CHAPTER 10

Losses, Damages and Return Period of Extreme Weather Events in the Maltese Islands

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Introduction

Full range economic costing of weather disasters tends to be quite challenging. Complete and systematic data on such impacts are often lacking, and most data sets generally tend to underestimate losses. The best estimates made by Hoeppe (2016) for the average global cost of natural disasters worldwide between 1980 and 2014 have caused a total of 1.7 million fatalities and at least $4,200bn damages, including $1,100bn insured losses. Around 65% of the overall losses were due to convective and hydrological events. And what about future trends? Nineteen years ago, William Nordhaus (1997) expressed his dilemma that is still haunting both scientists and economists of today. It relates to the current significant knowledge gaps between the projected increase of temperature (now with high confidence) and its translation into future ecological, economic and social outcomes. Many important sectors still lack a proper description of their future growth dynamics in the presence of such impacts (Hallegatte et al., 2016) and economists often resort to the modeling of long-term economic growth on the basis of current time horizon and climate change scenarios. In doing so, they are neglecting the possibility of potential deviations from presumed model conditions of economic growth, irrespective of whether adverse impacts affect rich economies or those already weakened by various disequilibria or inertia in their readjustment process.

The insurance sector is society's risk management tool that is capable of encouraging risk reduction like no other economical instrument (Zurich Financial Services Group, 2009). This is reinforced by its ability to collect records of damages caused by major weather catastrophes. Based on data available from Munich Re's NatCatSERVICE database among others), Mohleji and Pielke (2014) showed that global losses have increased at a rate of $3.1 bn per year from 1980 till 2008, during which losses resulting from storms and floods in North America, Asia, Europe and Australia account for 97% of the increase. Based on past records, Fischer and Knutti (2015) managed to show that for every 2oC of warming, the fraction of extreme precipitation events increased by about 40%. Such a very important statistic is expected to increase non-linearly with further warming.

In terms of insurance losses, data shows that European storms rank amongst the costliest (Jahn, 2015). Schwarze & Wagner (2004) showed how the insurance industry was hit hard by a catastrophic flood event in Dresden, Germany in 2002. The damages handled by Allianz Insurance Group alone totaled €770m (equivalent to 0.04% of Germany's 2002 GDP). The European Environment Agency estimated that between 1998 and 2009 flooding and storms in Europe have caused some 1,126 fatalities in 213 recorded flood events, with an overall loss of €96bn, out of which €25bn were insured economic losses (European Commission, 2016).

Scope of this paper

Remarkably however, research on weather disasters and their after-effect is considerably limited (Chaiechi, 2014), especially in small island states. Briguglio (1997) showed how small countries tend to be associated with high per–unit costs making them economically disadvantageous. Consequently they are highly vulnerable to the pervasive impact of natural disasters on their population, environment and economy (Wright, 2013).

Similarly, research in the area of extreme weather events and resulting impacts on the Maltese islands are almost non-existent. The scope of this paper is to feed into the much-needed evaluation of local extreme weather events and their economic impact, and even more challenging, on their return period in light of a changing climate. This is done by researching the insurance loss and damage following a select number of Maltese extreme weather events that have occurred between 2011 and 2013. It is hoped that this knowledge will encourage further national risk mitigation and prevention measures.

Methodology

Detailed, long-term information on losses and damages caused by natural disasters can be found in countries with a high insurance penetration like North America, Europe and parts of Asia. Such information is considered to be the most reliable natural catastrophe loss data available which is often used for risk assessment by insurers and reinsurers, social scientists and climatologists alike (Hoeppe, 2016). It must be said, however, that the assessment tools used to quantify the direct total economic losses (including repair, replacement or reconstruction of damaged infrastructure and private material losses) comprise some degree of uncertainty and tends to increase as a result of unaccounted indirect economic losses (such as business interruptions, loss of labour etc.).

The term ‘extreme’ used by this study falls within the context of local meteorology on the basis of occurrence extremity (extreme values of meteorological variables) and not on impact extremity (magnitude of impacts). The occurrence of an extreme meteorological event is met whenever the values of particular variables go beyond pre-defined absolute thresholds. A similar approach is adopted by NOAA Environmental Centers for Environmental Information (NOAA, 2016).

Extreme events data

This study looks at different types of locally convective weather extremes, namely floods, hailstorms and windstorms (inclusive of storm surges). Local weather storms generally have a short duration but are capable of producing heavy rainfall accompanied by hail and strong gusty winds (Galdies, 2011). In the central Mediterranean region, extreme storms usually take the form of mesoscale convective systems and are not uncommon between the end of August and September. Supercell Mesoscale Systems for example, are convective weather phenomenon capable of causing severe weather with hail, flooding, and tornadoes thus leading to many casualties and significant damages (Morel & Senesi, 2002).

Three locally extreme, isolated meteorological events were examined, which were further subdivided into main events and sub-perils (Figure 1) so as to standardize them with other global natural catastrophe databases for inter-comparative reasons (Hoeppe, 2016). These extreme events included a severe thunderstorm (29.10.2011), a mesoscale convective system (2-3.09.2012) and a hailstorm (15.01.2013).

Figure 1. Meteorological events examined by this study, which were further subdivided into main events and sub-perils

Source: MunichReNatCatSERVICEdatabase; https://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html)

Relevant information and data was collected from the insurance sector, official meteorological sources, news media, government reports and published scientific studies.

Analysis of extreme weather events

Meteorological data was gathered from various sources, including synoptic weather charts, satellite images and land observations. Land observations reported by the national climate station situated at the Luqa Airport (Malta) were collected, which included precipitation levels and rates, wind speed and direction, wind gusts and other relevant measurements. Information regarding the socio-economic impacts and damage to infrastructure and private belongings, incidents and fatalities were collected from archived local media sources.

Time-series trends

Surface synoptic meteorological observations published every 30 minutes by Malta's climate station (World Meteorological Organisation registered Climate Station Number: 16597) were reduced to one-hour intervals. The period 1973 till 2009 was analysed, generating 316,000 observations per hazard – equivalent to the processing of around 1 million local observations. Only the long-term trends of the occurrence of hail events (1973-2009) and the maximum hourly rainfall (1959-2015) rates were analyzed in view of space and time constraints.

Statistical analyses

Statistical analyses of weather data, which included data homogeneity testing, cumulative density functions, non-parametric correlation analysis and return periods, were carried out using Rainbow software (Raes, Willem and GBaguidi, 2006) on the basis of the reference meteorological and hydrological data.

Damages and losses

Information related to damages for the three events was gathered from the Ministry of Sustainable Development, Environment and Climate Change (for the thunderstorm event on the 29.11.2011) and from the Malta Insurance Association (for both the mesoscale convective system 09.2012 and the hailstorm on 01.2013).

The data collected from the Ministry included the damages reported by 185 local farmers (Dr. Justin Zahra, personal communication, 2015) as part of the government's effort to offer financial assistance to these farmers. The four different groups of damaged agricultural property available included crops, rubble walls, soil loss and structures.

The Malta Insurance Association (2017), which is tasked with the collection of statistical data from all of the insurance companies in the Maltese Islands (Adrian Galea, Director General of the Malta Insurance Association, personal communication, 2015), provided information on four major insured groups, these being home damages, commercial damages (shops, malls), pleasure craft damages (boats, yachts, ships) and motor damages (cars, buses, motorbikes). This data referred to payments made to insurants after submitting their reports. This information must be considered as partial since indirect losses are not normally accounted for (Kousky, 2014); moreover, the amount paid is often pegged to a predefined limit that is based on the insurant's premium and therefore could further lead to an underestimation of the total costs.

The monetary amounts were normalised by adjusting for wealth over time, as per Neumayer and Barthel (2011), in order to harmonize the damages brought about by all three events. No depreciation was made of the total amount stated. The approach is capable of highlighting the damages from any time period as relative damages with respect to the total wealth of a country, Nd_t=D_t/W_t , where Ndt is the normalized damage for year t, Dt is the total damage reported during t and Wt is the economic wealth (GDP per capita; source: NSO, Malta) estimated during year t. This approach does not require adjustment due to inflation as long as nominal damage in year t is divided by nominal wealth in the same year.

Results and Discussion

Description of events

29th November 2011

This weather event was triggered due to the descent of cold air over Northern Europe into the Mediterranean basin, resulting in the formation of a severe convective mesoscale system. This process led to intensive vertical instability, heavy precipitation, lightning, hail and strong winds. This intensive weather struck the Maltese Islands at approximately 06:00 GMT with moderate rain showers followed by a thunderstorm 6 hours later. At this point, the wind speed was at its peak with 33.4 km hr-1 (or 9.3 m s-1) gusting to 61.2 km hr-1 (or 17 m s-1). Figures 2a-d show the extent and severity of the mesoscale system at 18:00 GMT.

During this event, heavy precipitation was observed in Gozo, Comino and the northwest region of Malta with a total rainfall of 123.6 mm registered in Baħrija and 107 mm in Żebbuġ (Gozo) to name a few locations. In Mosta, a car was carried by floodwaters whilst a mother and her two children were rescued from a vehicle in Marsalforn (Gozo).

On that day, a number of arterial roads were damaged including the ones at Marfa, Rabat and Victoria (Gozo), while some homes were flooded in Rabat and Baħrija (Times of Malta, 2011).

Flooding event on 2nd and 3rd September 2012

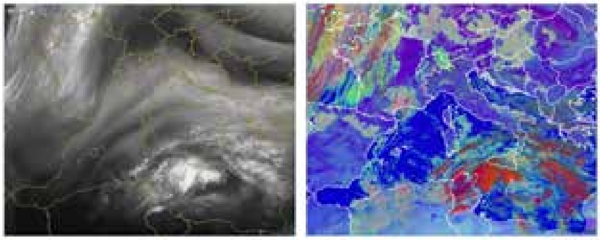
This Mesoscale Convective System was triggered by a 'cut-off' low over the western Mediterranean basin which formed during the latter part of August 31st. This slow moving feature led to intense precipitation, thunderstorms, waterspout formation and strong winds over the region. This low pressure system continued to move eastwards and started affecting the Maltese Islands on September 2nd at around 18:00 UTC (Figures 3a-d). Strong winds peaked at 06:00 GMT the following day with gusts reaching 89 km h-1 (or 24.7 m s-1) at Luqa Airport. A woman was saved from floodwaters in Birkirkara by the Civil Protection Department, and in Munxar (Gozo) a heavy water tank was blown by strong winds and landed on the roof of a house that led to its collapse. According to Sansone (2012), a waterspout was spotted to the south of Dingli. On September 2nd, a total of 48.6 mm of rainfall was registered at Luqa Airport, which is equivalent to 121% of the normal precipitation amount for September (i.e. 40 mm).

Hailstorm event on 15th January 2013

This meteorological event arose due to the slow descent into the Mediterranean of cold, polar continental air mass originating from Siberia on 12th January. A vigorous hailstorm struck the Maltese Islands on January 15th. The size of the hailstones was relatively larger than usual and somewhat oblate. According to Dalli (2013), the size of these hailstones was observed to be between 40 to 50mm, equivalent to 'H6' on the TORRO Scale (torro.org.uk/hscale.php) and an impact force of more than 800 J m-2.

Local meteorological observations taken at 12:00 GMT show strong winds reaching 50 km hr-1 (or 14 m s-1) gusting to 77.8 km hr-1 (or 22 m s-1) in a west-northwest direction. These wind gusts increased up to 83.4 km hr-1 (or 23 m s-1) by 18:00 GMT. Cooke (2013a-b) stated that Middlesea Insurance received a substantial number of claims for damages to property, which included damage to solar water heaters, photovoltaic panels, glass panels and water pipes. Gasan Mamo Insurance was in receipt of more than 300 claims made to its Motors department. Media reports indicated that Baħar iċ-Ċagħaq, Burmarrad, Għargħur, Madliena, Mosta, Naxxar, Pembroke, Rabat, San Pawl tat-Targa and St. Andrews were mostly affected by this hailstorm.

Figure 2a-b. Left (a): Water vapour image showing dense accumulation over the central Mediterranean region; Right (b): Microphysics image showing extensive red patches over the Maltese islands, indicative of convective clouds with severe updrafts and ice particles. Case study: 29 November 2011. Source: EUMEtrain.org



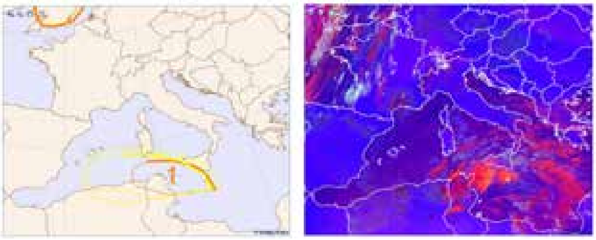
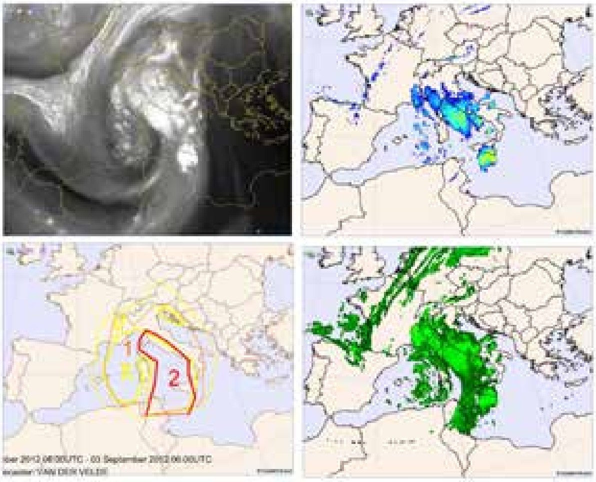


Figure 2c-d. Left (c): Area marked as ‘1’ refers to probability of severe weather within highlighted region; Right (d) Magenta patches over the Maltese islands refer to severe convection with cold cloud tops associated with severe updrafts and fierce weather. Case study: 29 November 2011. Source: EUMEtrain.org



Reported costs

The damages reported following the event of 29.11.2011 only originate from the agricultural sector and therefore can be considered as a case study that highlights the impact of a single occurrence on this sector. According to reports collected from farmers coming from various localities in Malta and Gozo, the total damage caused by this thunderstorm event was €1,831,292.85 (table 1) from which €1,682,639.46 was due to crop damage, €42,621 from damaged boundary walls, €12,990 worth of damages to soil, €50,685 damages to infrastructure and €42,357.39 due to other unspecified damages. In the agricultural sector, destroyed crops can be a major source of losses in the short-term. Necessary dependence on imports might generate additional losses in the long-term; however this could not be quantified by this study. The soil quality can also be negatively influenced for years due to washed-in contaminants – an indirect loss which cannot be determined due to lack of data.

Table 1. Normalised damage on the basis of Malta's GDP per capita. The reported damage for the 2011 event is related only to agricultural-related losses (see text for further details on sub-categories).

Event	Reported damage (€)	Estimated wealth (€)	Normalized damage (€); based on Malta's GDP per capita	Percentage of year-specific GDP (Indexmundi, 2017)
29.11.2011	1,831,293	16,582 (2011)	110.43	0.02
2-3.09.2012	5,073,000	17,221 (2012)	294.58	0.05
15.01.2013	4,341,000	17,919 (2013)	242.25	0.05

The number of insurance claims received due to the September 2012 event amounted to 1844, with a total of €5,073,000 worth of damages (residential: €1,057,000; commercial: €3,259,000; pleasure craft: €81,000; motor: €640,000). These various categories reflect the type of incidents encountered during the event, which ranged from flooding, strong winds, to storm surges and rough seas.

Similarly, the damage total of €4,341,000 claimed for the January 2013 event (made up of 2,763 claims) can be subdivided into the following categories: Residential: €427,000; Commercial: €441,000; pleasure crafts: €1,687; motor: €3,472,000.

This data does not include any indirect losses or damages related to non-market goods and services, and therefore the costs identified here are an underestimation of the full economic impact of these three extreme events. Moreover, a degree of artificiality is assumed in the case of the November 2011 reports compiled by farmers who were in need of external financial assistance.

The results also show that between 2012 and 2013 the economic 'shocks' caused by similar convective weather extremes and economic impact (% GDP; table 1) have been somewhat dampened by increased wealth. Yet, in spite of Malta's small economy, the insurance losses in terms of %GDP estimated for these three case studies, are close to other major European disasters, such as windstorms 'Kyrill' (Germany, 2007; 0.09% of GDP; CEA, (2009)), and 'St. Jude' (UK, 2013; 0.01% of GDP; Willis Re, (2013)). If in the future adaptation measures are put into place, then the effects of such shocks are likely to become more temporary, with a short turnaround period in different sectors of the economy after their occurrence.

The analysis of just three extreme weather events is however, not enough to identify a trend resulting from climate change. On a wider geographical scale however, Hoeppe (2016) describes how the observed increases and variability of similar losses can be correlated with changes in the meteorological potential for severe thunderstorms, where the main driver of these changes have been changes in the humidity of the troposphere. In Europe, the largest annual aggregated losses registered between 1980 annd 2014 have reached about €7.5bn with a significant increase of the number of events ($p<0.001$) by a factor of 4. Moreover, a shift from about 30 events per year to about 120 between has been observed. The largest convective losses worldwide have occurred in 2013 when a large hail storm hit Germany, resulting in an overall loss of €3.6bn and insured losses of €2.8bn (equivalent to 0.1% of Germany's GDP in 2013).

On the contrary, Neumayer & Barthel (2011) observed no significant upward trends in global disaster damage over the period 1980-2009, suggesting that it may be still far too early to detect such a trend even though they are expected to gain momentum over time. Mohleji and Pielke (2014) are also of the same opinion. Crompton et al. (2011) concluded that an anthropogenic climate signal will not be identifiable in US tropical cyclone losses for another 120-550 years and urged extreme caution in attributing global weather-related natural disasters losses in the near future to anthropgenic climate change. Bouder et al. (2007) points to issues related to data quality, low frequency of extreme event impacts, limited length of time series, and various societal factors present in the disaster loss record (including lack of indirect costs) as factors that are not helping in the determination of such damages. This is likely to remain unchanged in the near future.

Weather trends and return periods

Maximum hourly rainfall rate

In figure 4, the cumulative deviations from the mean of the maximum hourly rainfall for the full time series 1959-2015 (n=52). In this graph the vertical axis was rescaled and lines presenting various probabilities with which the homogeneity of the data can be rejected. Since the values fluctuated around zero and are far off from the lines where homogeneity is rejected, the data of the time series is homogenous (at 99% CL) with no breakpoints.

Figure 4. Homogeneity test for the time series of hourly maximum rainfall rate for Luqa Airport (Malta, WMO Climate Station: 16597) for the period 1959-2015. Data homogeneity is acceptable at 99% CL. Data for 2006 and 2007 are missing from dataset.

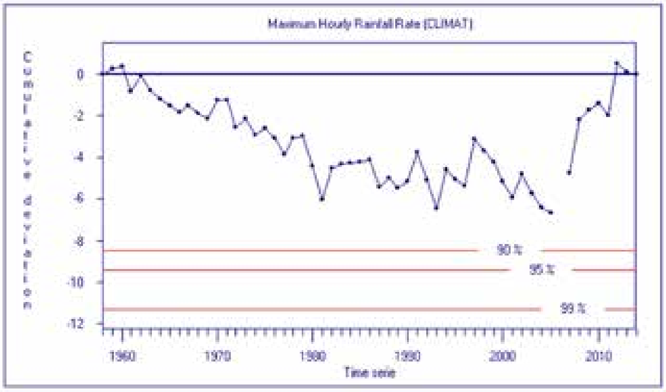
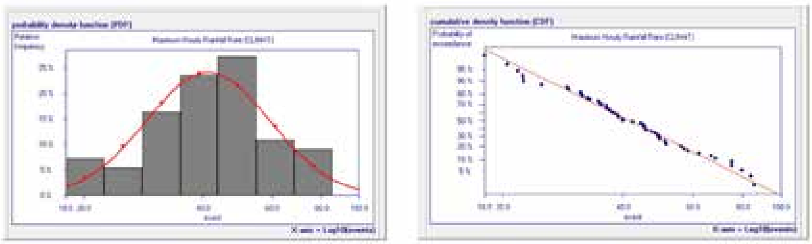


Figure 5 is the probability plot (PDF and CDF) of the maximum hourly rainfall rates versus their probabilities of exceedance. The scale of the event was transformed to log10 for best and most significant distribution at 95% level with an R-square of 0.98.

The extreme 2012 rainfall event showed an hourly rainfall rate of 84 mm hr-1. By plotting the value on the probability plot (Figure 5b), it is evident that the event was indeed the second highest throughout Malta's record period for this parameter. The return periods are shown in table 2. Statistically, the return period to reach or exceed the 2012 maximum hourly rainfall rate record is estimated to be around 41 years under current climatic conditions.

Figure 5a-b. Probability and cumulative functions (PDF and CDF; both significant at 5% level) of the maximum hourly rainfall rate for Luqa Airport (Malta, WMO Climate Station: 16597) on log10 probability for the period 1959-2014, with the highest hourly rainfall rate of 84 mm hr-1 recorded during the September 2012 event. Distribution of both PDF and CDF are acceptable at 95% CL.



(a) Probability density function of maximum hourly rainfall rate.

(b) Cumulative density function of recorded maximum hourly rainfall.

Probability density function of maximum hourly rainfall rate.
Cumulative density function of recorded maximum hourly rainfall.

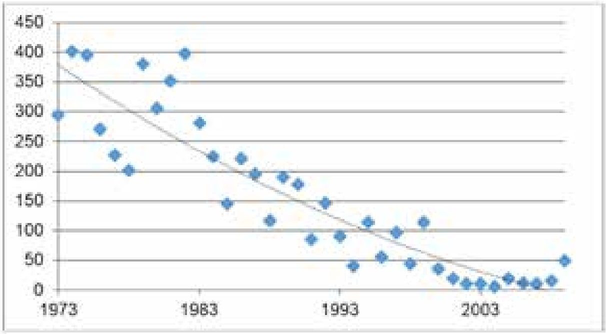
Table 2. Estimated hourly maximum rainfall rate for Luqa Airport (Malta, Climate Station: 16597 WMO) for selected probabilities and return periods from the probability plot (fig. 5).

Probability of exceedance (%)	Hourly rainfall rate (mm hr⁻¹)	Return period (years)
1	95.8	100
2	86.8	50
5	74.9	20
10	65.6	10

Extremes of hail

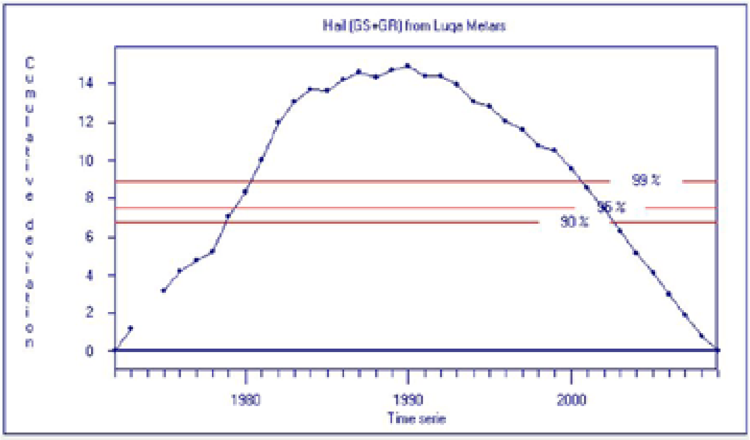
The total number of occurrences with hail during the period 1973-2009 is seen to be generally on the decline (Figure 6). The annual records varied between 400 (1974) and 5 events (2004). The average number of hail events for this 37-year period is 155.4 per year. The negative trend (which is significant at 0.05 CL) however, potentially reflects Malta's changing climate.

Figure 6. Total number of hail events recorded at Luqa Airport (Malta; WMO Climate Station 16597) for the period 1973-2009.



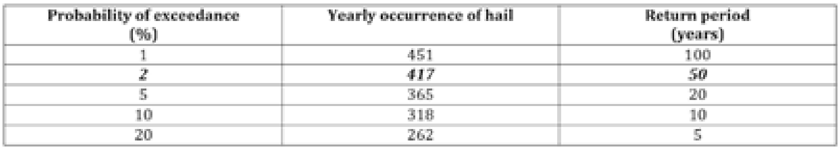
A shift is detected in the number of yearly hail occurrence throughout the study period. The homogeneity test shows a clear change of slope in the year 1990 (Figure 7). Over the period 1973-1990 the total number of yearly hail events was above normal while over 1991 – 2009, the opposite pattern can be observed. It is important to note that the estimation method remains the same for both periods. This is the best available local data we have for the occurrence of this meteorological phenomenon.

Figure 7. Rescaled cumulative deviation from the mean for the total number of yearly hail events for Luqa Airport (Malta. WMO Climate Station: 16597) for the period 1973-2009. The horizontal lines represent the 90, 95, and 99% probability at which the homegeneity of the data is rejected. (N=36; one outlier removed).



The reference period 1973-2009 can be therefore split up into two statistically significant periods different in their means: 1973-1990 with a mean of 265 hail events and 1991-2009 with a mean of 51 events. The jump in the mean between the years 1990/1991 separates the two periods. Based on best probability plot (R-Square=0.93), the return periods of occurrences of hail (and therefore a higher probability to record extremes) are shown in Table 3.

Table 3. Estimated return period of number of hail events for Luqa Airport (Malta, Climate Station: 16597 WMO) for selected probabilities and return periods derived from the probability of exceedance plot.



Probability of exceedance (%)	**Yearly occurrence of hail**	**Return period (years)**
1	451	100
2	***417***	***50***
5	365	20
10	318	10
20	262	5

The estimate return periods of between 50 and 65 years must be considered with caution. According to the official definition given by IPCC (2007), climate change is a change observed over a time period of 30 to 50 years or longer, and the time series used to derive the return periods might not contain a strong enough climate signal of such change (what Goodwin & Wright (2010) identified as a 'sparse' reference class for a typically 'chaotic' weather process). Moreover, being based on past values and records, statistically-derived return periods are mathematically possible on the assumption that the variability between past and future data sets remains stationary and that future time series will reveal frequency distributions similar to the observed ones. As the number of observations gradually increases, the error in determining expected return periods diminishes. Overall however, a period of 30 years and over is usually deemed to be very satisfactory for climate studies.

Conclusions

This chapter analysed the monetary impacts arising from direct damage to local infrastructure, property and services following three of the most recent weather-triggered convective events in the Maltese islands. It contributes unique research attempt to calculate the local economic losses due to weather-induced extreme events with an average return period of 58 years.

These results are tentative, but they indicate a research priority. Locally, empirical work on adaptation to future extreme events is scarce. This provides no reason for complacency. For the debate on climate change and its predicted increased occurrence of extreme weather events, our results should become part of an overall cost-benefit analysis on whether to increase or not our economic resilience by introducing certain adaptation measures. For example, more work is needed to ascertain future trends upon which appropriate adaptation strategies can be tailored. This paper has limited itself to empirical studies of the economic impacts of a select number of convective events. Parallel reviews of modelling studies, engineering estimates, case studies, and impacts of disasters on socio-political and health outcomes would be useful complements to this work. It also calls for actionable research by our local climate research community to make available tailored information and knowledge to strengthen the link between weather and disasters (van der Hurk et al., 2016). Such information is a rich source of inspiration to increase society's resilience to an unknown future.

Acknowledgements

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