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Safety – Sentinel for geohazard prevention and forecasting

Deliverable DE.4.6: Upgraded impact assessment on structures and infrastructures of the Canary Islands test site V2

A deliverable of

Task E: Geohazard impact assessment

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Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	
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EXECUTIVE SUMMARY

SAFETY is a two-year research project funded under the ECHO (European Commission's Humanitarian aid and Civil Protection department) call "Prevention and preparedness projects in Civil Protection and marine pollution", which started the 1st January 2016. The mission of the project is to improve the efforts in detecting and mapping geohazards (i.e. landslides and subsidence), by assessing their activity and evaluating their impact on built-up areas and infrastructures' networks. SAFETY will enhance ground deformation risk prevention and mitigation efforts in highly vulnerable geographic and geologic regions. The outcomes of the project will provide Civil Protection Authorities (CPA) with the capability of periodically evaluating and assessing the potential impact of geohazards on the selected sites.

Deliverable "D.E4.6, Upgraded impact assessment on structures and infrastructures of the Canary Islands test site (V2)" is the final deliverable of Task E, "Geohazard impact assessment", in the framework of the Action E4, "Impact assessment on structures and infrastructures". This deliverable aims at assessing the impact of detected geohazards on road networks and built-up areas. The final map consists in a simplified color scale map indicating the InSAR-derived areas of active deformation that affects structures and infrastructures in a territorial unit (municipality). The final goal is to provide an operable methodology, a protocol, which can be integrated into the Civil Protection prevention activities.

Safety

REFERENCE DOCUMENTS

N°	Title
RD1	DoW Part B
RD2	D5.1: Test site selection
RD3	D2.1: User Requirements

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1 INTRODUCTION

The Impact Assessment maps are one of the four deliverables foreseen in Task E, “Geohazard impact assessment”. This deliverable has been updated three times throughout the project, and aims at assessing the impact of detected and/or assessed geohazards on road networks and built-up areas. The final map consists in a simplified colour scale map indicating the InSAR-derived areas of active deformation that affects structures and infrastructures in a territorial unit (municipality). The final goal is to provide an operable methodology, a protocol, which can be integrated into the Civil Protection prevention activities.

For this purpose, the elaborated hotspot activity maps (action C.2) and the derived geohazard activity maps (action E.3) have been combined with the available geodatabases of vulnerable structures and infrastructures to assess the impact level on the most critical areas, by using analysis tools in a GIS (Geographical Information System) environment.

In this third upgrade of the Action E4, “Impact assessment on structures and infrastructures”, the final version of the methodology to derive the Impact Assessment (IA) maps over the Canary Island test site is proposed. Moreover, the structure of the database connected to the maps is for the first time presented. The IA analysis has been performed on the interferometric products delivered with the Deliverable C2.3 “Canary Islands deformation activity map V2”.

2 METHODOLOGY

In this section, we describe the methodology to generate the Impact Assessment maps on the basis of the Hotspot Activity maps (action C.2), the derived Geohazard Activity maps (action E.3) and the available catalogues of elements at risk (action D2). The methodology is performed in a GIS (Geographic Information System) environment, using basic analysis tools. In Figure 1 the work flow for the generation of an Impact Assessment map is presented.

The methodology aims at intersecting three types of products of the SAFETY project:

1. Hotspot (HS) Activity maps; derived from the Deformation Activity maps (action C.2). They define those areas with deformation higher than a specified threshold (4 mm/yr in this case) that represent a potential hazard;
2. Geohazard Activity maps (action D2). Three types of geohazard activity maps have been defined for the Canary Islands: Volcanic Susceptibility areas and Potential slope instabilities, and Terrain Settlement map for Tenerife Island and Landslide Prone Active areas for the Islands of Gran Canaria and La Gomera (C2.3 “Canary Islands deformation activity map V2”);
3. Classified Element at Risk (EAR) map, derived from the available catalogues of structures and infrastructures (action D2). This classification represents an evolution of the version proposed in the first delivery of the IA map (D.E.2 “Impact assessment on structures and infrastructures over the two test sites of the project – V0”).

In particular, for the elements at risk we propose a qualitative classification system based on the “Strategic Vulnerability (SV)”, parameter that considers the potential damages of a certain structure that is already used, or could be used, or would play a crucial role in the risk management chain of an area or of a municipality. The SV value is defined for three scenarios, referred to the three Civil Protection phases (Table 1):

- First scenario – Prevention Phase (PP). As defined by the European Union (Decision No. 1313/2013/EU of the European Parliament), prevention means ‘any action aimed at reducing risks or mitigating adverse consequences of a disaster for people, the environment and property, including cultural heritage’. The proposed PSI-based methodology provides to this phase tools to reduce the potential risks by forecasting and mapping potential geohazards. For this scenario, we define 3 SV classes:

   - High (H). Elements with not occasional occupancy or with high flow of tourism, emergency and health infrastructures, main road and supply networks;
   - Medium (M). Elements with occasional occupation with an economic or environmental or social value;
   - Low (L). Elements with occasional occupation with a less relevant economic value.
- Second scenario – Emergency Phase (EP). The response to a certain geo-hydrogeological event is defined by the United Nations Office for Disaster Risk Reduction (UNISDR) as 'the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected'. In this phase, PSI-derived data are used to monitor the post-event residual deformations threatening the population and affecting the most strategic infrastructures used within the emergency chain as well as to map secondary geohazards induced by the main hydrogeological event. For this scenario, we define 4 classes of SV:
   - Very High (VH). Most strategic elements, active part of the emergency chain in case of an event;
   - High (H). Elements with people living inside or/and that can be used as recovery structures in case of an event;
   - Medium (M). Elements that can be useful for single phases of the emergency management or with a relevant economic value that represent a valuable resource for the restoration of an area after an event;
   - Low (L). Elements that not constitute a main priority during the event management.
- Third scenario – Recovery Phase (RP). The recovery after a hydrogeological or volcanic event is defined by the UNISDR as 'the restoration of facilities, livelihoods and living conditions of disaster-affected communities including efforts to reduce disaster risk factors'. InSAR data are used in the Recovery Phase to evaluate the possible reactivation of already set off phenomena or the presence of precursors of new movements affecting the areas involved in the reconstruction. For this scenario, we define 3 classes of SV:
   - High (H). Elements that represent a main priority in case of damages restoration or reconstruction works because of their economic or strategic value.
   - Medium (M). Elements that represent an artistic or social value that have to be restored after the main priority elements.
   - Low (L). Elements with a subordinate importance in case of the definition of the actions related to the damages restoration activities.

The final output is composed of three maps, produced for every scenario previously defined. These outputs contain not only the information related to the HS but also to the territorial units in which the Islands can be subdivided. For the application of the proposed methodology, we chose to use the municipalities of the 3 islands as territorial units (21 for Gran Canaria, 6 for La Gomera and 31 for Tenerife). The final maps are composed as follows:

- Municipality polygons classified on the basis of the number of HS falling into the contours. A color bar is used for representing the classified polygons, if no HS are found the polygon is left blank;
- Pie charts, representing the VEAM classification for the HS and so the percentage of vulnerability classes for every territorial unit, are overlapped on the municipality polygons.

A second output of the methodology is composed of a GIS database for each HS selected in the framework of the proposed methodology, characterized by information about the localization of the HS, its characteristics (mean velocity and Quality Index), its Strategic Vulnerability and the potential geohazard. The database will be fully presented in the Chapter 4 of this deliverable.

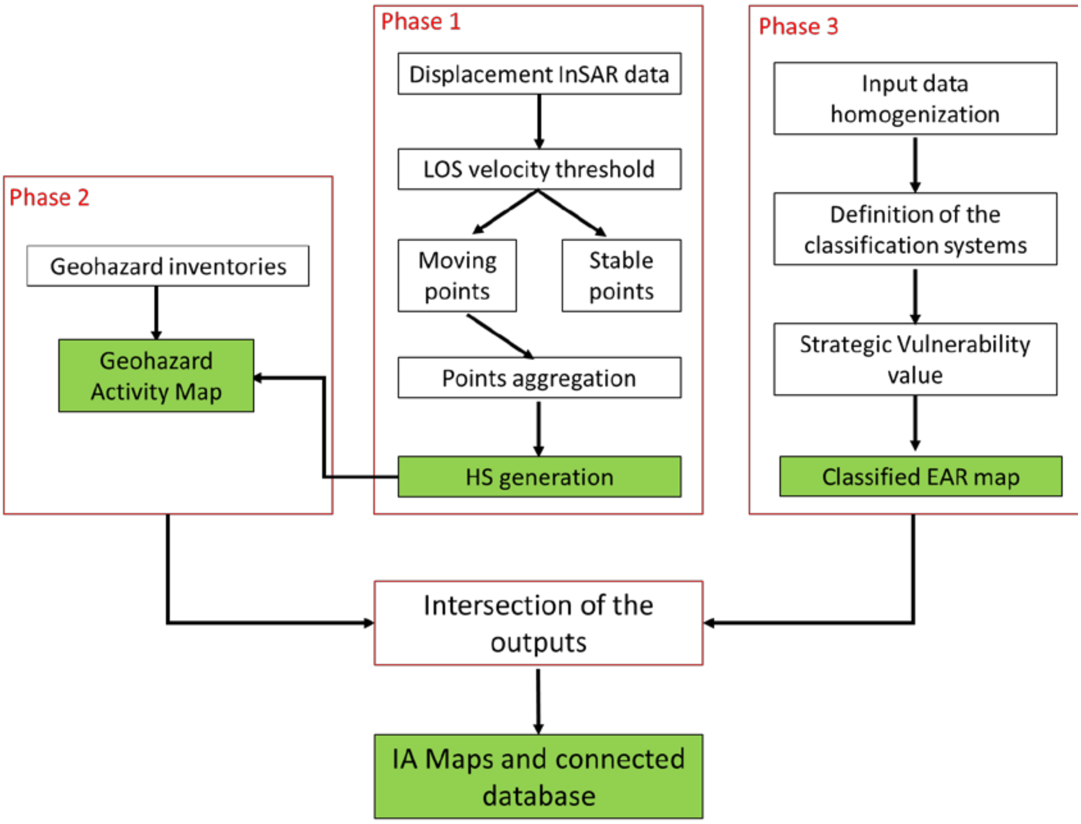

Figure 1 – Flow chart of the generation of the Impact Assessment map for the Canary Island test site. The green charts represent the intermediate and final outputs of the methodology.

Table 1 – Strategic Vulnerability values for each class of elements at risk in the 3 Civil Protection phases.

Type of Element at Risk	SV value for Prevention Phase	SV value for Emergency Phase	SV value for Recovery Phase
Cultural heritage	High	Medium	Medium
Agricultural activities	Low	Low	Low
Gas stations and fuel deposits	Medium	Medium	Low
Hospitals and health centres	High	Very High	High
Hotels	High	High	Medium
Industries	Medium	Medium	High
Markets and shopping malls	Medium	Low	Low
Media-related structures	Medium	Medium	Low
Main Roads and railway network	High	Very High	High

Parking areas and parking lots	**Low**	**Low**	**Low**
Power lines	**High**	**Very High**	**High**
Private houses with continuous occupancy	**High**	**High**	**Medium**
Private houses with discontinuous occupancy	**Medium**	**Medium**	**Low**
Public administration buildings	**High**	**Very High**	**High**
Recreational areas	**Low**	**Low**	**Low**
Secondary Roads	**Medium**	**High**	**Medium**
Schools	**High**	**Very High**	**High**
Sport centres	**Low**	**High**	**Low**
Urban security and Civil Protection structures	**High**	**Very High**	**High**
Waste deposits	**Medium**	**Medium**	**Low**
Warehouses	**Medium**	**Low**	**Medium**
Water supply network	**High**	**Very High**	**High**

3 IMPACT ASSESSMENT MAPS

Applying the methodology to the test site areas we detect 24 (33% of the total) and 39 (32% of the total) HS that affect one or more elements at risk in the first and second iterations of the Deliverable C2.3, respectively.

In the first iteration, 23 out of 24 HS are found in the Tenerife Island, involving 11 municipalities. The municipalities that record the highest number of HS affecting an element at risk are Adeje, Arona and Arico in the Southern part of the island, registering 4 HS each. The elements at risk involved are mainly roads and private buildings with continuous occupancy. In Figure 2 the percentages of HS for each SV class in the different Civil Protection phases are shown. In the Prevention and Emergency phase elements classified as *High* vulnerability are prevalent, whereas, in the Recovery phase, the highest number of HS are classified as *Medium* vulnerability. The derived Impact Assessment map is shown in Figure 3.

In the Gran Canaria Island, only one HS intersecting elements at risk is recorded in the Artenara municipality. Because of this result, the Impact Assessment map of Gran Canaria was not produced, but the HS was anyway implemented in the database associated within this deliverable. In the La Gomera Island any active deformation involves elements at risk.

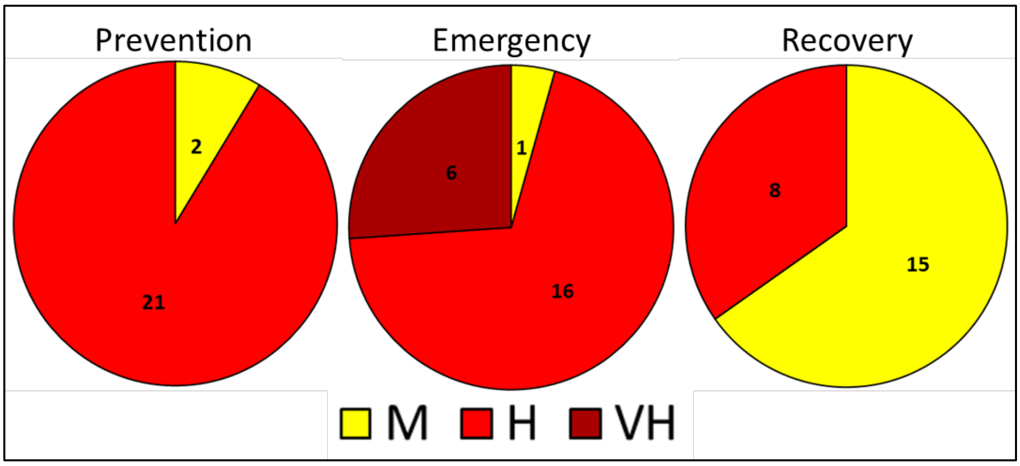

Figure 2 – Pie charts showing, for the 3 Civil Protection phases, the percentage distribution of the HS (first iteration) in each SV class for the Tenerife Island.

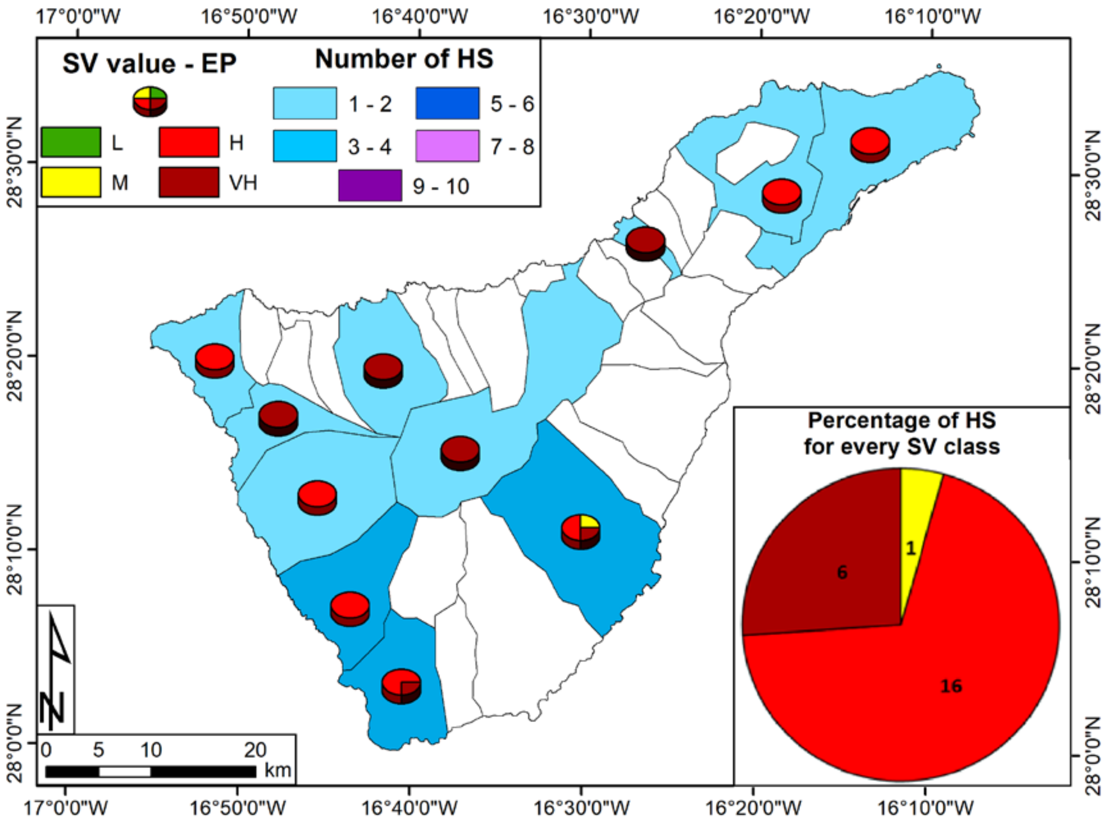

Figure 3 – Impact Assessment map for the Tenerife Island referred to the first iteration of the interferometric processing of the Deliverable C2.3.

In the second iteration, the 89% (35) of the HS intersecting elements at risk are found in the Island of Tenerife, involving 13 municipalities. Arico, Arona and San Cristóbal de La Laguna are the municipalities that record the highest number of HS (5, 9 and 4 HS, respectively). Again, the elements at risk involved are mainly roads and private buildings with continuous occupancy. This fact is in accordance to the fact that almost the 50% of HS selected by means of the proposed methodology intersect between the two processing iterations. In Figure 4 the percentages of HS for each SV class in the different Civil Protection phases are shown. In the Prevention and Emergency phase elements classified as High vulnerability are prevalent, whereas, in the Recovery phase, the highest number of HS are classified as Medium vulnerability. The derived Impact Assessment map for the Tenerife Island is presented in Figure 5.

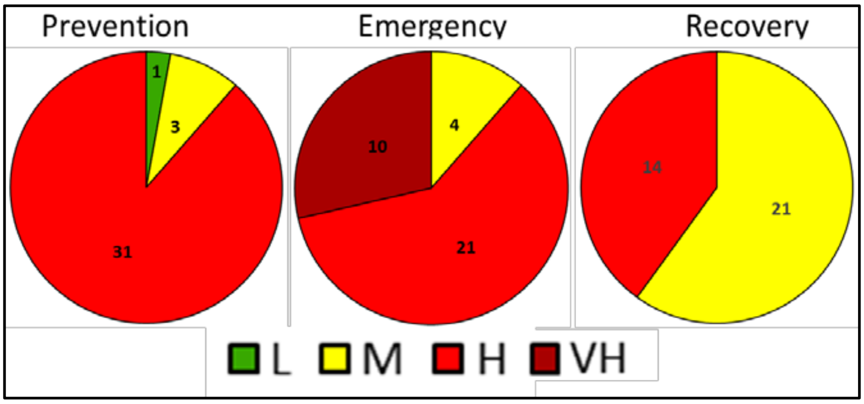

Figure 4 - Pie charts showing, for the 3 Civil Protection phases, the percentage distribution of the HS (second iteration) in each SV class for the Tenerife Island.

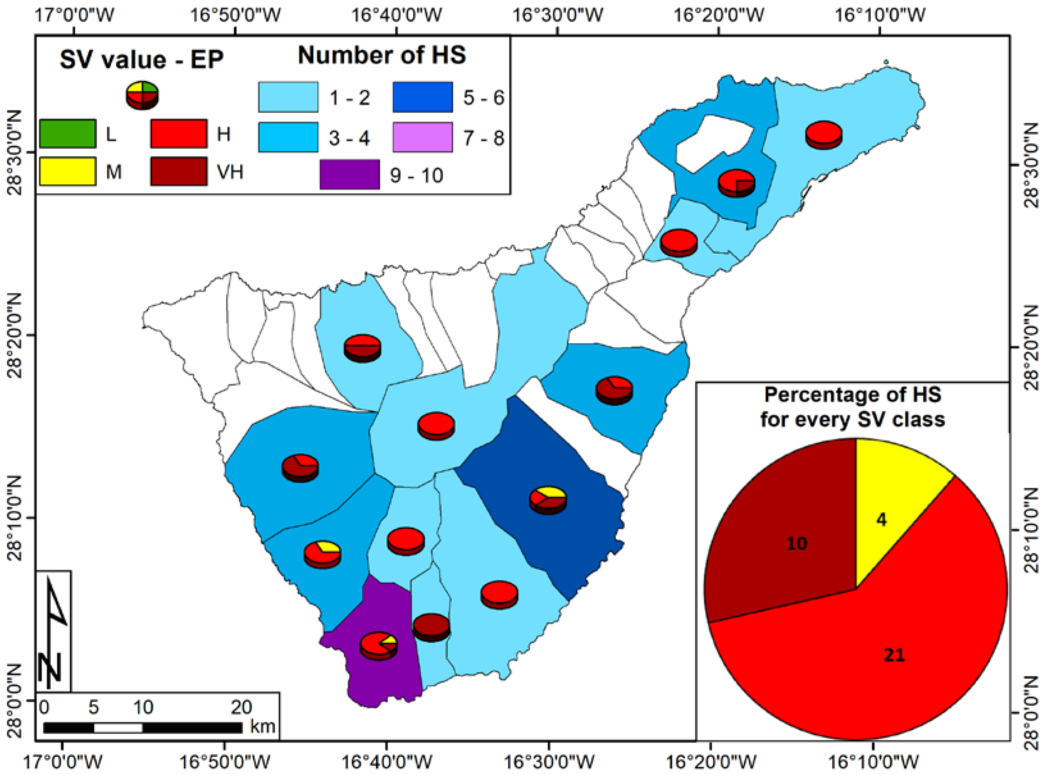

Figure 5 - Impact Assessment map for the Tenerife Island referred to the second iteration of the interferometric processing of the Deliverable C2.3.

Using the product delivered within the second iteration, 4 HS intersecting elements at risk are also detected in the Gran Canaria Island, involving 3 municipalities (Arucas – 1HS, Las Palmas de Gran Canaria – 1HS and Telde – 2HS). The elements at risk are mainly classified in the highest classes of Strategic Vulnerability in all the three Civil Protection phases. In Figure 6 the Impact Assessment map for Gran Canaria is shown.

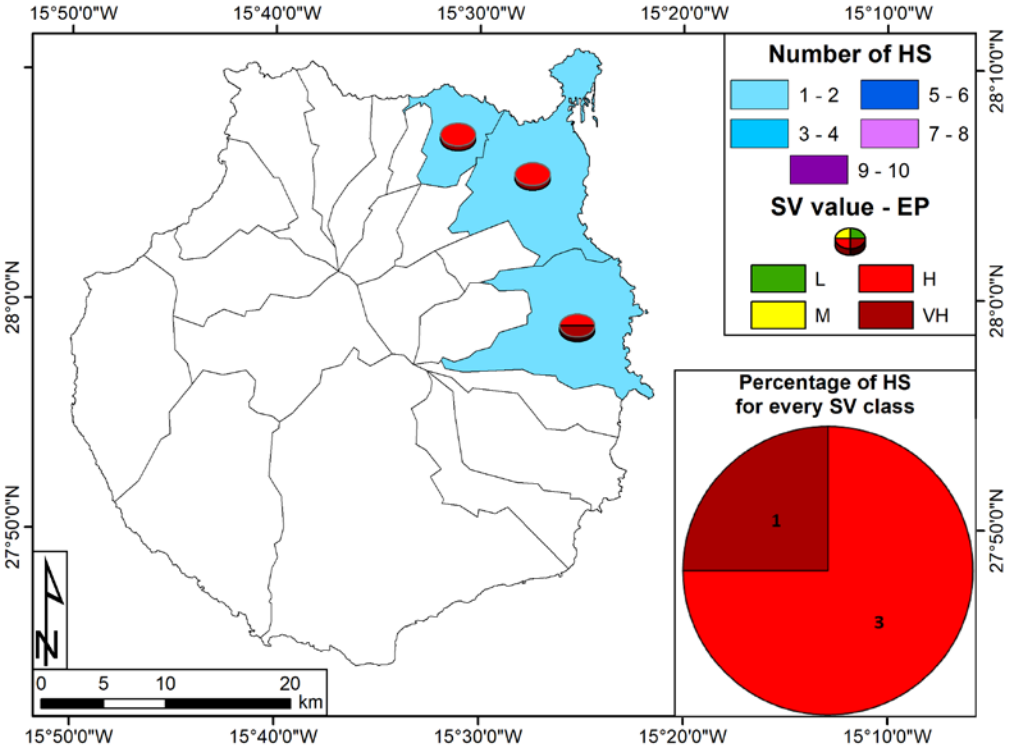

Figure 6 - Impact Assessment map for Gran Canaria Island referred to the second iteration of the interferometric processing of the Deliverable C2.3.

4 CONNECTED DATABASE

Because of the format chosen to represent the Impact Assessment maps, a connected database is needed to characterize the single HS selected within the proposed methodology. This database will be helpful for the Entities involved to know the characteristics of each HS.

The two databases delivered, one for each product of the Deliverable C2.3 "Canary Islands deformation activity map V2", are in shapefile format, easily manageable by the most commonly used GIS systems.

The attribute table of the shapefiles consists in the following fields:

Field	***Description***	***Units/values***
E	WGS84 UTM East coordinate	Meters
N	WGS84 UTM North coordinate	Meters
H	Height referred to the reference terrain model	Meters
Velo_mean	Mean velocity value of the points composing the HS	Millimetres/year
QI	Quality Index of the HS, as defined in the Deliverable C2.3	1 → Reliable HS and Time Series (TS)

		2 → Reliable HS and TS that can be carefully used 3 → Reliable HS and not reliable TS 4 → Not reliable HS
Area_sqm	Areal extension of the HS	Square meters
Island	Island in which the HS is found	\
Municipal	Municipality in which the HS is found	\
Toponym	Nearest geographical reference (name of a road, name of a district, etc...)	\
IA_Pr	Strategic Vulnerability value for the element/s at risk involved defined for the Prevention Phase	1 → High 2 → Medium 3 → Low
IA_Em	Strategic Vulnerability value for the element/s at risk involved defined for the Emergency Phase	1 → Very High 2 → High 3 → Medium 4 → Low
IA_Rec	Strategic Vulnerability value for the element/s at risk involved defined for the Recovery Phase	1 → High 2 → Medium 3 → Low
GAM	Potential slope instabilities and terrain settlement for the Tenerife Island, as defined in the Deliverable DE3.5 – DE3.6 "Upgraded geohazard activity maps over the two test sites of the project". Possible values:	NA → Not Applicable No Interpretation Anthropic Debris flow related Pyroclastic deposits
LPAA	Landslide Prone Active Areas for the Islands of La Gomera and Gran Canaria, as defined in the Deliverable DE3.5 – DE3.6 "Upgraded geohazard activity maps over the two test sites of the project".	NA → Not Applicable Flat Area Low Medium High Very High
Vol_Susc	Volcanic Susceptibility Areas for the Tenerife Island, as defined in the Deliverable DE3.5 – DE3.6 "Upgraded geohazard activity maps over the two test sites of the project".	NA → Not Applicable Yes → the HS fall into the Volcanic Susceptibility contours No → the HS do not fall into the Volcanic Susceptibility contours

5 CONCLUSIONS

This deliverable describes the final product of the Task E “Geohazard impact assessment” over the Canary Island test site. The methodology proposed is designed for defining areas of possible active movements at regional scale with a simple and reproducible work-flow that can be used by Civil Protection Authorities members and that can be implemented in the risk management chain. The obtained results are intended as a way to reduce the time needed for the analysis of an entire InSAR dataset (composed by millions of measurements), proving those areas that represents a critical issue for a territorial unit (municipality) and that can be monitored and validated by ground check surveys.