Dalla fotointerpretazione al modello dell'assetto morfo-strutturale: metodo, strumenti e applicazioni ad un caso di studio

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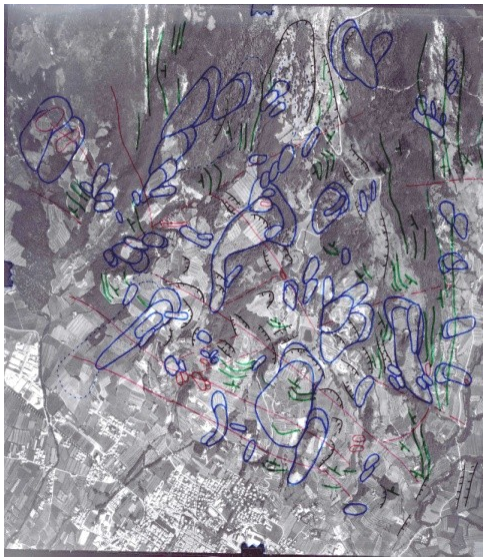
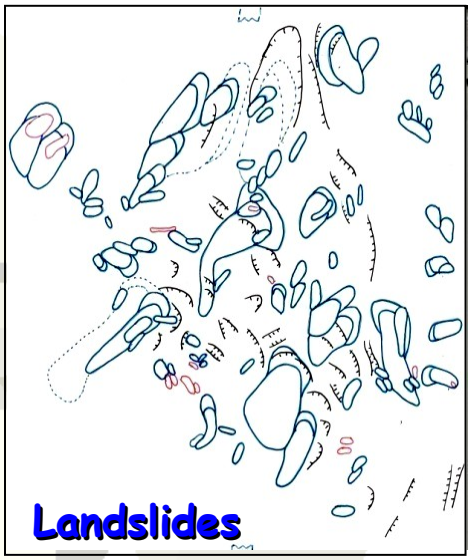
- Aerial Photo Interpretation (API) is widely used in geoscience.

- Among the others, the landslides and structural geology mapping are very common applications



On our side we are interested on the relations between landslides and bedding attitudes



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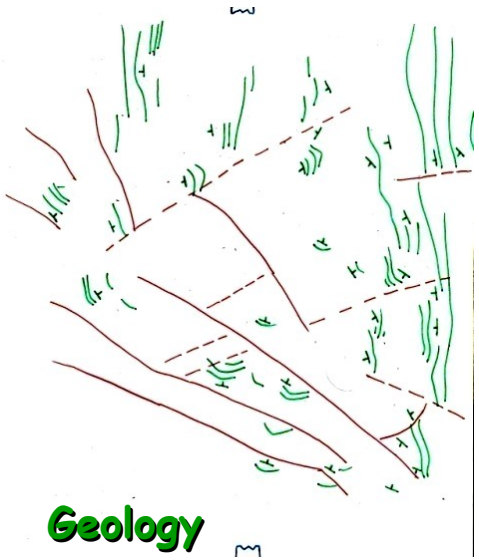

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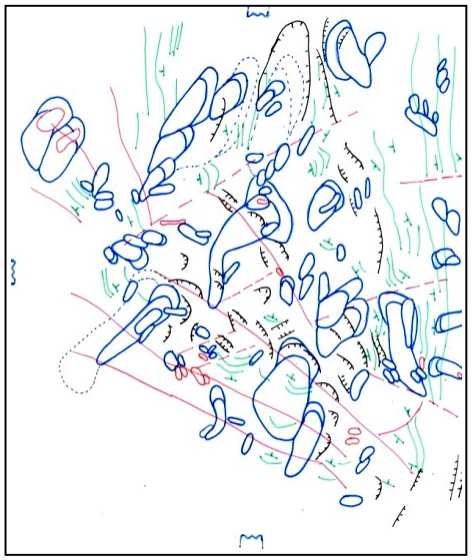
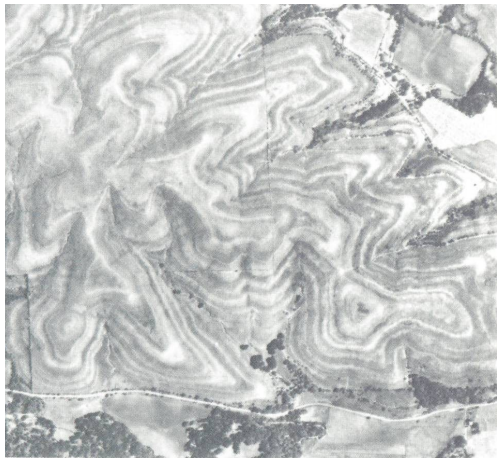
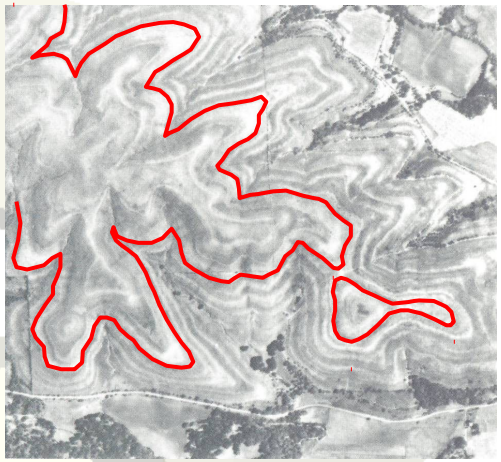


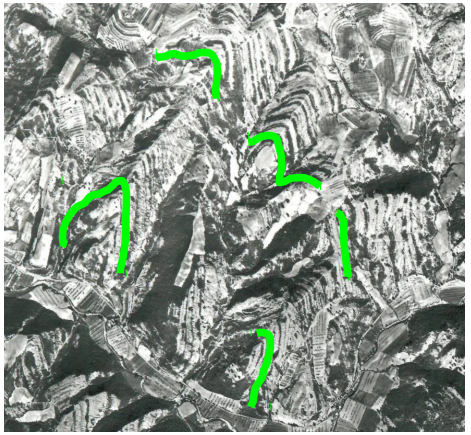
The “bedding traces” (BTs)

Colors and tones

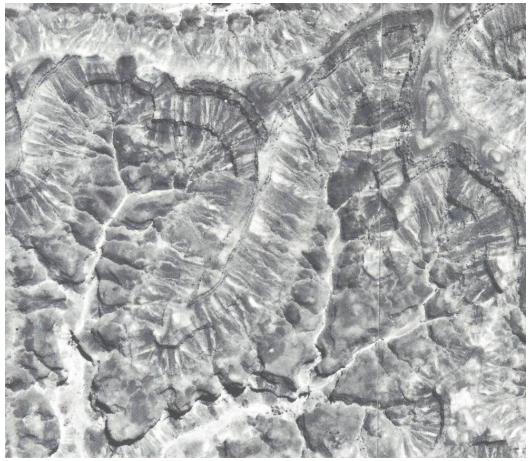




Vegetation



Relief



The “bedding traces” (BTs)

Using the photo-interpretation it is possible to study large zones in a relatively short time.
The obtained geological structural data, however, are often difficult to use in a quantitative way, if not with large approximations.

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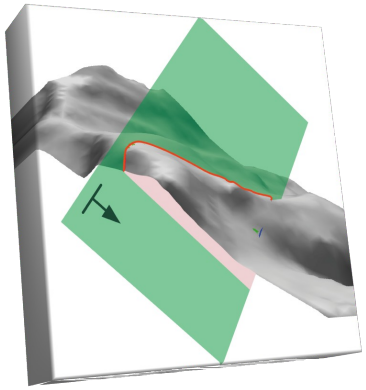
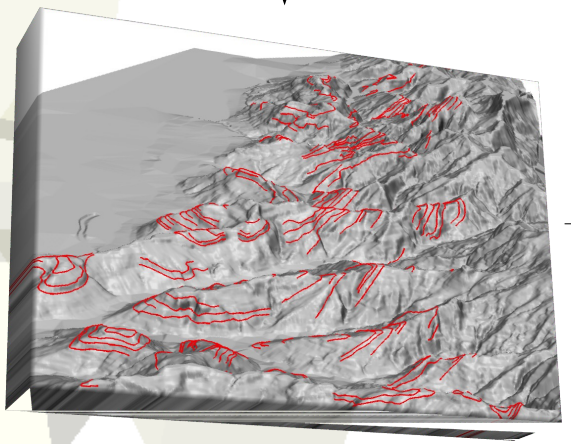
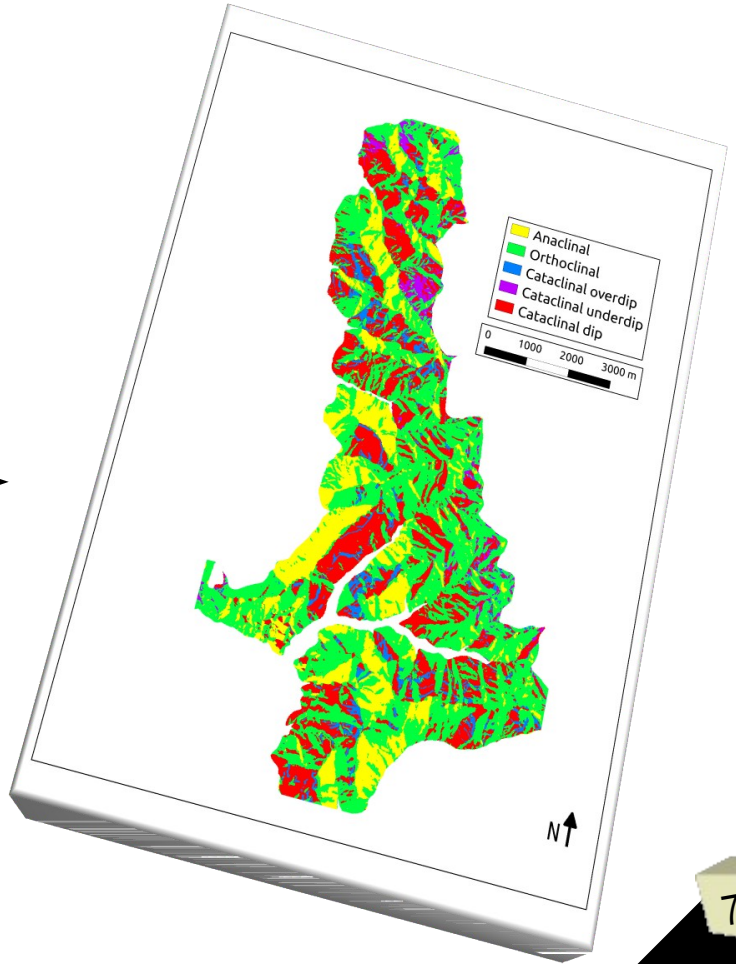
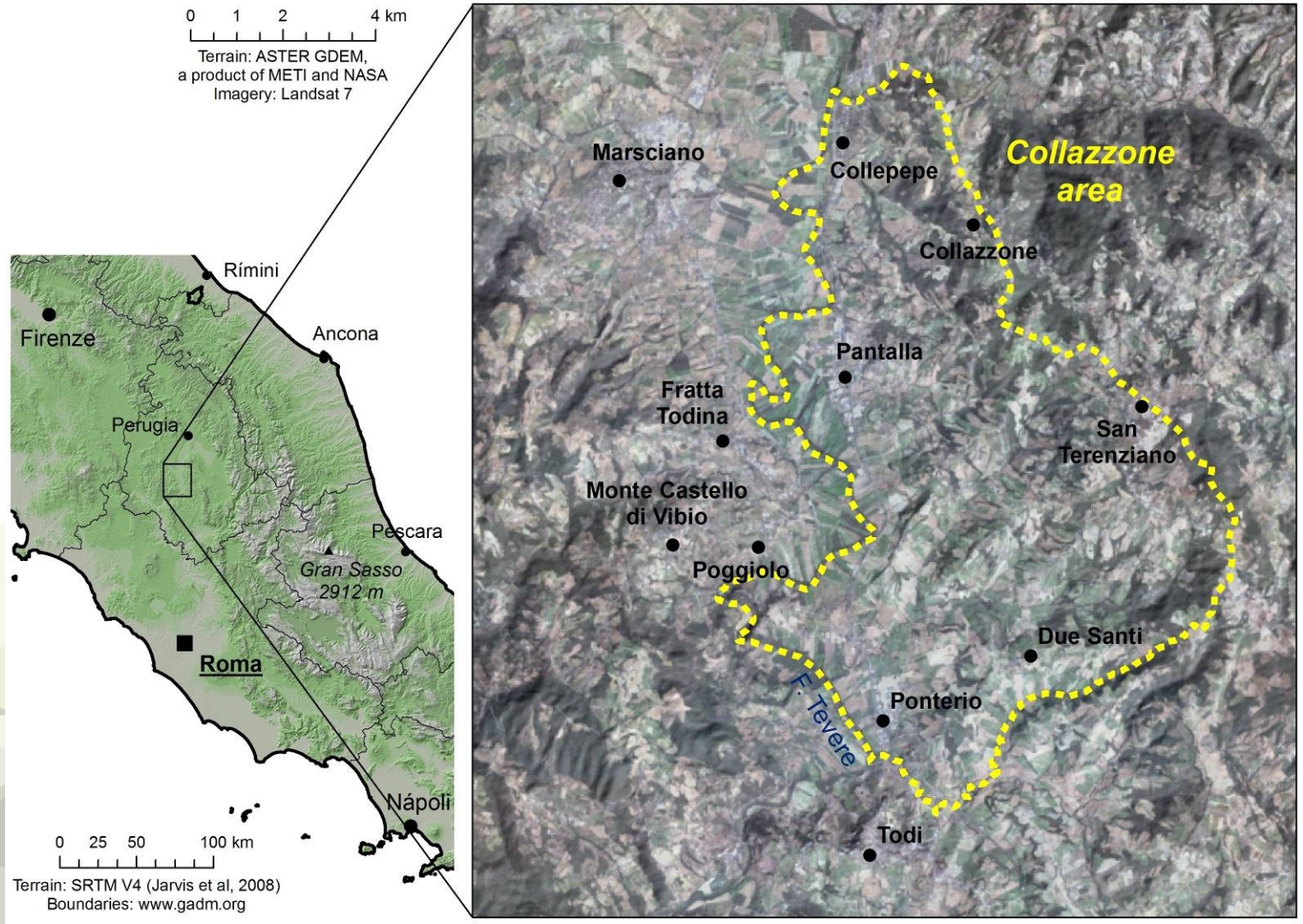
We present a procedure, implemented through Open Source software, aimed to obtain a morpho-structural map starting from the API. Then, for a case study, we show how this map can be related to the a landslide inventory map.







Case study area: Collazzone, Umbria



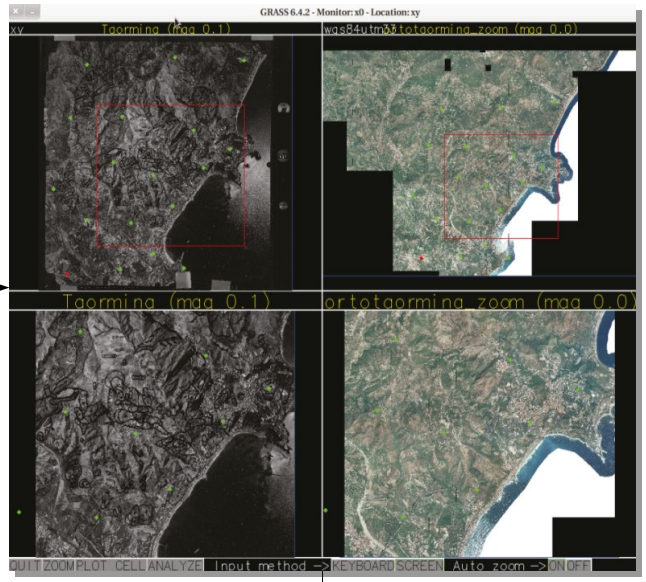
The procedure involves:

- The orthorectification of BTs obtained through API (if not already mapped through a StereoMirror technology - Ardizzone et al., 2013);
- The evaluation of the dip direction and inclination (bedding attitude) from the BTs;
- The interpolation of the bedding attitudes;
- The production of the morpho-structural map;

Ortorettifica delle BTs

GRASS GIS

i.ortho.photo

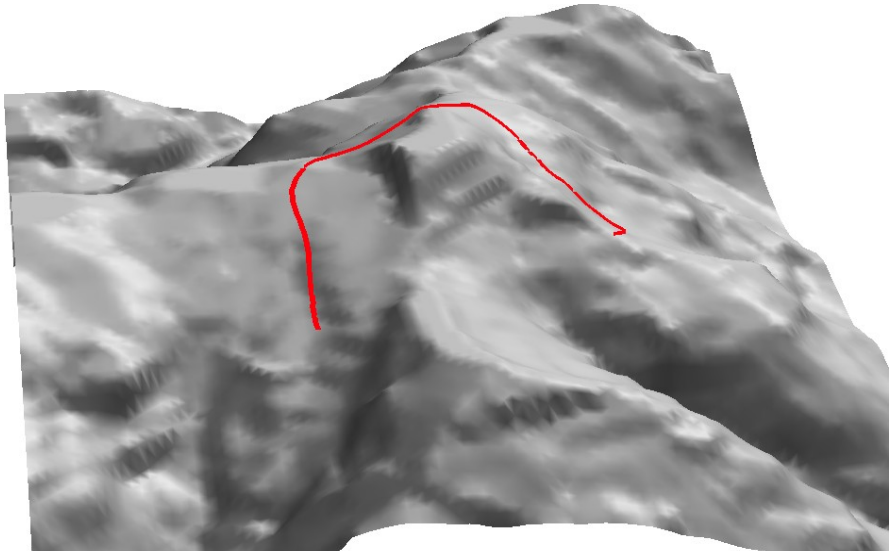


GRASS GIS

Bedding attitudes from the BTs

Five steps (loop for each BT)

- The BT is draped on the DEM, becoming a 3D line



Bedding attitudes from the BTs

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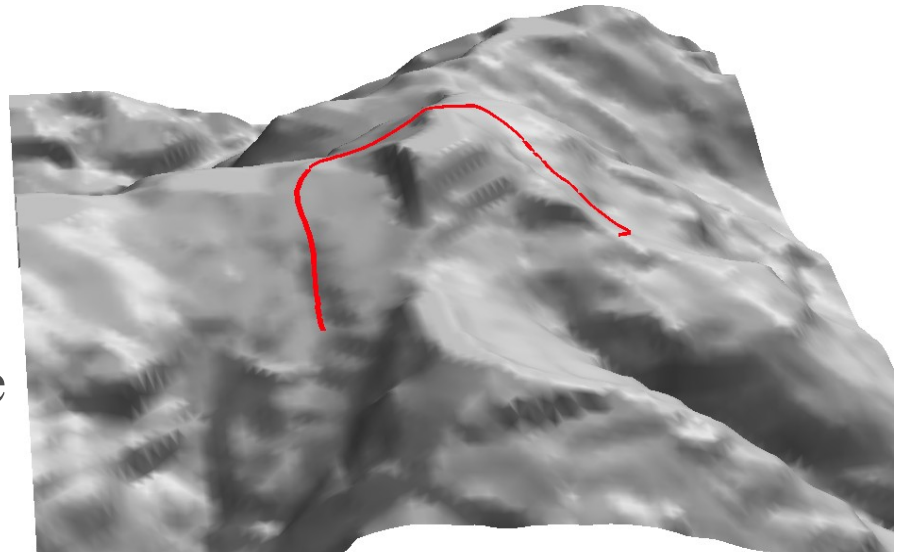
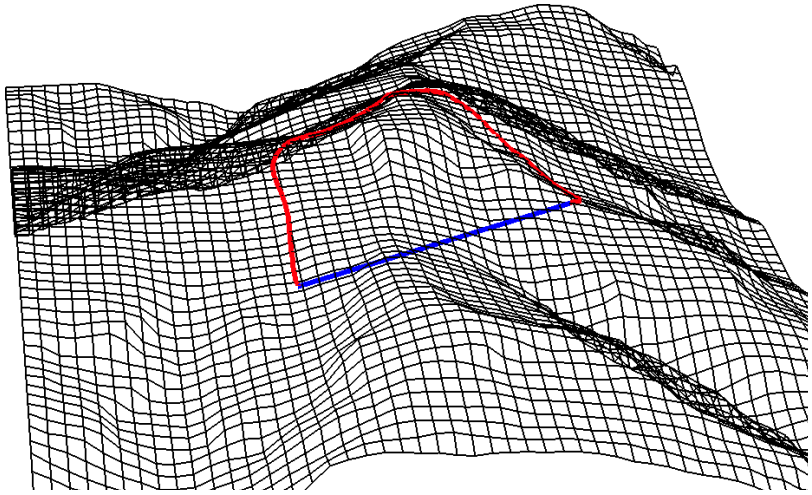
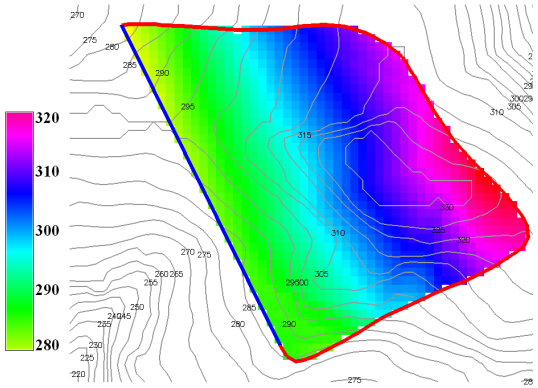


a three-dimensional segment, joining the two end nodes of the BT, is created



Bedding attitudes from the BTs

A 3D triangulation is performed. The result is a nearly flat surface corresponding to the bedding surface (BS).



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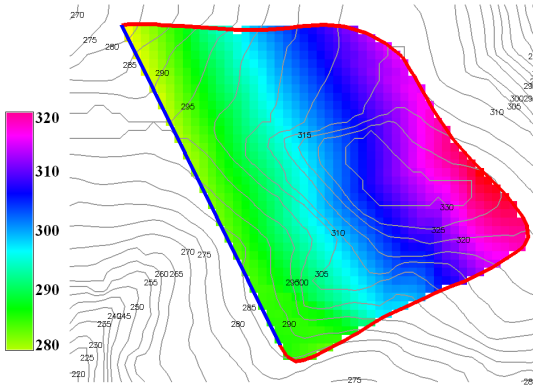
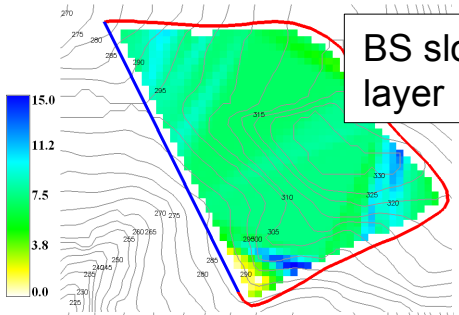
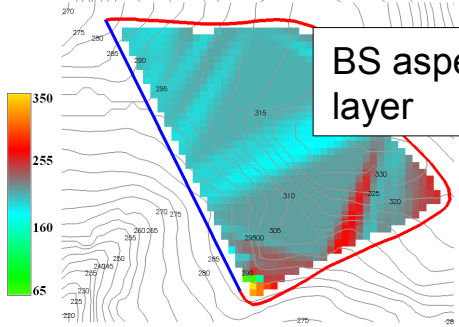




BS slope layer



BS aspect layer

4) Slope and aspect layer are created. Mean slope and mean direction are taken as dip and dip direction to define BA

Bedding attitudes from the BTs

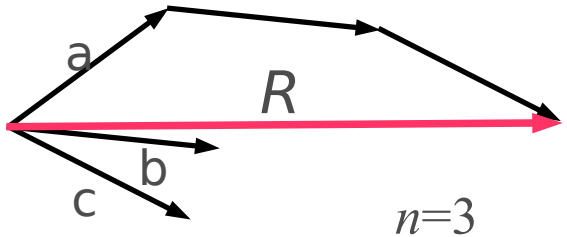
Uncertainty is calculated for

- mean slope: standard deviation,
- mean aspect: circular variance (**V**) and angular standard deviation (**S**)

Circular variance

$$V = 1 - \frac{R}{n}$$

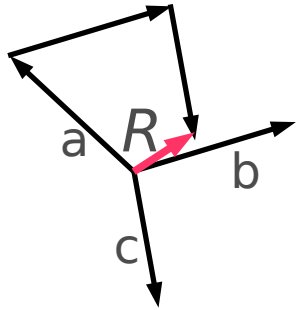
Low circular variance



n=3

$|\alpha| = |b| = |c| = 1$

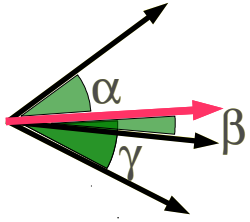
High circular variance



Angular standard deviation

$$S = \frac{1}{(n-1)} \sum_{i=1}^{n} \Delta_i^2$$

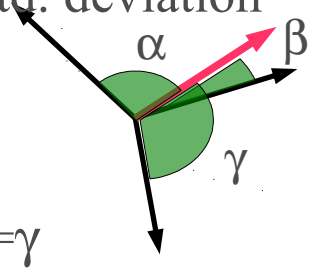
Low angular std. deviation



n=3

$\Delta_1=\alpha$, $\Delta_2=\beta$, $\Delta_3=\gamma$

High angular std. deviation



Bedding attitudes from the BTs

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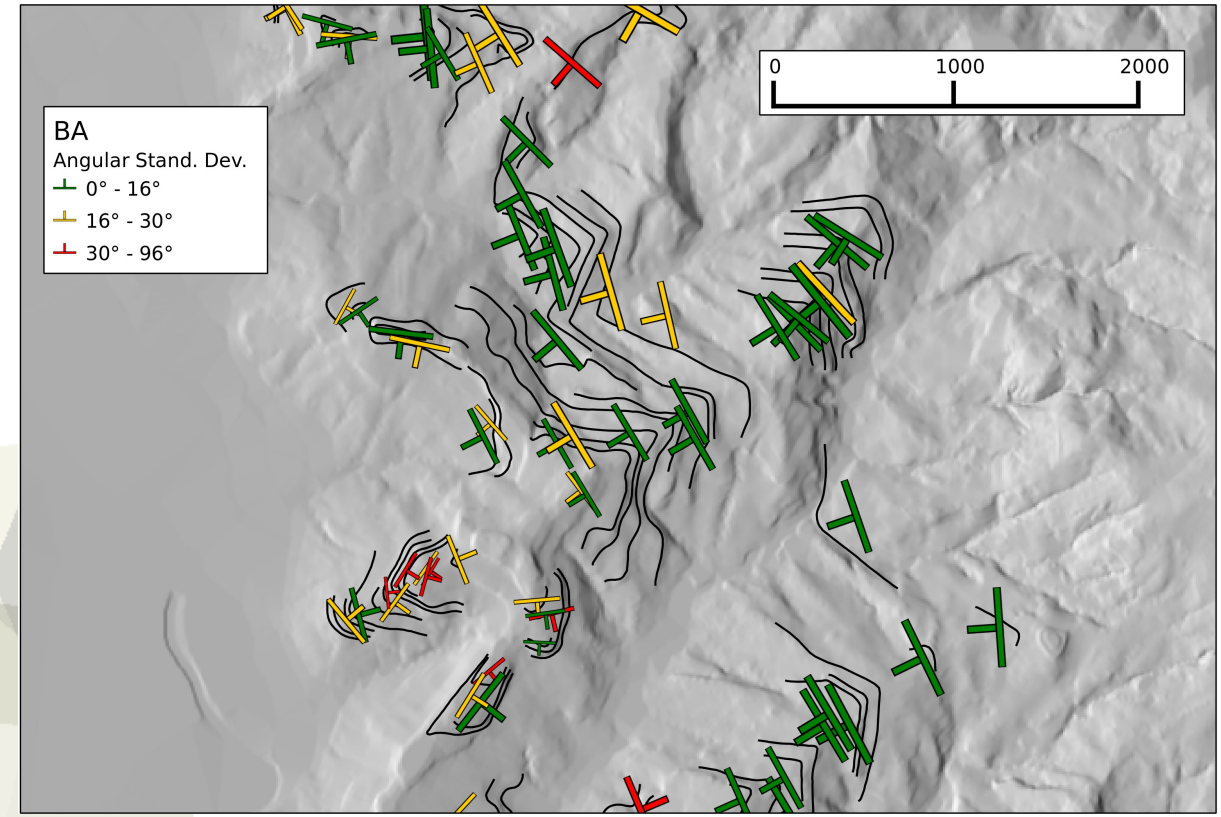
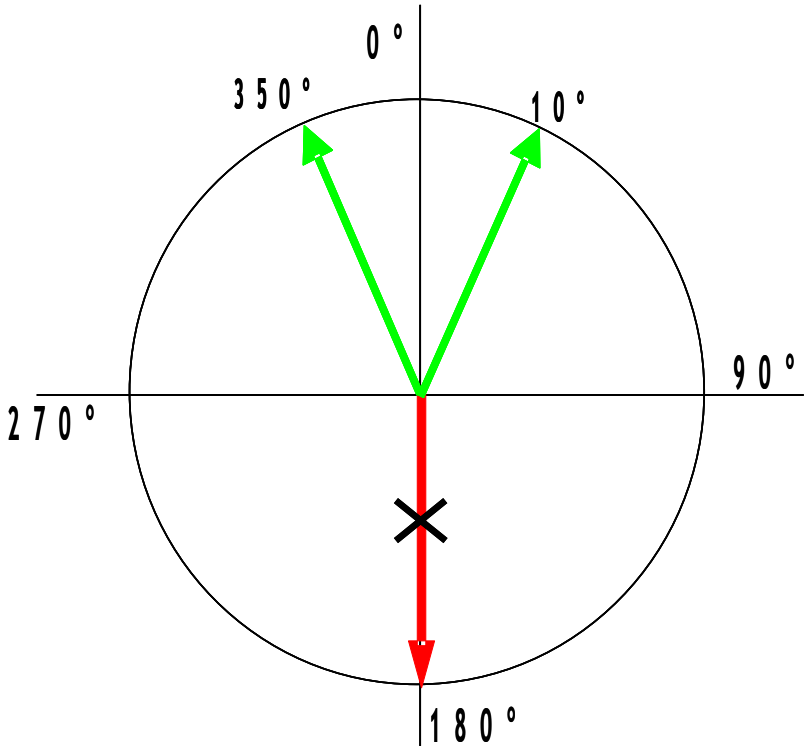
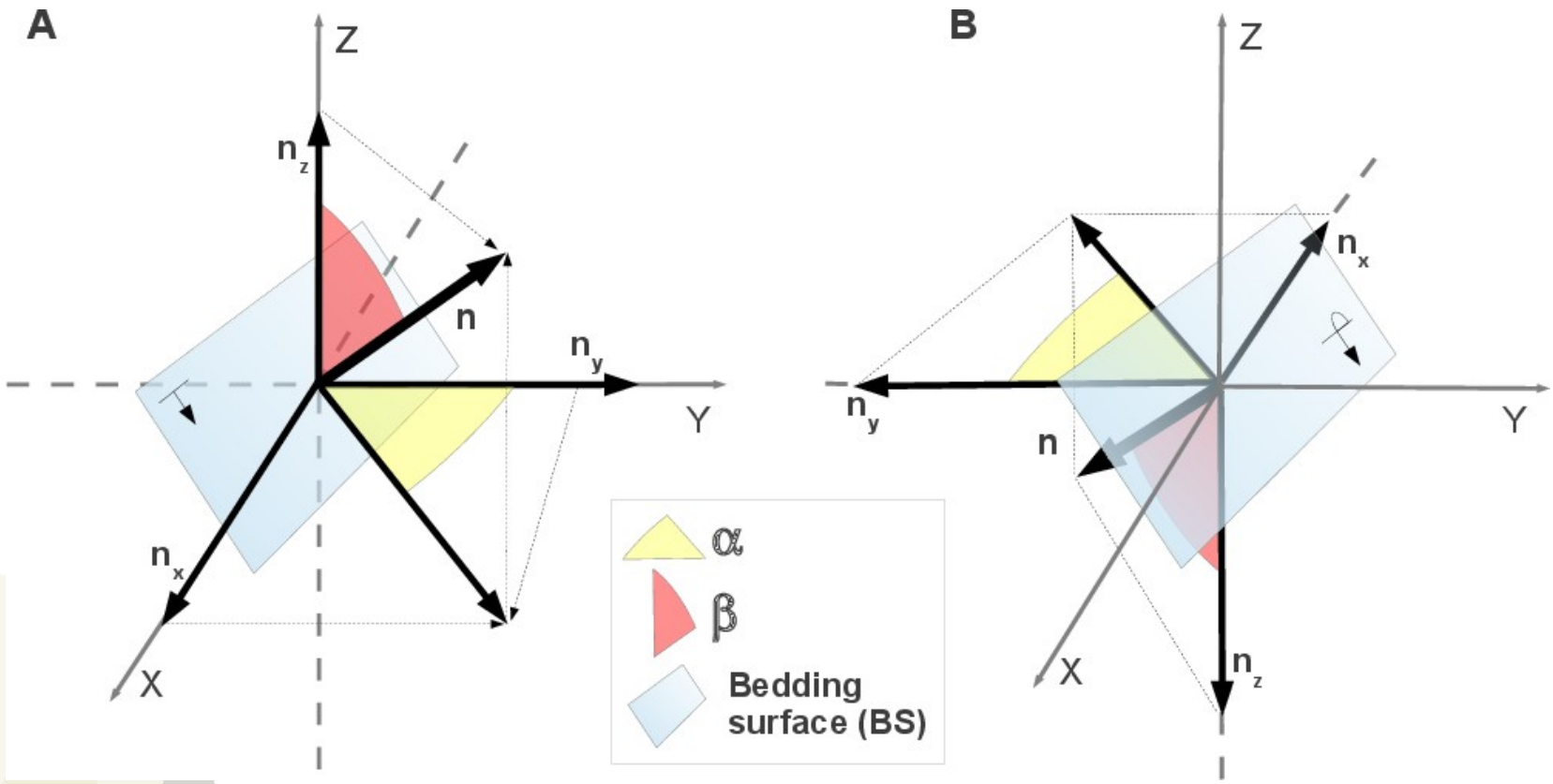


Bedding attitudes interpolation

Interpolation of bedding attitude data is not a trivial task chiefly because the strike direction are directional data



Bedding attitudes interpolation



$n_x = \pm \sin(\alpha)*\sin(\beta)$

$n_y = \pm \cos(\alpha)*\sin(\beta)$

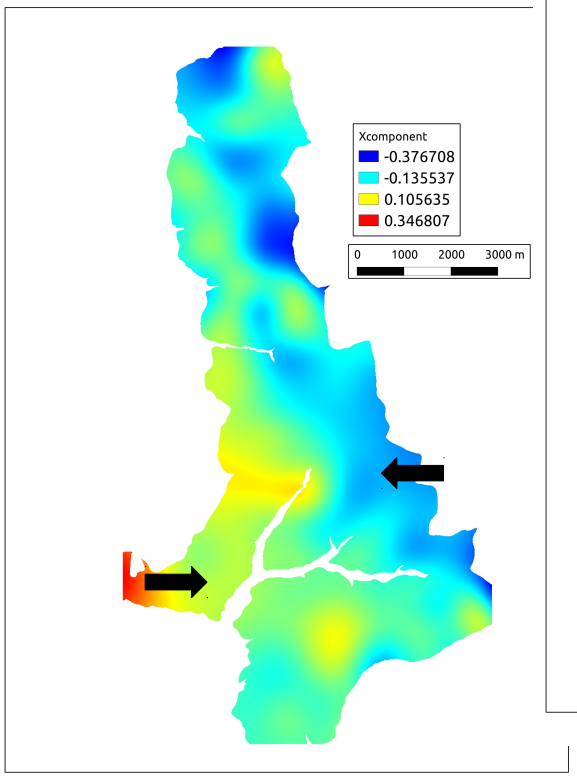
$n_z = \pm \cos(\alpha)$

Bedding attitudes interpolation

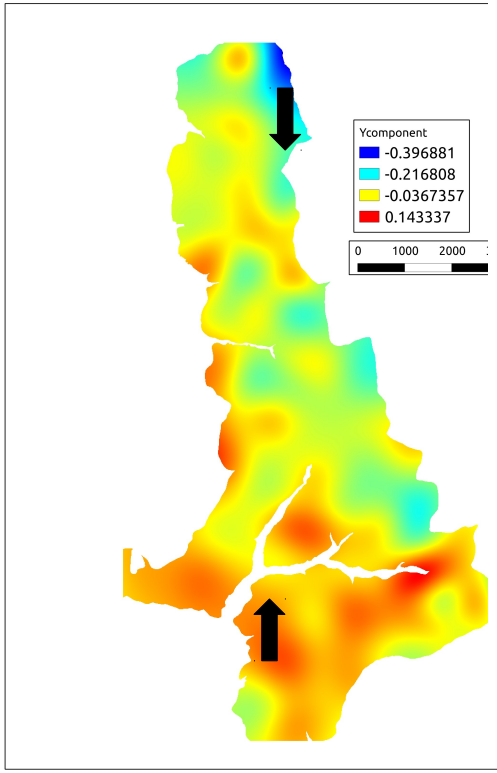
Regularized Spline with Tension (RST, Mitas and Mitášová, 1999)

GRASS GIS

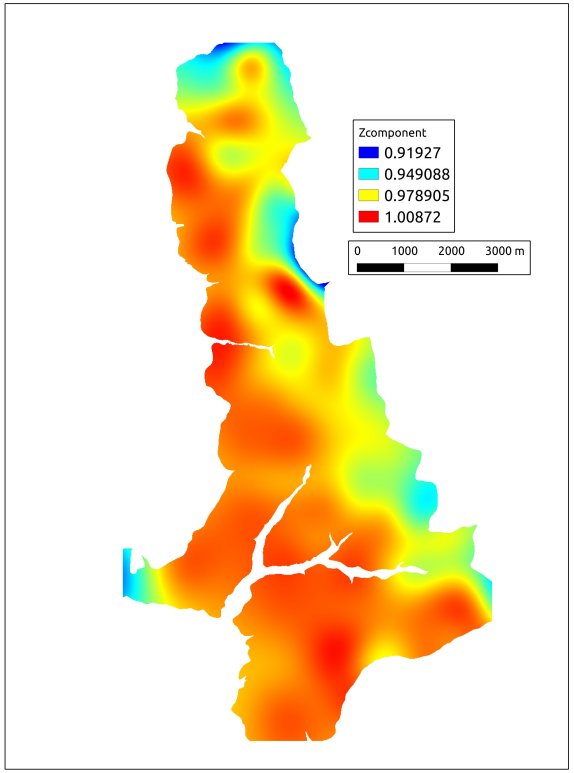
n_x



n_y



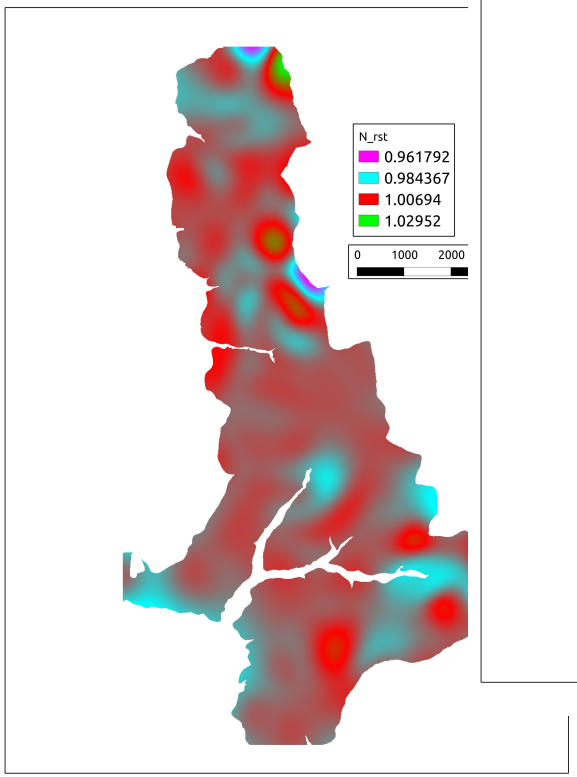
n_z



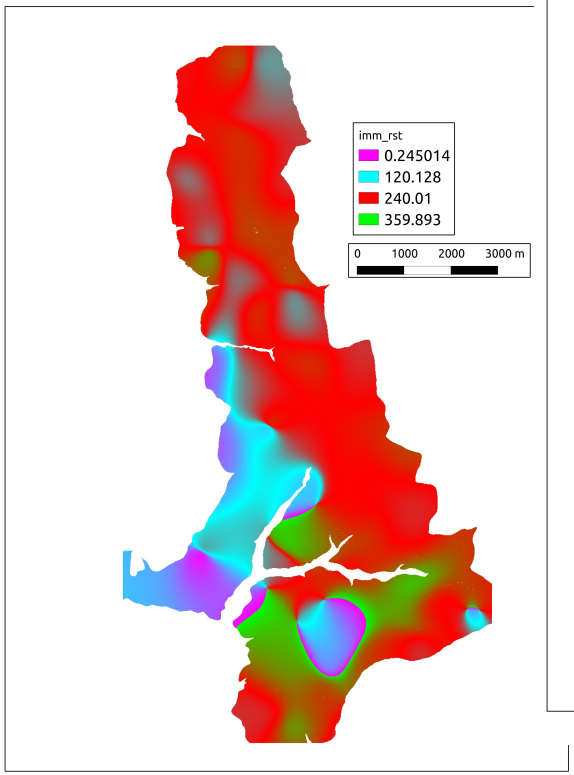
Bedding attitudes interpolation

n_x, n_y, n_z are then exploited to calculate: (i) the n layer, (ii) the dip direction layer, (iii) the inclination layer

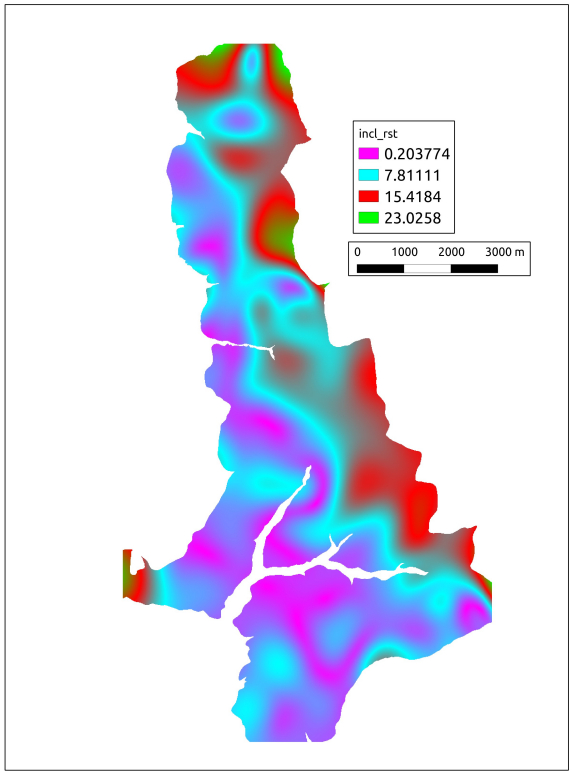
n (~1)



Dip direction (α)



Inclination (β)



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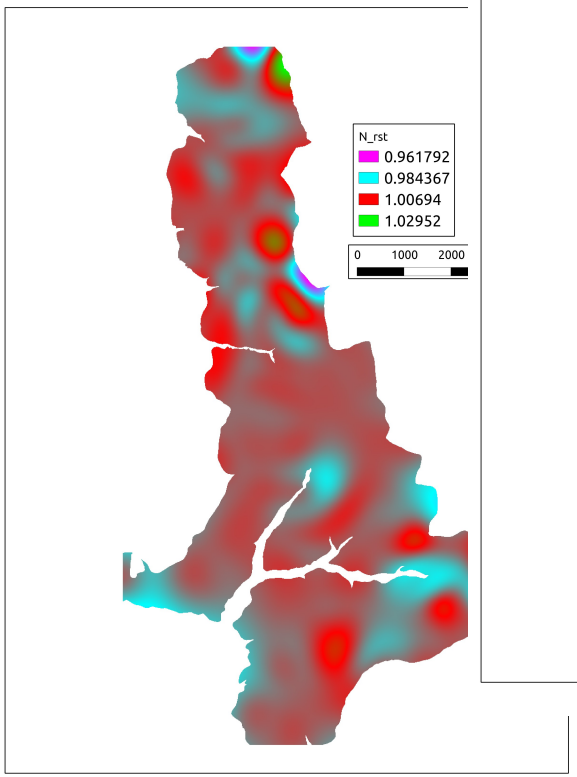
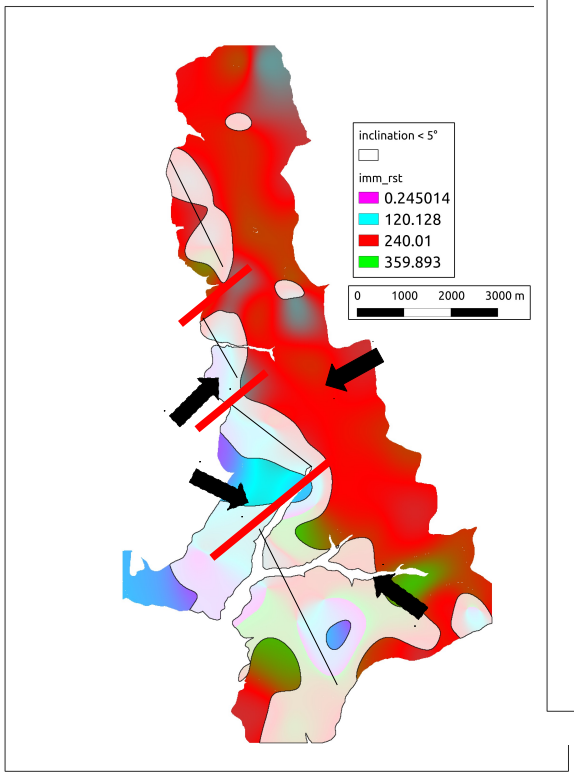
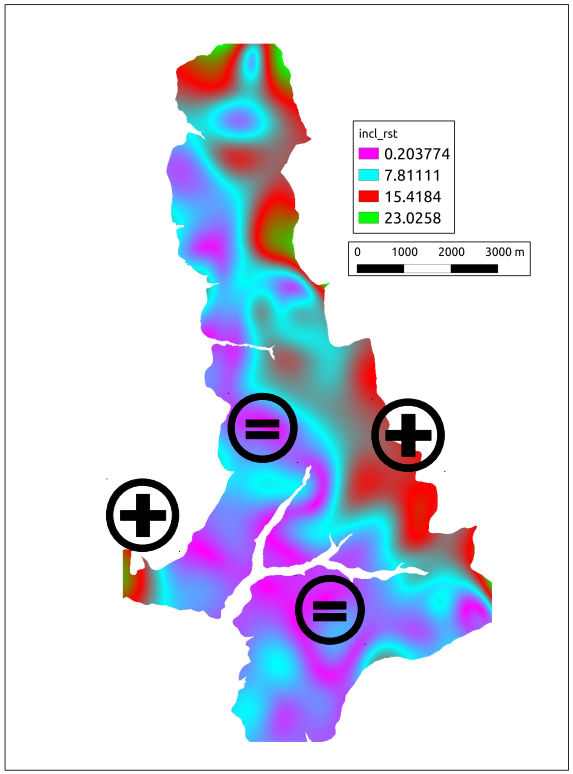


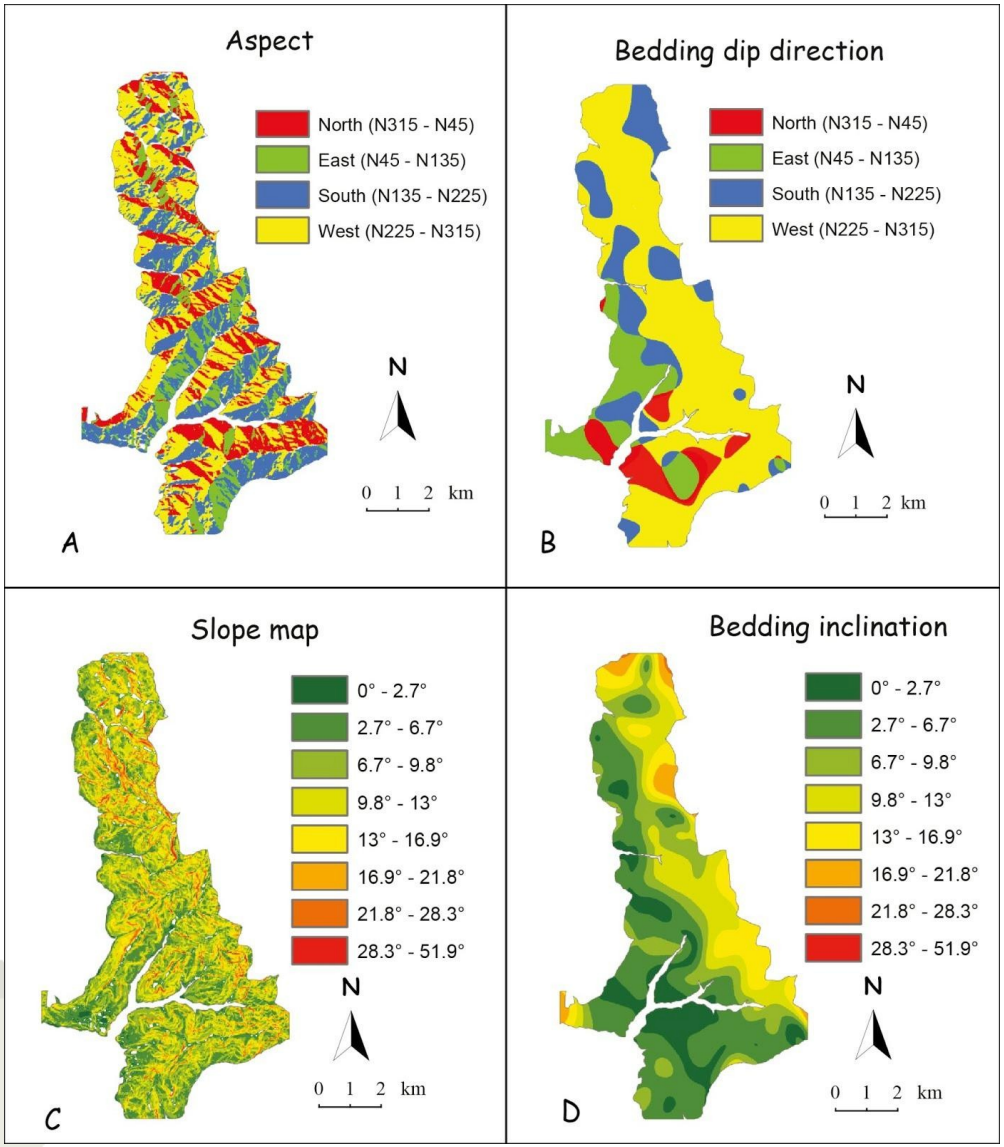
Dip direction (α)



Inclination (β)



Morpho-structural settings

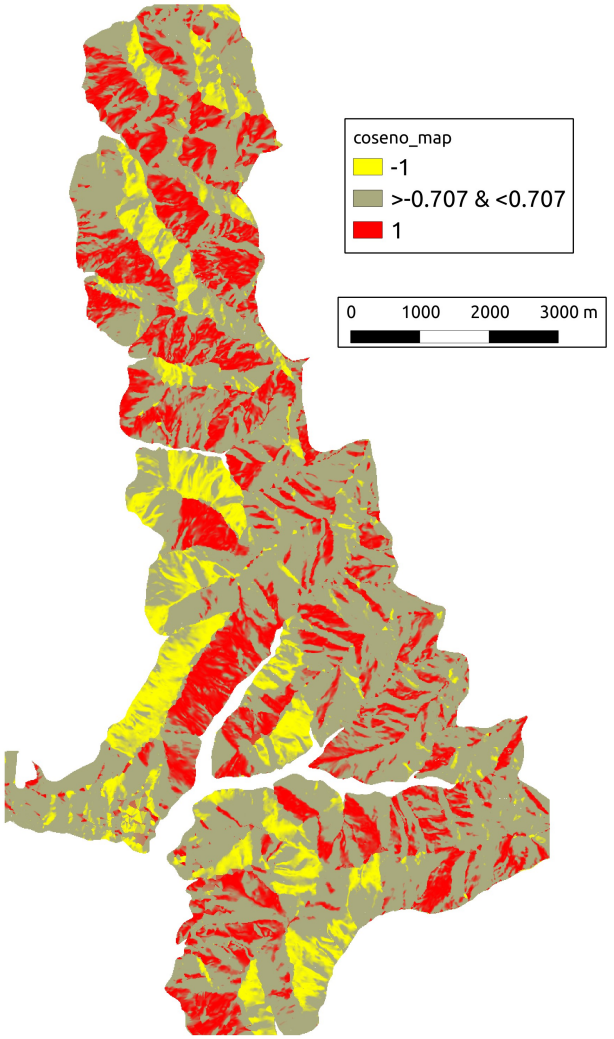


Morpho-structural settings

Directional cosine map: cos(α-A)

α(°)=Dip direction map
A(°)=Aspect map

if cos(α-A) > 0.707 → Cataclinal slopes
if cos(α-A) < -0.707 → Anaclinal slopes
if -0.707<cos(α-A)<0.707 → Orthoclinal slopes



Morpho-structural settings

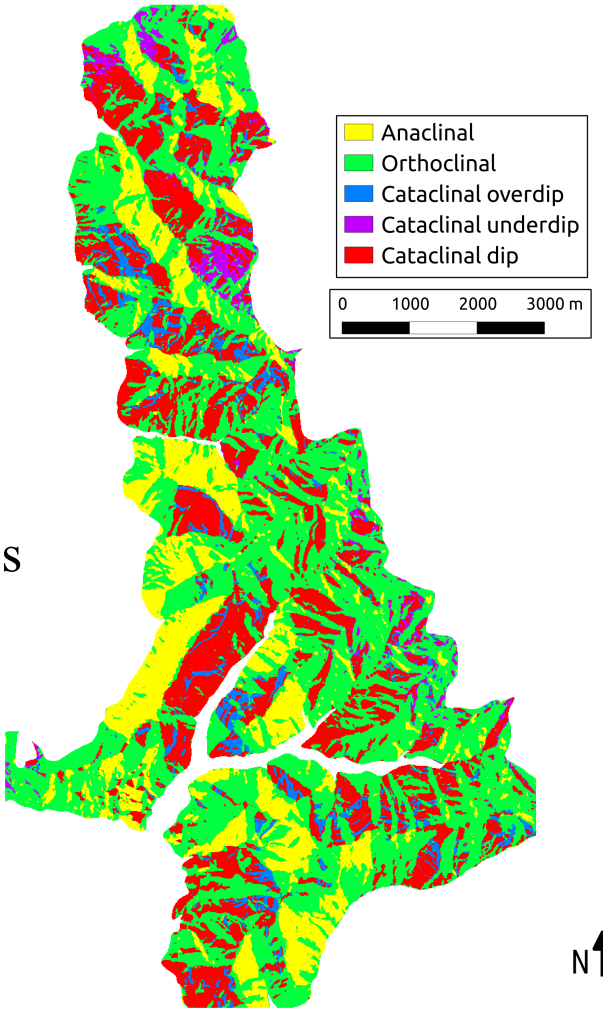
Morpho-structural map:

TOBIA index (Meentemeyer and Moody, 2000):

$T=\cos\beta*\cos S+\sin\beta*\sin S*\cos(\alpha-A)$

if $\cos(\alpha-A) > 0.707$ → Cataclinal slopes
  if $T<0.99$ & $\beta<S$ → Cataclinal overdip slopes
  if $T<0.99$ & $\beta>S$ → Cataclinal underdip slopes
  if $T>0.99$ → Cataclinal dip slopes
if $\cos(\alpha-A) < -0.707$ → Anaclinal slopes
if $-0.707<\cos(\alpha-A)<0.707$ → Orthoclinal slopes

Where
β = inclination map
S = slope map



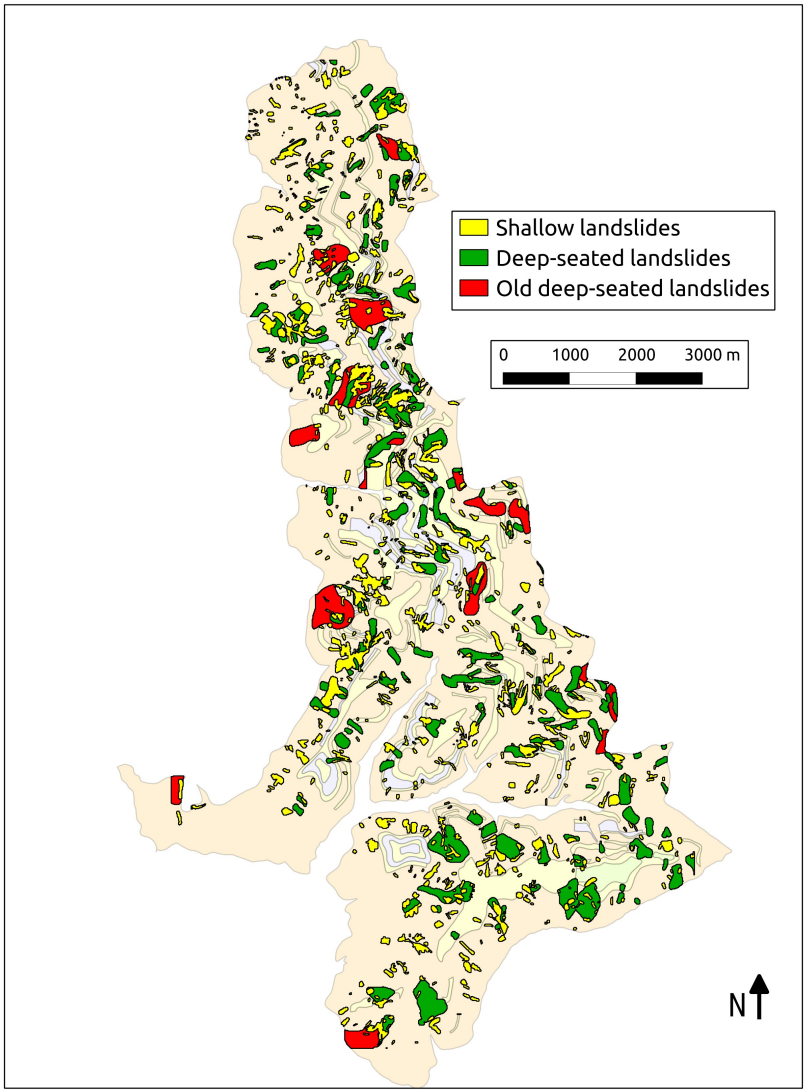
Landslides and morpho-structural settings

What about the relationship between morpho-structural settings and landslides spatial distribution?

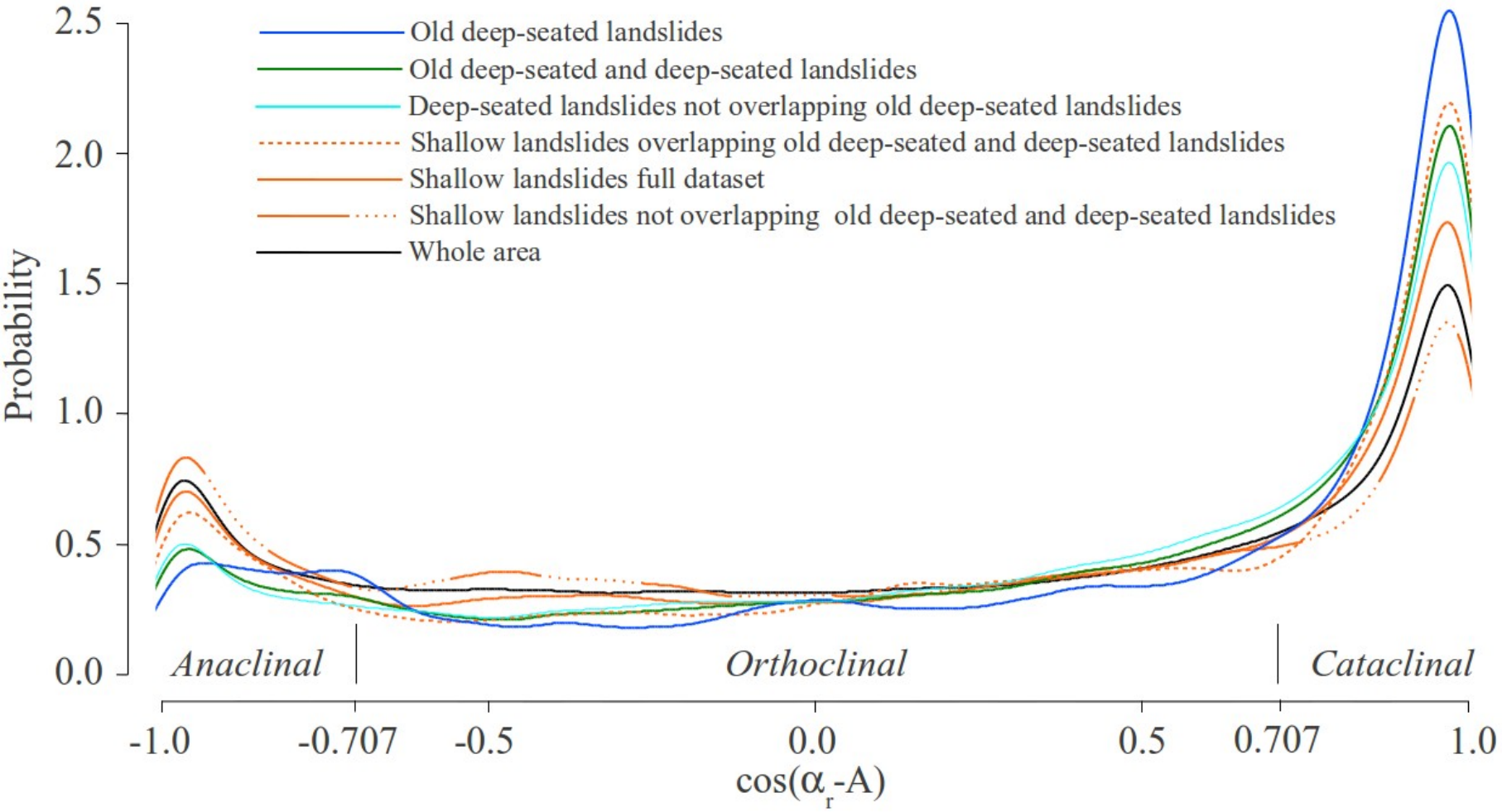
We exploited a large and very detailed landslide inventory: more than 1500 slope movements mapped in the period from 1941 to 2004

The landslides are classified as:

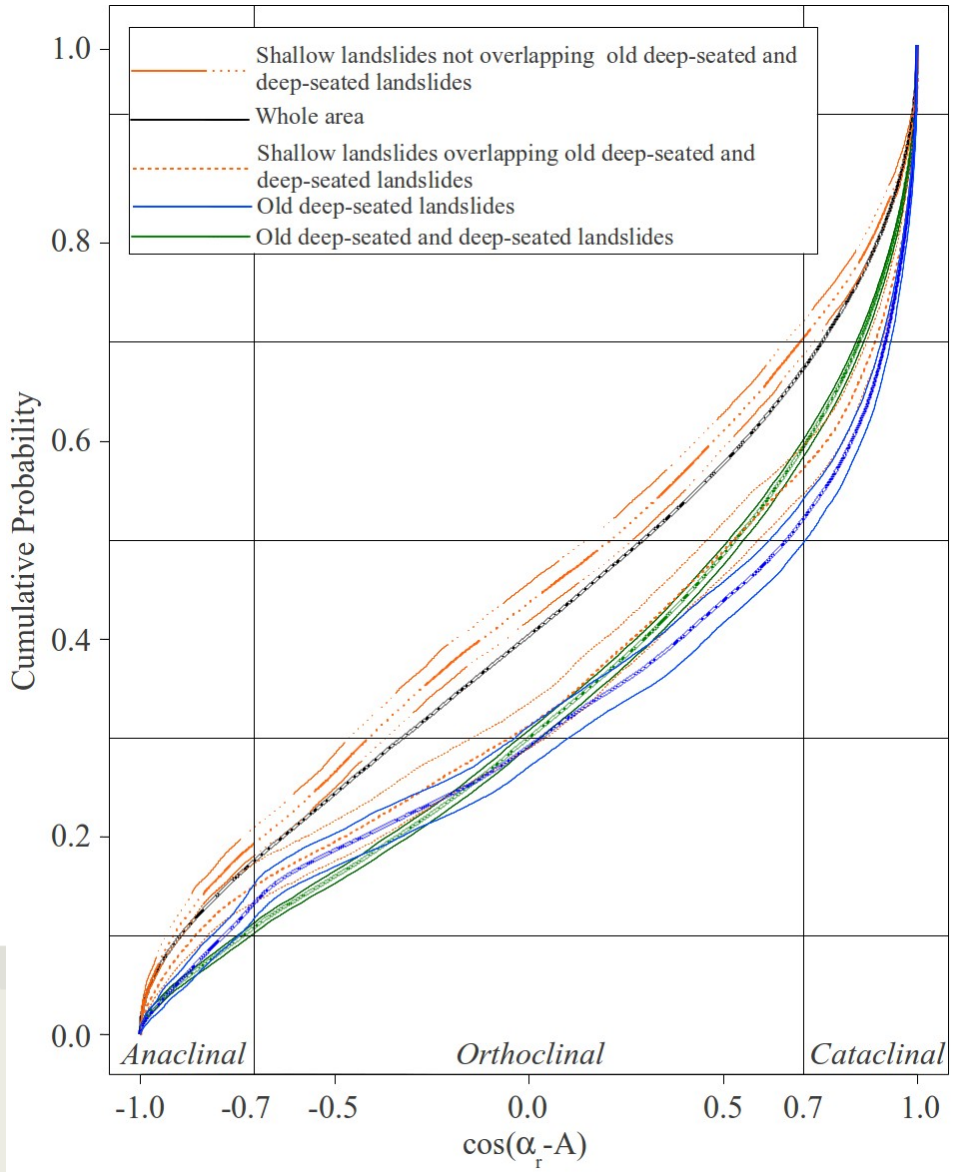
- Old deep-seated (relict) landslides
- Deep-seated landslides
- Shallow landslides



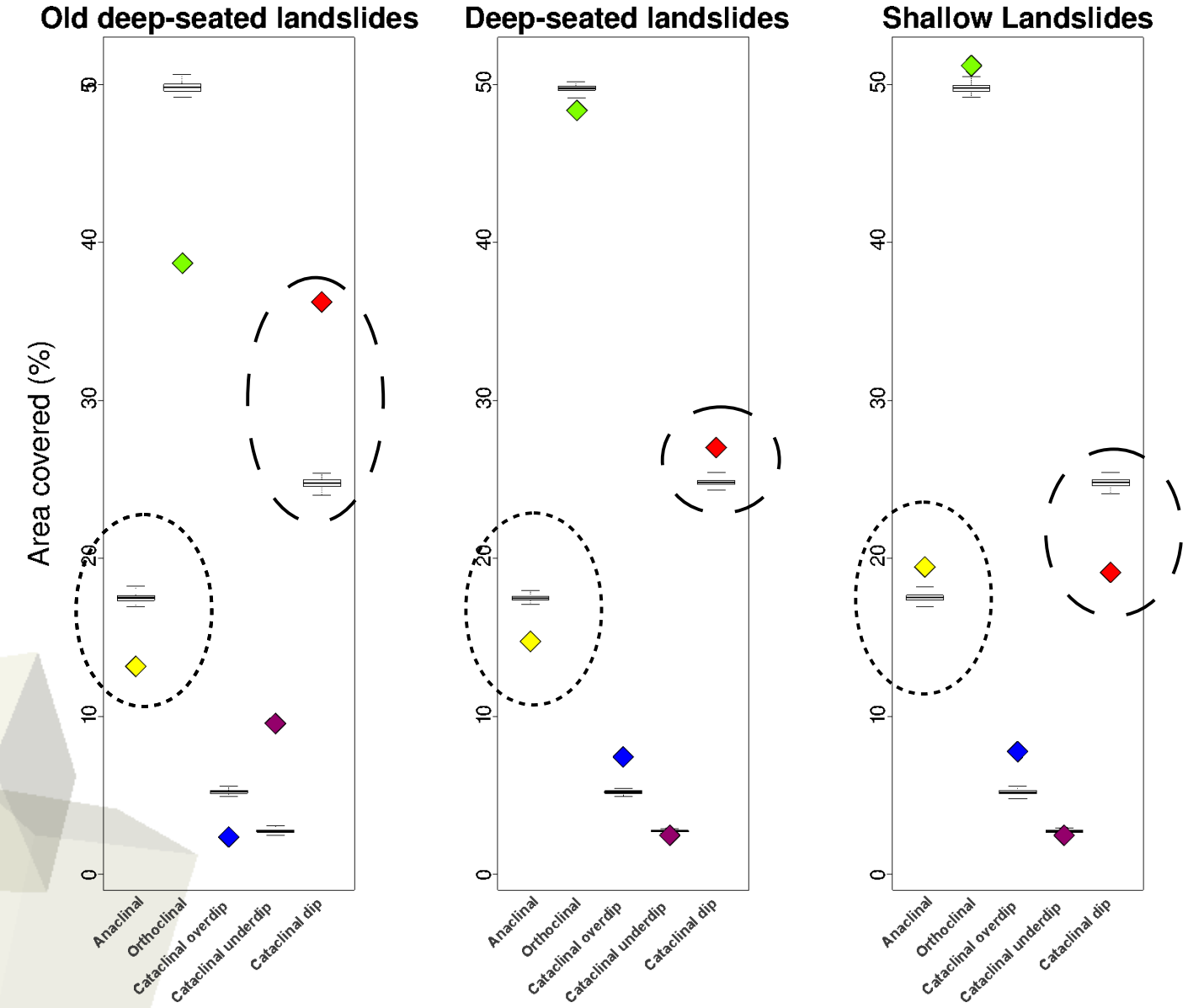
Landslides and morpho-structural settings



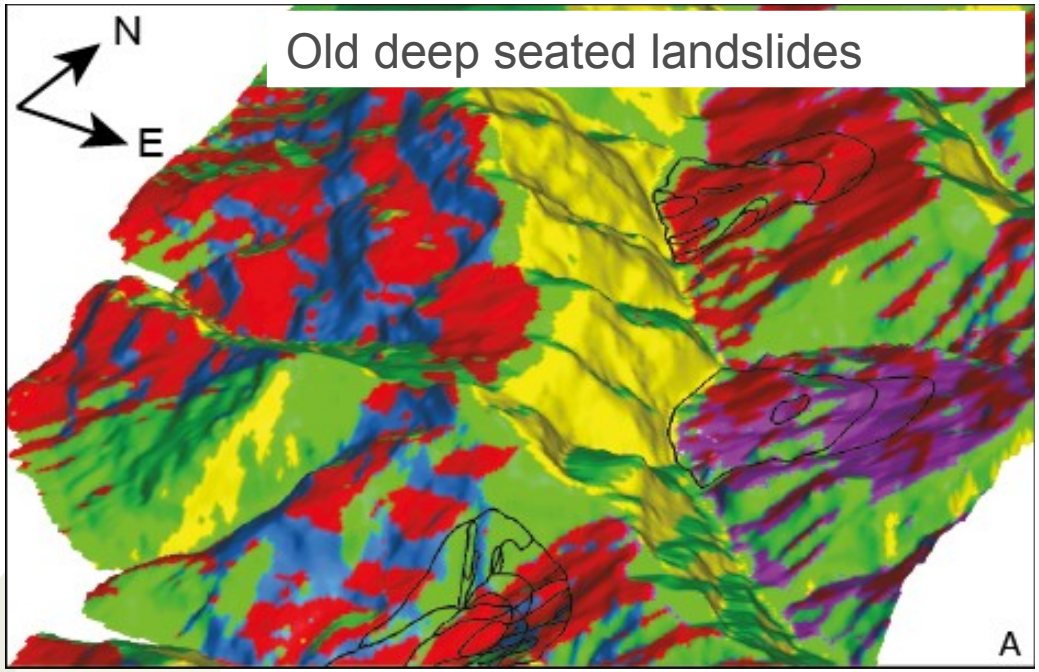
Landslides and morpho-structural settings



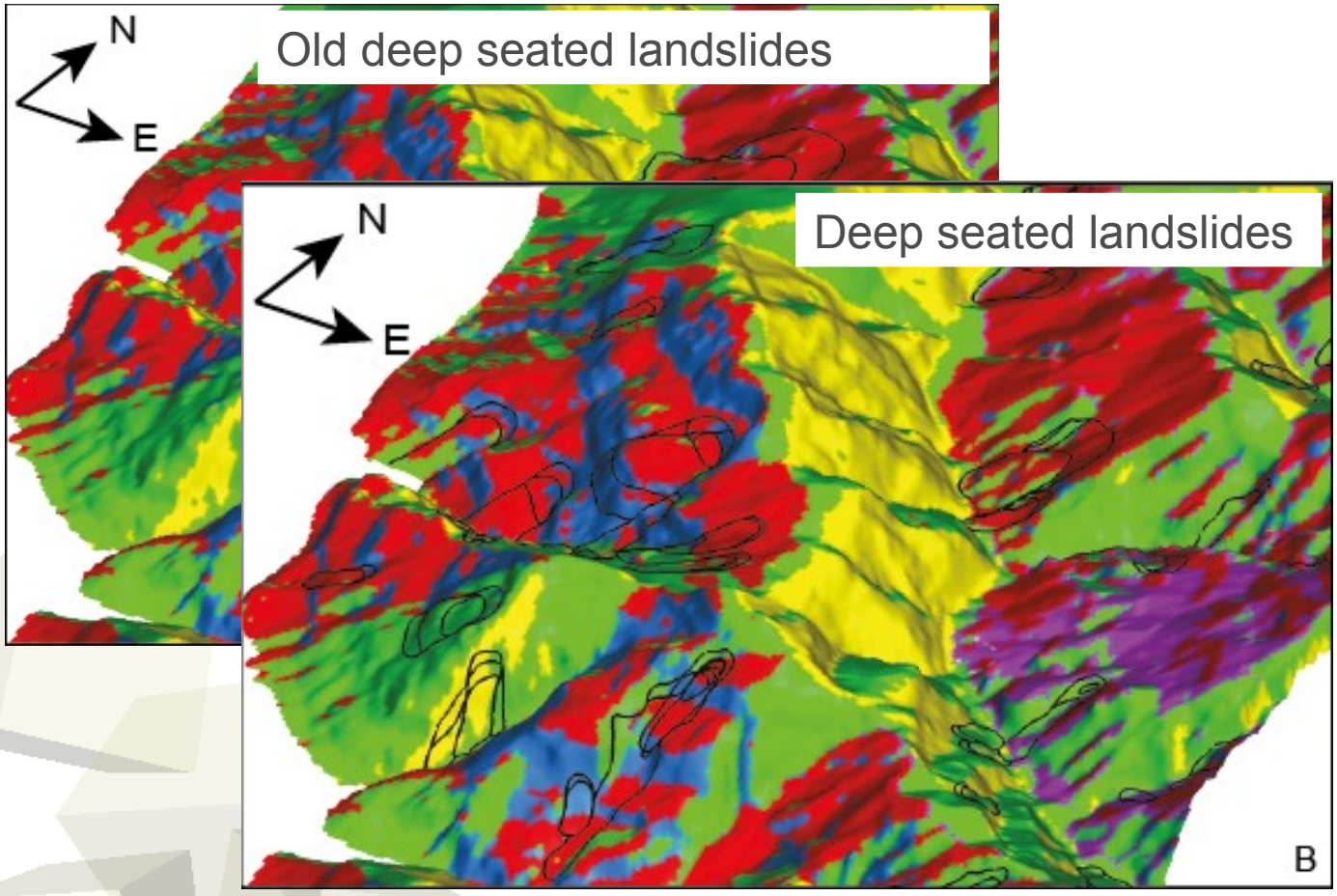
Landslides and morpho-structural settings



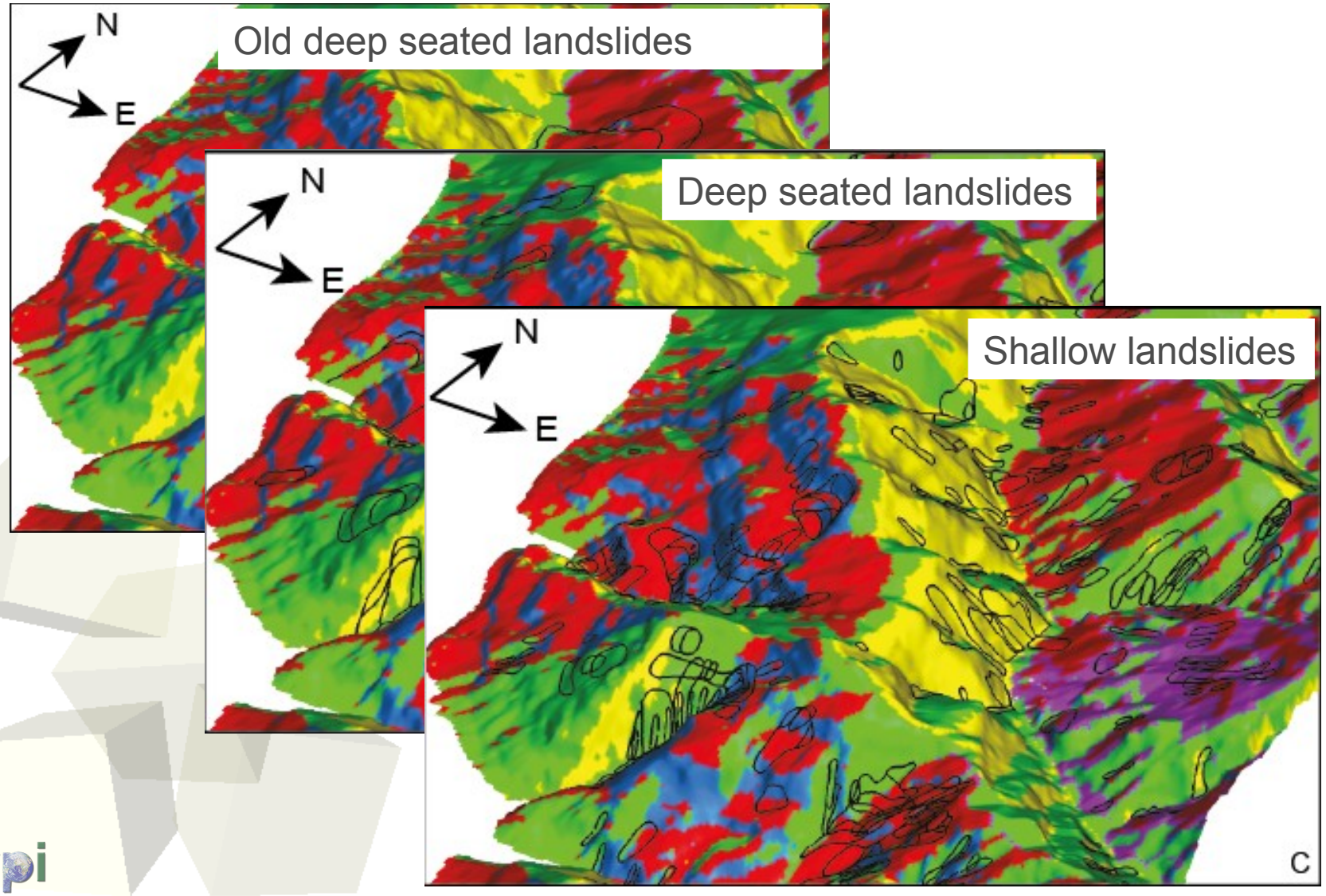
Landslides and morpho-structural settings



Landslides and morpho-structural settings



Landslides and morpho-structural settings

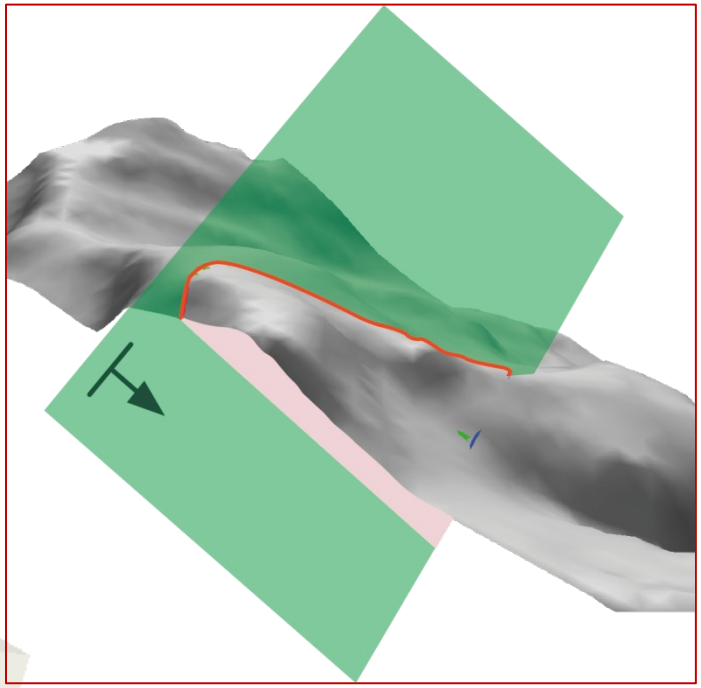


At IRPI we publish some experimental landslide-related WPS tools dealing with:

- **landslide size** probability
- **bedding attitude** estimation
- **morpho-structural domains** definition
- **slope-units** delineation

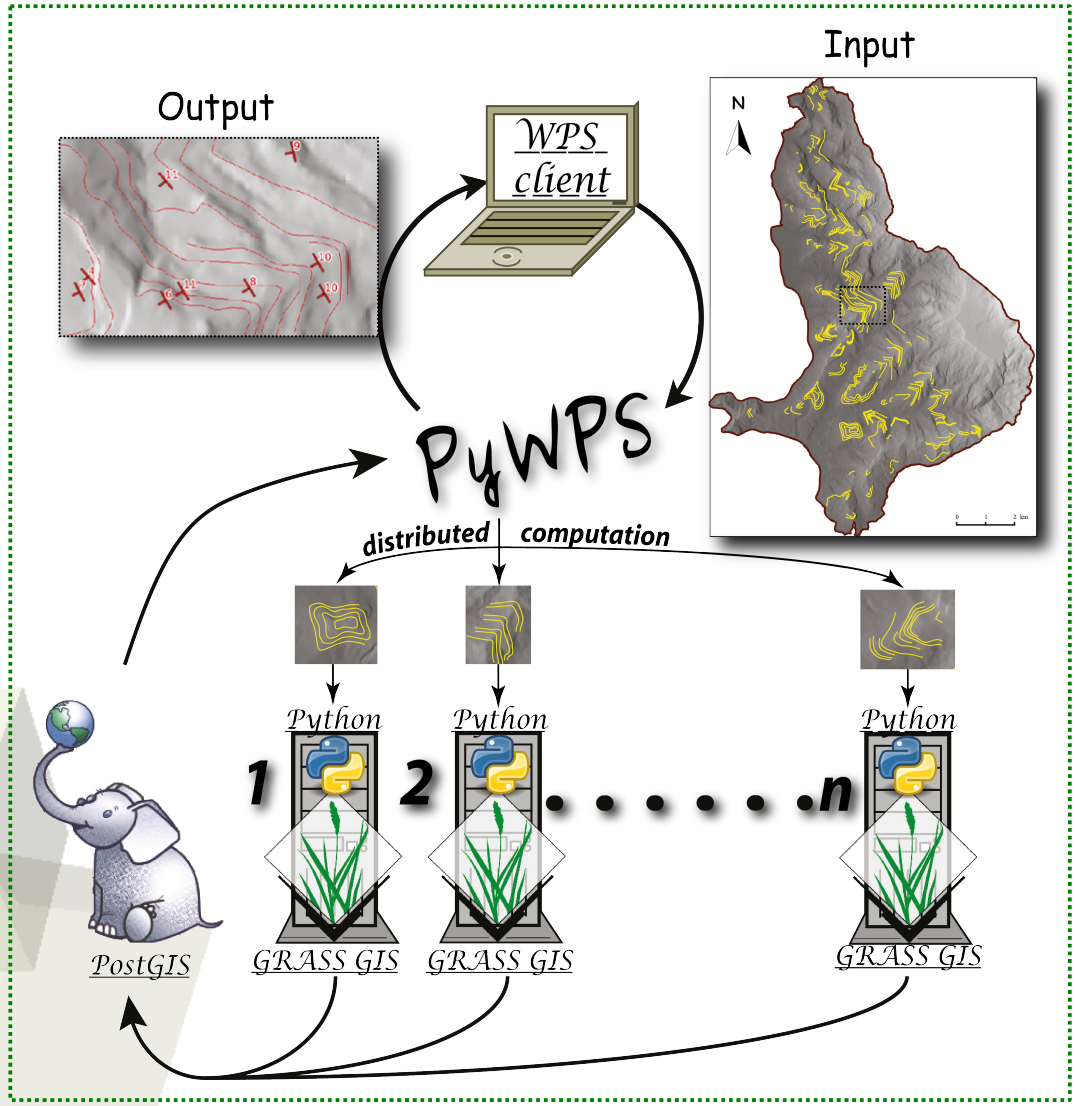
http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi

The second tool determines the **attitude** (dip direction and inclination) of multiple bedding planes in area, using a Digital Elevation Model (DEM) and a layer of the "bedding traces" (BT).

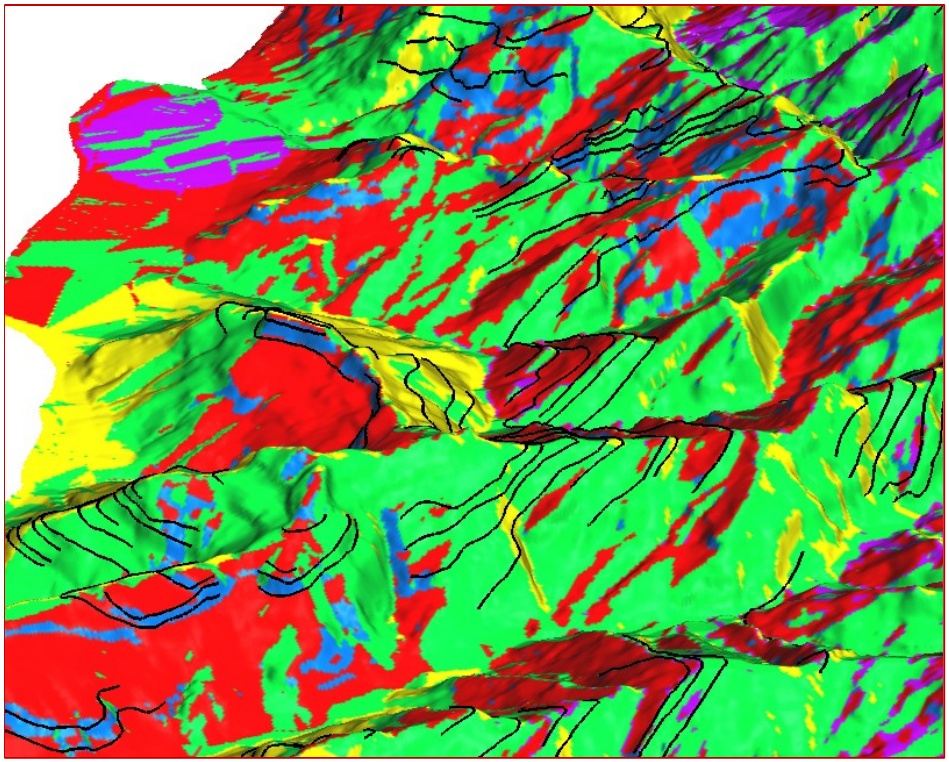


WPS tools implementation

- estimation of the attitude of bedding planes from the corresponding bedding traces,

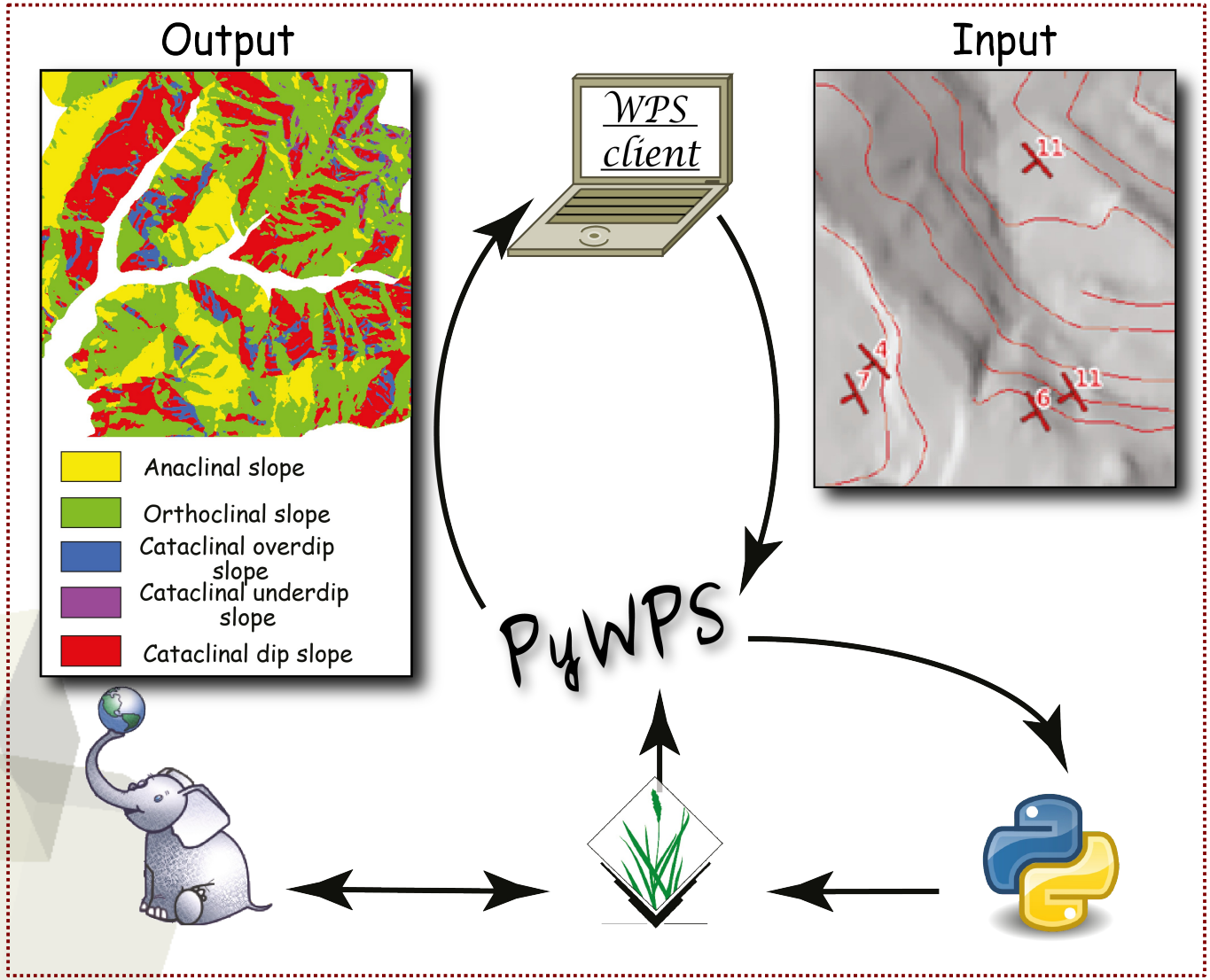


The third tool interpolates bedding attitude data to obtain **spatially distributed information** on the geometrical relationship between bedding and terrain slope.



WPS tools implementation

- production of maps showing the geometrical relationship between bedding planes and terrain slopes



Conclusions

- Through Open Source software, we developed some tools which, starting from a bedding trace layer, allow to obtain a morpho-structural map.
- The case study (Collazzone basin) clearly shows that bedding attitude only affect deep seated landslides
- The developed tools can be tested using WPS services

Thank you for your attention

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