Summary

The stark diversification of mountainous landscapes is the result of intense geological and geomorphic processes in the past – processes that continue uninterrupted to this day. On the steep slopes of Jezersko, very dynamic geomorphic processes are in action, from accumulation of rock fragments on screes to rockfalls and avalanches. Large amounts of rubble and other material are transported further by torrents and debris flows, and deposited in lower lying areas. These processes occasionally take place very violently and can endanger people and their property, which is why in the past people tried to avoid these dangers as much as possible by carefully choosing safe locations for settlements. This is clearly reflected in today's cultural landscape, and this approach must be preserved going forward.

Whilst we often do not even notice, very intense processes of surface transformation are underway in mountainous landscapes. Occasionally, destructive natural forces are unleashed, that can be extremely violent and cause damage, although natural systems themselves act to mitigate and reduce these forces. Forests play a key role in reducing them, as they slow down precipitation runoff on steep slopes, bind soil layers with their roots, and also serve as a barrier halting avalanches that develop on higher exposed slopes. In spite of this, each year natural denudation and erosion processes transport huge quantities of rocky debris from every square kilometer of surface area. Watercourses, which in mountainous landscapes have a markedly torrential character, contribute most significantly in these processes, with most of the geomorphological action occurring in just a few days of intense precipitation and high flows. The end result of all these processes are the surface formations we see today, including the relief structures that are especially characteristic of mountain landscapes, for example screes and alluvial fans.

Another factor that may have significantly contributed to the 'invisibility' of these natural processes is the degree to which people have encroached into mountain environments. Much of the study area has remained uninhabited to date, precisely because the threats that natural processes pose in such a dynamic environment are well understood. The prevailing settlement pattern has adapted to this situation, and takes the form of solitary farms that for centuries now have stood in exactly the same locations, and likewise, the centre of the village is positioned on the edge of the only piece of the flat terrain in the entire region. Restraint when it comes to encroachment in Jezersko's natural environment will also need to be incorporated into future spatial development plans. Namely, occasional torrential flows in the Kokra River and its tributaries, as well as the large rockfall at the Čedca waterfall of May 2008, should be seen as a warning that despite the exceptional beauty of the natural landscape, the 'non-living' nature acts in its own way. Finally, it is worth noting that Jezersko's picturesque landscape is the result of these same intense natural processes.

During the Pleistocene, glaciation significantly reshaped the Jezersko region. A previous interpretation of the extent of the glaciations by Lucerna and Meze indicated

that two glacier branches merged into a single glacier tongue that slid downhill into the valley. The main aim of this research was to analyse geomorphologic forms in the Jezersko region, with a particular focus on remnants of glaciation. The methods we utilised for interpreting the maximum extent of glaciation involved detailed morphographic analysis of the area and morphostructural analysis of outcrops of glacial deposits. Our results repudiate the previous interpretation of the extent of glaciation, since over the course of systematically mapping traces of glaciation we were unable to verify Lucerna and Meze's evidence purporting to a glacier of such size. The glaciers in both branches extended to the Jezersko Basin, where the lowest-lying glacial deposits can be found intact. The reach of the two glaciers was not such that they would have merged or stretched further downwards into the basin/valley.

The local climate of Jezersko can be divided into two topoclimatic units: higher and lower mountains. The topoclimate of the higher mountains covers the mountainous rim of the Jezersko basin (Jezerska kotlinica), which rises above the upper forest line. Typically, it experiences lower air temperatures (average annual air temperature from 0 to 4 °C), wet conditions (average annual precipitation of 2000-2600 mm), deep and long-lasting snow cover, and is well ventilated, especially at the mountain ridges. Due to the steep relief in the area insolation levels differ between slopes highly exposed to sunlight (average annual solar radiation of 1300 to 1660 kWh/m2) and sheltered slopes that receive little sunlight (up to 800 kWh/m2). Above sunny slopes, during the day when the weather is clear and calm, an uplift of warm air (anabatic winds) occurs. In contrast, during the night, cold air (katabatic winds) descends from higher to lower areas. Barren and sparsely vegetated ridges and peaks have a special topoclimate; during radiation weather, especially in winter, these experience very high insolation levels and are well-ventilated with exposure to winds of varying strength from all directions, while during warmer months of the year they are often blanketed in cloud cover.

The topoclimate of the lower mountains, lying below the upper forest line, encompasses the rest of the study area. The core of the area consists of the Jezersko basin together with the Ravenska and Makekova (kočna) cirques. Due to its lower altitude, this topoclimatic unit has higher air temperatures (average annual temperature of 2 to 6 °C) and slightly less precipitation (average annual rainfall of 1800-2000 mm); it also has fewer snow days (from 100 to 150 days). Most of the area has moderate levels of insolation (average annual solar radiation is 800 to 1300 kWh/m2). The south-western (shaded) slopes above the Makekova and Ravenska cirques, the southern slopes between Upper and Lower Jezersko as well as individual deep ravines stand out as locations with lower levels of insolation, receiving less solar radiation. Well insolated sections on the other hand include the northern and north-western rim of the Jezersko basin along the Karavanke Range as well as individual south-facing slopes above the Ravenska and Makekova cirques. Even though conditions are not ideal for the formation of distinct pools of cold air, given the openness of the basin and the flow of cold air towards the Kokra Valley, it is common during radiation weather for a temperature inversion to occur in the Jezersko basin and the Ravenska and Makekova cirques. The thermal inversions are not strong, according to our measurements ranging from 3.5°C (in the warmer half of the year) to 6 °C (winter), and they tend to be shallow.

Jezersko is part of the catchment area of the Kokra, a torrential alpine river, which emerges below the Virnikov Grintovec peak in the Komaterva Valley at about 1300 m above sea level. After approximately 34.5 km the Kokra flows into the Sava River at Kranj. The surface area of its catchment covers about 222 km2. There is a clear dichotomy in the catchment: the upper section above Preddvor, which also includes Jezersko, has the characteristics of a high mountain landscape with steep and deep cut, predominantly forested valleys and ravines, ringed by the high peaks of the Kamnik-Savinja Alps and Karavanke Mountains. It is sparsely inhabited; settlements are small with a predominance of hamlets and solitary farms. In contrast the lower part of the catchment, where the Kokra flows into the Ljubljana Basin, exhibits lowland characteristics. Given the more favourable natural conditions for habitation, it is more densely populated and cultivated, while it has also undergone more anthropogenic transformations.

In the period 1981-2010 the mean discharge (sQs) of the Kokra River in Kranj was 5.44 m3/s and specific discharge was 24.5 l/s/km2. While the Kranj water gauging station was in operation (1957-2016), mean discharge (Qs) decreased by 23% and lowest discharge (Qnp) fell by 39%. In recent decades, the river flow regime of the Kokra has shifted from a snow-rain to a rain-snow regime. These changes are likely the results of climate change, which is reflected in higher temperatures, higher evaporation and lower drainage, a greater share of autumn precipitation and a lower proportion of snowfall. High flow events on the Kokra can also exceed mean discharge by more than 40 times, although because the river bed generally cuts into the landscape and human activities are appropriately adapted, high-water events tend not to cause significant damage. Due to a reduction in pollution and an increase in the proportion of waste water being treated the Kokra River in Kranj is classified as having good chemical status and (very) good ecological status.

The main tributaries of the Kokra in Jezersko are the Jezernica, which originates from karst springs in the Ravenska cirque and flows towards Ravne, and the Reka, which originates in the Jekarica area below Storžič Mountain. Due to orographically influenced heavy and intense precipitation as well as high gradients, watercourses in the Jezersko area have a torrential character. Generally, high-water events and torrential rainfall do not threaten populated areas. Watercourse stream beds are mostly in a natural state or else are regulated in an environmentally sustainable manner. In the past, there were smaller mills and saws on watercourses with sufficient flows and/or high gradients. Nowadays, the energy of the water in Jezersko powers three turbines at small hydroelectric power plants: on the waterways of Jezernica, Murnov graben and Zabukovski potok. There are many springs of quality drinking water that still today serve as important sources of water for a substantial portion of the inhabitants of Jezersko, who live in remote, higher-lying, solitary farms. Probably the most well-known of Jezersko's springs are the Jezerska slatina mineral water spring and the Lehnjakov spring, which is credited for the formation of a large tufa deposit in Jezersko. Important elements of Jezersko's hydrological heritage include the Skuta Glacier (Ledenik pod Skuto) - the most south-eastern glacier in the Alps, which may soon vanish due to the atmospheric warming, and the Čedca waterfall, which used to be the highest waterfall in Slovenia. The Planšar Lake is also worth mentioning, as it serves as a symbol of Jezersko and at the same time is an important tourist attraction in the area.

There are low levels of water pollution in Jezersko, primarily because of the sparse population and moderate anthropogenic impacts, with these finding having been confirmed through analysis of basic physicochemical parameters on samples that we collected. A significant factor contributing to the good water quality in the area is also the significant self-cleaning capacity of watercourses, which is a result of the catchment's large amount of precipitation, high drainage ratio and high specific discharge rates as well as the high gradients, low water temperatures and predominantly natural condition of watercourses. Waste water treatment remains a challenge to address moving forward as almost half of the buildings in the municipality are not connected to the sewerage system. To respond to this, it is likely that small treatment plants will need to be constructed. Appropriately protecting the extremely sensitive water-ecological resources of the karst landscape of the Ravenska and Makekova cirques is extremely important in the ongoing development of the area, with these valleys contributing to the main water source used to supply Jezersko – the Anclovo reservoir.

In terms of its soil and vegetation composition, Jezersko is quite a typical alpine landscape. The geographical distribution of soils and vegetation as well as their characteristics reveal a strong association with natural factors that are typical of Slovenian high-mountain areas. In particular, we would point out the prevalence of carbonate rocks, high altitudes, very steep slopes, which receive a large amount of precipitation, and, proportionate to its altitude, low average temperature. Pedogenesis is therefore typically slow, and as such soils are accordingly shallow and poorly developed. On the other hand, vegetation typically presents as zonal on carbonate rocks, while azonal on siliceous rocksand in waterside habitats, as well as sites with distinct locally determined micro-climate conditions. In the study area upper boundaries are also present – forest, shrub and plant – as expected in mountainous landscapes. In general, all three boundaries are determined mainly by climate conditions, although they have been lowered as a result of human activity. In certain locations, exceptionally steep slopes, avalanches and screes have shifted them even closer to the lower sections of the area.

The harsh mountain climate and hard weathering-resistant rock facilitate the formation of young developmental soil types (Nudilithic, Eutric and Dystric Leptosols). These are the only soils found in great prevalence, although in the fieldwork we also encountered more developed soil types (Dystric Cambisols and Chromic Cambisols). In the end, 51 different types and subtypes of the above-mentioned basic soil types were identified. Determining the soil type was practically impossible in some places, since, particularly on carbonate bedrocks, there is a mosaic of intertwined different soil types, for example: Eutric Leptosols and Chromic Cambisols; Nudilithic Leptosols with shallow and skeletal Eutric Leptosols; or shallow Eutric Cambisols and typical Eutric Leptosols. Especially on moderate and steep slopes, Dystric Leptosols also intertwine with shallow and skeletal Dystric Cambisol soils.

In terms of vegetation there is a clear predominance of beech communities, characteristic of the mountain belt (500 m above sea level - up to the upper forest line); across an expansive area above 1600-1800 m there are fragmented sections of sparse scree vegetation and sections without any vegetation. In the study area there are a wide range of natural and human factors at play. At certain altitudes, trees and shrubs start to thin out, then at even higher altitudes, vegetation disappears or else can only be found in cracks, tufts or as solitary specimens. As mentioned previously, the upper forest line consists mainly of beech and spruce. On sunny, south-facing, and in places on west-facing slopes, larch grows alongside these species. On most slopes, above the upper forest line, the forest gives way to a ten to a few hundred meters wide band of scrub mountain pine. In certain places, especially below the peaks of Storžič, Grintovec and Skuta, tracts of scree and rockfall material extend far into the forest zone, which is most probably due also to avalanches. In some places, for example, below Virnikov Grintovec, there is a very stark transition and the band of scrub mountain pine is almost completely absent. Continuous forests in the municipality of Jezersko on average extend to an altitude of 1404 m with an average gradient of 33° and are predominantly north- or north-east facing. At its lowest point, the forest line drops to 1023 m at the aforementioned rockfall in the Makekova cirque, and at its highest rises to 1868 m below the peak of Mala Baba. Continuous forest grows even on slopes with a gradient up to 65°. The average altitudes from five smaller studied areas reflect fairly well the actual course of the forest line, found between 1400 and 1550 m. Continuous vegetation extends to an altitude of 2100 m, and it can also be found on inclinations over 75° and on slopes of all orientations. The highest example of continuous vegetation is found on the eastern slopes of the Kljuka Mountain, with the lowest found at the Čedca rockfall.

While inspecting the landscape as part of the geographical study of Jezersko and the surrounding area we also encountered a number of invasive species. Most frequently, we came across two species, namely, Japanese knotweed and annual fleabane. The Japanese knotweed appears in places along the main road and beside the Kokra River. We also spotted stand-alone thickets of it near the Kazina Hotel and on the banks of the Jezernica stream.