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DEGRADATION OF DOLINES ON LOGAŠKO POLJE (SLOVENIA)

DEGRADACIJA VRTAČ NA LOGAŠKEM POLJU (SLOVENIJA)

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Abstract UDC 551.435.8:551.44(44)

Mateja Breg: Degradation of dolines on Logaško polje (Slovenia)

As an example of long-term human intervention onto karst geomorphology, the article deals with the area of the Logaško polje, where degradation processes of dolines have been very intense during the last fifty years. The analysis of aerial photographs from different periods (years 1944 and 2000) was carried out on a study area of 604 ha. It showed that 77.5 % of dolines (441 of total 569) have completly disappeared mostly by being filled up with different waste materials (excavation material, municipal, industrial and building waste etc.) or they were built up while 22.5 % (128) of dolines have been entirely or partly preserved. Several anthropogenic factors that had an important influence on doline-changes are being evaluated. Despite the fact, that doline is a typical geomorphological feature in karst landscape the public (local or state) and the scientific sphere pay little attention on their geomorphological preservation and protection. Considering the paradigm of sustainability, the landscape and its landforms, as they are part of Earth's surface, would need to be classified as a non-renewable natural heritage or even non-renewable natural resources.

Key words: geography, doline, non-renewable natural resource, degradation, protection, sustainable development, Logaško polje, Slovenia.

Izvleček UDK 551.435.8:551.44(44)

Mateja Breg: Degradacija vrtač na Logaškem polju (Slovenija)

Kot primer dolgotrajnih antropogenih posegov v kraško geomorfologijo je v članku predstavljeno Logaško polje, na območju katerega je zadnjih petdeset let potekala zelo intenzivna degradacija vrtač. Na 604 ha velikem vzorčnem območju izvedena analiza letalskih posnetkov iz različnih obdobij (leto 1944 in 2000) je pokazala, da je 77,5 % vrtač (441 od skupno 569) popolnoma izginilo. V glavnem so bile zapolnjene z različnim odpadnim materialom (izkopni material, komunalni, industrijski in gradbeni odpadki) ali pozidane, 22,5 % (128) vrtač je bilo le delno pozidanih in preoblikovanih oziroma so se povsem ohranile. Ovrednotili smo številne antropogene dejavnike, ki so pomembno preoblikovali vrtače. Kljub temu da je vrtača tipična geomorfološka oblika kraške pokrajine, se tako v javni (krajevni ali državni) kakor strokovni sferi premalo pozornosti posveča njihovemu ohranjanju in zaščiti. Ob upoštevanju paradigme sonaravnega trajnostnega razvoja je treba pokrajino in reliefne oblike kot del zemeljskega površja opredeliti kot neobnovljivo naravno dediščino oziroma kot neobnovljiv naravni vir.

Ključne besede: geografija, vrtača, neobnovljiv naravni vir, degradacija, zaščita, sonaravni razvoj, Logaško polje, Slovenia.

INTRODUCTION

Landforms are among the most widely-spread and spectacular natural, non-biological features: dolines, river gorges, mountain peaks, natural bridges, maritime cliffs and others. They have always raised attention as attractive elements of the landscape but not only does the visual aspect of the landscape determine the importance of landforms, so does its cultural role. Besides that, the scientific, educational and research aspects have to be considered as well (Panizza and Piacente, 2003 in: Panizza, 2003).

While using natural resources man has for centuries selfishly subdued landscape and nature and transformed

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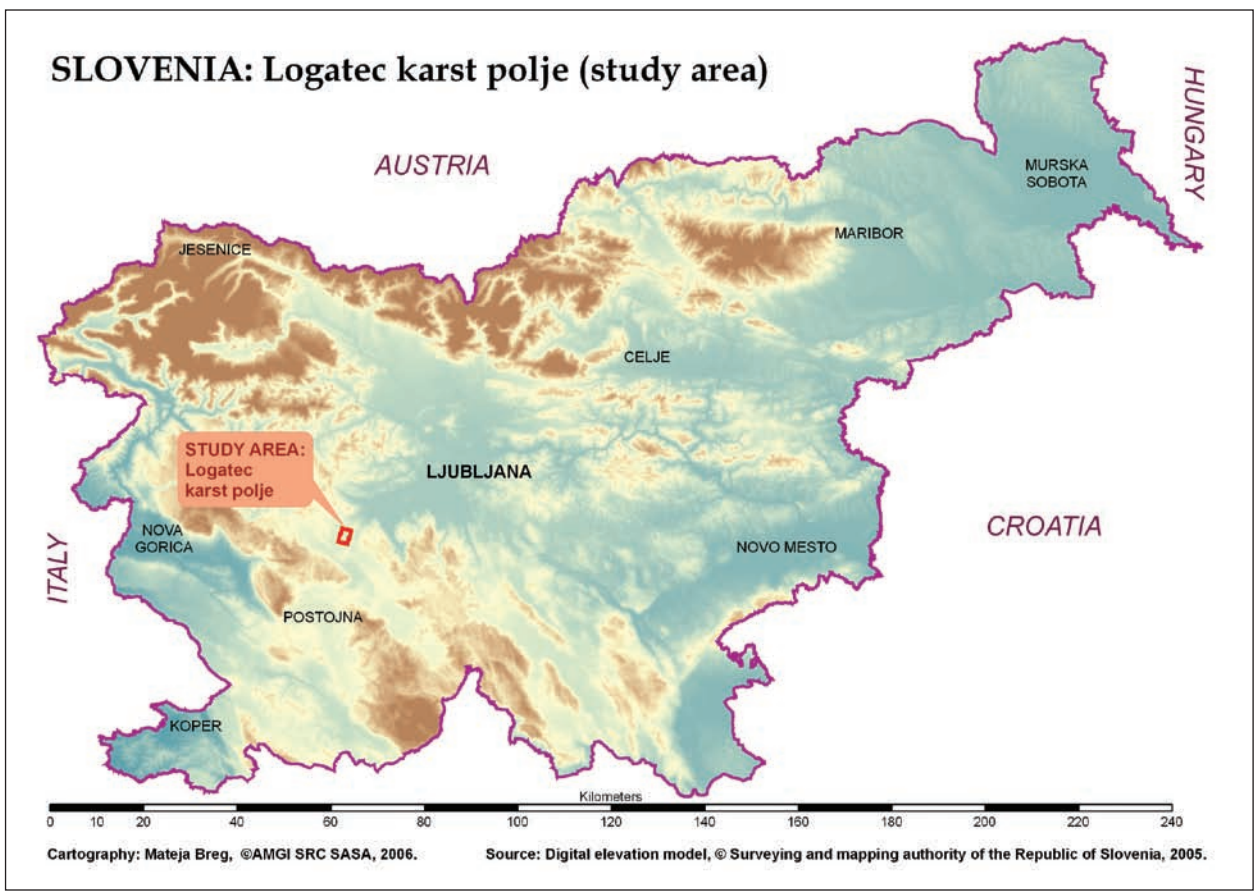
them in accordance to his needs. Cultivated dolines have been the site of various traditional activities (arable farming, gardening, pasturing, water supply etc.). In some Slovene areas (Kras, Bela krajina, Matarsko podolje etc.) these activities have survived to a smaller extent while in other places subtle cultural elements, such as dry-stone walls, speak of their past presence. Despite the apparent usefulness of dolines there had often been a desire among the inhabitants of karst regions, particularly in agricultural areas, to fill them up.

Many dolines today are filled up with different kinds of unknown waste material, covered with variable thick layers of cover-material or simply overgrown by vegetation. Waste materials (municipal, construction, industrial waste etc.) deposited in nature represent the most irresponsible activity affecting the karst features and processes that at one point became subject to degradation processes that had not only had a great effect on karst hydrology or ecology but also permanently influenced karst landforms and the entire landscape.

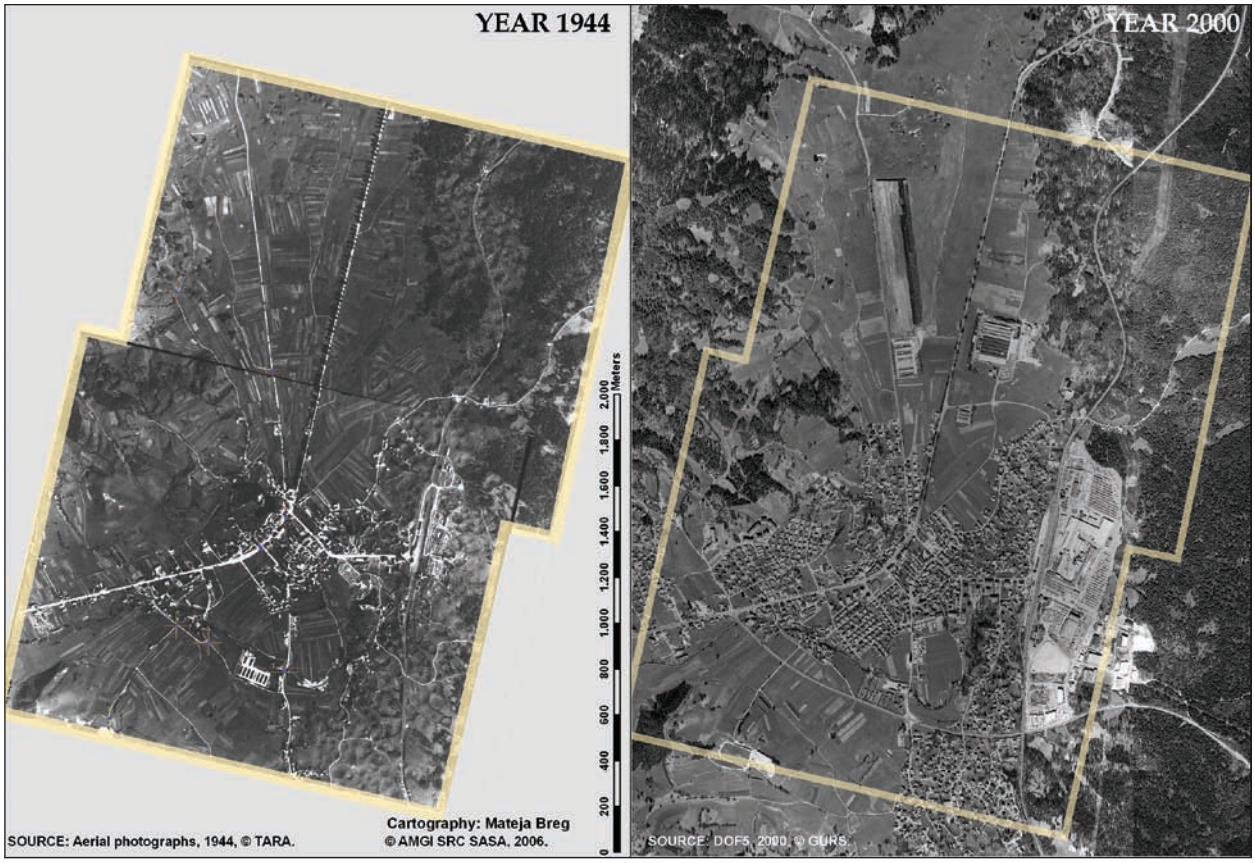
STUDY AREA AND WORKING METHODS

We have studied the North-East part of Logaško polje (map 1) where several dolines had been formed mainly on limestone bedrock (dark-grey limestone and grained dolomite) and river or stream deposits (Buser *et al.*, 1967). At the moment, the Logaško polje is under the biggest environmental pressure as several socio-spatial factors (proximity of Ljubljana, good transport connections, lower rents etc.) have caused immigration to its largest urban centre, Logatec (7616 inhabitants (SURS 2002)), and its surroundings. Furthermore the proximity of the motorway and a double track railway have stimulated the development of the secondary and tertiary activities and the expansion of the business-industrial zone.

The comparison of available aerial photographs from different periods can show how unsustainable the dealing with dolines had been over the last decades. The



Map 1: Logaško polje is located in the south-western part of Slovenia.



Map 2: Aerial photographs of study area in the years 1944 and 2000.

artificially defined test-area measures 604.8 ha (6.048 km²) and coincides with the surface of two partly covering digital b/w aerial photographs from 1944 (spatial resolution 1200 dpi). Archive aerial photographs from 1944 are the oldest known aerial photographs of the studied area and represent the starting point for the analysis of dolines-changes till the year 2000. The origins of the aerial photographs from 1944 are allied aerial observations during World War II. The documents are being kept in The Aerial Reconnaissance Archive (TARA) - University of Keele in the United Kingdom. The records are available in digital form but need to be georeferenced and their quality (colour, contrast, transparency) adjusted to get as much useful information as possible.

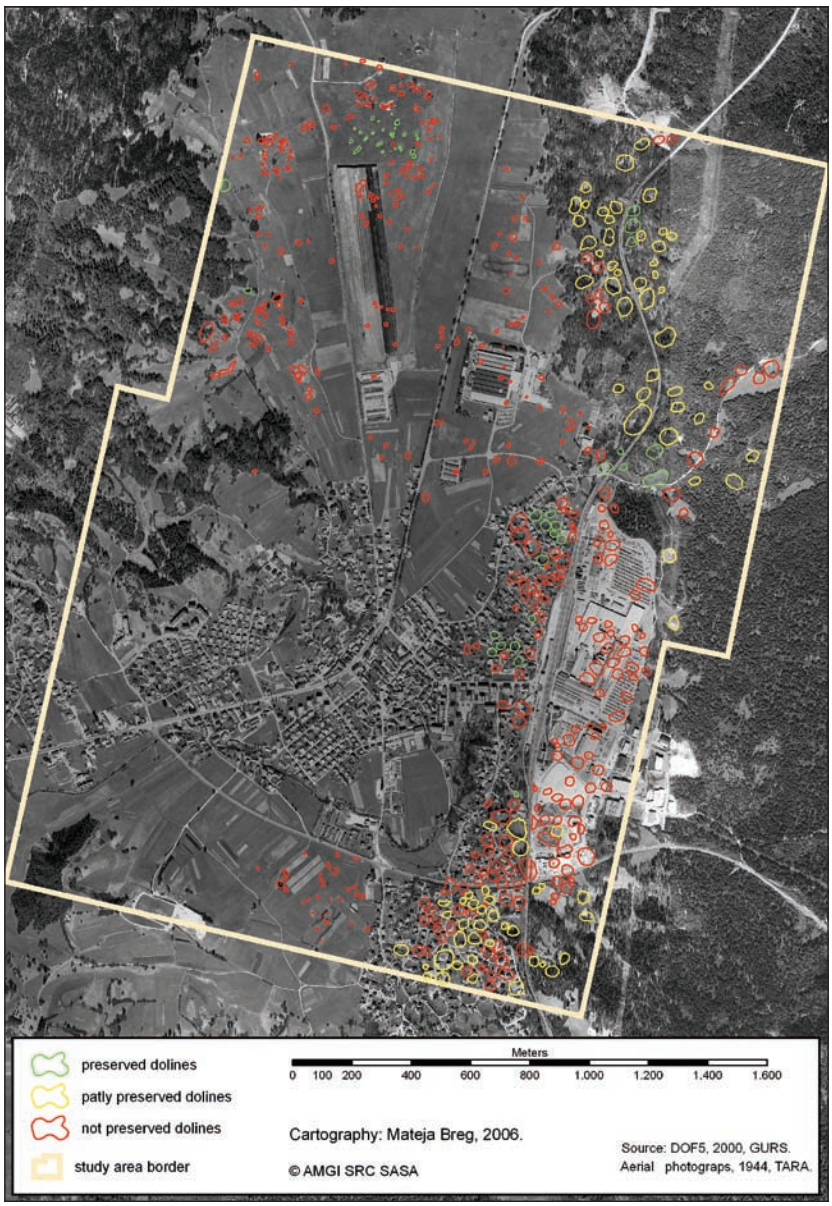
We have georeferenced the aerial photographs and adjusted them with the coordinate system DOF5 (Digital orthophoto image, scale 1 : 5000, Gauss-Krüger coordinate system). Based on selected old and new control point coordinates (buildings, junctions etc. that are present on both photographs) the computer program calculates the transformation parameters. The function contains formulas of linear mapping, un-linear mapping and the least squares method (Petek, Fridl, 2004).

The photointerpretation of the old aerial photographs and of the recent digital orthophoto (map 2) made it possible to digitalize the dolines (polylines) of the studied area at two points in recent history. The database was edited with separate attributes for each photograph. The identification of dolines and their main characteristics was based upon a photointerpretation-key that included following parameters: shape, depth (shadows give an impression of depth), colour (different shades of grey - the darker ones usually mark the bottom of dolines), texture. Attributes for each doline were defined with the help of visual photointerpretation and analysis. For the year 1944 the location, shape and dimension of each visible doline were determined and at the same time their actual presence was checked on the more recent photograph from the year 2000. Both sources served furthermore for identifying accessibility and land use of dolines. The gained data was statistically analysed.

CHANGES OF THE NUMBER AND LAND USE OF DOLINES IN THE LAST FIVE DECADES

On the aerial photograph from 1944, 569 dolines were evidenced and their shape, dimension and surface-cover determined. The spatial spread of dolines in the studied area is connected to its geologic structure: on limestone, dolines are larger and more concentrated, on fluvial deposits they tend to be smaller whereas there are almost none in the areas with dolomite bedrock. Dolines cover approximately 28.9 ha (0.288 km²), which represents 4.8 % of the total surface of the studied area. The average dimension of a doline is 507 m². The comparison shows that between the years 1944 and 2000 77.5 % of dolines (441 of total 569) have completely disappeared - in most cases they were being filled up with different waste materials (excavation material, municipal and building waste etc.) or they were simply built up. Furthermore 22.5 % (128) have been entirely or partly preserved (partly built up).

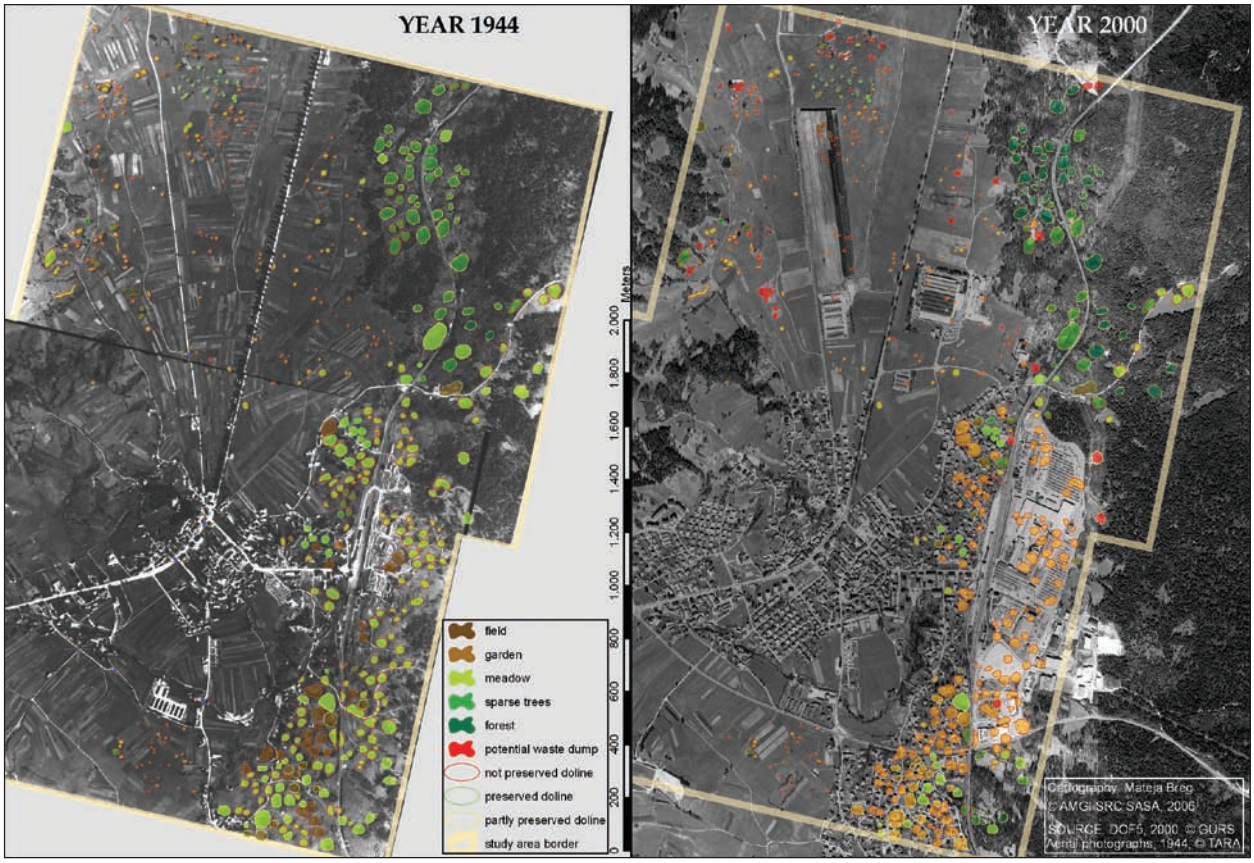
On map 3 red polygons mark the dolines which have not been preserved between the years 1944 and 2000, yellow polygons mark the partly preserved dolines and green polygons mark the preserved ones.



Map 3: Dynamics of the dolines-changes in the period 1944 – 2000.

Among the first to change the surface morphology were farming activities, most notably agriculture. The most important were agro-technical operations that were carried out in the lower part of the Logaščica stream basin in the year 1986 and continued in years 1987/88 on Pusto polje (in English: Bleak (empty) field). The prevailing process, that changed the landscape-morphology, was the filling up of dolines with soil, rock- and excavation material from other locations. For this purpose 12,000 m³ of material from an old railway embankment, dating from World War I, was used. At the same time municipal landfills in dolines, including industrial landfills with dangerous waste, were being covered (Bricelj, 1988).

The agricultural use of the doline's floor is conditioned by its shape and depth that defines the possible cultivation. Dolines covered with meadows (meadow-dolines) are usually cultivated in its entirety (bottom and slope) while the fields are usually located on the bottom of dolines and their flatter parts respectively. Field-dolines are best used if filled up and levelled to the surrounding height. Since the floor of dolines is mostly narrow the fields there are smaller, so in order to increase the arable land, dolines were filled up. A field on a greater surface consequently enabled a greater har-



Map 4: Land use in dolines in the years 1944 and 2000 regarding doline preservation.

	YEAR 1944				YEAR 2000			
Land use type in doline	*Number of dolines*	*Percent (%)*	*Area (m^2)*	*Percent of area (%)*	*Number of dolines*	*Percent (%)*	*Area (m^2)*	*Percent of area (%)*
Field	40	7	38,921	13	19	3	6,202	2
Forest	5	1	3,454	1	39	7	42,617	15
Meadow	448	79	186,050	64	230	40	52,965	18
Garden	1	0	669	0	9	2	5,238	2
Sparse trees, overgroving	73	13	59,510	21	41	7	40,215	14
Potencial waste dump	2	0	160	0	74	13	15,046	5
Built up, partly built up	0	0	0	0	154	27	125,146	43
Other	0	0	0	0	3	1	1,337	0
sum	569	100	288,765	100	569	100	288,765	100

Tab. 1: Land use in dolines in the years 1944 and 2000 (regardless the number and area).

vest. In the year 1944 the dolines coverd with fields (field-dolines) reached 7 % (40 counts) that represented 13 % of the total doline-surface.

The most common and the greatest were meadow-dolines as they represented 80 % of the dolines (448 counts) and 40 % of the total surface (186,050 m^2). Because the surface of a hemisphere is greater than the surface of a circle, meadows were economically more suitable and profited best from the available surface of the doline's concave structure. Grass can grow on the bottom and slope where the soil is thinner and thus gives, theoretically speaking, a greater "output" than it would

have from the flat and round surface, had the doline been filled up. Therefore the desire to fill up meadow-dolines should be superfluous, but nevertheless their number, in the studied time-interval, was halved (from 448 to 230) and their total surface decreased for 75 % (from 186,050 to 53,000 m^2). The mechanization in agriculture had a bigger impact on the diminishing number of meadow-dolines. With the transformation from manual labour to mechanised and more intensive agriculture, dolines became even more unpopular since they represented a relief obstacle to mechanised cultivation.

Fig. 1: Traditional meadow doline (photo by M. Gabrovec).

The construction of transport infrastructure in the area of Logatec had a strong impulse on relief changes in the past, particularly because of its geographic location. In the middle of the 19th century the so called "Southern railway line" was constructed through Logatec. Already at that time tracks were placed on filled up dolines that had been thereby lost forever and were even unable to be traced on the photograph from 1944. The burned waste of the railway however is the first known waste material that filled dolines around the Southern railway line. Furthermore it is not known how many dolines were filled

Fig. 2: The railway embankment of line Logatec – Idrija, closed after World War I (photo by M. Breg).

up with waste material from the railway embankment of the line Logatec – Idrija, close after World War I. Considering these historical facts there had probably been more dolines present in the studied area than were determined by the analysis of the aerial photograph from 1944.

Dolines have changed and disappeared also because of settlement-expansion as the area of Logatec has one of the most positive migration saldos in Slovenia. New neighbourhoods are being constructed increasing environmental pressures as more inhabitants cause more waste water, more waste dumps and consequently less dolines. Between 1944 and 2000, 154 dolines were fully or partly built-up representing 43 % of the total doline-surface (125,146 m^2). The number would increase greatly if the dolines that were destroyed by the commercial-industrial zone Logatec, which was built after the aerial photograph was taken in the year 2000, were included. Lost dolines that were covered with built surfaces during the last 50 years had been previously filled up with diverse materials – from excavation material to municipal and other types of waste.

FILLING-UP DOLINES WITH WASTE MATERIAL

On the study area of Logaško polje the degradation processes of dolines have been very intense during the last fifty years. From the aspect of nature protection and an environmental point of view it is important to identify the material used for filling up the dolines since these are areas of concentrated water through flow into the karst subterrain.

With the increase of municipal waste its percentage among the filling material rose. Over several decades the illegal waste dumps became a significant anthropogenic element in the karst landscape. Therefore not only their impact on karst aquifers and ecosystems has to be evaluated, but their influence on changes of surface geomorphology as well. With the used methodology and the acquired data it is difficult to define the number of waste-filled dolines since it is impossible to get access to the actual structure of the material. The clearest evidence is the abnormal texture identified on the aerial photographs (1944 and 2000) and typically characteristics for waste dumps. With this method, 74 dolines were marked

as a potential waste dump, but the greatest methodological weaknesses are several already overgrown and waste-filled dolines that were not marked as such.

Fig. 3: Waste dump (construction and demolition waste) in the meadow-doline (photo by M. Breg).

The increasing quantity of municipal waste was a suitable material for filling up dolines, especially during the 70's and 80's. A rather new phenomenon is the municipal waste of the recent decades. Regardless its size dumps contain different types of waste, also including domestic rubbish. Waste dumps in dolines were studied in detail by I. Šebenik (1994) in the scope of a research on illegal dumps in Slovenia. The author ascertains that areas with "suitable" locations for illegal dumps have several characteristics: they are accessible, less visible (physical depressions), covered by vegetation, remote, unfunctional and uninhabited. Two thirds of dolines filled with waste are located in the forest or are covered with a bushy-vegetation. Less than 15% of waste-dolines are in the form of meadows or abandoned pastures. Dumps in dolines are most commonly unspecific (these represent 84% of the waste), some are periodical or private. On both larger and smaller dumps mixed waste materials (including waste from households) prevail. A large part is in the form of dug material and tailings as a residue of different activities (e.g. house-construction), which are being transported to illegal dumps together with the rest of the waste. This kind of unusable material is very common in karst areas and in many cases represents the majority of waste materials. 75% of dumps are accessible through roads and only 10% of the waste is dumped beyond. Dolines are furthermore favourable dump locations due to their steep slopes that make depositing simple. In karst areas it is common to believe that dolines need to be filled up since they are only pointless and limiting holes (Šebenik, 1994).

With the handicraft and industrial workshops, new forms of hazardous waste products arrived that were dumped uncontrolled until the introduction of adequate legislation and the set up of regulated dumps. For the fill-up, different waste materials were used depending on their availability. With the growth of transport (railway), handicraft (blacksmith, charcoal-burning) and industrial activities (timber, cardboard-box and metal industry), hazardous waste products were produced. Several landfills that are already covered and overgrown contain heterogeneous and dangerous waste (sawdust, bark, industrial oils, galvanic sediment etc.) (Bricelj, 1988), that was deposited thirty years ago or even earlier.

With the population growth and production-activities, built-up surfaces and garbage quantity have increased. The municipality of Logatec produces yearly 4,000 tons of waste (SURS, 2005). Until the 90's the public collecting of municipal waste was gradually introduced in Slovene settlements that until then had to dump their increasing amount of waste somewhere nearby. Later it was taken over by public companies that continued to dispose the waste in dolines.

Regarding preliminary studies (Smrekar et al., 2005) active illegal waste dumps contain the highest percentage of construction waste (more than 70 %), while the percentage of municipal waste is decreasing. Considering these facts in combination with a growing migration and an increased interest for new or better lodging facilities on the Logaško polje the filling up of dolines with construction waste will most likely continue in the future.

INTEGRATED ISSUES FOR THE PROTECTION AND PRESERVATION OF DOLINES

Based on the presented example of the degradation of dolines on the Logaško polje and by considering the fact that it is a common problem in Slovenia (dumps and landfills in dolines in Slovenia, Šebenik 1994) it becomes obvious that dolines – a typical karst feature – are almost entirely ignored in the existing system of protection and planning of land-use, nature and environment. Dolines on the Logaško polje are the prevailing surface karst landforms and have in this form always been a strong element of the cultural landscape. The attitude of the population towards this landscape and the consciousness of the importance of its particularity have considerably changed with the diminishing role of agricultural activity (in society and space) and with the consequently diminished

dependency on natural factors. Secondary and tertiary activities, which are not exclusively based on local capital and natural resources, took the lead. The consequences provoked by non-agricultural activities in the karst landscape (construction, industry, transport etc.) are more unsustainable and less environmentally friendly than in the case of agricultural activities.

In the scope of the existing legislation it is necessary to define the possibilities for a long-term (sustainable) protection of dolines and to propose a new approach in spatial planning for geomorphologically unique doline-areas respectively. Considering the paradigm of sustainability the landscape and its landforms, as part of Earth's surface, would need to be treated as non-renewable natural resources – more precisely as a geomorphologic resource. Dolines are elements of the natural space which intervene with man's cultural space forming the unique karst landscape.

"A landform becomes a geomorphological resource only if it has social implications, that is, only if other parameters, external parameters, come into play to invest it with value (Panizza and Piacente, 1993). As long as a particular river, or a particular landscape are studied by and known only to scientists and researchers, it remains "private" knowledge and its potential as a resource do not materialize. However, if the scientist or the researcher publicizes it, making its cultural and environmental significance known to the general public and thereby giving it a social dimension, then the landform becomes a geomorphological resource in the eyes of society at large (Panizza, p. 22, 2003)." As a consequence it is necessary that dolines in the area of Slovene classical karst are considered as areas of geomorphological localities in the future planning of land use.

In comparison to subterrainean caves which are subject to the Cave Protection Act (Official Journal of the Republic of Slovenia (in further OJ RS), 2/2004), there is no similar act that would determine the protection and activity-management of doline-areas. The Environment Protection Act (OJ RS, 41/2004) foresees an environmental impact assessment prior to any activity affecting the environment. Before the start of such an activity it is necessary to conduct an environmental impact assessment, to obtain environmental protection consent from the ministry and to obtain an environmental protection approval (OJ RS, 41/2004, article 50-51). Thereby protected areas and natural values are being considered.

Considering the Nature Protection Act (OJ RS, article 37, 96/2004) the scientific evaluation measures are: exceptionality, typicalness, complexity, preservation, rareness and its importance for science and the ecosystem In case it isn't recognized as a natural value, a landforms can be incorporated in the framework of a protected environment. This guarantees a certain level of protection as any activity has to be in compliance with the protection arrangement of the relevant area. The Environment Protection Act defines further protected areas (national park, regional park and landscape park) and stricter protected areas (strict nature reserve, nature reserve, and natural monument).

In 1944 there were 569 dolines present in the studied area while until the 2000 only 51 (8.69 %) have been entirely preserved and 77 (13.5 %) have been almost (partly) preserved. In 46 years 441 dolines vanished resulting in the loss of almost 10 dolines per year. In accordance with the gained results from research-work and by considering sustainable and environmentally-friendly development dolines should be put under protection as a distinguishing karst feature and the level of endangerment for doline-areas to be determined. This would then represent the basis for future spatial-planning activities. As a unique feature dolines should be furthermore recognized by local inhabitants, as this is the only way to prevent their uncontrolled degradation.

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