A system for the assessment and mapping of vulnerability and risk related to high impact weather events in Greece: Yantas project

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A system for the assessment and mapping of vulnerability and risk related to high impact weather events in Greece: Yantas project

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Abstract: Weather-related phenomena such as floods, mass movement, windstorms, and hailstorms, cause extensive damages in Greece, while their frequency and intensity are expected to increase given the adverse climate change projections for the area. At the local scale, the interaction between meteorological conditions, geophysical and demographic features can affect the magnitude of damage and the consequent insured financial losses. Although the impact of weather-related events on insurance companies is significant, insurance practices have not yet been adjusted to account for and effectively address local weather-related risks. Towards this direction, the YANTAS project aims to meet a significant need of the Greek insurance market, specifically the part covered by the INTERAMERICAN insurance company, which is related to the assessment of weather-related risks and vulnerability at the local level. For this purpose, a science-based interactive tool is being developed and tailored to the requirements of INTERAMERICAN for mapping and analyzing insured losses in relation to weather hazards, as well as to vulnerabilities associated with geophysical and demographic conditions and human activities, at Postal Code level. This work is devoted to the presentation of the methodology applied for the development of indices of weather hazard, vulnerability, and risk of losses, followed by preliminary results. YANTAS is co-financed by the EU and national funds.

1 Introduction

Weather-related phenomena such as floods, mass movement, windstorms, and hailstorms, cause significant socio-economic impacts all over the world. According to the reinsurance company Munich Re (2020), in the last four decades the economic losses in Europe due to severe weather phenomena, with or without insurance coverage, have shown an upward trend. Among natural disasters, meteorological and hydrological damaging events dominate both overall and insured losses. All scientific analyses predict a high probability of a significant increase in both the frequency and intensity of severe weather events in the eastern Mediterranean region due to climate change (IPCC, 2012). Greece often experiences weather-related natural hazards with quite serious adverse effects, particularly due to its geomorphology, its socio-economic characteristics, its inadequate infrastructure, and the mismanagement of the country's natural wealth. According to the High-Impact Weather Events (HIWE) database (Papagiannaki et al., 2013) developed by the METEO Unit at the Institute for Environmental Research and Sustainable Development (IERSD) of the National Observatory of Athens (NOA), in the last 20 years, about 500 events have occurred. Floods and flash-floods are the most common type of weather-related natural hazard, largely connected to the increased runoff due to man-made interventions in the rivers' catchments and urban developments, the extensive destruction of forest vegetation, and the lack of technical work to address the problem.

Although the impact of weather-related events on insurance companies is significant, insurance practices have not yet been adjusted to account for and effectively address weather-related risks at the local level. However, the robust development of the insurance industry is in the interest not only of insurance companies but also of the society, as insurance enhances economic activity, creates data, and provides incentives for prevention. Towards this direction, the YANTAS (*System for assessment and mapping of vulnerability and catastrophic risk due to severe weather conditions in Greece*) project aims to meet a significant need of the Greek insurance market, specifically the part covered by INTERAMERICAN insurance company, which is related to the assessment of weather-related risks and vulnerability at the local level. For this purpose, a science-based interactive tool is being developed and tailored to the requirements of INTERAMERICAN for mapping and analyzing insured losses in relation to weather hazards, as well as to vulnerabilities associated with geophysical and demographic conditions and human activities, at the Postal Code (PC) level. In this work, we present the methodology applied for the development of indices of : (a) rainfall hazard, (b) vulnerability to rainfall and associated flooding, and (c) risk of losses, at Postal Code (PC) level. Moreover preliminary results for the specific branch of insured capital related to properties are presented.

2 Data and methods

At the local scale, the combination of meteorological conditions with geophysical and demographic features affects the magnitude of damage on properties and the consequent insured financial losses. Insurance data consist of a particularly useful approximation of the size of the damage and provide information about the cause and type of the induced impact. Therefore, when available, they are used for risk assessment, by analyzing their association with the hazard and the vulnerability (Cortes et al., 2018, Prahl et al., 2015).

In this work, property insured losses associated with rainfall events in Greece were estimated from detailed data on insurance claims, which were provided by the INTERAMERICAN insurance company. The data set comprises the compensated amount for each claim, followed by temporal, spatial, and impact-related details, for the period 2012-2019. Event losses were classified into 3 classes (low, medium, high) based on the mean, i.e., the expected value, and the value of the 99.5th percentile, above which lies the range of the worst-case scenario for the insurance company in order to be consistent with the Solvency II regulation (European Commission, 2007, 2009b) that specifies that an insurer should be able to withstand a 1 in 200 years loss (confidence level of 99.5% over a one-year period) and still have sufficient capital for risk to be fairly transferred to a third party. The selection of 3 classes for the indicators was made to enhance the usability of the interactive tool that will be produced within the YANTAS project.

For the development of indices for the rainfall hazard, rainfall data for each event and PC were derived from the the surface network of the 450 meteorological stations operated by the METEO Unit of IERSD/NOA (Lagouvardos et al., 2017). The identification of meteorological events and the calculation of relevant meteorological parameters were based on algorithms that identify the most representative meteorological stations of each area (namely within each PC), apply thresholds over which the phenomena can cause damage (Papagiannaki et al., 2015, 2017), and calculate the maximum accumulated rainfall for various time intervals (10, 30 and 60 min, and 2, 3, 12 and 24 h).

For the development of indices for the vulnerability to floods, geophysical, and demographic features, as well as exposure parameters such as the mean flow accumulations and the occurrence of damaging rainfall events, at the PC level have been used. The vulnerability parameters were selected after a thorough literature review of relevant studies (Tragaki et al., 2018; Lung et al., 2013; Khanduri & Morrow, 2003), while a statistical correlation analysis was also performed for possible multicollinearity. All the parameters were classified into 5 classes in a GIS environment with the Natural Jenks method. For the calculation of the final indicators, a comparative analysis of 2 methods was performed, the Principal Component Analysis (PCA) and the Analytical Hierarchy Process (AHP).

The risk assessment was done qualitatively at PC level, by developing a risk index as a function of loss occurrence due to rainfall, the expected loss, and the geophysical and socio-demographic vulnerability, as well as quantitatively at country level, based on logistic regression statistics that estimate probabilities for the occurrence of loss exceeding specified loss levels.

3 Preliminary results

3.1 Insured losses due to rainfall events

In the period 2012-2019, 2054 rainfall events with insured losses for the company have occured. Those events were spatially reported at PC level. Among the various rainfall measures, the maximum 24-h accumulated rainfall was found to have the strongest and statistically significant correlation both with the magnitude of the insured loss (Spearman's rho=.21, p<.001) and with the number of claims (Spearman's rho=.18, p<.001) independent of the PC. Figure 1 shows the classification of the 24-h rainfall and of the insured loss, as well as the cross-tab frequency distribution of the events based on the 2 indicators produced, which show the same statistical correlation as (Spearman's rho=.21, p<.001) that between the continuous parameters. Based on aggregate data at the PC level, the results showed a strong and statistically significant correlation between insured loss and the number of rainfall events (Spearman's rho=.62, p<.001). Figure 2 shows the geospatial distribution of the number of rainfall events and the associated losses for the period 2012-2019.

Parameters	Max 24-h rainfall	Event loss
Index class	**RI**	**LI**
1 - Low	<60 mm	< mean value
2 - Moderate	60-100 mm	mean - p99.5
3 - High	>100 mm	>p99.5

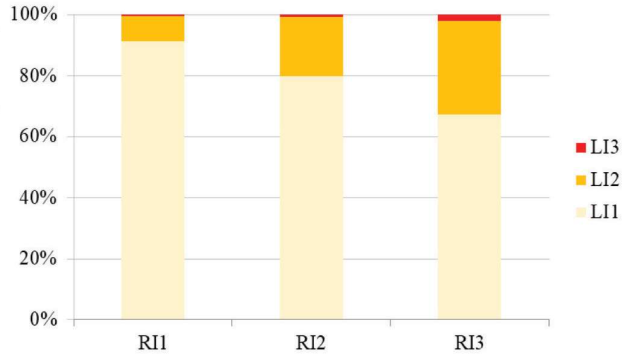

Fig. 1. Classification of events in 3 classes for max 24-h rainfall (RI1, RI2, RI3) and loss (LI1, LI2, LI3), and cross-tab frequency distribution (%) of events.

3.2 Geophysical and social vulnerability

Table 1 shows the descriptive statistics of the parameters included for the assessment of geophysical and socio-demographic vulnerability to rainfall at PC level. For usability purposes, within the framework of the YANTAS project, the final indices were re-classified into 3 vulnerability classes. Figure 3 illustrates the vulnerability map based on the index produced with the PCA method.

The correlation between vulnerability and the number of events was found to be significant, albeit weak (Spearman's rho = .14, p <.001), indicating that vulnerability related to the natural environment and human geography may affect the more frequent occurrence of rainfall-related damage. No correlation was found between vulnerability and losses at PC level, which is more likely to be related to the insurance portfolio profile and its interannual changes.

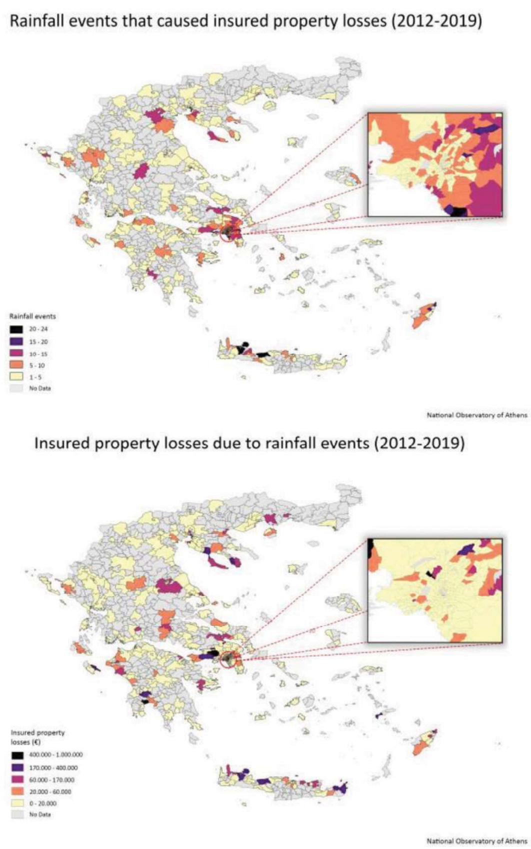

Fig. 2. Number of rainfall events (left) and insured property losses (right) in the period 2012-2019.

Table 1. Descriptive statistics of the vulnerability parameters

Vulnerability parameter	Mean	Std. Dev.	Min	Max	Source
Mean altitude (m)	324.10	316.29	0.91	1420.56	DEM (Digital Elevation Model).
Mean roughness	57.30	40.93	0.54	203.11	DEM (Digital Elevation Model).
Mean flow accumulation	1357.65	4140.89	2.56	70003.12	GIS-based
River land (m2)	223050	904571	0.00	11000000	Corine LCC 5.1.1
Flood events	6.10	8.67	0.00	30.00	HIWEdb, IERSD/NOA (Papagiannaki et al., 2013).
Urban population density	6.31	6.92	0.00	51.70	Census 2011
Education level (up to high-school) (%)	0.76	0.09	0.39	0.94	Census 2011
Age of buildings 21+ (%)	0.61	0.16	0.19	0.95	Census 2011
Urban area (%)	0.27	0.39	0.00	1.00	Corine LCC 1.1.1, 1.1.2, 1.2.1

3.3 Risk assessment

Figure 4a shows a qualitative loss risk index at PC level, which was based on the function:

risk = (frequency of occurrence) x (potential loss magnitude) x (vulnerability)

Specifically, the qualitative index attempts to categorize the already affected areas into 3 classes according to the potential loss magnitude, based on the available dataset covering the period 2012-2019. Thus, it can not be considered an indicator of future risk, the assessment of which presupposes a larger volume of data at such a high spatial resolution. In the context of the YANTAS project, the analysis of the company's exposure to financial risks related to the spatial distribution of weather risks in Greece will be further analyzed, to ensure the sustainable development of the company and its adaptation to current conditions, as these are shaped by the effects of the current climate and socio-demographic conditions.

Figure 4b shows the probability of occurrence (in a scale 0-1) of a high-loss event (loss risk index 3 which corresponds to loss exceeding the 90th percentile), as predicted based on the max 24-h rainfall regardless of the area of occurrence of the events, obtained through logistic regression. This example shows the capability to model the probability of occurrence of high-loss events based on detailed data of losses provided by an insurance company and a rainfall observations provided by a dense network of meteorological stations.

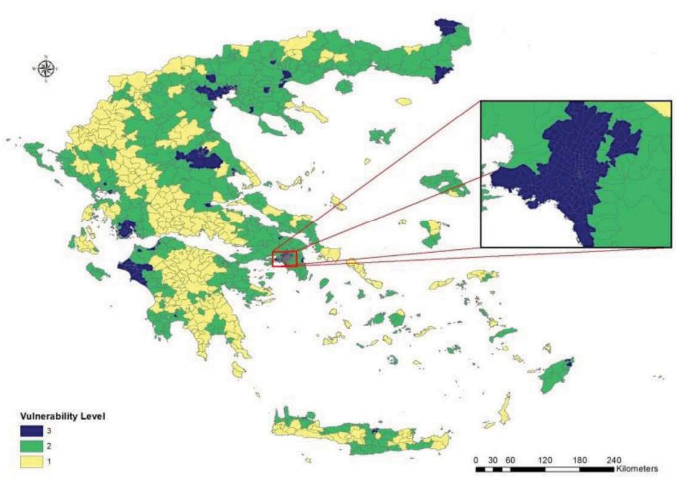

Fig. 3. Overall geophysical-sociodemographic vulnerability to flood hazard.

(a) **(b)**

Fig. 4. (a) Loss risk index (1:low, 2: moderate, 3: high) at the PC scale; (b) Probability of occurrence (0-1) of high-loss (above 90th percentile) as a function of max 24-h rainfall.

4 Conclusions

In the frame of YANTAS project a science-based interactive tool is being developed and tailored to the requirements of INTERAMERICAN for mapping and analyzing insured losses in relation to weather hazards, as well as to vulnerabilities associated with geophysical and demographic conditions and human activities, at Postal Code level. YANTAS project has 2 facets: (a) research by assessing and analyzinge the impacts of weather-related natural hazards on a quantitative basis; (b) capacity building in the insurance industry, towards the implementation of effective insurance practices accounting for local weather conditions. It is important to emphasize that YANTAS system is expected to lead to increased information and awareness concerning the risk by weather phenomena and the vulnerability of specific regions.

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