Climate change impact on the built environment in coastal regions

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1 Introduction

Malta, as a small island state is particularly exposed to the threats and challenges of Climate Change (WHO, 2018). As part of the effort to contribute in the global attempt to address and mitigate the effects of Climate Change, Malta has just launched a Low Carbon Development Strategy to map the trajectory to the island's decarbonisation by 2050 (MECP, 2021). Carbon neutrality is one of the pillars for economic growth and recovery post Covid-19 pandemic.

Malta ratified the United Nations 1992 Climate Change Convention in 1992, however prior to Malta's accession in the European Union in 2004, Climate Change was not mainstream in Maltese legislation and policy (Briguglio, 2017). Since then, Malta has established various national Policies, Strategies and Plans that address climate action including the Climate Action Act in 2015 and the Climate Emergency Resolution in 2019 that provide a legal framework for coherent and coordinated governance on a national level. The Climate Action Act (2015) subsidiary legislation enshrines international legal binding commitments including the 1992 United Nations Framework Convention on Climate Change (UNFCCC), 1997 the Kyoto Protocol and the 2015 Paris Agreement, besides other commitments as an EU member state into national law [1]. The European Union Climate Policy has been another important factor to drive local policy (MSDEC, 2017).

Considering that Climate Change affects all sectors in the local scenario, the Climate Change Action strategy involves inter-ministerial collaboration, the private sector and residents (MECP, 2021). The greenhouse gas mitigation policy-making in Malta is a combination of bottom-up sectorial adaptation and implementation of measures by stakeholder in the respective sectors (MSDEC, 2017). ENGOs contributed in the construction of climate change policy within a framework of multi-level governance Briguglio (2017). The top-down policy process is set also to provide a holistic and coordinated perspective (MSDEC, 2017) with the intent to spearhead adaptation measures that are adopted effectively (MECP, 2021).

This report provides an overview of the impacts of climate change in Malta. Considering the size of the Maltese Island, the whole territory is considered as a coastal region. This overview is based on official documents published by the Maltese Government over the past two decades as a means to provide a timeline on how the context evolved to the present scenario. Reference is made to the Mediterranean region as the backdrop of the local state of affairs. This report refers also to published research on the impact of Climate Change in Malta, mainly conducted at the University of Malta.

[1] https://environment.gov.mt/en/decc/Pages/climateActionAct.aspx

2 Background

The Maltese Archipelago is located at the centre of the Mediterranean Sea [35.9375° N, 14.3754° E]. It consists of three inhabitant islands: mainland Malta, Gozo and Comino and other small uninhabited islands: Cominotto, Filfla and St. Paul's Islands.

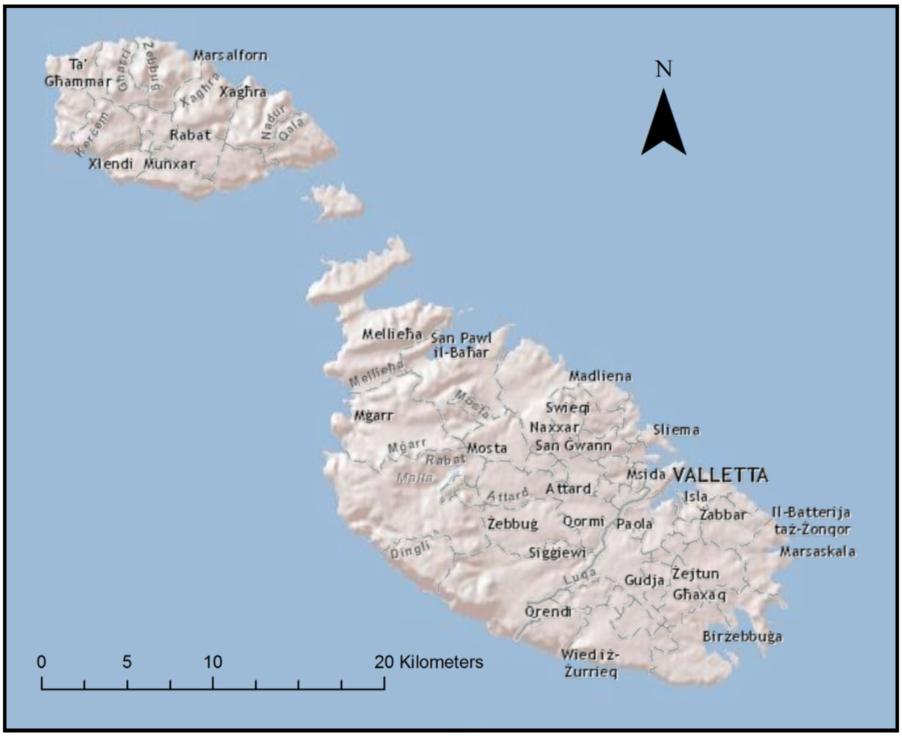

Figure 2.1 The Maltese Archipelago (Source: ESRI)

Figure 2.2 The location of the Maltese Islands at the centre of the Mediterranean Basin (Source: Google Maps)

Table 2.1 lists the geographical data for the Maltese Islands. Considering the small size of the islands the whole land area is considered as coastal region for the scope of this project.

	Malta	Gozo	Comino	Total
Area (km^2)	247	66	3	316
Shoreline (km)	c.200	71 (combined)		271
Max. Length (km)	27.4	14.5	-	-
Max. Width (km)	14.5	7.2	-	-

Table 2.1 Geographical data for the Maltese Islands (NSO, 2019)

The islands are composed of marine sedimentary rocks, mainly limestone of the Oligo-Miocene Epoch and minor Quaternary deposits (PAP/RAC, 2005). Due to tectonic activity mainland Malta is tilted with a south-west [253m] to north-east [less than 1 m above sea-level] tilt (Magri, 2006). This characterises the coastline with a variety of geomorphological features including steep cliffs and low-lying bays that offers different degrees of accessibility that determine the land-use along the coastal strip. Due to the geological setting that results from tectonic activities, geomorphological processes and sea-level oscillations, the littoral along the Maltese islands is prone to marine-related and gravity induced processes that may escalate with climate change (Rizzo, et al 2020)

The Maltese Islands do not have mountains and there are no rivers. 60% of the coast is considered inaccessible due to the relief and geological features, the remaining 40% is highly urbanised particularly close to the Harbour area (Micallef et al., 2017). In a small island state demands for urban and industrial development, including tourism along the accessible coastline is on the increase (MEPA, 2015.)

The total population of the Maltese islands as at the end of 2018 was 493,559 an increase of 4 % from 2017 and 20% since 2008. A contributory factor was the net immigration (NSO, 2019). The population density of mainland Malta in 2018, was 1,867 persons per square kilometre, contrasting with 486 persons in Gozo region. The difference in the population density correlates to the extent of the built-up area on the two islands. Tas-Sliema (17,431 persons per Km^2), L-Isla (17,019 persons per Km^2) and Il-Gżira (12,002 persons per Km^2) are the most densely populated localitie; these are coastal localities in the low-lying area close to the harbour and the capital city, Valletta. According to figures published by the National Statistics Office (2011) the total built up land area is 30%, agricultural land accounts for c. 50% whereas the remaining land cover is natural vegetation. The extent of the built-up area has increased during the past 10 years but no official figures have been published.

Being a small island state where main connections with neighbouring counties are via maritime routes and considering the geomorphological set-up of the littoral that limits the accessible coastal areas, there is an ever-increasing land use conflict between different sectors and stakeholders (PAP/RAC, 2005). Tourism has occupied the northern and north-eastern part of mainland Malta where there are gentle-slopes and few sandy beaches. Marsamxett Harbour is also tourist oriented whereas the Grand Harbour is industrial surrounded by the historical heritage of the Three Cities. Marsaxlokk Bay hosts the largest fishing community of the island amidst the Power Station and the Container terminal on either side of the Bay’s promontory.

Despite the continuous threat from anthropogenic influences, the Maltese coast supports several important habitats and species including saline marshlands, coastal dunes, rupestral communities, low-lying maritime rock communities and marine benthic zones (PAP/RAC, 2005). This diversity in habitats reflect the varied environment enclaves that support rich biodiversity including endemic species. Policies regarding coastal protection are carried out at a national level by a number of government-led institutions including the Planning Authority and the Environment Resources Authority (Micallef et al, 2018).

3 Climate change evidence in coastal regions

The Mediterranean is considered as one of the main ‘climate change hotspots in Europe’ (EEA, 2017). Projections suggest a substantial warming and increase in heat waves, dry spells and droughts in the region (EEA, 2017).

The effects of climate change on the Mediterranean regions may be categorised in the following projections:

- Change in the mean annual surface air temperature. This is attributed to an increase in greenhouse gas concentration with sulphur aerosol effects included is projected as 2.3 ± 0.3°C for the 2050s and 3.6 ± 0.8°C for the 2080s (IPCC, 2001).

- Change in the mean annual precipitation across the Mediterranean basin due to greenhouse gas concentration increases with sulphur aerosol effects included as –2.4 ± 8.6% for the 2050s and –0.1 ± 12.9% for the 2080s (IPCC, 2001).

- Storms and temperature extremes (heat and cold waves) are likely to become more frequent and more severe across the Mediterranean (Brauch,2003 in Dodds & Kelman, 2008).

- Climate change in the Mediterranean reportedly impacts several aspects and sectors such as soil and beach erosion, alien species invasion, increase in human disease incidences apart from agriculture and fisheries (Dodds & Kelman, 2008)

The climate of the Maltese Islands is typically a Mediterranean climate with hot, dry summers and relatively mild winters. The following tables [Table 3.1 and Table 3.2] provide data about the mean temperature and precipitation over a 30 - year period. The climate graph [Figure 3.1] illustrates the seasonal variations experienced.

Statistics for the mean temperature (oC)	
Count	**30 years (1961-1990)**
Average	18.62
Standard deviation	0.40
Coefficient of variation (%)	2.14
Minimum	17.9
Maximum	19.7
Range	1.8
Standard skewness	1.59
Data collected by the Malta Airport MetOffice	

Table 3.1 Summary of Statistics for the mean temperature (°C) (NSO, 2011)

Statistics for the mean precipitation	
Count	**30 years (1961-1990)**
Average	553.12
Standard deviation	156.99
Coefficient of variation (%)	28.38
Minimum	274.22
Maximum	874.10
Range	599.88
Standard skewness	-0.018

Table 3.2 Summary of Statistics for the mean precipitation (NSO, 2011)

Climate graphs illustrating the seasonal temperature and precipitation variations

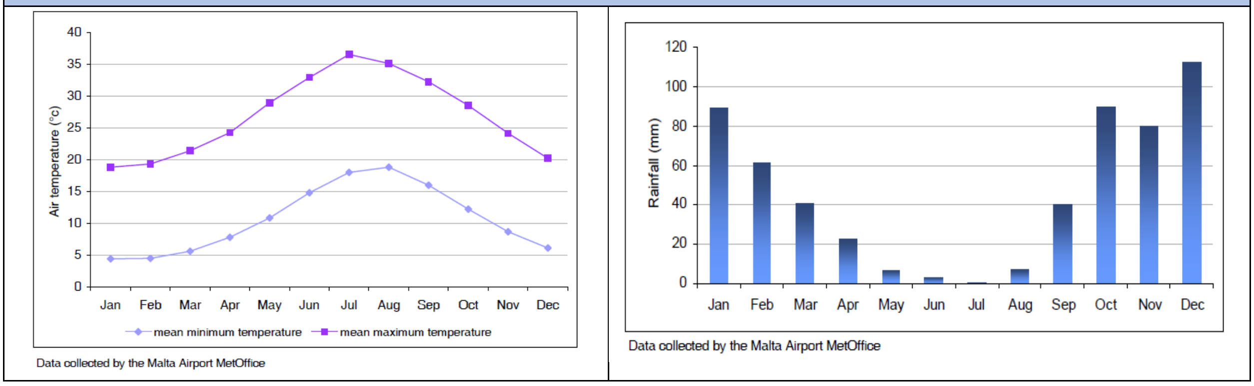

Figure 3.1 Climate graphs illustrating the seasonal variation of the climate of Malta (NSO, 2011)

The presence of the surrounding water mass determines significantly the climate of the Maltese Islands. The high thermal capacity of the sea reduces the large fluctuations of temperature but the surrounding warm sea is the source of heavy thunderstorms and intense precipitation towards the end of summer when the Azores High Pressure migrates south. The general weather is often cooler and more humid than what is experienced in inland areas of larger land masses (NSO, 2011)

3.1 Sea Level rise

According to the SRES scenarios, sea level rise on a global scale by the end of the 21st century is expected to be in the range of 0.18-0.59m above the reference level corresponding to the decade 1980-1999. On the basis of recent satellite observations, global sea level trends in the last 15 years are about 3.1 mm/year which is actually almost double the rate of sea level rise in the last century. This leads to an expected future sea level rise that may actually exceed the IPCC limit. Sea level changes express an integration of several factors and are, especially in the Mediterranean, characterised by strong geographical differences, and critically dictated by internal climatic influences and external signals like the North Atlantic Oscillation. Changes in sea level in the Mediterranean have not been regular over time. While trends in the Eastern Mediterranean are definitely high and positive, negative trends are observed in the northern Ionian Sea including in the proximity to the Maltese Islands.

The sea level of the Mediterranean has been declining since 1960; this could be part of a cycle related to the changing freshwater input in the sea (Tsimplis & Baker, 2000 in Dodds &Kelman, 2008). However the IPCC (2001) notes that sea-level rise is expected to take place in the second half of the 21st century due to the thermal expansion of the water.

Around 5% of Malta is about 7.6 m above sea level and 1% about 1m above sea-level (Briguglio, 2000); therefore sea-level rise poses an increasing threat to the low-lying areas. The urbanisation of these zones increases their vulnerability to inundation.

Dissertations at Bachelors level or Masters level and research projects studied the vulnerability of specific sites to sea-level rise. The research methods, assumptions and tools applied and the level of detail taken into consideration in these studies varied. This limits the possibility to compare the findings of the studies. The status assigned to the same bay – Ramla l-Ħamra by the two studies listed in Table 3.3 below is an example of this.

The following Table [3.3] outlines the findings of the research conducted vis a vie the sites under study.

Site	Observations	Source
Ramla l-Ħamra (Gozo)	Drastic change in the bay's morphology that will impact recreational activities and agriculture and biodiversity loss	Formosa & Bartolo, 2008
Ramla l-Ħamra (Gozo)	Low vulnerability	JM Said, 2018
Daħlet Qorrot (Gozo)	Very susceptible to sea-level rise. High vulnerability	JM Said, 2018
Marsalform (Gozo)	Low vulnerability because of effective artificial protection	JM Said, 2018
Ħondoq (Gozo)	Vulnerable beach .	JM Said, 2018
Il-Qbajjar (Gozo)	Very vulnerable bathing area	JM Said, 2018
Zone between Marsalforn and Ramla l-Ħamra	Highest vulnerability level both in terms of physical and social vulnerability	Rizzo et al 2020
Marsalform Bay	Medium level of overall vulnerability	Rizzo et al 2020
Żebbuġ (Gozo)	Medium social vulnerability level	Rizzo et al 2020
Nadur (Gozo)	Physical low vulnerability but high social vulnerability	Rizzo et al 2020
Xagħra (Gozo)	Physical low vulnerability but high social vulnerability	Rizzo et al 2020

Table 3.3; Research Observations – sea level rise vulnerability.

The studies do not measure the rate of sea-level rise but qualify the risks and vulnerability of the sites to possible sea-level rise. The Physical Oceanography Research Group within the Department of GeoSciences of the University of Malta has embarked in Real-time Meteo-Marine Observations by setting 3 stations: One at University in Msida, another one at Marsaxolkk bay and the third one at Portomaso in St. Julians. The stations feed-in data to the Mediterranean regional subsystem of the Global Sea Level Observing System (MedGLOSS) is a CIESM/IOC (Commission for Marine Research in the Mediterranean and UNESCO Intergovernmental Oceanographic Commission) network for the real-time monitoring of sea level in the Mediterranean and Black Seas. [2]

The stations measure general weather data as air pressure, temperature and wind. The station in St. Julian's measure also the sea-level. At the time when this report was compiles the data related to sea-level was no available.

Despite anomalous trends in sea levels in the Mediterranean, local observations show that between 1946 and 2007 the local mean sea level has risen by 19.5 cm. This local change agrees with published IPCC global sea level patterns. On the other hand, observations coming from many stations distributed within the Mediterranean basin show both decelerations and a decrease in sea level rise during the 20th century. This has been attributed to physical changes occurring in Mediterranean waters as well as to regional meteorological conditions (such as changes in air pressure) that could have favoured this trend. Longer time-series analysis and site-specific studies are needed to determine the characteristics of such a pressure. Sea level rise can have detrimental consequences to our natural and socio-economic amenities situated along low-lying part of the Maltese coastline. [ERA, 2018]

3.2 Changing weather patterns

The data and analysis presented in the Section [3.2] and the following Sections [3.3 and 3.4] related to the changing weather patterns in Malta, are based on the readings taken at Luqa Airport which is Malta's climate reference point (NSO, 2011). This data and analysis are published by the National Statistics Office in a report entitled: The Climate of Malta: statistics, trends and analysis 1951-2010. Certain weather elements show clear signs of a shift from Malta's climate norm; for other indicators the trend is not so clear with time, however an upward trend in the annual series is clearly evident (NSO, 2011). Changes in air pressure can have a significant effect on the weather since it can alter rainfall, temperature, winds and degree of storminess.

Analysis of the atmospheric pressure around Malta shows an increasingly positive trend by 0.6 hPa since 1951 as registered at Luqa Airport. This trend points towards weather that is calmer and fairer, with the possibility of an increase in ambient temperature and a lowering in humidity as a result of atmospheric air subsidence. This trend corroborates the observations included in Sections 3.3 and 3.4 (NSO, 2011). Atmospheric pressure gradient determines also the wind force affecting the area. A negative trend is seen in the incidence of days with gale-force winds. The Mann-Kendall test confirmed that the negative trend observed is significant with a 99 per cent confidence level. These results could reflect a decreasing occurrence of stormy weather over Maltese territorial waters (NSO, 2011).

[2] http://ioi.research.um.edu.mt/WeatherStations/index.php/welcome/portomaso/3/1

3.3 Temperature variations

Figure 3.2 illustrates the anomaly exhibited by the annual mean air temperatures from the climate norm of 1961-1990. The 3-year moving line average shows a rise in the anomaly after 1981 where the highest anomaly of +1.2oC was reached in 2001, followed by a reduction to +0.69oC in 2010. Both 2004 and 2005 appear to have been slightly cooler when compared to the preceding 21 years.

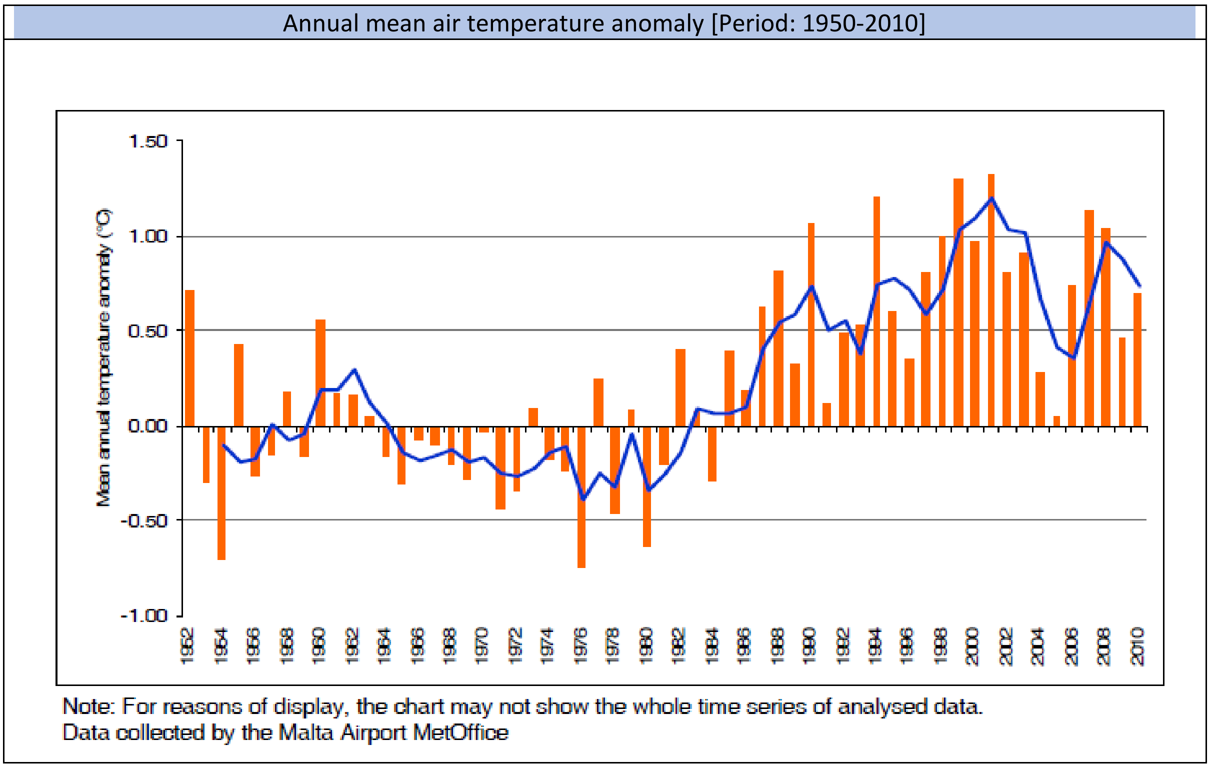

Figure 3.2 Annual mean air temperature anomaly [Period: 1950-2010] (NSO, 2011)

This rate of change in Malta is greater than what the Intergovernmental Panel on Climate Change (IPCC) reports for the global 100-year linear trend (1906-2005) of 0.7°C ± 0.2°C (IPCC, 2007). The global linear warming trend observed from 1956-2005 is nearly twice that for the period 1906-2005 (IPCC, 2007), which makes it slightly higher than the local rate of change (NSO, 2011). Local data shows a shift in both the mean and variance for the period 1951-2010. This means an increased hot weather and previous record high temperatures being exceeded far more often. The average temperature of 18.5ºC given by the data distribution for the period 1951- 1980 has shifted more to an average of 19.2ºC for the period between 1981-2010 (NSO, 2011).

The overall rate of warming is by far strongest in the summer period at around 1.5°C/100 years. The warming trend can also be traced from the incidence and magnitude of extreme temperature events. Yearly recorded maximum temperatures have gone up by close to 3°C over 100 years while minimum temperatures have tended to overall cooler temperatures, although the absolute lowest temperatures occurred earlier to 1980 and the coldest days in recent years have not gone below the 2°C threshold[3].

The sea temperature varies in conformity with the air temperature, with a yearly mean of 20°C. From September to April the mean sea temperature is higher than that of the air and lower from May to August. Measurements of sea surface temperature at Delimara show a steady increase at a hefty average rate of close to +0.05°C/year in the last 40 years. This rise is most evident during summer and is comparable to Mediterranean averages, which are well above the global average of +0.01°C/year. The warming of the sea and that of the air has a direct influence on the biodiversity and functioning of many marine ecosystems that respond both physically and biologically to changes in climate [4].

3.4 Precipitation changes

Rainfall in the Maltese Islands is unpredictable and the rainfall pattern fluctuates; but the highest precipitation rates occur between November and February. The average annual precipitation stands at approximately 530 mm. During the past century, the average monthly rainfall was highest for December (approximately 94 mm) and lowest in July (practically no rain at all). On average, precipitation has decreased over the years[5]. The duration of precipitation in Malta may vary from a few minutes to hours up to days. Torrential rain (short but intensive episodes) lead to flash floods in low-lying areas. Rain shortages range from weeks to months (NSO, 2011). Figure 3.3 shows the annual total rainfall anomaly for the period 1951-2010. The Mann- Kendall test did not confirm a trend at the 99 per cent confidence level, while significance testing indicates that there is no significant difference at the 95 per cent confidence level between the means of the periods 1995-2010 and 1951-1994 (NSO, 2011).

Rainfall patterns over the Maltese Islands are characterized by a relatively high spatial and temporal variability. Even the average wettest months can be very dry in particular years. There is however no definite trend in the observed precipitation. Over the last 85 years there has been no significant change in rainfall during winter and summer, whereas there has been a decrease of 0.14 mm/year during spring, and an increase of 0.8 mm/year during autumn. During the rainy season, the increasing number of days with thunderstorm (with an upward trend of +7 days over 55 years) implies that convective type rainfall is on the increase. This type of rainfall is of short duration and often quite heavy. This is corroborated by the positive trend in the daily maximum rainfall between 1923 and 2000, notwithstanding the fact that over a full year the absolute number of days with rainfall in the range 1-50 mm is decreasing [6].

Humidity tends to be high on the Maltese Islands, with little seasonal variation. The daily average humidity ranges from 65 to 80% and rarely falls below 40%. Temperature variations are accentuated by the relative high humidity[7].

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[3] https://mra.org.mt/climate-change/
[4] ibid
[5] ibid
[6] ibid
[7] ibid

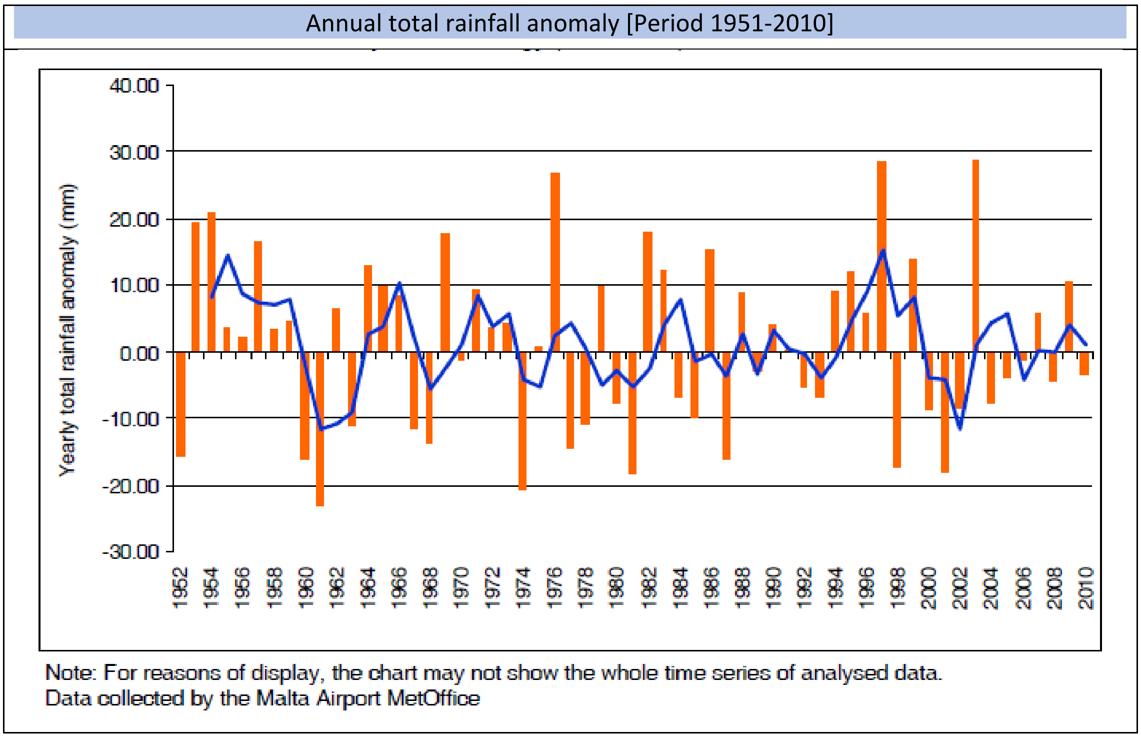

Figure 3.3 Annual total rainfall anomaly [Period: 1950-2010] (NSO, 2011)

3.5 Wind

North-westerly and north-easterly winds are the most common and the strongest. The north-easterly wind blows directly into the two main harbours on Malta, at times impeding marine operations. South-westerly winds are less common but are generally hot and accompanied by desert dust from North [8].

3.6 Climate Change in Malta

The overall positive trend in atmospheric pressure is indicative of reduced frontal activity on a yearly basis and more frequent anticyclonic situations which often enhance subsidence, thereby restricting convection, cloud formation and hence rainfall. This is corroborated by the recorded decrease in the mean annual cloud cover over the Maltese Islands amounting to –0.34 oktas in 45 years. The duration of bright sunshine showed a downward trend in the number of daily sunshine hours (–0.6h over 77 years) and is mainly attributed to changes in atmospheric composition, predominantly due to the higher atmospheric loading by suspended particles[9].

[8] https://mra.org.mt/climate-change/
[9] ibid

4 Disaster Risk and climate change

The United Nations Framework Convention on Climate Change (UNFCCC) considers small island developing states (SIDS) as the most vulnerable to the extreme weather events arising from climate change. As a means to safeguard the limited resources in SIDS and to allow time for the population to adapt to the shifting conditions as a result of climate change, adaptive measures and their implementation in these countries should be considered as high priority (UNFCCC, 2005). One cannot ignore that elements related to climate change interact with other non-climatic drivers such as urbanisation and other socio-economic modifications, land-use changes or changes in tourism (EEA, 2017). The relatively low topography of the coastline in Malta, combined with the financial and technical limitation and the adaptive capacities increases the susceptibility of Malta to extreme weather events including flooding and sea-level rise (Galdies et al., 2016).

4.1 Hazard

The National 2014 Communication of Malta to the UNFCCC lacked any detailed study on specific coastal area susceptibility to coastal hazards; it did highlight predicted sea level rise and increasing extreme weather events as a considerable threat to the island's highly populated coastal areas due to the potential impacts of inundation, coastal erosion and damage by storm surges, waves and high winds (Micallef et al, 2018).

The World Risk Index[10] considers the disaster risk for ca. 173 countries from earthquakes, floods, cyclones, drought and sea level rise (e.g. ADW 2011, 2014, 2016). It consistently ranks the Maltese islands in the penultimate position. However, it is argued that this is misleading since the islands are exposed and vulnerable to a variety of extreme natural events (Main et al, 2018). The argument states that the risk index does not take into account the changing population of the islands, not only over time but also seasonally due to tourism. It does not consider the changing urban footprint, fabric and infrastructure which expanded considerably in the past decades particularly along the coast, exposed to the effects of coastal cliff collapse and storm surges in particular and the risk of inundation by tsunamis (Main et al, 2018).

The Maltese Islands are exposed and vulnerable to a variety of natural hazards produced by tectonic, geological/geomorphological and climatic processes. This is evident even from historical records. Yet, irrespective of historical hazardous events, drought is becoming a persistent threat to the islands (Main et al, 2018) due to the over extraction of groundwater reserves to supply various sectors including Tourism, the change in amount of precipitation as a result of climate change but also the extent of the surfaced area that allows for the replenishment of the aquifer.

Due to the lack of a historical catalogue of specific hazardous events as karstic collapse hazards or landslides, DRR policies are practically missing. The starting point to formulate a hazard assessment is to consider the historical records and impacts of these hazardous events (Main et al, 2018).

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[10] CRED-EMDAT (2011) The OFDA/CRED International Disaster Database. Universite´ Catholique de Louvain, Belgium. http://www.emdat.be/.

4.2 Vulnerability

As a small-island state, Malta is considered as being prone to increased vulnerability to the impacts of climate change, compared to other countries. Malta's vulnerability to Climate Change is determined by the following aspects as listed by the Seventh National Communication (MRA,2017) provided hereunder:

- high susceptibility to natural phenomena and hazards, often as a result of the significant presence of socio-economic activities in coastal areas;
- extreme openness and high sensitivity to external market shocks, such that small island states would be highly susceptible to climate changes that influence not only them but also other countries;
- high dependence on tourism, a sector that is especially susceptible to climate change;
- high population densities, implying more extreme socio-economic effects over limited areas;
- poorly developed infrastructure, which reduces the scope for mitigation and adaptation;
- relatively thin water lenses that are easily disturbed by changes in climatic conditions.

In view of the above, a cross-sectoral vulnerability assessment for Malta identified the following major sectors as requiring attention when devising adaptation measures due to their current vulnerability as a means to address their proneness to risk from climate change (MRA, 2017):

- Water Resources;
- Infrastructure and Land Use;
- Natural Eco-Systems;
- Agriculture and Fisheries;
- Health;
- Civil Protection and Vulnerable Groups;
- Tourism;
- Immigration.

Second National Communication and the National Adaptation Strategy stress the risks that efforts to address the sectoral vulnerabilities may fail if these are not supported by a suitable framework required for good governance of adaptation to climate change namely, a robust institutional, regulatory, methodological and technological set up that is administered by highly skilled human resources and supported by the required funding for research and innovation that focus primarily on the local scenario (MRA, 2017).

Whereas the First and Second National Communication as well as the National Adaptation Strategy pointed out the importance of considering the needs of the individual sectors to prepare adequate preparedness to the adverse effects of climate change, the Seventh National Communication (2017) points out at the importance of a holistic screening of the sectors to ensure coherence, compatibility and equitable burden sharing across them. The report highlights the importance of this holistic approach through various examples such as the reference to the adaptation measured to the built environment would promote reduced costs in heating and cooling or how suitable water policy is in itself an essential to safeguard food security and hygiene (MRA, 2017).

The report states that the extent of vulnerability or risks Malta is exposed to, as a result of climate change is directly related to the degree of adaptation measures that are required to ensure preparedness and resilience to the effects of such a phenomenon. The limited space and resources and relative isolation, in addition to urgent economic growth and development targets are some of the features of island states to adapt (MRA, 2017).

The following tables outline the vulnerability index of each sector and the respective economic weight.

	Current		Future	
	Economic Weight (%)	Sector Vulnerability	Economic Weight (%)	Sector Vulnerability
Agriculture and fisheries	2.5	2.4	2.0	2.3
Industry	20.9	1.6	17.5	2.4
Distribution	11.5	2.3	9.0	2.3
Transport and Communication	10.0	2.5	10.0	2.7
Financial	4.5	1.4	10.0	1.4
Private Services	31.7	1.4	34.0	1.3
Public Sector (incl. Utilities)	18.9	2.2	17.5	2.7
Overall Production Vulnerability	**100.0**	**1.8**	**100.0**	**2.0**
*Index of Sector Vulnerability 0 = None; 1 = Negligible; 2 = Moderate; 3 = Strong				

Table 4.1 A qualitative assessment of climate change vulnerability according to sector [production activity] (MRRA, 2010)

	Current		Future	
	Economic Weight (%)	Sector Vulnerability	Economic Weight (%)	Sector Vulnerability
Private Consumption	33.9	1.7	35.0	2.3
Public Consumption	11.1	1.5	7.0	1.5
Investment	11.0	2.0	10.0	2.0
Tourism Exports	10.0	3.0	9.0	3.0
Other Exports	34.1	1.5	39.0	1.5
Overall Expenditure Vulnerability	**100.0**	**1.8**	**100.0**	**2.1**
*Index of Sector Vulnerability 0 = None; 1 = Negligible; 2 = Moderate; 3 = Strong				

Table 4.2 A qualitative assessment of climate change vulnerability according to sector [expenditure activity] (MRRA, 2010)

4.3 Exposure

It is estimated that 1.11 km^2 or 0.36% of the island's coastline as being susceptible to sea level rise, with beaches particularly prone to erosion. Coastal development, protected areas, ports, infrastructures and roads were highlighted as being particularly vulnerable to sea level rise whereas a wider range of largely coastal land-uses were considered as vulnerable to climate change in general (MRA, 2017). According to the Significant Wave Height Report (MMA, 2003), the Maltese coastline may be considered as 'exposed' to wave action on the basis of a wave height ranging between 1.5 and 4.0 m. Erosion is considered as having the highest hazard value depending on the specific coastal configuration, (Micallef et al, 2018)

About 45.7% of the Maltese coast a low level of erosion hazard, followed by 12.1% with a moderate level of 12.1%, and a high and very high level of erosion hazard of 12.6% and 18.4% respectively (Micallef et al. 2017). This pattern may be explained by the island's sedimentary geology and by the Blue Clay slopes along the shoreline (Micallef et al, 2018). The road networks close to the coast may also contribute to an accelerated rate of erosion as it interferes the sediment transfer to the coast and/or via the wave-reflecting action of road supporting seawalls. The inner parts of the Grand harbour, and the existing yacht marinas at Ta' Xbiex, Vittoriosa, and Msida were all classified as 'protected'. The outer parts of the harbour areas were classified as 'moderately exposed'. The index of the exposure of the Maltese coastline and the relevant hazard level through erosion is illustrated in Figure 4.1

The choice of erosion management strategy is determined by the availability of financial and physical resources rather than as part of a broader strategy (Micallef et al. 2017). For example, European funds were used for a storm water project against flash floods and flood relief projects which happen to affect coastal nodal routes in the inner harbour region. Coastal protection is largely limited to road/seafront protecting sea walls and harbour breakwater protection structures (Walker-Leigh, 2006).

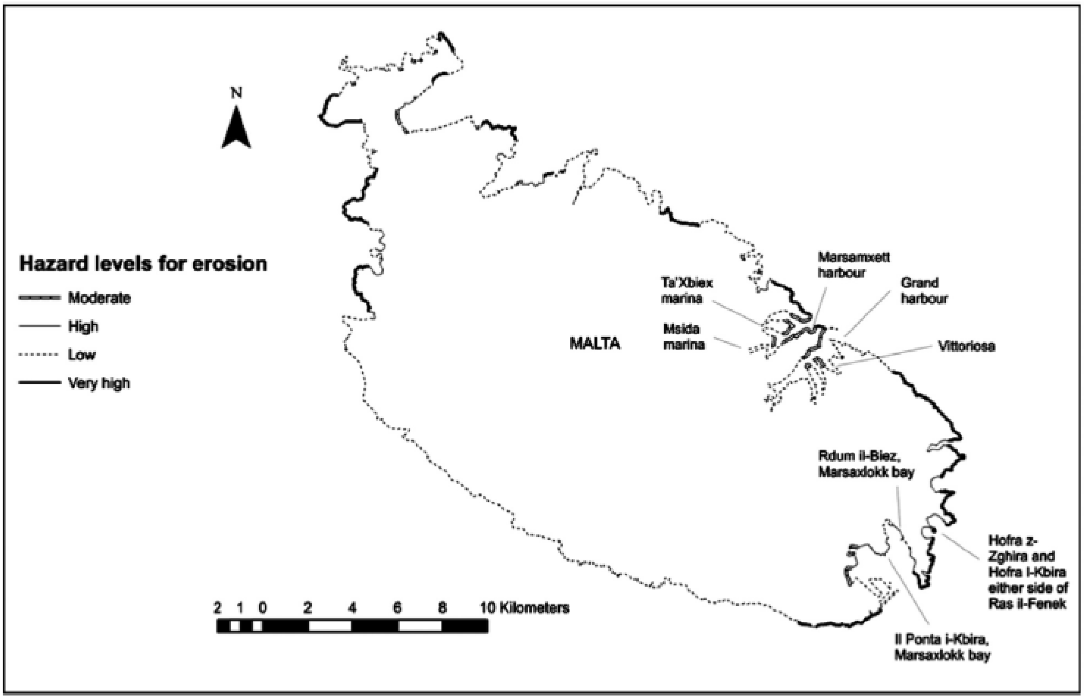

Figure 4.1 Coastal Erosion hazard levels of mainland Malta (Micallef et al. 2017)

5 Climate change Impact in coastal regions

The world's numerous small island states and territories are susceptible to environmental impacts, and have fragile economic systems; they are likely to experience large-scale shifts in their economies and labour markets as a result of the impact of global environmental change. Given their geographical parameters, agriculture (including viticulture), fisheries, tourism and transportation affect most small island states and territories and are four critical economic and labour market sectors, deserving special research and policy attention. (Baldacchino, 2015)

The Mediterranean is considered as the main climate change 'hotspot' in Europe since several sectors are expected to be affected (EEA, 2017).

- The sea temperature is expected to increase whereas run-off to the basin is projected to decrease and hence lead to an increase in salinity. The invasion and survival of alien species has been correlated with the warming trend in sea surface temperature (EEA, 2017).

- The change in soil moisture due to the decrease in precipitation is having a direct effect on terrestrial ecosystems (EEA, 2017).

- The decrease in precipitation is reducing water availability and crop yield, increase the risk of drought and forest fires, biodiversity loss and adverse impacts on human health and well-being and on livestock (EEA, 2017).

- Competition between different water users is expected to increase. (EEA, 2017).

- The energy sector will be affected by decreasing water availability and increasing energy demand for heating, particularly in summer. (EEA, 2017).

- The suitability for tourism is expected to decline during summer (EEA, 2017).

The Mediterranean is also vulnerable to the spill-over effects of climate change impacts in neighbouring regions, in particular with respect to agricultural trade and to migration flows (EEA, 2017).

5.1 Physical impacts

Malta has adopted a 'do nothing' and 'limited intervention' strategy about the management of coastal erosion (Micallef et al, 2018). This approach is interpreted as a consequence to the limited research conducted at a national scale on coastal erosion. Studies about coastal erosion tends to be site specific and fragmented usually stemming from undergraduate and post-graduate dissertations (Micallef et al, 2018). In the past the emphasis was on the generating forces (e.g. strong winds and sea storms) and consequences (e.g. flooding and loss of soil) rather on coastal erosion itself (Micallef et al., 2017).

The study published in 2017 about coastal erosion with the use of the Coastal Hazard Wheel[11] (CHW) identified coastal erosion as the highest levels of threat to the Maltese coastline. Almost half of the coast (45.7%) exhibited a low level of erosion hazard, 12.1% a moderate level, 12.6% a high level and 18.4% of the coastal zones studies were categorised as having a very high level of erosion hazard (Micallef et al,. 2017). Reference is made to Figure 4.1 above.

The rate of erosion is determined by wave and tidal exposure but also on the rock composition. The application of the CHW identified the eastern coast of Malta as exposed to all the erosion hazard level rating, ranging from 'low' to 'very high'. This study identified the highest erosion hazard levels on coastal areas characterised as 'exposed' to wave action, and composed of Globigerina Limestone. Coastal outcrops of Lower or Upper Coralline Limestone formations, were classified as having the lowest hazard levels, irrespective of their relative wave exposure. Marsaxlokk Bay (Marsaxlokk and Birzebbuga) is considered as having 'moderate' erosion hazard levels whereas the southern coast of Malta was characterised as 'exposed' to wave action but it is mainly composed of a hard geological formation (Lower Coralline Limestone) (MIcallef et al.,2017).

The coast along the western, north-western and north-eastern area of mainland Malta is characterised by varying geological formations and configuration. This geo-physical context explains why all 4 levels of erosion hazards were identified in this zone. For example, the area from Fomm ir-Rih to Qammieh Point was mostly allocated 'High' and 'Very high' levels of erosion hazard due to the boulder-strewn Blue Clay slopes. Yet, while still exposed to wave action Anchor Bay was categorised as having a 'Low' level erosion hazard due to the Upper Coralline Limestone boulders, the vertical cliffs (Micallef et al., 2017).

One cannot ignore that coastal vegetation contributes also to coastal stability by influencing the coastal sediment balance and erosion. Since local vegetation land-cover is highly susceptible to the influence by climate change it is important to consider coastal vegetation as an important factor in any study considering the hazard levels presented by erosion (Micallef et al, 2018).

Sandy beaches, which account to only 2.5% of the coastal morphology in Malta are highly valued dues to the increasing demands related to recreational activities and tourism. Over the past years, the Government efforts at mitigating erosion of sand beaches have been addressed via the development of beach nourishment projects. The motivation behind such a strategy has been related to tourism rather than as a direct concern on coastal erosion per se (Micallef et al, 2018).

Whereas the study does not refer specifically to the impacts of climate change on the rate of coastal erosion along the Maltese islands, considering the changing scenarios related to climate change such as sea-level rise, storm surges and the general climatic conditions it serves as a baseline study that indicates the exposure level and the hazard assessment of the area that allows for a foresight of the physical impact related to climate change.

[11] A tool that facilitates analysis of a number of coastal hazards including erosion, ecosystem disruption, gradual inundation, salt water intrusion, and flooding

Groundwater is the only natural source of water in Malta. This is replenished when rain water infiltrates through the permeable sedimentary formations. The abstraction of groundwater currently amounts to approximately 34 million m3 of groundwater each year. This is estimated to be 11 million m3 more than is considered to be sustainable or equal to recharge (Spiteri et al, 2015).

It is estimated that 75% of groundwater is used for agricultural practices which accounts for 15% of the landuse. The over extraction of groundwater has reduced water quality as it is becoming increasingly saline, with chloride levels exceeding 2000 mg/L, this is turn is compromising the crop yield (Hartfiel et al, 2020). Climate change is expected to aggravate the situation. The increase in temperatures that will lead to further extraction for irrigation and the episodes of extreme storms with torrential rains that will not allow enough lag-time for infiltration and groundwater replenishment will intensify the current situation. Moreover, with the expected sea-level rise, the saltwater in the aquifer will also rise hence limiting the freshwater lens (Hartfiel et al, 2020). Water scarcity and the resulting dependency on desalinization plants is creating also food and energy security challenge (Hartfiel et al, 2020).

5.2 Environmental Impacts

Climate change is influencing the physical dynamics and the hydrological structure of the Mediterranean basin (EEA, 2017). This is related to acidification of seawater, rising water levels and changes in the currents. Sea temperatures are increasing even in deep waters (PAP/RAC, 2005). These climate changes have different ecological consequences.

The warming of the Mediterranean Sea will modify the climate of the Maltese islands. The increase in temperature may lead to the shift of terrestrial and marine species and change their life cycles. Moreover, the increase in water temperature will lead to a reduction of dissolved oxygen mainly due to changes in both water stratification and thus water circulation, these changing circumstances will add stress on the local marine and coastal ecosystems (ERA, 2018). The State of the Environment Report for Malta (ERA, 2018) claims that at the time of reporting, no studies have been conducted to identify additional pressures arising from enhanced dissolution of CO2 and heat absorption in local waters, nor regarding changes in the general circulation of local coastal waters, and on the disappearance, if any, of economically important species.

However, monitoring of the pH of seawater as part of a coastal water quality monitoring programme has been conducted as part of the EU Water Framework Directive baseline surveys undertaken in 26 stations during the period May-November 2012. No significant changes have been observed during this monitoring campaign. However, further interpretation of the data available is not possible at this stage due to the lack of continuous long-term data. Such gaps could be addressed through the implementation of sustained monitoring programmes and further research is required urgently (ERA, 2018).

In 2012, the Department of Biology of the University of Malta updated its local list of alien marine species that have been recorded since 1990. The presence of those identified in local waters has been mainly attributed to the general warming trend of Mediterranean waters, increased marine traffic and aquaculture activities. As of 2012, a total of 48 species, have been included in the list of which 15.4 %

were considered to be invasive. In 2015 it was reported how a new species of *Caulerpa* was discovered in 2013 following its observation adjacent to *Posedonia oceanica* meadows which are legally protected since they are considered to be breeding grounds for a wide variety of species, and therefore are an important link in the overall sustainability of marine biodiversity (ERA, 2018).

As explained above, the limited freshwater resources available in Malta are already significantly stressed, making it more susceptible to climate change. The shift in precipitation patterns including increase in drought episodes could bring about variations in both water flow patterns in vulnerable valley systems and recharge of the aquifer, with detrimental effects on valley ecosystems. Unfortunately, the limited availability of local data and information on climate change impacts on this sector represents one of the major hurdles to freshwater management. The management of the local water sector is extremely important and urgent (ERA, 2018).

5.3 Economic Impacts

Historically, agriculture was a very important economic activity in Malta. Manufacturing and services sectors are important sectors of the country's economy with investment in microelectronics and pharmaceuticals. The services industry has in recent years expanded. It includes well established sectors as tourism, education, health, retailing and banking. More recently it expanded to the financial services sector and more specialised forms of tourism, such as language schools and diving centres, maritime and aviation activity, information technology and gaming (MRA, 2017). This section will focus on two main industries that are particularly prone to the impacts related to climate change: Agriculture and Tourism.

Agriculture

The Mediterranean region is projected to be affected by losses of agricultural yields. In parts of the Mediterranean area, the cultivation of some crops may shift from the summer season to the winter season, which could offset some of the negative impacts of heat waves and droughts during summer (EEA, 2017).

A preliminary evaluation on the economic vulnerability and potential for adaptation to climate change show moderate to strong impacts on agriculture. No detailed studies however exist on the quantification of impacts of climate change in the agricultural sector in Malta. However according to the Seventh Communication for Malta (MRA, 2017) the following issues are expected to be further exacerbated in the future:

- reductions in overall crop yield;
- reductions in cereal production in the southern Mediterranean;
- further deterioration of the water quality in Malta's aquifers as a direct results of sea level rise will decrease the quality of the soil and harm crops.

Table 5.1 indicates the impacts expected on the agrarian sector (MRA, 2017)

Impact on Soils	Soil erosion is expected to increase due to the intensity of rainfall. This is dependent on measures adopted to protect soils such as rubble walls, vegetation cover and so on. Soil fertility might be affected by heavy downpours, as well as logging of soils, especially in low lying areas, and through leaching.
Impact on Potato	Increases in atmospheric CO_2 leads to higher yields of potato, however this was not sufficient to recover the losses made through increased temperatures. There is a potential for potato pests and diseases to increase as a result of climate change.
Impact on Vineyards	Largest impacts from increases in temperature and distribution of rain. Accelerated ripening due to increasingly warmer temperatures, has serious consequences for precocious varieties. Malta's vineyards will suffer particularly during drought periods.
Impact on Livestock	Increases in air temperature may affect behavioural or physiological functions of livestock. Most of Malta's farms are not equipped with cooling devices and a reduction in produce, brought about by warmer temperatures is possible. A global reduction in availability, quality and price of grain will affect Maltese farmers since they import all feeds for livestock.
Impact on Agriculture Infrastructure	Heavy rainfall will affect critical infrastructure such as rubble walls and greenhouses. Rate of absorption of rainfall will decrease as heavy storms will fill reservoirs and wells fast but not for long. Lengthening of the dry season will force farmers to irrigate more, increasing the pressure on the aquifers and exacerbating the existing problem of illegal extraction from boreholes.
Alteration of Insect and Disease Distribution	The range and distribution of pests is affected by changes in temperature, wind and humidity. Whilst milder winters might increase the incidence of pest outbreaks, higher temperatures and longer periods of warm weather will allow proliferation of insect pests. Use of pesticides to control pests in itself can harm agriculture.

Table 5.1: The impacts expected on the agrarian sector (MRA, 2017?)

A survey conducted among Gozitan farmers indicate a perceived increase of adverse weather conditions during the past two decades. Results showed a common agreement between young and older farmers who both perceived negative climatic consequences to their farming practices. These were mainly attributed to increased periods of droughts (54.3%), intense periods of rainfall (35.1%) and the occurrence of strong winds (10.6%). The major perception related to increased periods of droughts is supported by the statistically positive trends of the increased incidence of heatwave and high heat-stress events (Galdies et al, 2016).

The majority of the farmers (66.7%, 69.1% and 75% respectively) stated that their current productivity has decreased compared to that of previous years. At the same time, very few farmers reported that their agricultural yield has improved (4.2%, 5.5% and 0% respectively) (Galdies et al, 2016). This observation concurs with the most recent official statistics which showed a loss of 11.6% and 14.8% in value of vegetables and fruit sold in 2011 com-pared to the previous year (NSO, 2015).

With regards to livestock farmers, 57.6% expressed a significant decrease in their yield in recent years. A total of 41% of this category of Gozitan farmers stated that their productivity has worsened with time principally because of increased heat stress on their livestock. This perception is strongly linked to the observations related to the increased heat stress hereby identified during the past twenty years (Galdies et al, 2016).

The majority of crop cultivating farmers (88.3%) stated that the rate of pest incidence affecting their current crop types has increased in recent time. They attributed this to prolonged, warmer climate that they have experienced during the past two decades Galdies et al, 2016).

Agriculture is a complex, skilled and highly evolved sector. It is directly dependent on climate, given that heat, sunlight, and water are the main drivers of crop growth. The impact of climate change on the agricultural sector will be substantial. Preparation is required to safe-guard sustainable supply of water in the light of it's projected scarcity. The sector will need to be prepared for the increased risk of extreme weather events, as well as reduced productivity growth, particularly in key cash crops. The Climate Change Strategy identifies an impact on phytosanitary and veterinary issues related to alien species and an increased incidence of plant and animal diseases. While some aspects of climate change, such as longer growing seasons and warmer temperatures may bring short-term benefits to this sector, it is recognised that careful preparation and planning against the range of adverse impacts, is merited, in order to ensure the immediate and long-term sustainability within this sector.

The main concerns include the following:

- Reductions in crop yield and quality as the result of reduced water availability and precipitation variability will have a negative impact on economic players in the agricultural sector.
- Direct financial loss for stakeholders in the agricultural sector is most likely to be further exacerbated by the need for increased spending as a result of damage caused by extreme weather events.
- Reduced crop yields caused by increased summer temperatures and drought risk.
- Additional problems arising from the introduction of new pests and diseases. The livestock sector is likely to be adversely affected by reduced yields of forage crops and perhaps also heat stress to the animals. Reduced rainfall and consequent changes (MRA).

Galdies notes that if the observed trend in ambient air temperature at the rate of +1:1 °C for the period 1951-2010 continues in the future, then it could well lead to detrimental impacts on local agricultural practices as well as on the current varieties of temporary and permanent agricultural crops. (Galdies 2012). In the study the authors report the results obtained from an island-wide survey aimed at researching an under-emphasized key feature of climate change adaptation namely willingness to adapt on the basis of the perceptions and beliefs held by the Gozitan livestock and crop farmers. Some of the main objectives of this study included the:

1. determination of whether the current perception is in line with the observed climatic changes at the local scale, and
2. identification of the typology of these farmers, together with those factors that affect both skepticism and acceptance of climate change.

This study provided an important first step in the objective validation of local farmers' perceptions of climate change, as well as in the development of a comprehensive understanding of their attitude, beliefs, willingness and capacity to adjust their practices in response to climate change. The results pointed to several important conclusions that can be used to inform research, outreach strategies and policy formulation, targeting the Gozitan farming sector to adapt to climate change without delay. The forgoing analysis showed a dire need for more information both on impacts and risks, as well as on ways how to introduce new farming techniques and practices (Galdies, 2015).

Fisheries and Aquaculture

The impact of climate change on aquaculture and fishery stocks includes the increased influx of alien species. The effects in changing sea temperature and other possible shifts in currents and nutrient flows are recognized as being a significant threat to species of key economic importance.

- Coastal Areas: In Malta much of the key infrastructure is located in coastal areas. The degree to which coastal infrastructure will be affected by climate change, in particular through an accelerated process of coastal erosion, will need to be determined through studies of sufficiently long time-frames.
- Ecosystems: A prime objective of the Climate Change Adaptation Strategy rests in preserving and strengthening the resilience of ecosystems and when, wherever possible, in reducing the pressures that could reduce their inherent capacity to adapt and counter the effects of climate change. The protection of essential resources such as water and soil will have a high priority in this context. (MRA, 2018)

Tourism

Tourism is considered to be a highly climate-sensitive economic sector similar even to the level of agricultural sensitivity. Indeed, climate change is not a remote future prospect for tourism. The varying impacts of a changing climate are becoming evident at a number of destinations around the world, to the extent that Climate Change is already influencing decision-making within the tourism sector.

Since environmental conditions are such a critical resource for tourism, a wide-range of climate induced environmental changes will have profound effects on tourism at the local and regional destination level. Changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (for example; food and wine tourism), increased natural hazards, coastal erosion, inundation, damage to infrastructure, and the increasing incidence of vector-borne diseases, will all impact tourism to varying degrees. In contrast to the varying impacts of a change climate on tourism, the indirect effects of climate induced environmental change are likely to be largely negative and cannot be seen as enabling a sustainable industry[12]. The Mediterranean also provides a fitting example where direct and indirect pressures from climate change are increasingly impacting on the often, unsustainable tourism developments along much of the Mediterranean coastline and hinterlands. Malta, in this respect, provides an interesting case where up to 29% of GDP is reliant on the tourist economy and where such pressures and vulnerability are increasing (Jones A., 2017).

[12] https://mra.org.mt/climate-change/adaptation-to-climate-change/

Serious environmental changes that are becoming highly significant to insular environments are arising from the ever-growing tourism industry; this is especially true for Mediterranean island tourism. It is obvious that such a growing demand on tourism opens new opportunities for the development of Mediterranean islands, including an increase in the real income and the generation of employment and wealth. This explains why island governments continuously see tourism as a promising opportunity to alleviate island communities from poverty, to maintain vibrant social welfare by also functioning as an investment to modernise the economic base and possibly to attract foreigners through increased employment. Viewed in a positive light, this path makes traditional tourism development inevitable in `warm water' islands. However, such factors as uncontrolled tourism expansion, landscape transformation and degradation, as well as increased waste generation as a result of tourism expansion are inherent disadvantages. (Baldacchino, 2015)

The natural and cultural heritage of the Mediterranean makes it the largest tourism region (EEA, 2017). However, its attractiveness and competitiveness may be compromised due to the increasing air temperatures (EEA, 2017). Moreover, the shift to warmer temperatures in the northern European countries may be detrimental to the north- south tourist flow (EEA, 2017).

The Maltese Islands has been marketed for the Sand Sea and Sun since the 1960s. Tourism accounts for 29% of the GDP and 17% of fulltime equivalent employment (MTA, 2015) apart from other jobs indirectly induced by travel and tourism. The sector has been growing steadily. Malta is considered as an attractive geotourist destination due to the strong interaction between the natural sites and the cultural heritage. 85% of the tourists visited Malta in 2017 for holiday, in 2018, the number of visitors reached 2.6 million. Travel and tourism is expected to contribute to 34.6% of the GDP by 2027 (Rizzo et al, 2017).
Malta has been moving towards sustainable tourism since the year 2000. The strategic plan issued by the Malta Tourism Authority in 2002 was to move away from the 3S (Sand, Sea and Sun) and to rejuvenate and diversify the market to maintain a competitive edge (Dodds & Kelman, 2008).
Several policies addressed sustainable tourism but these were not specifically meant to address climate change as this was neither mentioned nor implied. The focus was to upgrade accommodation and extend seasonality (Dodds & Kelman, 2008). For example, the eco-certification of hotels focus more on marketing purposes rather than to specifically to mitigation measures. Eco-certification programs do not measure specifically carbon emissions or include life-cycle analysis.
Hoteliers focus on reducing price inflation of utilities to reduce operational costs rather than safeguarding the environment. Their understanding of sustainable plans were mainly education programmes for employees or investment in advance technology (Palmieri, 2014).

Dodds & Kelman (2008) attributes this approach due to the high priority to sort-term economic gain and immediate job creation. Climate change is seen as an extra burden to the economy due to the continuous increase of operational costs, taxes and bureaucratic procedures that businesses are encountering (Palmieri, 2014).

Overall, tourism strategies are not integrated into Malta's development plans and the communication between the different entities is lacking, many policies are inhibited because of poor coordination and power struggles (Doods & Kelman, 2008).

Notwithstanding the disconnected approach and disjointed efforts of Tourism as a sector from Climate Change as an issue per se not encompassed under the umbrella approach of sustainability, Malta Tourism Authority (2012) has also highlighted significant threats posed to the tourism industry from climate and environmental change including; the deterioration of potable water supplies and quality, more frequent extreme weather events, soil degradation, erosion and an accentuated desertification process, threats to public health, changes in sea water mass characteristics and effects on fish stocks, coastal erosion and inundation together with biodiversity reduction.

The effects of these threats are already felt: Jelly fish blooms is transforming the local Maltese ecosystems and threatening the health of thousands of tourists, similarly the increase in bites incidents of the Asian Tiger mosquitoes. These are situations that risk jeopardising the growth of the tourism sector (Jones, 2015).

The EEA (2012, 2017) reports highlights the climate change impacts across the Mediterranean as outlined at the introduction of this section. The reports particularly highlights the vulnerability of the Southern Mediterranean regions, specifically coastal environments, areas of high population and high dependency on summer tourism at the forefront of current risks, all these aspects are elements of the Maltese context. This is a warning since the report concludes that “the suitability of Southern Europe for tourism would decline markedly during key summer months” (EEA, 2012).

Rise in temperature is considered as one of the most important impact of climate change that will affect Maltese tourism (Palmieri, 2014). With the shift of warmer temperatures to the North, potential tourists may be less inclined to travel to destinations as Malta. The need to diversify the sector and extend the seasonality is a survival approach rather than a way to address vulnerabilities related to the increase in temperature (Doods & Kelman, 2008).

These impacts can seriously affect travelling behaviour that might shift tourists to other destinations that are being less threatened by negative impacts of climate change or that might be positively affected by impacts of climate change. Malta as perceived by experts will be amongst the losers of climate change due to the negative impacts of climate change that will ruin its vulnerable natural environment (Jones, 2015).

The tourism sector in Malta will have to adapt to the changing patterns. The challenge includes better coordinated mitigation initiatives as otherwise the risks from climate and environmental change and the predicted negative impacts this will have on the Maltese tourism economy will inevitably threatening the very nature, economic sustainability and the continued sustainable growth of the industry (Jones, 2015)

Accessibility

Small islands are often poorly connectable to external economic markets, continental energy grids and other production and/or distribution systems, due to their physical distinctiveness, remoteness and peripherality. Efficient logistical communication linkages are therefore mandatory for a thriving island economy: something which can also be seen as an opportunity (as in the case of tourism). But such a drive to enhance connectedness often depends on the local environment, micro-climate and atmospheric conditions that can potentially affect the level of connectivity. Environmental changes that could induce the increased occurrence of strong winds and adverse sea conditions are some examples which could restrict transportation linkages and hence accessibility, unless strong investments in permanent physical links, if possible, are made available. (Baldacchino, 2015)

5.4 Social Impacts

Research suggests that there is a lack of knowledge on climate change among the Maltese population (Debono & Calleja, 2010,p. 147. Palmieri, 2014) and the impacts of climate change are not evident to everyone (Palmieri, 2014). Climate change is seen as an extra economic burden (Palmieri, 2010). However, research indicates that the drive to a change in behaviour to address the impacts of climate change is not instigated by the knowledge on climate change per se` but by the perception of climate change as a threat to health and well-being (Debono & Calleja, 2010,p. 147).

Temperature increases will certainly impact the number of heat-related deaths and respiratory and cardiovascular diseases. The most vulnerable are the elderly and one cannot ignore that the percentage of elderly people in Malta is increasing due to the increase in life expectancy (MRA, 2017). Higher temperatures compromise even food security. Studies showing that 25% of cases of salmonellosis in Malta were related to increased temperatures (Gatt, 2009). Changes in seasons might also affect the pollination processes likely to affect those suffering from allergenic diseases or respiratory conditions. The ISAAC study looked at the distribution of wheezing children in Malta between 1994 and 2002 and found already that the prevalence of wheezing in the 5-8-year-old age group increased between the period 1994 and 2002 (Fsadni, et al., 2012). Climate change affects also vector-borne diseases, the introduction of the Asian Tiger Mosquito (new species for the islands) has already been studied, however further investigation will be required to determine their impact in various climate change scenarios. Coastal flooding and flash floods from heavy rainstorms may have an indirect effect on health care services if it impacts infrastructure or access to hospitals, clinics and pharmacies. Particular sectors will also be affected through increased occupational health and safety concerns, for example construction workers and those working in the primary industries (agriculture, fisheries) and exposed the high temperatures, rainfall and extreme weather events.

In view of this scenario, which indicates clearly the link between the impact of climate change with respect to the health and safety of the population, the pretext of a call for the general well-being and health of the population would be a drive to introduce mitigation measures and practices among the population in order to address the adverse effects of climate change. The broad perception that climate change somehow influences health and well-being is a much stronger predictor of support for policy and a willingness to act than a correct knowledge about the human health effects of climate change (Debono & Calleja, 2010,p. 147)

The 'Human cost' of these climatic events depends directly on the vulnerability of the people exposed. Social and environmental determinants of health, such as poverty, support systems, concurrent environmental stresses (including polluted water, unprotected waste disposal or polluted air) and displacement, all contribute to population vulnerability.
Although climate change could have some short-term benefits, such as reduced winter mortality due to increases in temperature, most health impacts are projected to be negative and could be profoundly worsened if current accelerating trends continue unabated. The Environment Health

Directorate within the Ministry responsible for Health, Elderly and community care, in conjunction with the World Health Organization published a detailed study on the effects on public health induced by climate change with specific reference to Malta (WHO, 2009). The main health concerns outlined in the report include:

- Increased summer month mortality
- Increased risk of flash floods causing injury and isolation of essential health services
- Increased PM10 and PM2.5 pollution.
- Decreased food safety due to higher temperature.
- Increased requirement of control of Vector borne illnesses, and possibility of new vector borne illnesses to spread locally. [13]

5.5 Governance and Institutional Impacts

At this point in time the authorities are
undertaking the preliminary ground work that would serve to identify a variety of risks and ensure preparedness in order to:

- address the negative impacts envisaged as a result of climate change particularly upon vulnerable groups;
- assess socio-economic implications, which increased insurance covers for risks resulting from the likely impacts of climate change;
- identify financial guarantees and incentives amongst the various stakeholders in all sectors;
- intensify awareness and promote a change in behavioural patterns to improve adaptation to climate change;
- increase awareness of climate change impacts within the government, industry, and community sectors will support cultural change transitions that are required for the adoption of more climate change friendly technologies, designs, and operations by public and private operators;
- Carry out further research with the support of multilateral and regional institutions on the effects which climate change will have upon irregular migration.

As a means to address Climate Change different mitigation measures has been put into place to reduce Greenhouse gases. As the most important contributor to national emissions, the energy sector is the prime focus of mitigation action. The mitigation measures adopted in Malta can be said to be a combination of bottom-up sectoral adoption and implementation of measures by stakeholders within the respective sectors, and a growing emphasis on top-down policy processes looking at mitigation from a more holistic, coordinated perspective. The European Union climate policy serves as an important driver for local mitigation policy (MRA, 2017). Table 5.2 below summarizes the mitigation actions to reduce greenhouse emissions.

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Sector	Mitigation action focus
Energy consumption	Submarine electrical connection to European network; Rebates on energy efficient domestic appliances; Distribution of energy saving lamps in the domestic sector; Promotion of solar water heaters; Incentives for the uptake of PV systems; Grant on Purchase of micro wind turbines; Energy savings and RES measures in state schools; Energy saving measures in social housing; Action in the public sector; Energy saving measures in government owned industry; Support schemes for industry, SMEs and the commercial sector; Intelligent metering; Supply of natural gas to fuel existing and future generating plants; Energy Efficiency measures; PV - Grant Scheme; PV - FIT Scheme; PV - Competitive Bidding
Transport	The introduction of a biofuel 'Substitution Obligation'; Introduction of Autogas; Uptake of Electrical Cars; Promotion of E-working and Tele-working; Promotion of Transport Modal Shift towards Public Transportation and Public Transport Reform
Industrial Processes	Implementation of F-gases Regulation
Agriculture	Rural Development Programmes; Nitrates Action Plan
Waste management	Waste Management Plan for Malta Aerial Emissions Works at Maghtab and Qortin Landfills + Capping and Extraction of Gases from managed Landfills; Sant'Antnin Mechanical Biological Treatment Plant; Operation of Urban Wastewater Treatment Plant (UWWTP); Wastewater Sludge Treatment Plant

Table 5.2 Mitigation action to reduce Greenhouse emissions (MRA, 2017)

The National Adaptation Strategy seeks to address recommendations in various sectors which are vulnerable to climate change, viz. water, agriculture, human health and tourism. The strategy also addresses the financial impacts as well as any sustainability issues. There is an emphasis on the need for a legal framework which will address the important matter of adaptation adequately.

The Strategy clearly outlines the policy which should be adopted and it indicates which Authority or Government entity is responsible for the implementation. Time-frames within which such policy actions should be implemented are also included. The Strategy adopts a holistic approach to Climate Change Adaptation in Malta, identifying climate change impacts with particular reference to health and socio-economic policy, water and flooding as well as biodiversity, agriculture and fisheries. The Strategy also provides a recommendation of emergency plans and the circumstances under which they should be formed in high-probability, high-consequence risk areas. Moreover, timely adaptation action will help in reducing the costs and disruptions likely to emanate from adverse climate change conditions, as well as necessarily altering behavioural patterns and enabling better planning and decision-making. The Strategy identified the principal strategic climate impacts likely to affect Malta. (MRA, 2010 & 2017)

6 Climate change impact on built environment in coastal regions

Malta is a densely populated and from a Land use point of view, 22% of total land area in Malta is built-up. When considering other urban development such as airport, ports, industrial and commercial sites, mineral extraction sites, this value is almost 30% of the total area of the Maltese Islands (NSO, 2011). Agricultural land accounts for close to 50% of total land area while natural vegetated land accounts for the rest. As a small archipelagic state, all buildings and infrastructure are considered to be primarily exposed to coastal environments with increased vulnerability to climate change.

A third of the EU population lives within 50 km of the coast and the GDP generated by this sector of the population amounts to over 30% of the total EU GPD. In the EU, the economic value of coastal areas within 500 metre from the European seas totals between €500-1,000 billion and the costs of doing nothing against the effects of climate change in coastal areas are estimated to be higher than the annual costs of taking actions, which is estimated at around €6 billion by 2020. On the other hand, the net-benefits of adaptation are put at up to €4.2 billion (EC, 2021).

6.1 Impact on district level / city level

Urban Structure in Malta: In the 1995 census, the total dwelling stock was determined at 155,202 dwellings, with 23.0% of dwellings vacant (NSO, 1995) while the 2005 Census of Population and Housing (NSO, 2007) reported a total stock of 192,314 dwellings, of which 27.6% were vacant. While total stock increased by almost 24.0% over the 10 year period, vacant dwellings increased by 49.0%, contrasting with an increase of under 17.0% in occupied dwellings. Interestingly, while the number of terraced houses only increase slightly over the period 1995 to 2005, the number of flats/penthouses and maisonettes however increased significantly, reflecting a trend in the local construction sector in favour of concentrating residential units in clusters of more than one unit. This represents a shift in household choices in respect of the type of dwellings preferred, reflecting a change in attitudes and lifestyle and a reaction to property prices which in turn led to a shift in urban structure and infrastructure with more densely populated areas, increased demands on supporting infrastructure with higher exposure.

Various components addressed in the Impacts on Infrastructure section, including Water, energy, renewable energy, waste and waste water, are relevant at the district and city level; these are addressed taking into consideration of Malta as a small archipelagic state with a predominantly costal region.

6.2 Impact on infrastructure

6.2.1 Infrastructure in Malta

Water Infrastructure in Malta

The vision for the sustainability of water resources in Malta is expressed through The Water Catchment Management Plan (WCMP) for the Maltese Islands; an example of Climate Change adaptation action (MEPA / MRA, 2011). The WCMP is a holistic plan which addresses all aspects concerning water issues but the achievement of the plan's objectives impacts other sectors directly, including health, biodiversity, landscape, soil and climate factors.

The objectives related to groundwater include the following:

- preventing deterioration in the status of groundwater bodies;
- protecting, enhancing and restoring of all groundwater bodies;
- prevention of and limitation of the input of pollutants to groundwater;
- reversing any significant upward trend of pollutants in groundwater;
- achievement of good groundwater qualitative and quantitative status by 2015 or in specific circumstances by 2021 and 2027.

The WCMP measures were subjected to a climate change check to ensure climate change strategy compliance.

Energy and Power Generation in Malta

The National Energy Policy for Malta, (2012), takes into account Malta's economic and social development by encouraging a proactive and flexible approach aimed at overcoming the challenges that define the energy sector, whilst seeking to exploit the opportunities that may arise through technological advancement. The National Energy Policy is underpinned by five principles:

- Energy efficiency and affordability;
- Security of supply;
- Diversification;
- Flexibility; and
- Sustainability.

The following policy areas guide national action under the National Energy Policy:

1. Energy efficiency;
2. Reducing reliance on imported fuels;
3. Security of supply;
4. Reducing Emissions from the energy sector;
5. Delivering energy economically efficiently and effectively;
6. Ensuring the energy sector can deliver.

In addressing Malta's energy challenges, the National Energy Policy is significantly influenced by several EU energy and environmental policies. The targets set by the relevant EU Directives for Malta are as follows:

- Energy End Use Efficiency: 9% by 2016;
- Renewable Energy Target: 10% of final energy consumption by 2020, which includes a 10%
- Renewable energy target in transport.
- Indicative National Energy Efficiency target 2020: 264,282 toe (equivalent to 27% of the primary energy consumption in 2020 under a BAU scenario).

The National Energy Efficiency Action Plan (NEEAP) (2014) and the National Renewable Energy Action Plan (NREAP) (2011) referring to obligations arising from the EU energy acquis provide more detailed information on the actions being proposed and implemented to increase energy efficiency, particularly from an end-use perspective including the substitution of conventional energy sources with renewable sources. There is a shift towards more efficient technologies and the use of lower-carbon fuels in the supply of energy, especially in power generation, contributing towards reducing GHG emissions in the energy sector. The energy sector is the highest contributor to national GHG emissions, and the implementation of mitigation measures leads to a reduction in the national carbon footprint. A further important co-benefit of implementing mitigation measures refers to a reduction in emissions of non-CO_2 pollutants, particularly those related to air quality. The implementation of measures that impact the energy demand including the energy performance in buildings, also contribute further to emissions reduction while saving money for energy consumers.

Smart meters lead to a reduction in energy consumption by changing consumer behaviour through information on their daily consumption in buildings.The project to replace public lighting started in 2015 and consisted of retrofitting street lights in the Maltese Islands.

Renewable energy sources

The Promotion of Energy from Renewable Sources Regulations (S.L. 545.11) establishes the target for the share of renewable energy in the final energy consumption by 2020, including the intermediate trajectory, the obligation to submit the NREAP, the eligible sources of renewable energy and the methodology for calculating the contribution of each renewable source to the target. This Action Plan outlines measures that Malta intended to adopt to achieve the national targets of 10% renewable energy share of gross final energy consumption and 10% share of renewable energy in transport.
Malta planned to achieve its 2020 renewable energy targets by exploiting solar energy, waste-to energy conversion plants and biofuel blending substitution obligations. In Malta, renewable energy generation relies mostly on numerous small installations distributed across the Maltese Islands and some larger installations.

Waste

The overall share of greenhouse gas emissions from the waste sector is equivalent to 6% of the gross national emissions. The main gas emitted is methane, which accounted for 96% of the sector's emissions. Disposal of solid waste to land is the largest contributor of GHGs followed by wastewater management. Waste incineration at present (with current facilities) is only a minimal contributor to the sector contributing <5% of the total waste sector. The Waste Management Plan for the Maltese Islands, proposed measures to be implemented over the period 2014 – 2020 to move towards the achievement of national and EU set targets through a roadmap to move waste management up the waste hierarchy through increased prevention, re-use, recycling and recovery.

The Waste Management Plan is aimed at addressing key issues and challenges:

- Low rates of recycling;
- High landfilling rates;
- Unsustainable waste management;
- To break the link between economic growth and waste generation;
- Moving waste up the waste hierarchy;
- Moving towards sustainable waste management through waste prevention, increased recycling and recovery.

This strategy affects emissions of greenhouse gases and low carbon development by putting forward proposals that will lead to sustainable lower waste generation rates and thereby improve Malta's standing vis-a-vis the waste hierarchy.

Solid waste management

Over the years, the quantity of waste being deposited in landfills has gradually decreased due to improved recycling practices. Various initiatives over the past years, mark a shift away from landfilling in favour of more sustainable waste management options.

Waste water treatment

Malta's waste water handling infrastructure consists of two main networks that collect both domestic and industrial waste water as well as some storm water runoff. The sewerage system has been upgraded with the building of three new sewage treatment plants between 2006 and 2011 under the Government's Infrastructure Programme for the upgrading of the national waste water infrastructure and for achieving compliance with the requirements of the Urban Waste Water Treatment Directive.

6.2.2. Impacts on Sectors

National Communication of Malta to the UNFCCC identified various vulnerability and adaptation issues in individual sectors. (MRA, 2017). References is made to the most critical sectors identified as most vulnerable to climate change and related to the Built Environments. Both the cross-sectoral and the sectoral aspects give first an over view on the current state of play followed by vulnerabilities and measures.

6.2.2.1 Impacts on Water

Water Resources

Most of Malta's natural freshwater is stored in underground aquifers. Malta is amongst the world's top ten water scarce countries. The limited water resource makes the country dependent on desalinated water for around 60% of its potable water production. Climate change may impact the hydrological cycle and subsequently the water quality and availability.

The impacts of climate change on water refer to the following:

- the Maltese Islands are expected to experience a decrease in the national water resources mainly due to increased evapotranspiration rates, and
- alteration in subsurface water movements and sea level rise.

Additional impact on the availability of water resources:

- an increase in the mean annual air temperature of +0.69 °C in 2010 when compared to the climate norm of 1961-1990, showing a maximum increase of +1.2 °C in 2001. The highest maximum temperature increased by +2.0 °C in 2001, while the highest minimum increased by +2.0 °C in 2008;

- rainfall patterns show a relatively high spatial variability over the Maltese territory and no definite trend in the observed precipitation. The most recent study did not analyse the change in seasonal patterns or change in the frequency of thunderstorms;
- the recorded decrease in the mean annual cloud cover over Malta amounts to –0.2 oktas when compared to the Maltese climate norm of 1961-1990;

Water Vulnerability

Water security has always been a challenging issue in Malta due to low availability of natural water and a high population density, and hence, high water demand.

Climate change can significantly change the status of natural water resources in Malta; the hydrological cycle can be altered to cause a change in:

- the intensity and frequency of extreme rainfall events (floods and droughts);
- the amount of water available and the demand exerted thereon;
- water quality (e.g. temperature and nutrient content).

The characteristics of the main aquifers in the islands and the potential impact of climate changes are presented below. It is in this context that the potential outcomes that might prevail are to be seen to have the following potential effects on water resources in Malta namely:

a) variability in inter-annual and intra-annual rainfall will have corresponding effects on demand as well on the amount of water potentially available for recharge;
b) seasonal scarcity of precipitation when the water requirements of the agriculture and tourism sectors are highest (normally from June to August) could contribute to increased pressures on freshwater resources;
c) high rainfall intensity events, with shorter durations, will have a lower contributing effect to recharging groundwater resources and increase the generation of storm water runoff;
d) frequent occurrence of low rainfall years when groundwater recharge is likely to be low;
e) frequent occurrence of high rainfall years when runoff is likely to be high (this is dependent on the distribution of rainfall);
f) increased demand for water resources to combat the effects of higher temperatures;
g) higher evapotranspiration rates that will demand increased water volumes for cultivated areas;
h) a potential increase in the salinity of groundwater resources if sea water levels rise with salty water replacing freshwater sources.

The problems that are envisaged to cause lower availability of naturally renewable water resources as a result of changes related to climate are identified with respect to lower annual rainfall volumes, high rainfall intensity, and increased evapotranspiration.

Measures: Water

Malta is taking major steps to adapt the water sector to climate change:

- A comprehensive national Water Catchment Management Plan which mainstreams climate change adaptation obligations;
- A holistic approach to water management, by maintaining the quantity and quality and status of ground water sources, via the introduction of an integrated water resources management approach;
- The treatment of wastewater to provide alternative supply of water for industry and agriculture;
- Adoption of sustainable strategies for the management of rain water runoff;
- An assessment of the relationship and risks between climate change/water resources/food security/public hygiene.

Since climate change in the Malta would not only affect the quantity but also the quality of water resources, Maltese water law aims also to:

- address emissions and discharges that affect water, whether via point or diffuse sources, irrespective from where they originate, such as for example from fertilizers and pesticides in soils;
- prevent the deterioration of the status of all the bodies of water which is closely linked to the above and;
- implement the measures necessary to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to reduce progressively water pollution.

Desalination of sea water, and extraction of groundwater, are the main fresh water sources in Malta, and together with rainwater harvesting, and treatment of wastewater, they constitute all the fresh water sources in Malta. Although the energy requirements for desalination have decreased in the last decade, desalination remains an energy intensive process, so the need to address adequate management of groundwater already an overexploited resource, becomes even more crucial for adaptation in the water sector.

Malta’s Programme of Measures includes the launching of a National Water Conservation Campaign, the achievement of high efficiency levels in water supply distribution, the improved regulation of groundwater use, investment in desalination technology to optimise the energy efficiency of the process, the adoption of upstream sustainable drainage and nature based water retention solutions for the better management of rainwater runoff and the distribution of highly polished treated waters to facilitate their use in lieu of groundwater.

Adaptation measures in the water sector will also address coastal water management, a sector that is significantly vulnerable as a result of climate change both as a habitat and as a zone of intense economic activity.

6.2.2.2 Impacts: land use and Infrastructure

Land use and Infrastructure

As a densely populated island state of around 1,400 persons per square kilometre, infrastructure and land use requirements have long been considered as a major competing force against the conservation of natural habitats and eco systems. The impacts from climate change on the islands including sea level rise, changes in temperature, extreme weather events will have strong negative impact upon the built environment, including infrastructure. A better understanding of these impacts and the associated risks is necessary to plan and develop better the built environment and its supporting infrastructure.

Malta is densely populated, and land resources are scarce. Urban development, agriculture, industrial and commercial activities and quarrying are the main land uses, which add significant pressures on the Maltese countryside. A significant percentage of Malta's urban development also lies on the coast, covering 35% of the coastal zone in Malta and 19% of the coast of Gozo. Climate change will impact Malta's land use in a number of ways including flooding of coastal areas, drought stress on agriculture, extreme weather events (including flooding) and impacts on structures and infrastructure, secondary impacts on property values and insurance, impact on plants, vegetation and subsequently on human health. The infrastructure of the Maltese Islands will not be immune to climate change, albeit at different levels depending on its development, resilience and adaptability. Key areas are the following: energy, transport, telecommunications, buildings and waste.

Economic growth experienced in Malta during the past years was complemented with an intensification and growth in development and the building sector; changes to the laws regulating quarries (and their rehabilitation) and changes to the rural development guidelines, all having the potential to contribute to changes in land use in the islands. Agriculture accounts for almost half of Malta's land area (47.5%) whilst natural vegetation areas account for almost 20% of the land cover. The urban area, including industrial parks, airport and port areas cover an area of equivalent to 28% of the land. The Spatial Plan for Environment and Development (SPED, 2015) identifies the challenges of climate change and climate change adaptation, particularly related to changes in weather patterns and the rise in sea level, and the subsequent threats to water sources, vulnerable ecosystems and emissions.

In its spatial framework it also identifies Climate Change as a thematic objective: to control greenhouse gas emissions and enhance Malta's capacity to adapt to climate change. Nine specific measures are identified under this thematic objective.

1. Supporting the implementation of Malta's Energy and Water Policies.
2. Supporting the implementation of the National Mitigation Strategy and National
3. Adaptation Strategy.
4. Requiring the integration of small-scale renewable energy infrastructure into the design of
5. buildings, particularly in public, industrial and commercial sectors.
6. Promoting renewable energy sources and zero carbon modes for transport.
7. Directing large scale solar farms to areas as identified in the proposed Solar Farm Planning

8. Policy.
9. Promoting energy efficiency in the design of buildings.
10. Ensuring that development plans and proposals contribute to national targets for GHG
11. reductions and mainstream climate change adaptation measures.
12. Directing development away from areas which are prone to significant risk of flooding with
13. the exception of interventions required to manage these areas.
14. Improving public/collective transport as a high priority adaptation measure for Climate
15. Change.

Within this coastal zone lie also some of the most important infrastructures for Malta. In the case of energy, the islands are dependent on a national grid with all the electricity requirements generated locally in one power plant at Delimara. The Interconnector comprises a 120-kilometre high voltage alternating current (HVAC) system capable of bidirectional flow of electrical power, transferring 200MW of electricity.

Malta has over 2,600 km of road, mostly built to supply the growing demand for private mobility. This infrastructural situation has also encouraged significant use of the car, to the detriment of the public transport services.

Some of the major link roads in the network have been constructed in low lying areas (valleys) which are naturally prone to flooding and will be impacted by sea level rise. The percentage of arterial roads prone to flooding was estimated at 10 per cent, whilst 6 per cent of distributor roads and 7 per cent of rural roads would be prone to flooding. The national flood relief project intercepts rainwater through a series of underground tunnels and includes reorganized culverts and bridges, whilst replenishing the national water reserve.

Malta has three main gateway terminals which allow it to connect to other countries. The Malta International Airport ; The Grand Harbour Freight and Sea Passenger Terminals and the Valletta Cruise Liner Terminal (located close to the urban areas); the Malta Freeport is located in Marsaxlokk Bay and supports mainly container movements. Inter-island communication is through the Ċirkewwa and Mġarr Harbours which provide the necessary infrastructure for the existing ferry service operating between the two islands. The coastline is also dotted with small harbours and landing infrastructure. These infrastructures play an important role for the future development of the island. Preliminary investigations (Figure 6-12) show a potential impact of sea level rise on these infrastructures.

Malta's waste is managed through WasteServ, promoting and facilitating waste management. The infrastructure includes an engineered landfill, a waste treatment plant, a thermal treatment facility, over 400 bring-in sites and five civic amenity centres. Malta was the first Mediterranean country to treat all of its sewage before dumping it into the sea in 2012.

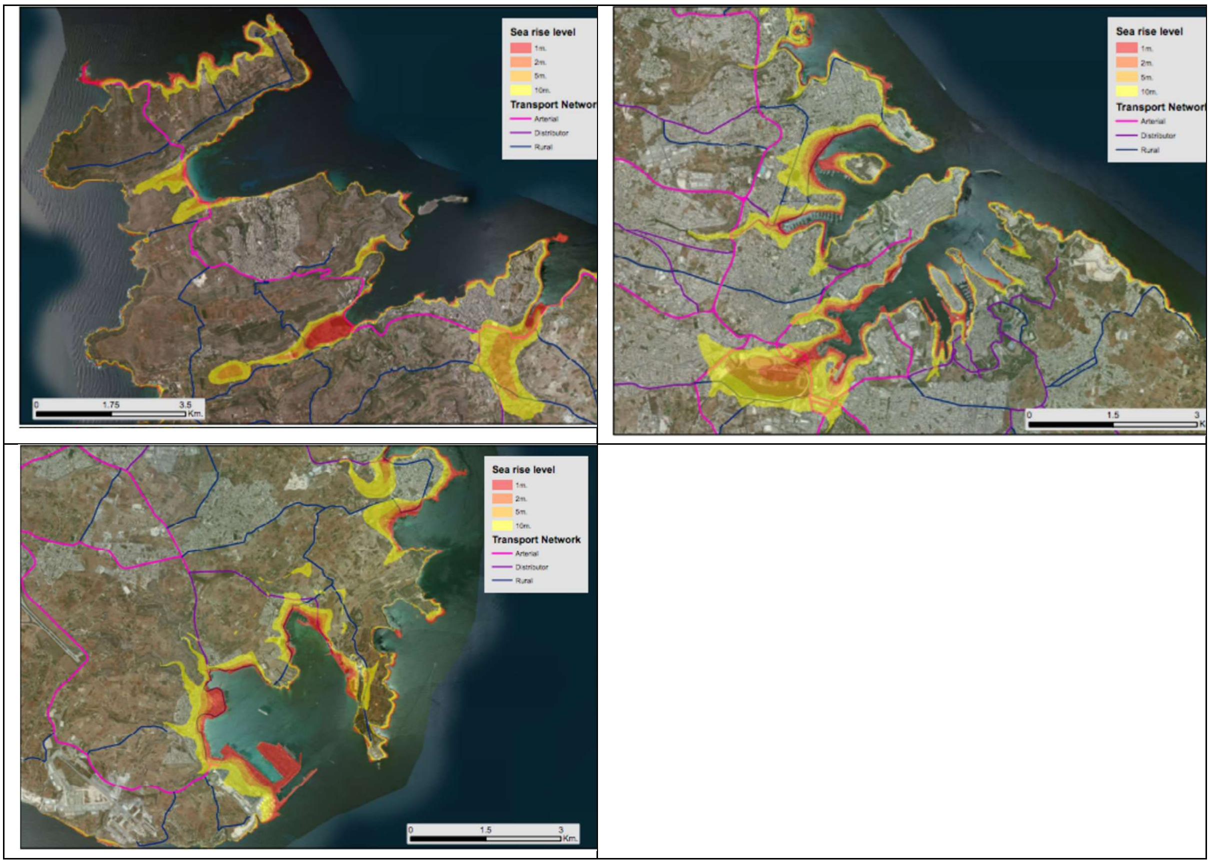

Figure 6.1; Sea level rise scenarios along the main island's coastline (Attard 2015, reproduced in MRA 2017).

Land Use Vulnerability

The predicted sea level rise and increase in extreme weather events pose a serious threat to coastal population, particularly high-density ones. The impacts range from inundation, coastal erosion (including loss or movement of beaches), and damage cause by storm surges, waves and high winds. Extreme weather events will also impact part of Malta's coast made up of fragile Blue Clay at sea level. A number of vulnerabilities associated with sea level rise, particularly related to coastal development, but also to protected areas, ports, infrastructures and roads have been identified.

Coastal zone density increased from 5 to 26% between 1990 and 2004, mainly with tourism and recreation development.

Table 6.1 ; Summary of land use vulnerability from climate change (adapted from (MRRA, 2010 and reproduced in MRA 2017).

	Land use vulnerability
1	Low lying transport infrastructure in the North of Malta.
2	Any land reclamation projects near the coast which the Government is currently considering.

3	Low lying coastal areas that have been modified over the years through development on the coast, and which will be prone mostly to storm surges.
4	A total land area of 1.11 Km2 (0.36% of land area) will be affected by a sea level rise of 50 m.
5	Beaches will be particularly affected as they might be obliterated, reduced in size or, in the case of new beaches, replenishment will be very costly.
6	Increased rain intensity leading to more flooding in some urban areas, with some needing to eventually relocate to alleviate the problem.
7	Loss of soil and nutrients for agriculture from intense rain events.
8	Longer drought periods can lead to desertification, in particular the areas under dryland
9	production.
10	Increase in wind gusting intensity will also affect the increasingly tall buildings which are being constructed mostly near the coast.
11	Extreme weather events, including the incidences of heavy hailstorms and thunderstorms will affect road surfaces, rubble walls (for the retention of soil in fields), retaining walls and power lines.
12	These impacts on agriculture, buildings and infrastructure will have a secondary impact on property values and insurance.

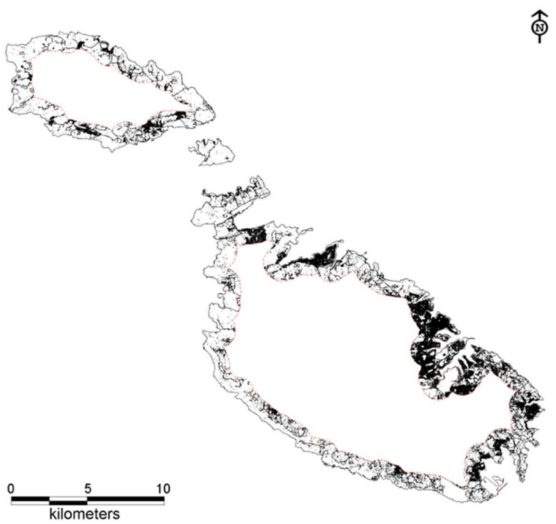

Figure 6.2; Built-up areas (in black) within 0 to 1 km of the coast (2004). (MEPA, 2006)

Infrastructure Vulnerability

With the current projections for increase in temperature, changes in precipitation patterns and sea level, there is a threat on infrastructures which can impact other aspects of society. Damage from storms, increased energy demands due to extreme weather, as well as threats to low-lying infrastructure from sea level rise are amongst the more obvious vulnerabilities identified for infrastructure.

Energy

In terms of energy, climate change will have a direct effect on both supply and demand. Decreased precipitation and heat waves are also expected to influence negatively the cooling process of thermal power plants. During heat waves and extreme weather, peaks of cooling and heating will affect the demand and distribution of electricity in the islands. Transport and telecommunication infrastructure are mostly affected from increased frequency and intensity of extreme weather events. Telecommunication infrastructure, if not underground is vulnerable to high winds, whilst exchange stations might be affected by extreme weather damage. Power outages and surges impact heavily on hardware.

Transport

As previously described transport nodes and links, such as ports, airports, bus interchanges and stops and roads are impacted by weather events which may lead to closure, but also damage over time. Excess heat causes also damage to infrastructure, such as thermal expansion on road surface, airport tarmac and concrete structure along the transport network. As reported previously this impact will shorten the life of infrastructure, increasing cost and potential structural failure during extreme events. The low-lying links in the road network, situated close to the coast are vulnerable to flood damage and inundation. This is particularly critical for the islands core and comprehensive TEN-T Network.

The Transport Strategy includes a reference to the risks associated with climate change and the need to assess the potential impact of climate change and adaptation. The Masterplan identifies a number of measures including:

- Measure 2.8.2.1 Establish the share of greenhouse gasses from transport that would fairly contribute to climate change targets and monitor progress of this Masterplan in line with these targets.
- Measure 2.8.2.2 Assess the impact of climate change and sea level rise on transport infrastructures.
- Measure 2.8.2.3 Incorporate climate change considerations at the planning and design stage to reduce retrofitting costs.

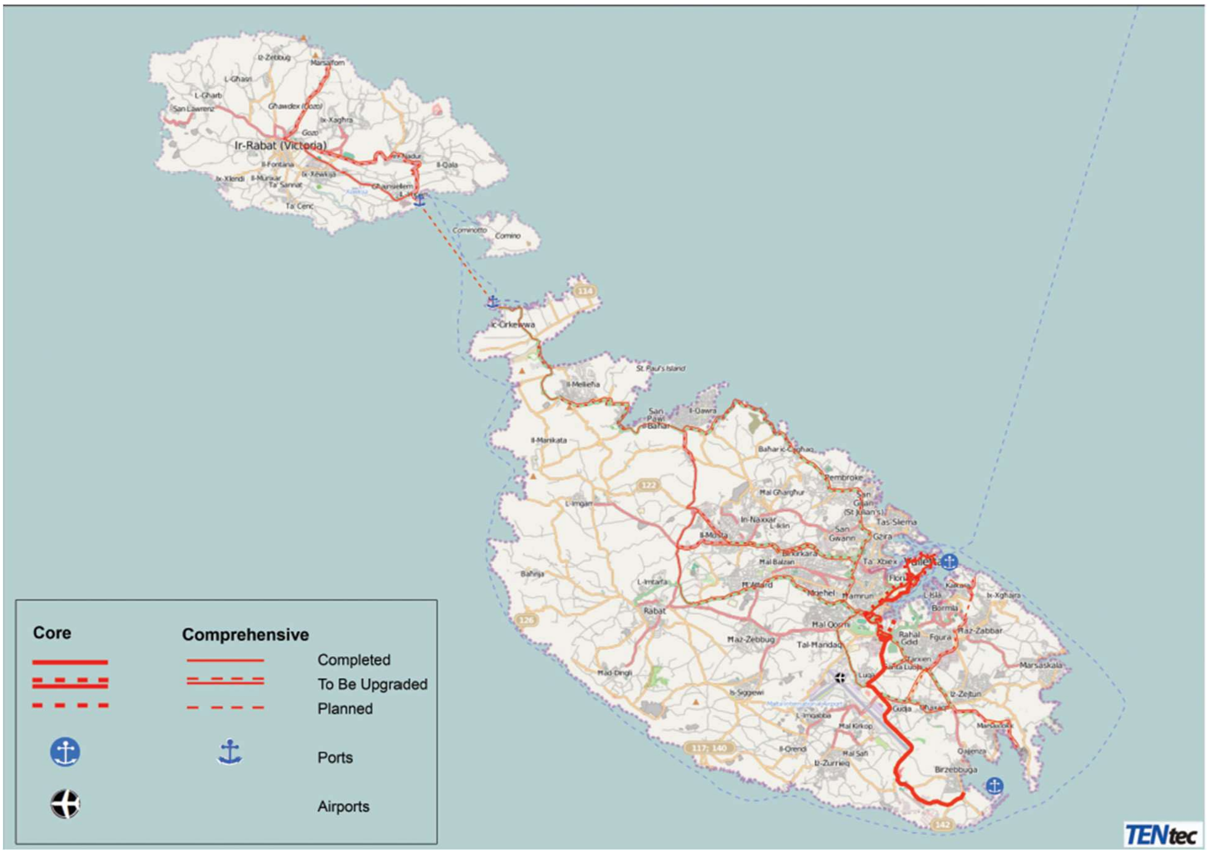

Figure 6.3; Malta TEN-T Core and Comprehensive Network as identified by the TEN-T Regulations 1315/2013 (European Commission, 2014).

Waste Management

Climate change has also the potential of impacting on waste management, particularly affecting facilities which handle waste. These include the changes to site hydrology and temperature which could affect landfill degradation rates, leachate production and composition; increased side dis-amenity; increased disruption of supporting infrastructure; and increased disruption to transport infrastructure due to flooding and the delivery of waste.

Measures: Landuse and Infrastructure

Adaptation measures must address infrastructural issues both with respect to land use in general and also to ensure preparedness to climate change within the built environment. Mainstreaming climate change adaptation measures in development planning and land use policy is still a priority area, which will help identify any specific legal requirements for the building industry as a means to adapt to climate change. Any adaptation measures that need to be implemented are likely to be closely related to mitigation measures such as energy conservation in buildings.

Furthermore adaptation measures could involve the revision of civil property rights to ensure that any measures adopted do not impinge on neighbouring properties and vice versa. Closely linked to land use and infrastructure adaptation, is the need for developing financial instruments to address socio economic implications such as property value and insurance. Property value may slump as a result of floods or sea-level rise. Although the first priority is to eliminate proneness to flooding and prevent loss of life and property by revising building policies in flood prone areas, the required financial instruments must be available to compensate for losses incurred on the part of the private and public sectors. In this context Malta is taking adaptation measures by:

- Carrying out a preliminary assessment to identify the areas within the Malta River Basin District which are prone to flood risk;
- Assessing the signficance of this flood risk in valleys and coastal areas;
- Mapping the areas which are prone to flood hazard and assets and humans at risk in these areas;
- Taking adequate and coordinated measures to reduce this flood risk;
- Reinforcing the rights of the public to access this information and to have a say in the planning process;
- Establishing flood risk management plans focused on prevention, protection and preparedness, notably by coordinating the implementation of the flood risk management plans and river basin management plans;
- Synergizing public participation procedures in the preparation of these plans making them available to public.

Malta followed the requirements of the Floods Directive (2007/60/EC) and a Preliminary Flood Risk Assessment Report which established the potential risk of flooding in the islands both from weather events and rising sea level. In this preliminary assessment the areas already experiencing flooding were identified. Future adaptation will be required to protect land and property from flooding events.

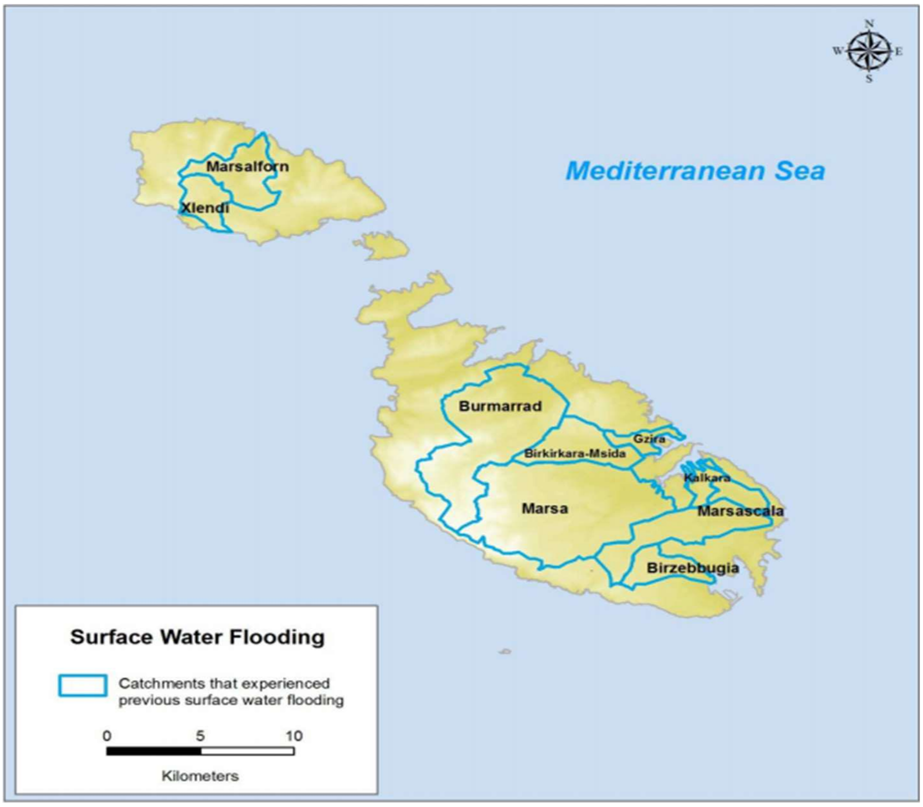

Figure 6.4; Areas of Malta affected by surface water flooding (MRA, 2013).

Adaptation measures continue to be mainstreamed into certain legal instruments such as in the Environment Impact Assessment (EIA) applicable for land development projects on a large scale and also a Strategic Environment Assessment (SEA) of certain public plans, policies.

6.3 Impact on Building Level

The impacts on buildings, including residential, commercial and public buildings relate primarily to resources for construction and waste generated, actions on structures, and Energy, Energy efficiency in Buildings and Renewable Energy.

Environmental Action

The impacts from climate change on the islands including sea level rise, changes in temperature, extreme weather events will have strong negative impact upon the built environment and buildings. Buildings in Malta are significantly exposed to rainfall and chemical action effects and wind erosion in particular for buildings with globigerina limestone building envelopes. Extreme action is likely to impact buildings through extreme action and accelerated degradation, as for infrastructure.

Energy efficiency

Efforts on the promotion of energy efficiency, mainly targeted the residential, commercial (mainly tourism) and industrial sectors. Government made substantial investment through support and incentive schemes to achieve the targets set in the Action Plan. The latest NEEAP has been re-designed to look towards the achievement of energy savings of 27% in 2020.

Malta Enterprise, the Government entity dealing with the promotion of industry has in recent years launched various schemes to incentivize energy efficiency measures in industry and SMEs. In 2016, in collaboration with the Energy & Water Agency, Malta Enterprise launched a scheme to incentivize high efficiency cogeneration, together with a new scheme in 2017 which promotes energy efficiency in the Malta's industrial and services market. Government grants were provided for the purchase of roof insulation, double glazing and energy efficient appliances in the residential sector. A nearly Zero Energy Plan for Malta has been developed. This has set targets for the shift towards nearly zero energy new buildings by 2020.

An increase of final energy consumption for H&C in Malta is expected by 2030, in particular within the services and industry while in the residential sector, the expected increase will be limited by energy performance requirements for new and refurbished dwellings. Despite the projected increase, the final heating demand will remain relatively low compared to what is needed to create favourable conditions for enhancing CHP and district heating. This expected low thermal demand does not make it financially feasible to install such technologies.

The Government embarked on an energy efficiency support campaign and advise on energy efficiency was provided to households. A project intended for Renovating Public Buildings to Increase Energy Efficiency and Reduce Greenhouse gases consisted of a number of energy efficient interventions at specific pilot buildings.

Renewable Energy

Small installations are integrated in existing building infrastructures, such as on rooftops, due to Malta's limited space and the conflicting use by other activities. The introduction of a feed-in tariff for solar photovoltaic systems (PV) has addressed the financial barrier holding back the further penetration of PV systems.

7 Conclusion

The focal point for climate-related research and systematic observation in Malta is the University of Malta where academics from various faculties, institutes and centres within the University are contributing towards increasing knowledge on climate change issues from a variety of perspectives, including scientific and technological, legal and economic. The Malta College of Arts, Science and Technology (MCAST) and the Meteorological Office also contribute towards research and systematic observation activities. Research on climate-related matters is further spearheaded through the recently launched National Research and innovation Strategy-2020. The sphere of formal education is a prime target for educational initiatives aimed at widening awareness on climate change issues. Education for Sustainable Development is now an integral part of the national curriculum. The Maltese government is also assisting capacity building in the area of climate change through the financing of scholarships for post-graduate level studies (MRA, 2017).

However, when considering the research conducted to chart the impacts of Climate Change on the Maltese islands, it is evident that there are missing gaps of knowledge. As indicated above some of the studies are conducted as dissertations at undergraduate and Masters level. Since this is not coordinated research within a nationwide project, the approach is fragmented. Considering the size of the islands and the vulnerability of Malta as an island state, one expects a coordinated effort that encompasses all sectors and the whole territory. The need for better coordination at different levels including on the legislative platform was stated by the 7th National Communication of Malta to the UNFCCC, 2017 (MRA, 2017). Some sectors, as Tourism seems to exploit the call for climate change mitigation measures to boost the marketing campaign.

Whist compiling this document it was observed that the research carried out within the local context as with regards to Climate Change includes a number of perception studies among the population rather than on the actual measured impacts of the phenomenon.

These perception studies indicate that there is recognition among the population of adverse climate and environmental events. This recognition can be considered as the basis for more efficient bottom-up approach to the mitigation measures in place. However, such initiatives and measures should be based on knowledge so as to address affectively the impact of climate change and hence stop short from a tokenistic approach to the situation. The top-down coordination through a holistic inter-ministerial effort is essential to avoid missing the opportunity to take the appropriate action on time.

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