LAND DEGRADATION IN A COMPLEX ENVIRONMENT: CHALLENGES OF LAND MANAGEMENT AT THE CONTACT OF FOUR MAJOR EUROPEAN GEOGRAPHICAL UNITS

BOOK OF ABSTRACTS AND FIELD GUIDE

Commission on Land Degradation and Desertification (COMLAND) of the
International Geographical Union (IGU) Meeting and Field Trip in Slovenia
June 23rd–June 27th, 2016

LJUBLJANA 2016

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Edited by:
MATIJA ZORN
MATEJA FERK
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***Edited by*: Matija Zorn, Mateja Ferk, Jure Tičar, Primož Gašperič**

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Front cover photography: Land degradation in the Julian Alps is either human induced, e.g. as a result of mining activity (on the left), or induced by natural processes, e.g. landslide (on the right) (photograph: Matija Zorn).

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SLOVENIA - THE CONTACT OF FOUR MAJOR EUROPEAN GEOGRAPHICAL UNITS

Slovenia is a Central European country (20,272 km^2) with **exceptional geomorphic and cultural diversity in its landscapes**. Within a diameter of barely 150 km four major European geographical units join and interweave; including the high **Alpine mountains** and valleys, the flat **Pannonian Plain** with islands of wine-growing hills, the mysterious karst landscape of the **Dinaric Mountains**, and the **Mediterranean** world with the pleasant influence of the Adriatic Sea. At the same time, **four cultural and linguistic spheres surround Slovenia**: Slavic, Germanic, Romance and Hungarian. Within this diverse physiographic and geomorphic setting four cultures have created **numerous distinctive types of cultural landscapes** that reflect the natural and social characteristics of individual areas. Because of the interweaving of so many and so contrasted natural, historical, political, and cultural elements, the natural and cultural heritage of **Slovene landscapes is outstandingly heterogeneous** (Perko 1998; Perko and Ciglič 2015). While the representative landscapes are of keen interest, they also undergo a range of land degradation processes, representing a challenge to land managers. The field trip will expose participants to these uniquely diverse types of landscapes and land degradation processes to consider - and discuss - prospective management strategies.

Figure 1: Diverse landscapes in Slovenia (Perko and Orožen Adamič 1998).

SOME FACTS ABOUT SLOVENIA

(Orožen Adamič 2001; 2004; Urbanc 2007; SI-Stat 2016)

Location

Slovenia is located in Central Europe.
Area: 20,273km^2.
Land border length: total 1,370 km, with Croatia 670 km, with Austria 318 km, with Italy 280 km, with Hungary 102 km.
Coastline: 46.6 km.

Landscape

Four major European geographical features meet in Slovenia; the **Alps**, the **Dinaric Alps**, the **Pannonian Basin**, and the **Mediterranean**.
Highest point: Triglav (2,864 m).
Deepest sea point: 550 m from Madona Cape, Piran (–38 m).
Longest cave system: cave system Migovec (> 35.8 km).
Number of caves: more than 11.600 (> 0.5 per km^2)
Largest lake: Lake Cerknica (*Cerkniško jezero*; intermittent, 26 km^2).
Longest river: Sava (221 km).
Average elevation: 557.3 m; *Average inclination*: 14.1°.
Waters: the land is crossed by some 27,000 km of rivers and streams and some 7,500 springs with potable water rise to the surface, including several hundred first-class therapeutic mineral springs.

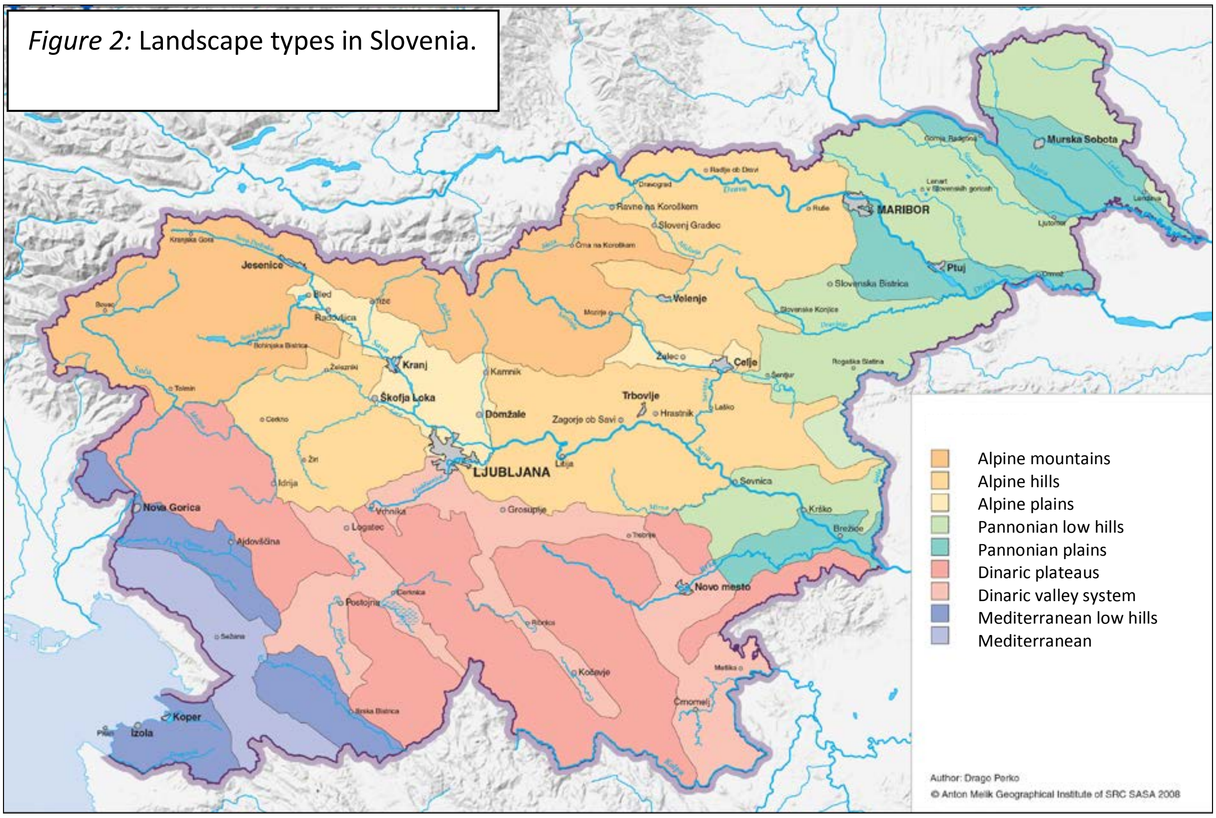

Figure 2: Landscape types in Slovenia.

Climate
Most of Slovenia has a continental climate with cold winters and warm summers. The average temperatures are –1.1 °C in January and +19.9 °C in July (Ljubljana). The mountains have an alpine climate, and the southeast a Mediterranean climate. The average rainfall is 1,000mm on the coast, up to 3,500 mm in the Alps, 800 mm in the southeast, and 1,400 mm in central Slovenia.

Biodiversity
Slovenia's varied geological composition and diversity of relief forms, combined with the fact that Slovenia encompasses four distinct bio-geographical regions, make possible a wealth of animal and plant species. Slovenia is home to more than 3,000 fern and flower species, and more than 50,000 animal species. There are also many native animal and plant species.

Nature conservation
Approximately 11% of Slovenia's territory is specially protected; the largest area with this status is Triglav National Park, with an area of 838 km^2. There are 3 regional parks with a total area of 439 km^2, 41 nature parks, 49 nature reserves, and 623 natural heritage sites. In addition, the Nature 2000 network includes 286 areas that altogether encompass 36% of Slovenia's territory.

Population
Total: 2,064,188 (2016).
Density: 101.8 inhabitants per km^2 (2016).

Ethnic minorities
Hungarians (0.3 %) in the northeast and Italians (0.1 %) in southwest are recognized as indigenous minorities with special rights under the constitution.

Some historical Milestones
Slavic groups first settled in the area of present day Slovenia in the 6th century.
7^th^ century: The Duchy of Carantania was the first Slovene state.
745: Carantania became a part of the Frankish empire; the Slavs converted to Christianity and gradually lost their independence.
10th century: The Freising manuscripts, the first known writings in the Slovene and Slavic dialect in Latin script.
14th century to 1918: All Slovene regions passed into the possession of the Habsburgs, later the Austro-Hungarian Monarchy.
16th century: The Reformation brought literacy and the first printed book in 1550, and in 1584 the first Slovene translation of the Bible was printed.
1809–1813: The establishment of the Illyrian Provinces – half of Slovenia was included in Napoleon's French empire.
1848: The United Slovenia movement demands the unification of all Slovenes in a single province within the Austrian Empire.

1918: At the end of World War I Slovene ethnic territory is divided among four countries (Austria, Kingdom of Italy, Hungary and Kingdom of Serbs, Croats, and Slovenes (later Kingdom of Yugoslavia))
November 29, 1945: The Slovenes secure their own republic within the Federal People's Republic of Yugoslavia.
April 1990: First democratic elections.
December 23, 1990: 88.5% of voters cast their votes for an independent Slovenia in a referendum.
June 26, 1991: Proclamation of Slovenia's independence.
May 22, 1992: Slovenia becomes a member of the United Nations.
March 29, 2004: Slovenia becomes a member of NATO
May 1, 2004: Slovenia becomes a member of the European Union.
January 1, 2007: Slovenia adopts the euro as national currency.

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Matija Zorn

ABSTRACTS

LANDSCAPE DIVERSITY IN EUROPE AND IN SLOVENIA

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Landscape diversity (also termed diversity, composition or richness) gives information about a number (or percentage) of certain categories (e.g., landscape types) in a certain geographical area. The areas with the highest landscape diversity are termed landscape hotspots, and vice-versa areas with the lowest landscape diversity are termed landscape coldspots (Perko and Ciglič 2015).
The presentation focuses on landscape diversity of Europe and especially on landscape diversity inside Slovenia. Thus it is divided into two parts. In the first part we explain methodology and show European landscape diversity (Ciglič and Perko 2013), and in the second part we present landscape diversity in Slovenia.
The main purpose of the first part of the analysis was to identify areas in Europe that can be described as very diverse according to four natural landscape classification that were officially published by scientific journals or established by European institution. In order to determine European diversity four geographical classifications of Europe were analyzed (*Environmental stratification of Europe* by Metzger et al. 2005; *European landscape classification* by Mücher et al. 2010; *Biogeographical regions* (*rev. 1* in 2011) by EEA 2013; *Terrestrial ecoregions of the World* by Olson et al. 2001). First, four maps of landscape variety were produced based on each division of Europe taken into account. This step was carried out for each cell by counting the number of different unique natural landscape types or regions that are present in a radius of 50 km around the cell. Each of these maps was then weighted; the cell values were divided by the number of all unique types/regions in a division. In the final stage, all of the maps were averaged into one map – landscape diversity of Europe. With the map it was possible to get an overview of Europe's landscape diversity, their landscape hotspots, and the most naturally heterogeneous countries.
Due to its position at the intersection of the Mediterranean, Alps, Dinaric Alps, and Pannonian Basin, Slovenia is considered as one of the most diverse countries in Europe. Thus in the second part we focused on internal landscape diversity of Slovenia. Based on digital data on relief, rock, and vegetation we determined the natural landscape diversity and landscape hotspots of Slovenia. Methodological steps were the same as they had been in the first part, with an exception of radius for variety calculation. For the detailed analysis of Slovenian diversity the radius was set to 1 km. The presence of landscape hotspots offers numerous advantages (e.g., availability of various natural resources and attractiveness for tourist visits) and also challenges (e.g., transfer of good practices is not as easy as in monotonous landscapes). Thus it is important to know their locations and properties.

Key words:
landscapes, landscape diversity, landscape hotspot, geographic information system, Slovenia, Europe

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MASS MOVEMENTS ON THE FRUŠKA GORA MOUNTAIN (SERBIA) - INTRODUCING AN EXCELLENT NATURAL LABORATORY FOR SLOPE MOVEMENT MONITORING

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The Fruška Gora Mountain is a low (539 m), elongated inselberg measuring 80x15 km in northern Serbia. Its surface is mostly covered by quaternary sediments and dissected by more than 60 smaller stream systems. Mass movements are represented from the smallest, shallow soil creeps caused by local processes on smaller scale, the medium sized slope failures on the valley sides initiated by varying natural and anthropogenic factors to the very deep landslides occupying nearly the entire length of the mountain beside the Danube, which are influenced mostly by hydrogeological conditions. Such environmental richness and spatial heterogeneity in geological, geomorphogical, hydrological and hydrogeological terms on a relatively small area provide excellent opportunities for identifying the influence of specific factors of slope movements and calibration of models trough intensive monitoring. In absence of previous detailed studies covering the entire mountain, an initial research of landslide susceptibility was conducted. The geomorphological inventory of slope movements was compiled from available sources. Landslides were classified based on their size and relative topographic position, which in the case of Fruška Gora most often reflect also their genetic, morphological and dynamic properties. A preliminary landslide susceptibility model was created using the available digital elevation model (DEM of 15 m resolution), geology, wetness index, pedology and land use datasets. Additional morphological factors were derived from the DEM (slope, curvature, aspect, profile and plan curvature) and used in the model. The obtained result showed over 75% overall accuracy.

Key words:
mass movements, susceptibility, monitoring, Fruška Gora Mountain, Serbia

THE DEVELOPMENT OF A LAKE AFTER LANDSLIDES

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A good quality coal mine was opened near the village Arló for the metal works in the industrial north of Hungary in the early 19th century. Due to mining together with the use of explosives in Csahó Hill, a large amount of trees, rocks, sand and earth slid down on the wet clayey surface into the valley in the mid-19th century. The fall blocked the flow of the small Szuhony Stream by an earth dam of a few hundred metres. The mining continued, which led to repeated landslides in the first third of the 20th century. The relatively fast rising of the water level of the newly formed lake in the small drainage basin was also fed by several new springs that developed on and under the fresh hillside. By the 1930s, the lake was born in its present form on a land that was formerly ploughland and pasture cultivated by the poor village farmers. Before World War II, plans were made and actions taken to drain the lake, save the villagers from a possible dam burst and reclaim the agricultural land for the peasants. Later, the locals discovered that it would be worth retaining the water in Lake Arló and develop it into a touristic attraction.

Instead of being a degraded land, the lake today has a surface of 8.1 hectares (500–600 m long and 140–150 m wide), its average depth is three to four metres. By now the lake with its facilities place has become a popular destination with the fishers, holiday makers and geographers. The area is an attracting place, though it is situated perhaps in the poorest, economically most depressed, formerly booming heavy industrial region of Hungary, which has been badly affected by unemployment and social conflicts in the past twenty-five years.

For basic information on the lake in English, see http://arlo-onkormanyzat.wix.com/arlo#!curiosity/c1nj9.

Key words:
landslides, landslide dam, tourism, Lake Arló, Hungary

SPECTACULAR BADLAND ON RHYOLITE TUFF IN NORTH HUNGARY

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Landscape degradation often depends on the resistance or on the rigidity of the surface-constituent rock type. It is well known that certain rock types, for example rhyolite tuffs, incline to be eroded rather quickly. On surfaces consisting of rhyolite tuffs typical linear erosion forms can easily evolve forming very spectacular degraded landscape similar to the famous North American badlands. The whitish strips, cliffs or bigger patches of the rhyolite tuffs can be seen in several places in Hungary, in lower hills and low lying mountains. Their series represents three different volcanic periods during the Oligocene–Miocene epochs. Among them the most frequent and thickest tuff amount is the Gyulakeszi Rhyolite Tuff Formation dated from the beginning of the Ottnagien Age (about 20 MA).
These tuffs are mainly ignimbrites, partly well-cemented, partly loose. If the covering vegetation becomes damaged, than the barren surface consisting of loose rhyolite tuff is an optimal spot for erosion processes, especially for gully development. Mostly during heavy rain, the process of the surface degradation is rapid and within a short time a series of deep gullies are developing. In North Hungary, close to village Kazár, the erosion forms of the biggest rhyolite tuff-outcrop represent such a spectacular badlands-like surface. Both there and on other outcrops of the formation peculiar erosion processes can be studied like exfoliation of the thin crust, piping, emergence of candle-like columns and earth pyramids etc.
Although these degraded landscapes look like cicatrices on the surface, their geological and geomorphic interest is the reason for pronouncing them to be protected. Therefore, the rhyolite tuff outcrop (the badlands) at Kazár has been declared a nature conservation area.

Key words:
rhyolite tuff, badland, erosional forms, gully development, earth pyramid, Hungary

ASSESSMENT OF CO-SEISMIC SLOPE PROCESSES IN SLOVENIA

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Earthquakes are relatively frequent in western Slovenia. Therefore, earthquake induced landslide and rockfall hazard is present in the area. Such co-seismic events may deliver large quantities of sediments to valley bottoms and alpine rivers, and often build landslide dams.
The main characteristics of earthquakes in the area, and the main characteristic of possible co-seismic slope processes will be presented. The analysis was done using the probability of triggering of co-seismic landslides and rockfalls by the Newmark's method. The method consists of landslide risk evaluation using stability factor and critical acceleration, while rockfall risk was assessed using an empirical equation. Locations of known landslides and co-seismic slope processes in the Soča Valley (Posočje) in 1988 and 2004 were used to determine the hazard.

Key words:
natural hazards, earthquakes, landslides, rockfalls, Newmark's method, Slovenia

Reference:

Komac, B. 2015: Modeliranje obpotresnih pobočnih procesov v Sloveniji (Co-seismic slope processes in Slovenia). Geografski vestnik 87-1, pp. 117–133.

INVOLVEMENT OF THE GEOLOGICAL SURVEY OF SLOVENIA IN THE FIELD OF NATURAL HAZARD RISK MANAGEMENT

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In recent years, Geological Survey of Slovenia (GeoZS) has been involved in several projects, financed from different programmes under European Commission, aiming to natural hazard risk management e.g. ClimChAlp, AdaptAlp, Start_it_Up, SafeLand and I2GPS in the past and ongoing Recall. In the frame of national projects (Debris-flow risk assessment, GH-14, MASPREM) methodology for assessing geologically induced hazards has been developed for the national and local level.
The project ClimChAlp applied PSInSAR methodology in Slovenian territory where the main focus was investigated (in)stability of Bovec basin and its surroundings. Oštir in Komac (2007) compared the use of methodology of PSInSAR and DSInSAR to observe the movements of the displacement rates in north-western part of Slovenia. Continued by the project AdaptAlp, PSInSAR data were obtained for the Škofjeloško-Cerkljansko area frequently exposed to landslide occurrences due to geological structure and diverse morphology. Impacts of climate change on slope mass movements' occurrences were examined through displacement rates of PS points and rainfall patterns (Žibret et al. 2012). The Start-it-up project was designed as capitalization project dedicated to the development of common "state-of-the-art" or "best-practice" in the field of Natural Hazard Risk Management (NHRM) and Risk Governance (RG). "Living with landslide risk in Europe" was the goal of FP7 project SafeLand, where different approaches to risk management and innovative approaches to risk mapping on European level were studied. In the frame of I2GPS project a novel device was developed, consisted of a Compact Active Transponder (CAT) and a Global Navigation Satellite System (GNSS) antenna and integrated two technologies InSAR and global navigation satellite system (GNSS). These units provided 3D displacement assessments of the monitored locations on the landslide and its vicinity. RECALL – Resilient European Communities Against Local Landslides, is a running project to design and implement smart, community based solutions supporting local authorities in better planning and implementing landslides and disaster prevention measures in their territories.
So far, in Slovenia, landslide and debris flows susceptibility map, both in the scale of 1:250,000 (Komac 2005, 2009) have been developed. Methodology can be also adopted and used for accurate assessments at the local level and in different environments. A similar study is still needed for rock-falls.
The Landslide susceptibility map for Slovenia was elaborated by the Geological Survey of Slovenia at national level 1:250,000 (Komac and Ribičič 2005) in 2005. Due to coarser scale the susceptibility map cannot be used for spatial planning at municipality level and has "only" informative role. In 2012, Ministry of agriculture and

environment of the Republic Slovenia financed a national project, called GH-14, where susceptibility assessment for landslides, rock-falls, debris flows, erosion, and avalanches in the scale of 1:25,000 was prepared directly for local municipal spatial planning (Bavec et al. 2012). Thus, the main results of project were susceptibility maps for 14 municipalities, web application and spatial database of existing phenomena of mass movements.
According to the above mentioned projects a special emphasis was given to the spatial database of slope mass movements, mainly because uniform and central gathering of triggered events in Slovenia is still inadequate. Therefore Administration for civil protection and disaster relief, Ministry of Defence, has established the working group to prepare the procedure for actions taken when landslides are triggered. Within this group a common inventory form and web application to collect event data and to assure higher quality of collection was developed.
In Slovenia, intense short and long duration rainfalls are induced numerous shallow landslides in the past two decades. To develop a landslide forecast system that will inform responsible authorities and warn inhabitants of an increased landslide hazard as a consequence of heavy precipitation a national project MASPREM has been set up financed by the Ministry of Defence of the Republic Slovenia (Komac et al. 2014). Calculation of landslide forecast predicts of an increased probability of a certain date can be access through a Web GIS interface and WMS/WFS services. At the same time the warning is send also via e-mail. Existing landslide prediction system is intended to be upgraded to facilitate specific needs for the infrastructure protection policies and approaches.

Key words:
natural hazards, risk management, EU projects, Geological Survey of Slovenia

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DEGRADATION OF HYDROLOGIC CONNECTIVITY ALONG LARGE RIVERS BY FLOODPLAIN EMBANKMENT

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Large lowland river valleys represent some of Earth's most distinctive facets of geodiversity, which support high levels of biodiversity. The size and characteristics of large river floodplains are scale-dependent, being intricately related to their upstream drainage basin controls, such as the headwater runoff and geology. Hydrologic connectivity is a fundamental natural process associated with large river floodplains, and is vital to the environmental integrity of floodplain ecosystems. Unfortunately, flood control infrastructure, especially dike construction, have tremendously reduced the physical dimensions of “active” floodplains along large rivers. In this study we document the scale and extent of floodplain constriction by flood control infrastructure, specifically main-line dike systems, one of the most fundamental human responses to flood risk and the oldest forms of societal impacts to natural systems. While there is much discussion about the pros and cons of dike construction and the impact to floodplain environments there is no systematic inventory which documents the magnitude and intensity of floodplain embankment to large lowland rivers.

We develop an inventory of large rivers, primarily those within the northern hemisphere of the United States, Europe and Asia. Data sources includes the U.S. National Levee Database, SRTM DEM, recently obtained high resolution satellite imagery, various national topographic map series, and hydrologic data from the published literature. These data are integrated into a GIS framework to facilitate the measurement and characterisation of floodplain embankment. Spatial indices of floodplain embankment are constructed, including the intensity of embankment and how it relates to the natural floodplain and constriction of flooding. The results document that the majority of large lowland rivers in the northern hemisphere have had their active floodplain reduced by more than half. Floodplain constriction ranges greatly, however, both spatially along a river and also between rivers. The lowermost reaches of large rivers have been reduced the greatest, with indices of floodplain constriction ranging from 60% to 90%. New “room for the river” approaches to flood and floodplain management need to be differentially considered depending on the degree of floodplain constriction.

Key words:
large floodplains, embankment, dikes, levees, hydrologic connectivity

THE REVIVAL OF COPPICING IN SARDINIA (ITALY): DOES SOIL MATTER?

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The growing demand for energy and raw materials, together with climate change and globalization, are predicted to result in increased demand for forest resources in the European countries. The European Union has set an ambitious target to achieve 20 % of energy sourced from renewables by 2020, and biomass is considered among the sources of renewable energy. In this context, the Forest Service of Sardinia (Italy) has recently approved two pilot projects to bring back into use cutting methods in 305 ha of the public forest of Marganai (south Sardinia), over a period of 12 years, and in 375 ha of the public forest of Is Cannoneris (south Sardinia), over a period of 10 years.
This study aimed to assess the short-term impact on soil of the coppice-with-standards (CWS) management applied in a Mediterranean holm oak forest, as a contribution to address appropriate recommendations to minimize possible negative effects of the silvicultural practices. For this purpose, soil surface features and topsoil properties were investigated in two representative areas located in the public forest of Marganai and coppiced in the periods November 2012 - March 2013 and November 2011 - March 2012, respectively. The study was conducted through a free survey and a survey by transects, with control plots, combining observations and measurements in the field with laboratory data.
Regardless of differences in soils and slope gradient, the same CWS management, in terms of final density of trees standing after the clear-cut and accumulation of brushwood in strips along the maximum slope gradient, was applied in both areas. Field observations and laboratory data highlighted the disturbances caused to the soil by the silvicultural practices in the CWS stands when compared with the undisturbed stands. Statistically, these differences are significant on a 0.05% level. These disturbances were mainly concerning the almost complete removal of organic horizons, with consequent negative impact on organic carbon content, and the activation of erosion processes, mostly related to rainsplash erosion. Although soil mobilization locally largely exceeded the tolerable erosion rates, the absence of extreme rainfall events after the coppicing did not produce critical situations at catchment level. Nevertheless, in large parts of the CWS stands the observed density of vegetation cover does not provide a satisfactory protection against the kinetic energy of raindrops and, consequently, the potential soil erosion risk is still very high.
As sustainable forest management should preferentially consider soil and promote its conservation, there is the necessity to adapt the CWS management to local soil, slope, and climatic conditions and to adopt post-harvesting conservation procedures to minimize the negative effects of the silvicultural practices. In this regard, the

adjustment of the final density of trees standing after the clear-cut in relation to soil properties, slope gradient, and the possibility of extreme rainfall events, a different brushwood management, and the restriction to the passage of wild animals have to be considered to minimise the negative impacts on soils.

Key words:
coppice-with-standards (CWS), Mediterranean holm oak forests, soil, organic horizons, soil erosion, Italy

DEGRADED KARST RELIEF: WASTE-FILLED DOLINES

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Dolines are a typical karst landform, and for centuries they been the sites of various traditional activities, such as arable farming, gardening, pasturing, and water supply. In Slovenian karst regions, the features that reflect the effort and ingenuity of past generations (traditional cultivated dolines) are disappearing. Despite their manifest usefulness, many dolines are completely filled today with various kinds of unknown waste material. In only a few decades after the Second World War, dumpsites in dolines became an anthropogenic element of landscape degradation that cannot be overlooked. The environmental impacts are conditioned by the physical and geographic characteristics of the doline and by the type of material used for fill. Filling dolines not only increases the danger of biochemically burdening the environment, but also permanently transforms aboveground landscape elements, such as surface morphology (i.e., relief), soil, and vegetation. Filled dolines are not dolines anymore; they are visually unrecognizable as typical karst landforms. Filling dolines with waste building materials arose in parallel with recent in-migration (suburbanization), demand for new and renovated homes, and commercial and industrial areas in growing settlements in karst regions. Filled dolines are mostly unrecognizable in the recent landscape because the area is level with the surrounding surface and overgrown with vegetation. Their locations are unknown to the general public and to spatial planners, to spatial development decision-makers, and, unfortunately, to companies that supply drinking water. We used historical sources and geophysical methods to determine the extent of their degradation. In addition to aboveground environmental impacts, waste-filled dolines also have subsurface environmental impacts. Not being able to determine the amount and type of waste is an unpredictable problem in karst hydrology and water supply.

Key words:
karst, doline, land degradation, waste disposal sites, Slovenia

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HUMAN IMPACT ON GEOMORPHIC PROCESSES IN THE MIDDLE EAST SINCE THE PALEOLITHIC PERIOD: THE ISRAEL CASE

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The Mediterranean-type climate region is an inherently unstable earth-surface system.
Human impact is a major factor in land degradation in the Mediterranean region. It starts with the appearance of Man in Israel about 1.5 million years ago, but the major effects on landscape modification occurred in historic times. Seven phases of land degradation are recognized, since the first one covering the Paleolithic period until the present one, covering the last three decades, when the degradation processes aggravated. Land degradation processes like wild fires and urbanization, increases the seasonality of flow stream, with higher runoff rates in the winter floods and less percolation into groundwater, decreasing springs discharge and lowering exploitable aquifers. The increased variability causes more flood damage and erosion, making water management a more complex and expensive task. Water recycling for irrigation increased soil salinization, as salt flushing by the natural river system was impeded. Forest fires have increased, and on average 5% of the forests in Israel are burnt each year. Urbanization changes the surface to an impervious one, increasing the runoff/rainfall ratio from 1-2% under natural conditions to more than 50%. The coastal area of Israel is a narrow and fragile strip, with an enormous human pressure for intense exploitation.
Human interference in the Mediterranean environment exacerbates the negative natural biophysical processes, and the results are more frequent and more severe geomorphic events, as floods, landslides and soil erosion.

Key words:
Mediterranean-type climate, erosion, water degradation, forest fires, urbanization, Israel

BLOWING SAND AS A RESULT OF PAST AND CONTEMPORARY DEFORESTATION: A STUDY OF THE SILESIAN-CRACOW UPLAND IN POLAND

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The Silesian-Cracow Upland, due to its exceptionally plentiful reserves of various natural resources, has been under intense human activity for nearly a thousand years. The economic development of the region began in the Middle Ages with the mining and smelting of iron, silver and lead ores, and, from the eighteenth to the twentieth centuries, it resulted from the intensive extraction of coal, zinc and lead ores, stowing sands, dolomite and limestone. Mining activities have almost always been associated with deforestation and exposition of sandy sediments of various genesis. Forests have been cut down both for access to mineral resources, as well as other reasons, primarily due to bullion metallurgy, as well as to increase the acreage of agricultural land, the construction of drainage galleries, casing of workings in underground mines, or for building purposes. The sandy substrate, devoid of vegetation, was subjected to aeolian processes because in the Silesian-Cracow Upland blowing sand has been the remnant of the various forms of human activity. In this paper, based on the analysis of archival and contemporary cartographic materials, as well as historical and archaeological studies and field geomorphological research, spatial distribution of blowing sand was determined, its origin, the time of creation and durability in the landscape of the region. An attempt was also made to describe and evaluate the implications of blowing sand in the landscape of the natural and socio-economic point of view. Research shows that in many areas of the Silesian-Cracow Upland, "anthropogenic" blowing sand appeared in the Middle Ages - in the thirteenth to fourteenth century, and its "desert" character persisted for 200-300 years, and sometimes even 400-500 years. They constituted a distinctive element of the landscape and were the cause of numerous inconveniences to local communities (backfilling of fields, pastures and roads, destruction of crops). In the second half of the twentieth century, most of the former areas with blowing sand were forested, but their distinctive, slightly undulating relief was preserved. One of the oldest areas with blowing sand in the region, the Błędów Desert, is protected by law and is now a tourist attraction due to the local occurrence of conditions for aeolian processes. In the twentieth century, blowing sand occurred in the vast Szczakowa sandpit in the eastern part of the Silesian Upland. After the cessation of stowing sand excavation, the bottom of the pit was levelled and artificial planting of trees was introduced. As a result of such reclamation, the former aeolian relief was levelled and the excavation has retained its artificial technogenic character.

Key words:
human impact, mining, deforestation, aeolian processes, blowing sand, Poland

MAKING THE PERIPHERAL "REGION" INDIA – FROM A CASE OF NAGARAHOLE NATIONAL PARK, KARNATAKA, INDIA

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The history of deforestation in India is long. After the 19th century in particular, the felling of high quality timbers to depend on the British colonial policy brought serious influence in quality of the Indian forest. After the Partition of India in 1947, the forest cover ratio has sequentially decreased from a demand of industrialization and a request of the social welfare policy. In response to a surge of the international interest in global environment that began in the 1970s, even in India, positive initiatives such as "Social Forest" policy in 1980s and "Joint Forest Management (JFM)", one of kinds of Community-Based Forest Management (CBFM), in 1990s, have been promoted. However, although there are studies about the "initiatives" itself, but it has not examined how these would run the connection with "the fact" of deforestation, and in future how and who take care of the forest which still existed wile deforesting. If in the future, CBFM hope to become a global mainstream, the actual condition of the region around "forest" must be considered. We have been promoting two international project, namely Forest Management as Regional Governance (FMaRG) and Regional Governance of Forest and its Fringe (ReGFF). In this presentation, I would like to introduce the theoretical results from both projects.

Key words:
forest management, forest, regional governance, India

COMLAND 2014 FIELD TRIP IN TASMANIA - A REVIEW

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A COMLAND Meeting and field trip was held in Tasmania (Australia) during October 2014. This was in association with the Annual Conference of the Environment Institute of Australian and New Zealand. The 5 day field trip showed the 13 attendees a variety of landscapes, land uses and environmental issues. These included forest management south of Hobart, grazing and land management in the central highlands, current and legacy mining issues in Queenstown as well as remote south west World Heritage landscapes and aquaculture. Professional and technical staff from Forestry Tasmania, the University of Tasmania, Copper Mines of Tasmania, EPA Tasmania, Wilderness Woodworks, NRM South and Redlands Estate generously gave their time and enthusiasm to critically show and discuss their research and activities. The EIANZ's hospitality and support was gratefully received.

Key words:
COMLAND, land management, Tasmania, Australia

FIELD GUIDE

NATURAL AND HUMAN INDUCED LAND DEGRADATION IN WESTERN SLOVENIA

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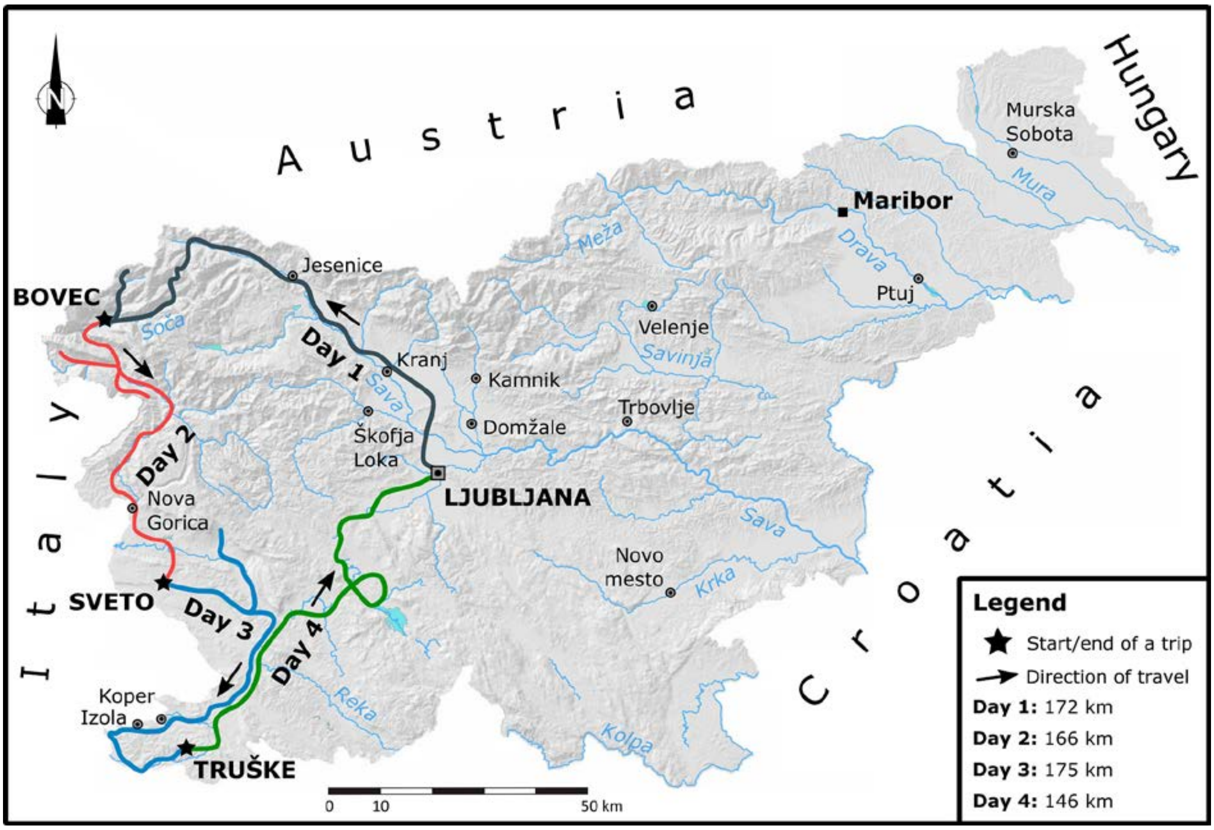
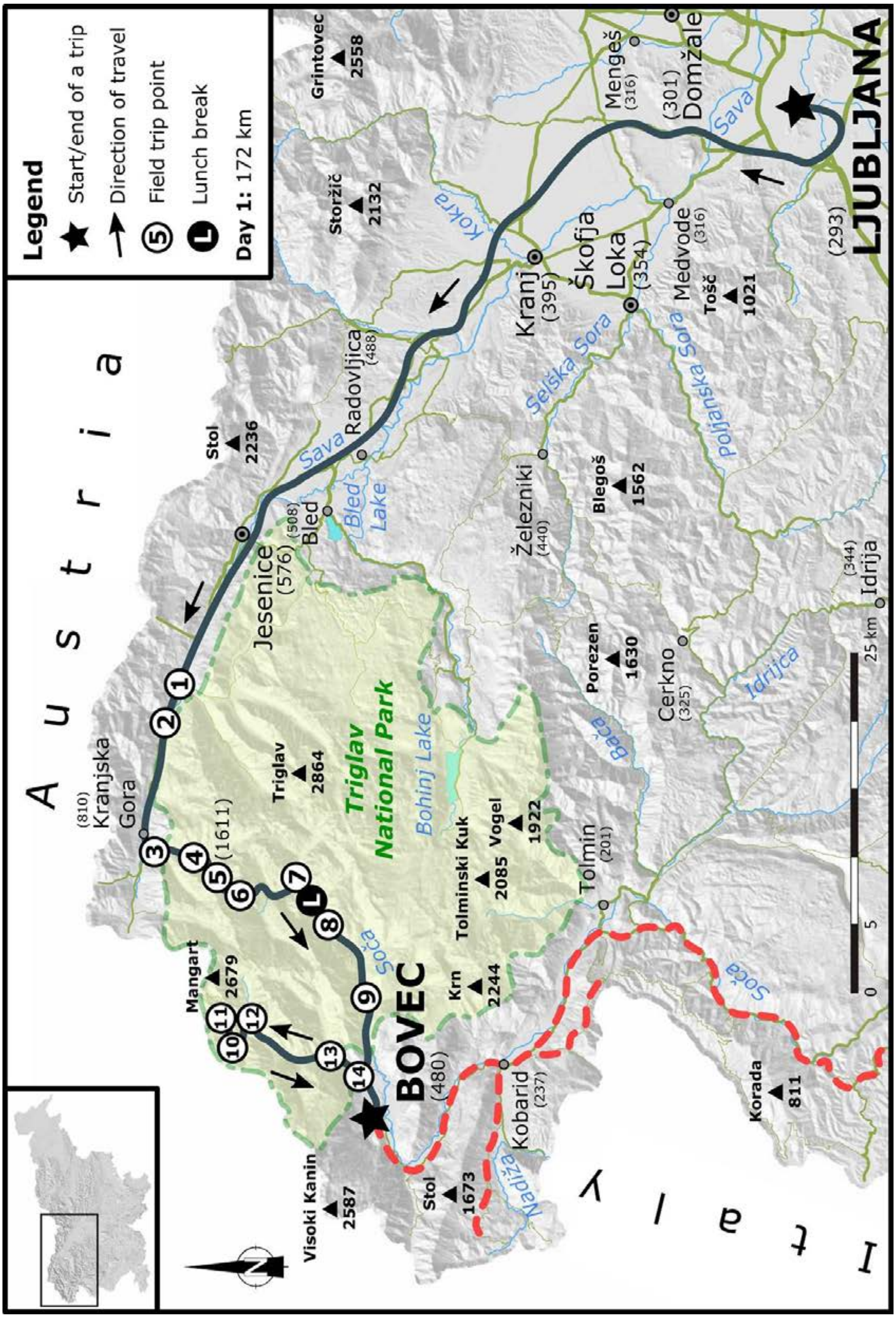


Figure 1: Route of the excursion.

Introduction

The excursion will take place in western Slovenia and will take us thru three Slovenian natural geographical units: the **Alps** (day 1 and 2), the **Mediterranean** (day 2 and 3) and the **Dinaric Mountains** (day 4). In the Alps we will on the first day focus on slope processes, e.g. avalanche risk on Vršic mountain road, rockfall risk and the debris flow in the village Log pod Mangartom. The next day we will remember the 100th anniversary of the WW1 Soča/Isonzo front as part of the Alpine front that took place in the Julian Alps. On day two we will also remember the 1976 Friuli earthquakes and look at the landslide risk in the flysch Goriška Brda Hills. On day three of the excursion we will focus on geomorphic processes in flysch – landslides and wind erosion in the Vipava Valley and coastal cliff retreat. On the last day of the excursion we will get to know “classical” karst features and talk about the vulnerability of karst landscape.

June 24th (Friday)
Topic: **Alpine landscape dynamics**
Location: **Julian Alps (NW Slovenia)**



Stop 1: General overview of the Julian Alps.

The Julian Alps (Slovene *Julijske Alpe*, Italian *Alpi Giulie*) are a mountain range of the Southern Limestone Alps that stretch from north-eastern Italy to Slovenia, where they rise to 2,864 m at Mount Triglav, the highest peak in Slovenia. They are built predominantly of Mesozoic marine sediments. A large part of the Julian Alps is included in the **Triglav National Park**. The Julian Alps cover an estimated 4,400 km² (of which 1,542 km² lies in Italy). They are divided into the Eastern and Western Julian Alps by the Soča River.

Stop 2: Belca Creek – debris flow risk in the Karavanke Mountains

North of the Julian Alps are **Karavanke Mountains** the border mountain range between Slovenia and Austria. The Karavanke are lower than the Julian Alps, but are lithologically more heterogeneous. Both mountains are divided by the Upper Sava River valley. Karavanke Mountains have relatively short water courses that in the Upper Sava River valley formed alluvial fans, some of which are today populated and at risk due to flash-floods and debris flows. Sodnik and Mikoš (2006) modelled magnitudes of rainfall-induced debris flows in 18 torrents in the **Upper Sava River valley**. The debris-flow magnitudes were of the order between 6,500 m^3 and 340,000 m^3, e.g. for Belca Creek with a catchment area of 17.6 km^2 and average slope of 65% debris flows were estimated to be 80,000–150,000 m^3.
The **Belca Creek** is an example of human influence on the hydro-geomorphic processes. In the early 20th century as a result of deforestation many badlands occurred. Sediment yield in this time was estimated to be from 20,000 to 50,000 m^3/year. Between 1945 and 1952, the material twice buried Jesenice-Kranjska Gora road. In 1951 the eroded material caused in a train accident, and in 1966 caused the collapse of the bridge of the Jesenice-Kranjska Gora road (Komac, Zorn and Pavšek 2010).

Stop 3: Lake Jasna – sediment supply from the Julian Alps (Velika Pišnica Creek)

The **Velika Pišnica Creek** is a typical Alpine torrent with a watershed area of 37.9 km^2, mainly in Triassic limestones and dolomites, with mean annual discharge of 2 m^3/s (Q_{100} = 128 m^3/s). The average slope of the creek is 67% and the total channel length is 9.2 km (Sodnik and Mikoš 2006).
According to older data the Torrent Velika Pišnica brings yearly around 10.000 m^3 of gravel sediments into the Upper Sava River, and so saturating it for kilometres downstream of the confluence (Mikoš 1998). This a considerable amount considering that app. 25 km downstream at the barrier for accumulation lake Moste the sediment

accumulation was measured to be up to 55,000 m^3/year in the years 1985–1995 (Mikoš 2000).
According to new (modelled) data the annual sediment yield is app. 69,000 m^3 (from 430 to 3,300 m^3/km^2) and estimated debris-flow magnitudes are determined to be from app. 16,000, up to 125,000 m^3 (Sodnik and Mikoš 2006).

Stop 4: Vršič mountain road (Russian chapel) – avalanche casualties

The **Russian Orthodox chapel** is located on the "Russian Road" on the northern side of the Vršič Pass. The chapel, dedicated to Saint Vladimir, was built by Russian prisoners of war (POWs) engaged in forced labour in the area during WW1. More than 10,000 Russians – far more than the combined population of the nearby villages and towns – worked on the road.
To ensure an uninterrupted supply of materiel to the front lines, the **Vršič Pass** was to be kept traversable year-round, and the POWs were made to clear the road of heavy snowfall. On 8 or 12 March 1916 (sources vary), an avalanche buried a POW work camp, killing approximately 110 prisoners and about 7 guards. During the time of the construction there were more than 380 casualties in total. Exact casualty figures were never determined, either for the victims of the avalanche of for those of the brutal overwork and appalling conditions.
The Russian camp was located roughly halfway up the slope of Vršic Pass. Until November 1916, the remaining prisoners built a small wooden memorial chapel. The building is of typical Russian design, with two small towers on either side of the nave, and is surrounded by prisoners' graves and a pyramid-shaped memorial marker to the immediate right of the chapel, with the Cyrillic inscription reading "*To the sons of Russia*" (Internet 1, 5).

Stops 5 and 6: Vršič mountain road (Erjavčeva mountain hut and Vršič Pass, 1,611 m) – avalanche and erosion risk

The **Vršič Pass** with an elevation of 1,611 m is a high mountain pass across the Julian Alps in north-western Slovenia. It is the highest pass in Slovenia, as well as the highest in the Eastern Julian Alps. The road across the pass, known as the Russian Road (*Ruska cesta*), was built for military purposes, to supply the Soča/Isonzo front of WW1. It was built by Russian prisoners of war. The construction began in May 1915, and was completed by the end of the year.
After WW1, from 1918 to WW2, the Vršič Pass was on the border between Italy and Yugoslavia. The Vršič Pass is considered an excellent starting point for excursions to surrounding peaks (Internet 1, 2).
The road over the Vršič Pass is the only one in Slovenia, which could be described as a real high mountain road and thus endangered by many natural hazards. It is very

important physical and social connection between Sava Dolinka and Soča valleys. Every year, due to high snow cover, snow drifts and many avalanches, the road is closed up to sometimes nearly half a year. But this is not the case within the last two decades, after having a lot of "green" winters, which enables the prolongation of its transportability. Yet we still have to deal with some periodical heavy snow events, which open each year's question about its permanent opening. From the first and the biggest avalanche accident on this road (as well as in and in Slovenia) during the WW1, the road's opening timetable is often a subject of a political question. In 2007 a draft project plan of paravalanche structures was made for the road section on the north side of the pass in order to maintain the road's permanent transportability. Its presentation to the public was under an expert and political debate, ending with the new, additional suggestion by making a tunnel under the pass (Pavšek 2008).
The Vršič Pass has a specific geologic structure because of the contact of the Middle Triassic dolomite and the Upper Triassic Dachstein limestone. Due to tectonic discontinuities dolomite is strongly fragmentised, which contributes to the occurrence of **badlands**. The rate of erosion is quite high, as we saw on stop 3. The intensity of erosion processes would be even higher if no man-made obstacles, e.g. torrent barriers were built (Kunaver 1990).

Stop 7: Triglav National Park Information Centre Trenta Lodge in the Trenta Valley

The **Triglav National Park** (*Triglavski narodni park*, TNP) is the only Slovenian national park. The park was named after Triglav, the highest mountain in the heart of the park, which is also the highest summit in Slovenia (2864 m). The origin of the name Triglav is rather uncertain. Triglav (»three-headed«) owes its name to its characteristic shape as seen from the south-east side or to the highest Slavic deity who was supposed to have its throne on the top of the mountain. The mountain is a true national symbol and is featured on the national coat of arms and the flag.
The Triglav National Park extends along the Italian border and close to the Austrian border in the north-west of Slovenia, that is, in the south-eastern section of the Alps. Its territory is nearly identical with that occupied by the Eastern Julian Alps. The park covers 880 km^2, or 3% of the territory of Slovenia.
The Triglav National Park is among the earliest European parks; the first protection dates back to 1924 when the Alpine Conservation Park was founded. The principal task of the Triglav National Park Public Institution is the protection of the park, but it also carries out specialist and research tasks (Internet 3).

Stop 8: Trenta Valley – "twin" rockfalls

The best known rockfalls in the Upper Soča region are the **»twin« rockfalls** (*podora Dvojčka*) in the Lower Trenta Valley. Twin rockfalls often appear in narrow alpine

valleys with glacially reshaped hillslopes when rockfalls occur on opposite hillslopes. The first rockfall occurred above the Plajer homestead on the left bank of the Soča and was triggered between June 28 and 29, 1989, from the north-western hillslope of Mount Mala Tičarica (1,797 m). It originated on the site of an older rockfall. About 300,000 m^3 of material was triggered.
Opposite the first rockfall, Berebica rockfall above the Fačer homestead was triggered. Two rockfalls have occurred here in the last twenty years – on December 12, 1993, and July 27, 1998.
These rockfalls not only presented a threat to the homestead but also damaged the Bovec-Kranjska Gora regional road in both cases. The unstable hillslope threatened the road and drivers for almost ten years until a 280-meter long gallery was completed in May 2001 (Zorn 2002).

Stop 9: Trenta Valley – Great Gorge of the Soča River

Just above Lepena Valley Soča River has carved 750 meters long **gorge**. The gorge is completely narrow at some points and its depth depends a lot on the water level: in the dry period it is up to 15 m deep, but at floodings Soča can fill it up completely (Internet 6).

Stops 10 and 11: Stože landslide debris flow – source area

In November 2000, heavy rains in Slovenia triggered numerous slope processes in Slovenia. Among the largest were the **Stože landslide** and debris flow in Log pod Mangartom (Zorn and Komac 2008).
At 12:45 on November 15, 2000, a Stože landslide was triggered west of Mount Mangart (2,679 m) above the valley of the Mangartski Potok stream. Lying between the altitudes of 1,340 and 1,580 meters, the original site of the landslide material was 900 meters long and three to four hundred meters wide. The average thickness of the landslide in source area was ten meters, and it reached forty meters in places. In all, 1.5 million cubic meters of material was shifted and dammed the Mangartski Potok stream. Above the landslide, crown cracks appeared that extended to the watershed divide ridge (Zorn and Komac 2008).
For more than 35 hours, water soaked the landslide material deposited on the floor of the Mangartski Potok valley until it became liquefied on November 17, 2000. A few minutes after midnight, a debris flow was triggered that travelled almost three kilometres downwards to the village Log pod Mangartom (stop 12) at a speed approaching eight meters per second (Zorn and Komac 2008).
The primary cause of the landslide and the debris flow was heavy and intense precipitation. The rain gauge in the village of Log pod Mangartom recorded 1,638 mm

of rainfall (more than 60% of the average annual precipitation) in the 48 days before the events (Zorn and Komac 2008).

An important cause of this event is the geological structure, particularly the 100- to 200-meter thick layers of Julian-Tuval limestone, marlaceous limestone, marl, and schist claystone. These so called Tamar or Rabelj (Raibl) layers alternate in the 700-meter deep stratified, tectonically damaged, and porous Karnian and Norian dolomite. At their contact are springs that are an added significant cause of landslides. The tectonically damaged rock also makes the slopes unstable. The clay minerals of the Tamar layers absorb water and swell and the schist claystone decomposes into clay, which leads to sliding (Zorn and Komac 2008).

Stop 12: Stože landslide debris flow – sedimentation area in the village Log pod Mangartom

Log pod Mangartom (651 m; population about 130) is a nucleate roadside settlement located on the right bank of the Koritnica River on the alluvial fan of its tributary Predelica stream. On November 17, 2000, a debris flow struck the village.

Part of the debris flow material was deposited in the bed of the Predelica stream upstream of the village, and more than a million cubic meters was deposited over an area of 15 ha in the Koritnica Valley downstream. For almost three kilometres, the valley floor was covered with a layer of alluvium several meters thick. The Koritnica River carried off a great deal of sediment: above its confluence with the Koritnica, the Soča River near Kršovec contained only 104 g/m^3 of suspended material while at the confluence it contained 2,971 g/m^3. On November 21, 2000, the highest concentration ever recorded in the Soča, 8,112 g/m^3, was measured (Zorn and Komac 2008).

The debris flow in Log pod Mangartom claimed seven lives and demolished or damaged eighteen houses and eight outbuildings. Two bridges were destroyed on the Predel Pass road that links Bovec in Slovenia with Tarvisio in Italy. The damage amounted to 31 million euros. After the debris flow, the Parliament of the Republic of Slovenia passed a law on dealing with the consequences of larger landslides, and in 2003 adopted a location plan for managing the area of the debris flow. Barriers were constructed in the Predelica Valley, and fifteen replacement houses were built in Log pod Mangartom for residents whose property had been destroyed, as well as two new bridges (Zorn and Komac 2008).

Similar events have occurred along the nearby Ugovizza stream (end of August 2003) in the Val Canale valley in Italy where already sources from the end of the 18th century report debris flows. On the basis of historical data that stretches back to the 16th century, it has been determined that larger such events have a return period of twenty-five years and smaller ones form three to six years (Zorn and Komac 2008).

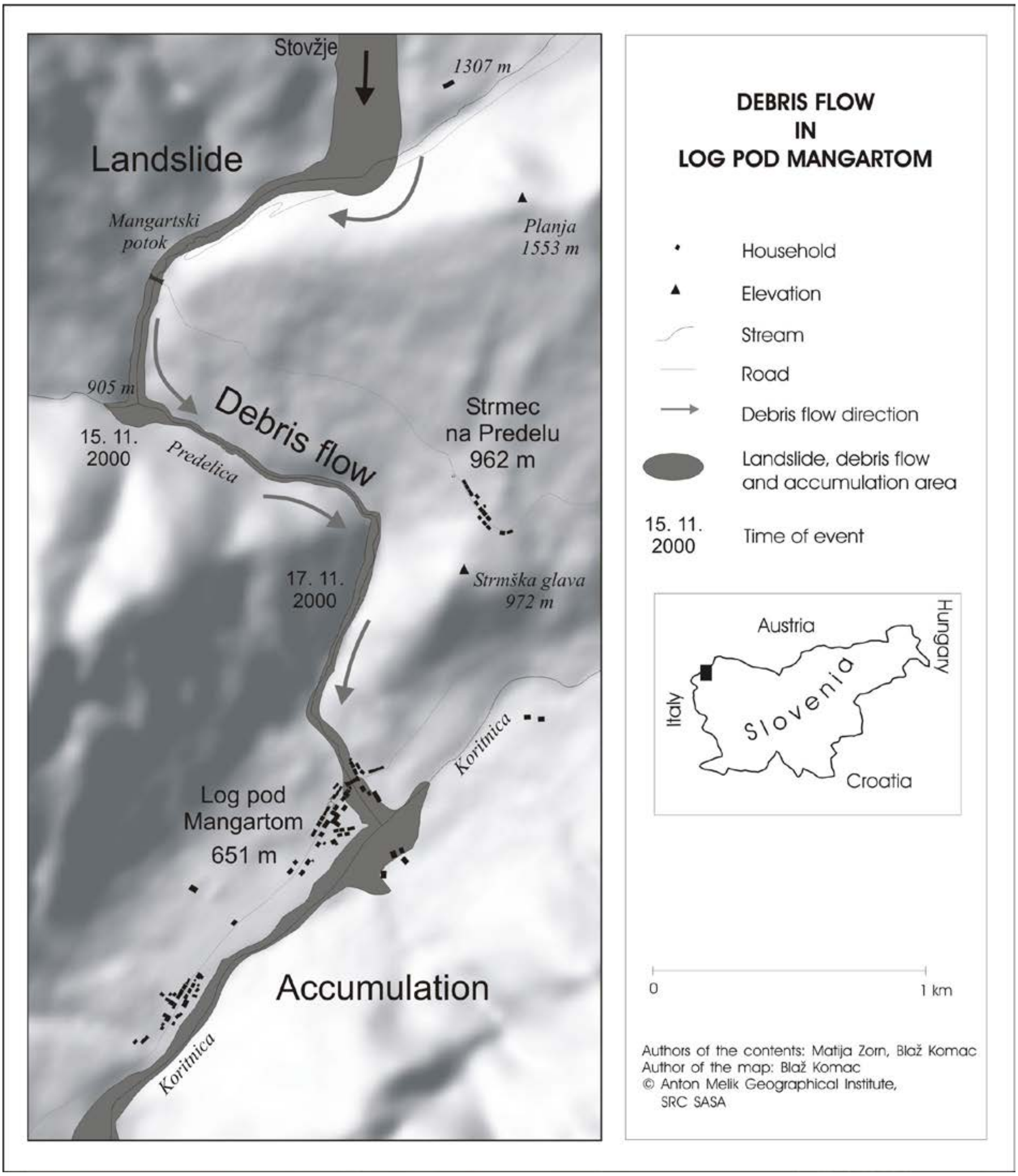


Figure 3: Map of the Log pod Mangartom landslide and debris flow (Zorn and Komac 2008).

Stop 13: Kluže fortress and gorge of Koritnica River

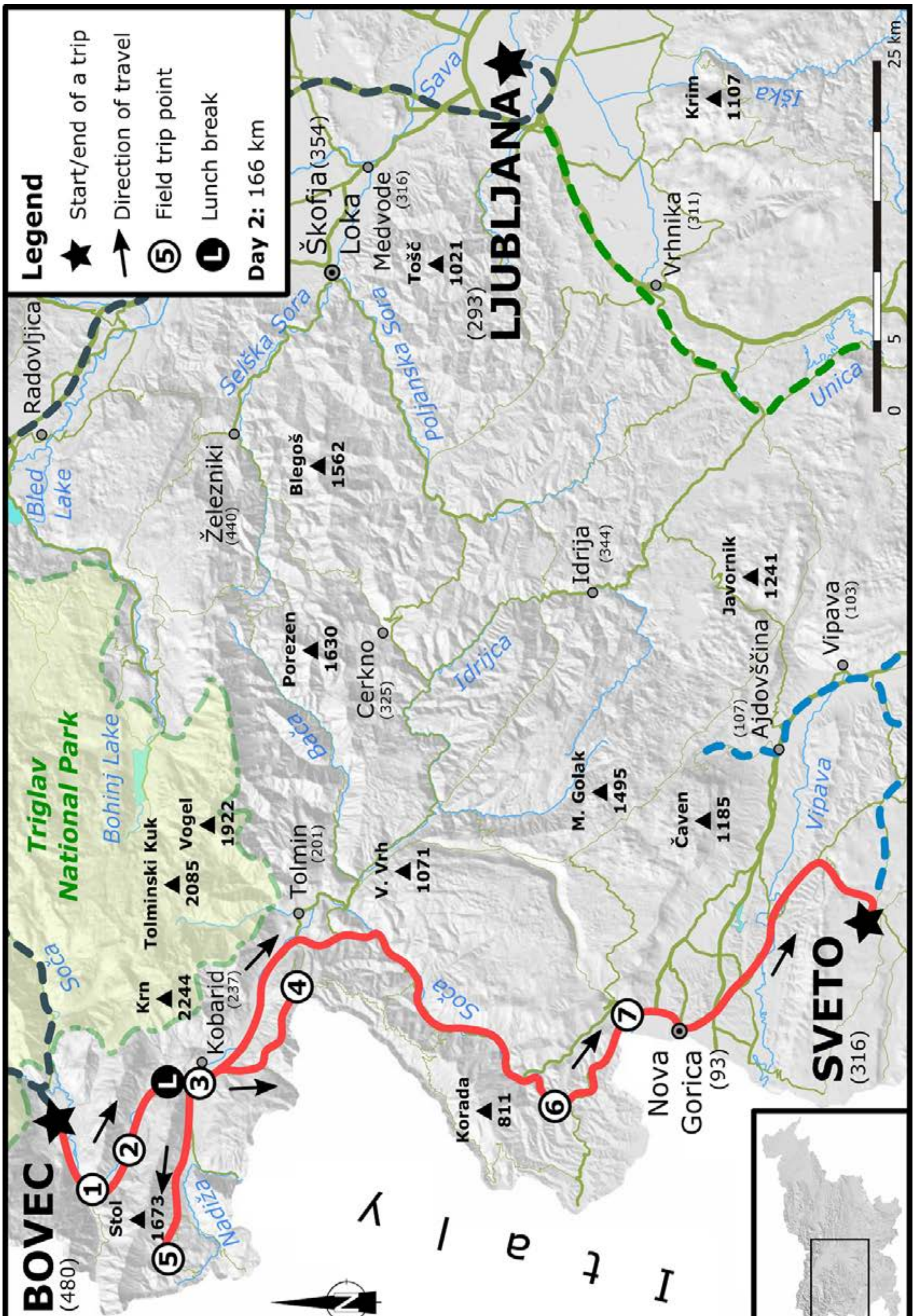
The **Kluže Fortress** stands at the top of a narrow **gorge**. It was erected as a control post at the crossing of the river. The time of origin of the older fortress at this site is not known, but a wooden building stood there already in the second half of the 15th century to defend the Friuli and the Venetian Republic against the Turks.

In 1797 the Napoleon French army burnt down and destroyed the medieval fortress. The new, present fortress was built on the same pass over the river in the years 1881–1882 (Internet 7).
At the Kluže fortress the kilometre-long Koritnica canyon narrows into a gorge that is just a few metres wide, 70 m deep and some 200 m long (Internet 8).

Stop 14: WW1 outdoor museum in Ravelnik

In the close vicinity of Bovec, on a minor hill **Ravelnik**, there is an outdoor WW1 museum. An arranged circular path runs along the onetime Austro-Hungarian first line of defence. In addition to trenches and connection tunnels there are also caves, pillboxes, machine-gun emplacements and restored cabins. There are a lot of remains here in a relatively small area (Internet 4).

June 25th (Saturday)
Topic: **World War I: Impacts on the landscape, 1976 Friuli earthquakes**
Location: **Julian Alps (NW, W Slovenia)**



Stop 1: Boka waterfall and Mount Kanin

The **Boka waterfall** is the highest waterfall in Slovenia and one of the most fluid. The waterfall falls freely 106 m and immediately after that has another 30 m in an incline.
High-mountain karst is characteristic of the **Mount Kanin**, an oblong mountain range reaching 2,587 m high in the western Julian Alps and covering almost 58 km^2. The geological structure of the Kanin massif causes springs to occur on its flanks, mainly in the Bovec Basin (e.g., Boka spring/waterfall). Only a few periodic springs are located higher on the slopes of the mountains. Water is forced to the surface due to the piezometric level in the Quaternary sediments or by impermeable rock layers. The water from several smaller karst springs is collected to supply potable water to the Bovec Basin settlements (Komac 2001).
More than eight hundred karst **caves and shafts** have already been discovered in the Mount Kanin, of which five are more than 1000 m deep. The deepest cave is Čehi II (1,502 m), and the world's longest vertical section (643 m) in a cave was discovered in 1996 in the Vrtiglavica cave (Internet 9; Komac 2001).
An estimated average of 5.5 m^3/s of water flows from the Kanin massif under normal water conditions. The Soča River receives the greater part of its discharge (4.76 m^3/s). Only a small amount of water (0.76 m^3/s) flows to springs in Italy, which has a much smaller catchment area of 8 km^2. The discharge ratio between Italian and Slovenian sides of the Mount Kanin is 1:5.5 and the catchment area ratio is 1:6.25. Radinja (1978) estimates that52 % of the inflow to the Soča River comes from underground sources (Komac 2001).
The **Boka spring** has an average discharge of 0.2 m^3/s with a maximum flow that may reach as high as 50 m^3/s during periods of heavy precipitation (the exact flow has not yet been measured) but may also dry up completely (Komac 2001).

Stop 2: Polovnik rockfall

Lower down the Soča Valley is the **Kuntri** (also known as Gorenji hrib or Hrib) elevation (530 m) between Srpenica and Trnovo ob Soči. It is the largest known rockfall in the Slovene Alps, although authors are divided regarding the origin of the accumulated material. Among older authors, Winkler (1926) favoured the rockfall origin of the Kuntri elevation and dated the rockfall to the period after the end of glaciation. Some later authors are of a similar opinion. On the other hand, the geology of the elevation was also mapped as non-agglutinated moraine or as a mixture of moraine and the rockfall material (Zorn 2002). According to some authors (e. g., Grimšičar 1988), the **Srpenica Lake**, which supposedly stretched into the Bovec Basin, was a consequence of a rockfall in the late Quaternary. Layers of lake chalk more than two hundred meters thick prove the lake's existence (Kuščer et al. 1974).

In the opinion of other authors, the Kuntri rockfall fell onto previously deposited lake chalk and did not cause the formation of Srpenica Lake (Bavec 2001). In either case, an accumulation of such size had to cause the damming of the Soča River.
The rockfall was probably triggered at the end of the Pleistocene or at the beginning of the Holocene. According to some latest studies, the event could have occurred 12,790 ± 85 years ago (Marjanac et al. 2001).
The Kuntri elevation and its continuation on the left bank of the Soča measure over 200 million m^3 according to our calculations. Bavec (2001) estimates its volume at 50–100 million m^3. The greater part of the rockfall material originates in the southern hillslope of **Mount Polovnik** on which a concave wall formation is clearly visible from where the material was triggered in a single event or in several events (Zorn 2002).

Stop 3: Kobarid WW1Museum

The **Kobarid Museum** presents the WW1 on the Soča/Isonzo Front, focusing on the Twelfth Soča/Isonzo Battle, known as the Battle of Kobarid. The battle turned into one of the most violent encounters in the history of this mountainous region and, besides the Eleventh Soča/Isonzo Battle, it was the most ferocious armed engagement Slovenia had ever experienced. It was also the most successful breakthrough operation in the WW1 and one of the first cases of a battle incorporating *Blitzkrieg* strategic elements (Internet 10).
The Museum also presents the history of the Kobarid region from its early beginnings until today. In 1993, the Museum received the Council of Europe Museum Award recognising its contribution towards European cultural heritage.

Some **effects of warfare on the natural environment** have been studied in the area. Shallow regolith and sparse vegetation are characteristic for the predominantly karst area, so traces of explosions are less visible on limestone bedrock comparing to the bomb craters in the thick regolith of some other battlefields (e.g., the Verdun battlefield in the Western front). Throughout the Soča/Isonzo Front, the landscape has been changed in particular by removing vegetation by explosions and digging regolith (trenches) and soil on the slopes. On the Soča/Isonzo Front more than 1000 km^2 of agricultural land and forests were damaged or destroyed and also chemically contaminated. Impact of vegetation removal was only transient, since it mostly recovered in the following decades. The time of natural restoration in the region of the Upper Soča Valley depends on the altitude and the amount of organic matter in the affected surface. Judging on the basis of certain natural hazards in the last decade in the region, natural restoration took approximately five years in low-lying areas rich in humus and more than ten years in low-lying areas with a lack of humus. In high karst mountains, long-term natural restoration can take hundreds of years, as it takes part in the absence of biotic factors (Zorn and Komac 2009a).

Stop 4: Kobarid WW1 Museum - the Kolovrat ridge outdoor museum and slope processes on and around Mount Krn

Along the right bank of the Soča extends the **Kolovrat ridge** between Tolmin and Kobarid. During the WW1, the Italian Army built their system of the third line of defence there. Today, an **outdoor museum** is arranged at this place, situated on the so-called "1114 point". Restored were commanders' and observation posts, machine-gun and gun positions, caves and the network of trenches. During the sightseeing, panoramic views open over the Soča Valley, the Krn range, and the Friuli–Venezia Giulia region in Italy (Internet 11).

On the opposite side of the Soča Valley is **Mount Krn** with evident rockfall activity which is connected to the **1998 earthquake**. During the earthquake that struck the Upper Soča region on April 12, 1998, with a magnitude of 5.8 (intensity of VII to VIII degrees EMS), around one hundred **rockfalls** were triggered. During the earthquake, several million cubic meters of material was moved. The belt of greatest damage to nature runs from Bovec along the south-western ridges above the Lepena Valley across the Krn mountain range (south-western ridge of Mount Krn and Mount Krnčica) to the source of the Tolminka Creek and the Polog mountain pasture area above the town of Tolmin. The greatest amounts of material were triggered on the south-western wall of Mount Krn (2,244 m) and on Mount Osojnica above the Tolminka Valley. In both cases, app. one million cubic meters of material was triggered. Below the south-western wall of Mount Krn, rockfall material covered an area of about 15 ha (Zorn 2002). After the **2004 earthquake** (on July 12; M 4.9), 50 rather superficial slope failures including 38 rock falls with total volume of 28,000 m^3 were registered (Mikoš, Fazaric and Ribičič 2006).

Above the village of **Koseč** below Mount Krn a **rockslide** caused secondary geomorphic phenomena. In December 2001 the Koseč rockslide with estimated 95,000 m^3 was triggered above the village. It was initiated at the contact between high permeable calcareous rocks (Cretaceous scaglia) thrusted over nearly impermeable clastic rocks (Cretaceous flysch). Soon after the rockslide initiation, a rockfall with a volume of 45,000 m^3 was initiated within the rockslide. The kinetic push of the rockfall caused the movement of a translational soil landslide with a volume of 180,000 m^3 that partially slipped into the torrential ravine of the Brusnik Stream. After a sudden drop of 15 m in December 2001, the rockslide average velocity exponentially slowed down to less than 10 m/year till the end of 2002, and came to a practical still stand in 2003. After the rainfall in spring 2002, small debris flows made of clayey gravels with a volume of up to 1000 m^3 started to flow from the zone of accumulation of the rock fall over the soil landslide to and along the channel of the Brusnik Stream. In 2002, more than 20 debris flow events were registered. The statistical analysis of the measured local rainfall intensities showed that debris flows

were initiated at daily rainfall reaching from 20 to 30 mm, depending on the antecedent precipitation (Mikoš et al. 2006).
The total volume of actively falling, sliding and unstable masses of the Koseč landslide was estimated at 310,000 m^3 (95,000 m^3 of initial rockslide and 215,000 m^3 of two soil landslides) (Mikoš, Fazaric and Ribičič 2006).
In mountainous alpine river basins such as the Upper Soča River Valley, with an estimated average sediment production of 2234 t/km^2 per year, local earthquake- or rainfall-induced erosive events (e.g. Stože and Koseč landslides) may release sediment in excess of 200,000 t/km^2 per year (Mikoš, Fazaric and Ribičič 2006).

Stop 5: Village of Breginj – Fruli 1976 earthquakes

The wider area along the border between Friuli, Italy, and the Soča Valley, Slovenia, is known for earthquakes (e.g., with a magnitude exceeding 5.0: these include a M 5.3 earthquake in 1279, M 6.5 in 1348, M 7.0 to 7.2 in 1511, M 6.2 in 1690, M 5.6 in 1788, and M 5.4 in 1857). In recent decades there were three “bigger” earthquakes in this area (Pipan and Zorn 2013):
- The **1976 earthquakes** with M 6.4 (6 May) and M 6.1 (15 September), or an intensity between IX and X and between VIII and IX on the EMS Scale. The epicentre was in the Venzone area in Italy and earthquake claimed 939 lives, and 157,000 people lost their homes. There were no deaths in Slovenia, but 12,000 buildings were damaged and 13,000 people were left homeless.
- The **1998 earthquake** (12 April, the “Easter Earthquake”) with an epicentre in the Krn Mountains in Slovenia had a magnitude of 6 and an intensity between VII and VIII on the EMS-98 scale. Approximately 4000 structures 25 were damaged in Slovenia.
- The **2004 earthquake** (12 July) with a magnitude of 4.9 and an intensity between VI and VII on the EMS-98 scale. Again, its epicentre was in the Krn Mountains. Nearly 2000 structures were damaged in Slovenia among others also individual structures that had already been renovated after the 1998 earthquake.

The situation in the village of **Breginj** was complicated even before the earthquake. Despite the efforts made by the Municipality of Tolmin and the Cultural Monument Protection Institute to preserve the architectural heritage, the local community was divided. After the 1976 earthquakes, the authorities ordered that the residents had to be in new houses. An agreement was reached to preserve and renovate only a very small part of the old Breginj. However, due to the lack of funds, this renovation was not carried out until 2004 (Pipan and Zorn 2013).
In Slovenia, as in Italy, the responsibility for recovery after the 1976 earthquakes was assumed by the municipalities. The communal assemblies of the municipalities of Tolmin, Nova Gorica, and Idrija established an inter-municipal board that coordinated post-earthquake recovery across the entire Soča Valley. The Municipality of Tolmin was most affected; however, because it did not have a majority on the inter-

municipal board, its needs may have been overruled by the other two municipalities, which had not been as badly affected and were also more economically developed at the time. The responsibility that the Municipality of Tolmin had did not include sufficient funding for spending on the entire public infrastructure needed, and especially the renovation of cultural heritage. With an area of 939 km^2, the Municipality of Tolmin was at that time the largest in Slovenia, which is why there was a clear gap in economic development between the municipal centre and its periphery. Spending as part of post-earthquake recovery was thus directed to the central area of the municipality (i.e., Tolmin), followed by the areas of Bovec and Kobarid. The disparity between the periphery and the centre was also reflected in the Kobarid area, where the local communities of Breginj and Borjana – that is, distinctly peripheral settlements compared to the centre of Kobarid – were most affected. Thus one could talk about a periphery at three levels: of the Municipality of Tolmin from the perspective of Slovenia, of the Kobarid area from the perspective of the Municipality of Tolmin, and of the local communities of Breginj and Borjana from the perspective of the Kobarid area. Thus for example, in the local community of Breginj the planned post-earthquake recovery was not fully implemented because of the allocation of funds at the municipal level (Pipan and Zorn 2013).

After the 1998 earthquake, the central government supervised the recovery in Slovenia. Thus a shift in responsibility from the local (municipal) level to the state level is evident after the change of the political system (capitalism vs. prior socialism). In order to avoid a repetition of the concept of recovery in the Breginj area in 1976, during which entire settlements were relocated, the law prioritized recovery at the same location. In order to protect cultural heritage, the recovery of damaged buildings had priority over new construction (Pipan and Zorn 2013).

Stop 6: Goriška Brda Hills – landslide risk

The **Goriška Brda Hills** is a range of hilly ridges in western Slovenia that covers 140 km^2 between Italy to the east and the Soča Valley to the west with elevations from 300 to 800 m. The ridges are mostly sedimentary flysch rock composed of alternating layers of sandstone, marl and carbonate turbidite, as well as limestone or calcarenite ranging from a few centimetres up to half a meter thick. The flysch rock in the Goriška Brda Hills is divided into the Early Paleocene Kožbana layers with several carbonate elements dominant in the north and the younger Lower Eocene Medana layers with a higher content of clay elements found more frequently in the south (Zorn and Komac 2009b).

In Slovenia the threshold precipitation that affects landslides in flysch regions is 100 to 150 mm in 24 hours (Komac 2005).

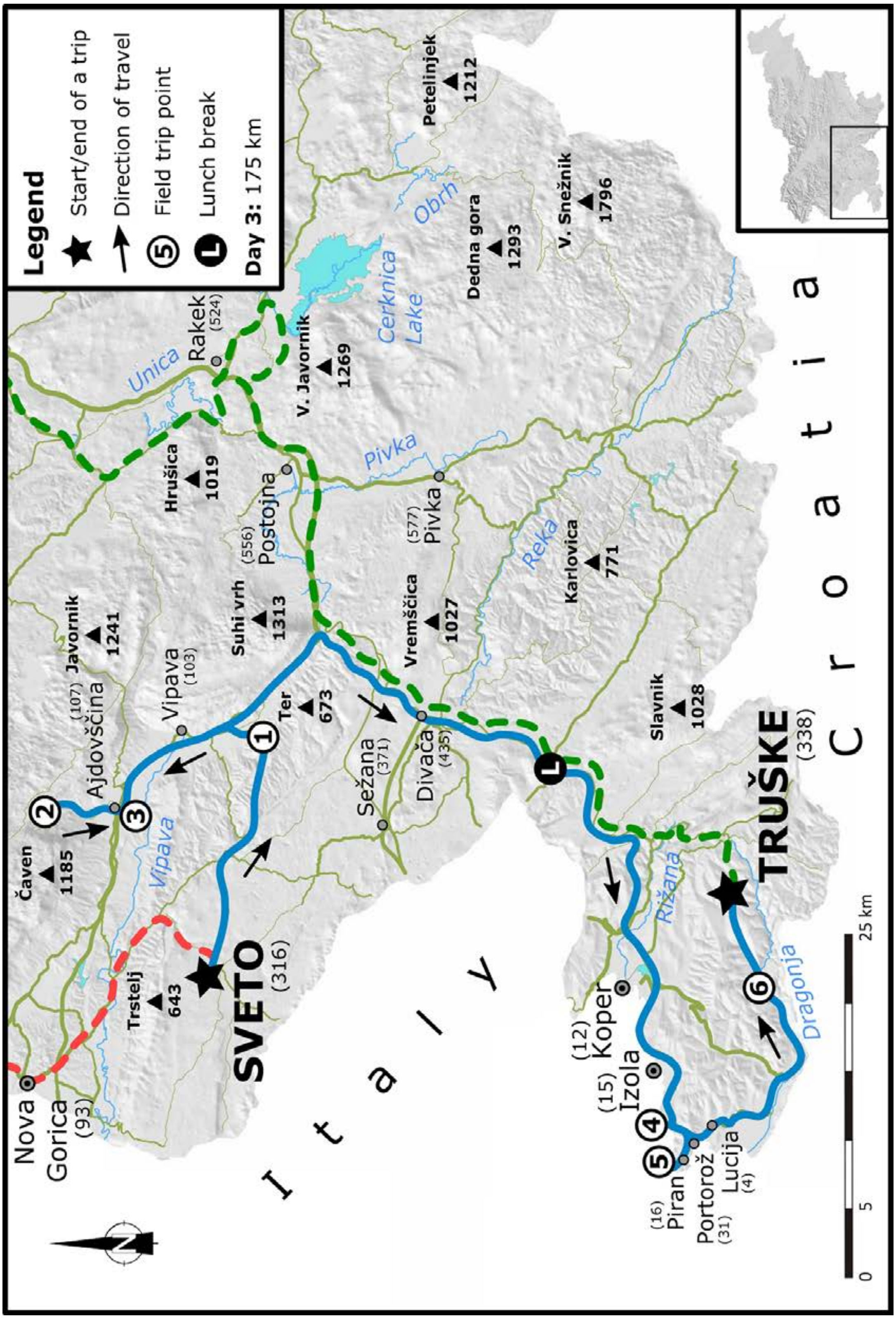
On September 6, 1998, 114 mm rainfall fell in the Goriška Brda Hills, and 100 mm on September 13. Both precipitation events reached a 5-year return period. On October 6, of the same year, the precipitation level reached 175 mm in only 24 hours. The

total cumulative precipitation reached a 50-year return period. Between September 28th and October 13th, 433 mm rainfall felled that equals to an average of 31 mm of rainfall per day. In the beginning of October, intense precipitation caused numerous landslides in the southern parts of the Goriška Brda Hills. There were over 800 landslides in the southern Goriška Brda hills, only counting those that affected farmlands and caused damage. In an area covering 41.32 km^2, landslides covered 1.7% of the total land surface. The most affected land use type were vineyards that cover approximately 40% of the Goriška Brda Hills, and more than 60% of the landslide-prone areas. Slightly less affected were meadows and woods that cover approximately one-third of the surface area. The least affected areas were meadows and other grazing lands as they are mostly located on flat surfaces. Less than 10% of the landslide-prone areas are covered by meadows, and fields and orchards cover about 20% each. Landslides occurred in approximately 3% of built-up areas, including infrastructure such as roads (Zorn and Komac 2009b).
Based on the triggered landslides and physical geographical conditions a landslide susceptibility map was made. On the basis of landslide susceptibility map, it was concluded that app. one-tenth of the area studied is highly landslide prone (landslide susceptibility category 5), and almost half of the area is moderately landslide prone (landslide susceptibility categories 3 and 4). Despite these the area has a relative landslide rate (Cendrero and Dramis 1996) of about 20. This means that, in this area, landslides and slumps make up at least one-fifth of all geomorphologic processes.
It was concluded that with intense precipitation with an app. 50-year return period, we may expect landslides in less than 2% of the affected area in flysch regions of western Slovenia. Their contribution to surface transformation in relation to other erosion processes (mainly soil erosion) has been great (app. 20%) despite the relative infrequency of such precipitation events (Zorn and Komac 2009b).

Stop 6: Solkan bridge

Solkan bridge is the most prominent bridge on the Bohinj Railway route between Jesenice and Gorizia (Italy). According to the known data, the bridge has the longest stone arch spanning over a river in the world and the longest stone arch among all railway bridges. The span of the main arch is 85 m. The length of the whole object is 220 m. The bridge was under construction for two years, from spring 1904 until December 1905. During WW1 the bridge, mined by the Austrian army, was severely damaged. After the Kobarid breakthrough in October 1917, it was provisionally repaired. After the war Italy thoroughly repaired it and the stone arch was rebuilt. The work lasted until 1927. Since then the bridge has been repaired several times, but it has preserved it original form and significance (Internet 12).

June 26th (Sunday)
Topic: **Erosion processes in flysch**
Location: **Mediterranean Slovenia (SW Slovenia)**



Stop 1: St. Socerb Hill – slope processes in the Vipava Valley

The **Vipava Valley** offers a unique insight into variety of different mass movement processes and opportunity to study the characteristics of the slope sediments of large fossil landslides as well as activity of the recent movement processes.
Slope sediments of the Vipava Valley represent a complex sedimentary system deposited by very different mechanisms of slope transport and sedimentary processes, which are largely controlled by a particular lithology and tectonic structure of the area.
Landslides are closely related to the geologic-tectonic predisposition of the area, while the micro-location of the occurrence of a particular slope process is directly affected also by very specific and local structural and hidrogeological conditions.
Upper part of the Vipava Valley represents a geomorphological boundary between the north-eastern Nanos mountain range and the south-western Karst plateau. The valley is characterised by a generally asymmetric transverse (NE–SW) profile; whereas the NE slopes (an area known as Rebrnice) are defined by a thrust front of Mesozoic carbonates over Tertiary flysch deposits, the SW slopes (Vipavska Brda Hills) are composed solely of flysch (Popit et al. 2014).

Stop 2: Vipava Valley – Stogovce landslide and large mass movement in the surroundings

From September 16 to September 20, 2010 heavy rainfall totalling between 300 and 520 mm caused large floods and triggered numerous rainfall-induced landslides across Slovenia. They affected 60% of Slovenian municipalities (137), and the total direct damage was estimated at more than 240 million Euros (Zorn and Komac 2011).
One of the largest landslides covering the area of app. 15 ha was triggered on flysch bedrock, just below a limestone overthrust zone. The sliding material properties, the inclinations of the slope, and the water catchment area indicate that the landslide may transform into a fast moving debris flow. **The Stogovce landslide** is one of the numerous rainfall-induced landslides that have occurred in Slovenia on flysch bedrock in the last two decades. It proves that landslide risk on flysch territory is increasing (Petkovšek et al. 2011). The landslide damaged the main road, which was moved up the slope.

Just a few kilometres to the west an even bigger **Slano Blato landslide** is located. It is more than 1290 m long, 60 to 200 m wide and 3 to 11 m deep with a volume of about 700 000 m^3. It was triggered in November 2000 after heavy precipitation and it is a direct threat to the village of Lokavec below (Logar et al. 2005).

Some kilometres west of Slano Blato landslide beneath the Mount Čaven (1,237 m) is a large Pleistocene fan-shaped sedimentary body – the **Selo landslide**. It covers an area of 9.92 km^2. The sedimentary body is up to 50 m thick with an average of 10 to 15 m. The volume is estimated to app. 172 million m^3 (Popit and Verbovšek 2011).

Stop 3: Vipava Valley – wind erosion

Wind erosion occurs in Slovenia predominately on agricultural land; its effects are influenced by soil type, climate and human activity. It is present especially in SW Slovenia where on certain weather condition (strong anticyclone over the Balkans and cyclone over the Mediterranean Sea) strong "bora" wind (over 55 m/s) blows. With regard to wind erosion the winter months are the most problematic as fields are without vegetation cover. From historical sources it is known that bora can blow constantly up to two weeks, but usually it blows a couple of days. In the last decades it blew rarely for two weeks together, but in the first half of February 2012 there were such conditions. Beside strong wind that had velocity up to 10.1 m/s (data from official meteorological station; or more than 50 m/s on stations more exposed to wind but not belonging to official meteorological network) (daily average for the period between December 28th to February 14th was 2.7 m/s) there were also other climatic factors that influenced the erodibility of the flysch soil, e.g. the coolest February since temperature measurement records exist (long-term average mean daily temperature in the period from year 1971 to 2000 for February is 4.1^{o}C; average daily temperature in February 2012 was 1.4^{o}C), and a long dry period. Last precipitation event with more than 0.2 mm of rainfall was between the 3rd and the 4th of January 2012 (42.9 mm), but dry period lasted from at least September 2011 as only 440 mm of rain felt from September 2011 till February 2012 (57% of long time average).

For wind erosion in the Vipava Valley anthropogenic factors are also important. In the early eighties of the 20th century big hydro-melioration and commassation works were conducted in the valley as the socialist government at that time wanted to transform the Vipava Valley into the "granary" of western Slovenia. While doing these works they were aware of the wind erosion problem, so they planned vegetation shelterbelts to prevent wind erosion. Unfortunately shelterbelts were not planted in all planned locations and in the last thirty year farmers also removed many of these belts to gain more agricultural land although the land with shelterbelts was not their property. Important factor was also that the framers ploughed the fields too early during this winter.

All these factors contributed that in February 2012 app. 1200 ha of agricultural land was affected by wind erosion. It is estimated that fields lost from 3 to 10 cm of topsoil resulting in the overall loss of soil of app. 600.000 t or app. 560 t/ha.

Stop 4: Strunjan Nature Reserve – flysch coastal cliffs

The **Strunjan Nature Reserve** is a part of the Strunjan Landscape Park and encloses 4 km along the northern coast of the Strunjan Peninsula. The reserve covers 160 ha, and the land:sea ratio is estimated at 1:2.5.

Among the most distinctive parts of the reserve is the wall of the **Strunjan cliffs**. It is up to 80 meters high and composed of flysch. The Strunjan cliffs form the largest known coastal flysch wall on the entire Adriatic coast. Its bottom part has been subjected to constant erosion by the sea, while its upper parts have been decomposed a great deal by the changing weather conditions. At the foot of the cliffs, a characteristic shingle terrace has formed between the steep slope and the sea, which in places is up to seven meters wide (Internet 13).

Till now there were no direct measurements of rockwall retreat but there were several attempts to estimate it (Zorn 2009b):

- In the area of Valdoltra near Ankaran it was estimated that in the last 900 years the rockwall has been retreating at a rate of 6 mm/year.
- In the town of Piran at the western end beside the buttresses below the Piran church the rockwall retreat rate was estimated to 2 cm/year in the last 300 years, and at the eastern end beside the buttresses at 1 cm/year in the last 200 years. Also in Piran the edge of the cliff near the rectory of the Piran church rockwall supposedly retreated by 2 m between 1901 and 1990, which is more than 2.2 cm/year.
- With the help of archaeological finds it was estimated that since Roman times the eastern coast of Simonov Zaliv Bay has retreated 60 m or by around 3 cm/year.
- Using topographical analyses in the same bay the rockwall retreat was established to be 15 to 20 m between 1922 and 1958, or 0.42 to 0.56 m/year.
- In some places the root network of the trees hangs up to one meter over the upper edge of the cliff, indicating the distance the cliff retreated during the period of the growth of the tree.

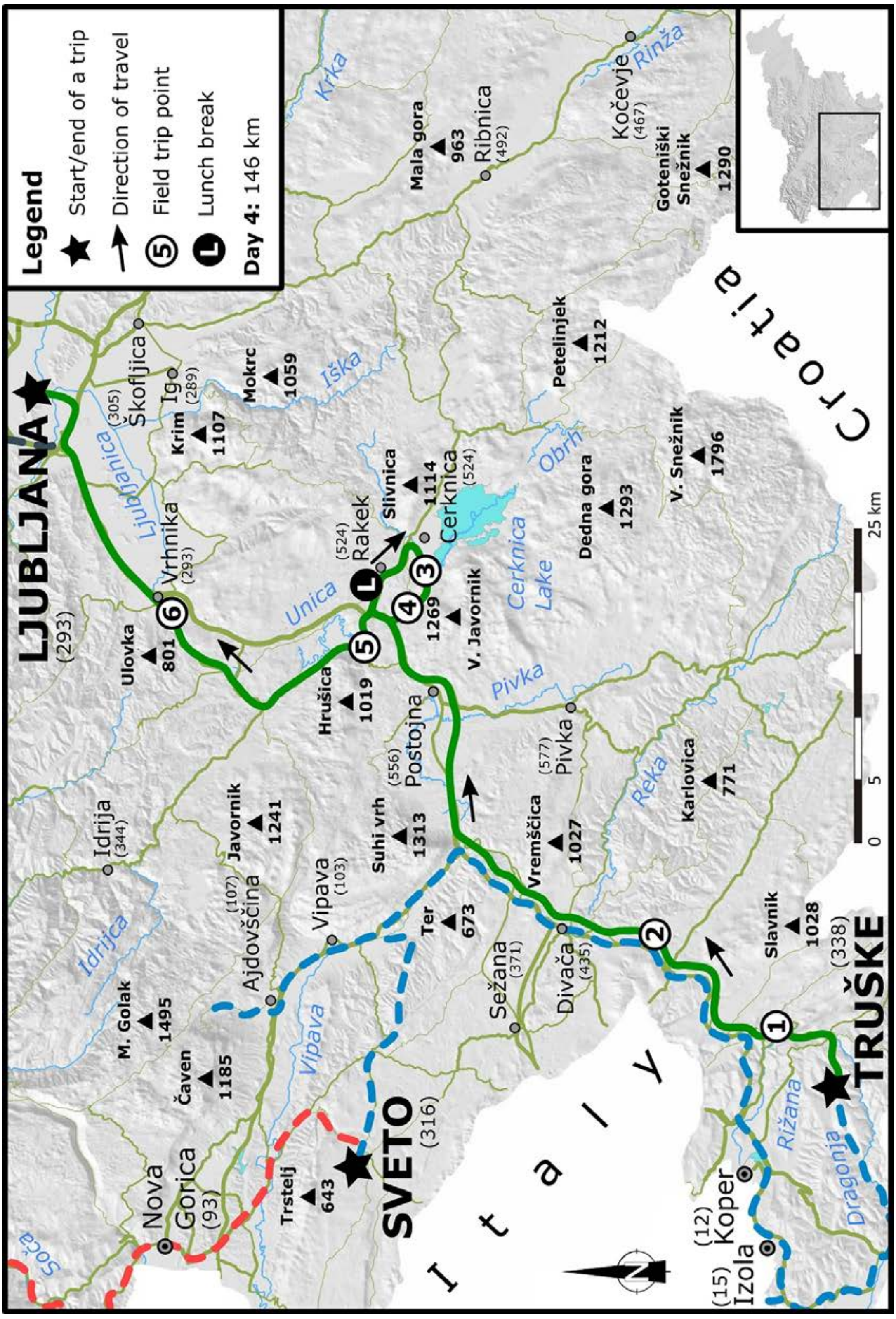
Stop 5: Town of Piran

Piran (Italian *Pirano*) is a town on the Gulf of Piran on the Adriatic Sea with a population of around 4,000. It is one of the three bigger towns of Slovenian Istria. The town has much medieval architecture, with narrow streets and compact houses. Piran is the administrative centre of the local area and one of Slovenia's major tourist attractions. The first settlements in the area date back to pre-Roman times (Internet 14).

Stop 6: Dragonja River Valley (Škrline) – soil erosion

The **Dragonja** is a 30-kilometre long river in the northern part of the Istria peninsula. The basin area is hilly region, between 150 and 450 m above sea level. The area of the watershed is 90.5 km^2. In the past the area was mainly inhabited in the hilly ridge tops. In the 1960s and 1970s the region depopulated and this led to the abandonment of agricultural land use. This caused natural reforestation of the land. The forest area has increased from 25% (in 1953) to more than 60% (today). The area is geologically composed of Eocene flysch. Soil is mostly carbonate rendzina. The Dragonja watershed belongs to the submediterranean climate region with mean annual temperatures around 14^{o}C and the annual precipitation of 1000 mm (coast) to 1300 mm (the upper watershed area). Snow is extremely rare. The changes in land-use changed the hydrology of the catchment at great deal, e.g. a decrease in minimal and maximal flows. At the same time no noticeable climate (precipitation and temperature) changes have been perceived (Šraj et al. 2006; 2008).
For the need of studying the processes of soil erosion and sediment production in badlands erosion plots were constructed. The measurements of **soil erosion** made on one-meter-square closed erosion plots south of the village of Marezige revealed that the greater part of the annual erosion was caused by only a few major erosion events. Between May 2005 and April 2006, interrill erosion amounted to 9,013 g/m^2 (90 t/ha) on bare soil in an olive grove with an inclination of 5.5^o and an average weekly proportion of specific runoff of 23%, 168g/m^2 (1.68 t/ha) on an overgrown meadow with an inclination of 9.4^o and an average weekly proportion of specific runoff of 8%, and 391 g/m^2 (3.91 t/ha) in a forest with an inclination of 7.8^o and 415 g/m^2 (4.15 t/ha) in a forest with an inclination of 21.4^o with an average weekly proportion of specific runoff of 6% regardless of the inclination. The amount of precipitation during the reference year was slightly below the long-term average (Zorn 2009a).
Sediment production of flysch rocks was determined by measurements on erosion plots and totals around 80 kg/m^2 per year on average, which means that steep bare flysch rockwalls retreat at a speed of 35 to 50 mm/year. The badlands not only contain flysch walls but also slopes already eroded by erosion rills and gullies. A dam in one of the erosion gullies with the catchment area of 0.1 ha captured 20 tons of debris in fourteen months (Zorn 2009a; 2012).

June 27th (Monday)
Topic: **Vulnerability of karst landscape**
Location: **Dinaric Karst (SW, S Slovenia)**



The **Dinaric Mountains** extent over approximately 60.000 km^2 along the Adriatic coast from Italy to Greece, and form the largest continuous karst landscape in Europe. Characteristic morphological features are high karst plateaus like Trnovski Gozd in Slovenia (1,495 m), Velebit in Croatia (1,758 m), Dinara in Croatian and Bosnia and Herzegovina (1,913 m), Durmitor in Montenegro (2,522 m), elongated in the NW-SE direction and separated by lower levelled surfaces or by tramontane enclosed depressions in which karst poljes have developed (Mihevc and Prelovšek 2010). Distinct surface features are poljes, uvalas, dolines, dry valleys, blind valleys, collapsed dolines, and caves. Over 20.000 caves are known in the area (Mihevc 2010). The Dinaric Karst is very rich in cave fauna, with many endemic animal species. Here first cave animals like the Olm (*Proteus anguinus*) and cave beetle (*Leptodirus hochenwartii*) were described (Gams 2003).

Dinaric Mountains in Slovenia are in the west and south part of the country. In general, the Slovenian part of the Dinaric Karst is divided to the Reka River catchment area in the west (drains towards the Adriatic Sea) and the Sava River catchment area in the east (drains towards the Black Sea). Because of the pure limestone only thin non-continuous soil cover developed on the karst. Traditionally this was the area of pasture, lime and charcoal production, and forestry. Today, mostly forestry remains, otherwise the karst area is characterised by modest natural resources and a low population density. However, more than the half of the drinking water in Slovenia comes from karst aquifers.

The research of karst has a long tradition in Slovenia. Karstology itself, as a scientific discipline, started to develop on the key examples from the Slovenian karst. Consequently, Slovenian terms for various karst features were passed on to the international karstological terminology. In Slovenian language the region Kras is referred to also as the "mother karst" in the sense of "the cradle of karst", and the karst area between Vrhnika and Trieste where the first karst features were described is called the Classical karst. The term classical stands for a typical karstic landscape and features that serve as the prototype features all other karst features throughout the world are compared with (Kranjc 1994; Ferk and Zorn 2015).

Stop 1: Kraški Rob – the edge of the Dinaric Mountains

The **Reka River** gathers water from an area of more than 350 km^2. The primary springs of the Reka River are to the south and west of the high karst mountains Snežnik and Gorski Kotar. After more than 30 km of surface flow on non-karstic rocks (i.e. mostly flysch rocks) it formed a large blind valley with a several kilometres long terminal canyon before it flows to the ponor cave **Škocjanske Jame** (UNESCO World Heritage). In the underground it continues the flow in northwest direction beneath the Kras Plateau. The river joins underground with the avtigene rainwater from Kras, and some tributaries from the rivers Soča, Vipava, and Raša. It emerges as the Timava River (in Italy) in three main springs on the Adriatic Coast. The springs are connected by a network of passages that reach a depth of about 80 m below sea level. The Reka River represents the main sinking river on the edge of the karst plateau Kras. The discharge changes through the year from a few m^3/s to more than 300 m^3/s. At the time of high discharges the water is dammed in the underground and the water level in the aquifer rises over 100 m (Mihevc 2001; Gams 2003).

Stop 2: Kras Plateau and the degradation of dolines

The **Kras Plateau** belongs to Adriatic–Dinaric Carbonate Platform of the External Dinarides composed of shallow marine fossil-bearing Cretaceous and Palaeogene carbonates. It is a 40 km long and up to 13 km wide limestone plateau on the elevation of about 300 m a.s.l. On the surface numerous dolines, caves and other karst features are formed (e.g., collapse dolines, unroofed caves). The epiphreatic zone of Kras is characterized by high flow variability of the Reka River which can be accessed through some deep vertical shafts. More than 300 m deep vadose zone, huge underground cavities, complex recharge and discharge conditions, and multiphase evolution resulted in a hydrological system that is far from being resolved jet (Mihevc 1996; 2001; 2007; Mihevc and Zupan Hajna 1996). About 3500 caves are registered on the Kras Plateau already (among them are the show caves Divaška Jama and Vilenica), but there are new discoveries every year (Cave Register of SAS 2015). The **Vilenica Cave** is located in south-eastern part of Kras Plateau near Sežana. It is the oldest show cave in Europe (Grom 1964); first documents reporting the use of the cave for tourist purposes are from the year 1633.
A different story is the **degradation of dolines** in the second part of the 20th century that continues up to today. In the last decade a research of former waste disposal sites in several karst regions in Slovenia was carried out (Breg Valjavec 2013; Breg Valjavec and Zorn 2015). In karstic regions in the past karst depressions (e.g., shafts, dolines, collapse dolines) in the vicinity of settlements were used as waste disposal sites for domestic waste, bulk waste, construction waste, agriculture waste etc. A comparative analysis of former and current surface morphology showed that many dolines were not only filed with waste, but later covered with sediments to level larger areas. Consequently, today it is difficult and time resuming to determine the exact of polluted areas. However, it is essential to do so anyway, because these locations have a high potential of becoming a pollution disaster. Due to low self-cleaning capabilities the karst aquifer is very sensitive to contamination, but crucial for the water supply in western Slovenia.

Stop 3: Cerknica Karst Polje

The **Ljubljanica River** is an important tributary to the Sava River (tributary to the Danube). The catchment area covers approximately 1800 km^2, from which about

1100 km^2 is of karstic rocks; limestones and dolomites of Mesozoic age. They were formed on the Dinaric Platform under conditions of continuous sedimentation which enabled high rock purity (i.e. up to 99.9 % pure $CaCO_3$). The total thickness of the carbonate sequence is almost 7 km. The highest parts are high karst plateaus Hrušica, Javorniki, and Snežnik. There are about 1500 accessible caves in the catchments area of the Ljubljanica River. The average length of the caves is 48 m and the depth 18 m (Cave Register of SAS 2015). However, the largest caves are the ponor (e.g., Postojna Cave, > 20.5 km) or spring caves (e.g., Planina Cave, app. 6.7 km). The hydrologic system of Ljubljanica River is divided into two main source areas: Pivka Basin in the west and Notranjsko Podolje in the east. The final springs of Ljubljanica River are at the Ljubljana Moor near the settlement Vrhnika.

Notranjsko Podolje is a lowered surface along the Idria slip-strike fault zone, elongated in northwest-southeast direction. The area is built of Triassic to Paleogene limestones and dolomites, and is mostly drained underground. Some surface streams are formed on dolomite, but they sink when they reach the limestones. In the lowest parts a sequence of six karst poljes is formed: **Babno Polje, Lož Polje, Cerknica Polje, Unec-Rakek Polje, Planina Polje, Logatec Polje**. Most of them are periodically flooded from 1 to 6 months every year. Floods cause lateral corrosion on the rims of the poljes, resulting in horizontal widening of the polje floors. The largest cave systems in the area were also formed by the aggressive water at the polje edges.

Stop 4: Rakov Škocjan Karst Basin

Rakov Škocjan Karst Basin is located between the Javorniki Mountains and Unec-Rakek Polje (45 km from Ljubljana, 10 km from Postojna). The basin is formed in a levelled karst plain between Cerknica and Planina Polje. The 3.5 km long basin is divided into two parts: the valley of **Rak River** and the hydrologically inactive depression of Podbojev Laz. Local geology exhibits pure Cretaceous limestones (Gospodarič et al. 1983), and more than 60 caves are registered in this area (Cave Register of SAS 2015). The basin was formed as a surface karst feature (i.e. karst polje) in several development stages, in which the location of springs and ponors has changed (Ferk 2011; Ferk and Stepišnik 2011). Complex morphological genesis (Habič and Gospodarič 1987) resulted in exceptional variety and quantity of karst phenomena (Šerko 1949). The amazing scale and astonishing forms of karst features in Rakov Škocjan have attracted people of various professions for centuries. In 1949 it was proclaimed the second protected area in Slovenian territory. Since 2002, the basin is also included in the Notranjska Regional Park.

In the north-eastern part of Rakov Škocjan the Rak River emerges from the **Zelške Jame Cave**. The cave system connects three main channels, formed in phreatic and epiphreatic conditions through different development stages; in some parts the hydrological processes are still active. The cave can be accessed through several collapse dolines; between two of them the Small Natural Bridge is formed. The Rak

River sinks to the ponor cave **Tkalca Jama**. It is a linear stream cave and accessible for cave divers only, namely the majority of passages are below the water table level. Occasionally in summer when the water table drops very low, the first 300 m of the cave are dry. The cave is draining water from Rakov Škocjan and the Javorniki Mountains towards the Planina Polje (Gams 2003).

Stop 5: Planina Karst Polje and Planina Cave

The **Planina Karst Polje** is the lowest karst polje in the river basin of karstic Ljubljanica River (Šerko 1951), and the most important area of water confluence in the river basin (Savnik 1960; Stepišnik et al. 2012). Planina Polje is formed in Cretaceous and Jurassic limestones and dolomites (Čar 1982). The flattened floor is on the elevation of 450 m a.s.l., and during rain periods completely flooded (Ravnik 1976). Usually twice a year a 5 to 8 m deep lake is formed (Breznik 1961). The surrounding karst surface is entirely karstified with no surface water flow appearance, consequently all the inflow and outflow is karstic. Beside several other intermittent springs, the largest spring is at Planina Cave in the southern part of the polje, where **Unica River** emerges. Its discharge varies from 1.1 m^3/s to 130 m^3/s. The ponors are scattered over a wider area, but the most picturesque is the north-eastern area called Babni Dol were the water sinks to the underground under 50 m high rock walls.
The entrance to the **Planina Cave** is at the end of a 1200 m long pocket valley under a 80 m high rocky wall. It is a horizontal epiphreatic cave and known for its underground confluence of rivers Pivka (flowing from Postojna Cave) and Rak (flowing from Rakov Škocjan). The main passages are more than 15 m wide and high.

Stop 6: Springs of the Ljubljanica River at Vrhnika

The Ljubljanica River emerges from several karst springs dispersed along the western edge of the **Ljubljana Moor** (Zorn and Šmid Hribar 2012), between Vrhnika and Bistra. The largest springs are Veliko Okence, Malo Okence, Močilnik, Retovje, and Bistra. The springs are at 300 m a.s.l. with a mean annual discharge of 38.6 m^3/s. Typically, the water emerges to the surface in pocket valleys that are up to 500 m long with steep 20 to 40 m high walls (Tičar 2015). **Pocket valleys** are amphitheatre-like steep-headed karstic valleys formed at the emergence of water from a karst aquifer either by gravitational undermining (spring sapping) and slumping of a slope or by irregular collapse of a cave roof above a subterranean water flow (Lipar and Ferk 2015).

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ANTON MELIK GEOGRAPHICAL INSTITUTE
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Short History

The Institute was founded in 1946 by the Slovenian Academy of Sciences and Arts. In 1976 it was named after Slovenia's greatest geographer, academy member Anton Melik (1890–1966), who served as the institute's first director. Since 1981, the institute has been one of the members of the Research Centre of the Slovenian Academy of Sciences and Arts. In 2002 the Institute for Geography (established in 1962) and the Geographical Museum of Slovenia (established in 1946) were joined to the institute.

Main Tasks

From the very beginning, the institute's main task has been to conduct basic and applied geographical research on Slovenia and its landscapes and to prepare basic geographical texts on Slovenia as a country and as a part of the world. Since Slovenia gained independence, in cooperation with other Slovenian geographers the institute's staff has prepared a large variety of basic geographical works on Slovenia as an independent country. These include national, world, school, and census atlases, a dictionary of geographical terminology, a lexicon of Slovenian place names, and a regional and general monograph. The institute participates in numerous projects in Slovenia and abroad, organizes academic conferences, trains junior researchers, and participates in professional exchanges.

Organization units

Department of Physical Geography
Department of Natural Hazards
Department of Human Geography
Department of Regional Geography
Department of Thematic Cartography
Department of Environmental Protection
Department of Geographic Information Systems
Geographical Museum
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We publish a peer-review journal *Acta geographica Slovenica* indexed in the Science citation index expanded (SCIE) (http://ojs.zrc-sazu.si/ags).