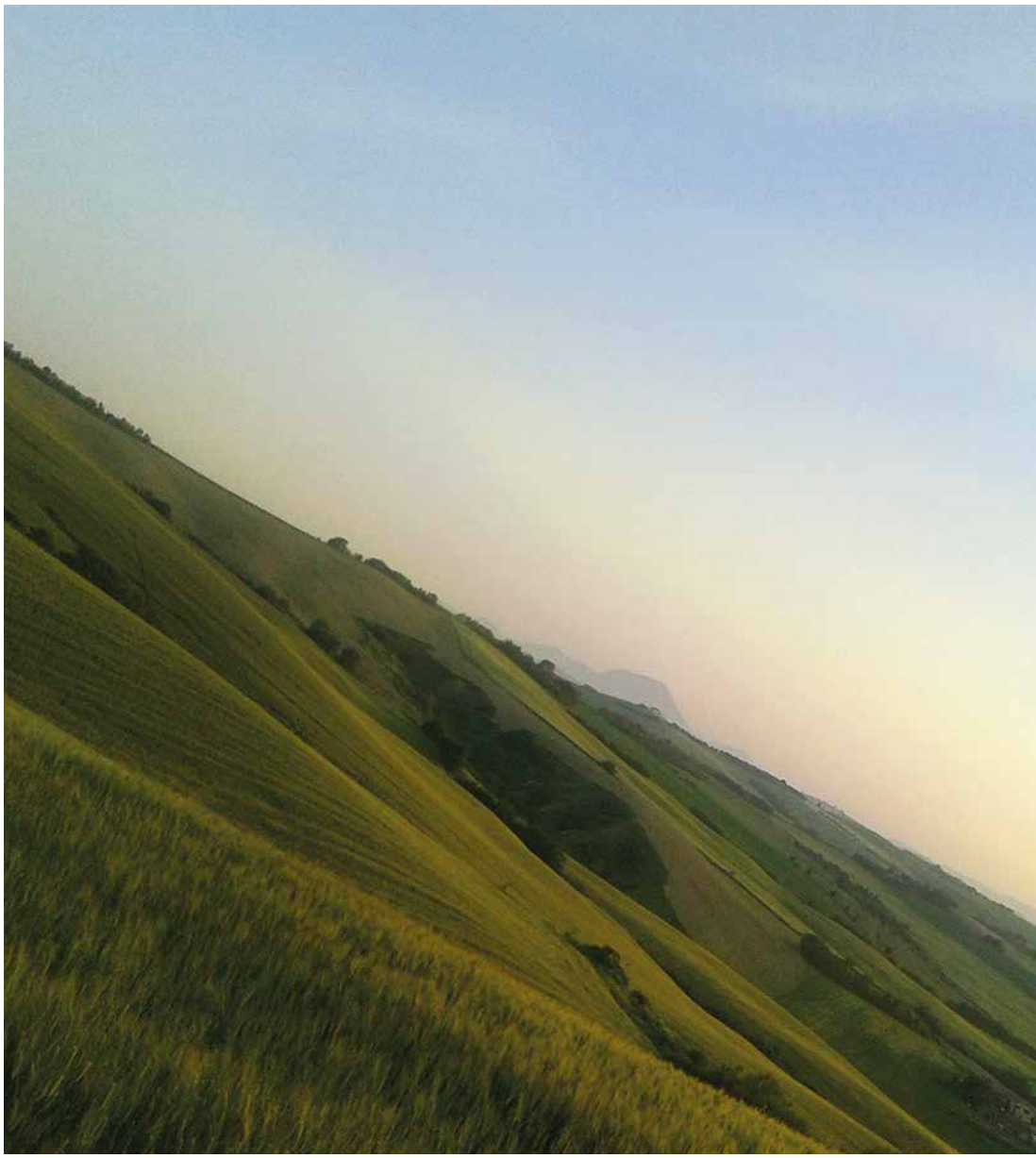
FINAL PUBLICATION
LANDSLIDE PROJECT



Project co financed by
Humanitarian Aid
and Civil Protection

LANDSLIDE
Plan, prevent and protect.

The LANDSLIDE project investigates practical methods for the evaluation of the landslide hazard level from daily weather data, and proposes a new approach for the assessment of a medium-long term index taking into account the effects of climate change.

This publication as well as more information about the Landslide project and its results can be obtained at the project's website or by contacting project partners (project partners and contact details can be found at the end of the publication).

www.landslideproject.eu

CONTENTS

THE LANDSLIDE PROJECT

Why?

Landslides occur in many different geological and environmental settings across Europe and are a major hazard in most mountainous and hilly regions. Every year landslides cause fatalities and large damage to infrastructure and property. Intense and/or long lasting rainfall represents the most frequent trigger of landslides in Europe, and is expected to increase in the future due to climate change. In addition, population growth and expansion into landslide-prone areas is further raising landslide risks in Europe.

Actual methods for landslide evaluation are today mainly based on scientific literature of geomorphologic studies and of historical landslide events which do not consider or underestimate the impact of climate change.

Therefore, it is important to provide new tools that can adapt to the new conditions by correctly evaluate and predict landslide hazards, which is a fundamental prerequisite for accurate risk mapping/assessment and for the consequent implementation of appropriate prevention measures.

"Ancona big Landslide", 1982 Italy

Objectives

Against this background, the aim of the LANDSLIDE project, financed by DG Humanitarian Aid and Civil Protection of the European Commission, was to develop an innovative risk assessment tool to predict and evaluate landslide hazards.

Drilling operation in Bielsko-Biala District, May 2015
Landslide project

Samples from drilling operation in Ancona, July 2015
Landslide project

This enables to make completely automatic predictions on a day to day basis of landslide hazards, as well as to correctly evaluate the impact of climate change, in a medium long term. The partnership, made up of 6 partner organisation coming from Italy, Bulgaria, Greece and Poland, have jointly developed, adapted and tested the model and software within four hydrographic basins selected as test sites.

In particular, the specific objectives were:

- to develop a Landslide Hazard Assessment Model and Software for shallow landslide events triggered by rain fall, that on the basis of weather forecasts, predicts the corresponding landslide hazard.

- to test and transfer the Landslide Hazard Assessment Model and Software into the civil protection systems of the partner territories involved, all located in landslide-prone areas.

- to involve other sectors concerned in risk prevention and mitigation, by providing them with the new landslide hazard/ risk maps, enabling to consider risk prevention into their respective planning and development policies.

- to involve the people directly concerned by the identified risks, to make them engage in self-protection and prevention activities and to distribute the responsibility for risk prevention at different levels of the community (land-owners, farmers, industry, citizens, etc.).

The novelty of this proposal is the practical approach used in developing an innovative method for the dynamic landslide hazard assessment (hazard depending on meteorological variables), the possibility to evaluate possible weather scenarios and the medium and long term landslide hazard through the statistical analysis of the day by day dynamic landslide hazard results; all elements which will support the prevention capacity. The main scientific tools for the construction of this system are the mathematical models for soil moisture dynamics, and slope stability analysis. Both these models have been developed on the basis of a wide scientific literature, and through an adaptation process carried out in four different hydrographic basins in four countries selected as test areas. Furthermore, the model and software has also been tested and transferred through the involvement, not only of the civil protection system, but also of the relevant authorities and socio-economic actors. This process of joint development, test and transfer will ultimately allow to provide other territories with proven methods, instruments and tools.

PROJECT ACTIONS AND RESULTS

Three action phases have been carried out to achieve set objectives and to produce the expected project results:

Development of the Landslide Hazard Assessment Model and Software

Testing the Model and Software through pilot activities

Setting up Local Cross-sector Risk Prevention Platforms and carrying out of Prevention Days

Action 1: Development of the Landslide Hazard Assessment Model and Software

The first action phase concerned the very development of the "Landslide Hazard Assessment Model and Software", the selection of 4 hydrographic basins (test sites) and the creation of a common framework for correct adaptation and fine-tuning of the model to the four selected test areas.

a) Development of the MODEL

The LANDSLIDE project provides new tools for predicting landslide hazards which is a fundamental prerequisite for accurate risk mapping. These tools are based on physical models and allow for an automatic adaptation to new weather conditions arising from climate change.
Precipitation is the most important landslide cause; it increases the load on the soil surface and the water pressure inside the soil pores that is estimated from the soil water content.
The LANDSLIDE software combines the dynamics of the soil moisture, with a model that calculates the slope stability for a quantitative evaluation of landslide hazard.

The University of Camerino (Italy) and the Institute of Information and Communication Technologies (Bulgaria) developed and implemented the LANDSLIDE software. The main outcome of the software is given by the Hazard maps and the Depth maps. The Hazard map (see Figure 1) indicates the probability that a landslide occurs in the considered area. The Depth map (see Figure 2) shows the depth at which the hazard index (shown in the Hazard map) is computed; so it can be used to evaluate the volume of the eventual landslide.

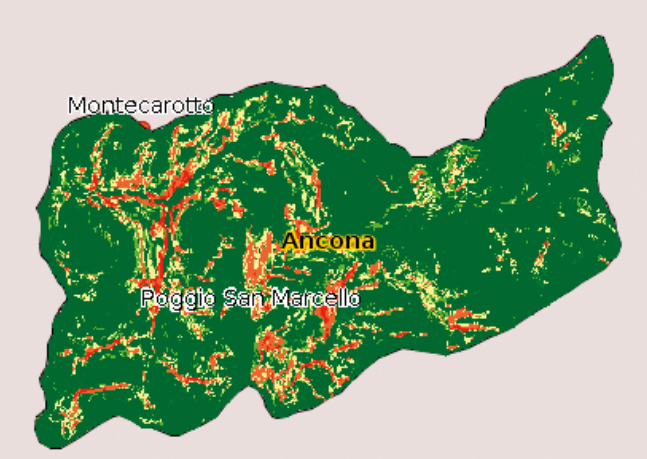


Figure 1: Hazard map of Ancona area (Italy)

Figure 2: Depth map of Ancona area (Italy)

The operational structure of the LANDSLIDE software is mainly composed of two types of operations: on-line operations (performed automatically) and off-line operations (when requested by the users).

On-line operations are given by the following actions:

1. At the beginning of the day, it acquires the weather forecast for the next 24 hours;
2. It computes the soil moisture for the next 24 hours on the basis of weather forecast data;
3. It computes 4 landslide Hazard maps (1 map every 6 hours) and the corresponding Depth maps;
4. It waits for the end of the day;
5. It gets the data measured by the weather stations on the territory;
6. It computes the soil moisture at the end of the present day on the basis of weather stations data.

Off-line operations are:

- Statistical analysis of the landslide hazard maps: the user can obtain the cumulative landslide hazard map on time periods of a week, a month, a year.
- Scenario analysis of the landslide hazard: the user can obtain the evolution of the current landslide hazard by providing a scenario for future weather data.

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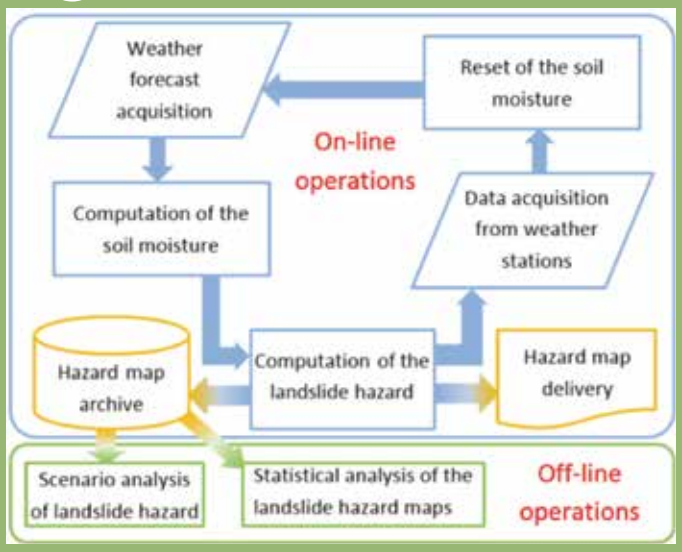

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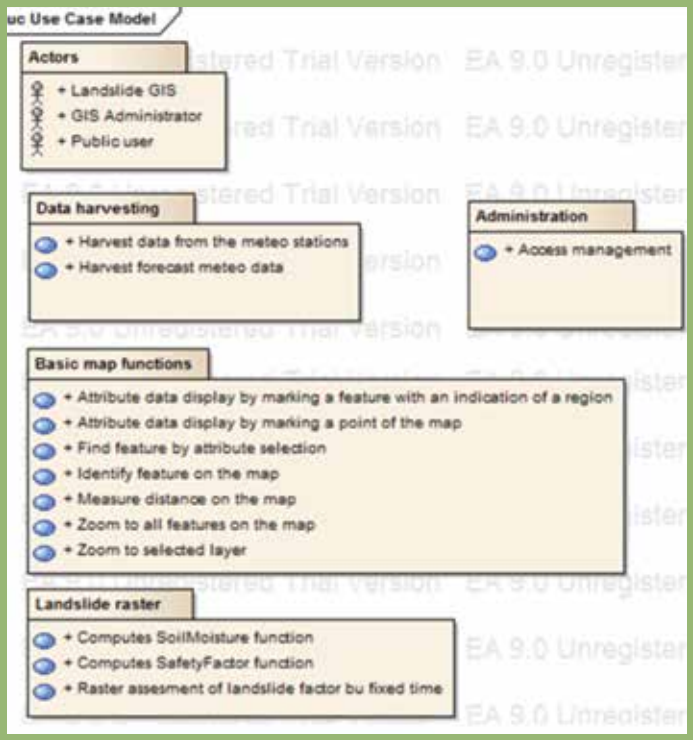

Figure 3
LANDSLIDE flowchart

Figure 4
Use case model in the LANDSLIDE project

b) Development of the SOFTWARE

E-platform architecture and design in the LANDSLIDE project

During the first year of the project lifetime the team from IICT-BAS together with the help and support of the University of Camerino and the partner territories started data collection for all appointed test sites in Italy, Poland, Bulgaria and Greece into one common GIS (Geographic Information System) database. This was done in order to make the model, developed by the University of Camerino in Italy, able to start validate and test its functionalities by processing all incoming meteorological and soil data from the test regions. A summary of the software use case model is shown in Figure 4.

Main road connecting Smolyan region with central Bulgaria Landslide March 2015

The main actors were divided in three general groups in the system. The first group is dedicated to users from the project, the second is dedicated to the GIS administrators of the system and the third which is public is oriented to the WEB users of the system.

The system architecture was made in a way that the WEB site can dynamically generate map content and present any kind of spatial data or attribute query for it. The architecture was done in a way to be compatible with any kind of platforms (UNIX, Windows etc.), with J2EE compliant server. The tool design was done to be compatible and run on any JAVA enabled Internet browser or standalone ones including any platform with JRE 1.1.8 or greater for SUN Microsystems.

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Figure 5
General view of the web application

The e-platform general visual representation

During the second year of the project lifetime the use case models together with the project web-site designers developed a user-friendly web dynamic map for landslide risk assessment based on a server application called TIMS (Technologica internet map server) in order to have as close as possible to the real eye perception environment for the representation of the landslide probability maps. All designed tools were incorporated from widely spread GIS environment tools helping and supporting the users to better navigate themselves on the web map. The entry map for a new user can be seen in Figure 5.

The dynamic web entry map has all information of the meteorological and soil data incorporated in the test areas and every user can see the information if entering the test site of interest. The registered users have offline options and download opportunities as extra utilities in order to perform analysis with the collected information.

Action 2: Testing the Model and Software through pilot activities

Once the model and software were developed, a pilot phase was launched in which the Landslide model and software could be tested. This was ensured, first through training courses for civil protection staff to learn how to use and run the software, and subsequently through a test phase where each partner could test and use the software in the framework of its respective risk mapping and prevention activities. This phase was also accompanied by a helpdesk service to sustain the process of transferring and implementing the model and software into the local civil protection systems of the respective partners.

Region of Western Greece
hit by the "Panagopoula" landslide in April 1971

Landslide in "Karia" village
South East of Patras city, 2001

The last decade Region of Western Greece struggles to manage the landslides' impacts. Several landslide events occur every year in many locations, each one with different characteristics. The majority of events are serious threats to infrastructures (villages, enterprises, transport networks), and restoration consumes too much time, resources and effort. National Observatory of Athens selected as pilot project in the Region, the "Panagopoula" landslide, where impacts are extended closure of both road and rail network connecting capital of Greece (Athens) with main western Greece port (Patras). In "Panagopoula" major infrastructure works are in progress (rail and road tunnels). The availability of past data, coupled with Landslide drillings results allowed testing reliability of Landslide model and software. This pilot case is famous in Greece helping NOA to attract interest from other authorities in landslide risk prone areas.

The initial training events differentiated in synthesis of audience, ranging from civil protection personnel to mayors, public servants, researchers, engineers and representatives of public work construction companies. The major training event was held in Patras within the premises of Region of Western Greece, involving all key stakeholders' and end users' groups. The top issues raised, were reliability of results and conditions for achieving transferability to other areas facing landslides. Fulfilling those demands, model and software will be adopted by many end users after project termination.

Another major training event took place in Florina city, capital of Region of Western Macedonia, where synergies with the project RECALL –dealing with landslides from a different perspective– were sought. There, LANDSLIDE model and software were judged complementary to efforts done by local teams to identify precursor phenomena and also in prioritizing prevention actions.

State Electricity Company (ΔΕΗ) showed also great interest in LANDSLIDE results, as many dams in mountainous areas are being threatened by landslides and both model and software could support on time diagnosis and subsequent corrective measures. A team of engineers were trained in a series of events in various locations of Northern Greece.

Training events made evident the great interest in LANDSLIDE project model and software. As landslides are not usually considered top priority in civil protection, wide participation of stakeholders and end users underlined the maturity of society to seek and implement solutions that are reliable, transferrable and can be used at reasonable cost.

The Marche Region, mainly due to its morphological and geological configuration, is a region very prone to landslides. This phenomenon regards almost the whole part of the territory, from the Apennines chain on the west to the central-eastern zone, where population, economic activities and infrastructures are concentrated.

The pilot area for the LANDSLIDE project (in Italy) covers a territory of about 11 square kilometres and was selected for different reasons: the characteristics of the zone could represent very well the situation of a large part of the Marche region, it is a hilly area with a large number of landslides, with main roads that connect small cities, and with the presence of several economic activities in the territory.

Furthermore in the selected area, previous geological and geotechnical studies of past landslide events are available as well as information from weather stations of the regional meteorological network located nearby.

Drilling operations were carried out in the area concerned and the measure of the spread of the soil moisture with the depth, together with data from other surveys and analysis conducted in the past, have allowed to reach a good knowledge of the ground.

The test phase started during late spring, by acquiring knowledge of the software and the different functionalities of the web platform. So the use of the software application included the daily control, during the entire test period, of the software outputs (maps), especially when rainfall was predicted by the meteorological forecast. This was important, to survey the correspondence between the increasing hazard degree in the map with the amount of cumulated rainfall and the related soil moisture contents. The display of the trend for the different data of the weather stations is also useful, as it quickly provides important information for the users. The application is very easy to use.

The "download" command, that permits to have the historical information of the hazard and depth map in the past is very interesting. These functionalities could be very important not only for prevention activities in the landslide management but also for other types of studies, e.g. to find a correlation between rainfall during the seasons and the state of the safety factor in the area in question.

The test phase has highlighted the needs for some improvements: how to manage the outputs downloaded, what is the most useful number of classes to be visualized in the legend of the depth map or hazard map (e.g. many classes of Safety Factor values could be useful for better evidence of the actual situation and the different hazard degree of the slopes in the area or, on the contrary, the reduction of the classes to evaluate only the real dangerous situations at the moment).

Finally, it is important to consider that this instrument could be implemented also in other areas, so this model could become a useful support also in other local contexts.

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Photo 6
New weather station in Greece
Landslide project

Photo 7
Landslide event in the hilly part of Marche region, 2011

Photo 8
Testing the Landslide Software
Marche Region, Italy, 3 October 2016
Landslide project

Action 3: Setting up Local Cross-sector Risk Prevention Platforms and carrying out of Prevention Days

The project's final action phase then aimed at taking a sustainable approach to risk prevention, both cross-sectors, and at different levels involving the individual level. This was done through two types of actions:

a) Setting up "**Local Cross-sector Risk Prevention Platforms**" in each partner country through the carrying out of several meetings with stakeholders from different sectors. The aim was to:

- present the Landslide model and software, the training platform and other project outcomes;
- to ensure that all relevant services and sectors get a better understanding of the landslide risk in their area and how their policies and activities affect or are affected by landslide risks;
- to start a permanent process of integrating risk reduction into respective development policies and plans.

b) Carrying out of **Prevention Days** in each partner territory to make e.g. individuals/residents, farmers, and/or other groups of individuals living in the risk area or else having an interest in the area to understand:

- the risk and the potential consequences caused by a landslide event;
- how their activities and/or behaviour affect, or are affected by landslide hazards in order to make them engage in landslide prevention, self-protection and resilience, to reduce present and future vulnerability.

Specifically designed awareness raising events took place in each partner territory, tailored to the risk groups and the identified risk of the areas concerned.

Overall aim:

To present the developed model, the training platform and the software forecasting the occurrence of earth movements, for a wide range of stakeholders across various sectors. Discussion about ongoing and future actions taken in the framework of the project.

Organising body:

Bielsko-Biala District

Other organisations involved:

Mountain Volunteer Rescue Service

Place of implementation:

Headquarter of Mountain Volunteer Rescue Service in Szczyrk

Target groups / Participants:

District Crisis Management Team: Chief Officers of combined rescue services (State Fire Service, Police, Emergency Ambulance Service, Mountain Volunteer Rescue Service, Water Volunteer Rescue Service), the directors of district organizational units (Family Assistance Center, Road Administration, Building Supervision Inspectorate), the officers in charge of the interacting units (Military Replenishment Command, Veterinary Officer, Sanitary and Epidemiological Station, Silesian Provincial Board of Land Melioration and Water Units, Forest Inspectorate, Crisis Intervention Centre of Podbeskidzie region), together with the management and the selected heads of the District Office Departments in Bielsko-Biala (i.e. the department of: Environment, Agriculture and Forestry, Construction, Health, Communications and Transport, Property Management, Organization and Supervision) and employees of the Crisis Management Department.

Date of implementation:

9th September 2016

Platform meeting:

During the meeting, a presentation was delivered showing some basic information about the project, defining it's duration, goals and work progress. The participants became familiar with every stage of the project being implemented by Bielsko-Biała District Office, starting with the selection of research area up to the ongoing stage, namely: the implementation of "Prevention Days" and meetings with the project's stakeholders. Each person became acquainted with the elaborated model, the training platform and the software developed in order to predict the occurrence of any earth movements.

Bielsko Forest Inspectorate owns a weather station located within a distance of 14 km from the landslide area, and that station was connected to the international website OpenWeatherMap which has been used to download and upload current data provided to the elaborated model. A discussion took place about some further sharing of data coming from the weather station and the creation of a separate software account for Bielsko Forest Inspectorate.

Material/tools used:

Multimedia presentation, the Training Platform, the Landslide software, promotional gadgets, leaflets.

Feedback and evaluation:

All the staff members of the District Crisis Management Team are very much interested in the further development of the project and the perspectives to use its outcomes in order to monitor some future landslides. The Forest Inspectorate of Bielsko-Biala agreed to keep lending the weather station; moreover, they would like to be provided with their own account to be able to use the Landslide software.

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Photo 9
Local cross-sector meeting in Bielsko-Biala District, Poland, September 2016
Landslide project

Photo 10
Prevention Day in Bielsko-Biala District, Poland, August 2016
Landslide project

Photo 11
Prevention Day in Bielsko-Biala District, Poland, September 2016
Landslide project

Overall aim:

Presenting the project (objectives, activities, achieved results), organisation and activities of the self-operative volunteer units to risk prevention. Discussion about how to implement the Landslide Hazard Assessment Model and Software for disaster prevention and mitigation.

Organising body:

Project Team of Regional Administration Smolyan, Bulgaria

Other organisations involved:

Chief Directorate Fire Safety and Civil Protection

Place of implementation: *Hall 115 in the building of Regional Administration – Smolyan, Bulgaria*

Target groups / Participants:

representatives of self-operative volunteer units of Civil protection from 10 Municipalities in the Region of Smolyan.

Date of implementation: *20 October 2016*

Prevention Day: *25 People were invited and attended the prevention day. Several presentations were shown in connection with presenting the project, the developed software, as well as some main issues about the organisation and activity of the self-operative volunteer units and their contribution to risk prevention. A discussion was held on options for implementing the developed Model and Software in the municipalities in the Region Smolyan. The desire to upgrade the project with possibility of financing the implementation of the Model and Software in other areas was expressed.*

Material/tools used:

Presentations, folder, pen, project flyer, Guideline "Protection at critical moments and preventive measures against major natural hazards"

Feedback and evaluation:

All participants completed an evaluation form for the event and the overall assessment is very good, because of great importance for the development of tourism in Smolyan Region are the roads; to be normally passable and to be prevented and not closed due to landslides. We hope that the developed Model and Software will be able to anticipate and prevent landslides. The participation of the Regional Administration Smolyan in this project is of paramount importance and we are grateful that we can use the good experience from our partners from Italy, Poland and Greece. It would be better to upgrade this project to have financing for its implantation into other areas of the field.

Press & media in Smolyan Landslide project

Prevention Day in the Region of Smolyan, Bulgaria, October 2016 Landslide project

FURTHER READING, PROJECT TOOLS AND CONTACT DETAILS

Please consult:

- The **Practical Handbook** that can be downloaded from the Landslide website at the following address: www.landslideproject.eu/index.php/tools
- The **Training Platform**: www.elearning-landslides.net
- The **Landslide Hazard Assessment Model and Software**: http://93.123.110.111/landslide
- The **Tutorial web based tool**, i.e. Q&A during the implementation of the pilot phase: www.landslideproject.eu/index.php/tools
- The project **Bulletins**: www.landslideproject.eu/index.php/online-bullettin
- **Landslide project website**: www.landslideproject.eu

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Photos: the photos included in this publication illustrates activities carried out by the partner organisations of the Landslide project, as well as damages caused by landslide events in the partner regions.

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Landslide Risk Assessment Model for Disaster Prevention and Mitigation

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