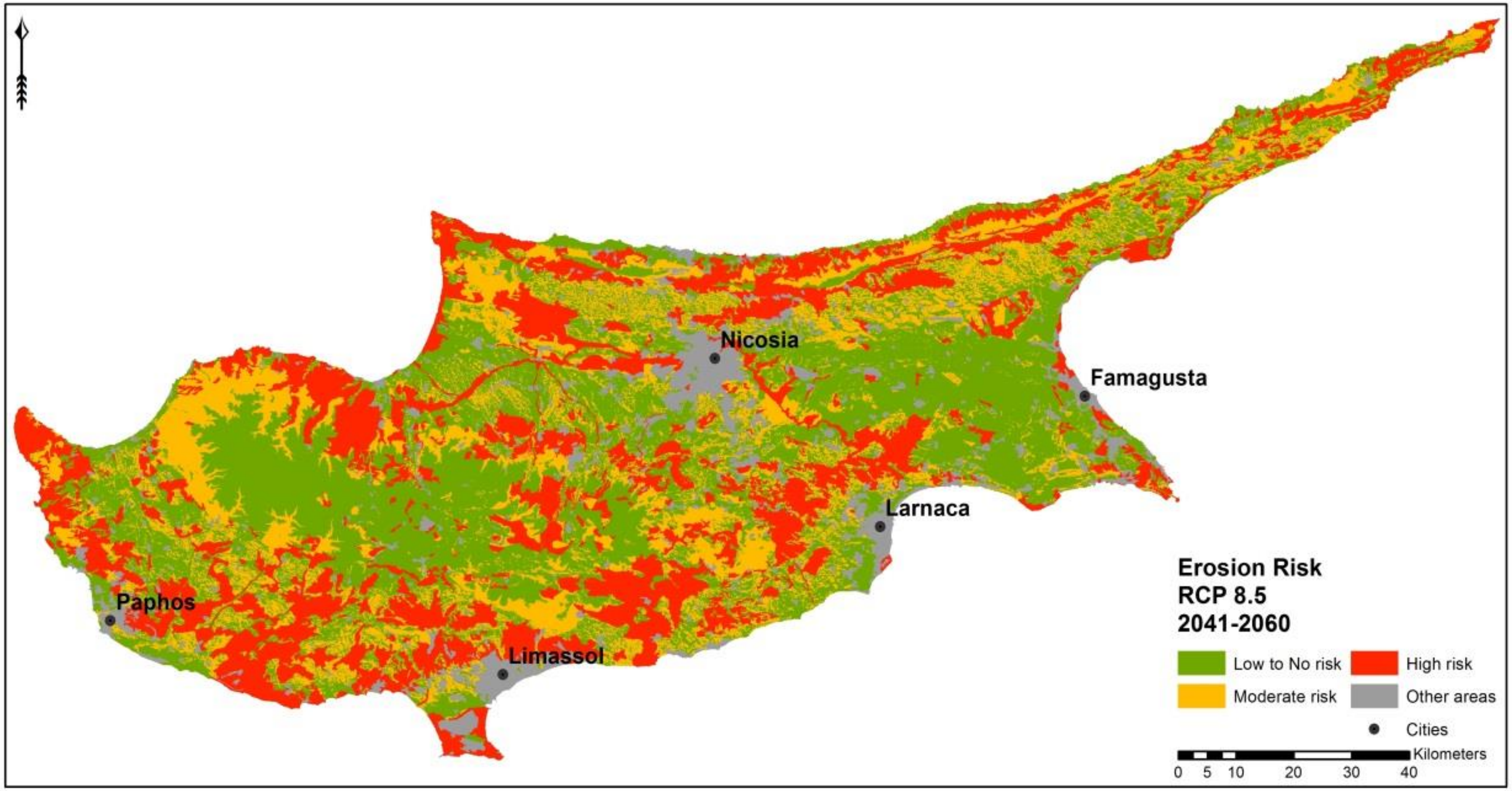


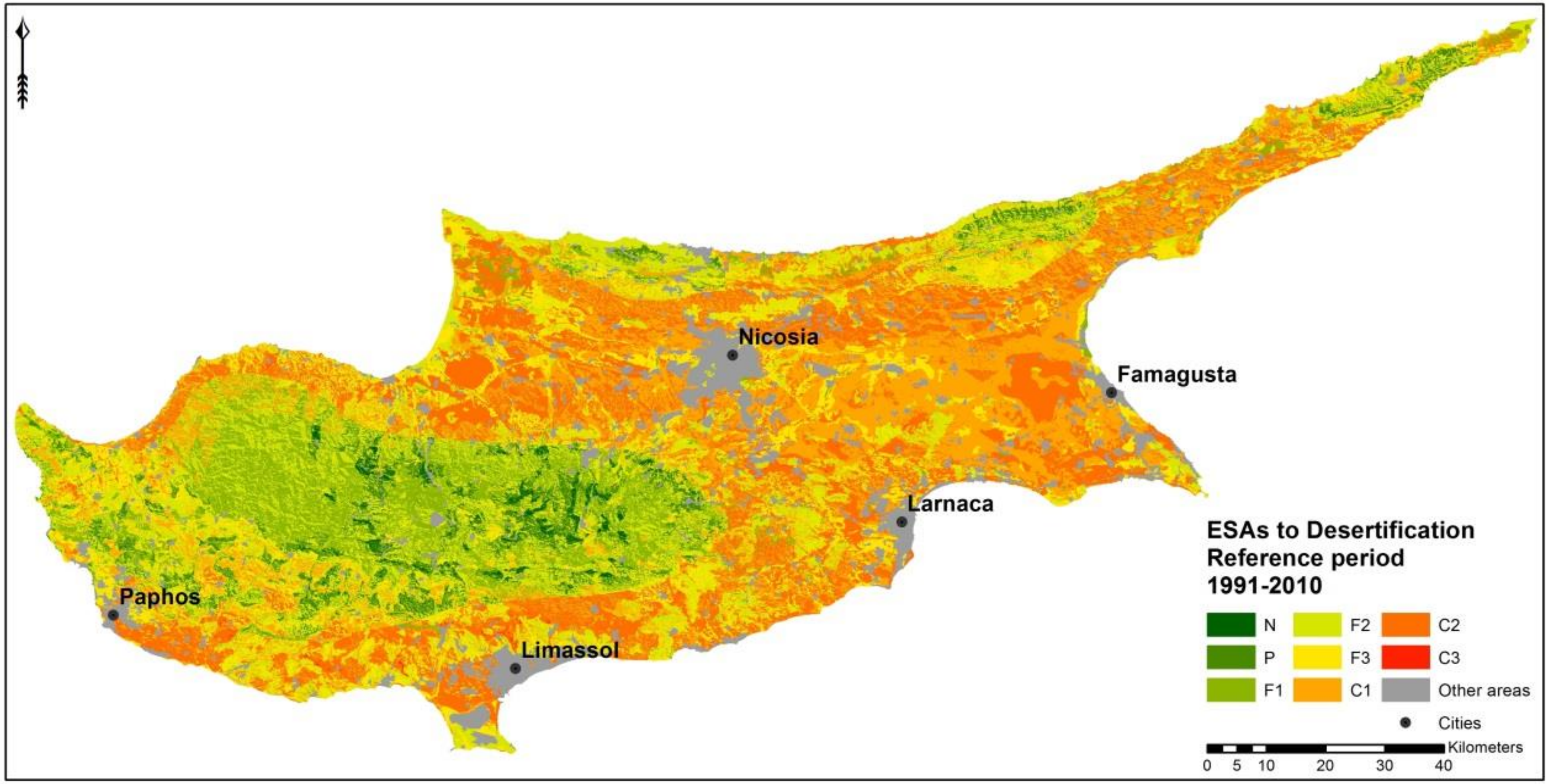
Figure 2.2.3. Assessment of soil erosion risk for (a) the reference period (upper), (b) period 2041-2060 (middle), and (c) period 2071-2090 (lower) for the climate projection RCP8.5

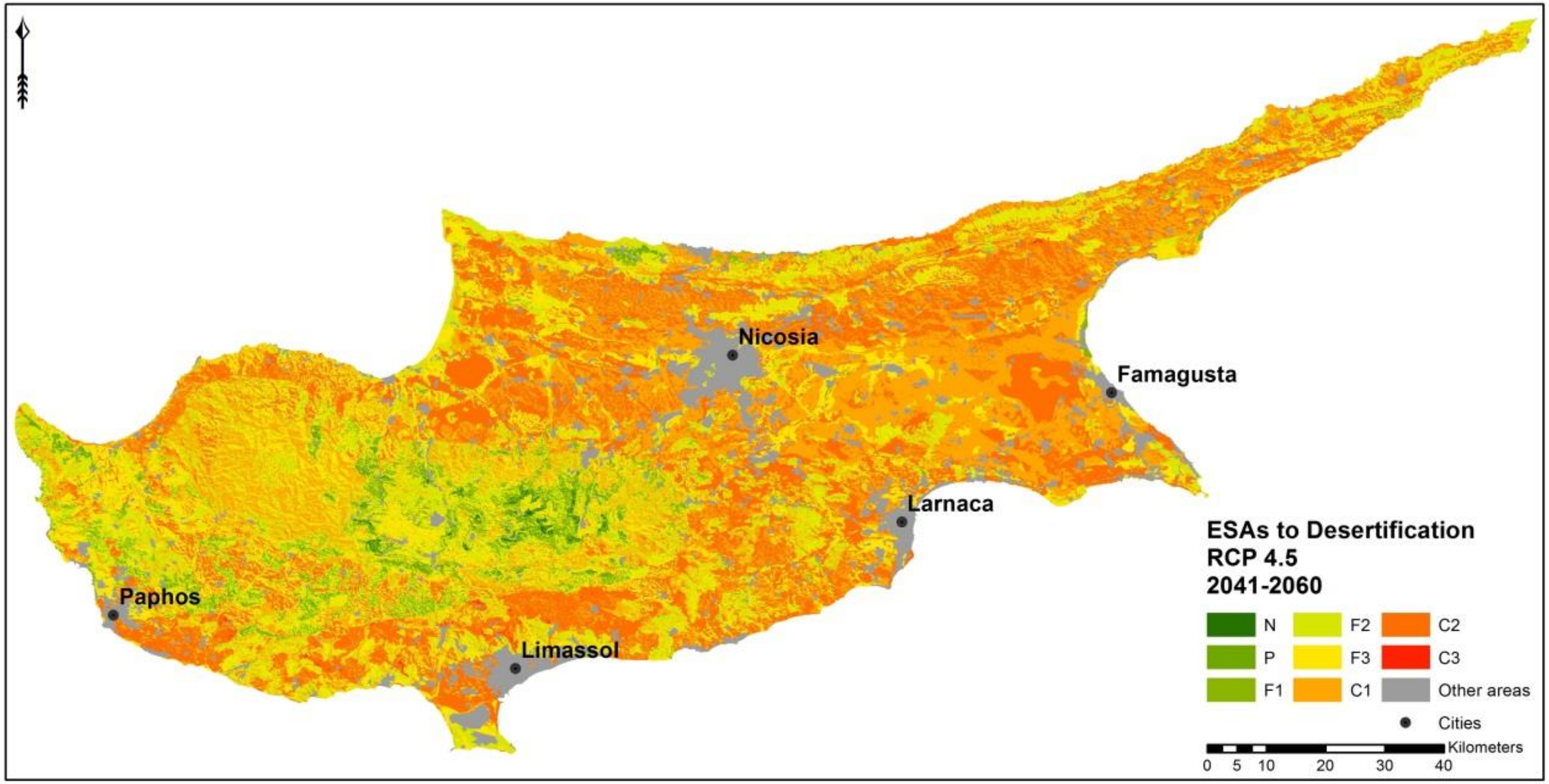
2.2.2.2. Land desertification risk assessment

Climate projection RCP4.5

The island of Cyprus is mainly characterized by critical and fragile type areas to desertification (Figure 2.2.4), covering 42.9% and 44.6% of the total land, respectively. Potentially non-threatened areas to desertification cover only 3.9% and 0.8% of the land, respectively (Table 2.2.6). The expected decrease in the rainfall and the increase in air temperature accompanied by an increase in aridity index will result in the increase of the vulnerability to desertification in the whole island of Cyprus.

Some areas which are characterized as prone to desertification under the reference period climatic conditions will change to fragile, while areas characterized as fragile are expected to change in critical to desertification. Areas critical to desertification are expected to increase from 42.9% (reference period) to 52.0% in the period 2041-2060 to 54.9% in the period 2071-2090. In addition, areas characterized as critical sub-type C2 is expected to increase from 19.6% (reference period) to 24.4% in the period 2041-2060 to 27.7% in the period 2071-2090. This change is mainly expected from the conversion of critical sub-type C1 to critical sub-type C2 due to the increasing aridity. However, critical areas to desertification sub-type C1 are expected to increase due to the increased vulnerability to desertification of the fragile sub-type F3 areas. Areas prone to desertification are expected to decrease from 3.9% (reference period) to 1.4% and 1.1%, and fragile sub-type F1 from 11.3% (reference period) to 3.3% and 2.8% in the periods 2041-2060 and 2071-2090, respectively, and to be converted mainly to fragile sub-types F2 and F3 (Table 2.2.6).


Nicosia
Famagusta
Larnaca
Paphos
Limassol
ESAs to Desertification
Reference period
1991-2010
N
P
F1
F2
F3
C1
C2
C3
Other areas
Cities
Kilometers
0 5 10 20 30 40



Nicosia
Famagusta
Larnaca
Paphos
Limassol
ESAs to Desertification
RCP 4.5
2041-2060
N
P
F1
F2
F3
C1
C2
C3
Other areas
Cities
Kilometers
0 5 10 20 30 40

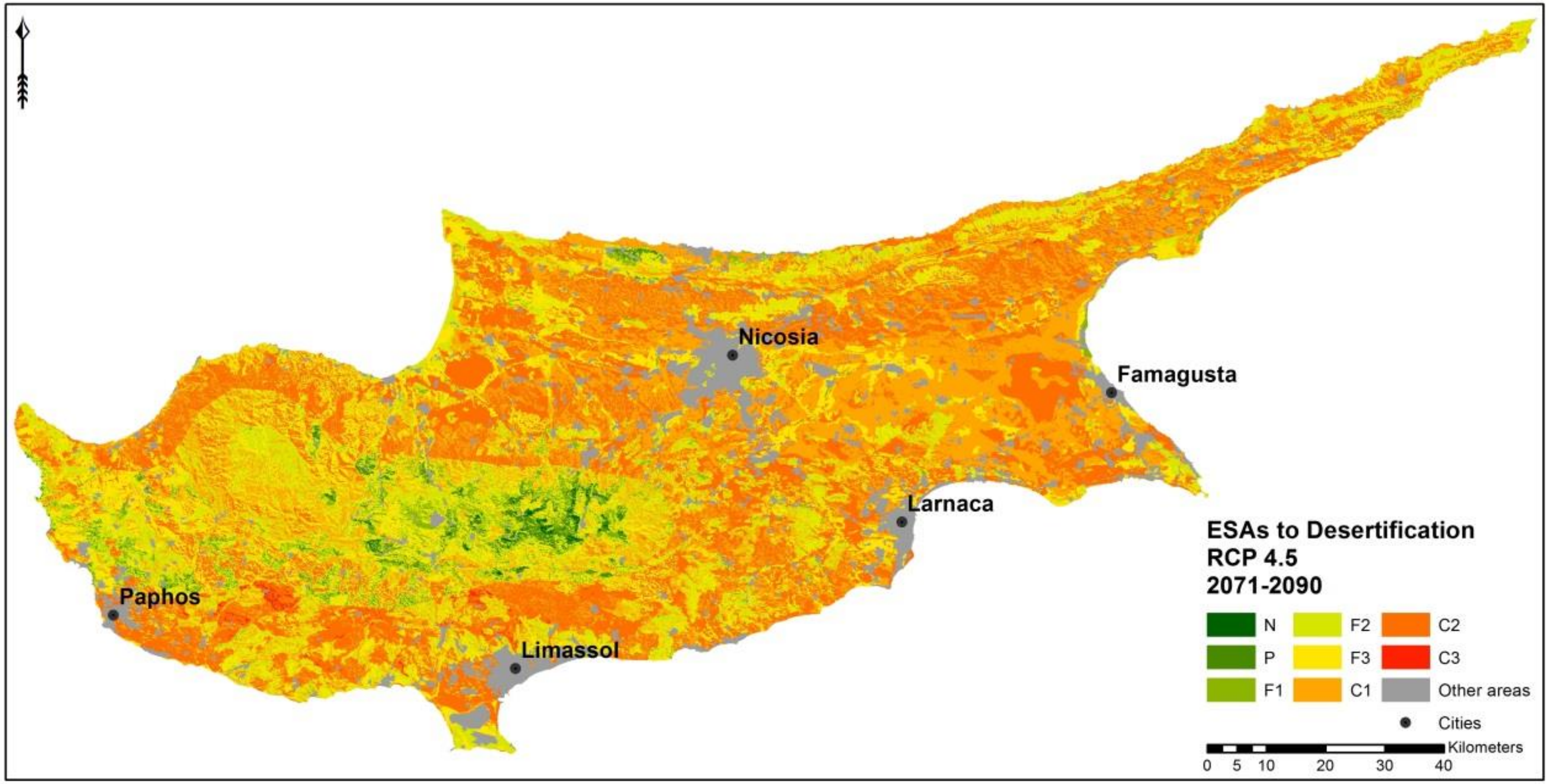


Figure 2.2.4. Assessment of land desertification (a) the reference period (upper), (b) the period 2041-2060 (middle), and (c) the period 2070-2095 (lower) for the climate projection RCP4.5

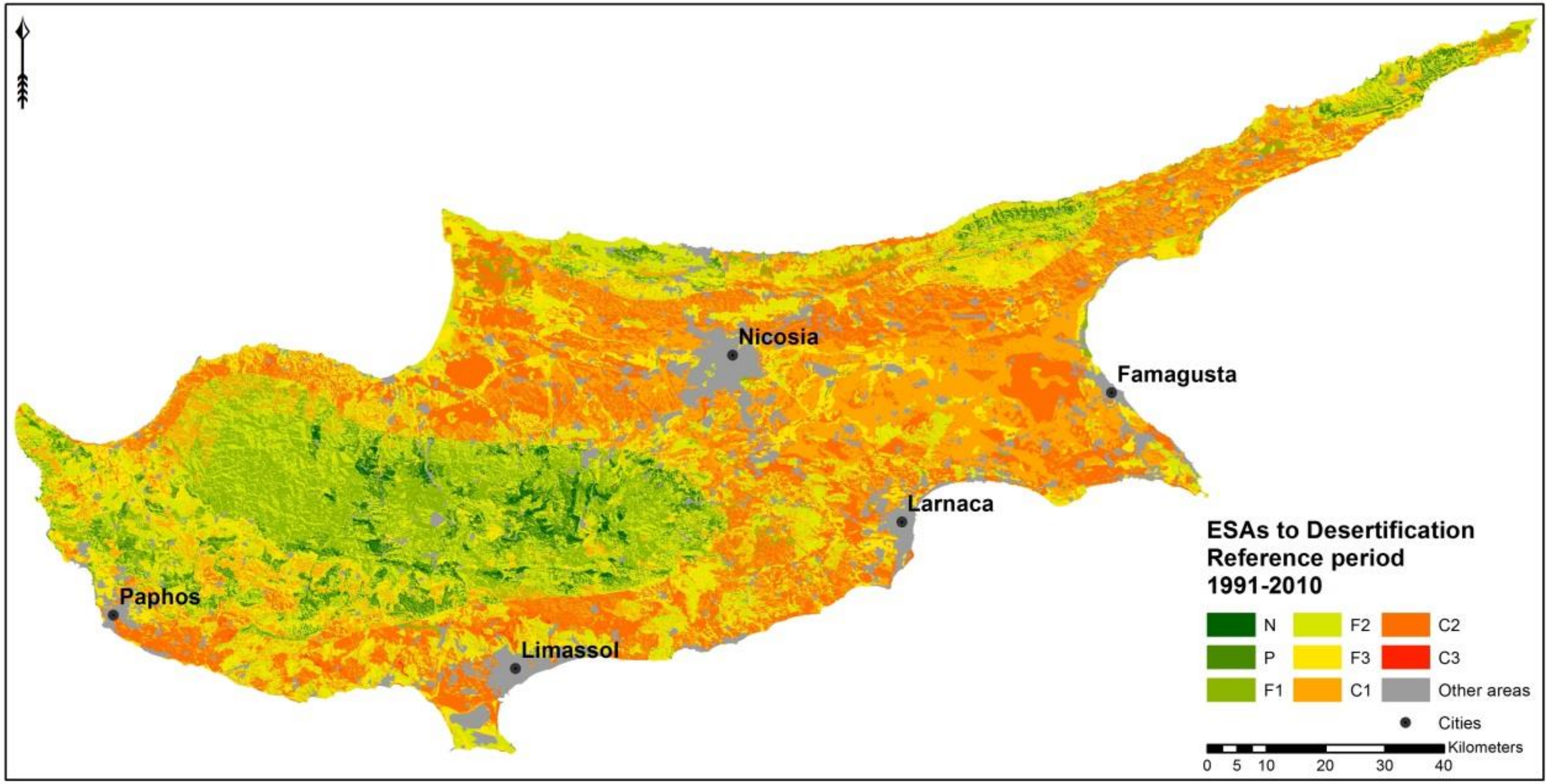
Table 2.2.6. Distribution of environmentally sensitive areas to desertification for the reference period, period 2041-2060 and period 2071-2090 for the climate projection RCP4.5

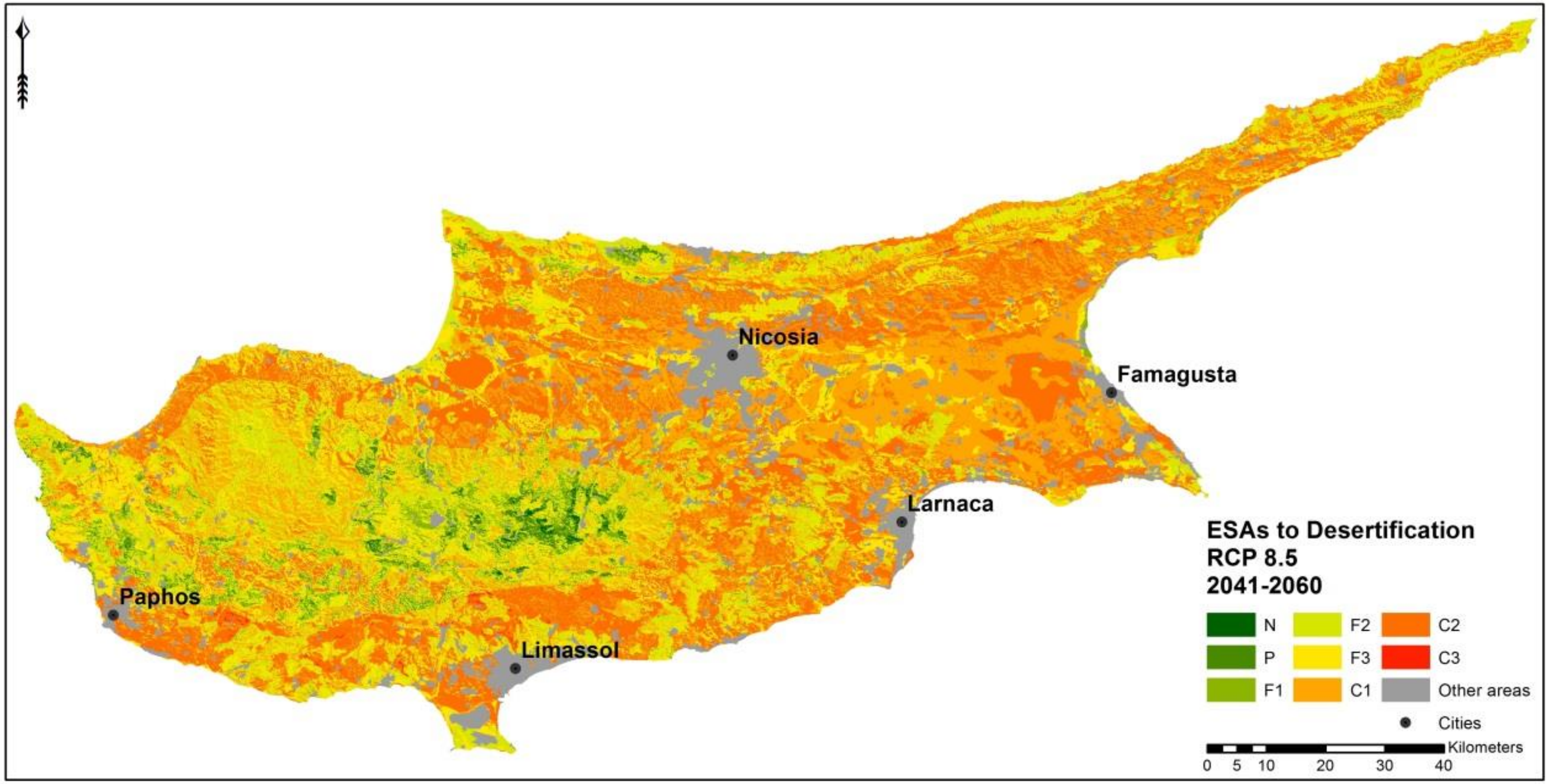
Environmentally sensitive areas to desertification (ESAs)	Reference period		Climate projection RCP4.5 (period 2041-2060)		Climate projection RCP4.5 (period 2071-2090)	
	area (ha)	area (%)	area (ha)	area (%)	area (ha)	area (%)
Critical-C3	452,1	0,1	646,7	0,1	1809,6	0,2
Critical-C2	181000,0	19,6	225305,0	24,4	249360,3	27,0
Critical-C1	214132,9	23,2	253736,2	27,5	255099,7	27,7
Fragile-F3	121303,9	13,2	168676,2	18,3	161389,3	17,5
Fragile-F2	185660,5	20,1	157161,3	17,0	144823,3	15,7
Fragile-F1	104167,7	11,3	30134,1	3,3	25615,9	2,8
Potential-P	36207,2	3,9	12694,3	1,4	9994,7	1,1
No threatened-N	6981,3	0,8	1551,8	0,2	1813,0	0,2
Other areas	72144,9	7,8	72144,9	7,8	72144,9	7,8
TOTAL	922050,5	100,0	922050,5	100,0	922050,5	100,0

Climate projection RCP8.5

The analysis of the climatic data of climate projection RCP8.5 has shown that the hazard of land desertification risk is expected to increase as in the climate projection RCP4.5 (Figure 2.2.5). Critical areas to desertification are expected to increase from 42.9% of the total land (reference period) to 52.3% in the period 2041-2060 and to 55.5% in the period 2071-2090. In addition, fragile areas are expected to decrease from 44.6% (reference period) to 38.3% in the period 2041-2090 and 35,9% in the period 2071-2090. Generally, the expected decrease in rainfall and increase in air temperature will increase aridity index and therefore vulnerability to desertification if it is considering that the other parameters remain approximately constant.

Areas characterized as critical sub-type C2 are expected to increase from 19.6% (reference period) to 24.9% in the period 2041-2060 to 27.5% in the period 2071-2090. This change is mainly expected from the conversion of the critical sub-type C1 to critical sub-type C2. However, critical areas to desertification sub-type C1 are expected to increase due to mainly the expected vulnerability increase to desertification of the fragile sub-type F3 areas. The sub-type F3 is expected to change from 13.2% (reference period) to 18.0% in the period 2041-2070 and then to 17.3% in the period 2071-2010 (Table 2.2.7). As in climate projection RCP4.5, areas prone to desertification are expected to decrease from 3,9% (reference period) to 1,3% and 1,0%, and fragile sub-type F1 from 11.3% (reference period) to 3.3% and 2,6% in the periods 2041-2060 and 2071-2090, respectively, and converted mainly to fragile sub-types F2 and F3 (Table 2.2.6).


Nicosia
Famagusta
Larnaca
Paphos
Limassol
ESAs to Desertification
Reference period
1991-2010
N
P
F1
F2
F3
C1
C2
C3
Other areas
Cities
Kilometers
0 5 10 20 30 40


Nicosia
Famagusta
Larnaca
Paphos
Limassol
ESAs to Desertification
RCP 8.5
2041-2060
N
P
F1
F2
F3
C1
C2
C3
Other areas
Cities
Kilometers
0 5 10 20 30 40

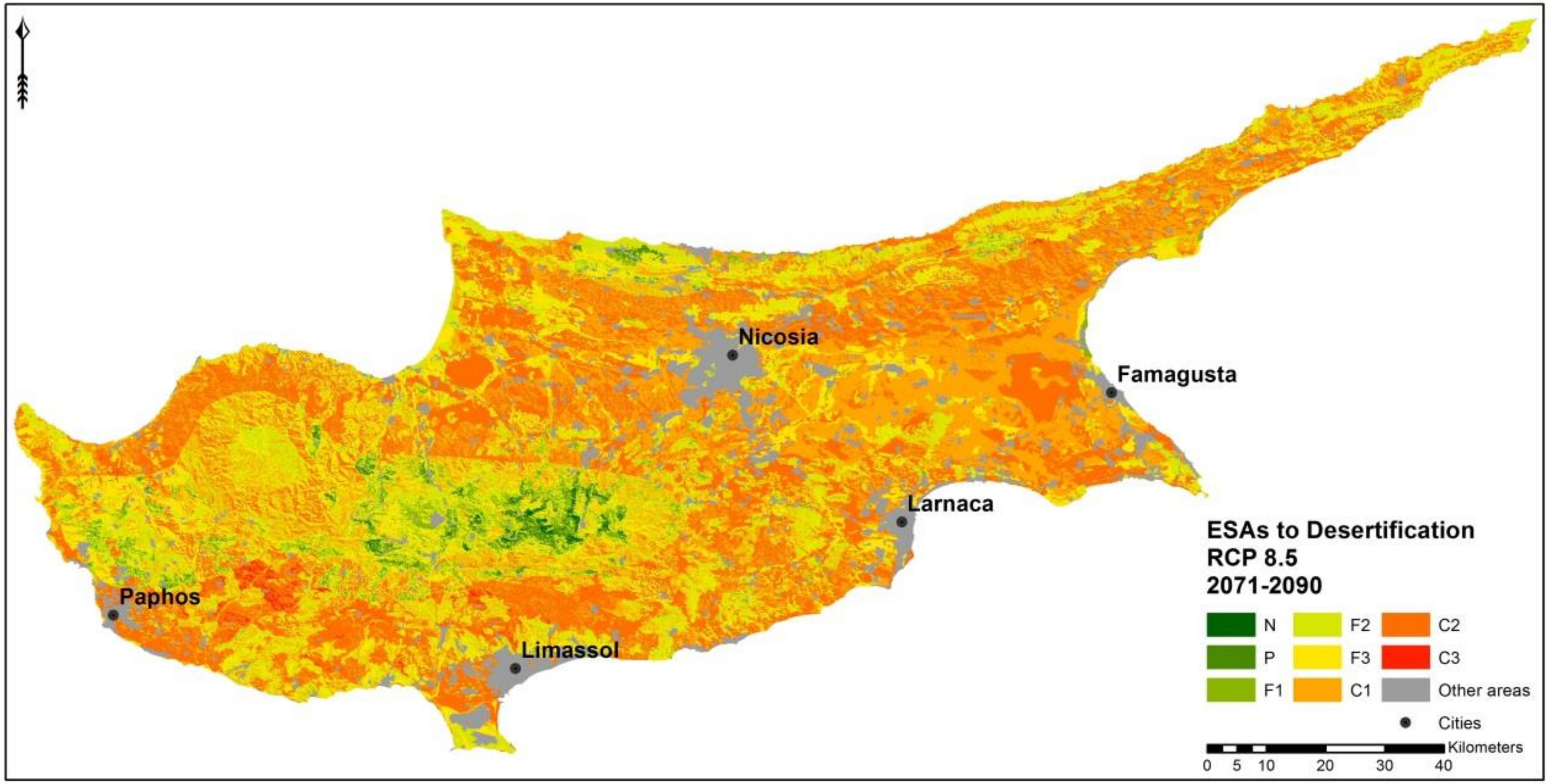

Nicosia
Famagusta
Larnaca
Paphos
Limassol
ESAs to Desertification
RCP 8.5
2071-2090
N
P
F1
F2
F3
C1
C2
C3
Other areas
Cities
Kilometers
0 5 10 20 30 40

Figure 2.2.5. Assessment of land desertification (a) the reference period (upper), (b) the period 2041-2060 (middle), and (c) the period 2070-2095 (lower) for the climate projection RCP8.5

Table 2.2.7. Distribution of environmentally sensitive areas to desertification for the reference period, period 2041-2060 and period 2071-2092 for the climate projection RCP8.5

Environmentally sensitive areas to desertification (ESAs)	Reference period		Climate projection RCP8.5 (period 2041-2060)		Climate projection RCP8.5 (period 2071-2090)	
	area (ha)	**area (%)**	**area (ha)**	**area (%)**	**area (ha)**	**area (%)**
Critical-C3	452,1	0,1	1014,5	0,1	2626,6	0,3
Critical-C2	181000,0	19,6	229834,5	24,9	253679,9	27,5
Critical-C1	214132,9	23,2	251991,4	27,3	253122,3	27,5
Fragile-F3	121303,9	13,2	166326,8	18,0	159089,6	17,3
Fragile-F2	185660,5	20,1	156405,7	17,0	146100,0	15,8
Fragile-F1	104167,7	11,3	30355,6	3,3	24241,6	2,6
Potential-P	36207,2	3,9	12129,6	1,3	9376,9	1,0
No threatened	6981,3	0,8	1847,5	0,2	1668,5	0,2
Other areas	72144,9	7,8	72144,9	7,8	72144,9	7,8
TOTAL	922050,5	100,0	922050,5	100,0	922050,5	100,0

Conclusions

Desertification in Cyprus is an important process of land degradation especially in the olive and cereal cultivation zone, in pine forested areas and shrubby grazing lands. The main biophysical and socio-economic factors affecting desertification are adverse climatic conditions, sloping terrain, moderately deep or shallow soils, moderate availability of water resources over-exploited in many cases, relatively frequent fires in forested areas, usually intensively cultivated agricultural land or overexploited grazing land resulting in unsustainable land use practices, inadequate measures for land protection, low or moderate implementation of existing regulations for environmental protection. The main process of land degradation and desertification is soil erosion.

Based on the climate change as assessed in projections RCP4.5 and RCP8.5, such process is expected to become more acute, if as forecasted the annual rainfall will decrease and the air temperature will increase, adversely affecting the derived aridity index. Soil erosion is expected to be more severe under climate projection RCP8.5. Land desertification is a serious threat under the reference period climatic conditions, and it is expected to be aggravated under climate projections RCP4.5 and RCP8.5.

Many areas characterized as fragile to desertification under the reference period climatic conditions will be converted to critical areas to desertification if the forecasted climate change would occur. In addition, several areas characterized as prone to desertification are expected to change to fragile and the vulnerability to desertification will increase. Furthermore, changes in the vulnerability to desertification within the same type of environmentally sensitive areas are expected under the predicted climatic scenarios. For example, fragile areas of sub-type F2 are expected, in many cases, to change in sub-type F3, which means increasing sensitivity to desertification.

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