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Landslide Hazard Assessment on Regional and Local Scale: Pilot Implementation in Greece

www.scinetnathaz.net

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SciNetNatHaz project – Final Stakeholders Meeting – Istanbul, November 2015

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Acknowledgments

The whole research team that has been involved and worked **for LHA on Regional and Local scale**:

- **Stelios SKIAS,** Associate Professor DUTh
- **Yannis MARKOU,** Associate Professor DUTh
- **Manos PSAROUDAKIS,** Civil Engineer DUTh, MSc UoPatras
- **Theologos LAZARIDIS,** Civil Engineer DUTh, PhD Bristol University
- **Eleni PETALA,** Civil Engineer DUTh, PhD candidate
- **Yannis GKIOUGKIS,** Geologist AUTh, PhD candidate
- **Konstantia MAKRA,** Dr Civil Engineer AUTh, Senior Researcher ITSAK-EPPO
- **Manos ROVITHIS,** Dr Civil Engineer,Researcher ITSAK-EPPO

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Landslide Hazard Assessment in the Blaxi area. The….Gaps!

- **Usable Data are lacking**. Inventories of past landslides do not exist or are not accessible.
- **Metadata** are not supplied so it's very difficult to assess **reliability and accuracy** of available data (if found!).
- **Different LHA methodologies** are used even in the same country, **making comparison** of outputs, **impossible.**
- **Hazard identification & Risk assessment on regional and on local scales** (that could provide the essential information for planning typical preventive measures) has only been **sparsely implemented**.

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Selected, Adapted to local conditions and Applied Methodologies

A. **Mora & Vahrson** methodology (Sergio Mora C., & Wilhelm-Gunther Vahrson (1994): Macrozonation Methodology for Landslide Hazard determination. Bulletin of the Association of Engineering Geologists, Vol. XXXI No.1, 1994, pp.49-58.

B. **F**ederal **E**mergency **M**anagement **A**gency (FEMA, USA) methodology – **HazUS** (https://www.fema.gov/hazus)

C. **Factor of Safety** calculation (Infinite Slope Model & Circular Landslide)

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Implementation areas - Hellas

Both areas of pilot implementation fall inside the Black Sea Programme eligible area:

A. **S**erres

B. **K**omotini-Nymfaia

Scale of Regional Implementation

1:50.000 (input data & analysis)

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A. Mora & Vahrson Methodology

Calculates the “Intrinsic Landslide Susceptibility” (SUSC)

Taking into account the:

Slope Factor (**Sr**)

Lithology Factor (**Sl**)

Soil Humidity Conditions (**Sh**)

And the Triggering Factor (TRIG)

Derive from the combination of

Seismic factor (**Ts**)

Precipitation factor (**Tp**)

HI = SUSC * TRIG=

= (Sr * Sl * Sh) * (Ts + Tp)

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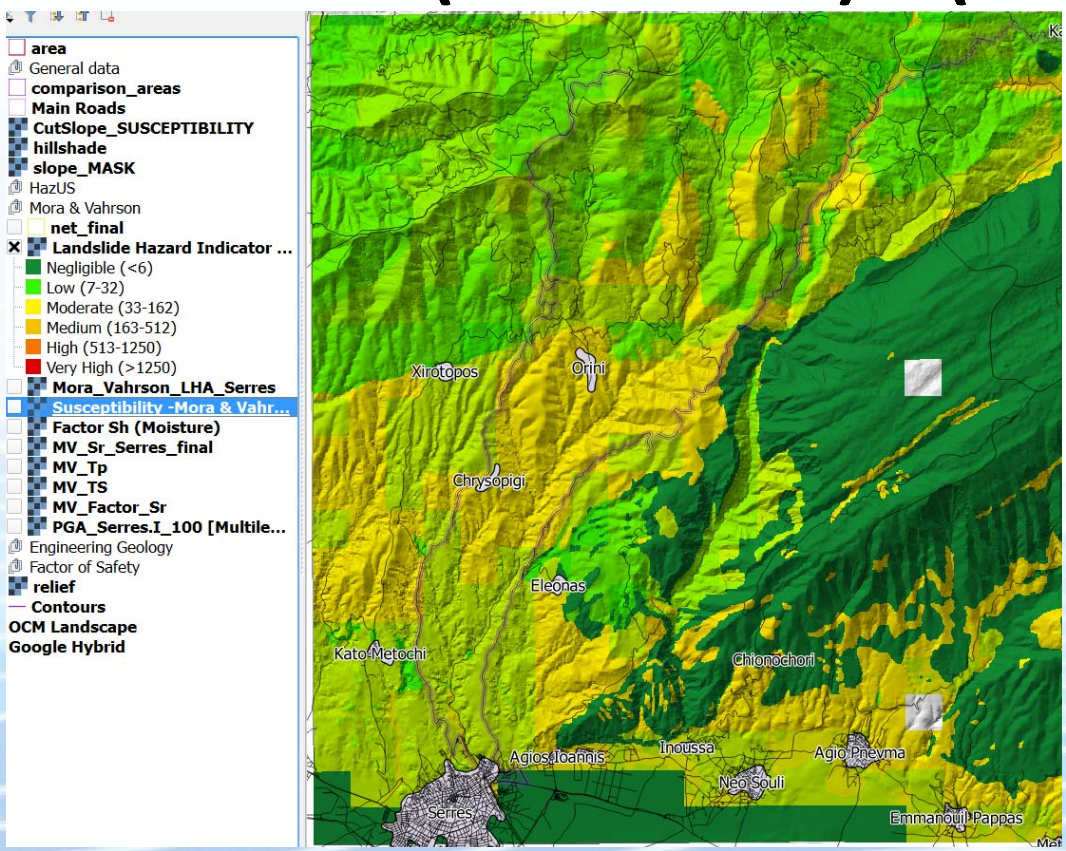
Classification of Landslide Hazard Indicator (HI)

HI = SUSC * TRIG = (Sr * Sl * Sh) * (Ts + Tp)



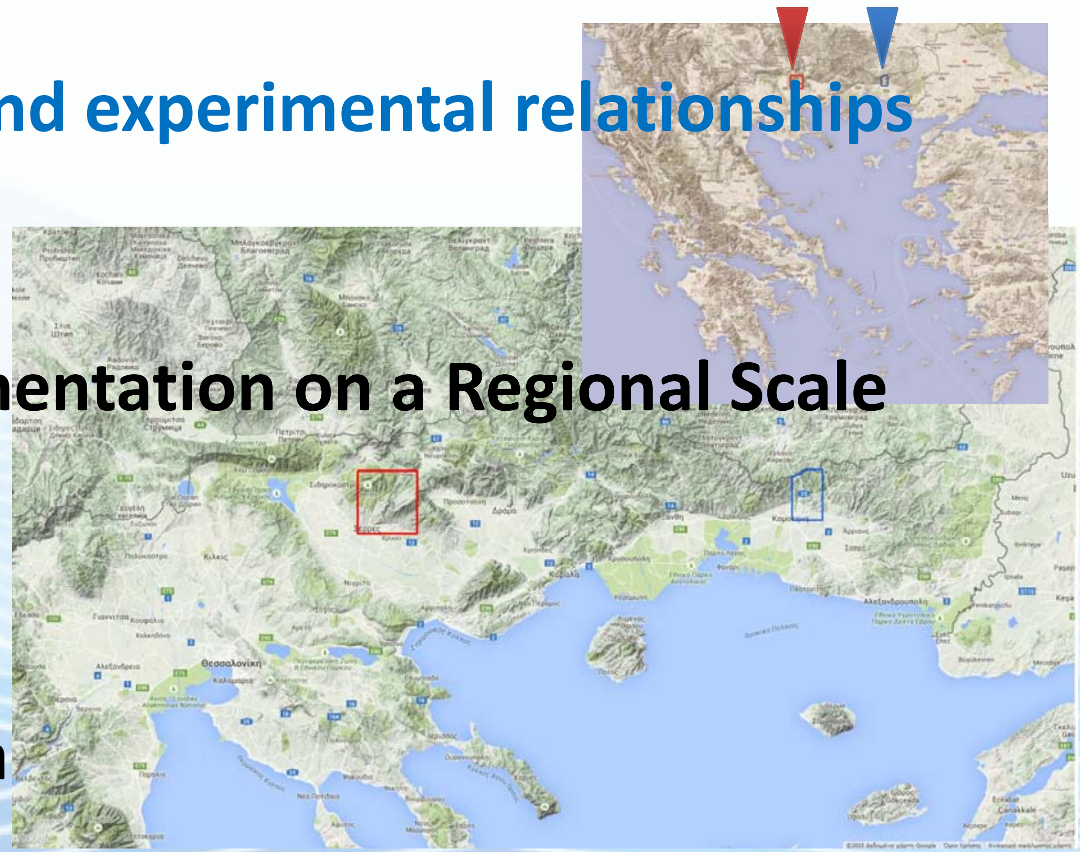
B. FEMA methodology (Hazard US)

Based on empirical and experimental relationships

Areas of pilot implementation on a Regional Scale (1:50.000)

A. **S**erres

B. **K**omotini-Nymfaia



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Landslide Hazard Assessment (FEMA)

1. **A**ssess Landslide **Susceptibility** (under static conditions)
2. **A**ssess the **Critical Acceleration** (Ac) & compare (**Ac/PGA**) the Critical Acceleration (Ac) with the actual Peak Ground Acceleration (PGA)
3. **C**alculate **Permanent Ground Displacements**

All the above parameters are calculated for two different moisture/ groundwater conditions: “DRY” and “WET” whereas **“DRY”** corresponds to groundwater level **BELOW** surface of failure and “**WET”** corresponds to groundwater **ON** ground surface.

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Landslide Susceptibility under static conditions

Table 8. Landslide susceptibility under static conditions

(HazUS MH, Chapter 4 – PESH)

Geologic Group		Slope Angle, degrees					
		0-10	10-15	15-20	20-30	30-40	>40
(a) DRY (groundwater below level of sliding)							
A	Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^{o}$)	None	None	I	II	IV	VI
B	Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^{o}$)	None	III	IV	V	VI	VII
C	Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^{o}$)	V	VI	VII	IX	IX	IX
(b) WET (groundwater level at ground surface)							
A	Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, $c' = 300$ psf, $\phi' = 35^{o}$)	None	III	VI	VII	VIII	VIII
B	Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, $c' = 0$, $\phi' = 35^{o}$)	V	VIII	IX	IX	IX	X
C	Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, $c' = 0$ $\phi' = 20^{o}$)	VII	IX	X	X	X	X

scale I: less susceptible

scale X: most susceptible

- None
- I
- II
- III
- IV
- V
- VI
- VII
- VIII
- IX
- X

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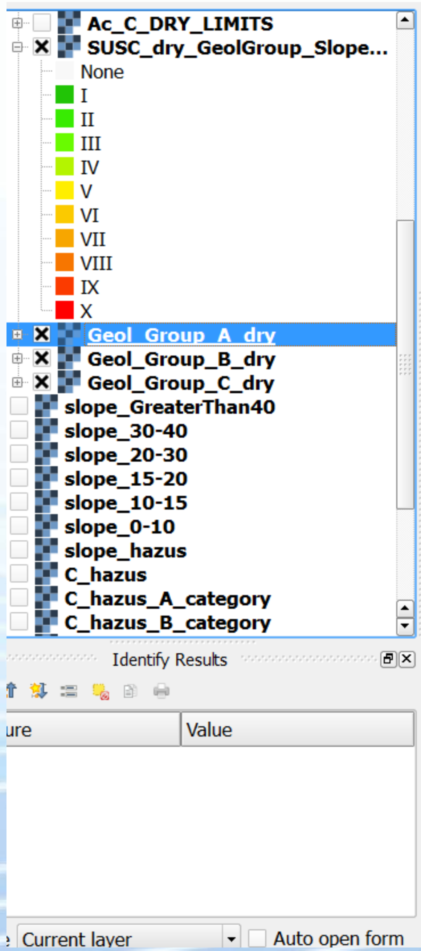
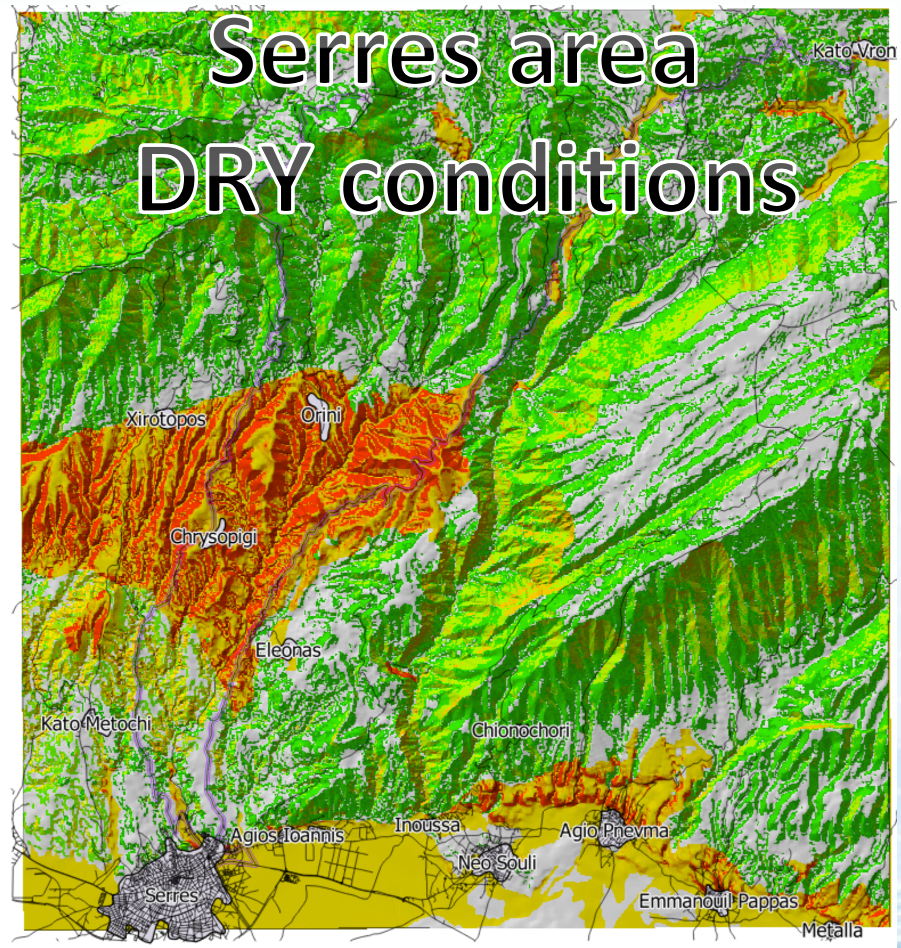
Landslide Susceptibility under static conditions

Susceptibility under different moisture conditions

is calculated by adding the individual Susceptibilities Per Geologic Group





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Landslide Susceptibility under seismic conditions

Limit Equilibrium Method principle: an earthquake is considered as a horizontal force (seismic coefficient * weight of the potentially sliding mass of a slope)

Critical Acceleration (A_c) is defined as the **horizontal acceleration that produces a F_S = 1.0**

The ratio: A_C /PGA is the critical parameter to classify susceptibility under seismic conditions.

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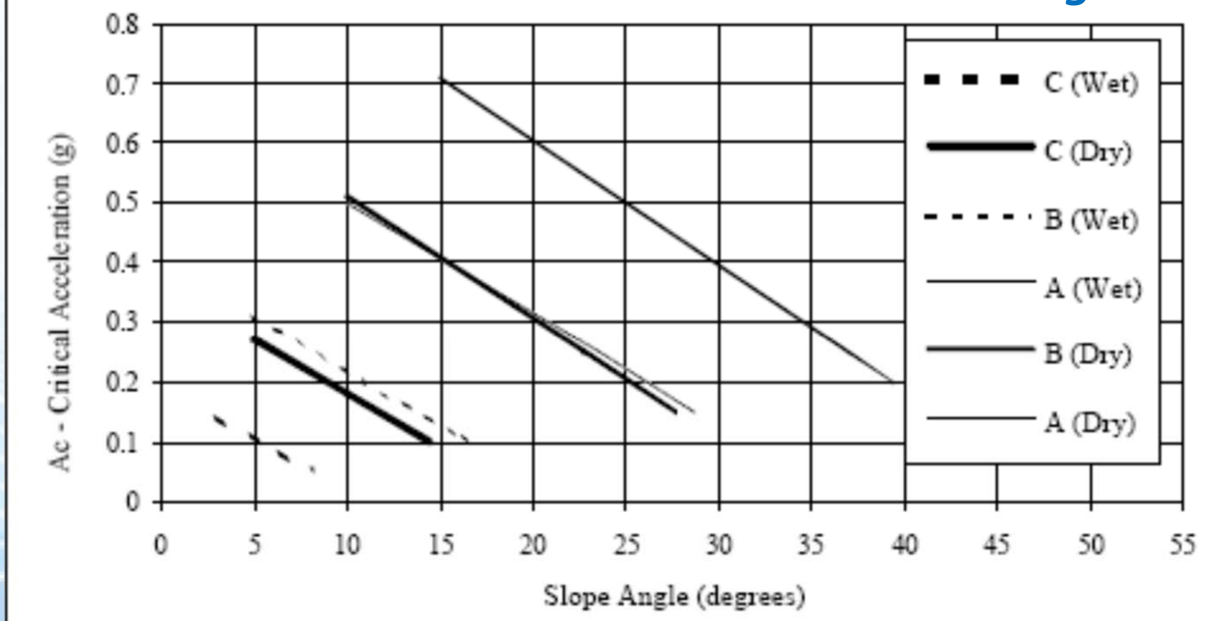
Calculating the Critical Acceleration A_c

Critical Acceleration (A_C) is a complex function of **slope**, **geology**, **steepness**, **groundwater table**, **type of landsliding** & **history of previous slope performance**.

There are certain **limits (bounds)** for these relations (as shown in the graph)

Fig. 1



Critical Acceleration as a Function of Geologic Group and Slope Angle (Wilson and Keefer, 1985).

Permanent Ground Displacements (PGD) assessment

- The FEMA method is based on the assessment of **PGD (Permanent Ground Displacements) for landslides** (Goodman and Seed, 1966)

$$E[PGD] = E[d/A_{is}]*A_{is}*n$$

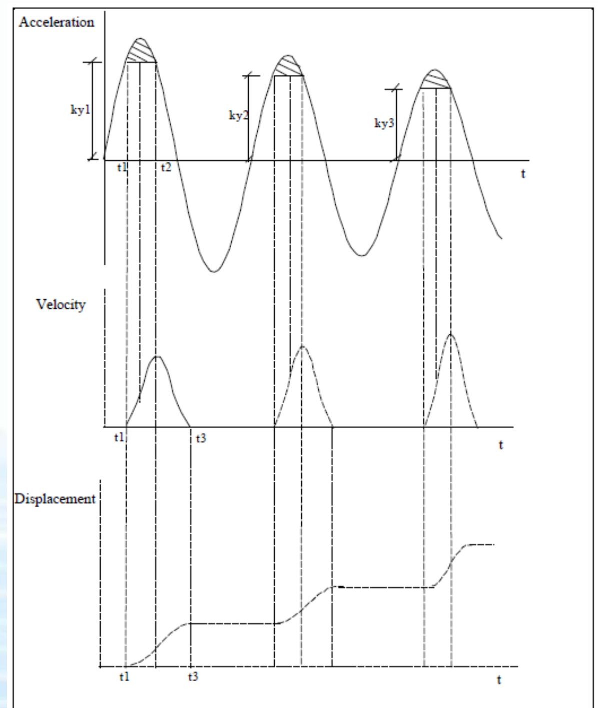
A_{is}: induced acceleration (g) – A_{is} = PGA

n: number of cycles (function of earthquake magnitude M_w)

$E[d/A_{is}]$: expected displacement factor for each cycle

A_{is} = PGA : for shallow landslides

A_{is} = 2/3*PGA: for massive, deep and large landslides



Note: Critical accelerations in figure are ky1, ky2 and ky3. In applications, critical acceleration is usually taken as a single value.

Figure 4.11 Integration of Accelerograms to Determine Downslope Displacements (Goodman and Seed, 1966).

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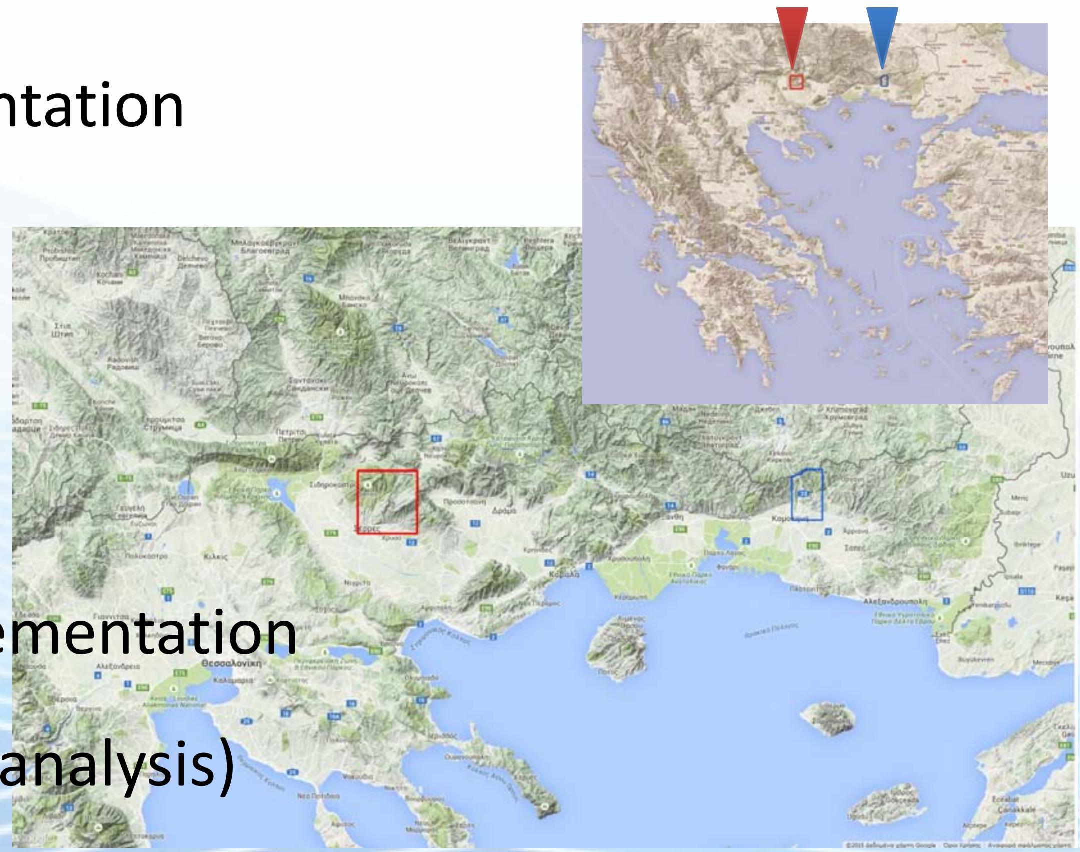
C. Landslide Hazard Assessment - F_S

Areas of pilot implementation

A. **S**erres

B. **K**omotini-Nymfaia



Scale of Regional Implementation

1:50.000 (input data & analysis)

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Landslide Hazard Assessment - F_S

- **Physically based landslide hazard assessment methods** are based on *modeling of slope failure processes*
- the factor of safety F_S computation method **(triggering factors: rainfall & earthquake)**

LHA Factor of Safety -Data requirements

- Scale of Implementation 1:50.000
- Topographic data (topographic Maps, elevation data, lattice points etc). In case topographic data at a 1:50.000 scale are not available, ASTER DEMs can be used at the expense of accuracy.
- Geologic Maps
- Engineering geologic/geotechnical parameters (cohesion, friction angle, unit weight)
- Ground Motion data (PGA values)
- Mean Monthly Rainfall (mm) and MAX daily precipitations

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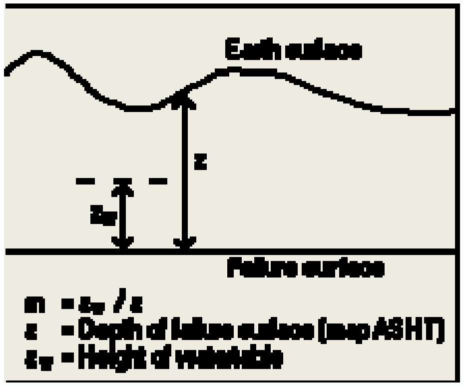
Landslide Hazard– Static conditions / Precipitation

Infinite Slope Model (Factor of Safety)

$$F_S = \frac{c' + (\gamma_{app} - m * \gamma_w) * z * \cos^2\beta * \tan\varphi'}{\gamma_{app} * z * \sin\beta * \cos\beta}$$



$$\gamma_{app} = \gamma * (1 - m) + \gamma_{sat} * m$$

If totally dry slope, then $\gamma_{app} = \gamma$ (m=0%)

If totally saturated slope, then $\gamma_{app} = \gamma_{sat}$ (m=100%)

ϕ': **effective angle of friction** of geomaterial (^{0})

c': **effective cohesion** of geomaterial (kPa),

γ: **specific weight** (kN/m^3),

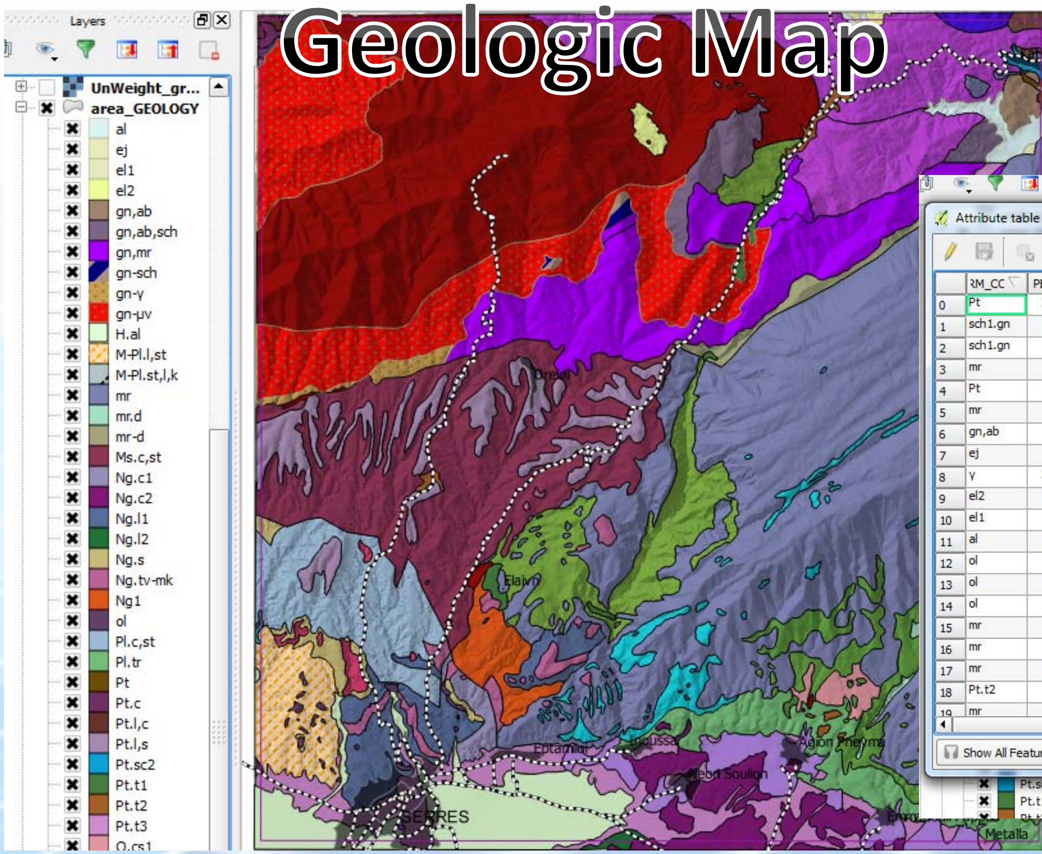
β: **slope angle** (Deg),

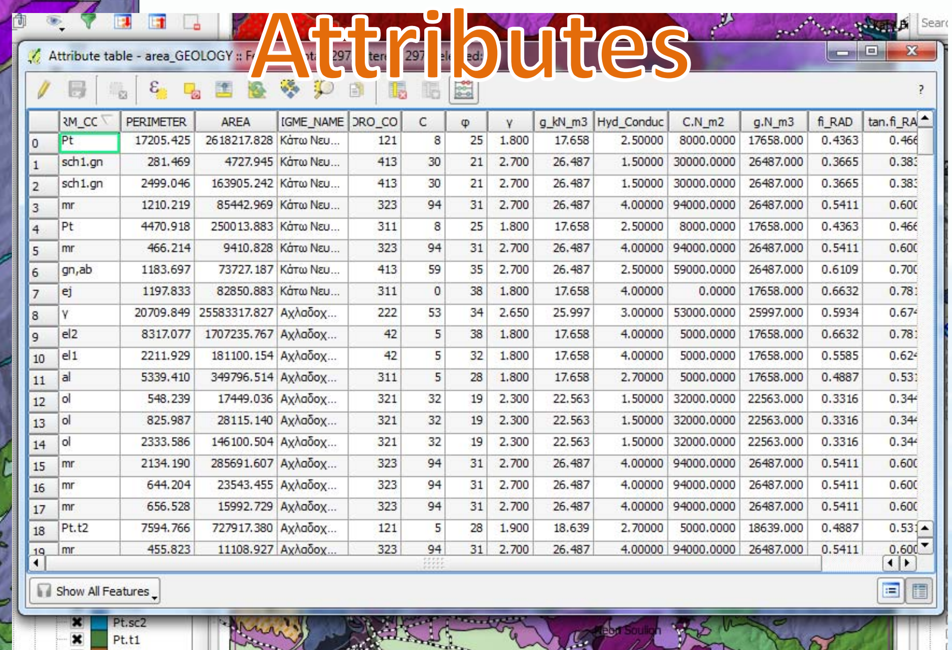
γ_w: **specific weight** of the water (kN/m^3),

z: normal thickness of the failure slab (m)

m: percentage of the water **saturated** failure slab (%)

Geotechnical Parameters Spatial Distribution





	ꓤM_CC	PERIMETER	AREA	IGME_NAME	ꓷRO_CO	C	φ	γ	g_kN_m3	Hyd_Conduc	C.N_m2	g.N_m3	fi_RAD	tan.fi_RA
0	Pt	17205.425	2618217.828	Κάτω Νευ...	121	8	25	1.800	17.658	2.50000	8000.0000	17658.000	0.4363	0.466
1	sch1.gn	281.469	4727.945	Κάτω Νευ...	413	30	21	2.700	26.487	1.50000	30000.0000	26487.000	0.3665	0.383
2	sch1.gn	2499.046	163905.242	Κάτω Νευ...	413	30	21	2.700	26.487	1.50000	30000.0000	26487.000	0.3665	0.383
3	mr	1210.219	85442.969	Κάτω Νευ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600
4	Pt	4470.918	250013.883	Κάτω Νευ...	311	8	25	1.800	17.658	2.50000	8000.0000	17658.000	0.4363	0.466
5	mr	466.214	9410.828	Κάτω Νευ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600
6	gn,ab	1183.697	73727.187	Κάτω Νευ...	413	59	35	2.700	26.487	2.50000	59000.0000	26487.000	0.6109	0.700
7	ej	1197.833	82850.883	Κάτω Νευ...	311	0	38	1.800	17.658	4.00000	0.0000	17658.000	0.6632	0.781
8	γ	20709.849	25583317.827	Αχλαδοχ...	222	53	34	2.650	25.997	3.00000	53000.0000	25997.000	0.5934	0.674
9	el2	8317.077	1707235.767	Αχλαδοχ...	42	5	38	1.800	17.658	4.00000	5000.0000	17658.000	0.6632	0.781
10	el1	2211.929	181100.154	Αχλαδοχ...	42	5	32	1.800	17.658	4.00000	5000.0000	17658.000	0.5585	0.624
11	al	5339.410	349796.514	Αχλαδοχ...	311	5	28	1.800	17.658	2.70000	5000.0000	17658.000	0.4887	0.531
12	ol	548.239	17449.036	Αχλαδοχ...	321	32	19	2.300	22.563	1.50000	32000.0000	22563.000	0.3316	0.344
13	ol	825.987	28115.140	Αχλαδοχ...	321	32	19	2.300	22.563	1.50000	32000.0000	22563.000	0.3316	0.344
14	ol	2333.586	146100.504	Αχλαδοχ...	321	32	19	2.300	22.563	1.50000	32000.0000	22563.000	0.3316	0.344
15	mr	2134.190	285691.607	Αχλαδοχ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600
16	mr	644.204	23543.455	Αχλαδοχ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600
17	mr	656.528	15992.729	Αχλαδοχ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600
18	Pt.t2	7594.766	727917.380	Αχλαδοχ...	121	5	28	1.900	18.639	2.70000	5000.0000	18639.000	0.4887	0.531
19	mr	455.823	11108.927	Αχλαδοχ...	323	94	31	2.700	26.487	4.00000	94000.0000	26487.000	0.5411	0.600

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H=5m

Low normal stress (σ)

Analysis of Rock Strength using RocLab

Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 25 MPa
GSI = 32 mi = 8 Disturbance factor (D) = 1
intact modulus (Ei) = 16875 MPa
modulus ratio (MR) = 675

Hoek-Brown Criterion
mb = 0.062 s = 1.2e-5 a = 0.520

Mohr-Coulomb Fit
cohesion = 0.027 MPa friction angle = 34.17 deg

Rock Mass Parameters
tensile strength = -0.005 MPa
uniaxial compressive strength = 0.069 MPa
global strength = 0.723 MPa
deformation modulus = 503.42 MPa

c' = 27kPa

ϕ' = 22^0

High normal stress (σ)

H=50m

Analysis of Rock Strength using RocLab

Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 25 MPa
GSI = 32 mi = 8 Disturbance factor (D) = 1
intact modulus (Ei) = 16875 MPa
modulus ratio (MR) = 675

Hoek-Brown Criterion
mb = 0.062 s = 1.2e-5 a = 0.520

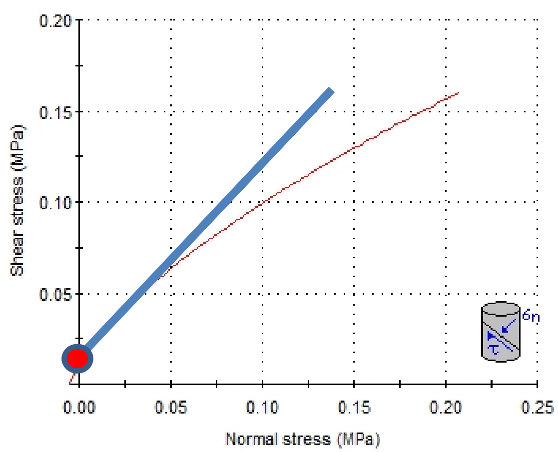
Mohr-Coulomb Fit
cohesion = 0.072 MPa friction angle = 21.91 deg

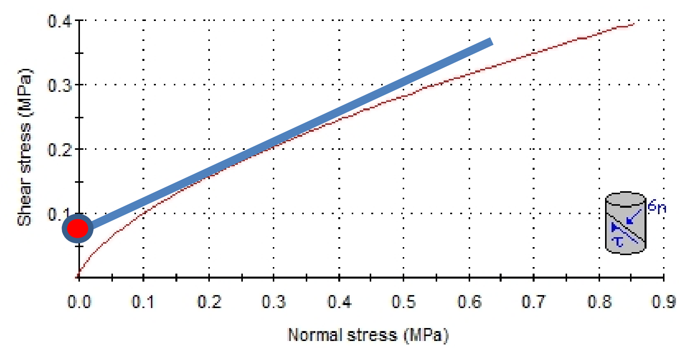
Rock Mass Parameters
tensile strength = -0.005 MPa
uniaxial compressive strength = 0.069 MPa
global strength = 0.723 MPa
deformation modulus = 503.42 MPa

http://www.rocscience.com

http://www.rocscience.com

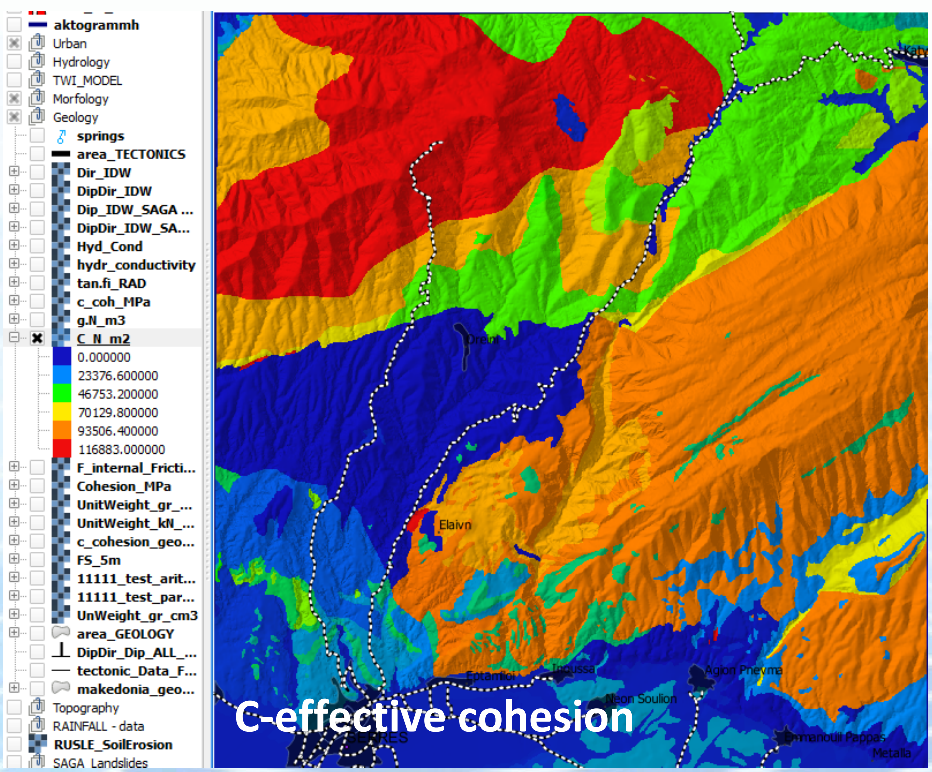
A reliable freeware software **"RocLab"**

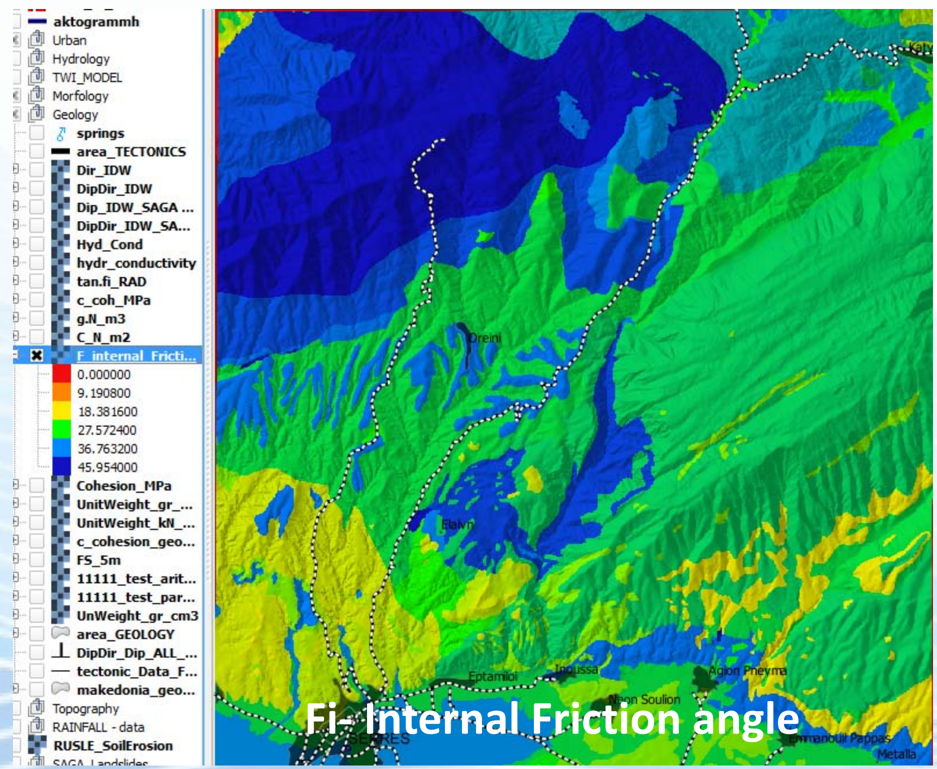




Calculating effective Cohesion (c’) and friction angle (ϕ’)

- Preparing the parameters for the calculation of Factor of Safety (convert vector to Raster); c’ – effective cohesion and ϕ’-Internal Friction angle





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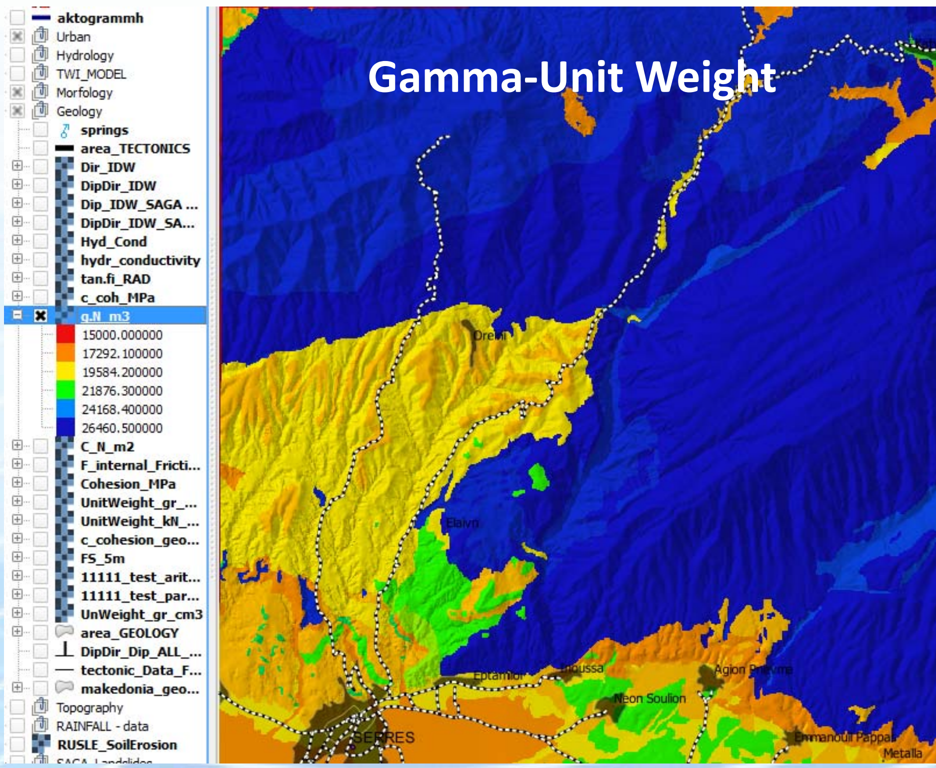
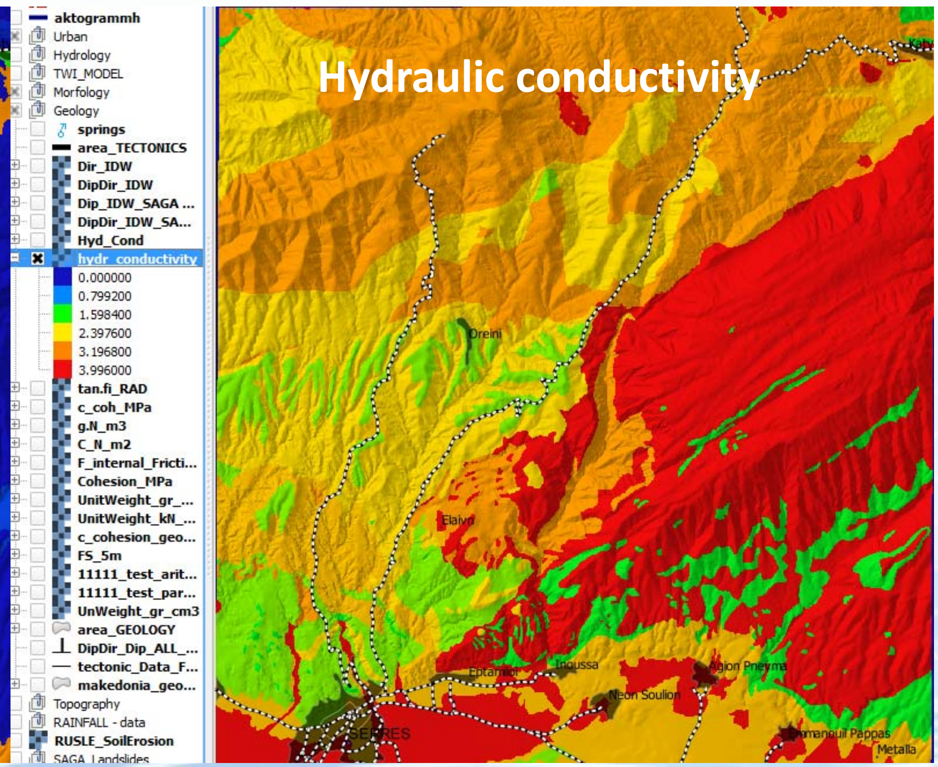
Unit Weight & Hydraulic Conductivity Spatial Distribution

- Preparing the parameters for the calculation of Factor of Safety: Unit Weight and Hydraulic Conductivity (**needed to calculate Saturation in SAGA GIS**





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Thickness and saturation of sliding slab

- **The Normal thickness of failure slab (z)** can be defined parametrically (i.e. 1m, 5m, 10m) and taken into account as such **or physically based models can be used to link it to soil (and regolith) development;**

Indicative Relative Research: Dietrich and Reiss, 1995; Catani et.al, 2010; Shafique et.al, 2011.

Potentially useful info:

- Pan-European Soil Databases fpr Landslide Mapping (JRC)
- ESDAC Data Inventory
- EU Soils

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Saturation percentage of sliding slab

- **Percentage of saturation (m %)** needs to be correlated with ***rainfall (mm)*** and ***a mean return period for the rainfall event*** (if such data exist for the examined region)

- **Create the Saturation Percentage (SP)** using the WETNESS module in SAGA GIS

- Please note! The **SP** is **calculated** for a **respective sliding mass thickness**

- References and help are given within SAGA GIS (shown below).

References:

- Beven, K.J., Kirkby, M.J. (1979) A physically-based variable contributing area model of basin hydrology. Hydrology Science Bulletin, 24, 43-69..
- Montgomery D. R., Dietrich, W. E. (1994) A physically based model for the topographic control on shallow landsliding. Water Resources Research, 30, 1153-1171.

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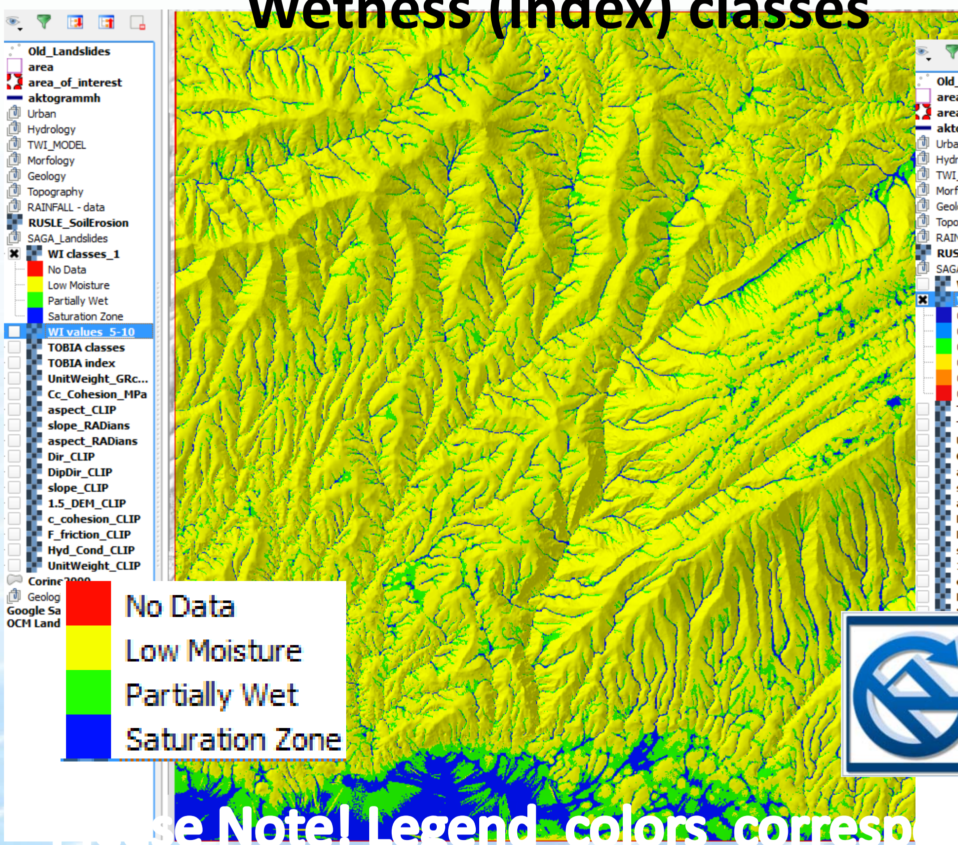
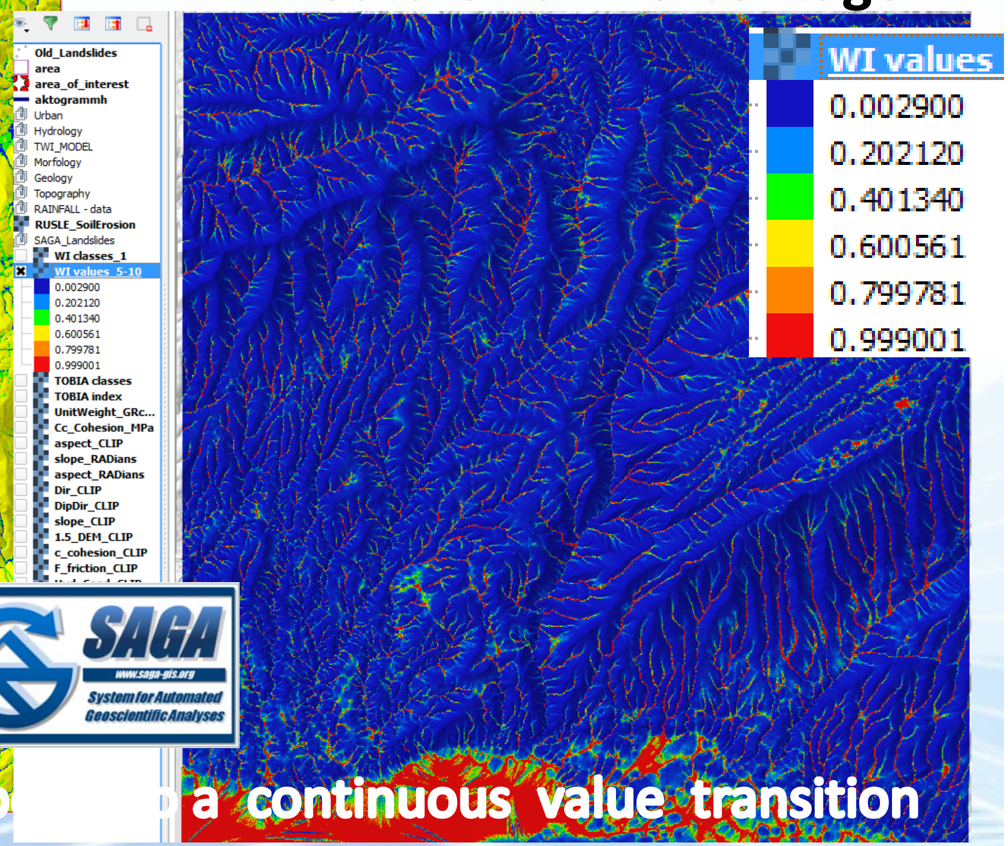
Saturation percentage of sliding slab

Wetness (Index) classes



Saturation Percentage



…se Note! Legend colors corresp… a continuous value transition

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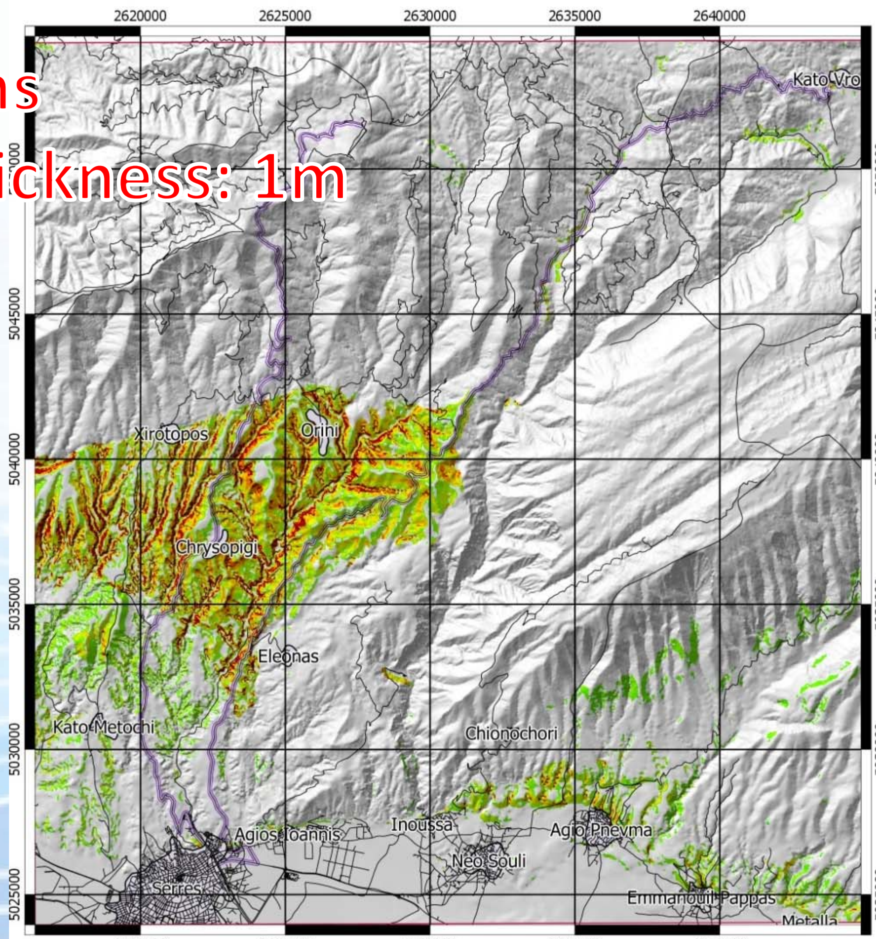
Factor of Safety – Serres Pilot Implementation Area

WET conditions

Sliding slab thickness: 1m



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200713

Infinite Slope Model
Factor of Safety map

Triggering factor: Precipitation (200 yrs)
Sliding mass thickness: 1m
Moisture conditions: Wet

Legend

Factor of Safety
- <1
- 1
- 1.01 - 1.2
- 1.21 - 1.5
- 1.51 - 2
- 2.01 - 3
- >3

General data
- Urban Areas
- Road Network
- Main Roads

1 0 1 2 3 4 5 km

Scale 1 : 125000

Coordinate Reference System: HGRS
(Hellenic Coordinate Reference System '87)

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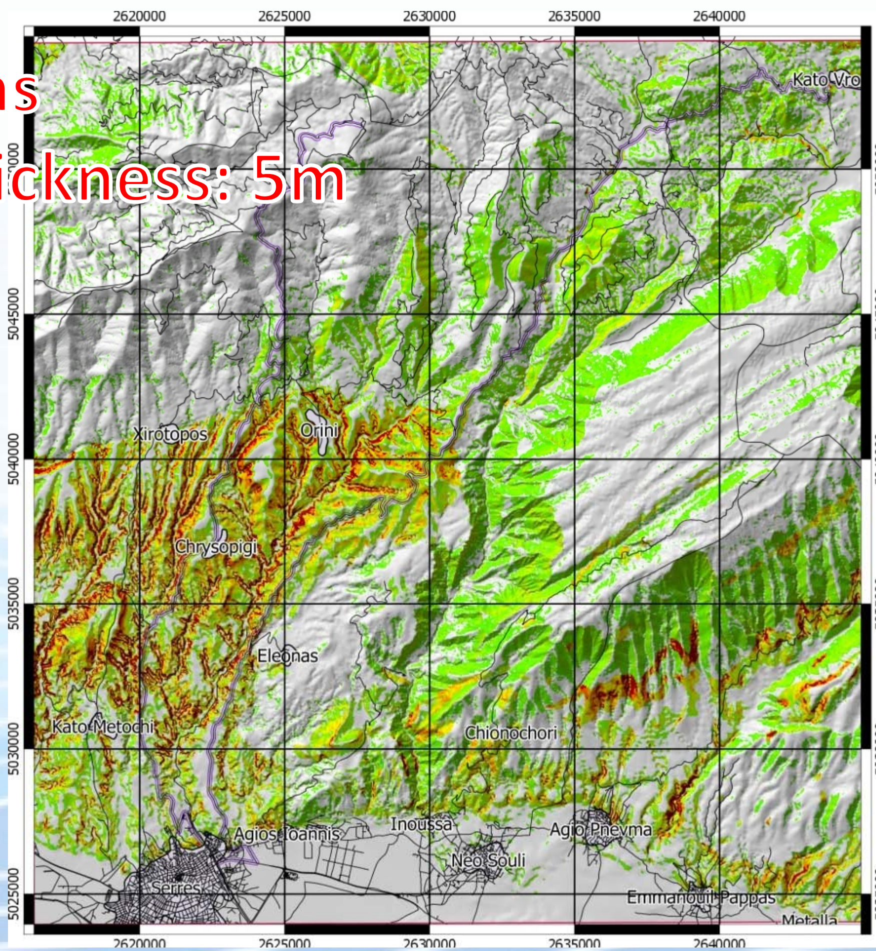
Factor of Safety – Serres Pilot Implementation Area

WET conditions

Sliding slab thickness: 5m



SciNetNatHaz Project
Black Sea Basin JOP
200713

Infinite Slope Model
Factor of Safety map

Triggering factor: Precipitation (200 yrs)
Sliding mass thickness: 5m
Moisture conditions: Wet

Legend

Factor of Safety	General data
<1	Urban Areas
1	Road Network
1.01 - 1.2	Main Roads
1.21 - 1.5	
1.51 - 2	
2.01 - 3	
>3	

1 0 1 2 3 4 5 km

Scale 1 : 125000

Coordinate Reference System: HGRS
(Hellenic Coordinate Reference System '87)

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Landslide Hazard – Seismic/Wet conditions

Infinite Slope Model (Factor of Safety for a Wet slope)

$$F = \frac{c' + (z\gamma\cos^2\beta - z\rho\alpha\cos\beta\sin\beta - \gamma_w z_w\cos^2\beta)\tan\phi'}{z\gamma\sin\beta\cos\beta + z\rho\alpha\cos^2\beta}$$

φ': effective angle of friction of geomaterial (^{0})

c’: effective cohesion of geomaterial (kPa),

β: slope angle (Deg),

ρ: bulk density (Kg/m^3)

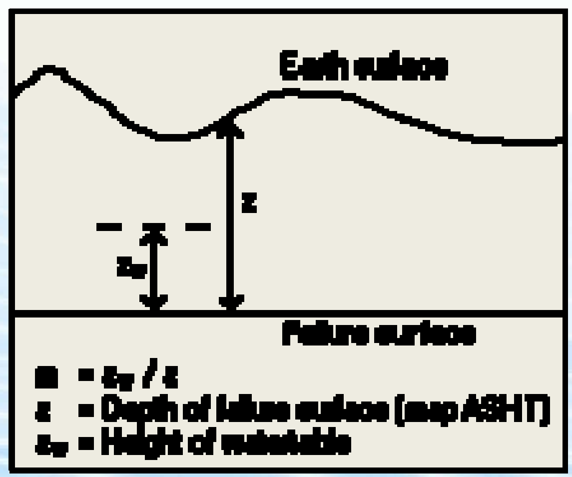
γ: specific weight (kN/m^3),

γ_w: specific weight of the water (kN/m^3),

a : earthquake acceleration (m/sec^2)

z: normal thickness of the failure slab (m)

m = z_w/z % of the water saturated failure slab



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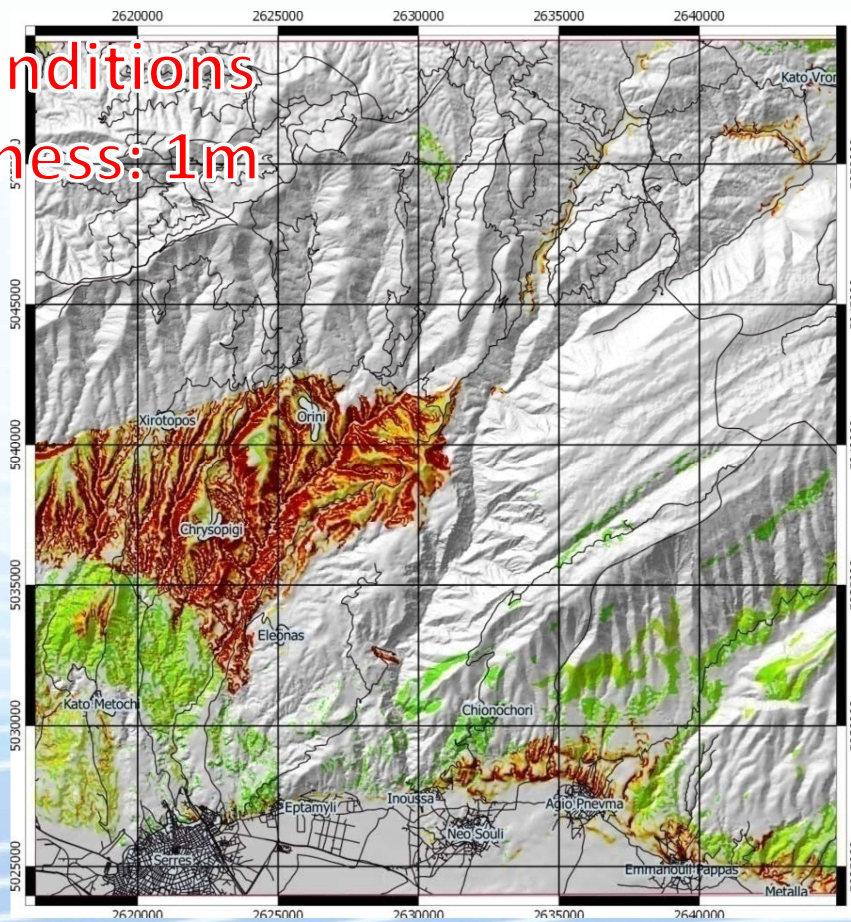
Black Sea CROSS BORDER COOPERATION

Common borders. Common solutions.

Factor of Safety – Serres Pilot Implementation Area

Seismic & DRY conditions
Sliding slab thickness: 1m



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2007-13

Infinite Slope Model
Factor of Safety map

Triggering factor: Earthquake (475 yrs)
Sliding mass thickness: 1m
Moisture conditions: Dry

Legend

Factor of Safety
- <1
- 1
- 1.01 - 1.2
- 1.21 - 1.5
- 1.51 - 2
- 2.01 - 3
- >3

General data
- Urban Areas
- Road Network

1 0 1 2 3 4 5 km

Scale 1 : 125000

Coordinate Reference System: HGRS
(Hellenic Geodetic Reference System '87)

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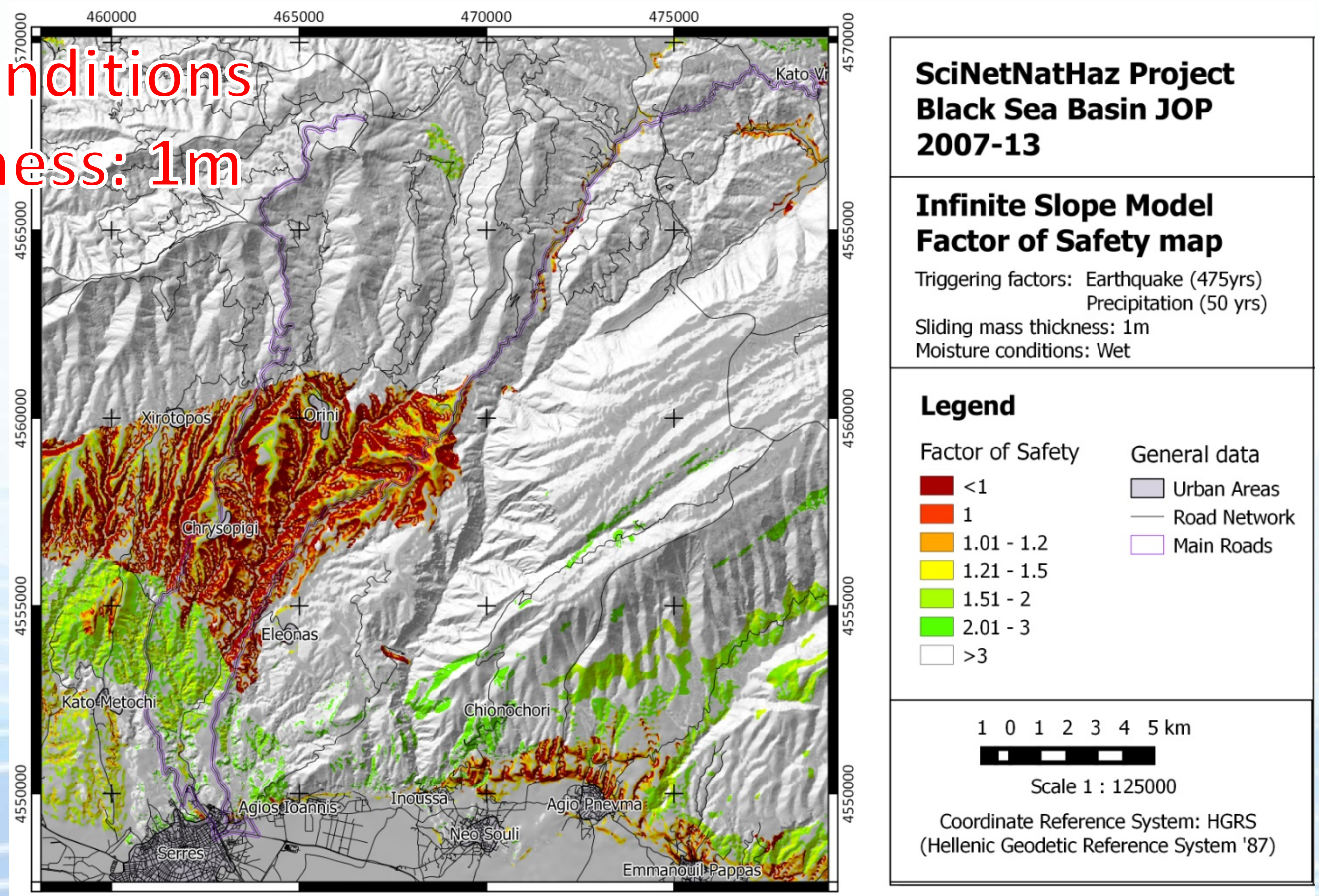
Factor of Safety – Serres Pilot Implementation Area

Seismic & WET conditions

Sliding slab thickness: 1m



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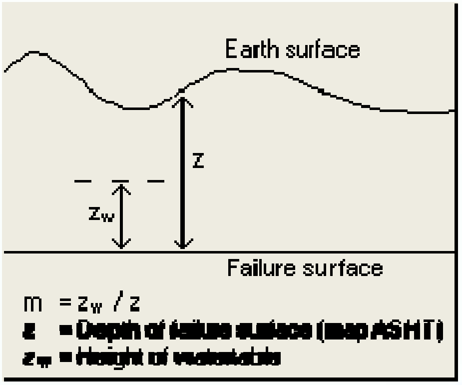
Landslide Hazard– Static conditions / Precipitation

Deterministic Model for circular landslides (Ferentinou et al., 2006)

$$F_S = 4.32 * \left[\frac{c'}{\gamma * H * \sin\beta} \right] + 1.22 * (1 - r_u) * \frac{\tan\phi'}{\tan\beta} + 0.005$$



φ': **effective angle of friction** of geomaterial (^{0})
c’: **effective cohesion** of geomaterial (kPa),
γ: **specific weight** (kN/m^3),
β: **slope angle** (Deg),

γ_w: **specific weight** of the water (kN/m^3),
H: Height of Slope (m)
r_u: **percentage** of the water **saturated** failure slab (γ_w/γ)

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EVALUATION of Outputs

Evaluation (among methodologies) by comparison of Outputs

- Complexity, precision of outputs
- Practical use of outputs

Evaluation by comparison of LHA assessment to field records:

- Landslides
- Slope failures
- Geotechnical measures taken to stabilize natural and cut slopes

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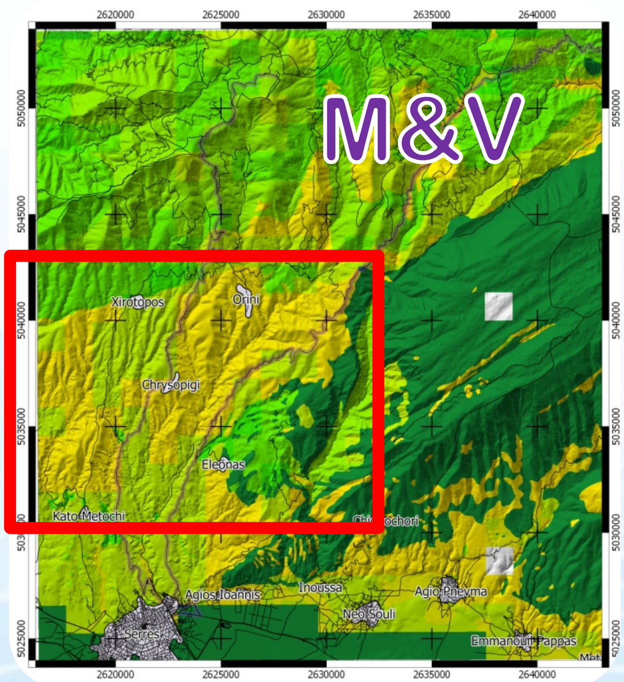
EVALUATION of Outputs – comparison of outputs

Serres PIA – Landslide Hazard Assessment



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Landslide Hazard Assessment
Mora & Vahrson
Methodology

Triggering factors: Earthquake (100yrs)
Precipitation (100 yrs)

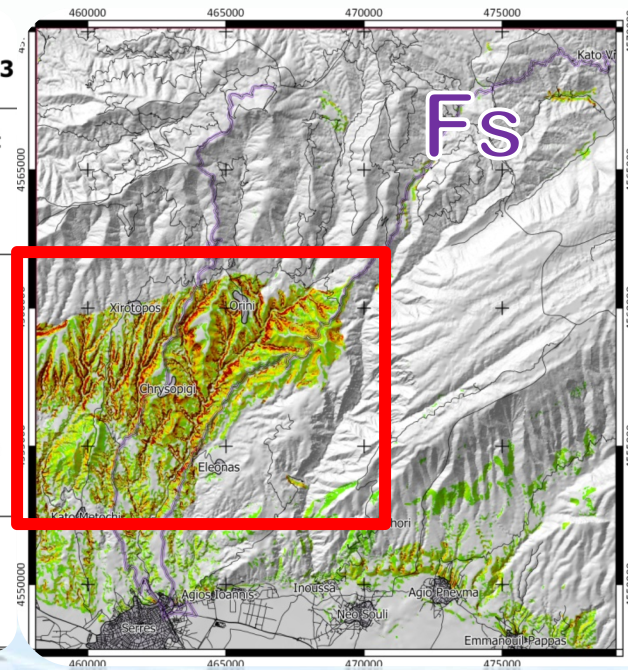
Legend

Landslide Hazard Indicator (HL)
- Negligible (<6)
- Low (7-32)
- Moderate (33-162)
- Medium (163-512)
- High (513-1250)
- Very High (>1250)

General data
- Urban Areas
- Road Network
- Main Roads

1 0 1 2 3 4 5 km

Coordinate Reference System: HGRS
(Hellenic Coordinate Reference System '87)



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Infinite Slope Model
Factor of Safety map

Triggering factors: Earthquake (100 yrs)
Precipitation (50 yrs)
Sliding mass thickness: Variable
Moisture conditions: Wet

Legend

Factor of Safety
- <1
- 1
- 1.01 - 1.2
- 1.21 - 1.5
- 1.51 - 2
- 2.01 - 3
- >3

General data
- Urban Areas
- Road Network

1 0 1 2 3 4 5 km

Scale 1 : 125000

Coordinate Reference System: HGRS
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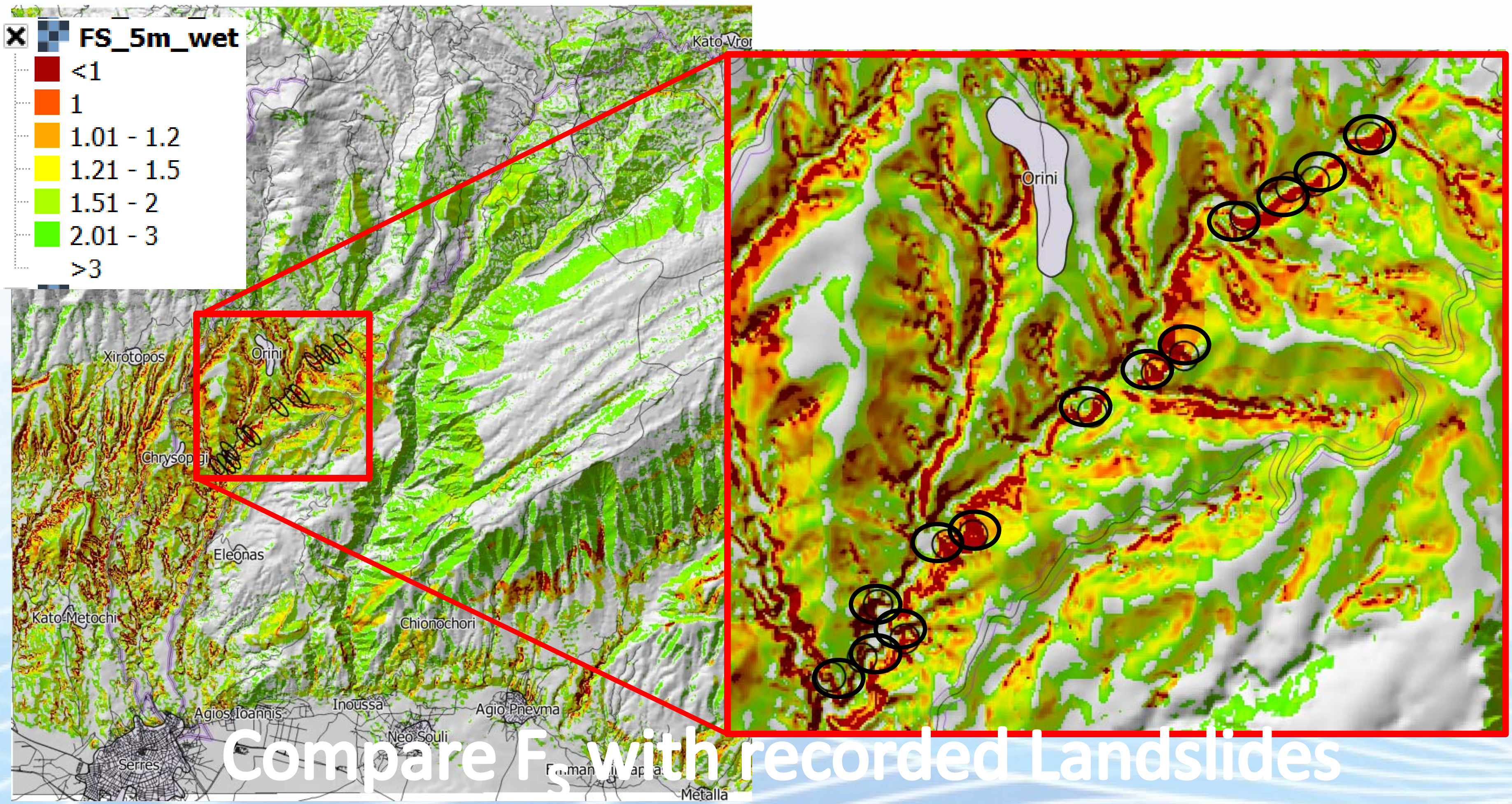
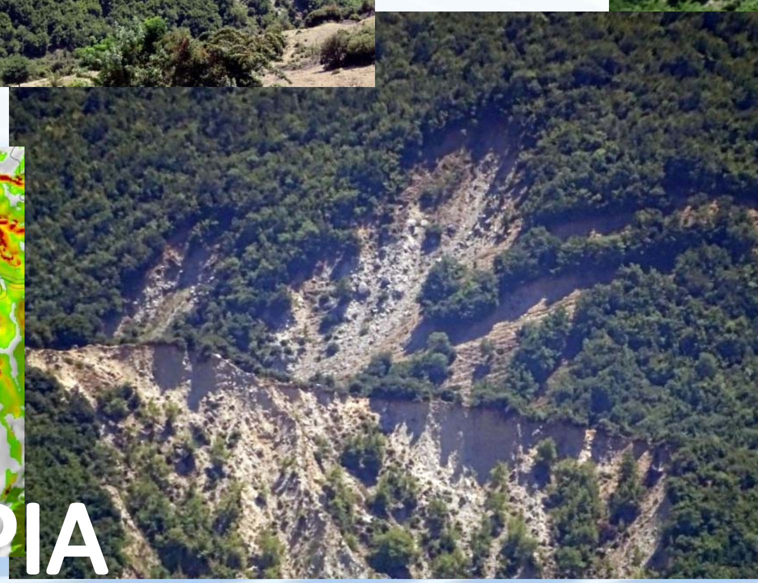
EVALUATION of Outputs – wet; z=5m, Natural slopes



Compare F_S with recorded Landslides

LHA assessment - Recorded Landslides on Natural slopes



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Results & Discussion

- All methodologies require about **the same type and accuracy level of data (to the exception of FEMA)**. Their “feasibility” is therefore linked to the complexity they present to the potential user.
- Mora & Vahrson (M&V) methodology **outputs are generalized and relatively crude** as a result of the many generalizations embedded in the methodology.
- FEMA’s methodology is **more complex to use** requiring both a number of estimations and reference to diagrams and a lot of intermediate products. Results are **more “interesting” than** those provided by the **M&V** methodology, since .
- The Factor of Safety calculation requires a good sense of the engineering properties of rocks but it’s the more **flexible, relatively easy to implement and precise** in terms of the spatial distribution of the calculated Fs. Moreover, its **outputs can be readily used** in other applications.

Weaknesses

- Geologic formations **are not homogenous nor isotropic** over large areas as are the ones covered by the Landslide Hazard Assessment at a regional scale.
- **Fracture zones exhibit much poorer engineering properties** than intact rock proportionally to the degree of fracturing.
- Rain water infiltration (which is a triggering factor) and moisture is also related to fracturing.
- Finally, weathering is in most cases, related to fracturing. Weathered zones, rich in clayey minerals with very poor geotechnical behavior, develop in fractured zones.
- As is evident, **the incorporation of such a parameter to calculate the Factor of Safety could greatly improve the final estimations**

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Improving the LHA performance using Remote Sensing

- Fractured zones can be detected using **remote Sensing data**.
- They correspond to **“lineaments”** in satellite images. **Not all lineaments are fractures** in rocks so there’s a need for a detailed, visual interpretation.
- **Landsat TM and ETM+ data were used for both PI areas to map lineaments and detect fractured zones.**
- Buffer zones of 15m were drawn around each lineament / fracture, representing a fractured zone of 30m width.
- Rock Engineering parameters were assigned to those zones, taking into consideration the type of rock and its initial properties.
- The new data were incorporated into the initial engineering geologic map and the new map was used for the calculations of the Fs.

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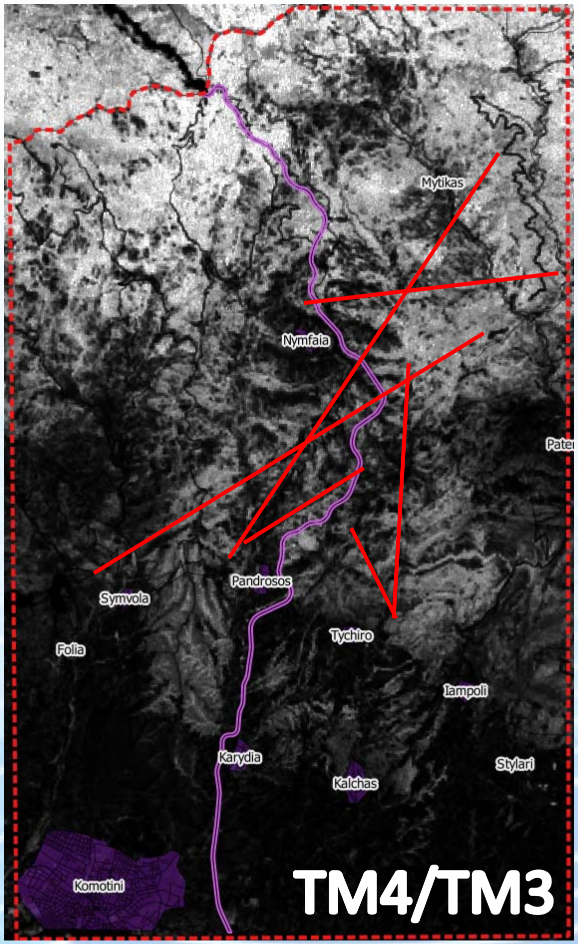
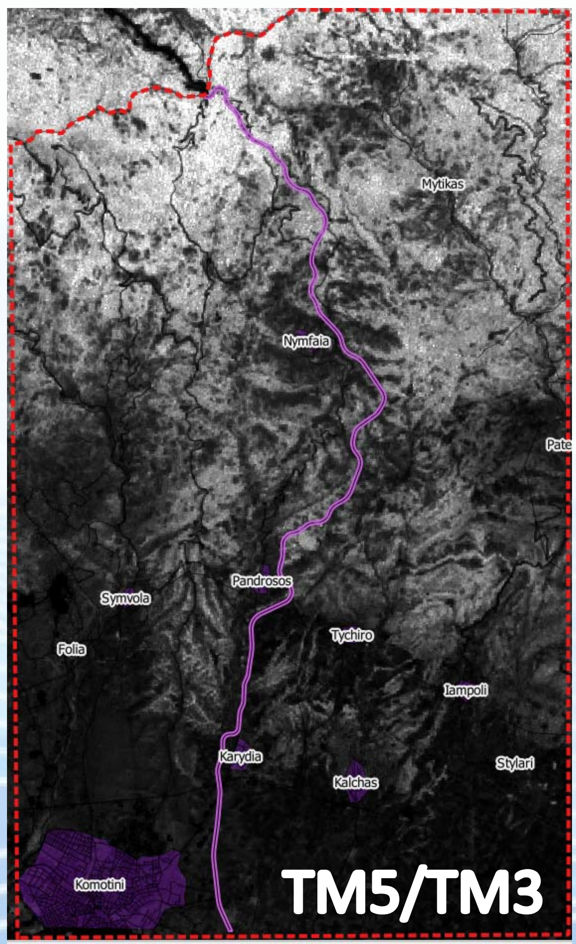
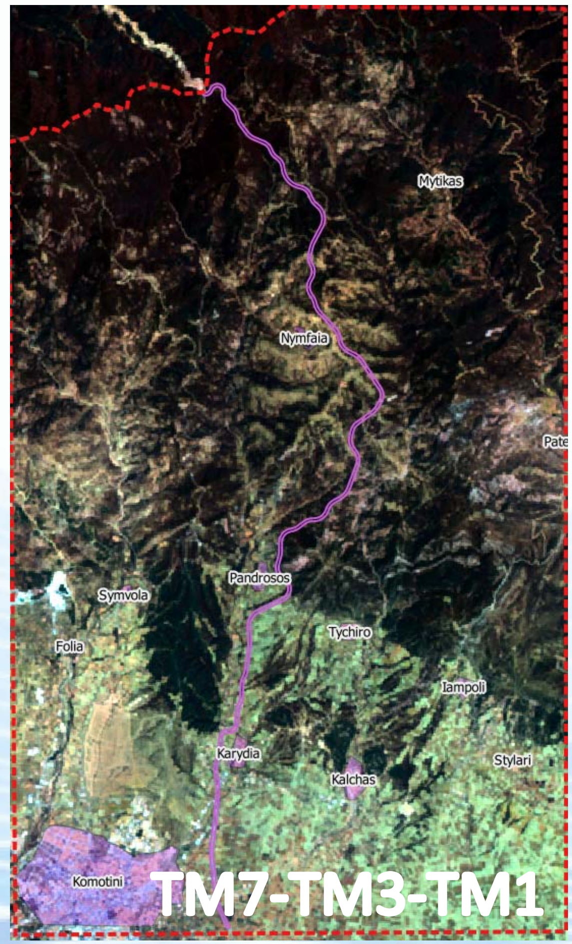
Improving the LHA performance using Remote Sensing







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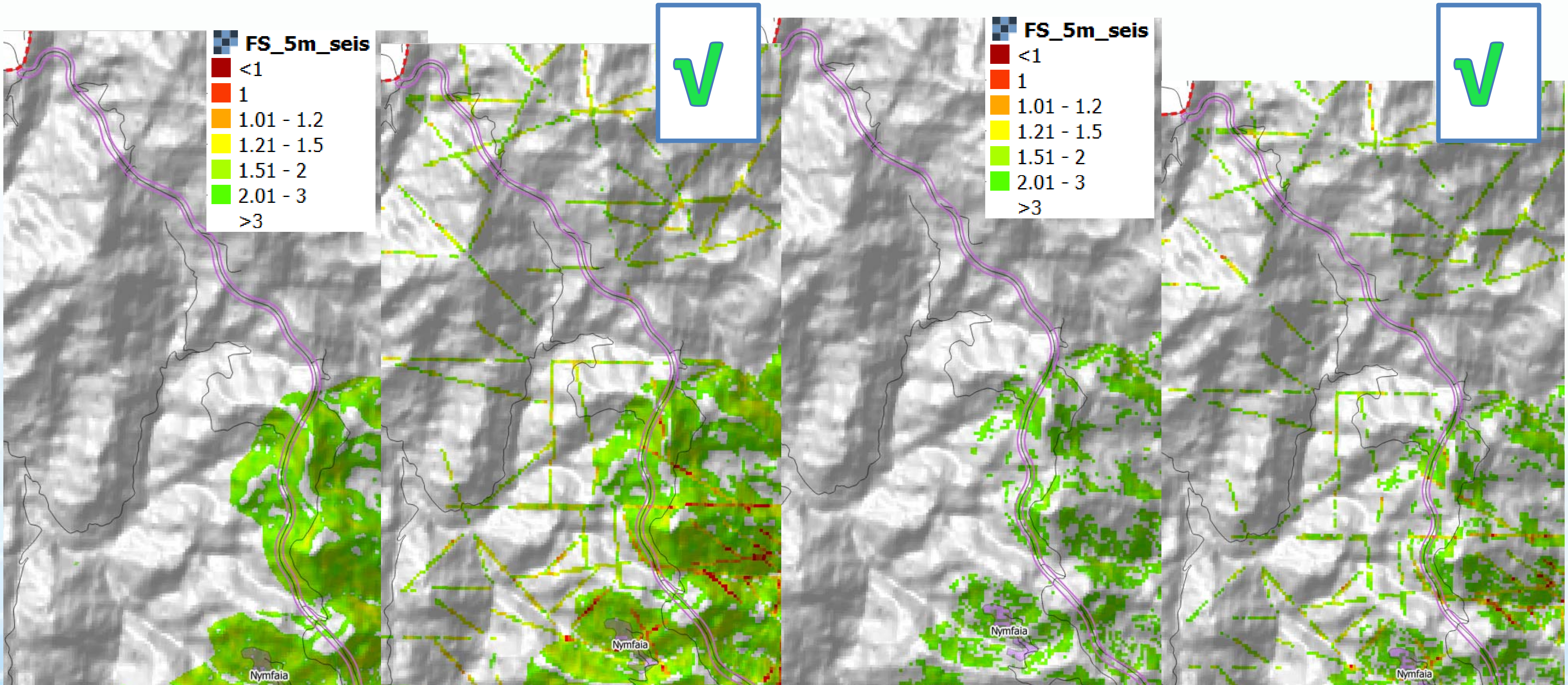
Improving the LHA performance using Remote Sensing



Triggering factor: Earthquake
Normal thickness of failure slab: 5m

Triggering factor: Rainfall (T=50 years)
Normal thickness if failure slab: 5m

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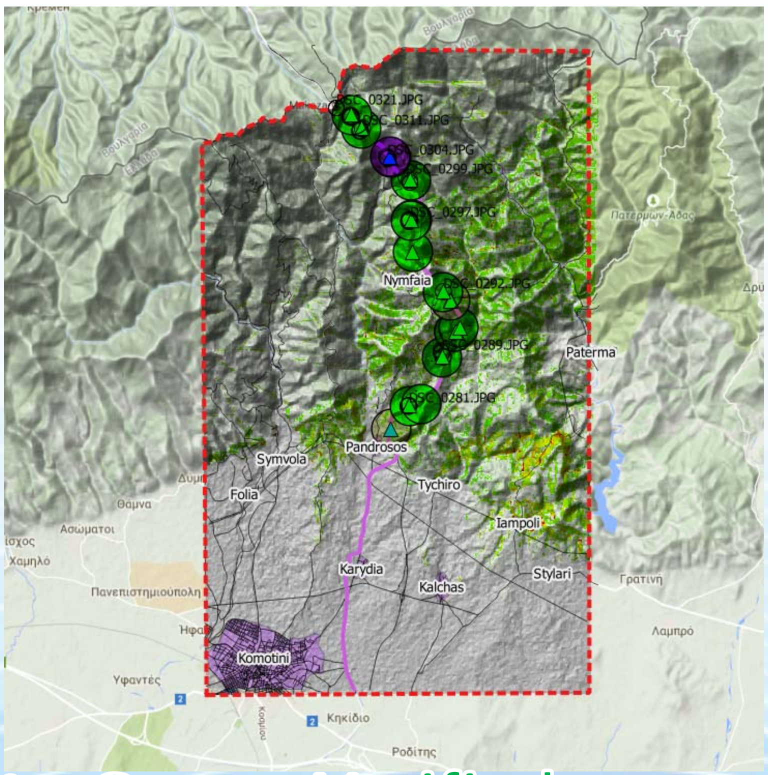
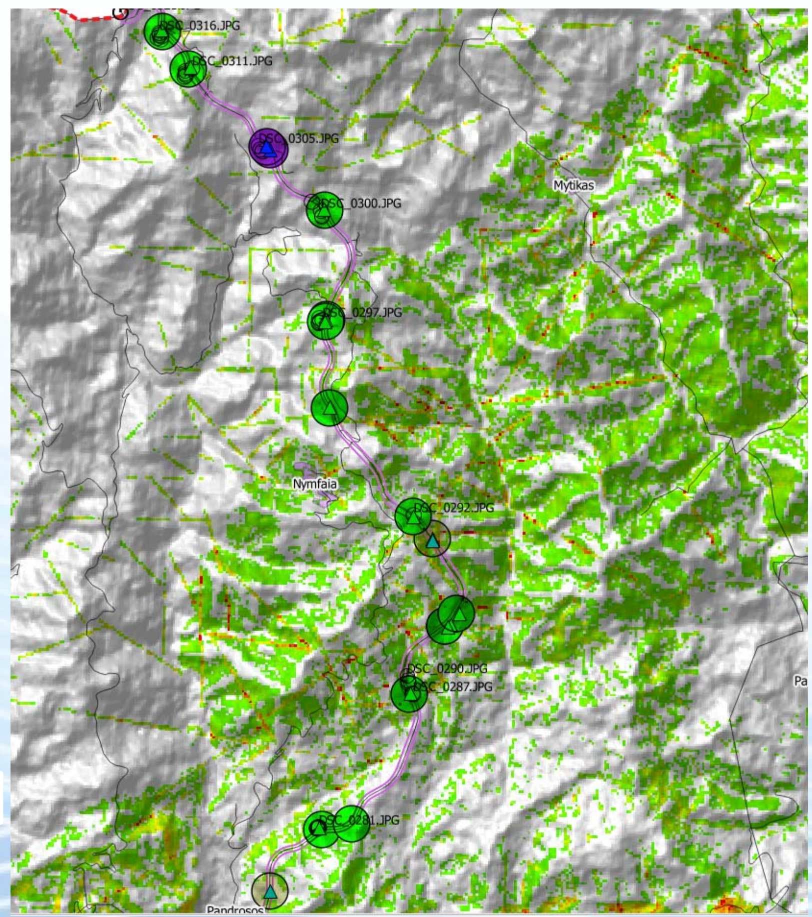
LHA assessment evaluation – Nymfaia PIA





- Green: Verified successful
- Purple: NOT successful

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PIA: vertical axis Komotini-Nymfaia

36 cut slopes along the vertical road axis Komotini – Nymfaia – Hellenic Bulgaria borders

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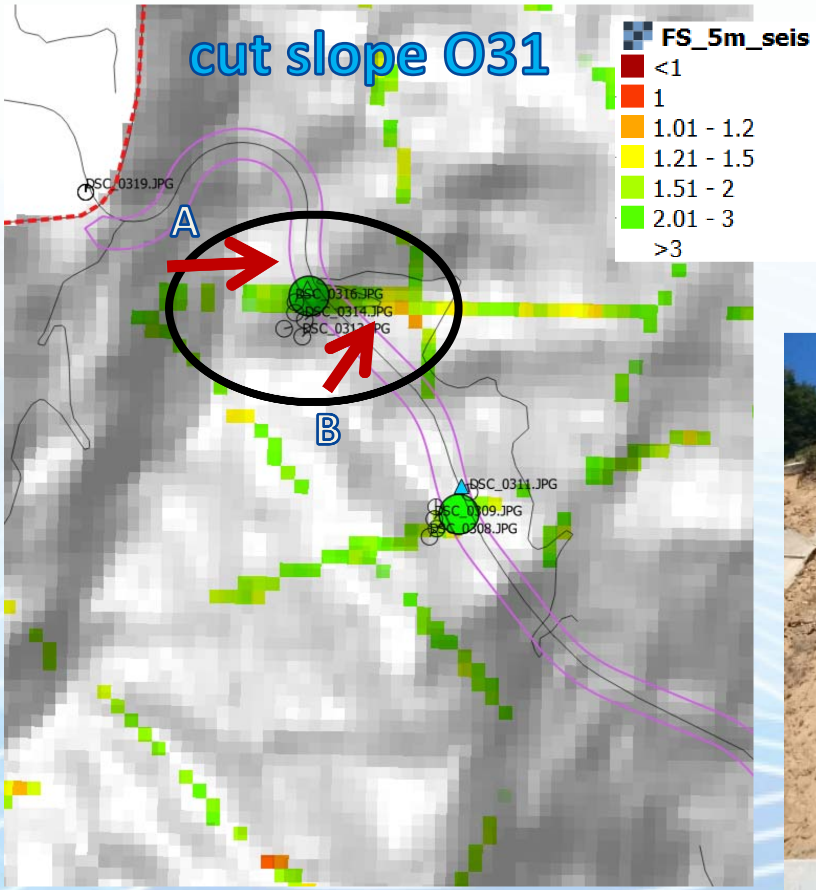
Level of Precision



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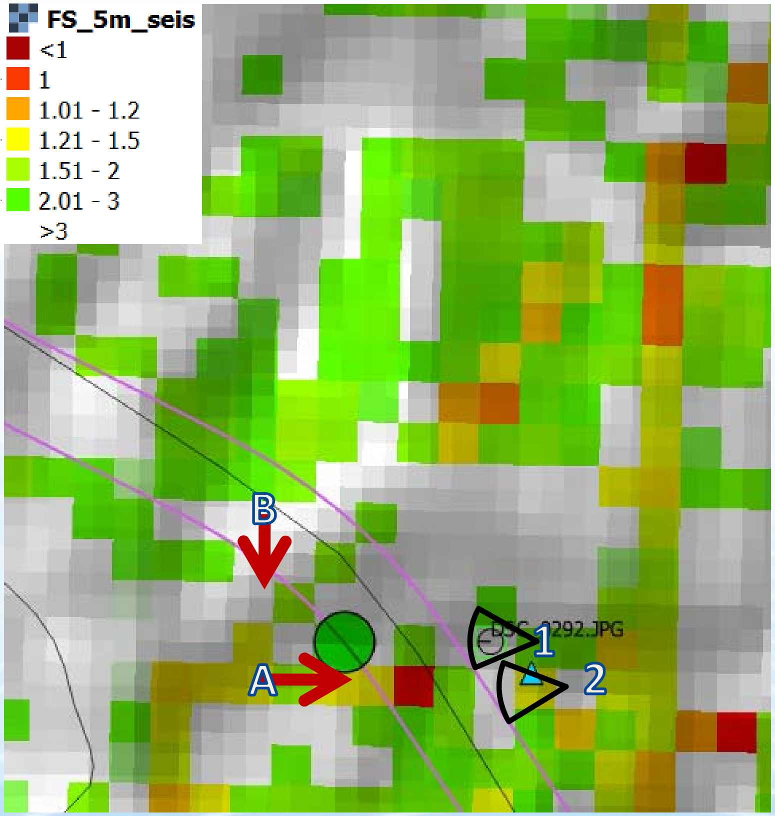
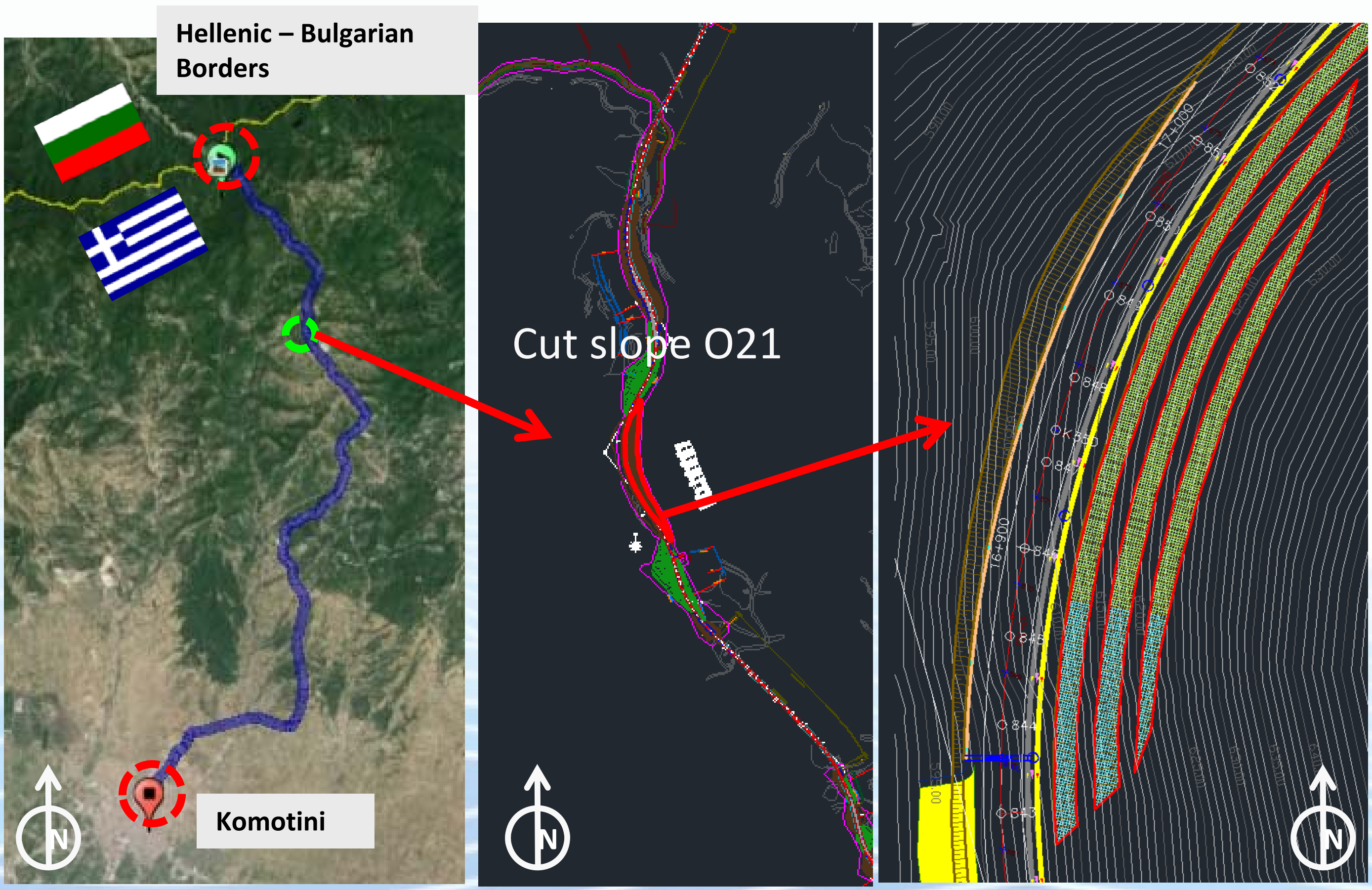
Level of Precision – cut slope O21 (point B)



1.21 < Fs < 2.0 on natural slopes (regional scale)

Cut Slope O21 : km: 16+640 – 17+080



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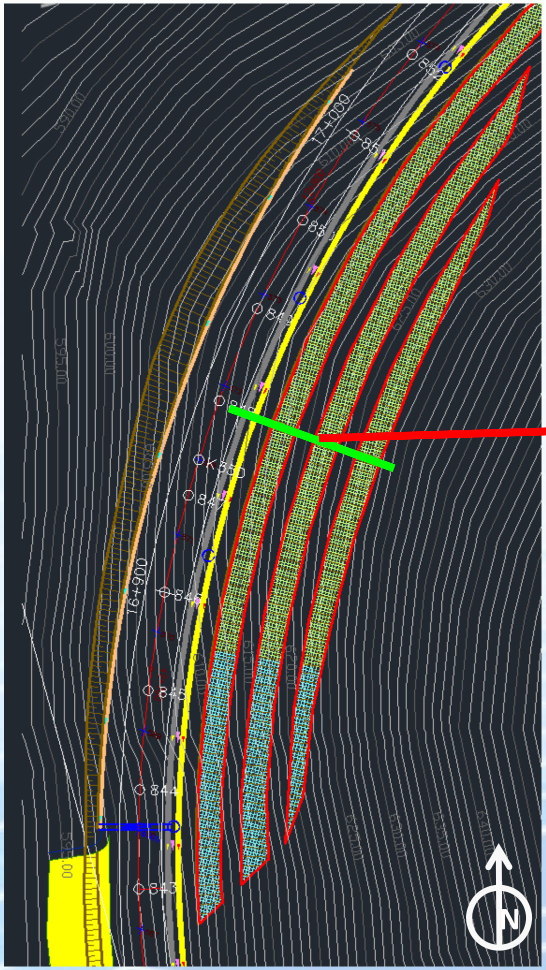
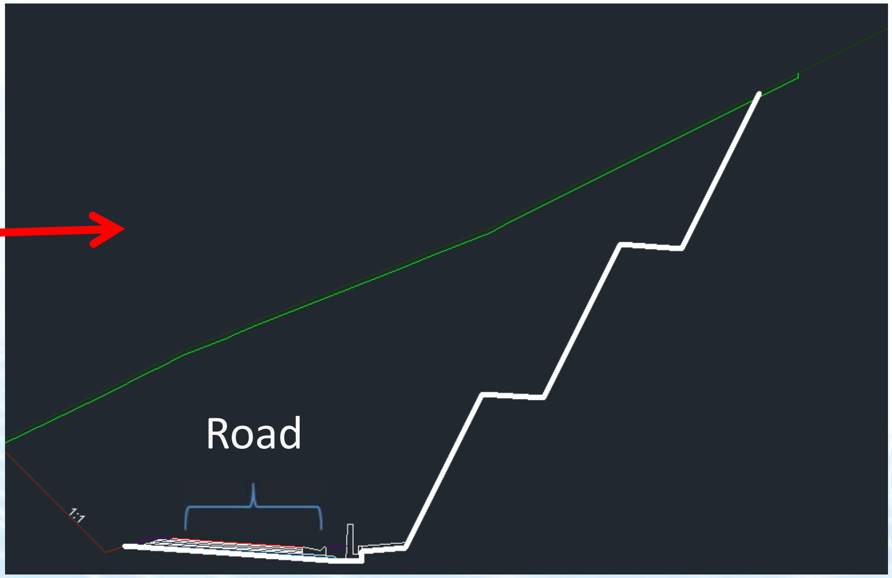
Cut Slope O21, Section: 848





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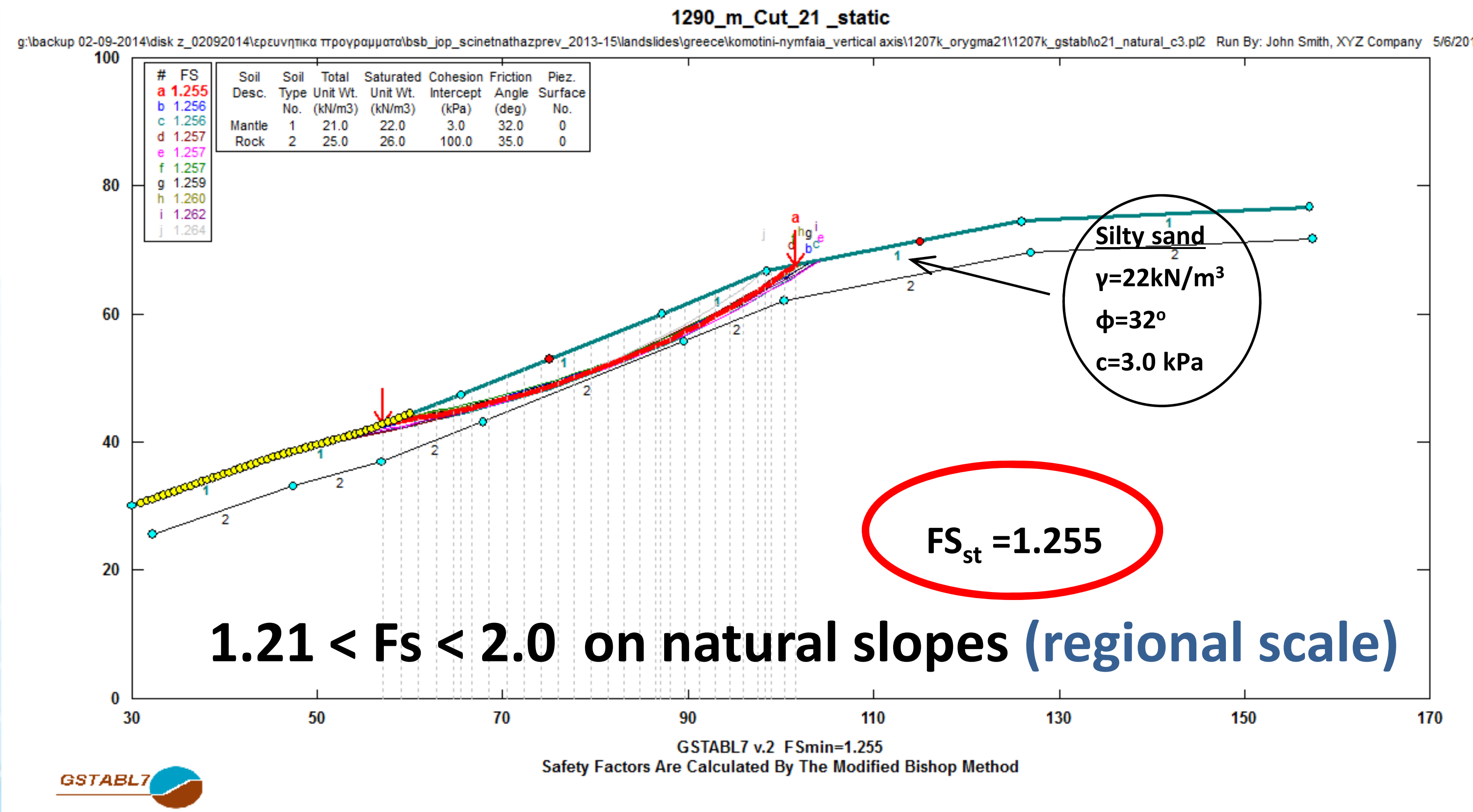
Natural Slope : Static Conditions (local scale)



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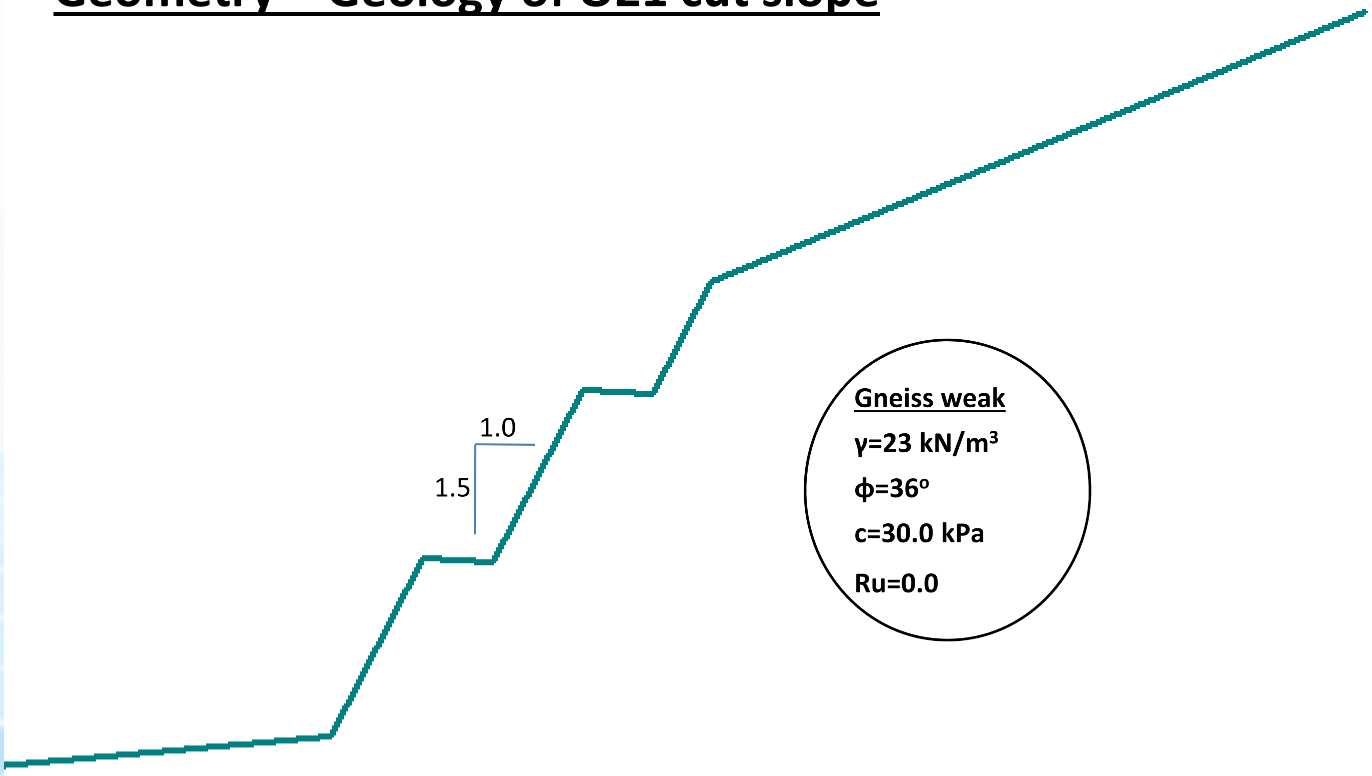
Geometry – Geology of O21 cut slope



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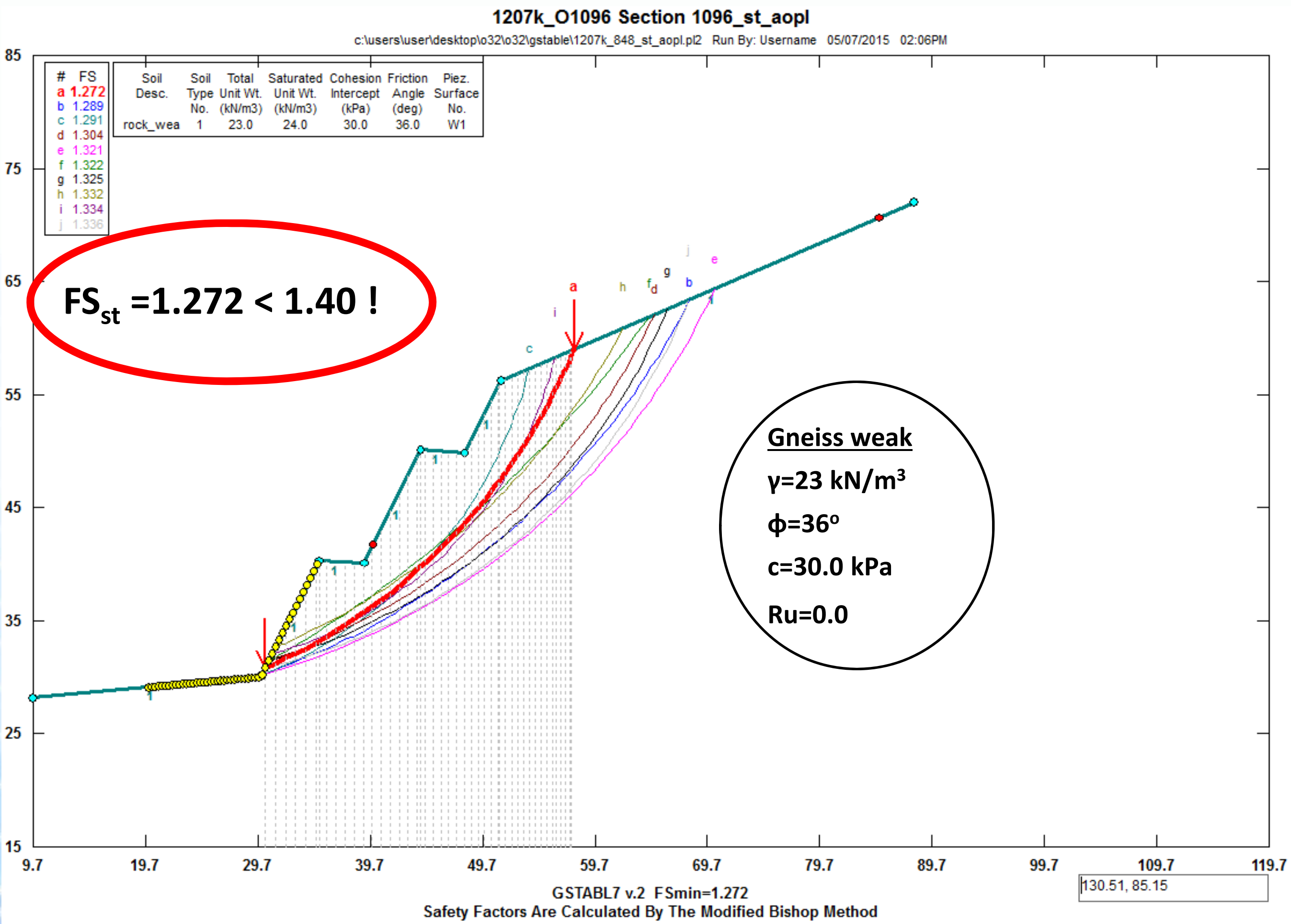
Cut slope O21: static conditions without any countermeasures



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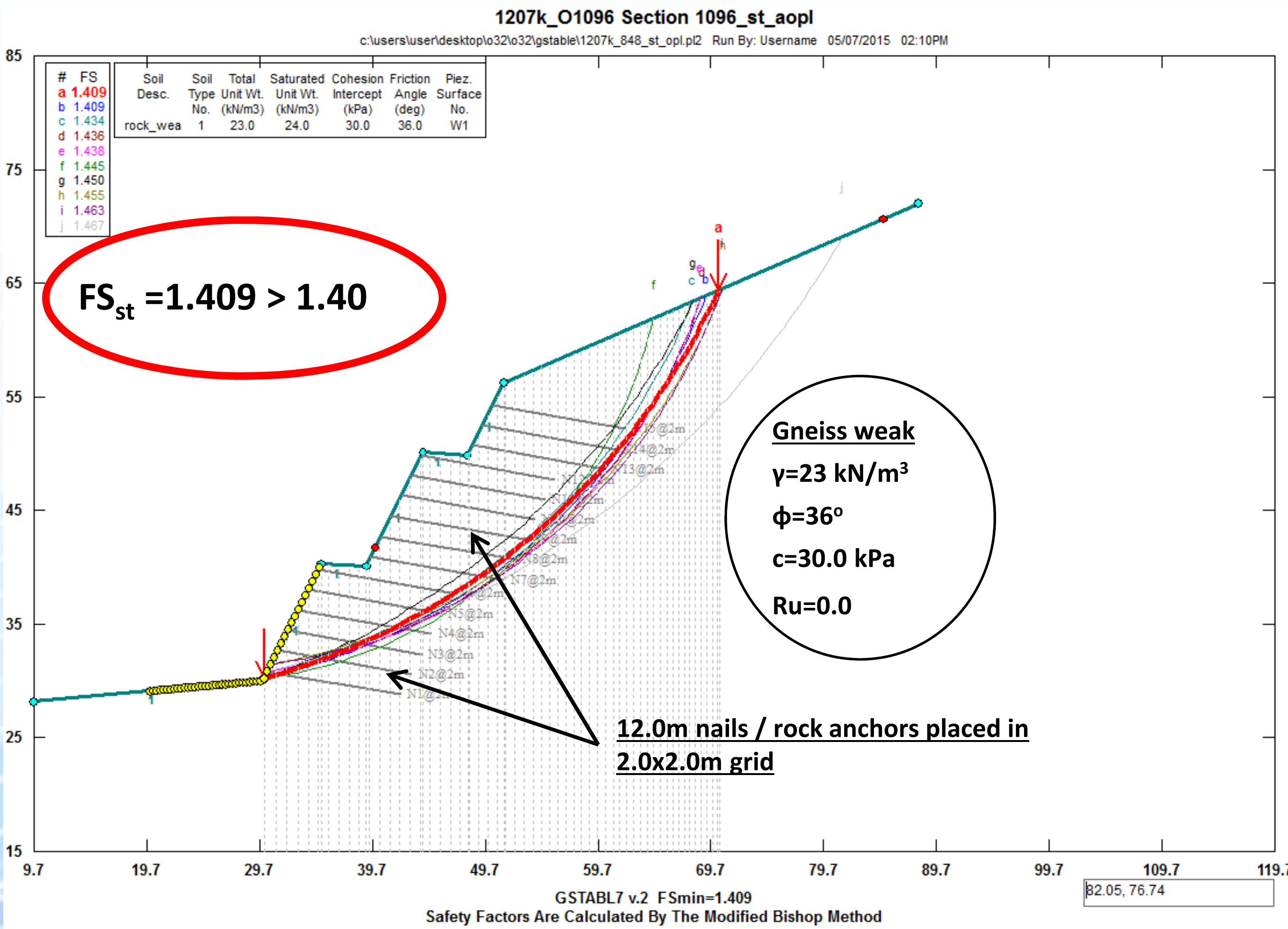
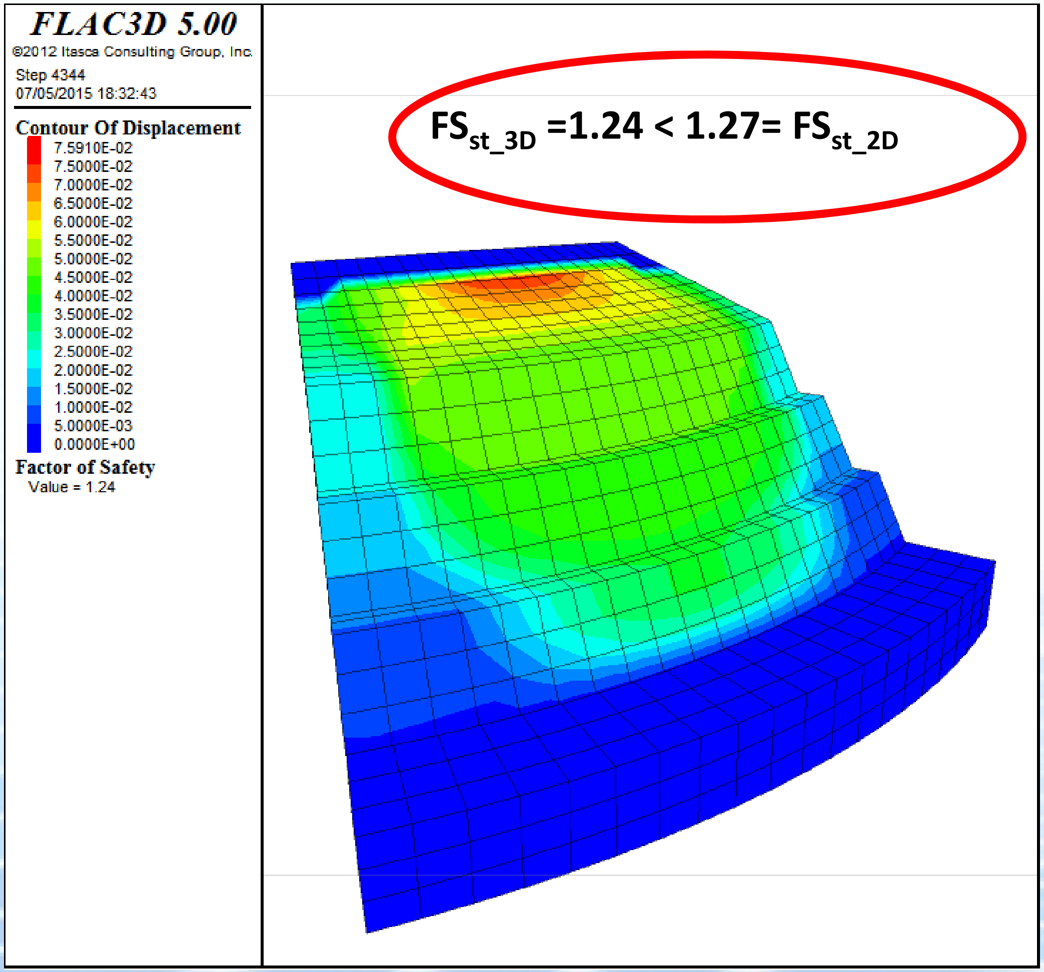
Cut slope 021: Static with countermeasures (nails / passive anchors)



Conditions: Static – 3D Geometry convex cut slope



Displacements expected: **8cm**

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Landslide Hazard Assessment on Regional and Local Scale: Pilot Implementation in Greece

Thank You All for your Attention!

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