Cartography M.Sc.

TECHNISCHE UNIVERSITÄT DRESDEN

Helmholtz Institute Freiberg for Resource Technology

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

TU BERGAKADEMIE FREIBERG

Landslide hazard in Central Asia

*Understanding the relationship between **slope instabilities**, **tectonic** and **geomorphology** using satellite data and integration into a landslide susceptibility model*

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Supervised by:

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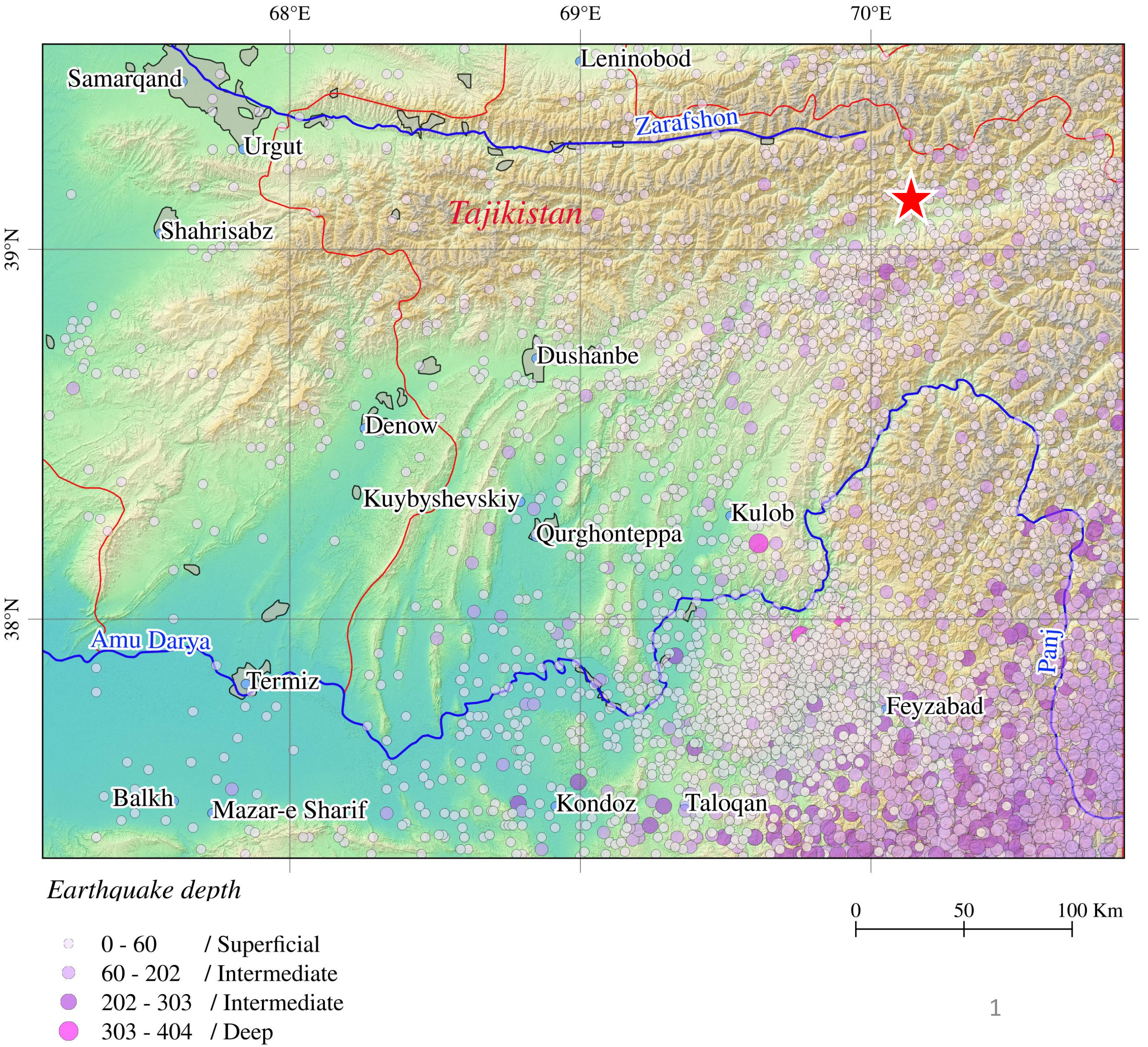
Richard Gloaguen
Louis Andreani
Barend Köbben

MOTIVATION:

Landslides are natural hazards that leads a huge economic and life losses.

Triggered by rainfall events and/or earthquakes.

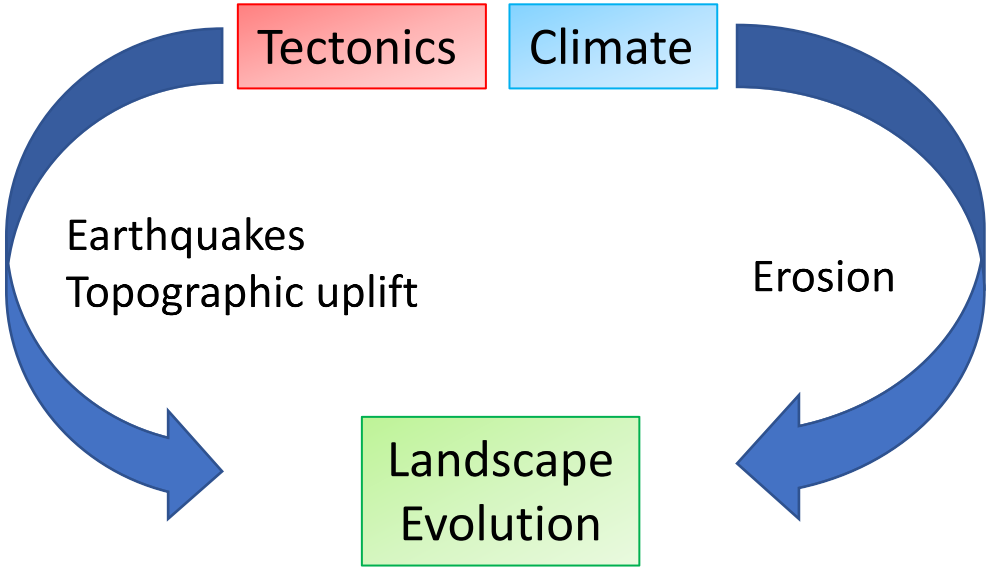
★ Khait Earthquake (M 7.4), 1949

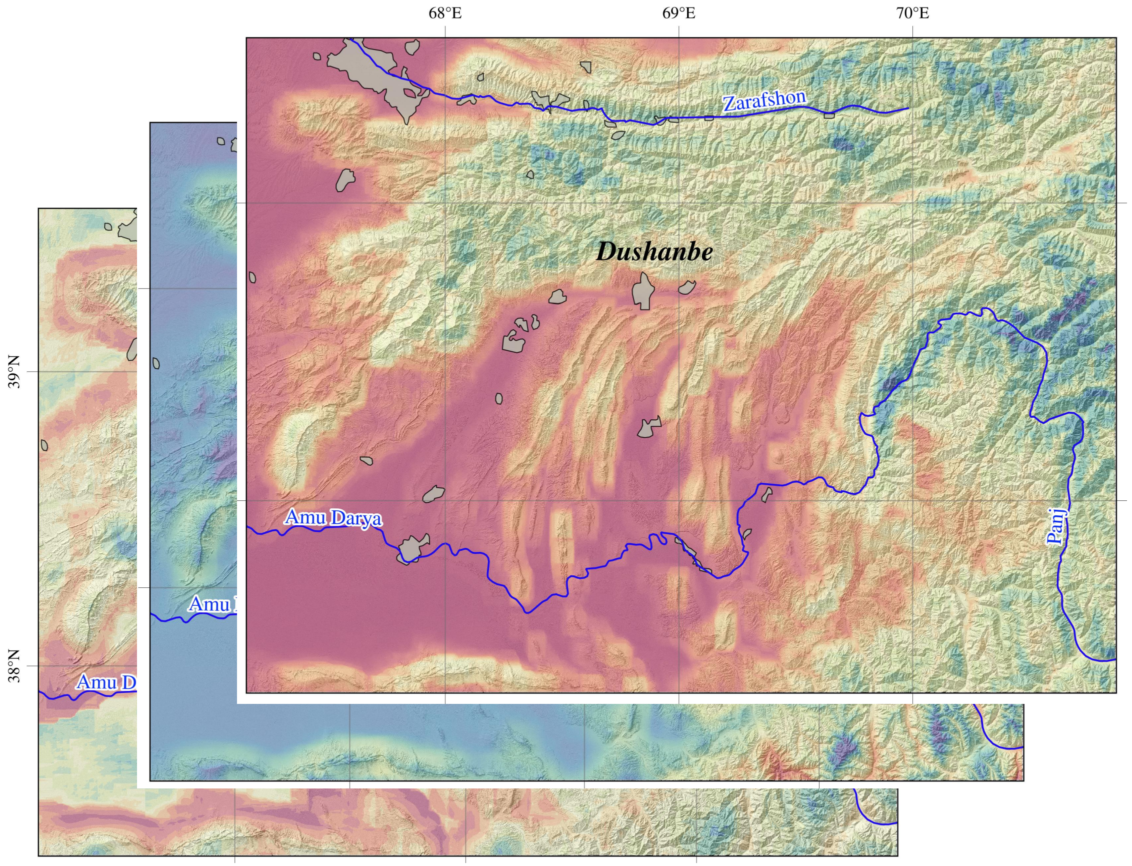


PROBLEM:

- Poor landslide catalogues
- Limited amount of data to implement a landslides susceptibility model

Characterization of the surface processes using **geomorphic indices**.





Relation of triggering factors and the landslide occurence

Landslide susceptibility

Likelihood of occurrence of a landslide given certain local conditions.

Probability of spatial occurrence of slope failure basis on certain conditions (Chung *et al.* , 1999).

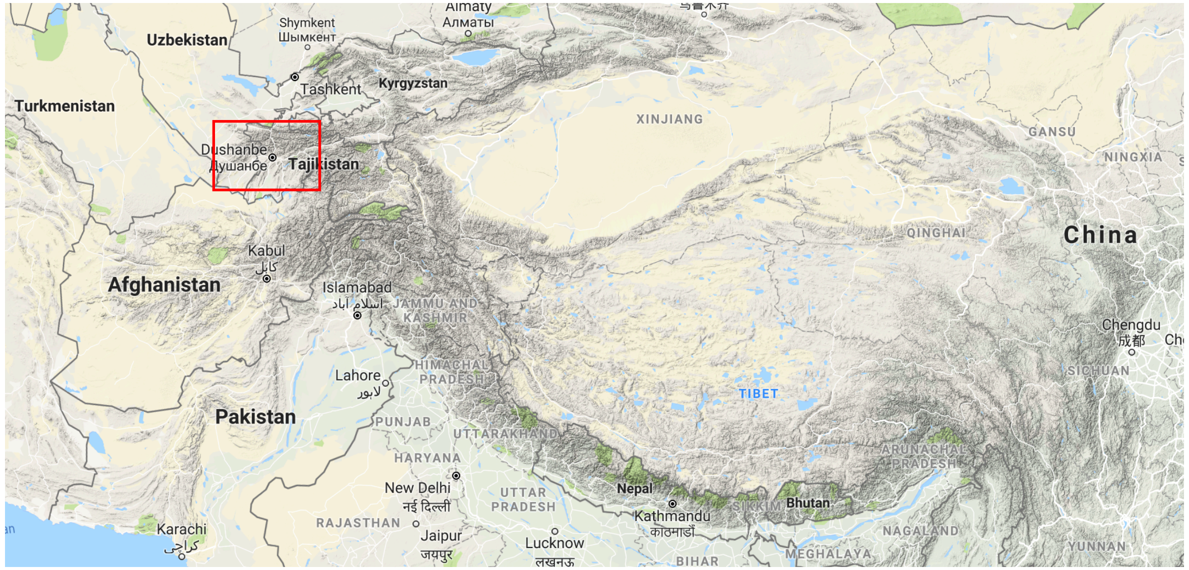
Where

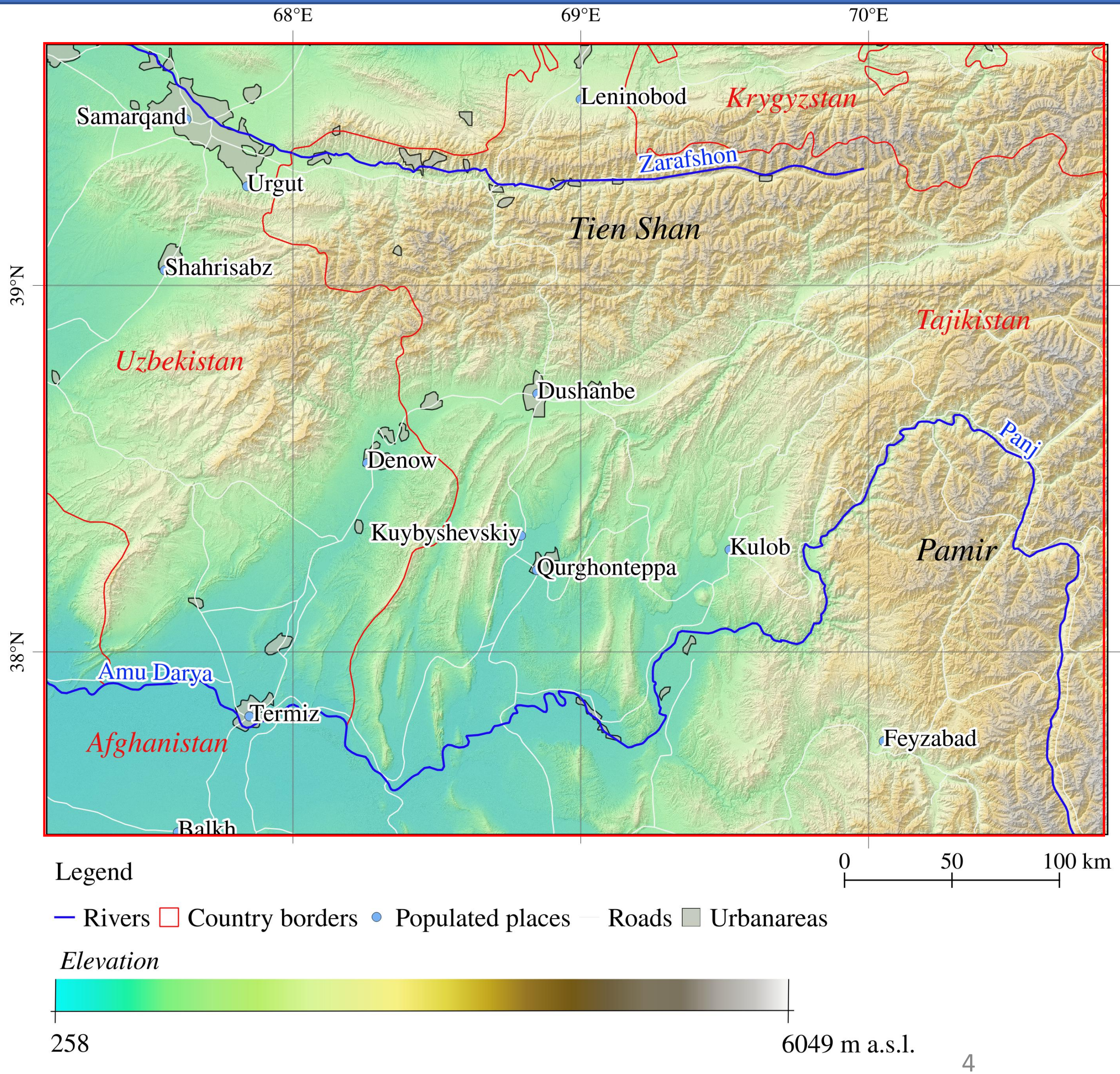
RESEARCH SIGNIFICANCE:

- Improve of the landslide catalogue
- Creation of regional thematic information
- Methodologies based on free sources programs and the handling of large dataset.

CENTRAL ASIA

- 188 316 km^2
- 4 countries
- 1 Capital city
- 2nd highest dam in the world
- 2 mountain ranges





LANDSLIDE CATALOGUE

Main landslide type: Rock slide or rock fall

Drainage blockage

Yagnob River - Tien Shan

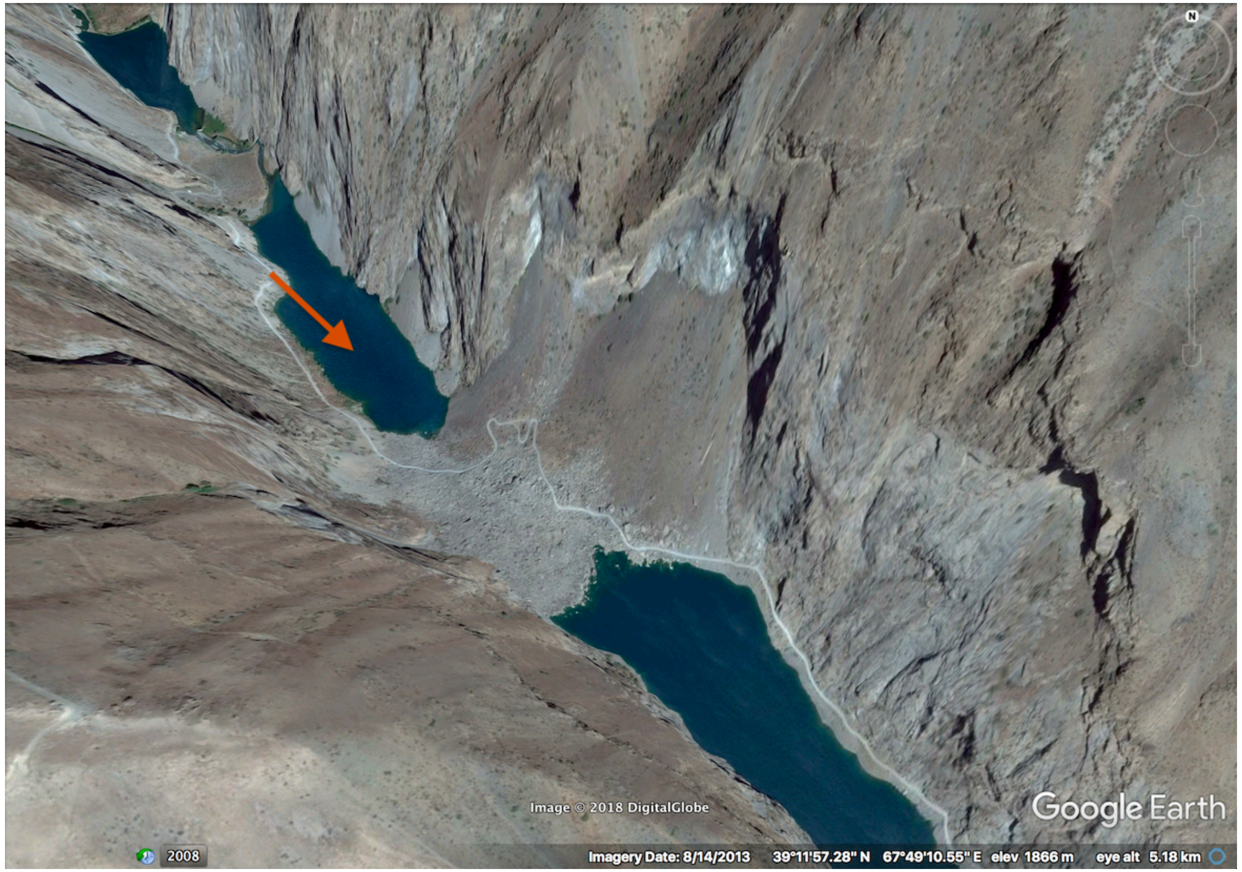
Red arrow: location of the view of the picture

LANDSLIDE CATALOGUE

Main landslide type: Rock slide or rock fall

Drainage blockage

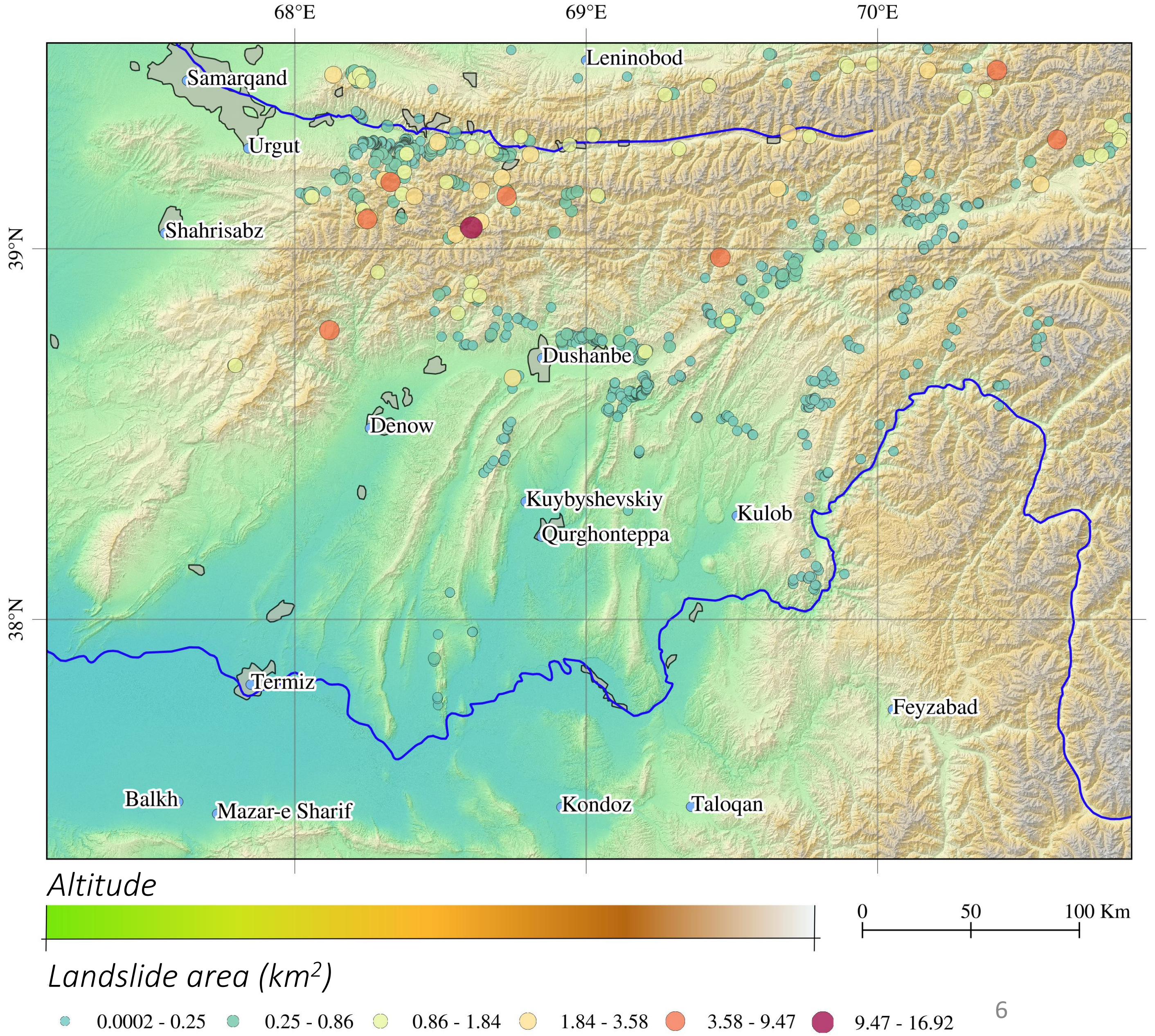
Seven Lakes – Tien Shan



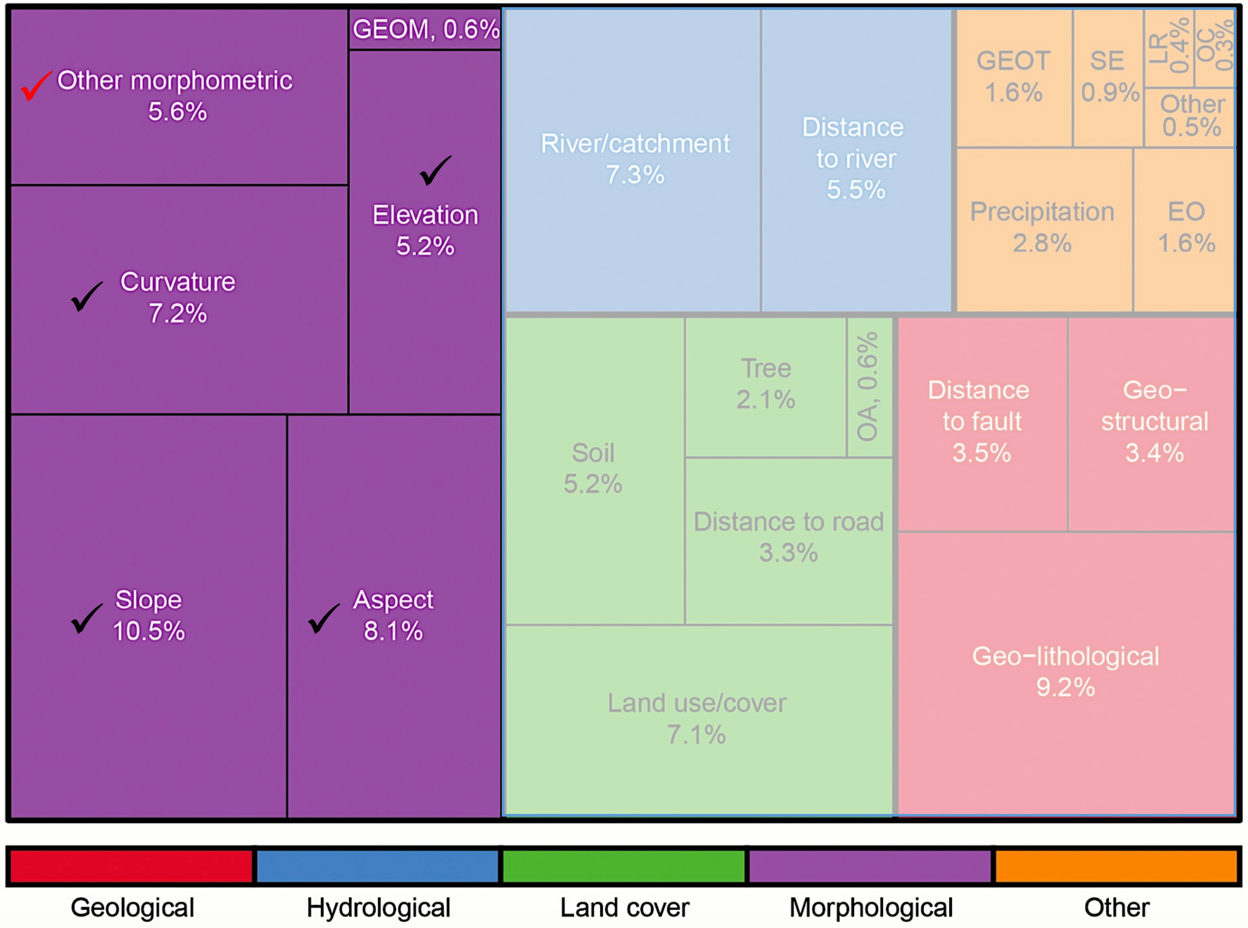
Red arrow: location of the view of the picture

LANDSLIDE CATALOGUE

- Inhomogeneous distribution of landslides
- Lack of information in the South of the Panj River (High mountainous areas where less remote sensing data is available)



THEMATIC VARIABLES



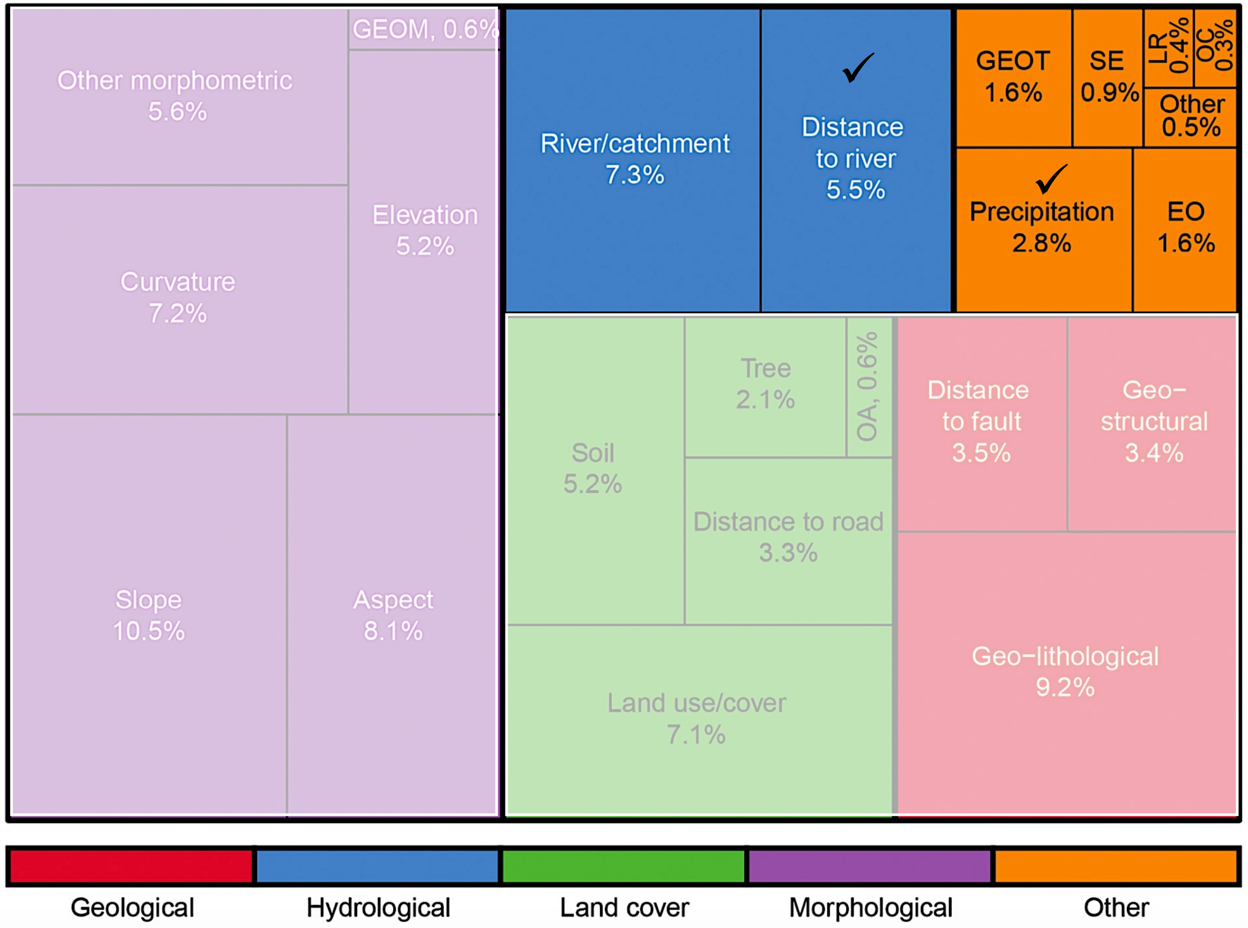
(Reichenbach et al., *2018)*

EO, Earth observation; GEOM, geomorphological; GEOT, geotechnical; LR, landslide related; OA, other anthropic; OC, other climatic; SE, seismic.

Geomorphology

- Slope
- Aspect
- Topographic position index (TPI)
- Surface Roughness (SR)
- Elevation Relief Ratio(ERR)
- Surface Index (SI)
- Local Relief (LR)
- EigenValues

THEMATIC VARIABLES



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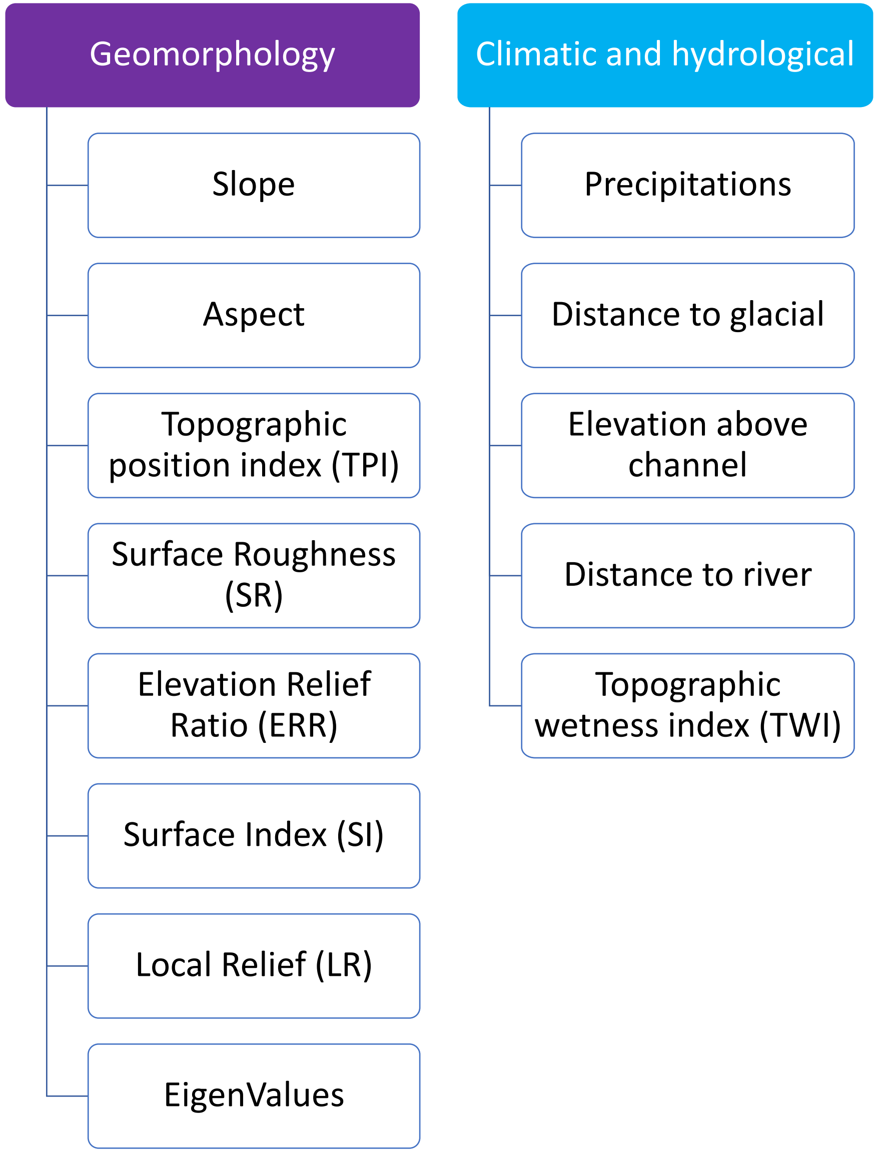
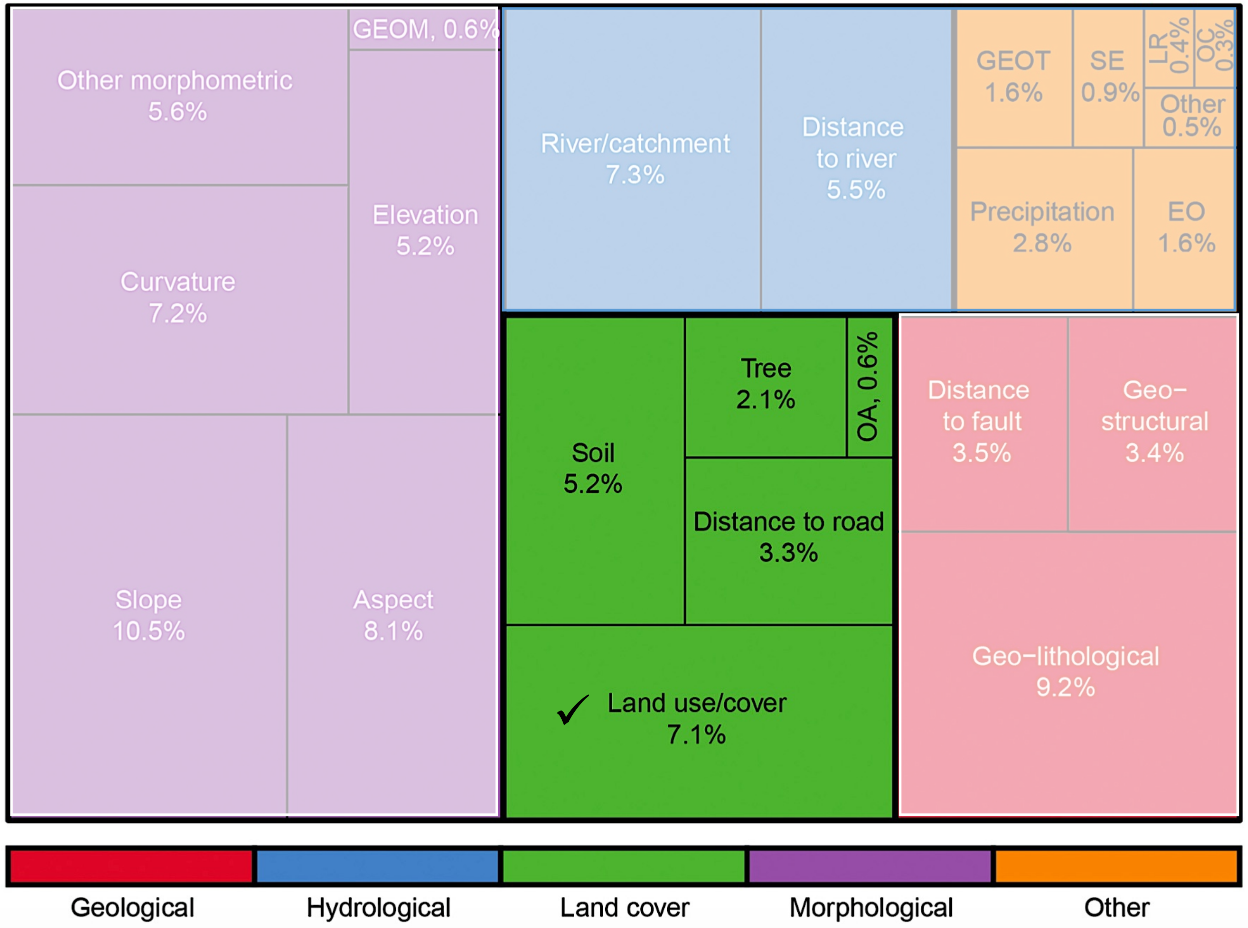


THEMATIC VARIABLES



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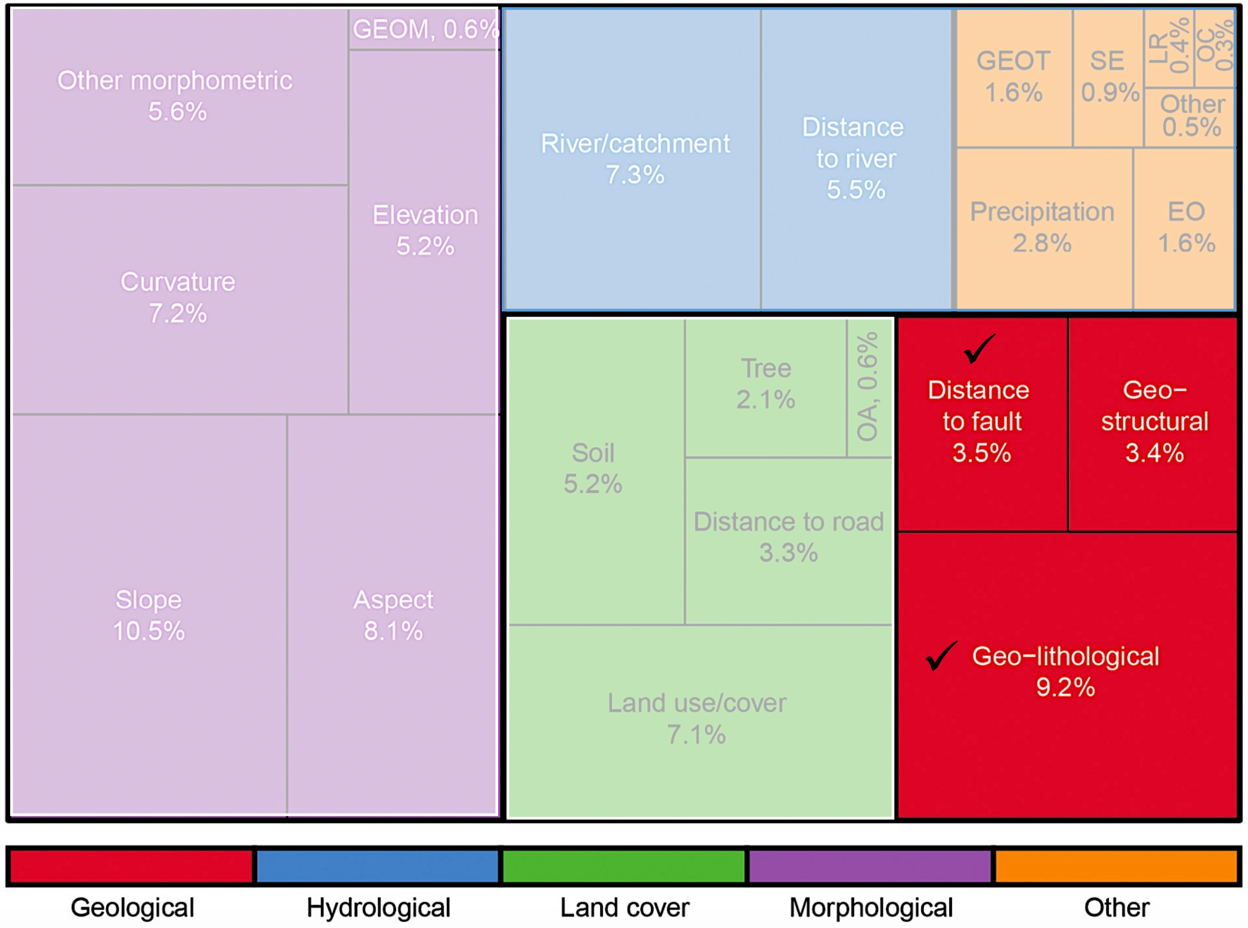
- Local Relief (LR)
- EigenValues

Climatic and hydrological
- Precipitations
- Distance to glacial
- Elevation above channel
- Distance to river
- Topographic wetness index (TWI)

Land cover
- NDVI

THEMATIC VARIABLES



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Land cover
- NDVI

Tectonic
- Distance to fault
- Seismo-zones

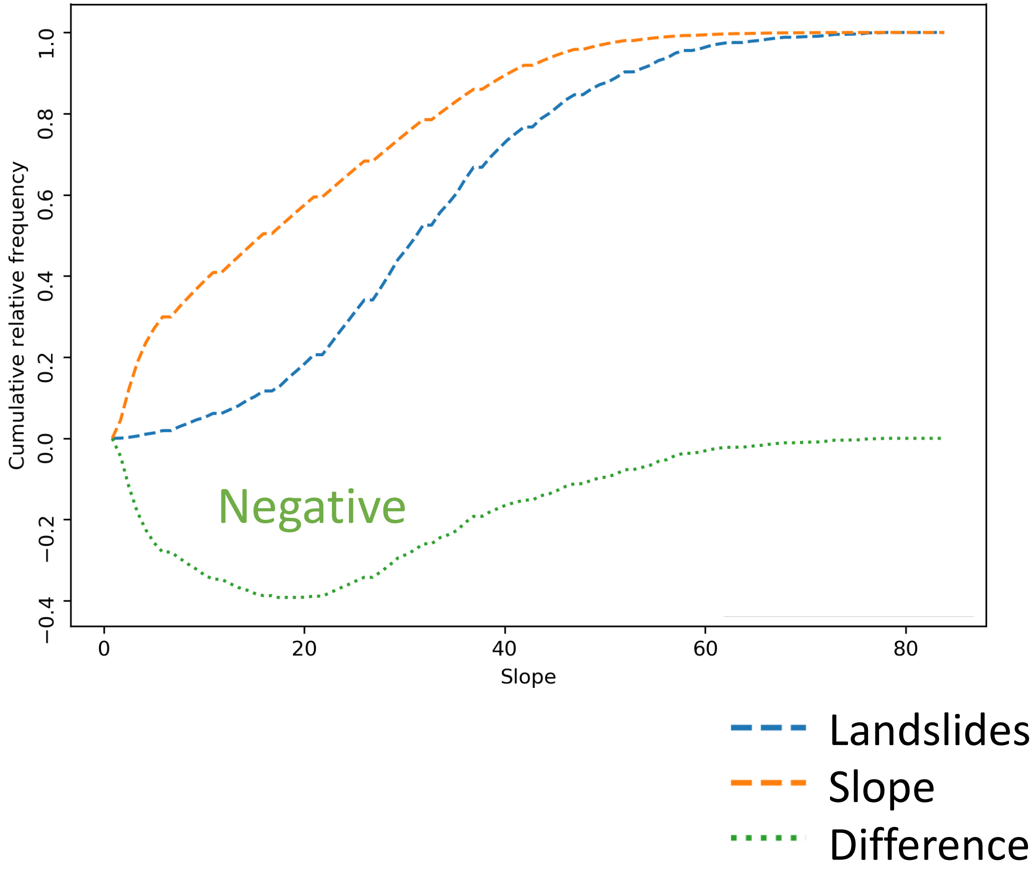
Geology
- Lithology

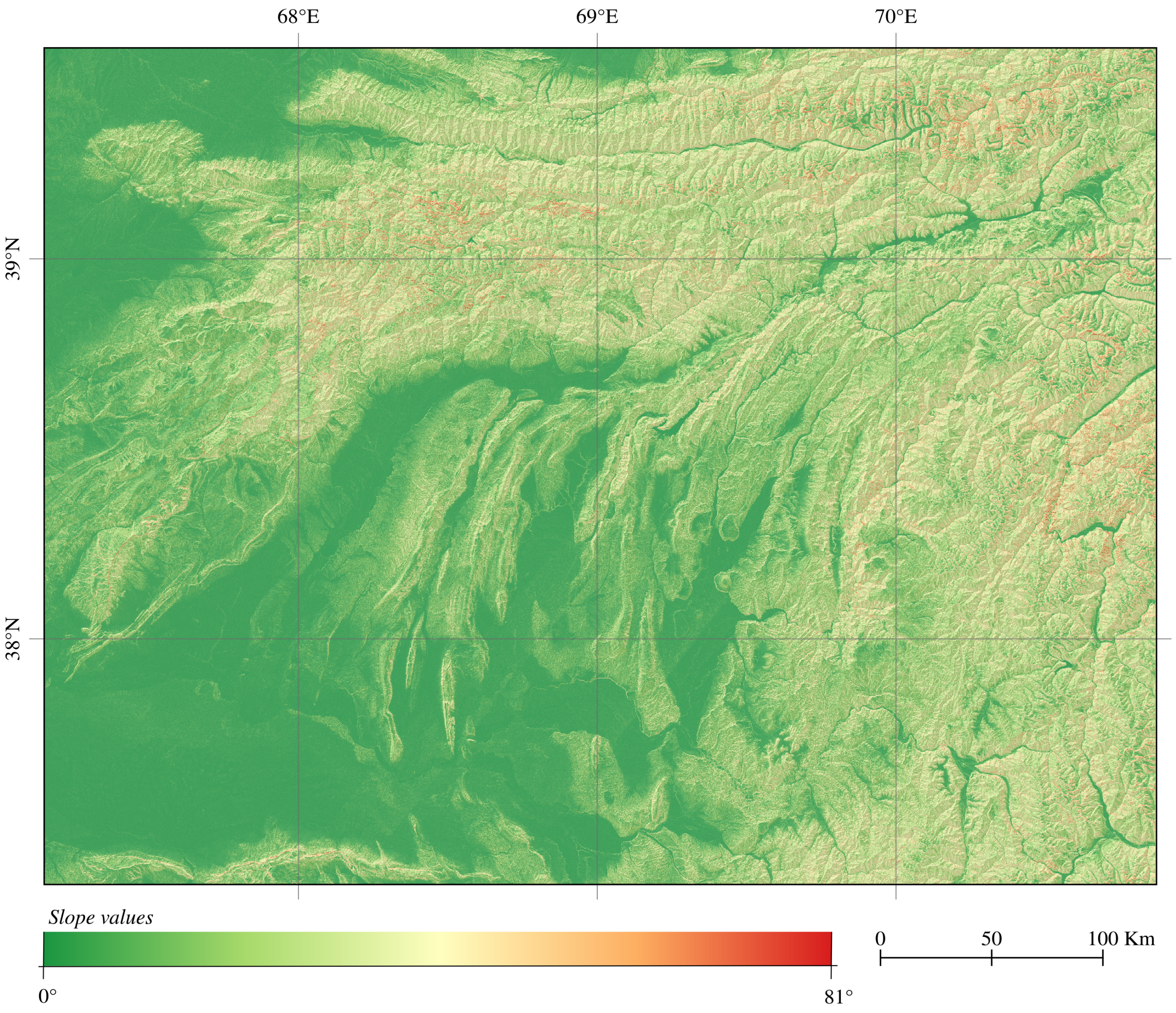
THEMATIC VARIABLES

Local description

- *Slope*
- Aspect

Spatial association





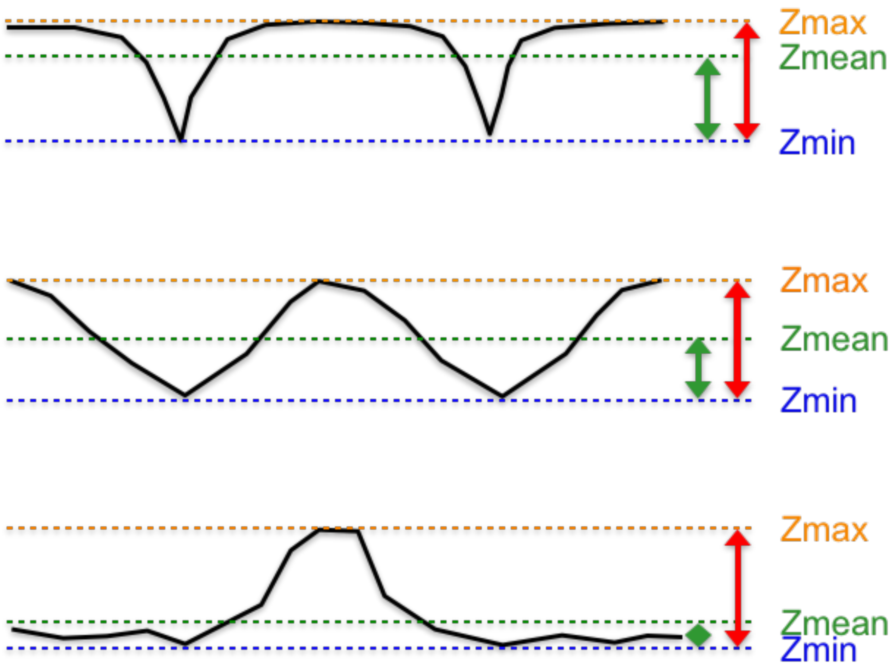
THEMATIC VARIABLES

Broad description (Window size)

- *Elevation relief ratio* → Characterization of the landscape

$$ERR = \frac{Z_{mean} - Z_{min}}{Z_{max} - Z_{min}}$$

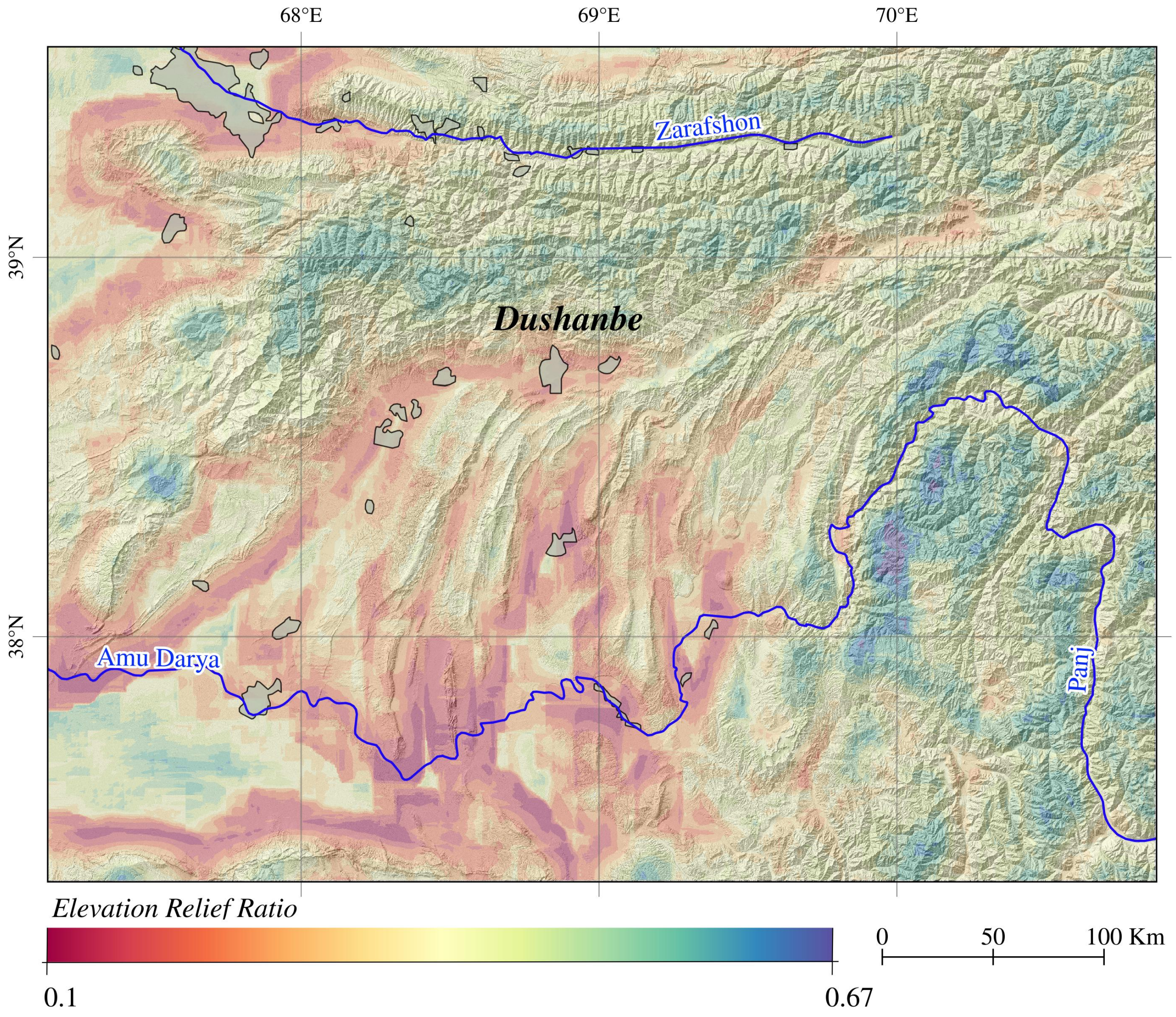
Window size



High (>0.5)

Low (0.2-0.5)

Very Low (0.0-0.2)



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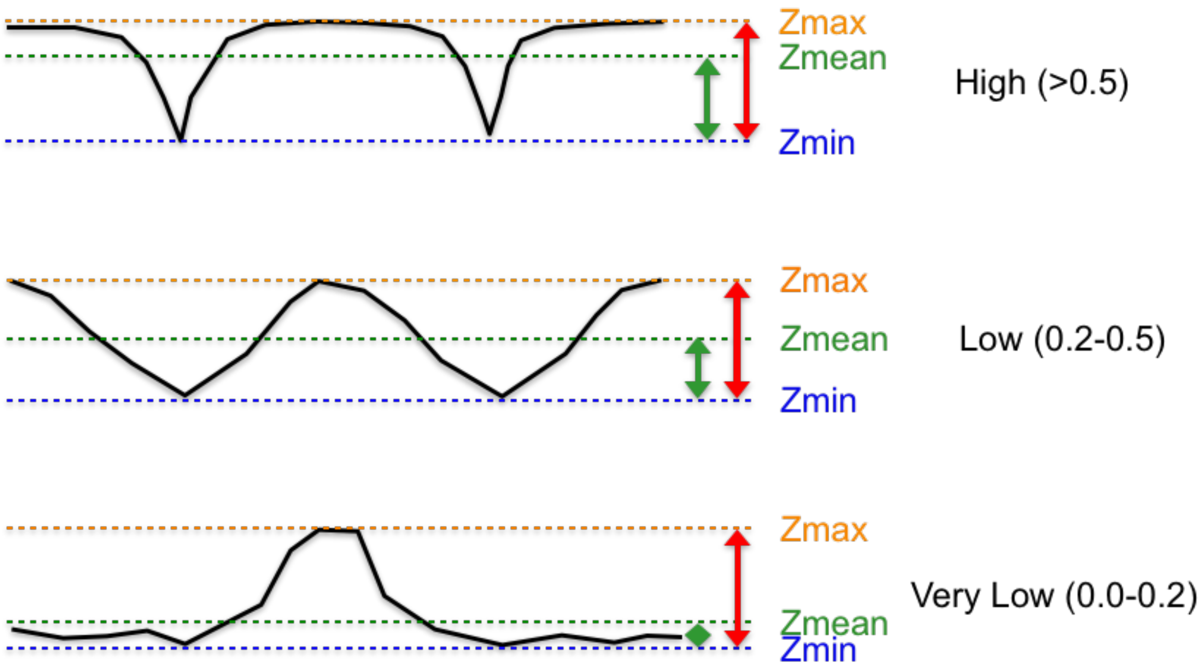
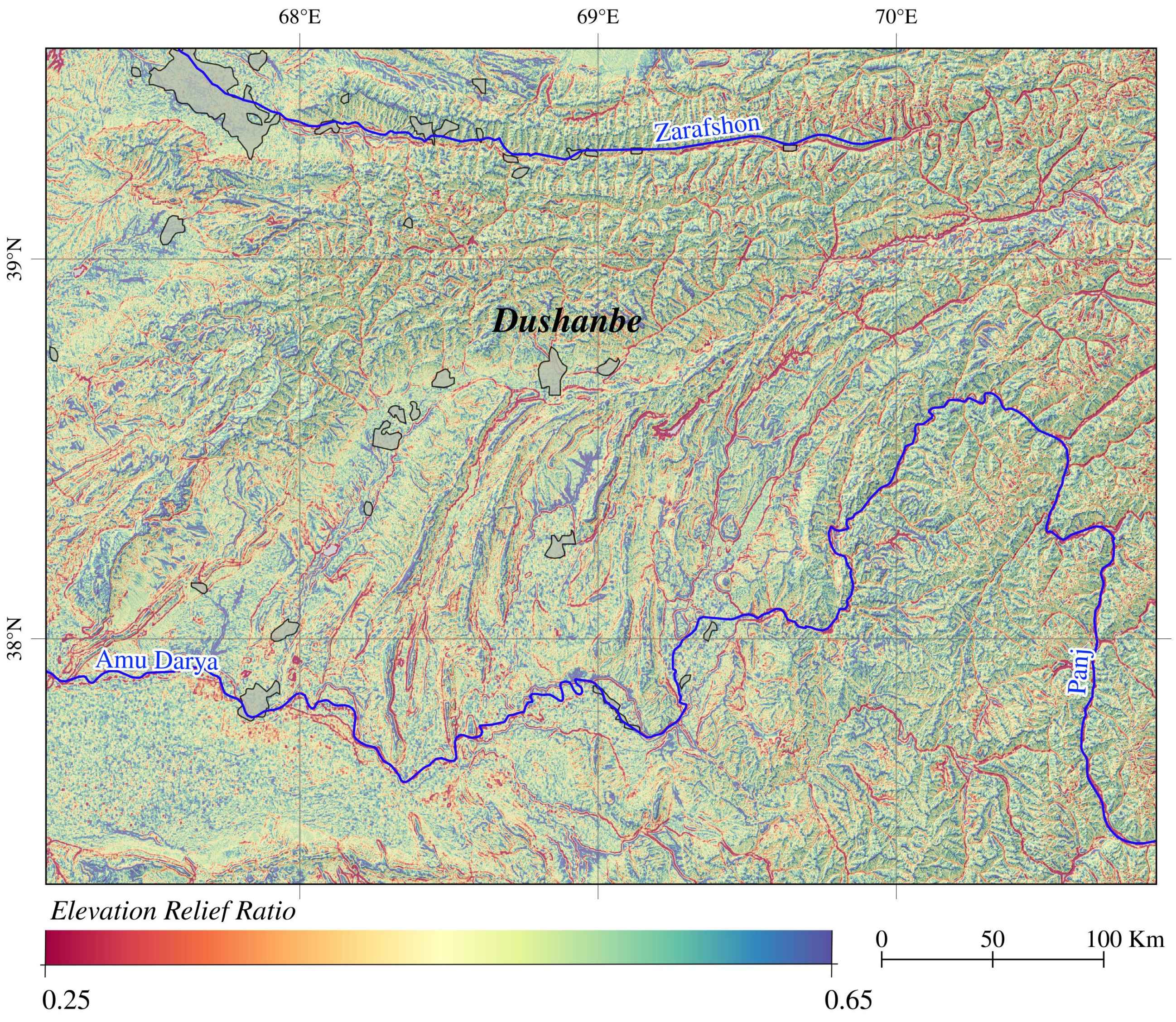


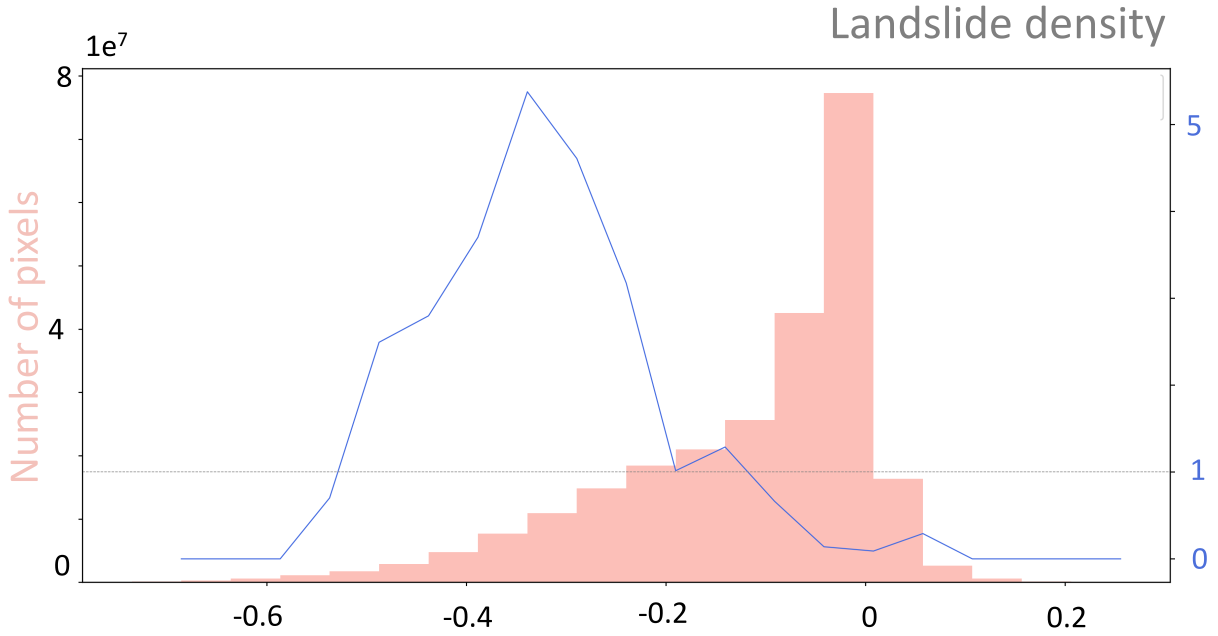


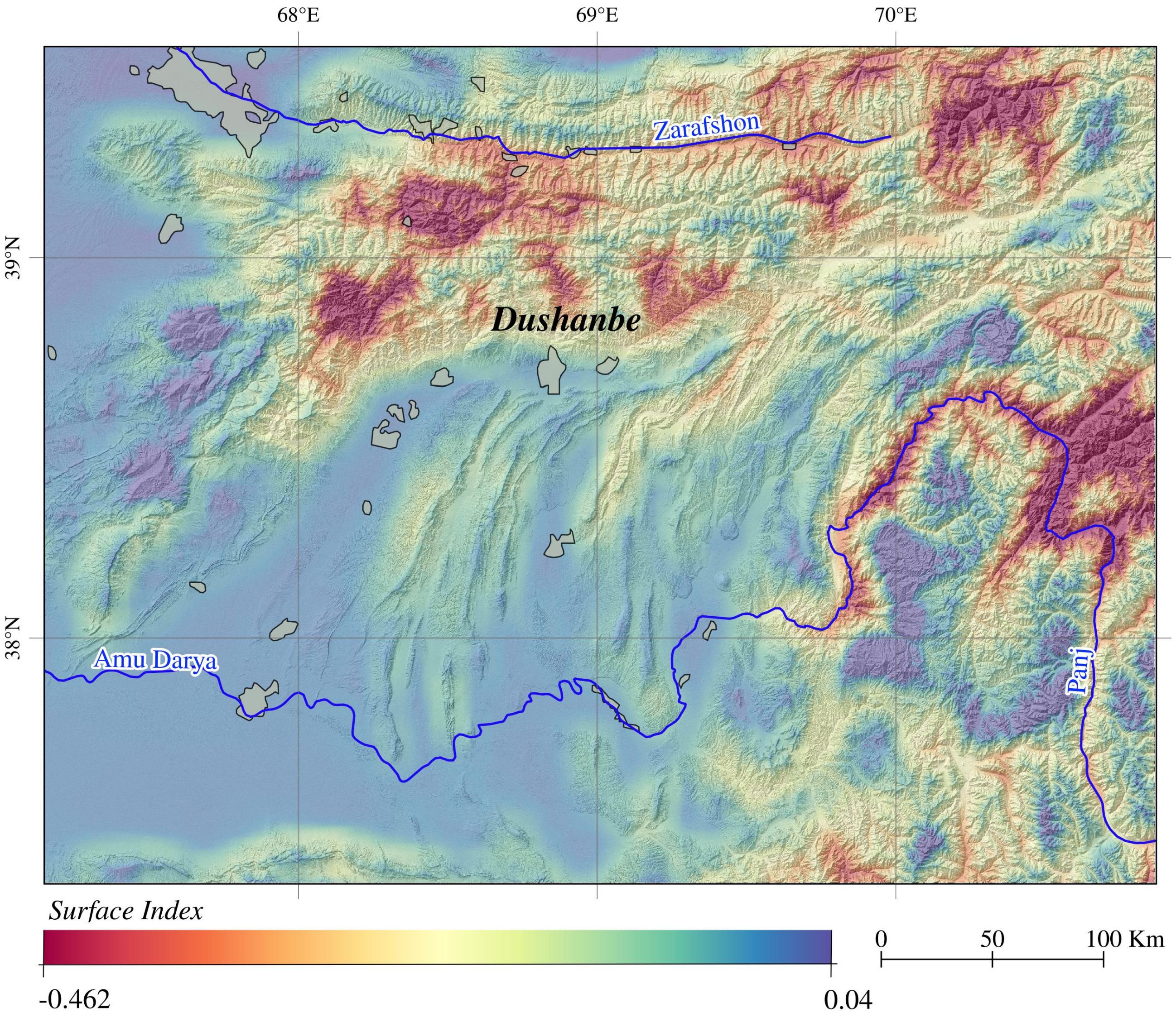
THEMATIC VARIABLES

Broad description

- *Surface Index* → Discrimination between erosional and steady-state landscape

$$SI = (DEM \times ERR) - SR$$



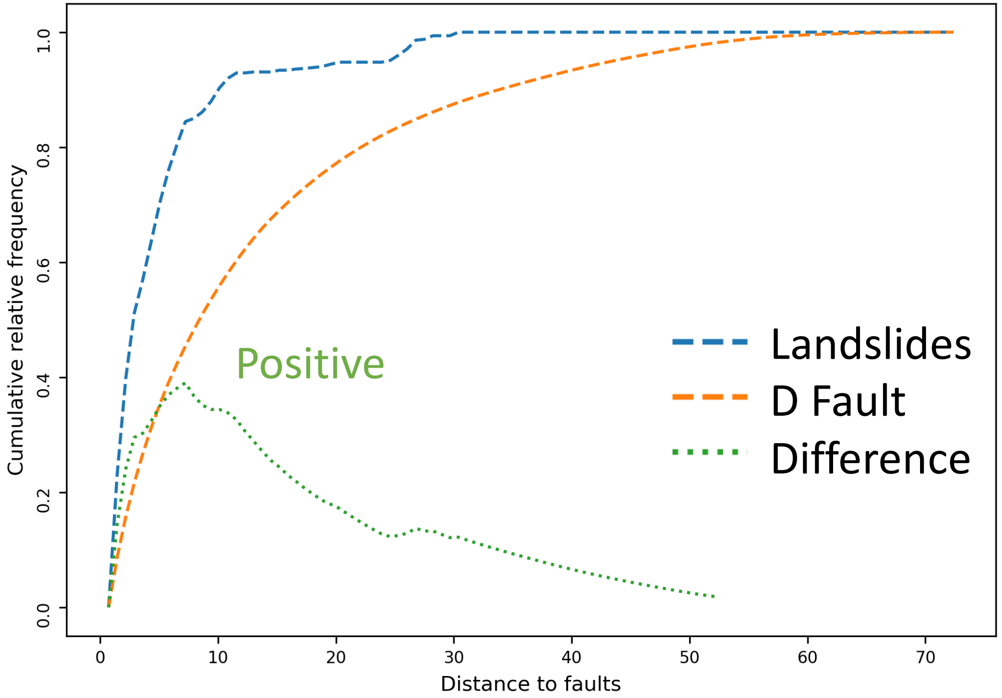


THEMATIC VARIABLES

Tectonics

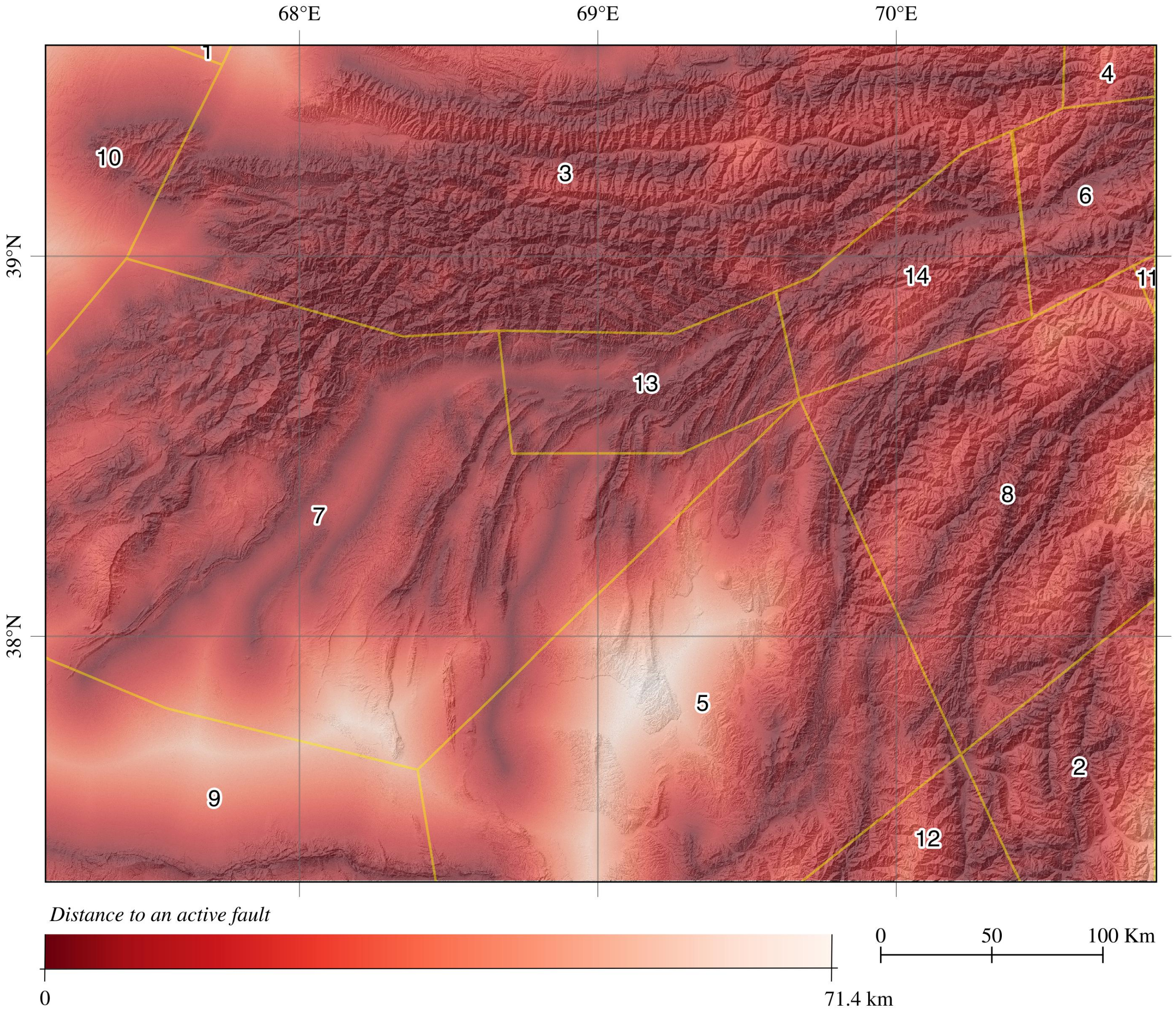
- Distance to fault

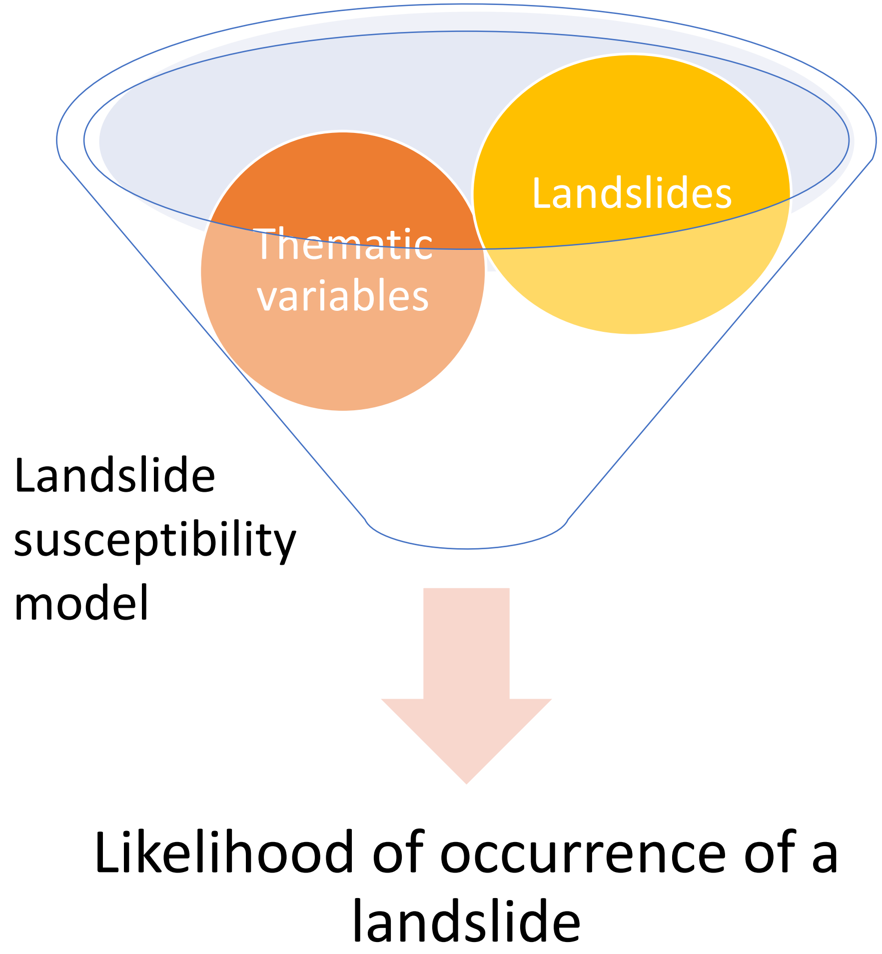
Spatial association

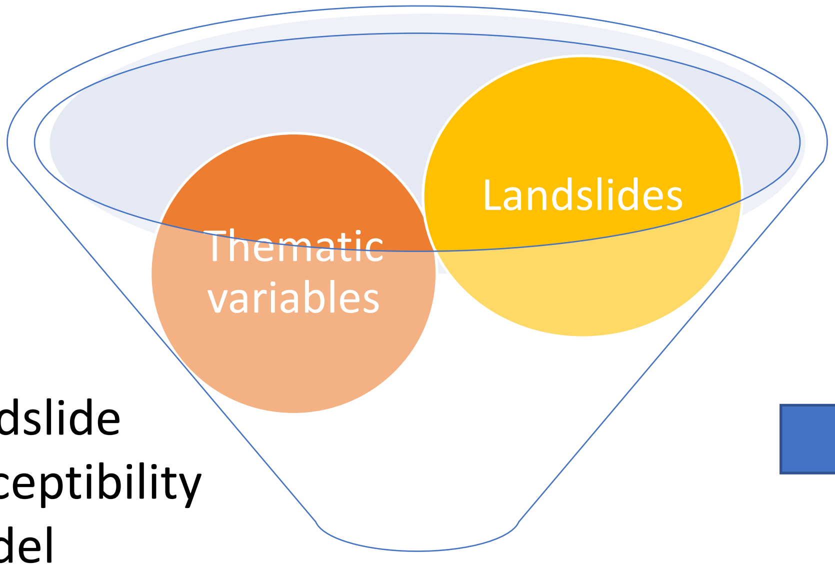


- Seismo-zones

Zones:
2-5-12 -- Subduction area
6-13-14 – Cortical shortenning




Landslides
Thematic variables
Landslide susceptibility model
Likelihood of occurrence of a landslide



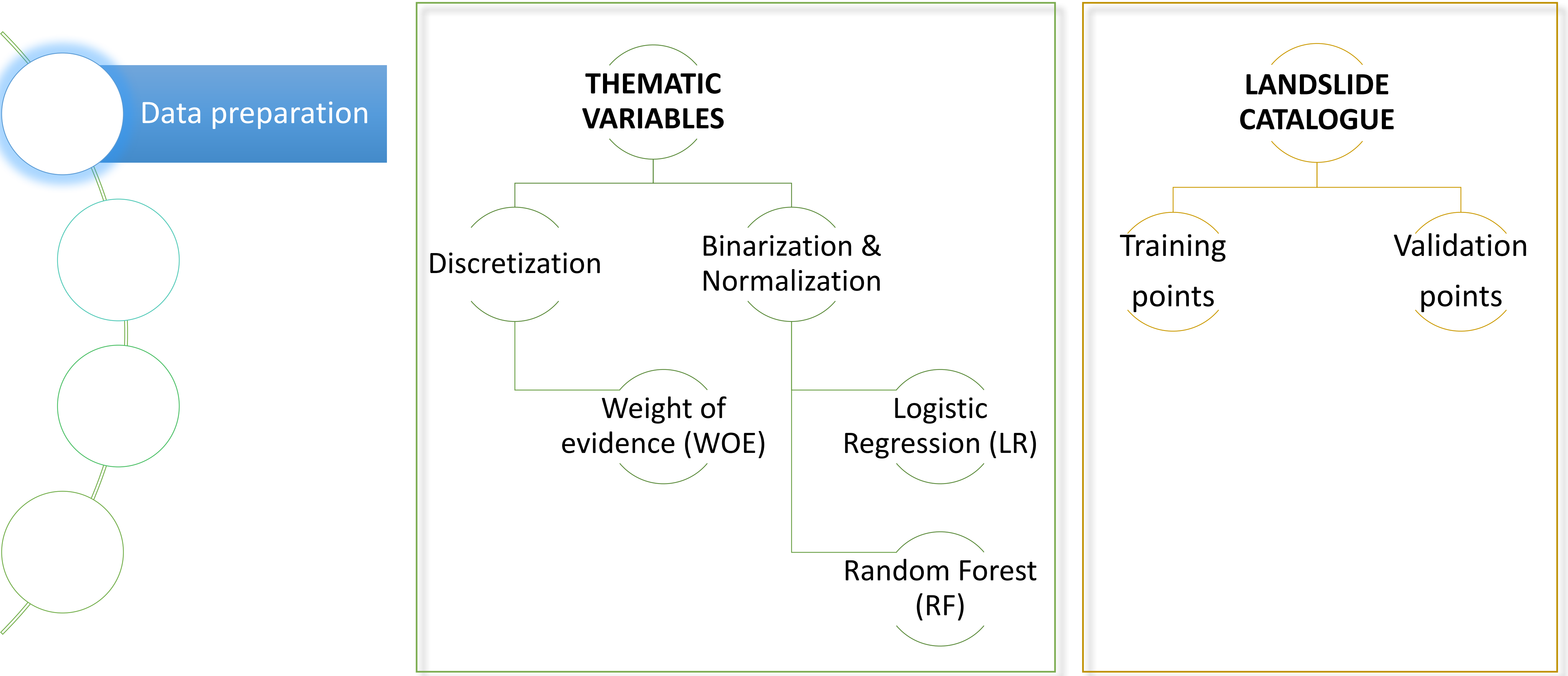
Landslide susceptibility model

Statically based- model

Likelihood of occurrence of a landslide

(*Reichenbach* et al., *2018)*

GENERAL WORKFLOW

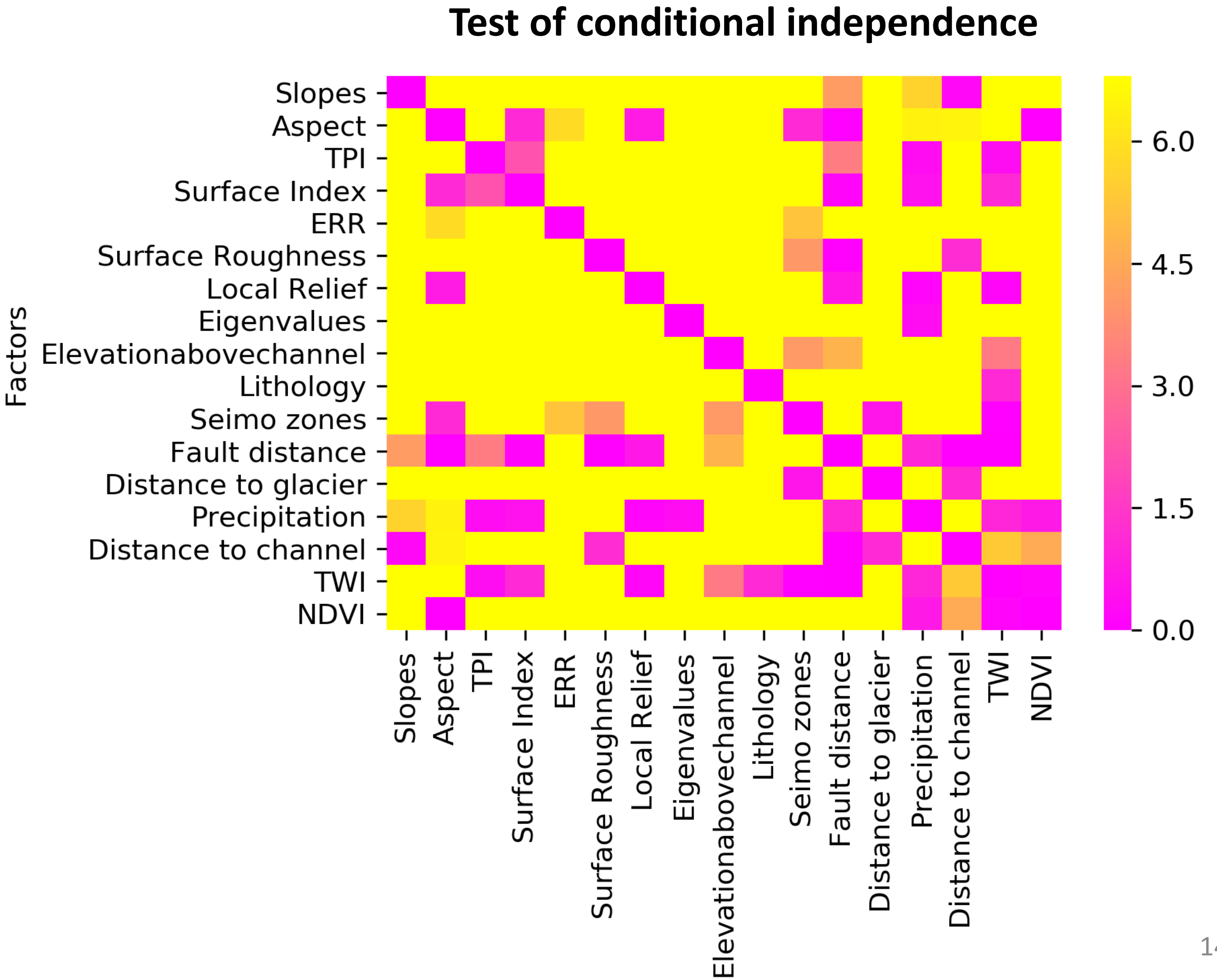


GENERAL WORKFLOW

WEIGHT OF EVIDENCE

Data preparation

Selection of thematic variables



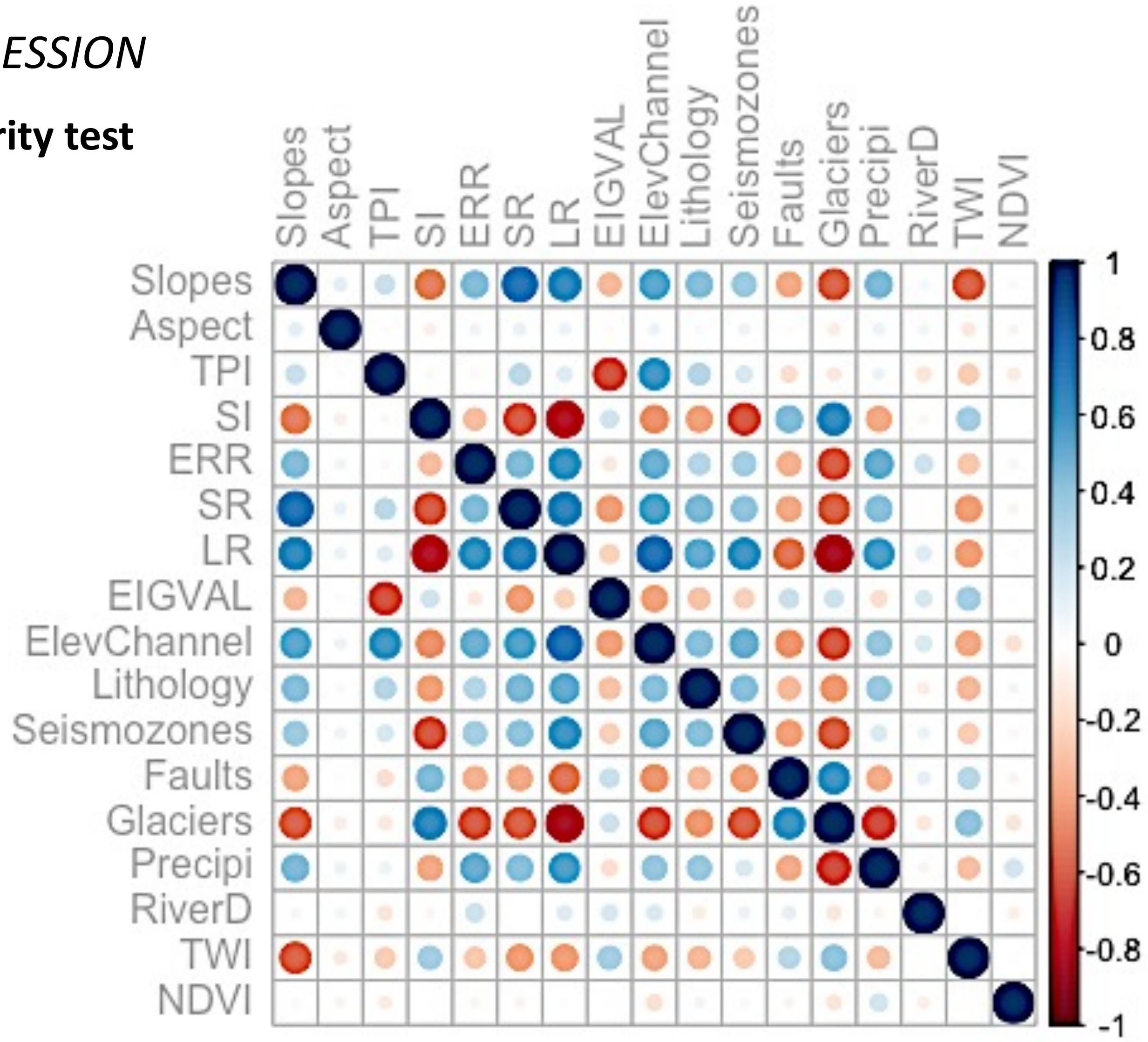
GENERAL WORKFLOW

Data preparation

Selection of thematic variables

LOGISTIC REGRESSION

Collinearity test



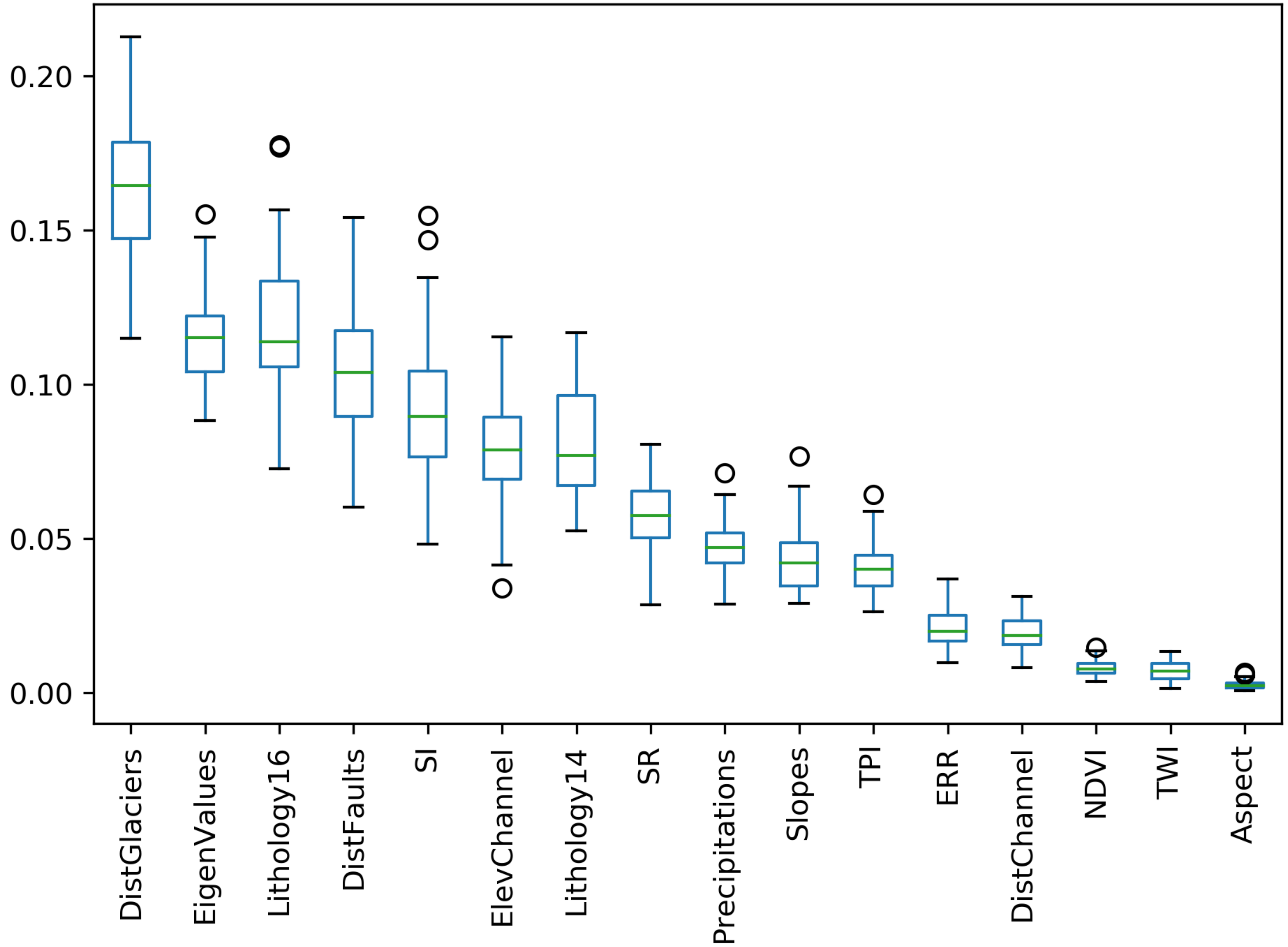
GENERAL WORKFLOW

Data preparation

Selection of thematic variables

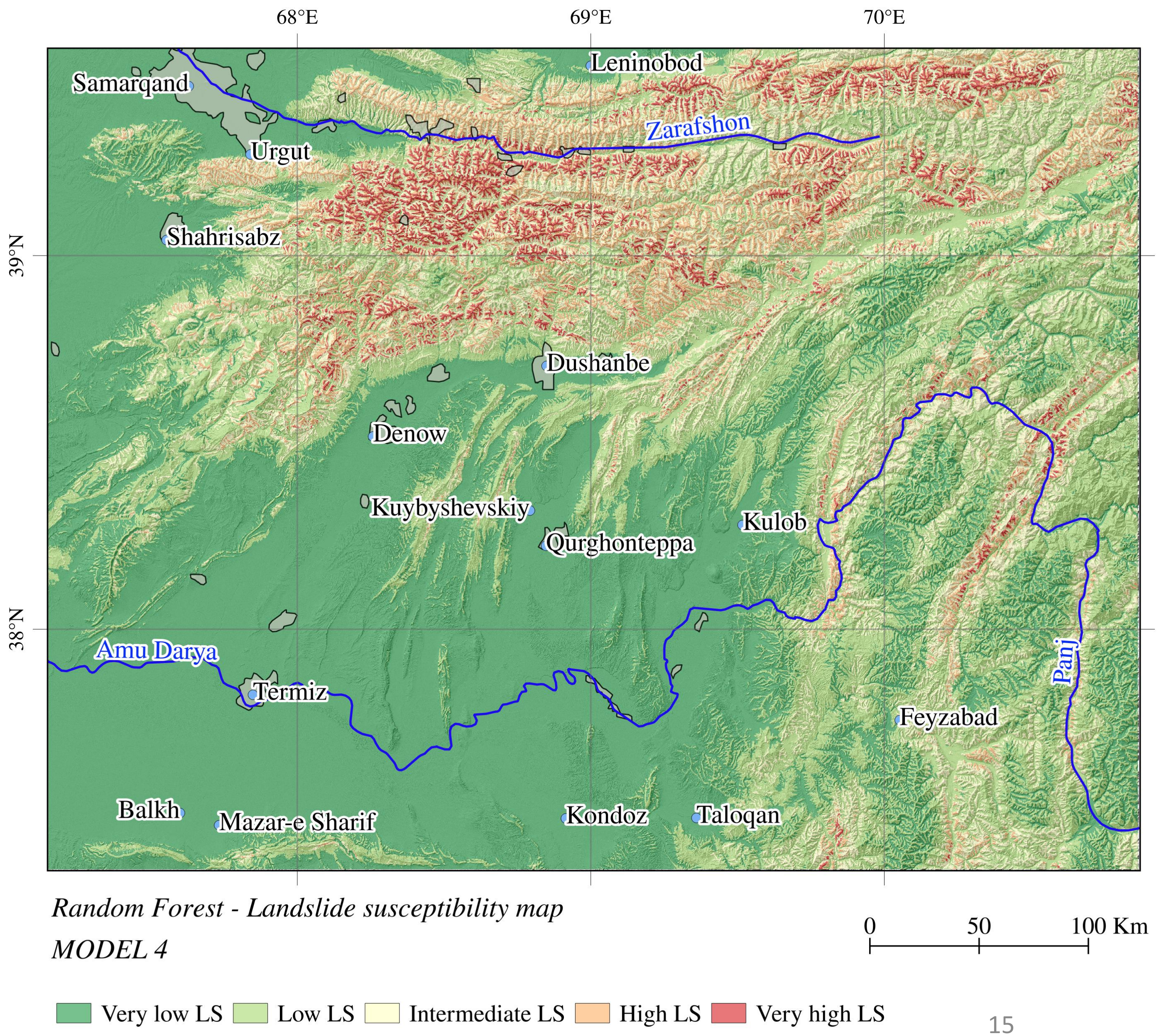
RANDOM FOREST

Ranking of importance



GENERAL WORKFLOW

- Data preparation
- Selection of thematic variables
- Model implementation



Random Forest - Landslide susceptibility map
MODEL 4

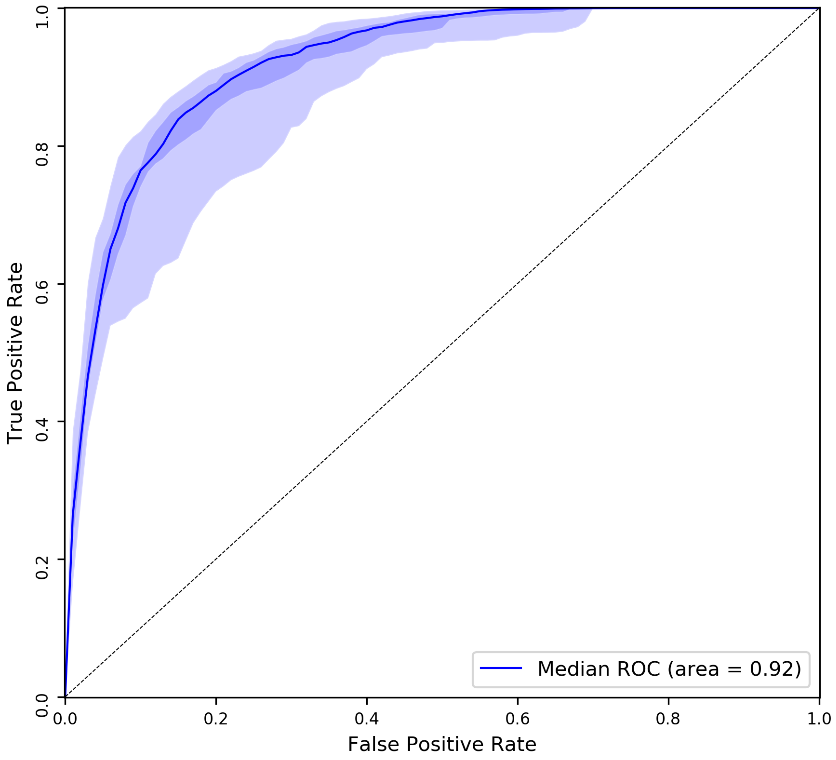
WOE = Total weight
LR = Probability of be or not a landslide (1-100)

GENERAL WORKFLOW

- Data preparation
- Selection of thematic variables
- Model implementation
- Model evaluation

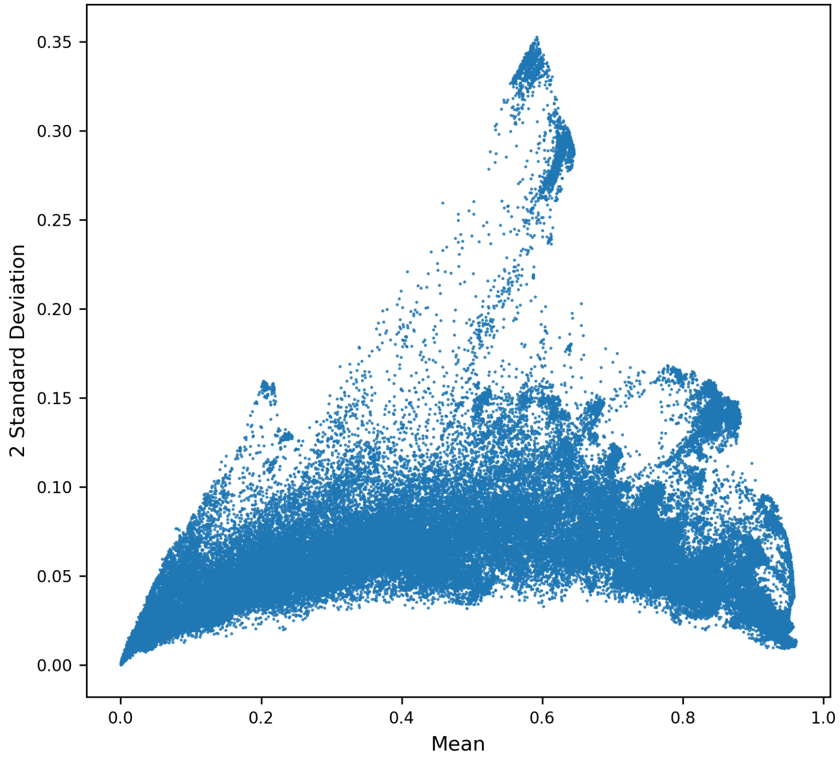
Receiver operator curve (ROC)

Measure of model performance



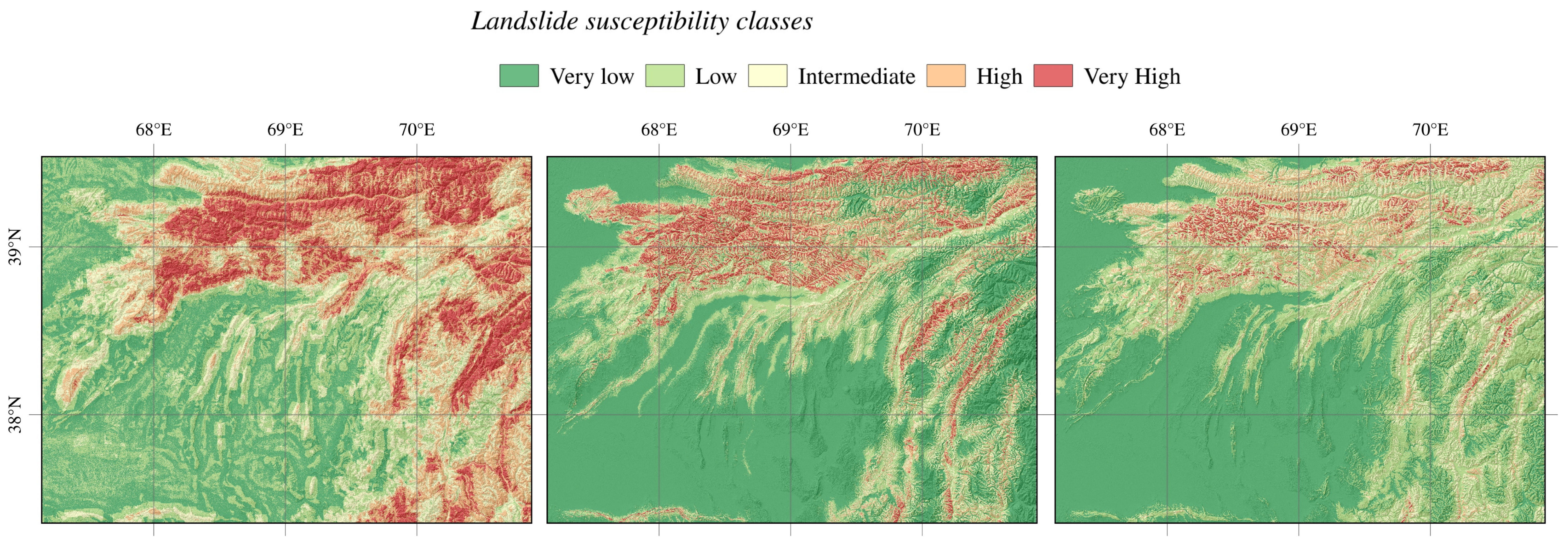
Model error dispersion

Measure of overfitting



Same model 50 times

BEST MODEL



Landslide susceptibility map
Weight of evidence

Landslide susceptibility map
Logistic regression

Landslide susceptibility map
Random forest

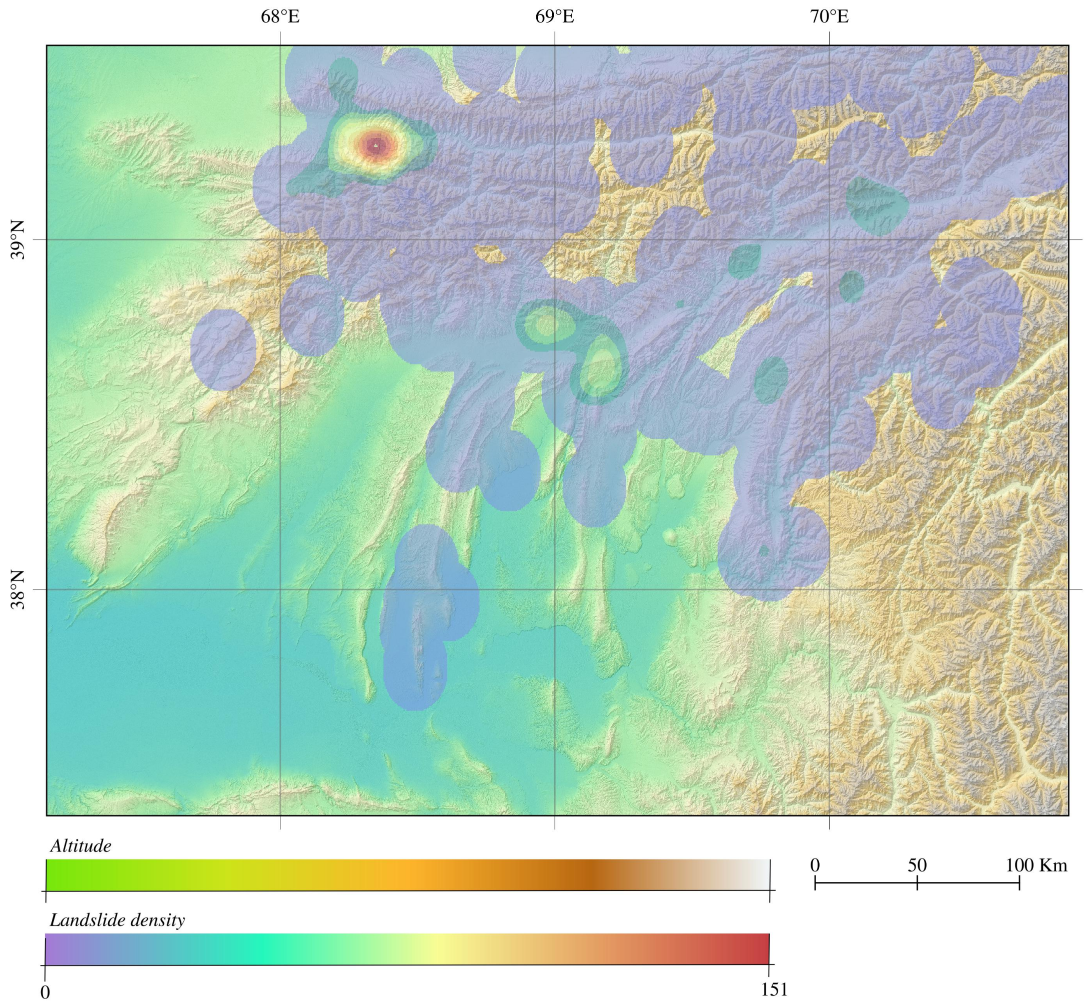
0 50 100 Km

Mean ROC = 0.88

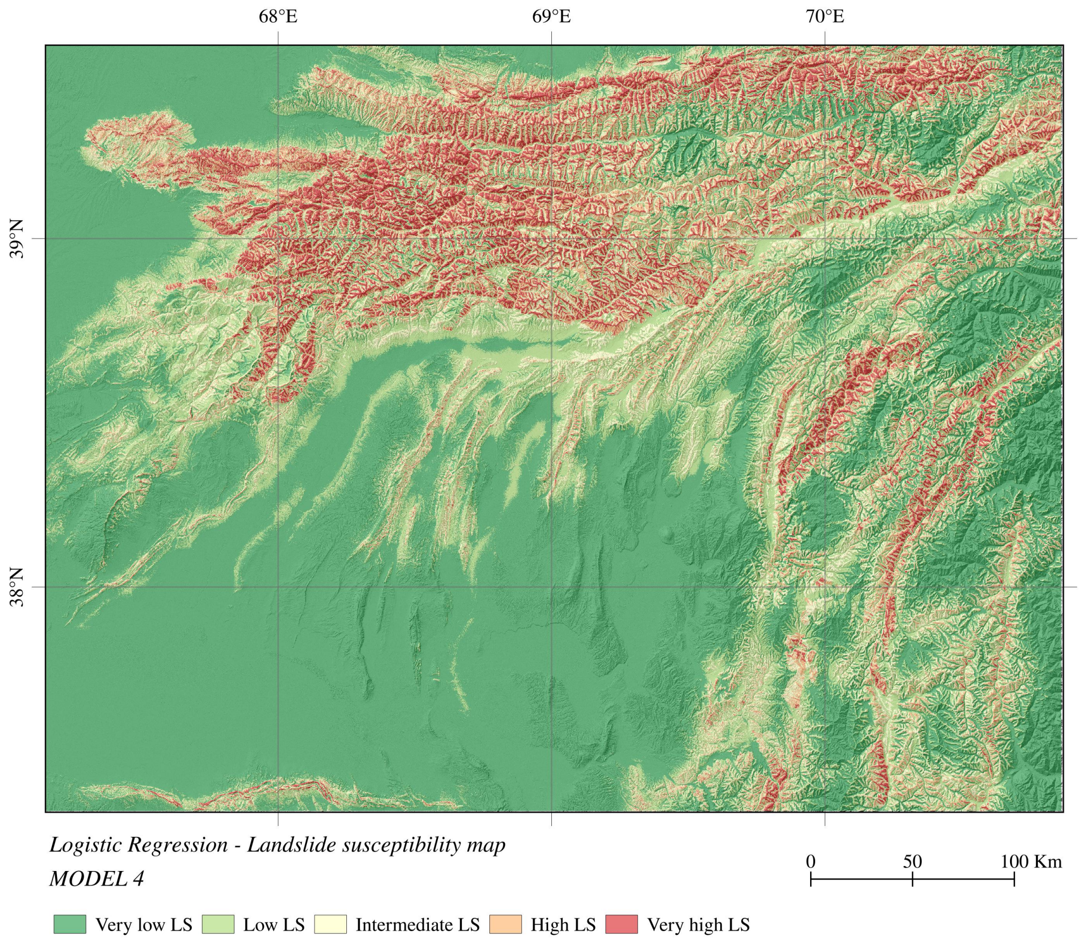
Mean ROC = 0.89

Mean ROC =0.92

INFLUENCE OF THE LANDSLIDE CATALOGUE



Spatial distribution bias.
More landslides in Tien San than in Pamir



Influence in the reliability of the results.
Results are less significant in the Pamir.

THEMATIC VARIABLES

More relevant

- <u>Lithological information</u>

  Cretaceous and Jurassic sequences where calcareous rocks and shales are dominant

- <u>Valleys and ridges</u>

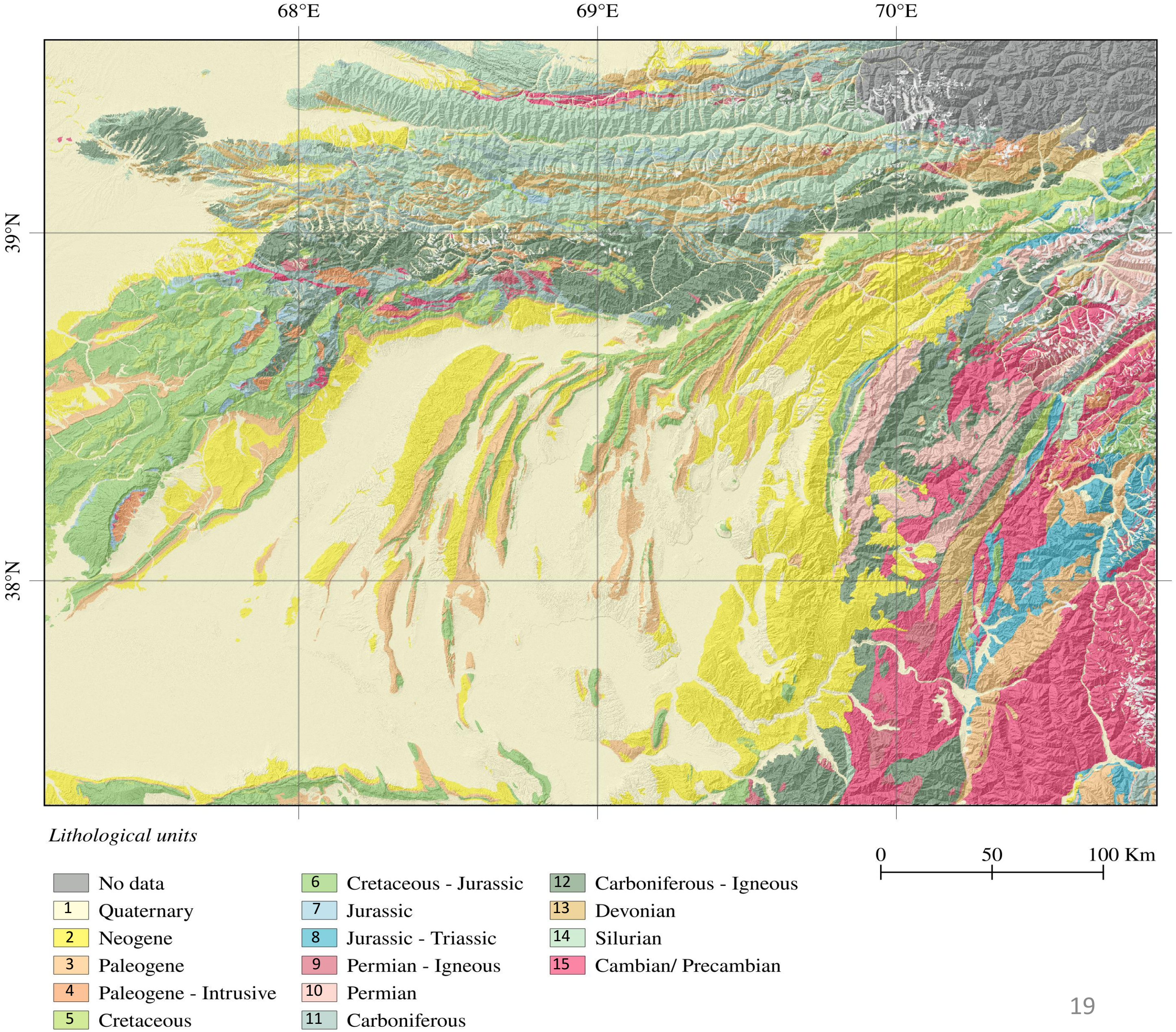
  EigenValues – TPI and Elevation relief values

- <u>Identification of erosive areas</u>

  Surface roughness

- <u>Tectonic influence</u>

  Surface Index



THEMATIC VARIABLES

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Cretaceous and Jurassic sequences where calcareous and shales are dominant

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- Identification of erosive areas

Surface roughness

- Tectonic influence

Surface Index

THEMATIC VARIABLES

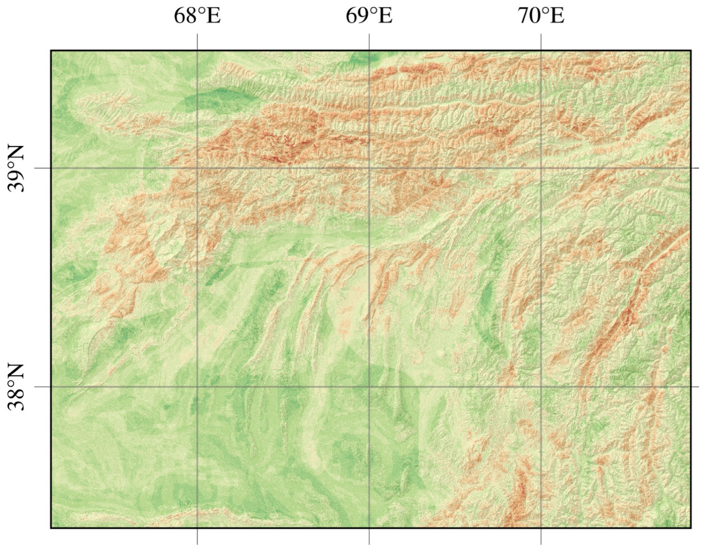
Relevant but not used

- <u>Distance to glaciers</u>

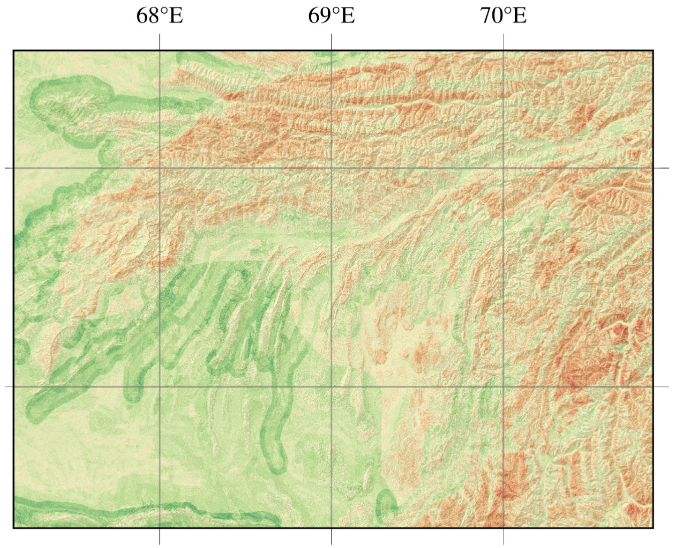
  Important geomorphological environment; however, create zonation.

- <u>Precipitation</u>

  Detailed data is need in order to be considered a more relevant input.



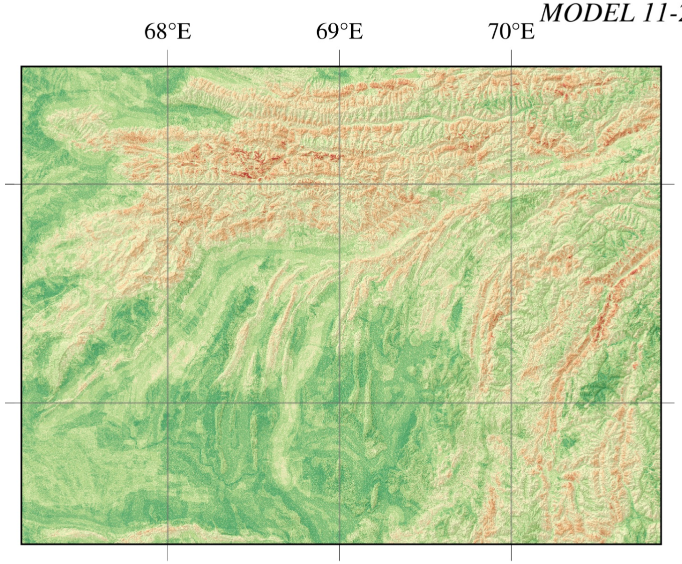
Weight of evidence - Landslide susceptibility map
MODEL 11-1



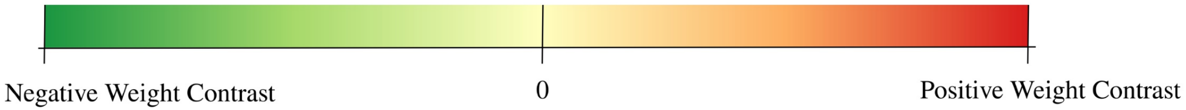
Weight of evidence - Landslide susceptibility map
MODEL 11-2

Distance to glaciers & Precipitation

Precipitation



Weight of evidence - Landslide susceptibility map
MODEL 11-3

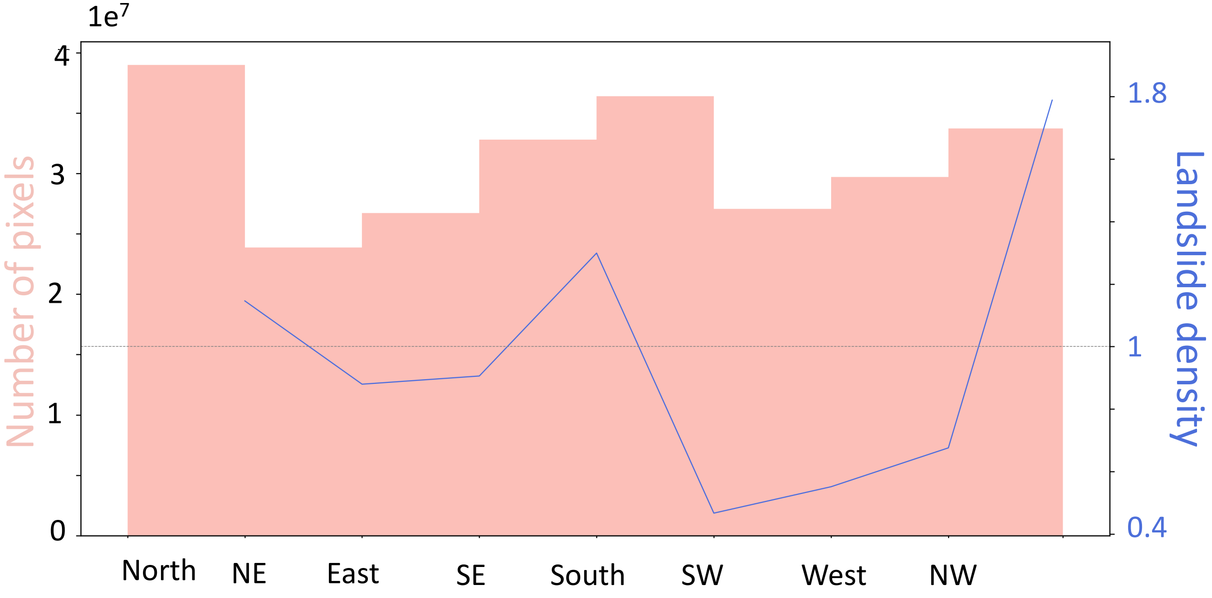


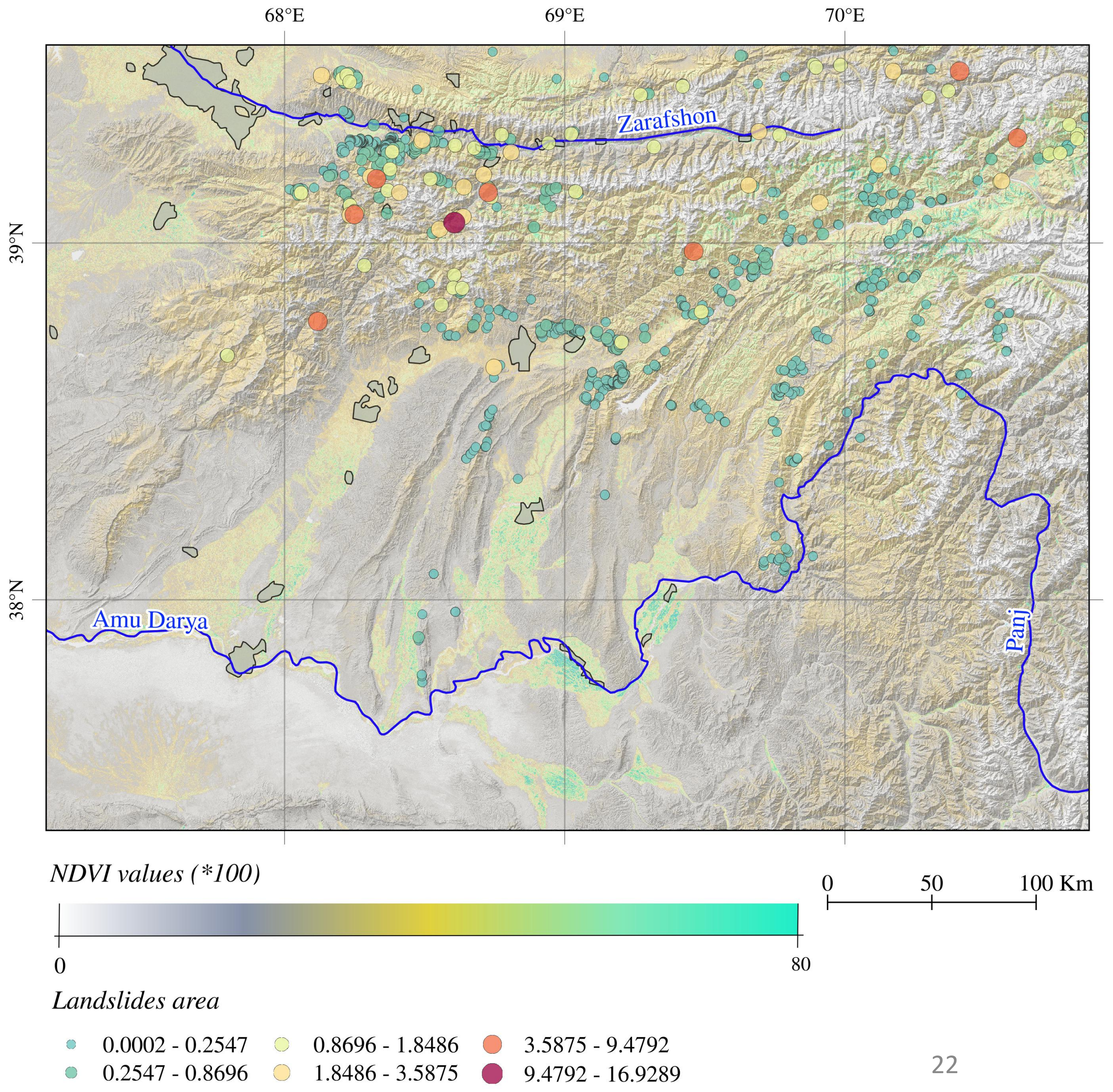
RELEVANT THEMATIC VARIABLES

Less relevant

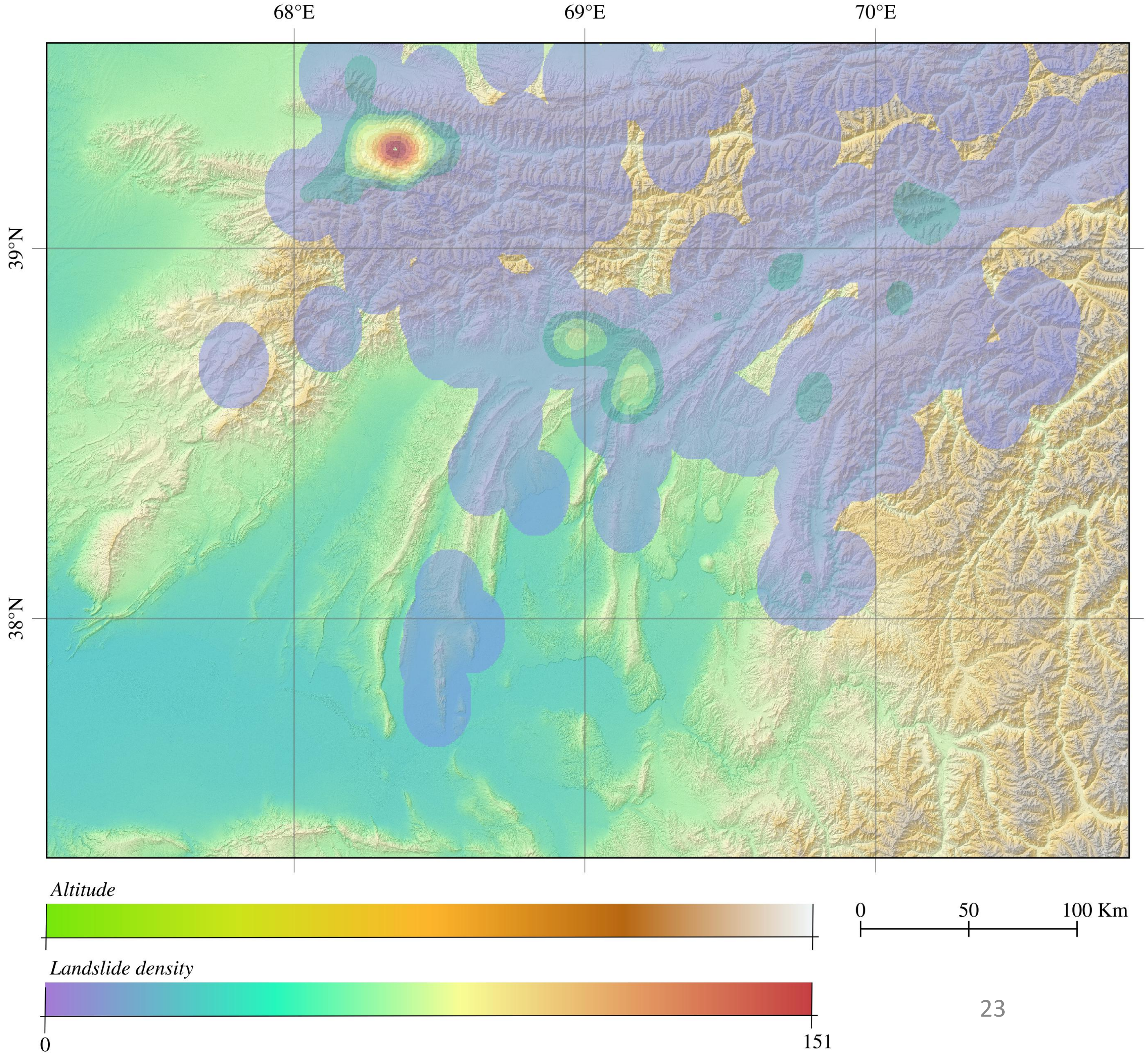
- NDVI
- Aspect
- TWI

The values associated to the landslides are similar to the areas with no landslides.

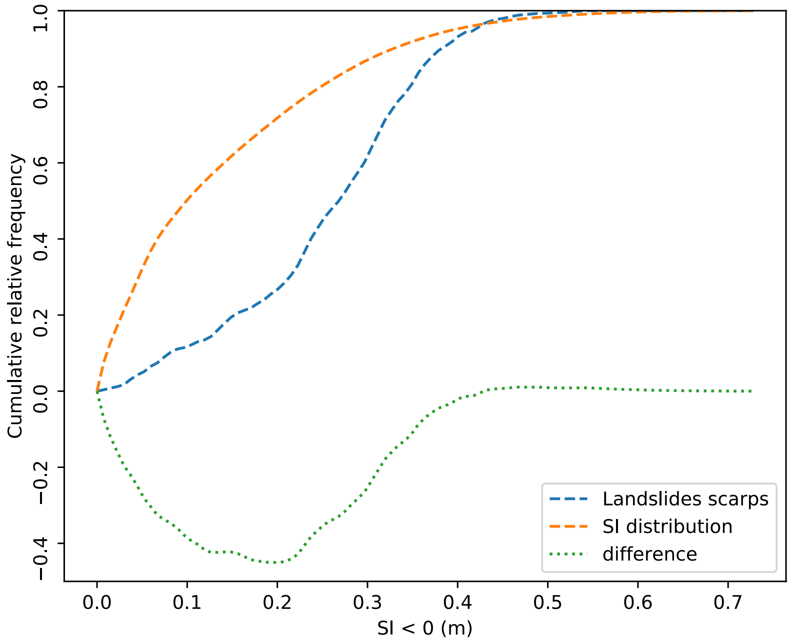




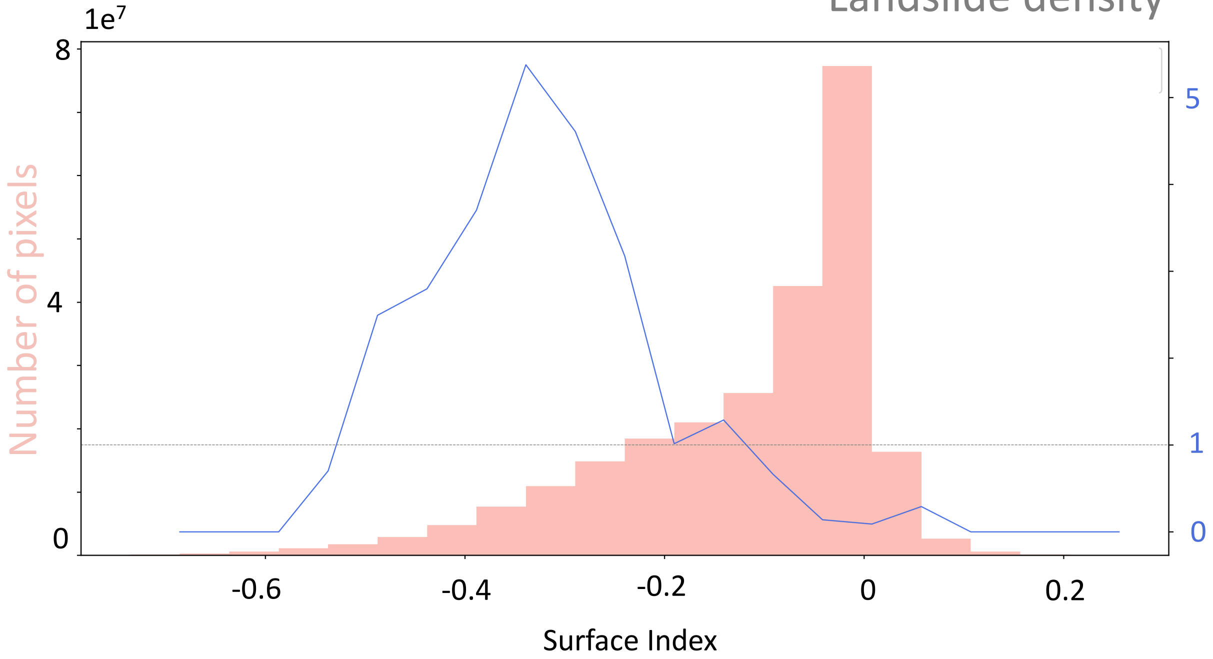
The **landslides catalogue** created allows an assessment of the landslides susceptibility of the area; however, also biases are introduced to the models.

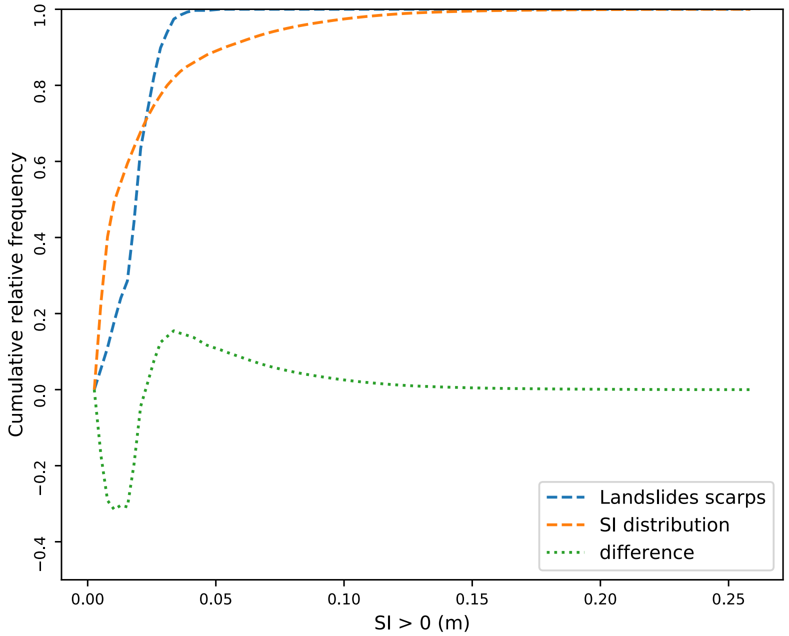


The interaction and the **spatial association** between different factors and mass movements is analyzed based *on landslide density* and *cumulative frequencies*.



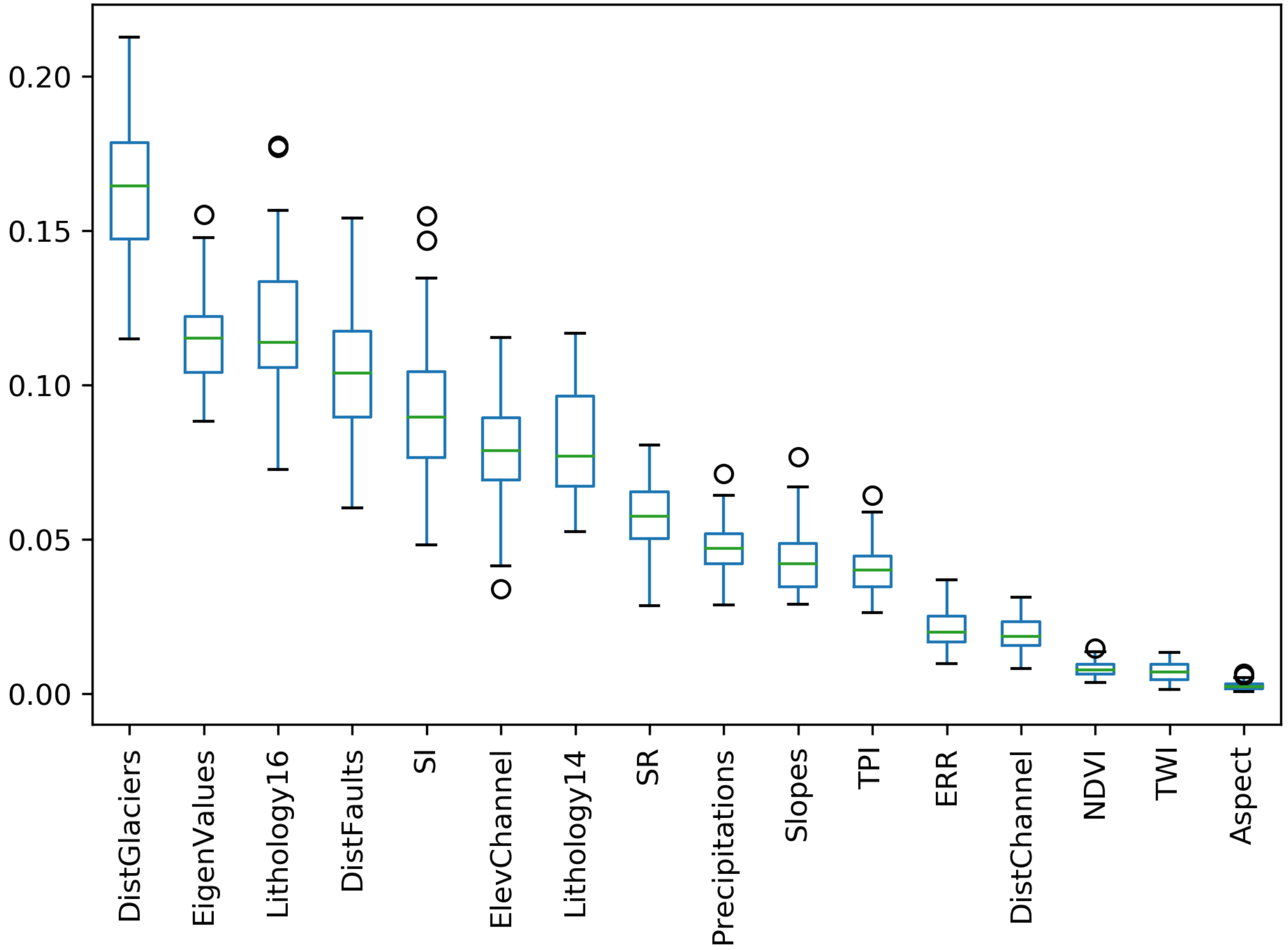
Landslide density



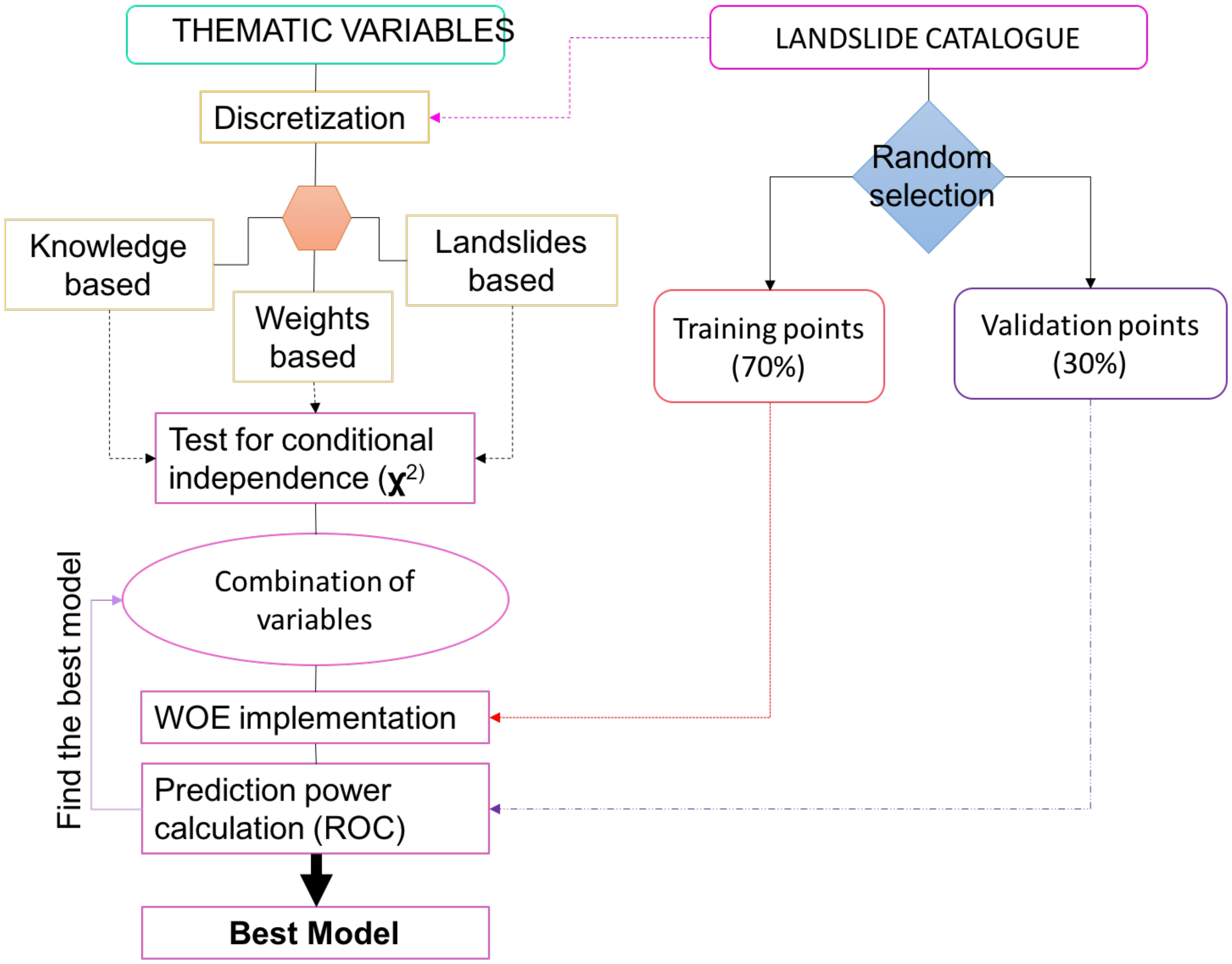


The **importance** of each of the thematic variables is analyzed by the implementation of three different approaches to landslide susceptibility.

Different **geomorphological parameters** are proven as **relevant** in the improvement of the results of the landslide susceptibility models and the understanding of the relation between the different processes that modify the landscape.



Individual methodologies are created to implement each of the statically-based landslide susceptibility approaches. All of them based on free sources programs.




THANKS
http://autourduglobe.com/2016/11/21/valee-de-jizeu-route-de-pamir-tadjikistan-3/

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