17 Natural Hazards in Slovenia

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Abstract

Almost all types of natural hazards that are typical for Europe also occur in Slovenia, with the exception of some major events such as volcanic eruptions or ocean-related natural hazards such as large tsunamis. The greatest economic damage is caused by natural hazards affecting agriculture, such as drought, hail, rainstorms, and frosts. Great damage is caused by floods in settlements and by landslides and avalanches in mountain areas. Periodically earthquakes occur, and heat waves are increasingly frequent. Large differences exist among Slovenian regions with respect to the types and intensity of natural hazards. In the Alpine mountains in the west and north of the country, there are frequent rockfalls, landslides, debris flows, and avalanches. Landslides and torrential floods are characteristic for the Alpine hills in central Slovenia. The Dinaric regions in the south of the country are characterized by flooding of poljes. Fires characterize the Mediterranean landscapes in southwestern Slovenia. The Pannonian lowlands in the southeast are subject to flooding, whereas the drier and agriculturally more intensive Pannonian region in the northeast of the country is most often affected by drought. Seismic hazard is high in the western as well as central and southeastern parts of the country.

Keywords

Geography of natural hazards · Flood · Drought · Landslide · Avalanche · Earthquake · Economic damage

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17.1 Introduction

Slovenia is susceptible to various types of natural hazards (Fig. 17.1; Perko 1992; Komac and Zorn 2007) due to its diverse lithological composition, varied relief (Hrvatin and Perko 2009), different climate types, and high landscape diversity (Ciglič and Perko 2013; Perko et al. 2017). Most common are drought, hail, floods, rainstorms, and landslides, and there are also numerous forest fires, frosts, avalanches, and, in the last two decades, heat waves. Glaze and earthquakes are rarer occurrences (Fig. 17.2).

Natural disasters in Slovenia result in few casualties but considerable damage. Since the second half of the nineteenth century up until the Second World War, natural disasters caused on average 4.7 deaths per year; in the second half of the twentieth century, this number fell to 2.4 deaths per year. Avalanches are responsible for the greatest number of victims, followed by lightning, floods, and rainstorms. Avalanches took over a thousand lives during the First World War alone, and several hundred more in the remaining period. Between the second half of the eighteenth century and the end of the twentieth century, avalanches accounted for more than half of all victims of natural disasters, on average one to two per year (Orožen Adamič 1998a; Pavšek 2002; Malešič 2005).

Between 1991 and 2008, the greatest direct economic damage was caused by drought (27%), followed by hail (18%), floods (16%), rainstorms (14%), and landslides and avalanches (9%). In the same period, the direct damage caused by natural disasters amounted to an average of 0.48% of annual GDP or an average of €45 per capita annually. The greatest amount of direct and indirect damage was caused by the two earthquakes of 1976 (about one tenth of annual GDP) and the floods in 1990 (about one fifth of annual GDP; Table 17.1; Zorn and Komac 2011). In 2017, major natural disasters caused €168.8 million in damage (around 0.12% of annual GDP), of which the most was caused by drought (€65.3 million), floods (€56.3 million) and frost (€46.8

D. Perko et al. (eds.), *The Geography of Slovenia*, World Regional Geography Book Series,
https://doi.org/10.1007/978-3-030-14066-3_17

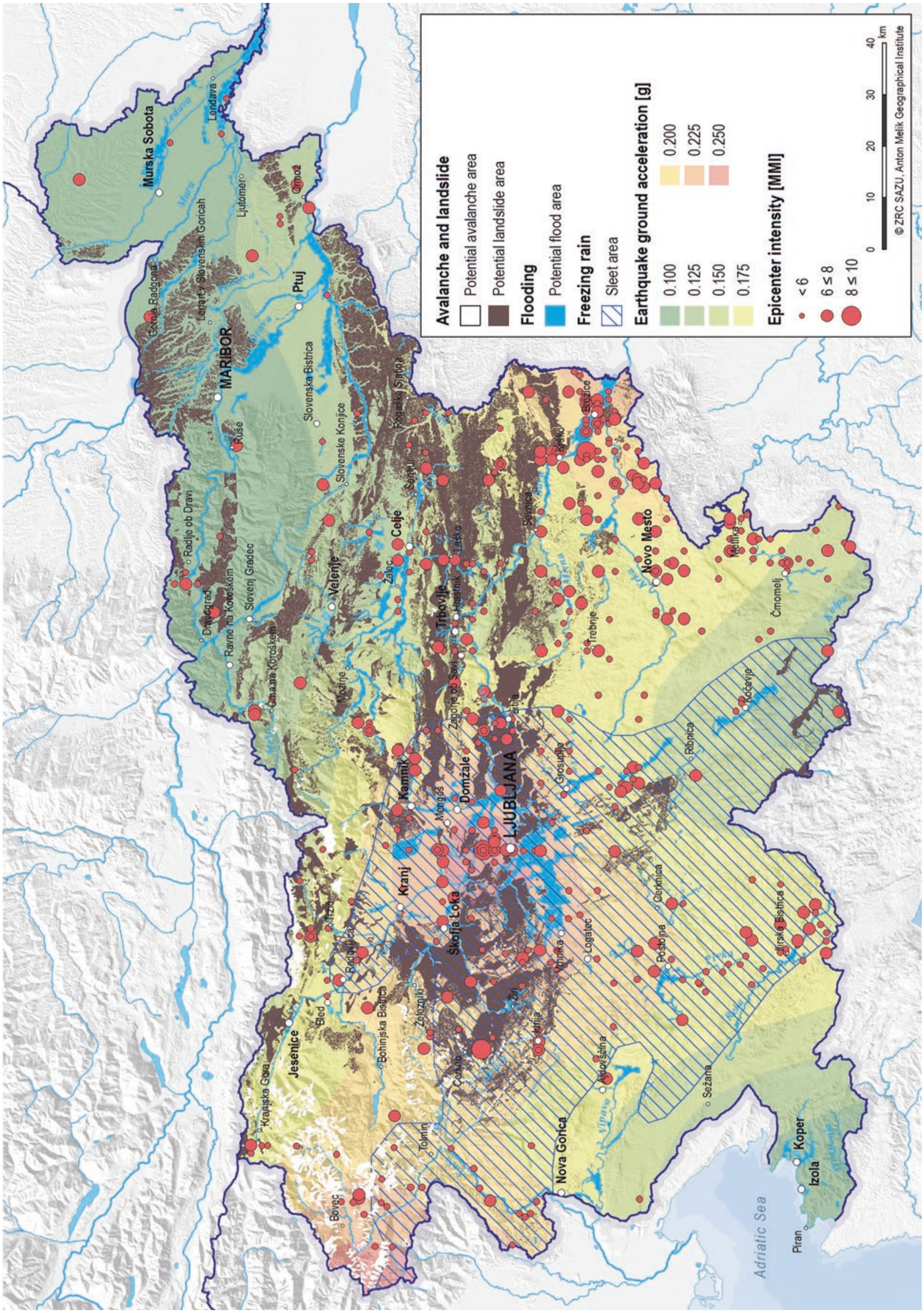

Fig. 17.1 Most frequent natural hazards in Slovenia. (Orožen Adamič 1998b)

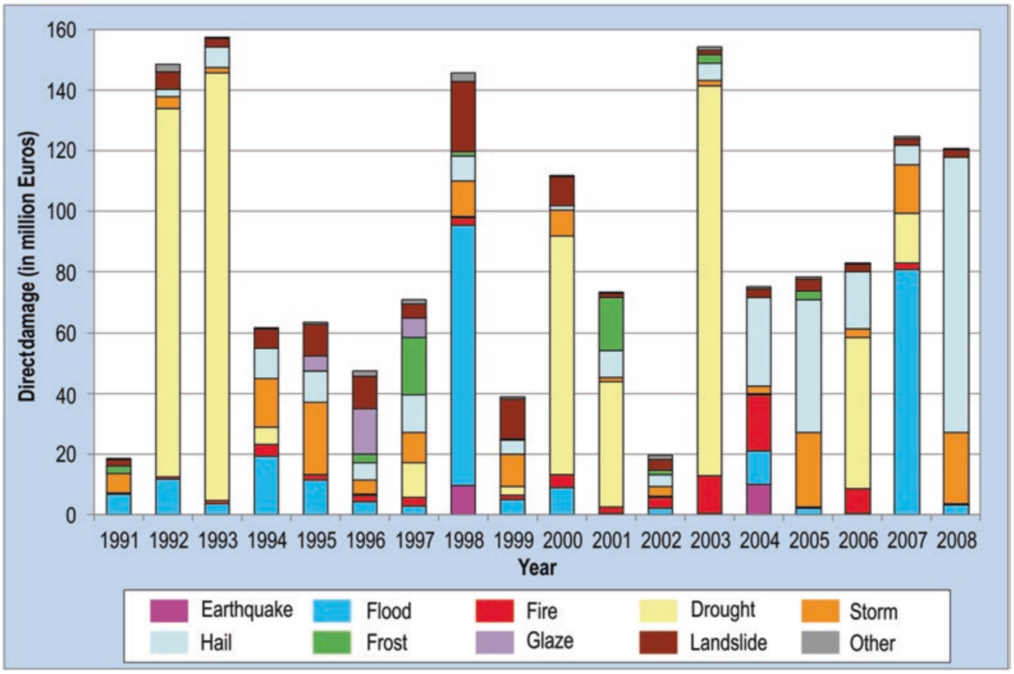

Fig. 17.2 Economic damage due to natural disasters between 1991 and 2008. (Zorn and Komac 2011; Zorn and Hrvatin 2015)

Table 17.1 Natural disasters in Slovenia causing the most direct damage between 1990 and 2014

Natural disaster (year of occurrence)	Direct damage, € million
Flood (1990)	552
Glaze and flood (2014)	430
Flood (2012)	311
Flood (2010)	207
Flood (2007)	187
Flood (1998)	173
Drought (1993)	141
Drought (2003)	128
Drought (1992)	122
Hail (2008)	91
Drought (2000)	79
Drought (2017)	65
Flood (2017)	65
Drought (2006)	50
Frost (2017)	47
Hail (2005)	44
Drought (2001)	42
Flood (1994)	30
Hail (2004)	29

million). That same year, the national government invested about €30 million and municipalities an additional €40 million in preventive measures (But 2018).

There are large differences among Slovenian regions with respect to the type and intensity of natural hazards. The intensity of geomorphological hazards declines from the Alpine west and north toward the Pannonian east and the Mediterranean and Dinaric south. Rockfalls (Zorn 2002), landslides, debris flows (Zorn and Komac 2002), and avalanches (Pavšek 2002) are common in the Alpine ranges in the west and north of the country. Landslides (Zorn and Komac 2008) and torrential floods (Komac et al. 2008) are typical of the Alpine hills of central Slovenia. Lowland floods predominate in the Pannonian plains in the east. Intermittent karst floods characterize the Dinaric landscapes in the south of the country (Komac et al. 2008). Drought most frequently affects the drier and agriculturally more intensive Pannonian regions in the northeast, and fires are a problem in the karst and Mediterranean areas in the southwest of the country. The seismic hazard is high in the west and in central and southeastern Slovenia (Perko 1992).

17.2 Geological and Geomorphological Natural Hazards

Predominant geological and geomorphological disasters in Slovenia are landslides, rockfalls, and debris flows (Komac and Zorn 2007). Between 1991 and 2008, *landslides* annually caused more than €100 million in damage (Zorn and Komac 2011). A maximum daily rainfall exceeding 130 mm can be critical for landslide occurrence, especially in looser soils and less resistant rocks (Komac 2005; Rosi et al. 2016). In areas of high and low hills, more than 7000 landslides have been recorded in the national database of landslides, which occur over an area of roughly 1200 km^2 (Fig. 17.3; Komac and Hribernik 2015); one-fourth of them pose a threat to infrastructure and buildings. They are characteristic

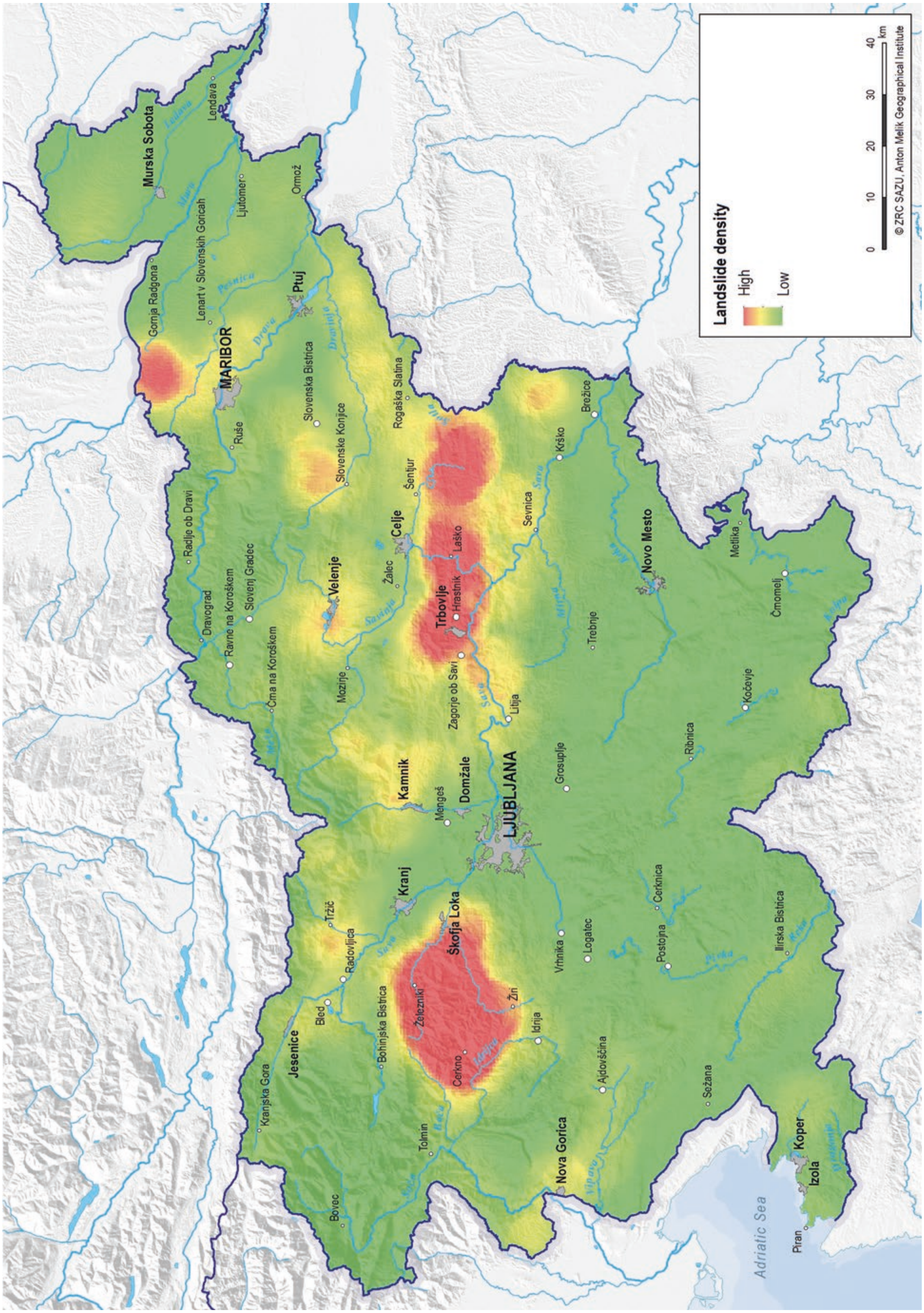

Fig. 17.3 Density of landslides in Slovenia based on the national landslide database. (Zorn and Komac 2008)

Fig. 17.4 In July 1989, when 150 to 200 mm of rain fell a 24-h period, more than 5000 slumps, or 47/km^2, were triggered in the predominantly marlstone area of Haloze low hills in northeastern Slovenia. (Zorn and Komac 2008) (Photo by Milan Orožen Adamič, GIAM ZRC SAZU Archive)

mainly of Alpine hills (e.g., the Škofja Loka, Idrija, Cerkno, Polhov Gradec, and Sava hills) and Alpine mountain ranges, especially the Karawanks, where shale clays and quartz sandstone predominate. Landslides also reshape the relief in the flysch Mediterranean hills of southwestern Slovenia and the marlstone Pannonian low hills of northeastern Slovenia, composed of tertiary rocks, where slumps are common during heavy rainfall (Fig. 17.4). The Dinaric regions of southern Slovenia are less susceptible to landslides due to the presence of limestone and dolomite (Zorn and Komac 2008).

Among major landslides are the Pleistocene landslide near Selo in the Vipava Valley in southwestern Slovenia, with a volume of about 150 million m^3, and a landslide in the region of Ilirska Bistrica (also in southwestern Slovenia), both of which occurred at the thrust contact of carbonate rocks above flysch, and the landslide near Vransko in the Celje Basin in central Slovenia (Zorn 2002; Placer and Jamšek 2011).

Among major landslides in contemporary times, caused for the most part by the contact of an upper layer of carbonate rocks on impermeable ones and triggered by heavy precipitation, are several landslides in the Vipava Valley: the Slano blato Slide in 2000 (700,000 m^3), the Rebernice Slide (400,000 m^3) triggered by construction of the freeway in 2001, and the Stogovce Slide (80,000 m^3) in 2010, which carried off a kilometer of state road (Fifer Bizjak and Zupančič 2009), and the 1990 Macesnik Slide (2,000,000 m^3) in the Upper Savinja Valley (northern Slovenia) with a bridge being built over it. The most destructive of all was the landslide triggered above Log pod Mangartom in the Upper Soča Valley (northwestern Slovenia) in 2000 (1,500,000 m^3), which turned into a debris flow (Fig. 17.7; Zorn and Komac 2002). There was a significant landslide in the Upper Soča Valley above the village of Koseč near Kobarid in 2001 (180,000 m^3), which also led to some small debris flows (Mikoš et al. 2006a).

Instances of landslides in degraded areas are also well known. In 1987 a slide of mine tailings was triggered in Zagorje in central Slovenia (Komac and Zorn 2007).

Rockfalls are common in the mountains of the Alpine and Dinaric regions of western Slovenia (Vidrih et al. 2001; Mikoš et al. 2006b; Komac 2015). The greatest number is in the limestone high-mountain areas of the Julian Alps, the Karawanks, and the Kamnik–Savinja Alps. They are also characteristic of the up to 80-meter-high flysch cliffs along the Adriatic coast (Fig. 17.5; Šegina et al. 2012).

The biggest known example, the Kuntri rockfall, was triggered in the Pleistocene on the southern slope of Mount Polovnik in the Julian Alps and blocked the flow of the Soča River with 200 million m^3 of material for an extended period of time. Other prehistoric rockfalls in the Upper Soča Valley occurred between Kal–Koritnica and the Soča village, near Kobarid and at the confluence of the Soča and Tolminka rivers. In the Upper Sava Valley, rockfalls occurred below Mount Planinski Vrh in the Jesenice area, where there are also a number of erosional hotspots in the dolomite rocks of the Karawanks (Sodnik and Mikoš 2006). Among historical rockfalls, noteworthy is the 100 million m^3 earthquake-induced rockfall on Mount Veliki Vrh in the Karawanks from 1348. Major recent rockfalls are to be found in the Soča Valley on Mount Javoršček and Mount Mangart and in Trenta Valley, and particularly notable are the approximately 100 earthquake-induced rockfalls in the Upper Soča Valley in 1998 (Fig. 17.6; Zorn 2002). Some rockfalls can reach the valley floor and block watercourses, as happened in the Idrijca Valley during the 1511 earthquake, when a rockfall dam caused floods in the town of Idrija (Cecić 2011), in Luče in the Savinja Valley in 1990, and in the headwaters of the Tolminka River above Tolmin in 2004 (Komac and Zorn 2009). Coseismic slope processes are especially characteristic of northwestern Slovenia (Komac 2015). Rarely, rockfalls

Fig. 17.5 The Slovenian coast and swimmers are threatened by frequent slope failures from flysch coastal cliffs; here at cape Debeli rtič in 2013. (Photo by Matija Zorn, GIAM ZRC SAZU Archive)

Fig. 17.6 The earthquake in the Upper Soča Valley on April 4, 1998 (M: 6), triggered a major rockfall (about 1 million m^3) from Mount Krn (2244 m; photo by Matija Zorn, GIAM ZRC SAZU Archive)

threaten buildings and infrastructure; below the rockfall at Trenta in the Soča Valley, a gallery was built to protect the road.

Debris flows were common in western Slovenia at the end of the Pleistocene, in recorded history there is evidence of their occurrence in the settlements of Log pod Mangartom

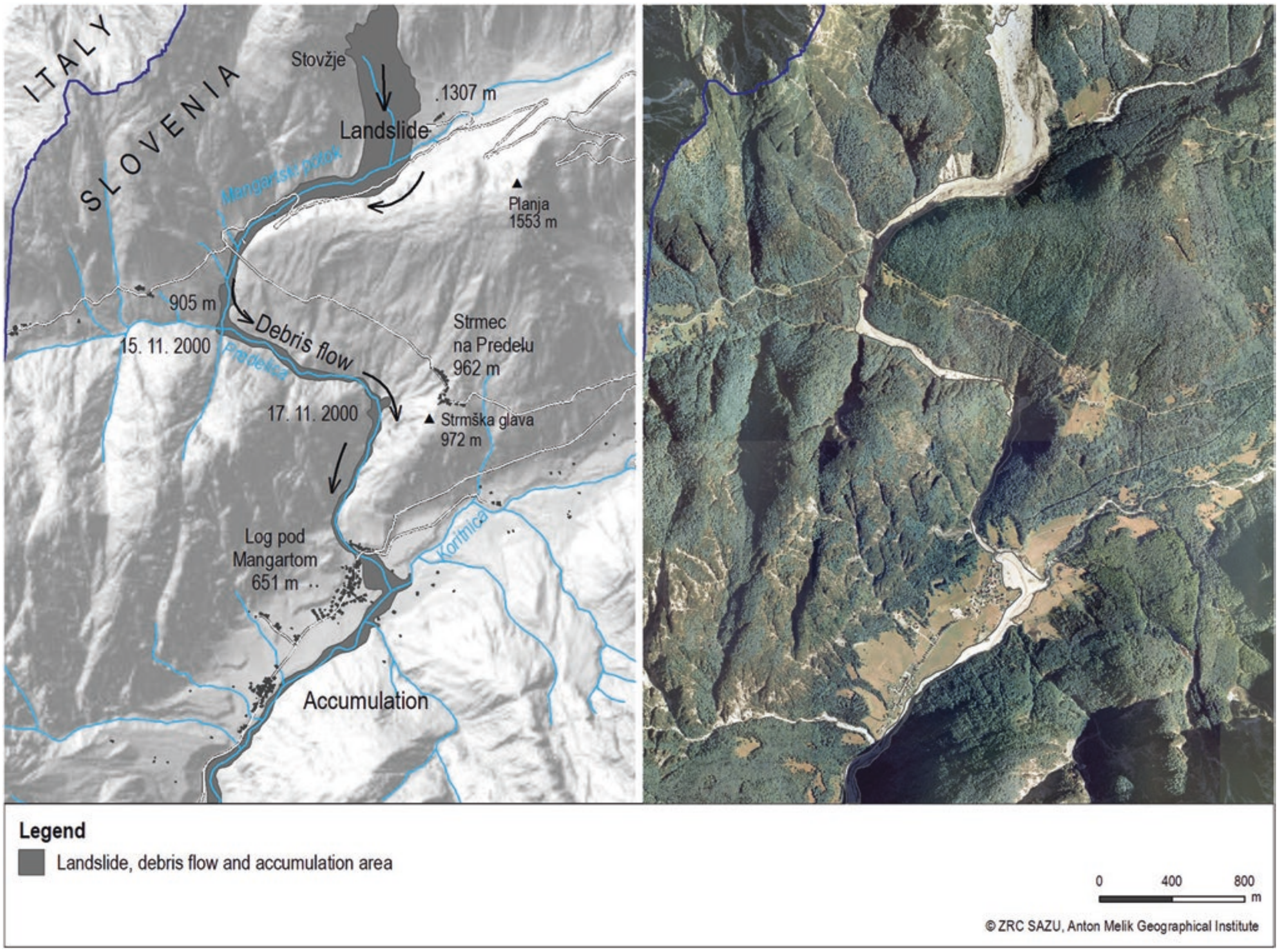

Fig. 17.7 The figure shows an orthophoto (Source: Surveying and Mapping Authority of the Republic of Slovenia 2005) of a debris flow triggered west of Mount Mangart (2679 m) in the Upper Soča region in November 2000 due to heavy rainfall. In November 2000, 1234 mm of precipitation fell in the area, which is roughly half of the average annual precipitation. A debris flow was created from the landslide mass (top: 1,500,000 m^3) that had been triggered at an elevation between 1340 and 1580 m, and the debris flow reached the village of Log pod Mangartom (bottom) at an elevation of 650 m, where it claimed 7 lives, demolished or damaged 18 houses and 8 other buildings, and deposited 700,000 m^3 of material over an area of 15 hectares. It caused €14 million in damage, and the survivors had to be relocated for 3 months. Over the next decade, the village was rebuilt, and with the help of government funding, 15 homes, a debris flow breaker, and 2 bridges were constructed (Zorn and Komac 2002). In the same period, a 50,000 to 80,000 m^3 landslide was triggered from the western slope of Mount Ciprnik (1745 m) in the Planica Valley, which partially turned into a debris flow. It decimated forest and part of the road near the world-famous ski-jumping area in Planica (Mikoš et al. 2007). Several smaller debris flows, up to 1000 m^3 in volume, were also created by the landslide above Koseč. Because they threatened the settlement, a larger bridge was erected in the middle of it (Mikoš et al. 2006a)

and Koroška Bela, and from recent decades three significant cases are known: major events in Log pod Mangartom (Fig. 17.7) and the Planica Valley in November 2000 and a series of small debris flows in Koseč, near Kobarid in the Soča Valley, in 2001. The settlement of Koroška Bela in the Upper Sava Valley is threatened by several landslides in the Karawanks that could turn into debris flows (Jež et al. 2008; Peternel et al. 2017).

Slovenia experiences a mild *earthquake* nearly every day, and the country is frequently affected by stronger ones because it is located at the seismically active southern edge of the Eurasian Plate and at the northwestern edge of the Mediterranean–Himalayan seismic belt. Most earthquakes occur at a depth of 5–15 km. The earthquake hazard is highest in western, central, and southeastern Slovenia, where the projected peak ground acceleration can reach 0.25 *g* (Lapajne et al. 2001). Based on known data, there have been about 60 destructive earthquakes in Slovenian territory up until the present.

An earthquake with an epicenter in Friuli (Italy) in 1348 and a magnitude of 6.5 achieved the strongest effects, with an intensity of X on the EMS-98, in the area of Villach, Austria, not far from the Slovenian border. It damaged many castles, fortresses, and settlements in what is today northern and northwestern Slovenia (Vidrih 2008).

Fig. 17.8 The damaged city center of Ljubljana after the 1895 earthquake. (GIAM ZRC SAZU Archive)

The Idrija earthquake of 1511 with an epicenter in Friuli (Italy) and a magnitude of 6.8 achieved an intensity of X. Due to numerous descriptions of injuries from Idrija with its world-known mercury mine, its epicenter was at first placed in the area of Idrija, and so it was called the Idrija earthquake (Ribarič 1979; Camassi et al. 2011).

The Ljubljana earthquake of 1895 with a magnitude of 6.1 and intensity of VIII to IX claimed ten lives. A tenth of the city's buildings had to be razed due to damage (Fig. 17.8). One positive effect of the earthquake was the urban renewal of Ljubljana and the establishment of a seismological service in the Austro-Hungarian Monarchy, as part of which the first earthquake observatory in Austria-Hungary was set up in Ljubljana in 1897 (Vidrih 2008).

There followed earthquakes in Brežice (1917; M: 5.7), Ilirska Bistrica (1956; M: 5.1), and Litija (1963, M: 4.9). An earthquake in the Kozje region (in eastern Slovenia) in 1974 with a magnitude of 5.1 and intensity of VII to VIII damaged 5300 buildings and affected 15 thousand people (Vidrih 2008).

The two 1976 Friuli earthquakes, the first with a magnitude of 6.5 and intensity of IX to X and the second with a magnitude of 6.1 and intensity of VIII to IX, with their epicenter in the Venzone area in Italy, claimed 990 lives in Italy and 157,000 people lost their homes. In Slovenia the toll was 1 dead and 31 injured. A total of 10,552 buildings were damaged (Cecić 2016) and 13,000 people lost their homes (Orožen Adamič and Hrvatin 2001). The same area of northwestern Slovenia was hit again by an earthquake in 1998 with a magnitude of 5.7 and intensity of VII to VIII (Fig. 17.6) and one in 2004 with a magnitude of 4.9 and intensity of VI to VII (Kastelic et al. 2008; Vidrih 2008). These last two earthquakes caused 18% (in 1998) and 13% (in 2004) of the total damage caused by natural disasters in Slovenia as a whole (Zorn and Komac 2011).

The Slovenian construction profession applied the experience gained from earthquakes in Skopje, Macedonia, in 1963; Banja Luka, Bosnia and Herzegovina, in 1969; the Kozje region in 1974; Friuli in 1976; and the Upper Soča Valley in 1998 and 2004 to the post-earthquake reconstruction of stone buildings (Benedetti and Tomaževič 1984; Tomaževič and Lutman 2007).

17.3 Hydrological Natural Hazards

The flooding of major rivers in Slovenia threatens an area of about 500 km^2, which is roughly 2.5% of the country's territory. Torrential flooding and lowland flooding occur as well as flooding of poljes, and Slovenia also experiences coastal, urban, and artificial floods (Natek 2005).

About 7.3% of the population of Slovenia lives in flood-prone areas, with the greatest proportions living in the Savinja River drainage basin (12.9% of the population of that area), in Carinthia (11.6%), in the Central Sava Valley (10.3%), and in central Slovenia (9.3%; Komac et al. 2008).

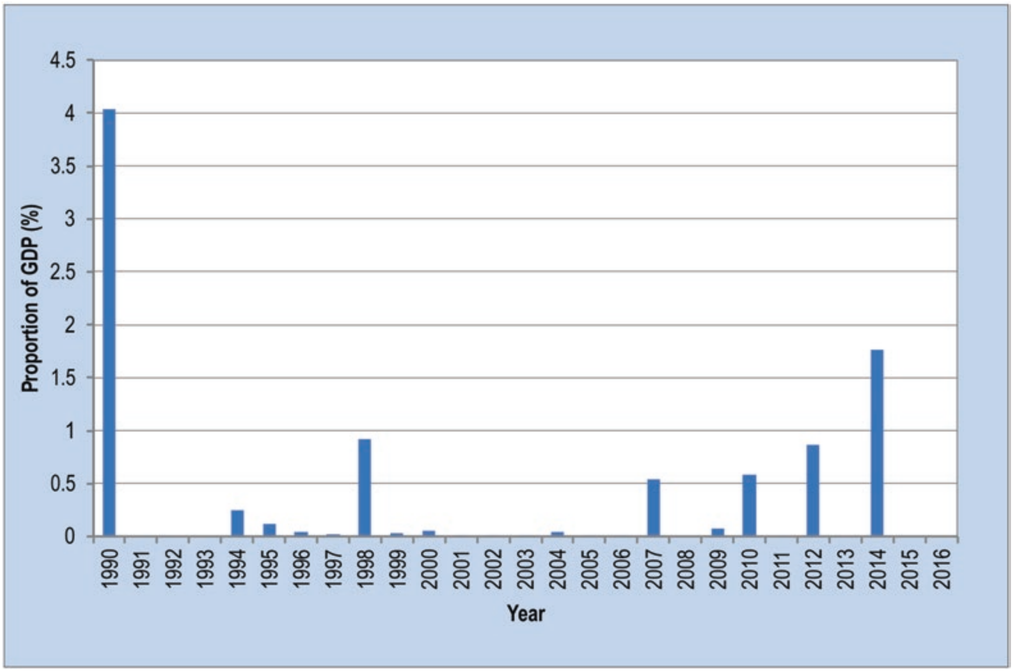

Fig. 17.9 Direct damage due to floods from 1990 to 2015 as a proportion of GDP (%). (Ocena … 2015)

On average, about €14 million in damage per year was caused by floods from 1991 to 2008 or 16% of the total damage caused by natural disasters in this period (Zorn and Komac 2011). The greatest damage was caused in the drainage basin of the Savinja in 1990 (more than €500 million in direct damage), and in the last decade direct economic damage exceeded €200 million on three occasions (2010, 2012, and 2014; Table 17.1, Fig. 17.9).

Overbank floods occur during high river discharges resulting from heavy precipitation in autumn or melting of snow in spring (Hrvatin 1998). At present they only rarely extend over large areas of flood plains because they were artificially reduced by extensive regulation and melioration of the majority of rivers in the twentieth century (Komac et al. 2008). In the past, flood plains were uninhabited rich ecosystems of wetlands, but they later became farming and urbanized areas (Fig. 17.10) that need suitable flood protection measures (Natek 1992). In order to mitigate overbank floods, levees were often artificially raised.

Overbank floods affect a large part of the country and typically occur in plains in the lower reaches of major rivers such as the Ljubljanica, Savinja, Krka, Drava, Mura, and Sava, as well as along smaller rivers such as the Gradaščica, Pšata, and Kamniška Bistrica near Ljubljana, the Pesnica and Ledava in eastern Slovenia, and the Vipava in the southwest (Komac et al. 2008).

The largest flood-prone areas are the Ljubljana Marsh (80 km^2), along the Dravinja (66.5 km^2) and the Krka (62 km^2) and along the lower reaches of the Savinja, Sava, Sotla, and Kolpa rivers and in the Cerknica Polje. Since the beginning of the twentieth century, there have been major lowland floods in 1901 (all of Slovenia), 1910 (Drava River), 1923 (Soča, Sava, and Savinja rivers), 1925 (Mura River), 1926 (Ljubljanica and Savinja rivers), 1933 (Sava and Savinja rivers), 1954 (Savinja River), 1972 (Mura River), 1990 (Savinja River), 1998 (Sava River), 2000 (Savinja River; Polajnar 2002), 2004 (Bač Rivera), 2005 (Sava River), 2007 (Sora River), 2010 (Ljubljanica River), 2012 (Drava River), and 2014 (Ljubljanica and Mura rivers).

Torrential floods are characteristic of mountainous and hilly areas (Fig. 17.11) and upland areas with a preponderance of narrow valleys. Of 27,000 km of watercourses in Slovenia, a third are torrential ones that appear occasionally. They are important because they threaten 237,000 hectares of land, or about 12% of the country's territory. Along the Dragonja and Drnica rivers in the Mediterranean hills in the southwest, the valley floors are sparsely settled and torrential floods do not cause a considerable damage (Zorn 2008). In the Julian Alps, torrential floods are limited to the steepest mountain slopes (Kolbezen 1996). In the Karawanks, torrential floods are typically frequent along torrential streams such as the Belca, causing damage in the newer parts of settlements and to infrastructure (Komac et al. 2008). In hilly central Slovenia, with the Sora and Savinja rivers, traditional settlement retreated to higher fluvial terraces and inactive alluvial fans in order to avoid torrential floods, but today these valley floors are densely settled (Meze 1991; Natek 1992; Trontelj 1997; Komac et al. 2008). In the northeast, torrential floods are common in the Slovenian Hills and Haloze Hills, and in the north they are limited to the Pohorje

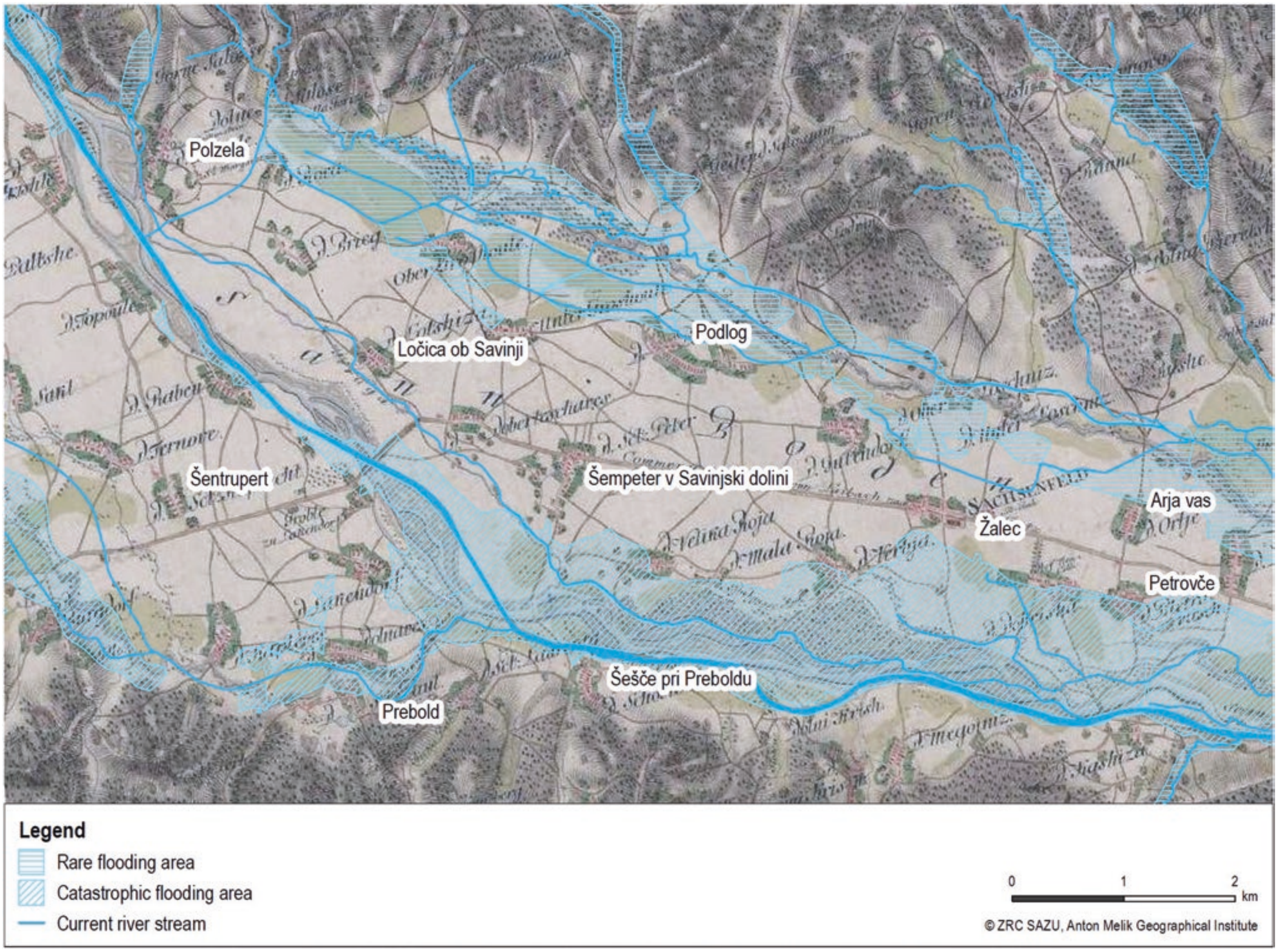

Fig. 17.10 The Lower Savinja Valley between Prebold and Žalec (central Slovenia) on a Habsburg military map from the second half of the eighteenth century. A number of former side channels of the Savinja can be seen on the old map, with the present channelized riverbed of the Savinja added. Former side channels coincide with the former flood area and show that settlement has come too close to the river. (Zorn 2017)

and Kozjak Hills, where the greatest torrential river is the Mislinja (Gams 1991). In the southeast, torrential floods occure in the Gorjanci Hills (Tičar et al. 2018).

Coastal floods are fairly common in the autumn months, when storm waves develop due to the combined influence of winds, low air pressure, and tidal bores, and bring flooding to the lower-lying parts of coastal towns. Annual floods affect about 1% of the territory of coastal municipalities and extreme events about 4%. Extreme floods in the Municipality of Piran affect about a sixth of the territory. Between 1963 and 2003, the sea caused limited flooding on 256 occasions, and in 1967, 1970, 1980, 1981, 1983, 1987, and 1994, floods were quite extensive (Robič and Vrhovec 2002; Kolega 2006). Despite the seismic hazard, major tsunamis caused by earthquakes are unlikely in the Adriatic Sea; however, in narrow bays there sometimes occur meteotsunamis, which are created at times of rapidly changing air pressure, and these cause damage.

Karst floods are a distinctive phenomenon on poljes in the Dinaric karst region in southern Slovenia. They occur where the karst aquifer groundwater level rises above the elevation of the polje floor and percolates slowly through hundreds of cracks and voids in the floor and rim of the poljes. A unique trait of karst floods is the clarity of water due to the low sediment load, creating transparent intermittent lakes that last for several weeks or even months (Komac et al. 2008; Ferk 2016). In their normal extent karst floods are not categorized as natural disasters because they do not threat settled areas (Fig. 17.12), but during the highest water levels, they may reach to the edges of some settlements (Stepišnik et al. 2012). The most typical periodically flooded poljes are the Planina (Fig. 17.12), Cerknica, Lož, Račna (*Radensko*), Ribnica, and Kočevje poljes (Komac et al. 2008). Since 2000 there have been major flood events in 2000/2001, 2008/2009, and 2014 (Frantar and Ulaga 2015).

Fig. 17.11 Impact of a torrential flood in the Davča Valley (Škofja Loka Hills) in 2007. (Photo by Matija Zorn, GIAM ZRC SAZU Archive)

Fig. 17.12 Normal annual flooding in poljes does not threaten settlements. A normal annual flood in the Planina Polje. (Photo by Miha Pavšek, GIAM ZRC SAZU Archive)

Avalanches are in first place in Slovenia with respect to the number of victims claimed by natural hazards. They occasionally cause damage to forests, roads, and buildings. There are about 1000 areas in Slovenia that are identified as having a high avalanche hazard (Pavšek 2002; Volk Bahun 2016).

The worst avalanche disaster took place in 1916, during the construction of the military road across the Vršič Pass (Julian Alps, 1611 m) during the First World War, claiming about 250 victims (Pavšek 2002). The first extensive study of avalanches in Slovenia (Gams 1955) took place following two extremely snowy winters that took the lives of a number of victims and caused enormous damage at the beginning of the 1950s, and a comprehensive study of the problem was produced half a century later (Pavšek 2002). The most recent extensive avalanches occurred in 2006, when a number of them also caused damage in the floors of major valleys such as the Logar Valley (*Logarska dolina*) and Makek Cirque (*Makekova kočna*) in the Jezersko area.

17.4 Meteorological Natural Hazards

The greatest damage from natural disasters is caused by *drought*. It occurs most frequently in Pannonian, Mediterranean, and Dinaric regions, with the first two also being regions with intensive agricultural production (Pavlič 2013; Sušnik et al. 2014). From 1991 to 2008, it caused direct damage totaling €600 million, or more than a third of all damage caused by natural disasters in the country. Extreme droughts occurred in 1961, 1968, 1971, 1978, 1980, 1983, 1992, 1993, 2000, 2001, 2003, 2006, and 2007 (Matajc 2002; Zorn and Komac 2011).

Drought is often accompanied by *heat waves*. Average temperatures in Slovenia have been rising over the last half century (Tosić et al. 2016), and the number of hot days is also increasing. Severe temperature extremes were recorded in 2003 and 2013. There were three heat waves in Slovenia in 2013, with a corresponding increase in mortality (Hojs et al. 2015), and there were also more deaths than expected during the 2003 heat wave (Šelb Šemerl and Tomšič 2008). The phenomenon is especially pronounced in cities (Zalar et al. 2017) due to urban heat islands (Komac and Ciglič 2014; Komac et al. 2017).

Rainstorms are particularly common in Slovenia along the Alpine–Dinaric mountain barrier. The region of the Ljubljana Basin and the Kamnik–Savinja Alps is among the stormiest areas of Europe, with about 100 rainstorms per year, a consequence of the extreme heating of the air on the plain of the Ljubljana Basin in summer. Extreme and stormy winds with abundant precipitation, hail, and rainstorms with blasts of wind cause downing of trees and property damage in the amount of €10 million annually. Between 1991 and 2008, rainstorms associated mainly with the passage of cold fronts and storm clusters caused €173 million in damage, with the annual damage exceeding €20 million in 1995, 2005, and 2008. Especially noteworthy are the tornado near Vrhnika in 1986 (Trontelj and Zupančič 1987), the downing of trees due to wind on the Jelovica Plateau in 2006 (Klopčič et al. 2010), and the gusting winds that hit the eastern part of the Ljubljana Basin in 2008. Rainstorms are accompanied by *strong winds* such as the sirocco and bora in the southwest of the country, by *lightning strikes*, which are common along the Alpine–Dinaric mountain barrier, and by *hail*, which is very unevenly distributed. There are between 30 and 50 days per year in Slovenia with hail (Sušnik 2002). Hail caused €270 million in damage between 1991 and 2008. In 2004 the level reached €29 million, in 2005 €44 million, in 2006 €19 million, and in 2008 as much as €91 million in damage.

Frost causes damage in the agricultural southwestern and southeastern parts of Slovenia, particularly to fruit production and viticulture. Frosts are typical for the period between October and May and were especially severe in 1977, 1988, 1985, 1994, 1997, and 2001. Between 1991 and 2008, they caused a total of €50 million in damage, with the greatest amounts in 1997 (€19 million) and 2001 (€17 million).

Glaze causes damage primarily to forests and infrastructure in the Dinaric Alps in southwestern Slovenia (Vrhovec and Kastelec 2002). Particularly noteworthy are the years 1995, 1996, and 1997 (Zorn and Komac 2011) and above all 2014, when 51% of Slovenia's forests were affected and, along with accompanying floods, suffered €430 million in damage. About 250,000 people were left without electricity; in the town of Postojna (population 9000), the outage lasted over a week, rail traffic between Ljubljana and Koper was halted for an extended period, and 21 people lost their lives in forestry accidents in the aftermath (Beguš 2015).

Fires in Slovenia most threaten the karst Mediterranean areas in the southwestern part of the country. These areas experience frequent droughts and strong winds (the bora). The cause for roughly half of fires is unknown, and for the other half, human carelessness is generally at fault (Jakša 1997).

Fires are most frequent in February and March and in July and August. People have increased the threat of fires by planting Austrian pine (*Pinus nigra*) and Scots pine (*Pinus sylvestris*; Jakša 2002; Šturm 2017). A great deal of damage was caused by fires in 2003 and 2004, and altogether fires caused €68 million in damage (€4 million annually) between 1991 and 2008 (Zorn and Komac 2011).

17.5 Conclusion

Based on the variation coefficient of the cost of damage by natural disaster between 1991 and 2008 (Zorn and Hrvatin 2015), it was determined that most predictable damage was caused by windstorms, landslides, and avalanches because they occurred every year, but such damage was never extremely high. Somewhat less predictable was the damage caused by fires, hail, and drought. In general, these disasters occur every year, but their intensity can vary greatly. They can cause tens of millions of euros of damage in individual years. Even less predictable are floods and frost, which can be less significant and cause little damage for several years in a row, but strike extensive areas severely in a specific year. Ice storms and earthquakes vary the most. Glaze and strong earthquakes occur fairly rarely, but when they do their impact

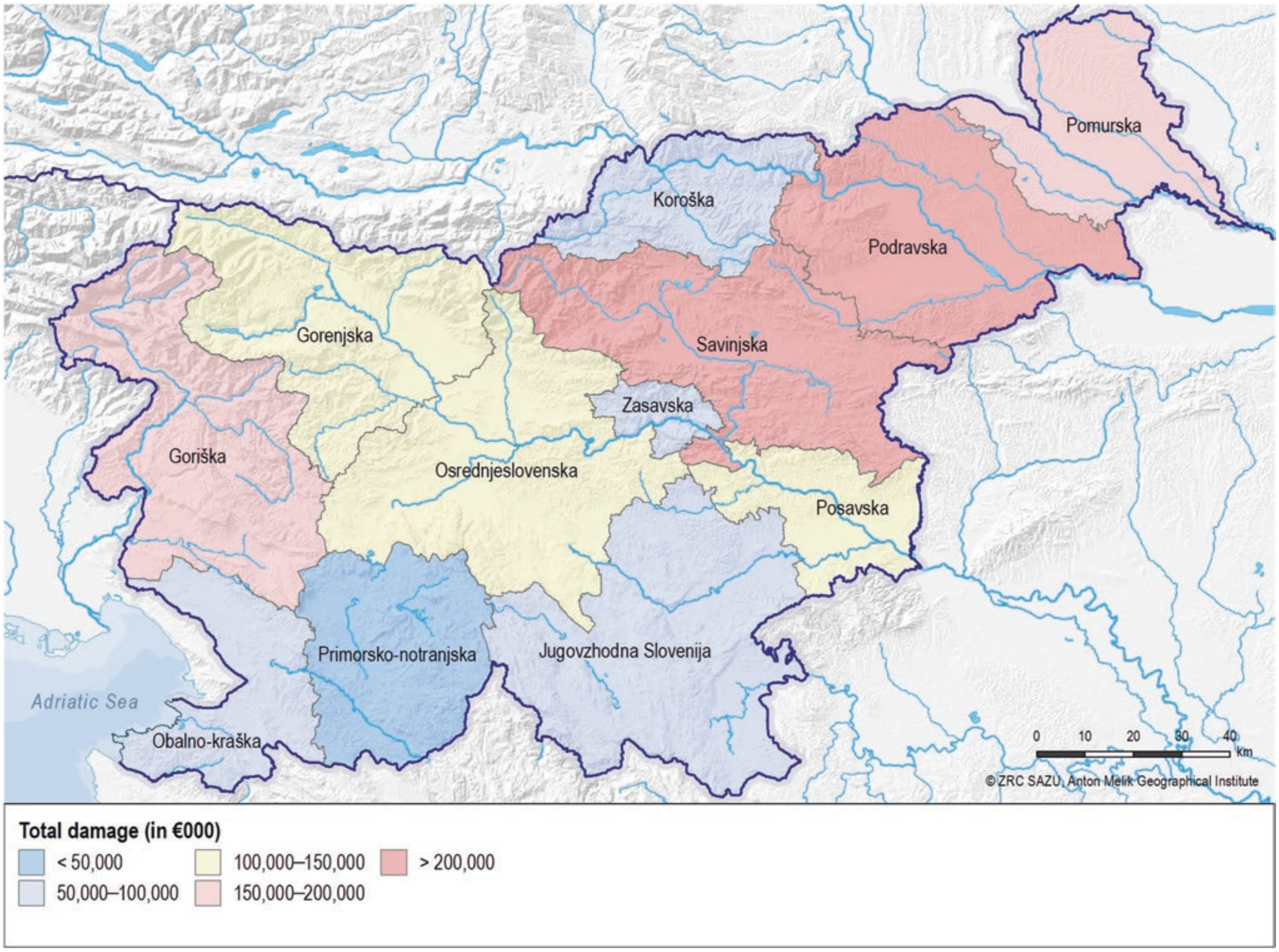

Fig. 17.13 Total damage caused by natural disasters by statistical region (EU NUTS-3 regions) from 1992 to 2008. It is evident that the statistical regions in northeast Slovenia (the Savinja (*Savinjska*), Drava (*Podravska*), and Mura (*Pomurska*) statistical regions) recorded the greatest damage. In western Slovenia, only the Gorizia (*Goriška*) Statistical Region is included in the top class. Considering that drought was the most frequent natural disaster, this kind of distribution across the most important agricultural statistical regions was expected. Moderate damage was recorded in central Slovenia (the Ljubljana Basin, Central Slovenia (*Osrednjeslovenska*), and Central Sava (*Zasavska*) statistical regions), and the least damage was recorded in the Dinaric and certain Alpine areas, where arable farming is only a secondary activity. (Zorn and Hrvatin 2015)

is great and extended recovery is required. Moreover, the damage varies significantly between individual Slovenian regions (Figs. 17.13, 17.14 and 17.15).

Especially meteorological disasters as well as landslides are often ascribed to climate change, but in Slovenia there are other often social reasons that are more important in reducing society's resilience to natural hazards (Kuhlicke et al. 2011; Komac and Lapuh 2014; Zorn and Komac 2015; Komac 2017):

– Inadequate spatial planning; for example, urbanization of hazardous areas (Figs. 17.16 and 17.17). Only a few municipalities have susceptibility maps for various natural hazards.
– Lack of supervision; for example, low quality of post-earthquake reconstruction revealed in a subsequent earthquake.
– Insufficient insurance policies; for example, insurance against natural hazards is not obligatory.
– A mix of politics and capital influences because, despite laws prohibiting the practice (e.g., the 2002 Waters Act (Zakon o vodah 2002) and the 2007 Spatial Planning Act (Zakon o prostorskem … 2007)), one finds hundreds of instances of legally built new buildings in hazardous areas.

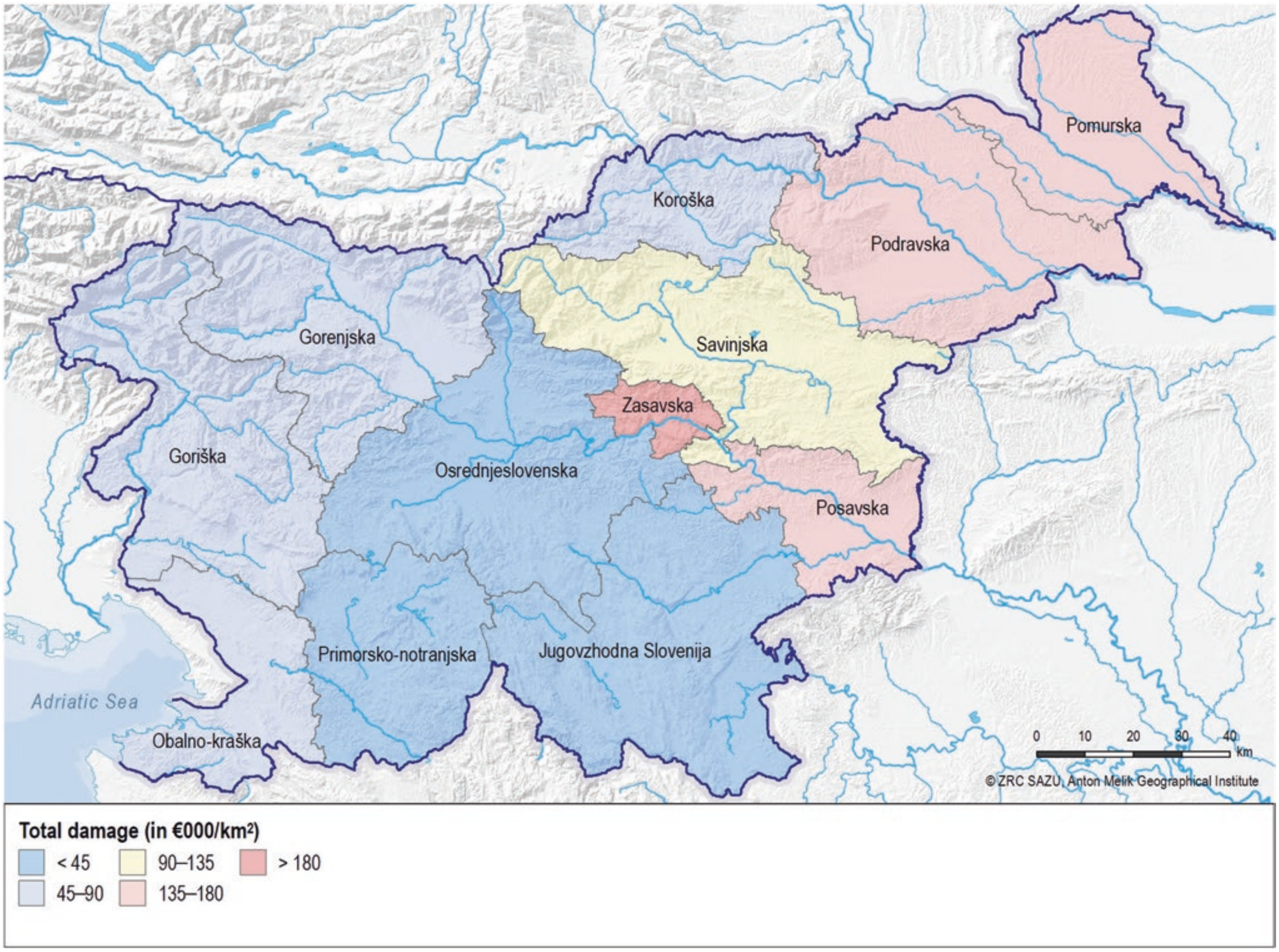

Fig. 17.14 Total damage caused by natural disasters per km² of statistical region, 1992–2008. This map, too (perhaps even more than Fig. 17.13), highlights the damage caused by drought in the most important arable farming areas in Slovenia. In every statistical region of eastern Slovenia, this damage exceeded €130,000/km², and a large part of western and central Slovenia recorded damage below €60,000/km². The least damage, barely €16,000/km², was recorded in the predominantly wooded and sparsely populated Dinaric region. (Zorn and Hrvatin 2015)

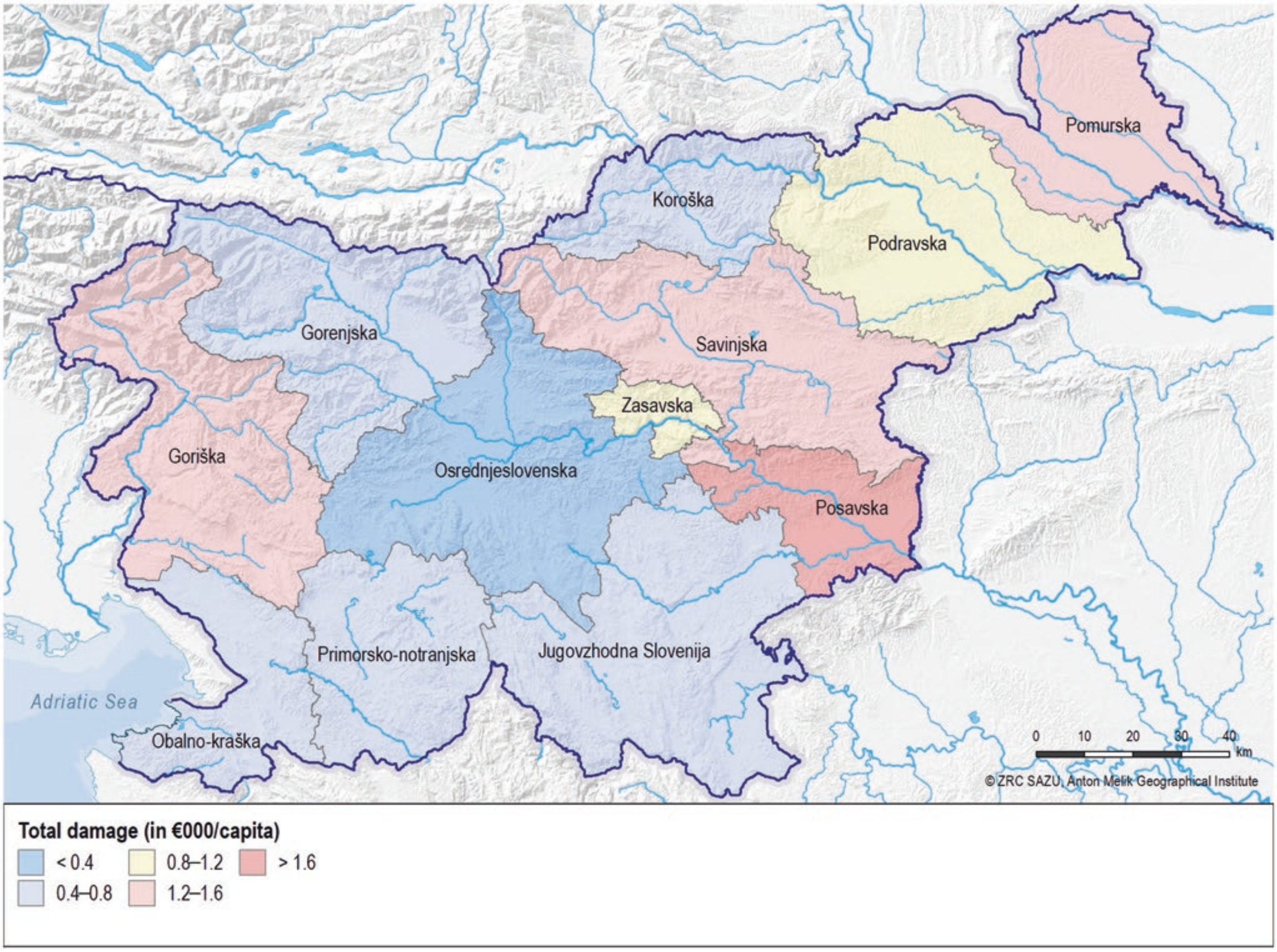

Fig. 17.15 Total damage caused by natural disasters per capita by statistical region, 1992–2008. Also in this case, the highest classes with damage exceeding €1000 per capita include the statistical regions in northeast and eastern Slovenia (the Mura (*Pomurska*), Drava (*Podravska*), Savinja (*Savinjska*), Central Sava (*Zasavska*), and Lower Sava (*Posavska*) statistical regions). Another statistical region highlighted on the map is the sparsely populated Gorizia (*Goriška*) Statistical Region, which was affected the most by multiple earthquakes, and not drought. Due to the moderate damage suffered and fairly high population density, the Central Slovenia (*Osrednjeslovenska*) Statistical Region is in the lowest class, with damage of €224 per capita. (Zorn and Hrvatin 2015)

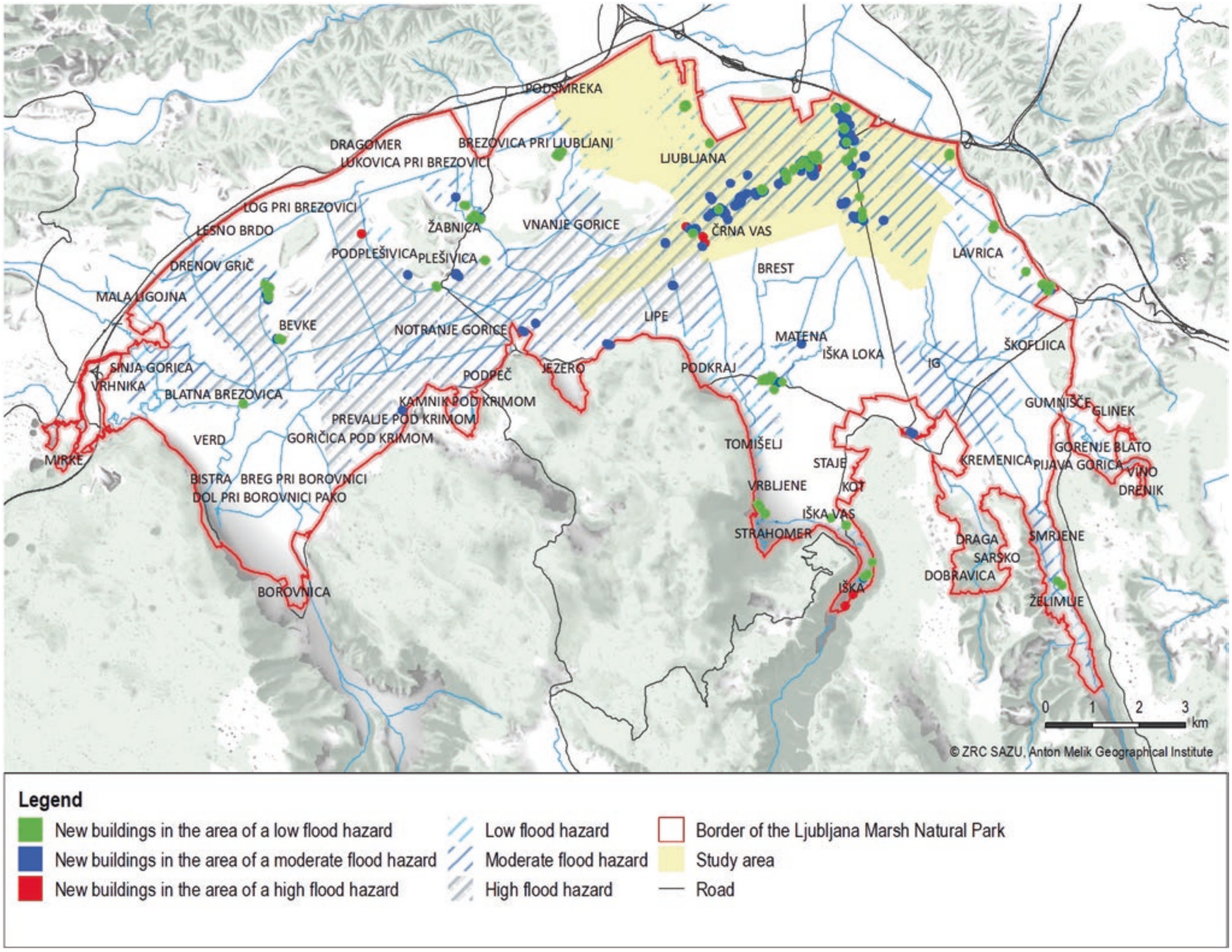

Fig. 17.16 New construction between 2003 and 2015 in flood-prone areas of the Ljubljana Marsh. Due to its proximity to Ljubljana, good transport connections, and natural environment, the Ljubljana Marsh is an attractive place of residence. New construction is rare in areas with a high flood hazard, but for this reason all the more common in areas with a moderate or low flood hazard. The value of new construction in flood-prone study area is estimated at €22 million, occupying an area of nearly 20,000 m^2. Unfortunately, the case of the Ljubljana Marsh is not an exception because one can find similar cases in numerous flood-prone areas around Slovenia. (Goluža and Zorn 2017)

Fig. 17.17 Flooding in September 2010 affected new construction in the Ljubljana Marsh. (Photo by Miha Pavšek, GIAM ZRC SAZU Archive)

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