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LANDSLIDE
Plan, prevent and protect.

The LANDSLIDE project: the assessment of hydrogeological risk

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EUROPEAN COMMISSION
Humanitarian Aid & Civil Protection

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Period: 1 gennaio 2015 – 31 dicembre 2016

Total budget: 574.939,97 €

Project consortium

- University of Camerino, Italy (coordinator)
- IICT, Bulgarian Academy of Sciences, Bulgaria
- National Observatory of Athens - Institute of Geodynamics, Greece
- Marche Region, Italy – Test area 1
- Regional Government – Smolyan, Bulgaria – Test area 2
- Bielsko-Biala District, Poland – Test area 3
- Region of Peloponnese, Greece (lettera di supporto) – Test area 4

Project objectives

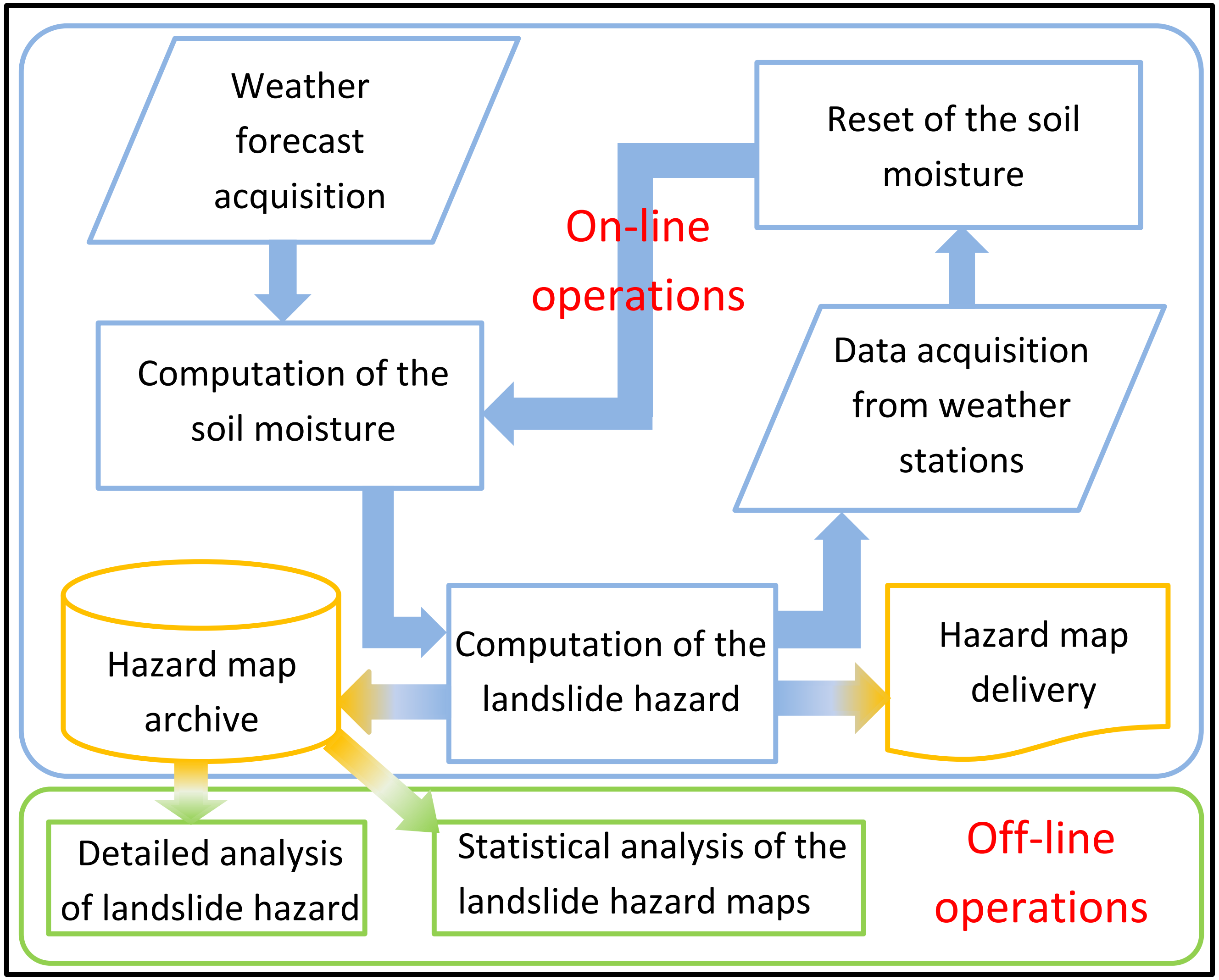
- To develop an assessment model for the landslide hazard from weather events and to implement this model in a web-based tool to compute the daily hazard level.

- To test and validate the model and the computational tool in operational environment.

- To involve the civil protection system and other institutions that are responsible for the hydrogeological risk management.

- To involve the population exposed to hydrogeological events in information events on prevention and self-protection measures.

General scheme of the information system



Mathematical models involved in the system

- Water movement in the soil (porous medium): *Richards equation*, that is a physical model easily adaptable to different geographical areas.

- Slope stability (safety factor):
  - *Infinite slope model* for the analysis of large geographical areas,
  - *3D-column model* for the analysis of limited geographical areas with critical situations.

- Time-series analysis of the short-term risk indices to compute long-term risk indices (susceptibility index + weather impact).

Water movement in the soil

The three dimensional subsurface flow of saturated and unsaturated porous medium can be described by Richards equation:

$$\left(C(\psi) + S_s \, \frac{\theta(\psi)}{n_\varepsilon}\right)\frac{\partial \mathrm{h}}{\partial t} = \frac{\partial h}{\partial x}\left(K(\psi)\frac{\partial h}{\partial x}\right) + \frac{\partial h}{\partial y}\left(K(\psi)\frac{\partial h}{\partial y}\right) + \frac{\partial h}{\partial z}\left(K(\psi)\frac{\partial h}{\partial z}\right) + W$$

where:

$h = \psi + z$ (where z is the elevation) is the hydraulic head,

ψ is the pressure head,

$C(\psi)$ is the specific capillary capacity,

S_s is the storage coefficient,

n_ε is the porosity,

W is the recharge term

$K(\psi)$ is the hydraulic conductivity,

$\theta(\psi)$ is the volumetric moisture content,

Remark: the functions $\theta(\psi)$ and $K(\psi)$ are described by empirical formulas: the Van Genuchten model [van Genuchten, *Soil Science Society of America Journal*, **44**(5) 892, 1980] is one of the most used in the numerical computations.

Remark: the initial and boundary conditions describe the initial distribution of the hydraulic head h inside the space domain and the interactions along the domain boundaries

Numerical approximation scheme

- Predictor-corrector iteration based on Euler and Crank-Nicolson schemes
- Parallel computing implementation

[Egidi et al., *International Journal of Computer Mathematics*, **97**(1-2) 2, 2020].

Slope stability analysis

The shear strength S acting on the slip surface is compared with the shear strength S_f of the materials resisting along the slip surface. The fraction of these contrasting forces gives the factor of safety FS

$$FS = \frac{S_f}{S}$$

$FS>1$ indicates a stable slope, $FS=1$ indicates a state of limit equilibrium, while $FS<1$ indicates slope failure.

Mohr-Coulomb law:

$$S_f = c + \sigma \tan(\phi)$$

c soil cohesion

σ normal stress

ϕ soil friction angle

Infinite slope model

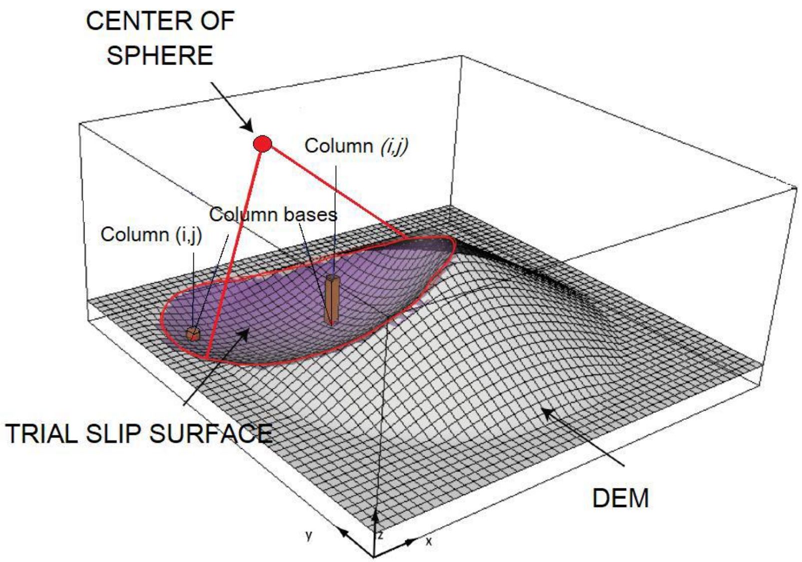
$$FS = \frac{\tan(\phi)}{\tan(\alpha)} + \frac{c + \psi(d,t)\rho_w \tan(\phi)}{\rho_s d sin(\alpha)\cos(\alpha)}$$

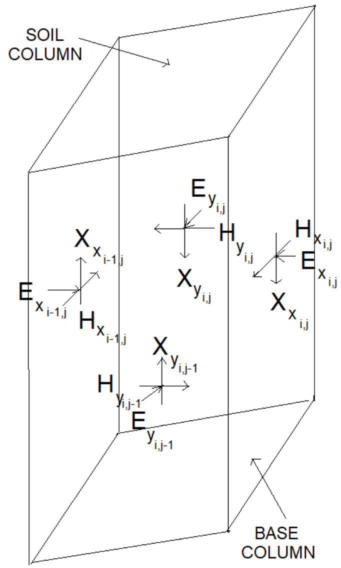
α slope angle

d depth

ρ_s, ρ_w mass densities (soil and water)

3D-column model





Data

Maps (scale 1:10.000-1:5.000): topographic, geologic, geomorphological, lithotechnical, and geologic sections.

Land cover

Position of the weather stations

Landslide events (n.3-5) and relative weather (3 months before)

Direct measurements: core soil samples (depth 10-20m) for

- Water content (1 sample per meter)
- geotechnical analys of the soil (2 samples each drilling)

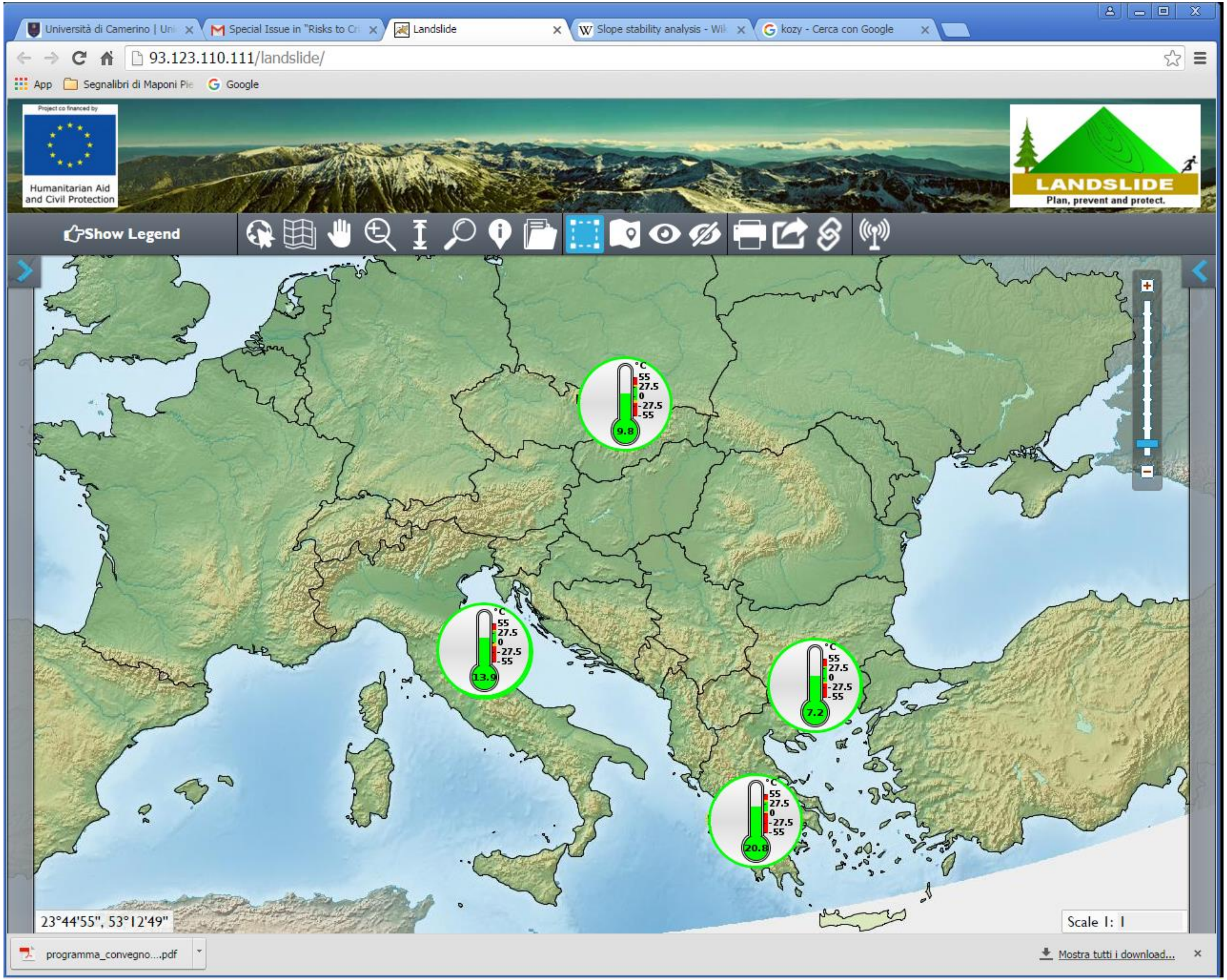
Test areas

Test area 1 – Province of Ancona, Italy: central part of the Esino basin (surface 11.69 km^2)

Test area 2 – Region Smolyan, Bulgaria: between the town of Smolyan and Mountain Snejanka (surface 7.4 km^2)

Test area 3 – District of Bielsko-Biala, Poland: within a former stone quarries in the municipality of Kozy, near the Mountain Small Beskidin (surface 14.7km^2)

Test area 4 – Region Peloponnese, Grece: located at the morth-west of Peloponnese, 15 km away from Patras, near the road to Athens (surface 0.88km^2)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Concluding remarks

The LANDSLIDE project gives a method for the landslide hazard assessment from weather conditions.

Further information: www.landslideproject.eu

Uncertainty level on the data and model sensibility analysis.

Possible developments:

- dynamics of the landslide mass
- hazard assessment of flood and forest fire,
- evaluation of measures for the hydrogeological risk reduction

EU Funding & Tenders Portal - European Commission → Union Civil Protection Mechanism (UCPM)