ARTICLES

MASS MOVEMENT SUSCEPTIBILITY MAPS IN SLOVENIA: THE CURRENT STATE

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ABSTRACT
Mass movement susceptibility maps in Slovenia: The current state
Mass movement susceptibility maps offer a quick and effective way to determine areas that people should not exploit or where it is known that any development would require special construction and other measures. In recent years, such maps have been made for landslides, rockfalls, and debris flows at the national scale for Slovenia, and the first maps for municipalities have also been created. This article presents the current state of production of such maps in Slovenia.

KEY WORDS
geography, natural disasters, mass movement, prevention, susceptibility maps, Slovenia

IZVLEČEK
Zemljevidi nevarnosti za večje pobočne procese v Sloveniji: trenutno stanje
Zemljevidi nevarnosti za večje pobočne procese omogočajo hitro in učinkoviti določanje območij, ki se jim je bolje izogniti oziroma na katerih je kakršenkoli poseg povezan z posebnimi gradbenimi ali drugimi ukrepi. V zadnjih letih so bili v Sloveniji v državnem merilu izdelani zemljevidi nevarnosti zaradi zemeljskih plazov, skalnih podorov in drobirskih tokov. Poleg tega so bili izdelani tudi prvi tovrstni zemljevidi za občine. Predstavljeno je trenutno stanje na področju izdelovanja tovrstnih zemljevidov v Sloveniji.

KLJUČNE BESEDE
geografija, naravne nesreče, pobočni procesi, preventiva, zemljevidi nevarnosti, Slovenija

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1 Introduction

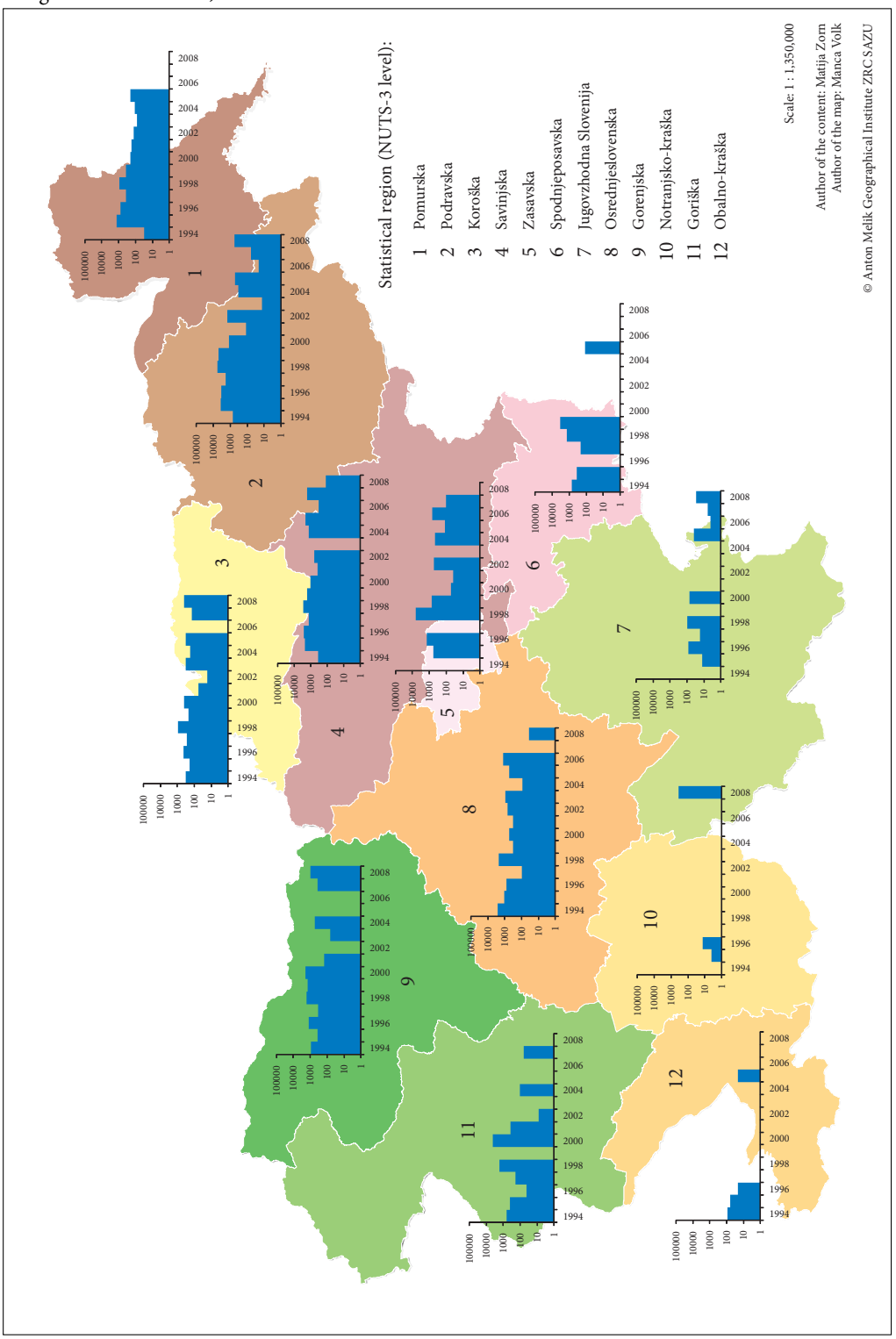
Mass movement is a geographical constant in certain areas in Slovenia, and in the past some writers have used expressions such as *slippage-prone region* or *landslide-prone region* for certain parts of the country (see sources in Zorn and Komac 2011a). Nonetheless, spatial planning encounters difficulties in such areas because these geomorphic processes are still considered to be interfering factors rather than component parts of them.

On average, the landslide hazard is the greatest in Slovenian alpine (and pre-alpine) regions, where areas most susceptible to landslides cover more than 20% of the entire area. In the Pannonian regions, the most landslide-prone areas cover around 10% of the area, and in Mediterranean regions around 8%. The areas least threatened by landslides are the (predominantly) limestone Dinaric regions, where the areas most susceptible to landslides represent around 7% of the area (Zorn and Komac 2008a; Komac and Zorn 2009). From 1994 to 2008, damage caused by landslides and avalanches amounted to 0.033% of GDP, or nearly 8% of the annual damage due to natural disasters (Figure 1; Zorn and Komac 2011a; 2011b; 2011c). With regard to this damage, landslides and avalanches are ranked fifth, behind drought (nearly 26% of average annual loss due to natural disasters), hail (just over 20%), flooding (nearly 19%), and strong winds (just over 12%).

This article presents the efforts made with regard to mass movement prevention after the adoption of the Waters Act (Zakon o vodah 2002) and some other intervention acts (e.g., Act on the Measures to be Taken to Repair the Damage Caused by Certain Large-Scale Landslides in 2000 and 2001; Zakon o ukrepih … 2002), and after the occurrence of some major landslides (e.g., the Stovžje landslide above Log pod Mangartom: 2,500,000 m^3 (in 2000), the Slano blato landslide near Ajdovščina: 1,000,000 m^3 (in 2000), the Koseč landslide above Kobarid: 675,000 m^3 (in 2001); Zorn and Komac 2008, 36).

Article 83 of the Waters Act (Zakon o vodah 2002) defines areas threatened by hydro-geomorphic processes and stipulates that these areas should be classified into various hazard categories. This can be achieved by producing susceptibility maps, which are one of the basic methods of mass movement prevention. However, the problem is that there is no uniform methodology for producing these types of maps (neither between various disciplines nor within the disciplines themselves). Specifically, the Waters Act (Zakon o vodah 2002) does not define this methodology and leaves it to a different legal document, which has not been adopted yet.

In Slovenia, national funds are primarily used for recovery, and less so for prevention. It would certainly be good if a greater portion of these funds could be earmarked for prevention; only 15% of the funds that were used from 2002 to 2010 alone to clean up seven major landslides (approximately € 30.5 million; Koliko denarja … 2011) would, in theory, have been sufficient to produce quality mass-movement susceptibility maps for all of Slovenia's municipalities (Komac and Zorn 2005, 92). Such maps are also defined in Article 57 of the Spatial Management Act (Zakon o urejanju prostora 2002), which also legislates the presentation of threatened areas. This is also prescribed by Article 87 of the Spatial Planning Act (Zakon o prostorskem načrtovanju 2007).


Statistical region (NUTS-3 level):
1 Pomurska
2 Podravska
3 Koroška
4 Savinjska
5 Zasavska
6 Spodnjeposavska
7 Jugovzhodna Slovenija
8 Osrednjeslovenska
9 Gorenjska
10 Notranjsko-kraška
11 Goriška
12 Obalno-kraška
Scale: 1 : 1,350,000
Author of the content: Matija Zorn
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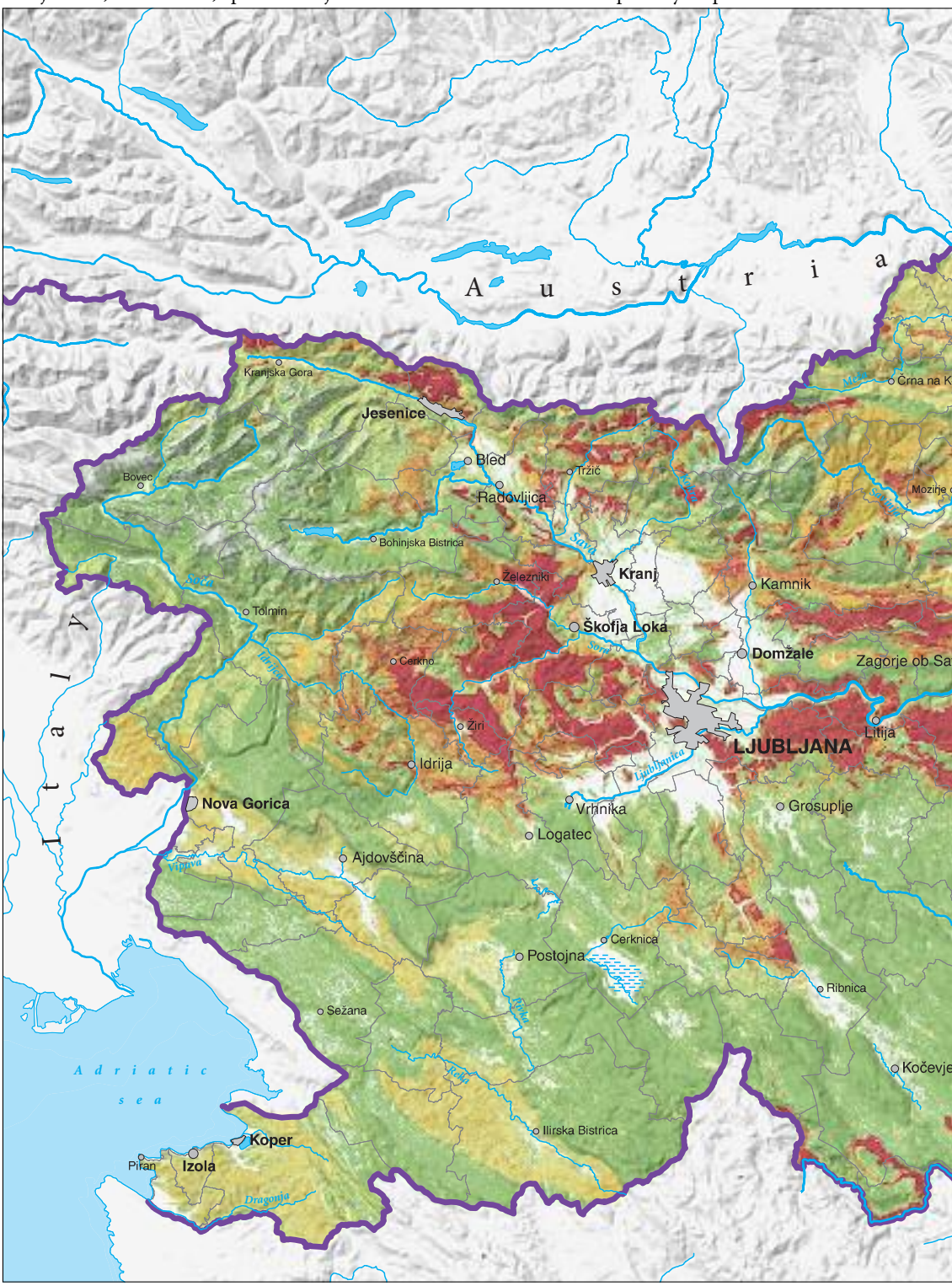
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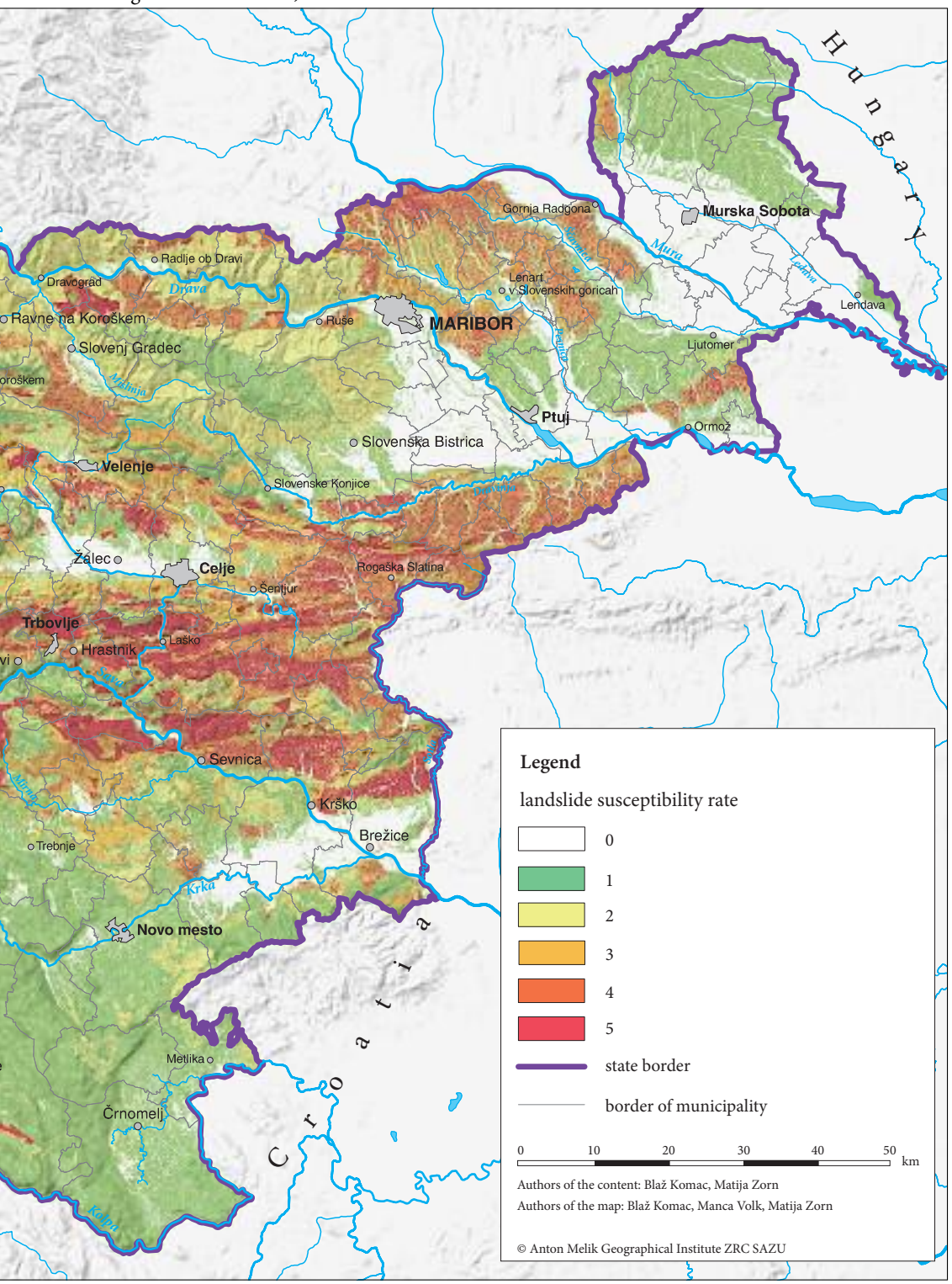
Hungary
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Dravograd
Ravne na Koroškem
Slovenj Gradec
Ruše
MARIBOR
Lenart v Slovenskih goricah
Lendava
Ljutomer
Ormož
Ptuj
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Rogaška Slatina
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Trebnje
Novo mesto
Metlika
Črnomelj
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Meža
Savinja
Sotla
Krka
Kolpa
Legend
landslide susceptibility rate
0
1
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state border
border of municipality
0 10 20 30 40 50 km
Authors of the content: Blaž Komac, Matija Zorn
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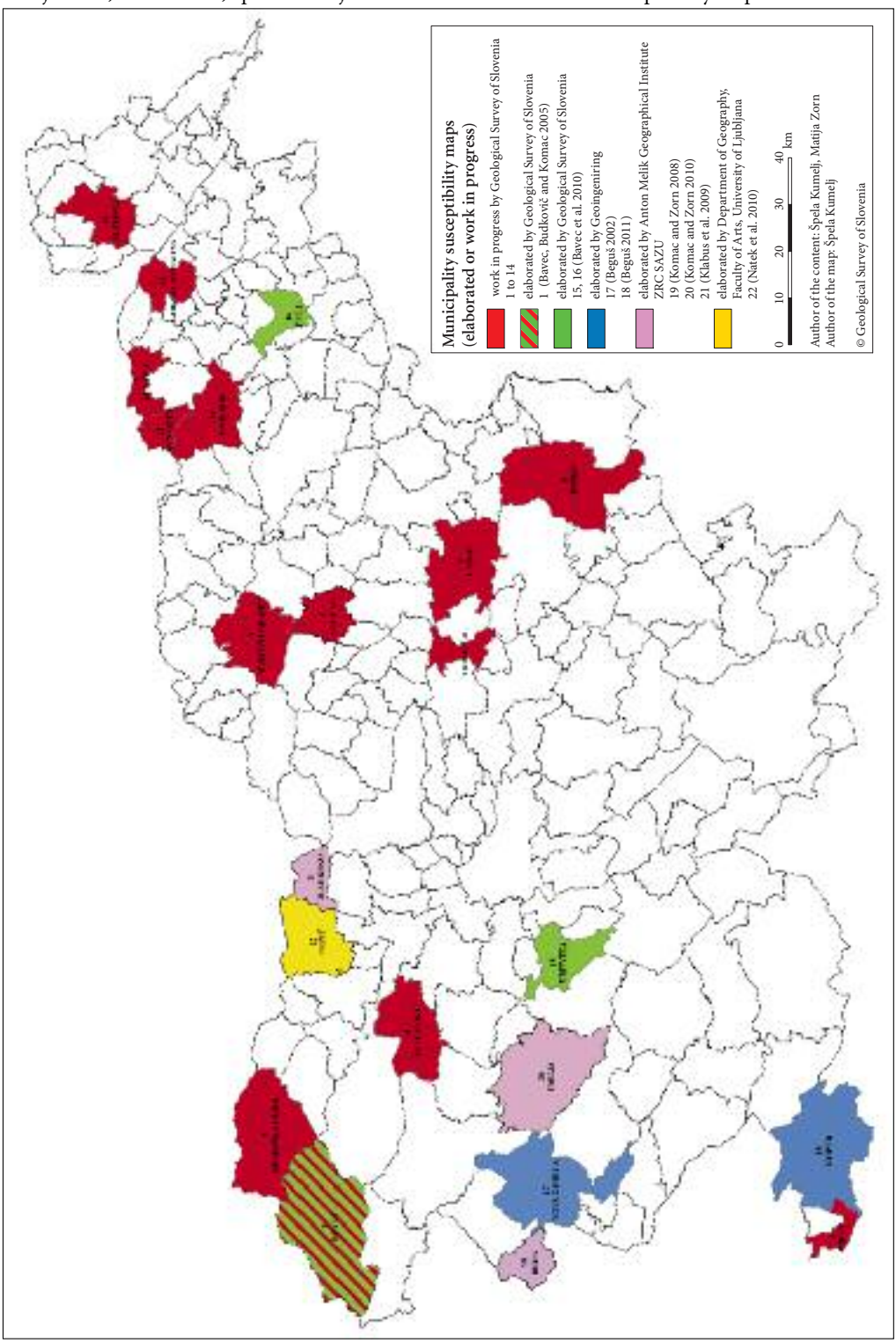
Municipality susceptibility maps
(elaborated or work in progress)
work in progress by Geological Survey of Slovenia
1 to 14
elaborated by Geological Survey of Slovenia
1 (Bavec, Budkovič and Komac 2005)
elaborated by Geological Survey of Slovenia
15, 16 (Bavec et al. 2010)
elaborated by Geoingeniring
17 (Beguš 2002)
18 (Beguš 2011)
elaborated by Anton Melik Geographical Institute ZRC SAZU
19 (Komac and Zorn 2008)
20 (Komac and Zorn 2010)
21 (Klabus et al. 2009)
elaborated by Department of Geography, Faculty of Arts, University of Ljubljana
22 (Natek et al. 2010)
0 10 20 30 40 km
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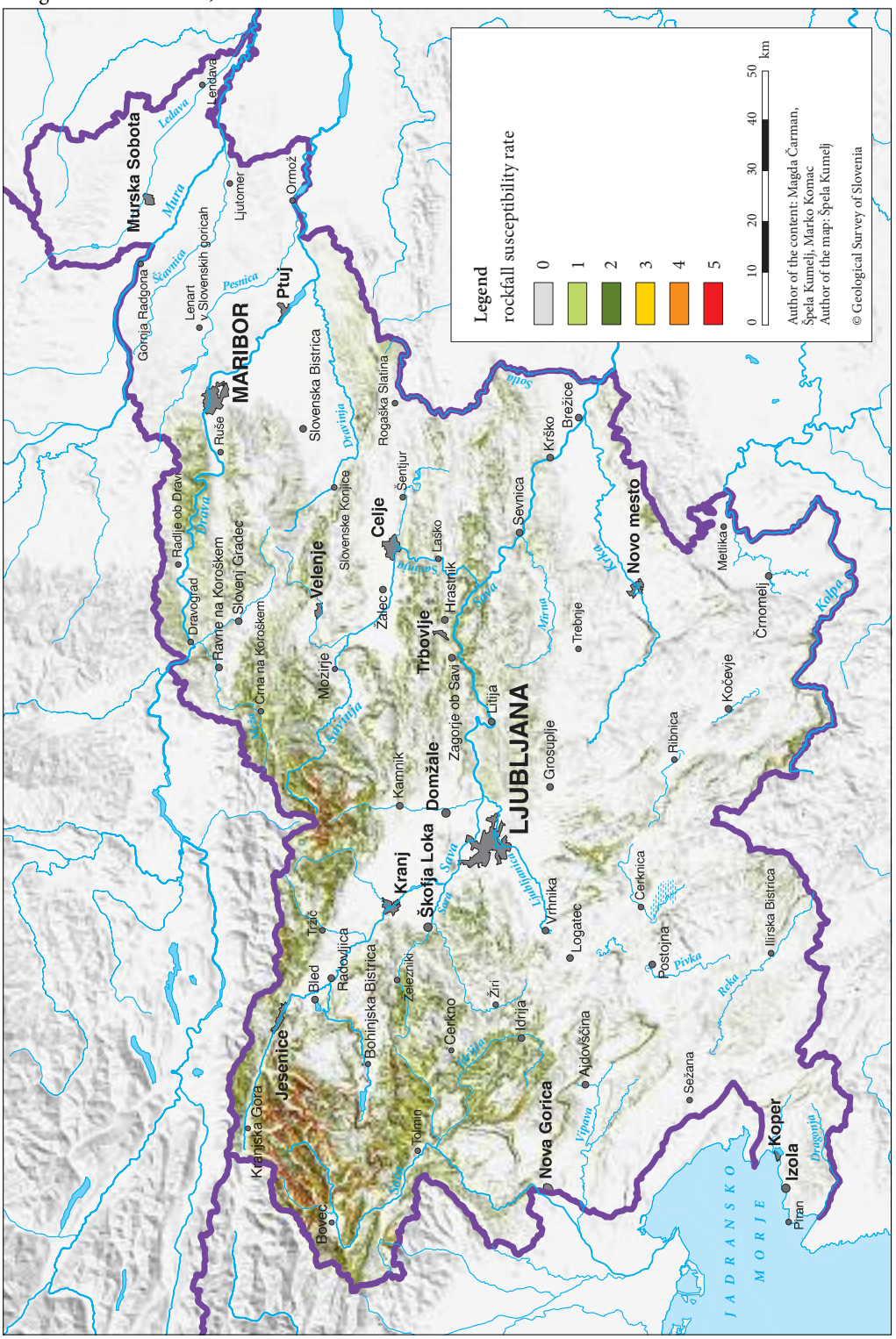
Legend
rockfall susceptibility rate
0
1
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0 10 20 30 40 50 km
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Lendava
Ljutomer
Ormož
Ptuj
MARIBOR
Gornja Radgona
Lenart v Slovenskih goricah
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Črna na Koroškem
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Mozirje
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Zagorje ob Savi
Litija
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Tolminka
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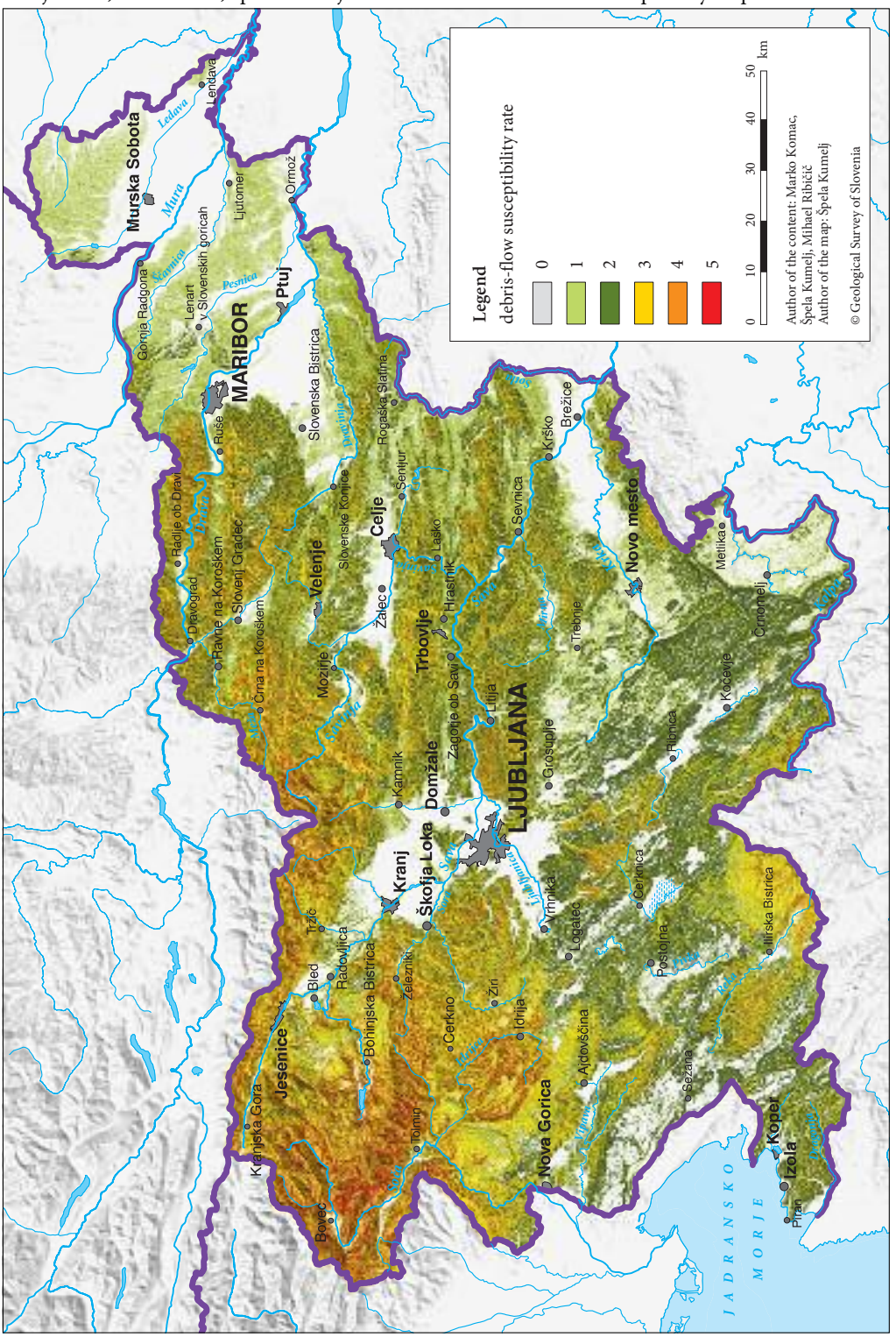
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debris-flow susceptibility rate
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0 10 20 30 40 50 km
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Author of the map: Špela Kumelj
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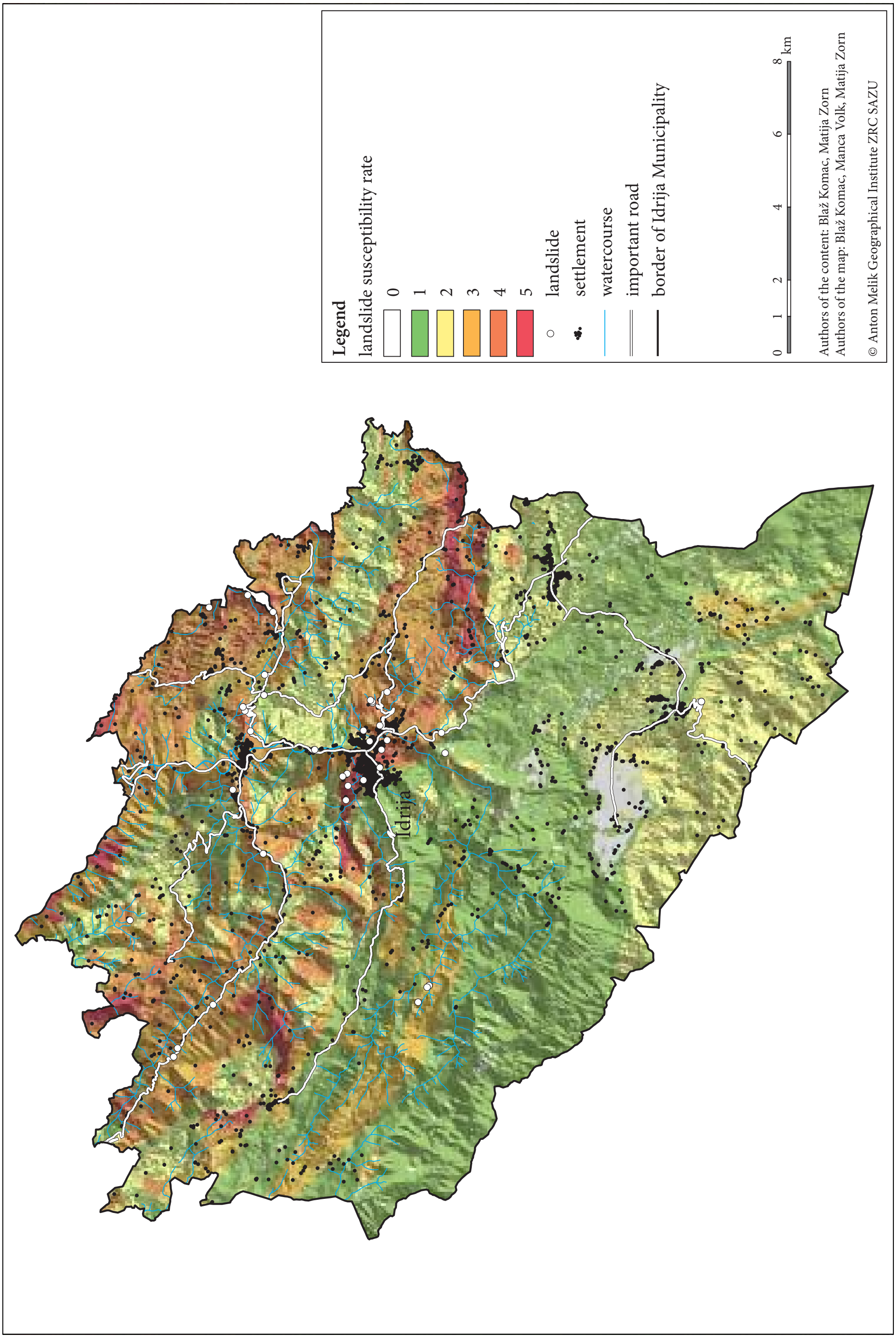
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landslide
settlement
watercourse
important road
border of Idrija Municipality
0 1 2 4 6 8 km
Authors of the content: Blaž Komac, Matija Zorn
Authors of the map: Blaž Komac, Manca Volk, Matija Zorn
© Anton Melik Geographical Institute ZRC SAZU
Idrija

2 Mass movement susceptibility maps in Slovenia

Mass-movement susceptibility maps (Figures 3–6) offer a quick and effective way to determine areas that people should not exploit or where it is known that any development would demand special construction and other measures. In Slovenia these maps are produced using geographical information system methodology, which includes digital elevation models (with 25 × 25 m grid resolution for the national scale, 12.5 × 12.5 m grid resolution for the regional scale, and more detailed grid resolution for the local scale (e.g., a 5 × 5 m grid; e.g., Jež et al. 2011)), several physical geographical landscape elements (e.g., lithology with tectonics, surface inclination, dip of strata, surface derivations (slope, curvature, aspect, energy potential), land use, maximum 24-hour precipitation, distance from watercourses, and the energy potential of the waters), and in the case of landslides also the National Landslide Database. Considering physical geographical landscape elements, the data differ in terms of their presentation method, they can be vector- or raster-based, and they are often not homogenous because they have been collected by various people or institutions that followed the rules or methods selected to varying extents. This can significantly reduce the model's accuracy. Data on actual mass movement (predominantly landslides) are collected in the National Landslide Database (Nacionalna 2006; Komac et al. 2008). This database was established in mid-2005, but unfortunately has not been updated since. It contains information on about 6,602 mass movements (approximately 0.33 per km^2), of which 3,257 are precisely spatially located. The vector data include information about relative location (to roads, buildings) and absolute location (Gauss-Krüger coordinates), information about the width, length, and depth of landslides, and information about their activity. It also includes information about sources of information and damage caused by landslides.

To develop a uniform methodology for producing these types of maps, in the past the Ministry of Defense financed two applied research projects:
1) Methodology for Defining Risk Areas and Dividing Land into Risk Zones (Mikoš et al. 2004);
2) Debris-Flow Risk Assessment (Mikoš et al. 2008).

Because to date a uniform methodology still has not been adopted, the developers of these types of maps have a relatively free hand in selecting the methodology. Given the public procurement rules in Slovenia, where map developers are usually selected only based on the price rather than the effectiveness of methodology, the quality can vary significantly.

In Slovenia deterministic, statistical, and probabilistic methods have already been used to produce landslide, rockfall, or debris-flow susceptibility maps (e.g., Zorn and Komac 2008a; 2009; Ciglič et al. 2010). At the national level, we have already produced susceptibility maps for landslides (Figures 3; e.g., Komac and Ribičič 2008; Zorn and Komac 2008a), rockfalls (Figure 5; e.g., Zorn and Komac 2004, 74; Čarman et al. 2011) and debris flow (Figure 6; Komac, Kumelj, and Ribičič 2010). For developing landslide susceptibility maps, known landslide locations were used for statistical analyses in relation to physical geographical landscape elements (Komac and Ribičič 2008; Zorn and Komac 2008a). In cases of debris-flow and rockfall susceptibility maps, the classification of the physical geographical landscape elements and their weights in the model were chosen on the basis of literature, expert knowledge, and a small number of historical events (because there are no databases on debris-flow and rockfall events; Komac, Kumelj, and Ribičič 2010; Čarman et al. 2011).

These are large-scale maps and therefore they are not suitable for spatial planning at the local level. Unfortunately, there are few municipal maps that are suitable for these needs (Figure 2). The burden of producing these types of maps lies with the municipalities (Zakon o urejanju … 2002), which do not have sufficient funds and knowledge to produce them. The production of municipal susceptibility maps would cost tens of thousands of euros per municipality or more (depending on the size of the municipality; Bukovec 2005, 18; Komac, Pavšek, and Zorn 2007, 263). Of the 212 Slovenian municipalities, to date only a few have funded the production of maps on their own (e.g., Nova Gorica, Jezersko, Tržič, Ptuj, and Vrhnika). In the Municipality of Vrhnika, the cost of map production was estimated at nearly

€ 25,000, or approximately € 220/km^2 (Sprememba … 2009, 10/3). By comparison, in Switzerland the production of a geomorphological processes map alone, which serves as the basis for producing susceptibility maps, costs approximately € 3,000/km^2 (Raetzo 2004).

After the last few natural disasters (e.g., floods and landslides in 2007, 2008, and 2010), the government has also realized that a number of Slovenian municipalities need these types of maps and has thus approved a project for producing mass movement susceptibility maps for fourteen selected municipalities as well as water-erosion susceptibility maps for eleven municipalities, and avalanche susceptibility maps for four municipalities (Figure 2). This value of project is estimated at approximately € 700,000 (Tematsko … 2011, 9), of which approximately two-thirds has been earmarked for mass movement maps. Based on these funds, the average costs of producing mass-movement susceptibility maps are approximately € 34,000 per average size of the fourteen municipalities, or approximately € 230/km^2. With this project, which is planned for completion by the end of 2012, 10% of Slovenia's territory will be covered by these types of maps. Including the maps already produced, one-sixth of the country will be covered by at least one type of mass movement susceptibility map (Figure 2).

3 Conclusion

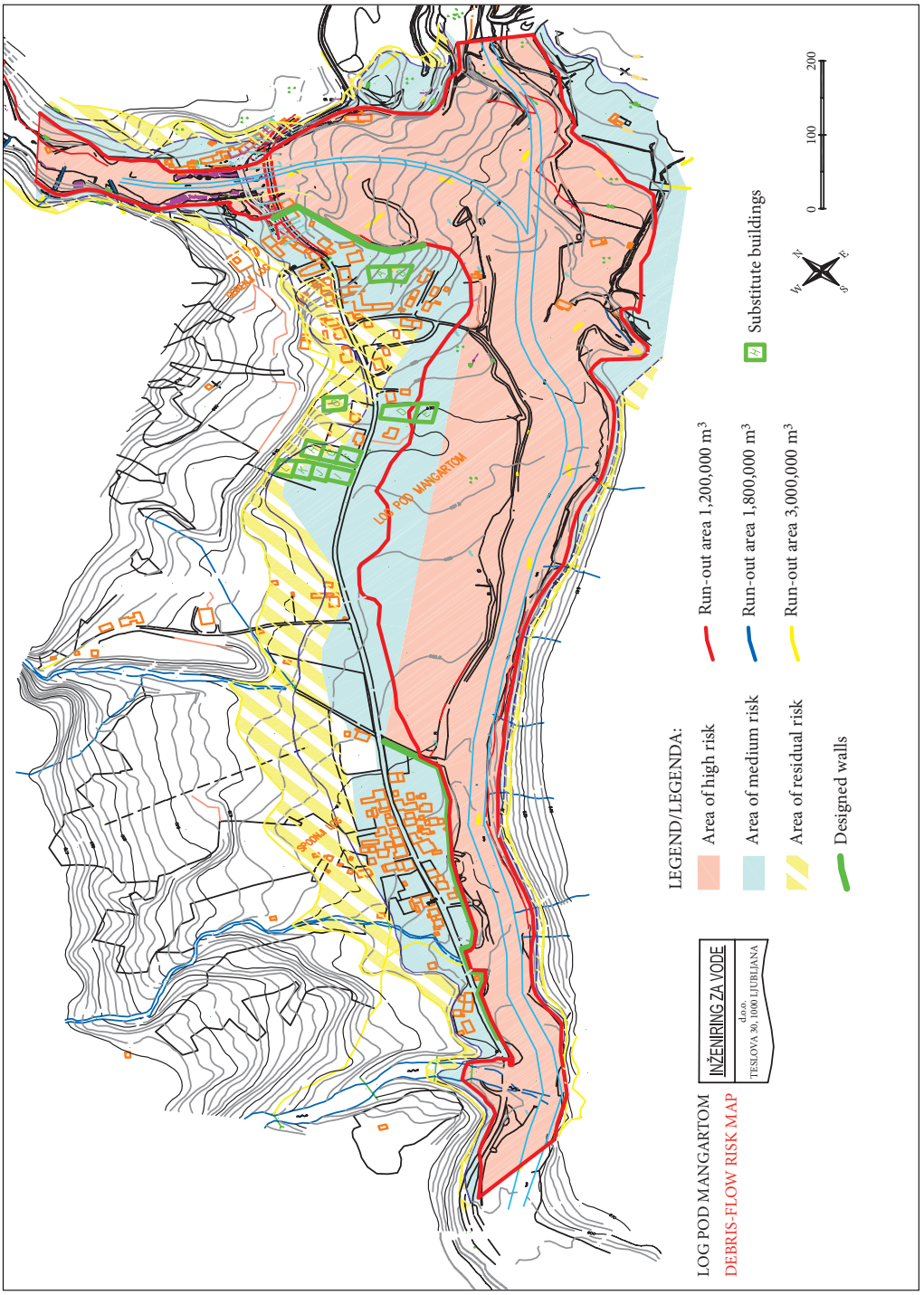
In many Alpine countries, susceptibility maps are one of the basic prevention approaches to managing hydro-geomorphic natural hazards (Komac and Zorn 2005; Zorn and Komac 2006). They show the degree of natural-process hazard or the level of society's threat from them. The better the knowledge of past events in a specific area, the better the maps and the more accurate the assessment of the importance of individual physical geographical landscape elements during the production process.

Modern cartographic methods and geographic information systems can be used to assess the spatial distribution of natural hazard areas with a relatively degree of certainty. The maps enable (depending on the scale) spatial planning at the national, regional, and municipal levels, in which in the long run settlement and other human activities are directed to specific areas and restricted or prohibited in others. However, in Slovenia these types of models are not supported by dynamic elements such those used in weather and water outflow forecasts (Arattano et al. 2010), and also not connected with insurance companies. The only detailed mass movement risk map produced in Slovenia to date that has also taken into account the dynamic elements is the risk map in Log pod Mangartom (Figure 7) after the devastating debris flow in November 2000 (Zorn and Komac 2008b).

Based on the data presented above, in Slovenia the costs of producing mass movement susceptibility maps amount to approximately € 230/km^2. Because landslides threaten approximately 20% of the country's territory (Zorn and Komac 2008), nearly € 1 million would be spent on producing susceptibility maps for these areas alone; this is approximately 1% of the direct damage (€ 99 million; Zorn and Komac 2011) caused by landslides and avalanches in recent years (1994–2008). To include the entire country, one would need a full € 4.5 million, or just under 5% of the direct damage caused by landslides and avalanches in recent years. In (more) landslide-prone areas, the average direct annual damage caused by landslides amounts to approximately € 24,000/km^2, and approximately € 4,800/km^2 for all of Slovenia. In comparison, Siegel (1996) reports that the ratio between the savings due to prevention and the funds invested in recovery ranges from 1 : 10 to as much as 1 : 2,000.

Among other things, Slovenian geographers are striving for these maps to be not only important parts of natural disaster prevention activities, but also part of the society's orientation to both risk management and risk governance, as well as the culture of sustainable coexistence with natural disasters. A great deal about the possible ways society can adapt to natural disasters can already be learned from

Figure 7: Debris-flow risk map of Log pod Mangartom, with run-out areas of debris flows shown, and classification into risk areas, originally given at a scale of 1 : 2,000 (Mikoš, Fazarinc, and Majes 2007, 182). ►


LOG POD MANGARTOM
DEBRIS-FLOW RISK MAP
INŽENIRING ZA VODE
d.o.o.
TESLOVA 30, 1000 LJUBLJANA
LEGEND/LEGENDA:
Area of high risk
Area of medium risk
Area of residual risk
Designed walls
Run-out area 1,200,000 m3
Run-out area 1,800,000 m3
Run-out area 3,000,000 m3
Substitute buildings
0
100
200
N
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LOG POD MANGARTOM
SPODNJA VAS

Slovenian history. In the Alpine regions alone, an entire range of methods and measures is known that not only made it possible for people to live in (sometimes) hostile regions, but also made their lives there considerably easier.

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