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CO	Confidential, only for members of the consortium (including the Commission)	

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Rısk from natural hazards and its direct effect in disrupting human livelihood is of special interest for maintaining a sustainable development.

This report focuses on monitoring the exposure term of risk and consequently stresses on the importance of remote sensing in locating the exposed elements. As a result, the highlighted areas would efficiently guide the efforts on hazard, vulnerability and risk assessment.

A set of tools have been developed by the team in cooperation with other FP7 projects and tested over the urban area of Istanbul. This megacity represents an almost unique combination of geohazard level and number of inhabitants, and it is thus a particularly significant test area for our satellite-based exposure mapping approach.

2 EXPOSURE AND VULNERABILITY

The concept of risk has been evolving during the last five decades. It extends from being only hazard-dependent to more complicated approaches considering the mutual interaction of the added components: exposure, vulnerability and capacity. A complete assessment should not be limited to hazard but instead entail all the components of risk. The quantification of the risk notation is often carried through the following equation:

$$\text{Risk} = \text{Hazard} * \text{Exposure} * \text{Vulnerability}$$

Vulnerability is defined as the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards [1]. The term exposure refers to people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Measures of exposure can include the number of people or types of assets in an area [2].

Focusing on the physical vulnerability of a building, it is defined as the probability of a structural failure in the extreme situation of natural hazards like earthquakes. Building-related physical vulnerability can be expressed in the form of indices or curves:

- *indices* - vulnerability is estimated with indicators that are not directly related to the hazard intensity;
- *curves* - based on the interaction between hazard intensities and damage; in particular, they reflect the monotonic increasing relationship between the damage state and the hazard intensity level.

Information related to monitoring the extent of an urban area and its expansion in time are used to complement the previously introduced per-building physical vulnerability.

An integration of efforts with the EU FP7 project SENSUM[1] was fundamental in order to determine the seismic vulnerability interpretation of the area-of-interest. The list of seismic vulnerability indicators included in Table 1 is a product of this close cooperation. It is the result of a broad and comprehensive literature review, including more than 70 papers related to risk and remote sensing techniques. Aim of this list is to define an intersection between capabilities offered by remote sensing and the parameters necessary to define the vulnerability of a given area-of-interest. More details about the suggested algorithms for the extraction of indicators are included in [3].

Table 2. List of seismic vulnerability indicators

Indicator		Data source			
		Remote Sensing		Ancillary Data	Selected references
		Med. Spatial Resolution	High Spatial Resolution		
1	Age of built- up area	X	X	Supplementary	[4] [5] [6] [7] [8] [9]
2	Built- up area	X	X	Supplementary	[8] [9] [10]
3	Land use	X	X	Supplementary	[11] [12]
4	Building Density	X	X		[13]
5	Building footprint		X		[14] [15]
6	Neighbourhood		X		[16]
7	Building age		X	Supplementary	[8] [9]
8	Roof Type		X	Supplementary	[17] [18]
9	Footprint Regularity		X		[18] [19]
10	Building Height		X	Supplementary	[20] [21] [22]
11	Building Alignment		X		[23] [24] [25]
12	Street network	X	X	Supplementary	[26] [27] [28]
13	Road width		X	Supplementary	[25] [28]
14	Construction type		Supplementary	X	[17] [18]
15	Public transportation network		Supplementary	X	[24] [25] [29] [30] [31]
16	Communication Towers		Supplementary	X	
17	Surface pipelines		Supplementary	X	
18	Power Supply units		Supplementary	X	

[1] www.sensum-project.eu

19	Bridges		Supplementary	X	
20	Dams		Supplementary	X	
21	Water supply units		Supplementary	X	
22	Accessibility		X	Supplementary	
23	Open space		X	Supplementary	

3 BUILT-UP AREA EXTRACTION

Built-up areas and their evolution in time are of key importance for exposure monitoring. Satellite remote sensing demonstrates its usefulness thanks to the regular revisit time and the coverage of long time spans that are being increasingly made available on open policies. Extraction of urban areas from satellite imagery is still an open field of research in the scientific community with several different approaches suggested.

The availability of Landsat imagery with its open policy enables public access to one of the longest archives of Earth observation that extends over 40 years. Moreover, the similar spatial resolution for the multispectral bands of the Landsat 5, 7 and 8 enabled a consistent derivation of information from the acquisitions. This type of data was therefore considered as the main input for the algorithms for urban area monitoring with the aim to automatically extract built-up areas using different solutions.

4 ISTANBUL TEST-CASE

The megacity of Istanbul in Turkey extends on a total area of 5,343 km^2. It is situated very close to the North Anatolian fault, running from northern Anatolian to the Marmara sea. The combination of earthquake propensity and high population concentration finds a dangerous and possibly dramatic intersection in the city of Istanbul, reporting a population of more than 14 million people in 2014 [32].

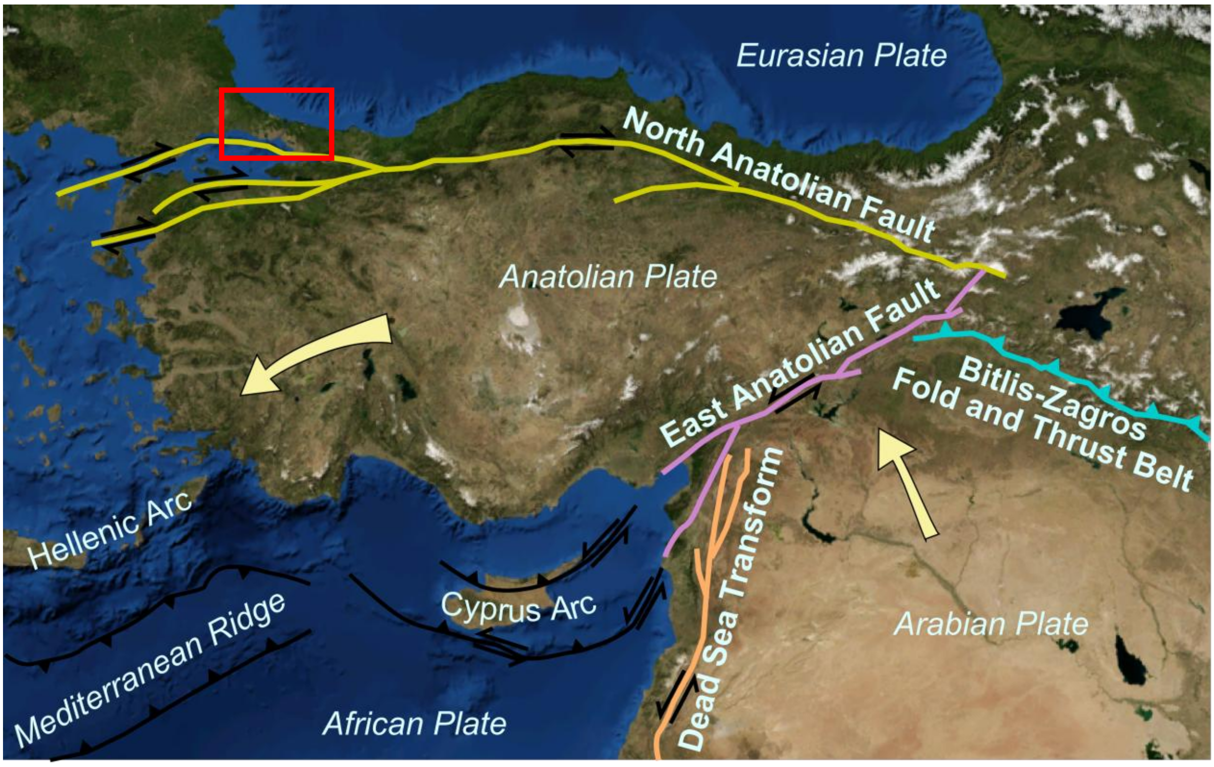

Figure 1. Fault map around the city of Istanbul (highlighted by the red box). Source: Wikipedia

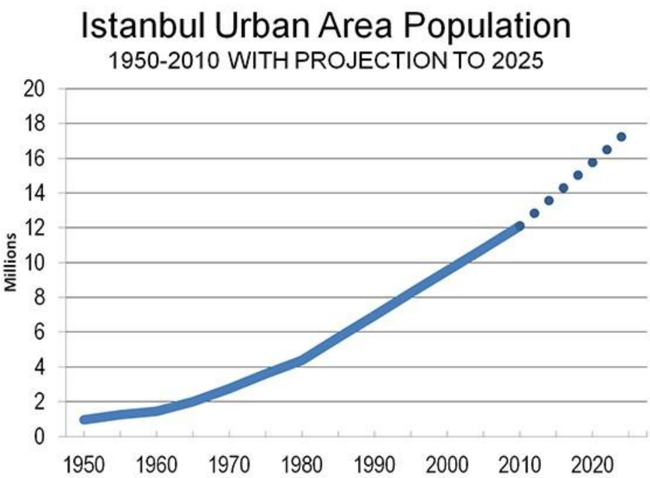

Figure 2. Population of the Istanbul area [33].

The graph in figure 3 shows the population growth, further supporting the statement that the Istanbul megacity is a meaningful test-case. Figure 4 shows the combination of different extractions performed using the dissimilarity-based method [34] over different years. It can be noted how the urbanization on the northern edge of the European side of Istanbul reported in the last decade has been made well visible by mapping the urban area extent at different dates.

These algorithms are included as part of the "SENSUM Earth Observation Tools QGIS plugin", developed by our research group and available from the official QGIS repository[2]. The same procedure can be applied to any relevant site in the Marmara area, thus helping to map the exposure of people and property in the concerned region.

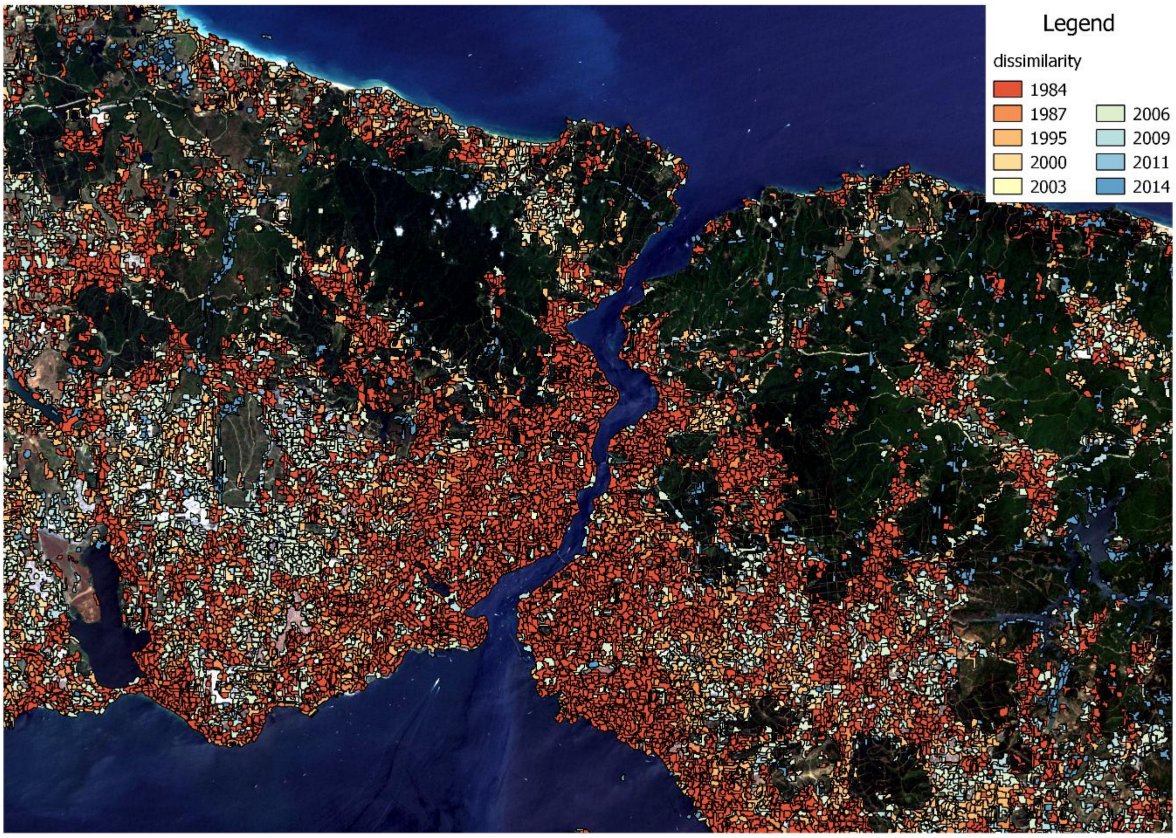

Figure 3. Results of the built-up extraction starting 1984.

5 CONCLUSIONS

This document presented the use of the algorithms developed for exposure mapping to the important test-case of Instabul. In particular, different built-up extraction methods have been applied. The authors would like to spread the word about the algorithms used and to encourage people to test and provide feedback related to the algorithms.

[2] https://plugins.qgis.org/plugins/sensum_eo_tools/

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