Grant Agreement No. 718679
Safety – Sentinel for geohazard prevention and forecasting

Deliverable - E2.1 Susceptibility map of the southern Tuscany (Volterra area) test site

A deliverable of Task E:

Geohazard impact assessment

Due date of deliverable: 31/10/2016
Actual submission date: 17/11/2016

Lead contractor for this deliverable: CNR.
Partners: UNIFI

Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
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TN	Technical Note, not a deliverable, only internal for members of the Consortium	

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EXECUTIVE SUMMARY

SAFETY is a two years research project (1 January 2016 – 31 December 2018) funded under the ECHO (European Commission's Humanitarian aid and Civil Protection department) call, "Prevention and preparedness projects in Civil Protection and marine pollution". 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.

D.E2.1 "Susceptibility map of the southern Tuscany (Volterra area) test site" is a deliverable of Task E "Geohazard impact assessment", in the framework of the action Action E.2 "Susceptibility and hazard maps". The action will focus on generating susceptibility and hazard maps using data available in the project test sites (Task D). The results of the susceptibility and hazard assessments will be used to evaluate the impact on the urban areas and infrastructures. The report will describe the susceptibility map prepared for the Volterra test site.

REFERENCE DOCUMENTS

N°	**Title**
RD1	DoW – FormT3a
RD2	

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1 INTRODUCTION

The project Safety aims to provide to the Civil Protection Authorities (CPA) the capability of periodically monitor and assess the impact of geohazards (landslides and subsidence, volcanos, earthquakes) on urban areas. The project's objectives are to improve the ability to detect and map landslides, to assess and forecast the impact of triggered landslide events on vulnerable elements, and to model landscape changes caused by slope failures. Safety is mainly addressed to the CPAs at different administrative levels.

Landslide susceptibility (LS) is defined as the likelihood of a landslide occurring in an area on the basis of local terrain conditions (Brabb 1984). It is the degree to which an area can be affected by future slope movements, i.e. an estimate of “where” landslides are likely to occur (Guzzetti et al., 1999, 2005, 2006a, b). In mathematical language, it can be expressed as the probability of spatial (geographical) occurrence of slope failures, given a set of geo-environmental conditions (Chung and Fabbri 1999, Guzzetti et al. 2005, 2006a).

Landslide susceptibility models and maps were prepared for the Volterra test site located in southern Tuscany. The area presents different types of physiographical and environmental settings, and diverse types of ground failures.

2 LANDSLIDE SUSCEPTIBILITY MODEL

In this chapter, we describe the activities carried out to prepare a landslide susceptibility model at regional scale for the Volterra test site located in southern Tuscany. LAND-SE developed by Rossi and Reichenbach (2016) was used to prepare the landslide susceptibility zonation in the area. The model is quantitative, based on a statistical approach, and follows the framework described in Deliverable “D.E1 Report on tailoring existing knowledge and tools”. The model exploits different methods of multivariate statistical classification: (i) linear discriminant analysis model (LDA); (ii) quadratic linear discriminant analysis model (QDA); (iii) logistic regression model (LRM); and (iv) self-optimizing neural network model (NNM). Moreover, the model considers the combination (CFM) of the single modeling susceptibility results (LDA, QDA, LRM, NNM) or some of them exploiting a logistic regression approach. The analysis requires two input variables: a binary grouping variable (i.e. dependent) showing the absence or presence (respectively 0 and 1) of a landslide, and a set of explanatory variables (i.e., independent). The explanatory variables describe the environmental characteristics for each cartographic unit. The model application follows two phases: (i) a training phase, and (ii) a validation phase. In the training phase the model reconstructs the relationships between the two variables (dependent and independent) whereas in the validation phase, these relationships are verified in different conditions.

2.1 Study area and available data

Volterra municipality is located in the Tuscany region, in central Italy. The municipal area extends for about 250 km^2, between the Era River and the Cecina River valleys (Figure 1). The site is characterized by hilly morphology, with moderate relief and gentle slopes, with elevations ranging from 60 m up to about 630 m a.s.l. From a geological point of view, the area is located in the Pliocene graben-basin, known as Volterra basin, oriented NW-SE and bordered by normal faults (Giannini et al. 1971). The territory is extensively affected by slope instability, mainly shallow slow-moving and complex landslides, triggered by rainfall, falls (Volterra Crags), and gully erosion process in the badland landscape.

To prepare the landslide susceptibility model, we used the following set of thematic data (Data are described in detailed in the Deliverable DD.1: Test site characterization):

- *Geological map.* The formations were grouped in the following 10 lithological classes, considering the geo-mechanical properties and their predisposition to erosion: alluvial deposits, colluvial deposits, conglomerates and breccias, sands and silts, clays, limestones, sandstones, ophiolites (basalts, serpentinites and gabbros), evaporites (gypsum, travertine, anhydrite), marls.

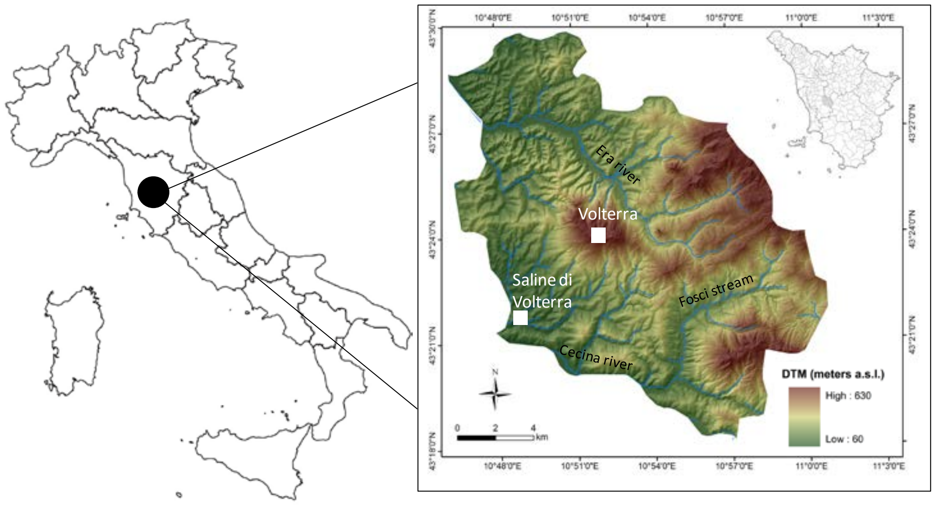

Figure 1. Location of the Volterra municipality.

- *Land use map.* Classes were derived from CORINE Land Cover project in Italy referred to 2006 (CLC, 2006). The level of classification distinguishes among: woods, sparse vegetation and scrubs, pastures, bare soils, agricultural, urban areas.
- *Digital Elevation Model.* The DEM with 10 x 10 m grid resolution was obtained from TINITALY/01 DEM Project and was used to derive slope and curvature (longitudinal and profile) maps.
- *Landslide Inventory Map.* Landslides are classified on the basis of their typology and state of activity.

2.2 The susceptibility zonation

To prepare the susceptibility zonation, we selected the pixel as mapping unit subdividing the territory in cells with a grid resolution of 10 m x 10 m. The landslide inventory map was used as grouping variable and the other environmental and thematic data were used as explanatory variables. Before running the model a data pre-processing phase was necessary to prepare the input variables. Landslide pixels were considered unstable (value 1), the remainders were considered stable (value 0). The DEM was used to derive slope and curvature maps. The Corine Land Cover and the Geological Map were reclassified according to the percentage of landslide in each class. The model was computed using as training data set, the unstable pixel and an equal number of stable pixels and for the validation the entire original area.

In the Volterra area, the analysis was computed selecting only three single different methods of multivariate statistical classification (linear discriminant analysis, quadratic linear discriminant analysis and logistic regression model). Moreover, the combination (CFM) of the single modelling susceptibility results was applied exploiting a logistic regression approach.

For the susceptibility zonation, Figure 3 shows the fourfold plot, the ROC curve and the prediction rate curve (considering the entire study area). The fourfold plots show the contingency table obtained by comparing the grouping variable of the model (0 or 1) to the landslide susceptibility values classified by using a probability threshold equal to 0.5 (i.e. values from 0 to 1 are classified as 0 or 1). The ROC curve (Fawcelt, 2006) obtained for the three kernel. In the graph the area under the ROC curve (AUC_{ROC}) is an index of the performance of the model, a value equal 1 indicates a perfect prediction of the observed data, a value of 0.5 indicates a bad performance of the model, a value less than 0.5 indicates a reversed prediction. The prediction rate curve is a measure of the model performance.

The map in Figure 4 represents the uncertainty associated to the susceptibility model.

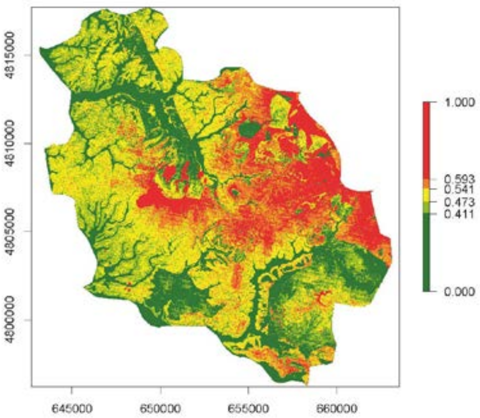

Figure 2. Volterra Municipality. Landslide susceptibility map results in validation phase: (A) Different colours indicate different landslide susceptibility (LS) levels (SL): (i) red, very high susceptibility; (ii) orange, high susceptibility; (iii) yellow, medium susceptibility; (iv) light green, low susceptibility; (v) dark green, very low susceptibility.

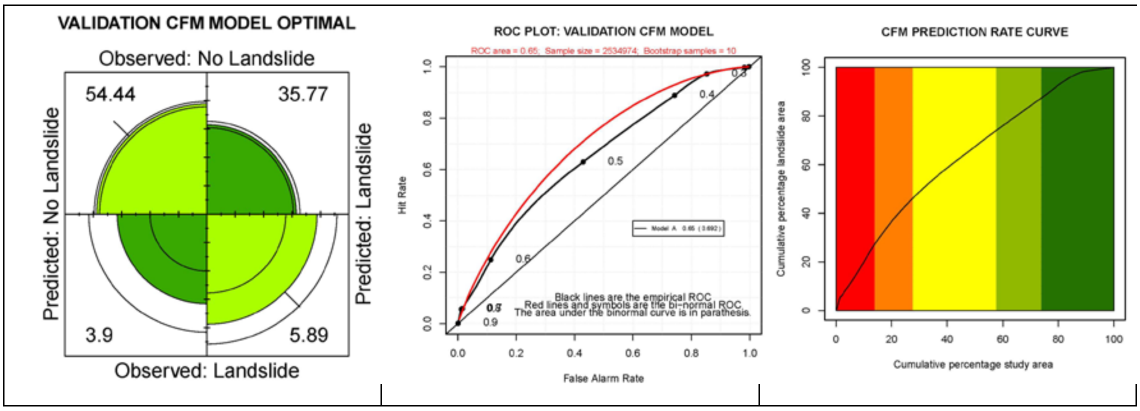

Figure 3. Volterra Municipality. Fourfold plots: in the graphs is shown the percentage of the true positive (TP), true negative (TN), false positive (FP) and false negative (FN); the ROC curve and the prediction rate curve (considering the entire study area).

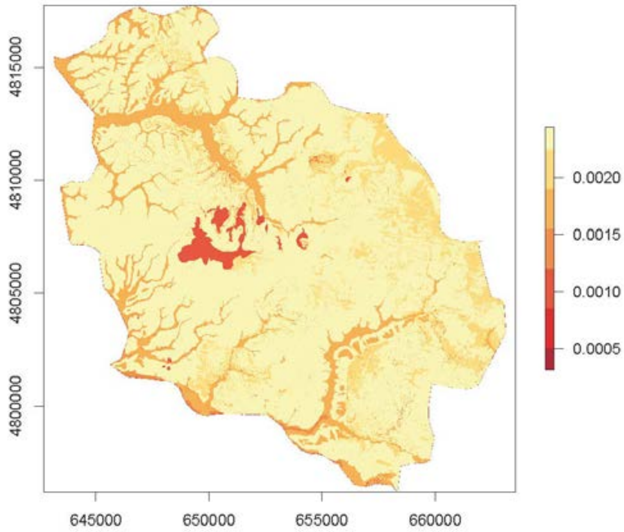

Figure 4. Volterra Municipality. Uncertainty map.

3 CONCLUSION

The susceptibility model and zonation obtained for the Volterra Municipality using a pixel approach, show acceptable results that should be improved with further analysis. The uncertainty map shows locally high values probably associated with the effect of the reclassification of the categorical variables. In further analysis, the selection of polygonal mapping units (slope unit) should be exploited and more pre-processing analysis should be dedicated to prepare the input variables.