Landslide Hazard Map

Dr. Blaž Komac

Matija Zorn

Anton Melik Geographical Institute ZRC SAZU

Goriška brda – the rocks

- Hilly region between the Idrija and Soča rivers.
- Altitude: 300–800 m.

- **Flysch rocks** (sandstone, marl, claystone, limestone, calcarenite), delimited by limestone in the North and alluvial sediments in the South:
  - upper Paleocene **Kožbana flysch layers** (turbidite sediments, includes limestone, breccia and conglomerate intrusions),
  - Lower Paleocene **Medana flysch layers** (sandstone, marls) are prone to landsliding.

Fliessen – Flow – **Flysch**

- Flysch is prone to landsliding because it:
  - is built of different alternate rock layers
  - may contain considerable amount of **water** and is relatively impermeable,
  - it is **layered** and builds **hilly** relief with **steep** slopes.

Landslides in Goriška brda

❑ Landslides cause **considerable damage** in the Goriška brda region. Farmers repair the terraces for few weeks per year.

❑ Most of the landslides are triggered on **steep concave slopes** due to increased water content being a consequence of high precipitation or human influence.

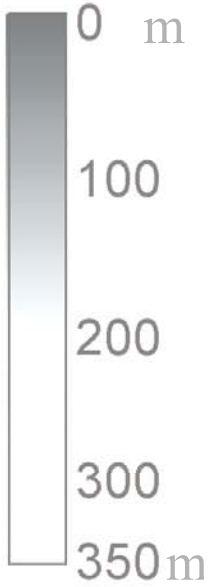
❑ Farmers often **repair** small landslides themselves by canalizing water and thus leading it to lower areas in a *safe* way.

Landslides in Goriška brda

- "… ***Small landslides*** *occur all over the Goriška brda region and especially its central part where marls and steep slopes occur while shallow debris landslides mostly occur in the SW part of the region …*" (Grimšičar 1962, 9).

- **Large, deep seated landslides** are not so often and mostly occur in the lower parts of slopes. They are usually triggered by human impact or high waters of the streams.

Input data:
800 landslides in 1998



- **Heavy precipitation** was recorded in Goriška brda in September and October 1998:
  - 13. September – 100 mm
  - 6. October – 175 mm (50 years reoccurence period)
  - 28. September – 13. October = **433 mm.**

- High intense precipitation is one of the most important triggering factors. **Critical** (landsliding) **precipitation intensity** is about *100–150 mm/24 h* or *130–180 mm/48 h* in Slovenia.
- More than **800 mostly shallow landslides** were triggered occupying about **1,7 % of the area** considered.

Susceptibility map elaboration method (based on the 1998 event data)

- Eight factors were taken into consideration:
  - lithology,
  - slope,
  - curvature,
  - dip of the strata,
  - stream power index,
  - wetness index,
  - maximum 24-hour precipitation,
  - land use.

Susceptibility map elaboration method (based on the 1998 event data)

- Dempster-Shafer theory of evidence **algorithm** (Dempster 1969, Shafer 1990) was used to elaborate the map using the programs *Idrisi* and *TAS*.
- First, the actual values are **hierarhically compared** to the factors, mentioned before. For each factor **characteristic values** are obtained which are then compared to the neighbouring values.
- The final map shows **landslide susceptibility** (0–1), taking into account all the factors and the measured values. The final map is then produced – making classes on the basis of standard deviation.
- Some **factors and results** shall be discused into detail:

Susceptibility map elaboration method (based on the 1998 event data)

In the Goriška brda region landslides usually appear on

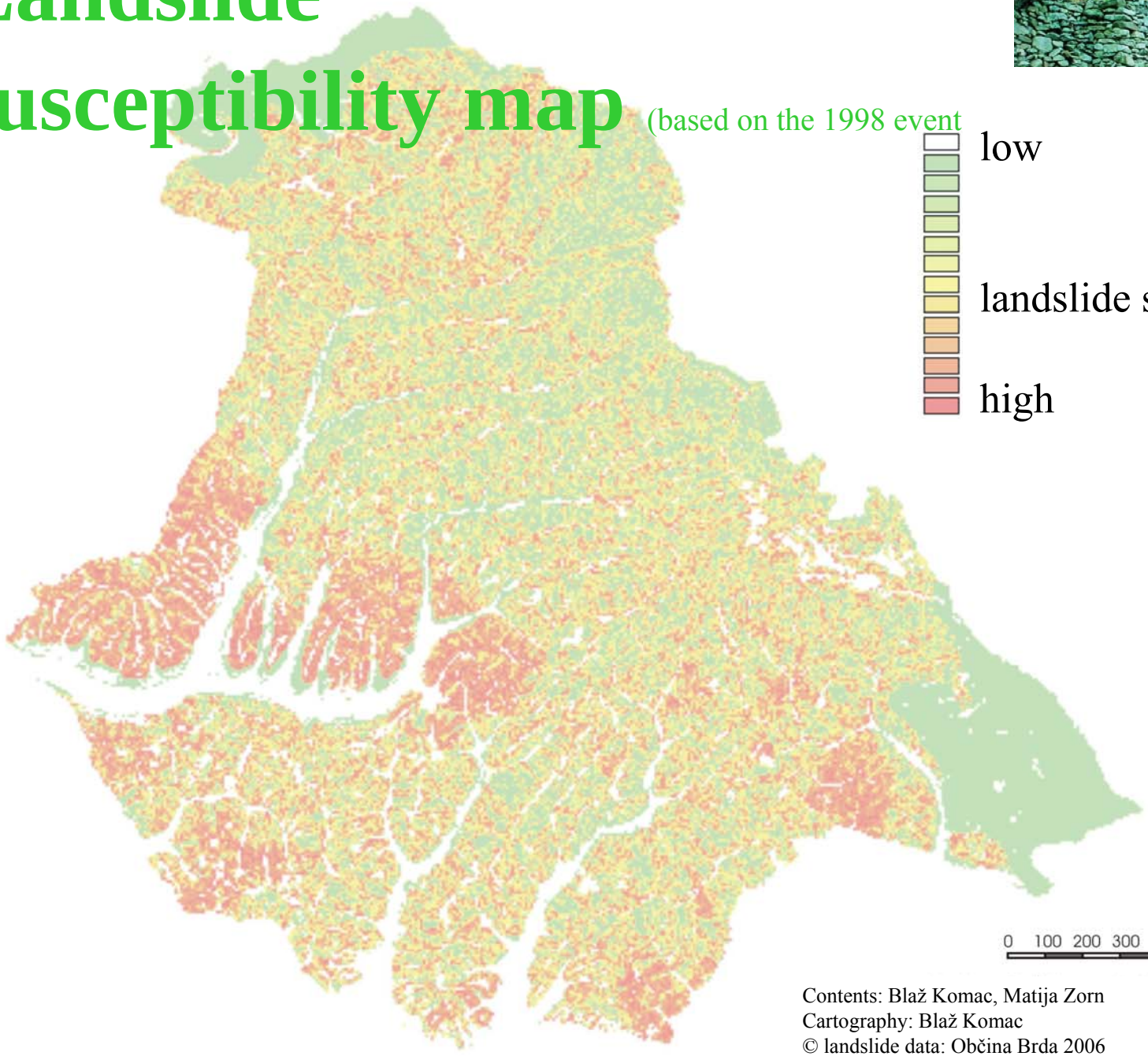
NE or SW oriented **concave** slopes

having an **inclination** of about 20^{o}

that are covered with **vineyards**.

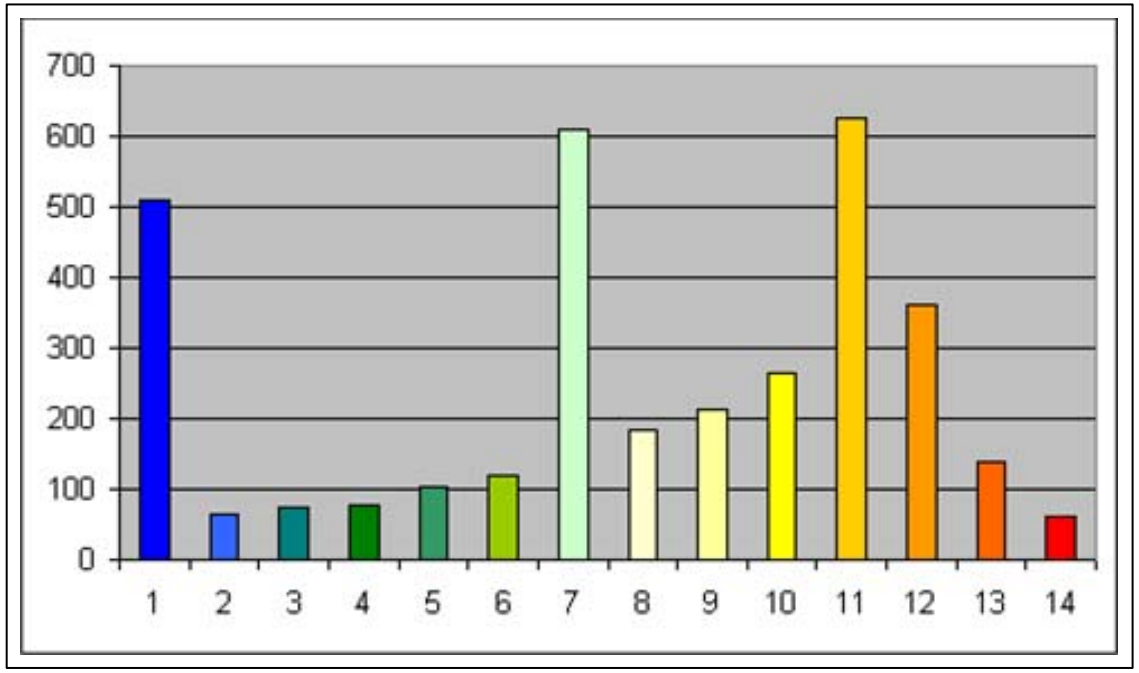
On average, the landslides appear about **70 m** below the ridges.

Landslide susceptibility map (based on the 1998 event



Contents: Blaž Komac, Matija Zorn
Cartography: Blaž Komac

Landslide susceptibility categories



- Landslide susceptibility categories (ha)

- NOTES

- 7. High value due to summing of data ($\overline{X} \pm 0{,}1$ standard deviation)

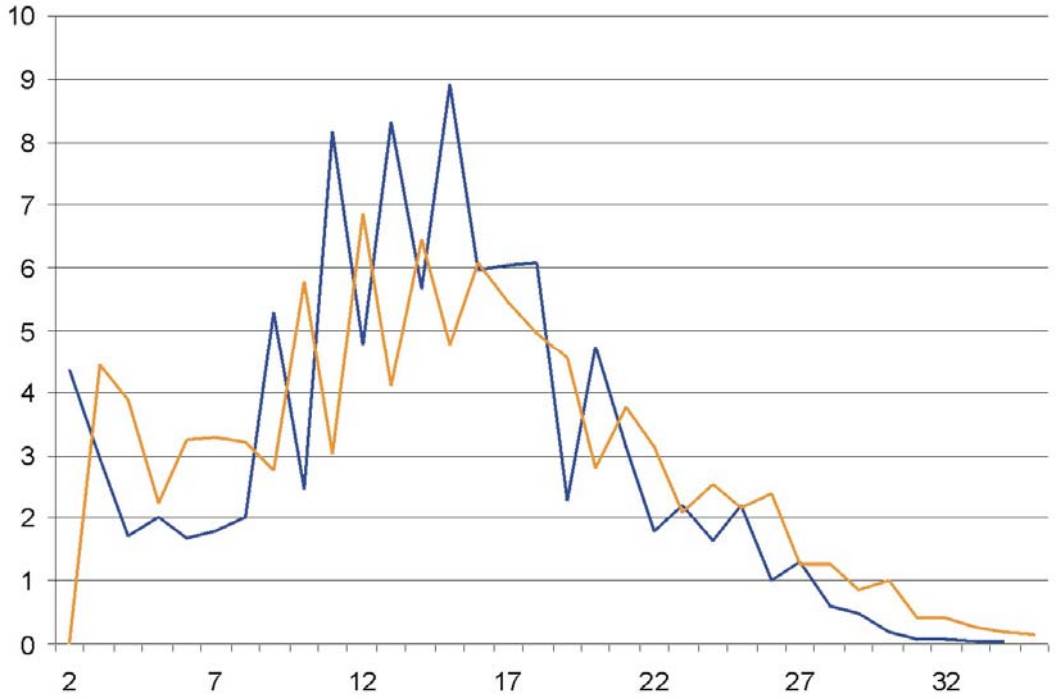
- 11. High value due to high vineyard share comparing to other land use categories.

Inclination of slope

- Beside lithology, slope is the most important factor for landsliding.

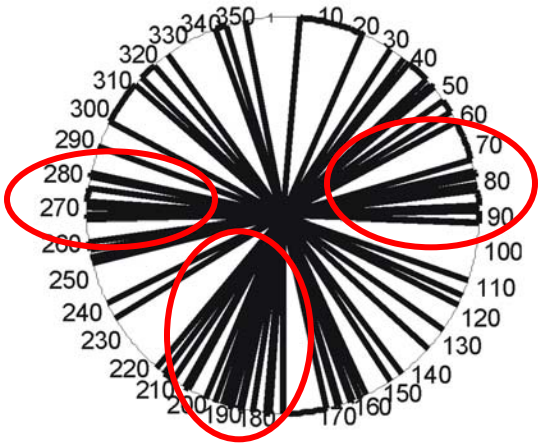
- **Half** of the landslides were triggered at **12–20º**, a quarter at 6–12º, and a sixth at 20–32º. The correlation between frequency distribution of slope inclination and landslide areas is statistically imporatant.

COMPARISON:
Haloze hills, 4. 8. 1989
150–200 mm/24h, 5000/106 km^2.
0–5º : 0,0%
6–10º : 3,7%
11–15º : 24,6%
16–20º : 32,0%
21–25º : 20,3%
26–32º : 13,5%
above 32º : 5,9%

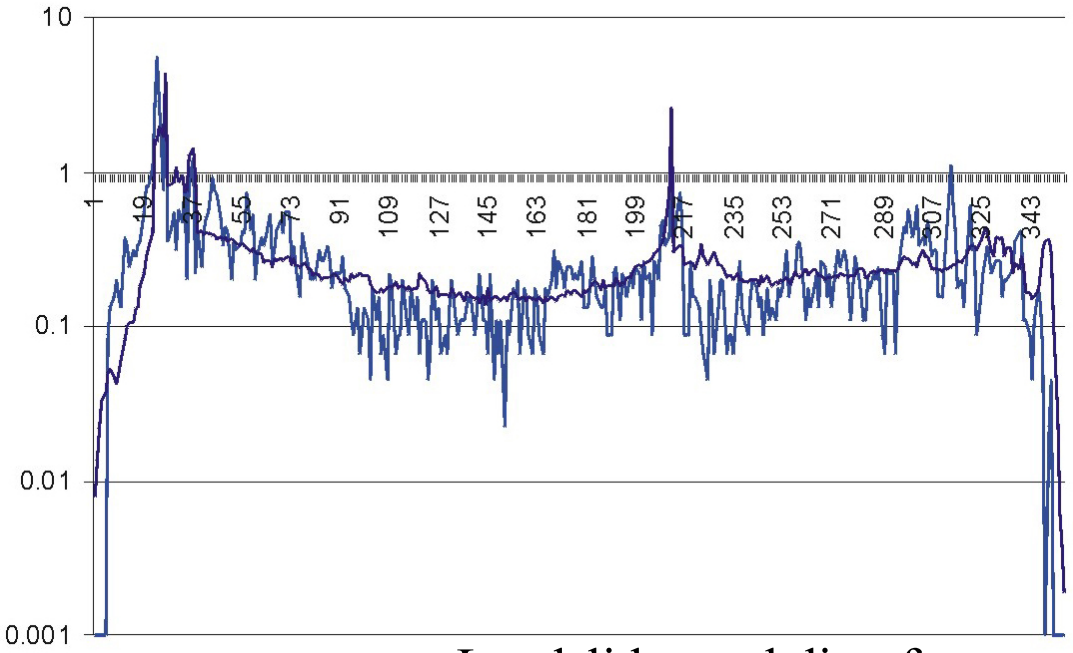


Dip of flysch strata

- The majority of landslides was triggered on the **NE, SW and NW** facing slopes.



Dip of strata in the Goriška brda region



Landslides and dip of strata – measured and expected values (in degrees)

Land use

- Total landslide susceptibility is rather high due to high share of **vineyards**. Landslide susceptibility is lower than expected in **forests and urban areas**.

	Expected (%)	measured (%)
Fields	2,94	2,63
Vineyards	41,20	70,01
Intensive Orchards	5,28	4,30
Extensive Orchards	3,00	2,34
Olives plantages	0,04	0,27
Other plantages	0,00	0,00
Extensive meadows	7,94	7,55
overgrowing of forest	1,39	1,07
Mixed use	1,99	0,80
Forest	30,22	9,80
Urbanised	5,87	1,23
Not overgrown	0,01	0,00
Waters	0,14	0,00

COMPARISON (Haloze hills, 1989): 16% of the landslides were triggered in vineyards, 5% in the fields/orchards/forests. The average inclination of slope of landslides in forests was 23°, 14° in the fields and 18° in the orchards.

- "*... Unexpected high number of landslides (5%) were triggered in the terraced vineyards – regarding to relatively small total area of terraces ...*"

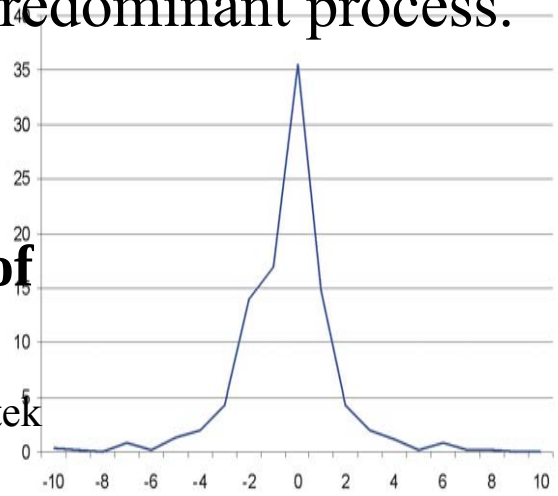
(Natek 1990, 13).

planar curvature

- 40% of slopes are convex, 35% linear and 25% concave. The majority of landslide appeared **below the upper convex parts** of slopes that are far enough from the ridges.

- The result are **convex-concave slopes**. Denudation and landslides prevail in the convex part while accumulation in the concave parts.

- Landslides are very important morphogenetic factor controlling the evolution of upper parts of the valleys – typical flat-floored valleys appear. In the lower parts erosion is usually the predominant process.

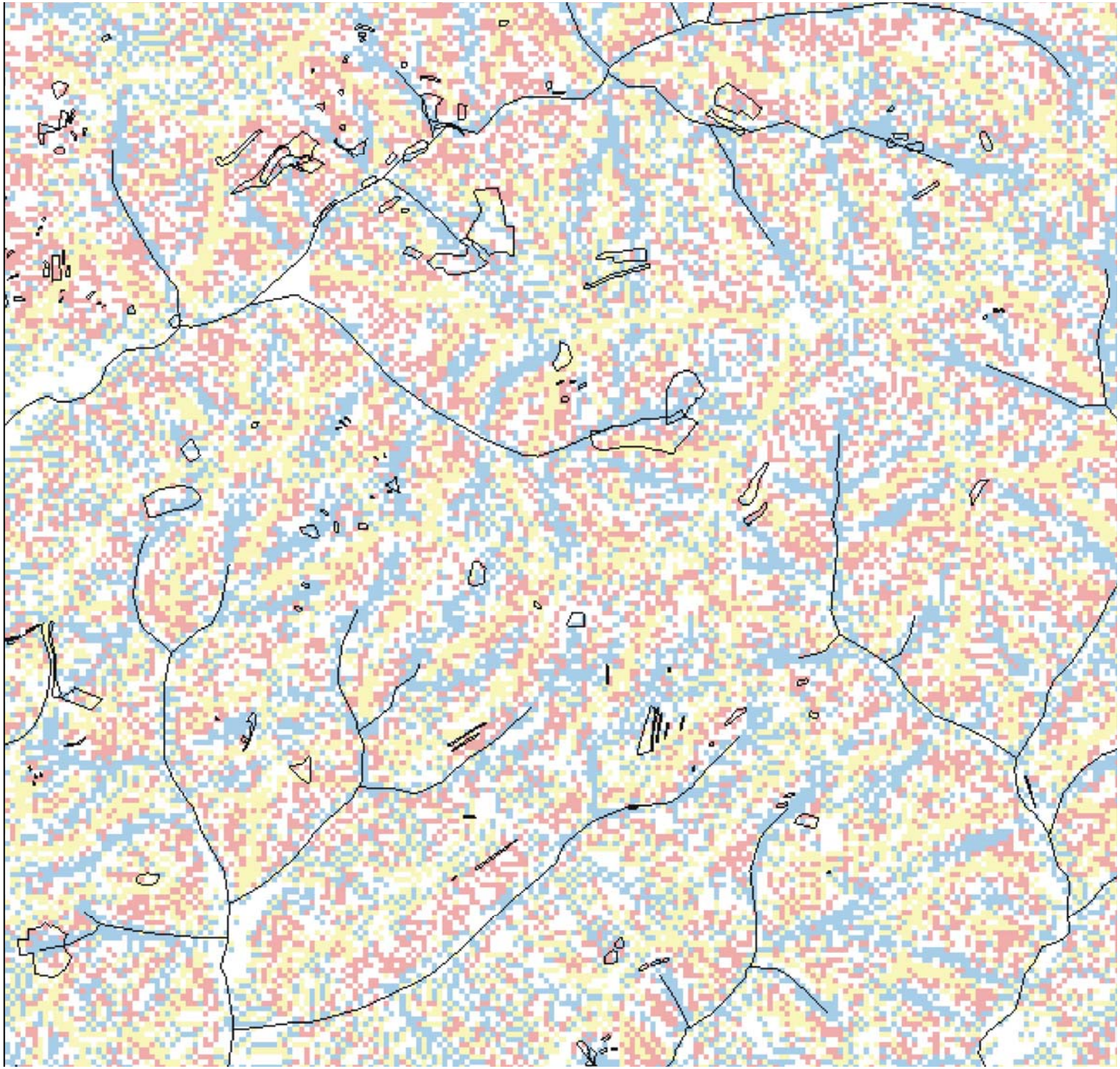


COMPARISON (Haloze, 1989):

- **44%** of the landslides appeared in the **middle parts of the slopes**.
- 1/3 of the landslides originated in the **valley ends** (Natek 1984, 147–148).

Most of the landslides were triggered in the middle parts of slopes just below their upper – convex parts.

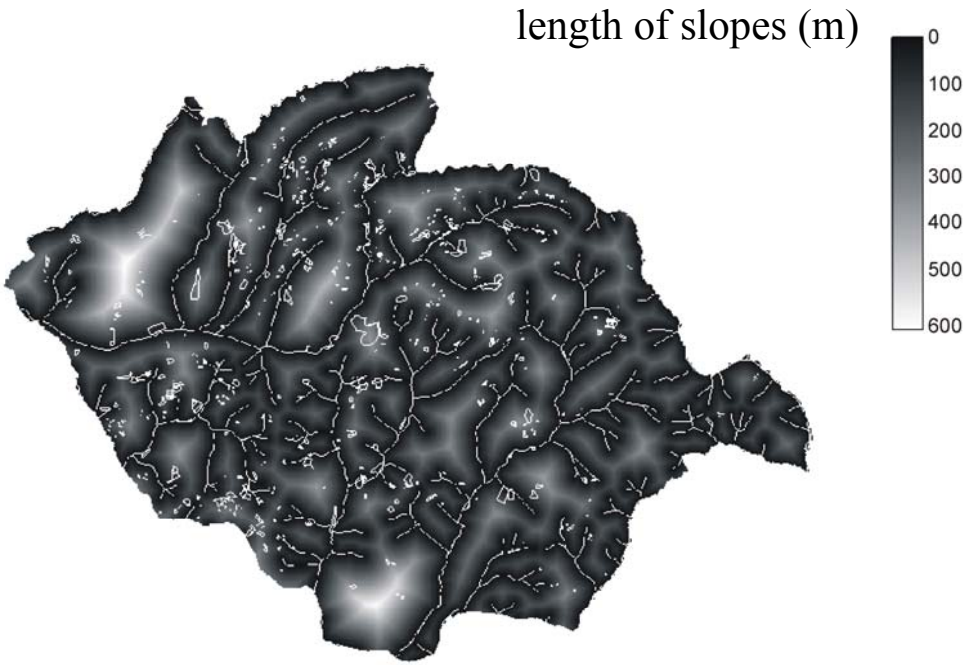
Blue color shows **concave** relief forms, red color **convex** relief forms and yellow color **linear** slopes.



Length of slopes

- The majority of slopes are rather short:
  - a quarter of them is shorter than 20 m
  - **half of them shorter than 50 m**
  - a quarter longer than 100 m).

The landslides were triggered **70 metres** below the ridges on average (40–100 m).



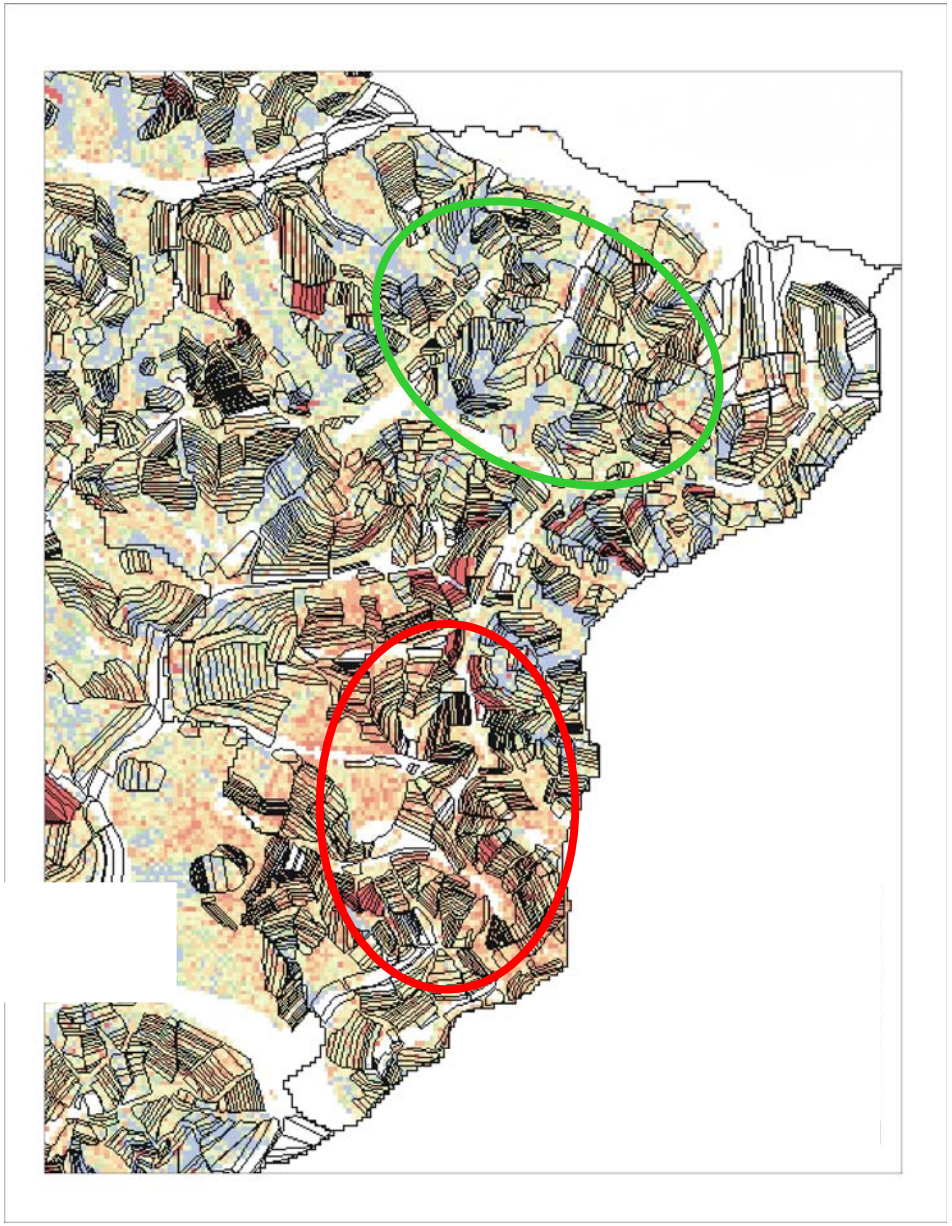
The **quantity of** (surficial and ground) **water** flowing down the slopes is **big enough to change** the characteristics of the material in the distance of few 10 m from the ridges .

Terraces

Inclined slopes are the most suitable relief type for viticulture but they are also areas prone to landsliding on the other hand.

Winegrowers have to adapt to the situation. That is why almost **half of the terraces** are built on the landslide-prone areas and only **a quarter** of them on less hazardous areas.

The terraces comprise more than 40% of the territory in Goriška brda.

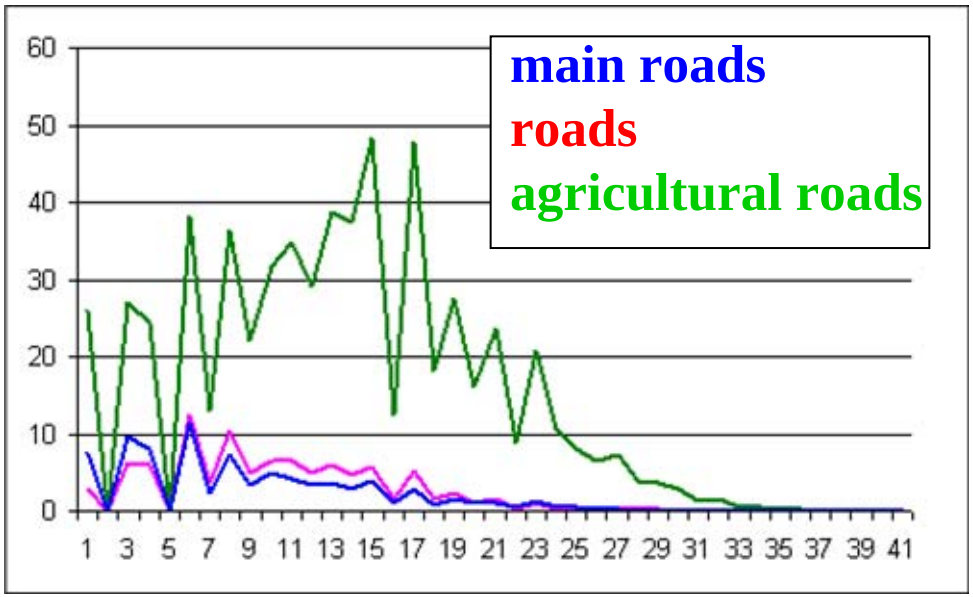


Roads

- **About 1/10** (~10 km) of the main roads are built on the areas prone to landsliding and about ¾ are relatively safe from them.

- Almost a **quarter** of roads are endangered by landslides and more than a half (54 km) of them are safe from landsliding.

- More than **two thirds** of agricultural roads are endangered by landslides. **One quarter** of them is highly endangered, and one quarter (110 km) is safe from landsliding.



Model /map reliability

- Landslide susceptibility map is a model and an estimation of the effects of geomorphic processes. Its reliability depends on the quality of the data used, the method and the geomorphological knowledge of the producer.

+ The model includes high number of landslides that were triggered at known conditions (precipitation amount). The most important controlling factors are included. The data are not weighed but compared by a hierarhic statistical method. The map is useful for further detailed field mapping.

– The map is a model and thus only partly describes nature and natural processes. It is based on one (time) series of data. The data are not 100% reliable as they were not collected by scientists.

Conclusion

❑ "*... Gentle slopes facing SW and having a thin layer of debris are safe from landslides. That is why there are not a lot of landslides in northern Goriška brda ...*" (Grimšičar 1962, 8).

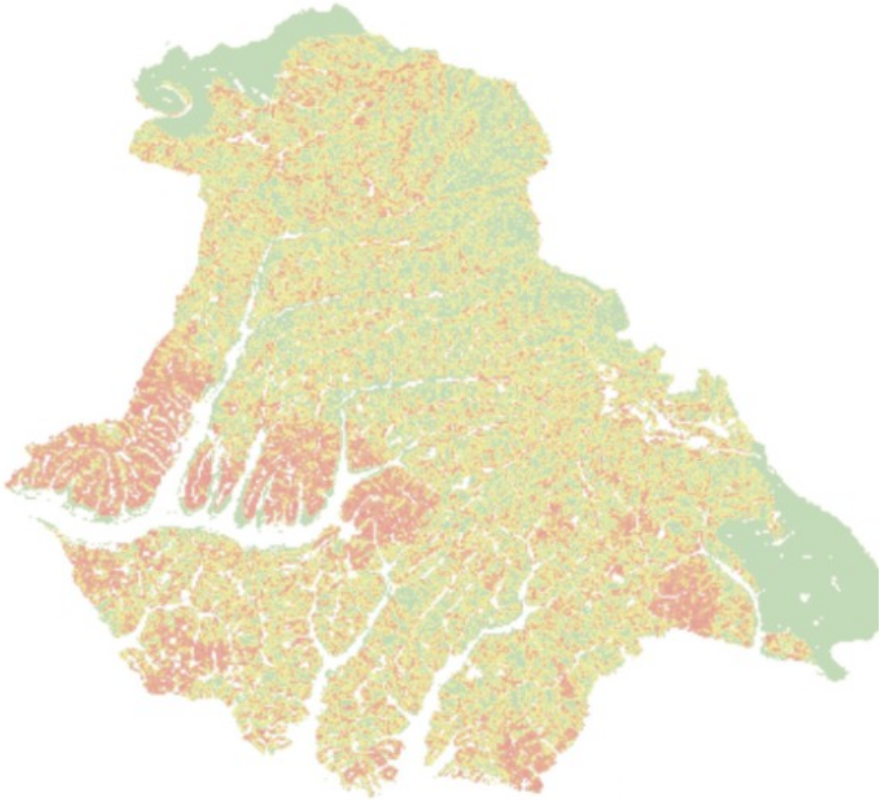
❑ Landslides are often triggered by the activity of man. For example, more than half half of the landslides in Haloze (1989) were indirectly caused by human activity (Natek 1990).

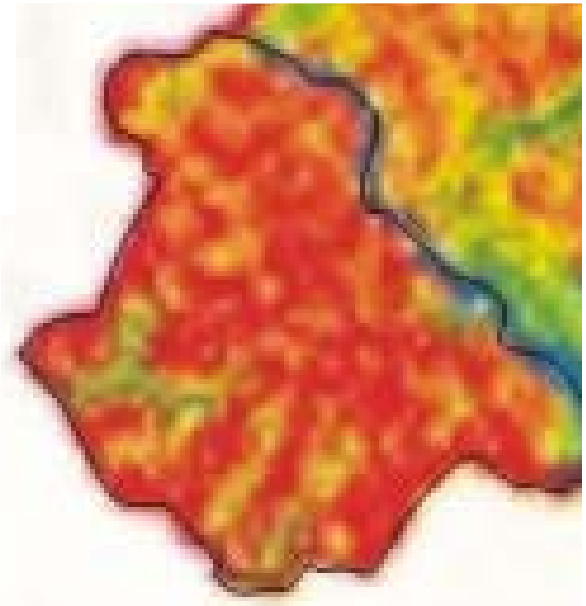
❑ About ¾ of the area put into consideration is more or less prone to landsliding. **Slope, dip of strata** and **depth of mobile material** (debris) seem to be the most important controlling factors.

❑ Terrace and road building shall follow the guidelines and historic experience of inhabitants, farmers. Building process should be carefully pre-considered from the natural, agricultural and economic point of view.

Thank you for your attention!

blaz.komac@zrc-sazu.si





Landslide hazard map. In: Komac, M. 2006: Potencialno plazovita območja v Sloveniji in izpostavljenost človekovega okolja. Geografski informacijski sistemi v Sloveniji 2005–2006, p. 73–82. Založba ZRC. Ljubljana.