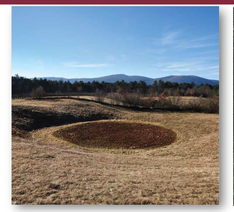
SUCCESSIONAL STAGES IN DOLINES (SINKHOLES) AS SOIL ORGANIC CARBON RESERVOIRS IN KARST AREAS, SW SLOVENIA

A. ČARNI[1,2], A. MARINŠEK[3], D. ŽLINDRA[3], M. ZORN[4] and M. BREG VALJAVEC[4]

[1] Research Centre of the Slovenian Academy of Sciences and Arts, Jovan Hadži Institute of Biology, Novi trg 2, SI-1000 Ljubljana, Slovenia
[2] University of Nova Gorica, Vipavska 13, SI-5000 Nova Gorica, Slovenia
[3] Slovenian Forestry Institute, Večna pot 2, SI-1000 Ljubljana, Slovenia
[4] Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, Novi trg 2, SI-1000 Ljubljana, Slovenia



In the research area soil is a deficient resource and deeper soils can only be found in the bottom of dolines. Thus, dolines have been throughout history reshaped to suit farming needs. They were mostly used for pastures, meadows, fields or gardens. Today they are agriculturally mostly abandoned and we can see one cultivated doline (left) and one abandoned under reforestation process (right).

INTRODUCTION

The paper presents the importance of specific but most characteristic and numerous **karst surface landforms - dolines** - as the potential **C_{org} sinks**. The research took place on karstic plateau in NW Dinaric Mts (Kras Plateau) in SW Slovenia. Dolines can range from several metres up to over a hundred metres in diameter and can be several metres to several dozen metres deep (Breg Valjavec et al., 2018; Mihevc et al. 2021).

Following previous studies in karst regions (Ogrinc et al., 2016; Mali et al., 2018) the contents of SOC and Total Nitrogen (TN) were lowest in cropland and highest in forest.

AIM

We investigate and compare the Soil Organic Carbon (SOC) stocks (t/ha/40cm) in soils in dolines under three land use types: forests, grasslands, and succession (scrub to towards natural afforestation) and evaluate the role of current and past land use.

We hypothesised that the amount of SOC is higher in dolines, where the current land use is forest, followed by succession and grassland dolines and discuss about the role of past land use and succesion on SOC storage.

METHOD

Soil organic carbon (SOC) refers to the carbon component of SOM measured in mineral soils passing through a 2-mm sieve.

SOIL SAMPLING METHOD

Soil samples were collected from the centres of the dolines (bottom) according to ICP methodology (Cools & de Vos, 2016) in 40 cm soil layer and calculated in tones per hectar in 40 cm layer (t/ha/40 cm).

VEGETATION SURVEY

Current land use and vegetation cover was sampled and assessed by standard methods (Braun-Blanquet, 1964).

LAND USE ANALYSIS

Ongoing land use changes throughout Kras Plateau over the past two decades were assessed on the 2002 and 2012 Slovenian Land Use Maps (MKGP, 2020).

RESULTS

The results of soil sampling and statistical analyses for SOC, nitrogen, C/N ratio, carbonate, reaction and texture is shown in Table 1. On average, SOC stock under different land uses decrease with the soil depth (Fig. 1) in all land use types.

The graph shows that the largest supply of C_{org} is in dolines, which are in the youngest stage of overgrowing with shrubs, while with the degree of woodiness and increasing tree density, the stock is declining in the direction towards the SOC stock in the forest. The highest value of nitrogen is found in the soils of dolines of natural reforestation, while the lowest mean share was obtained in the soils of dolines covered with forest. The mean C/N ratios under different land uses is in order of forest > natural afforestation > grassland, but non-significantly.

Considering the trend of agricultural land abandonment in the Kras Plateau (Tab. 2), even more overgrowth of dolines, and consequently an increase of SOC stocks in their soils can be expected.

	Soil sampled in 22 dolines							Forest soils outside dolines[9] [Mean]
	All dolines				Dolines classified by land-use			
	N	Mean	Std. Dev.	Coef. Variance	Grassland (7)	Succession (6)	forest (9)	
SOC (t/ha/40cm) *per location*	22	116.42	22.21	19.08	106	130	116.64	67.83 [b]
SOC (g/kg) *per location*	22	30.25/*48.51*[10]	6.68	22.07	27.06/*43.68*[10]	35.24/*53.04*[10]	*29.41*/*48.82*[10]	21.2 [b] / *44.95*[10,b]
TN (%)	88	0.27	0.12	43.87	0.26	0.27	*0.35*[10]	*0.27*[10,b]
C/N	88	11.30	1.48	13.12	10.6	11.8	*13.6*[10]	*19.01*[10,b]
pH (0.01M $CaCl_2$)	88/*22*	6.17/*5.77*[10]	0.77	12.60	6.63/*6.22*[10]	6.4/*5.92*[10]	*5.5*/*5.19*[10]	*5.12*[10,b]
Clay <0.002mm (%)	22	*34.44*[10]	*8.56*[10]	*24.84*[10]	*26.45*[10]	*36.41*[10]	*39.32*[10]	*45.05*[10,b]
Fine silt 0.02-0.002mm (%)	22	*41.92*[10]	*4.25*[10]	*10.13*[10]	*39.81*[10]	*44.1*[10]	*42.1*[10]	*35.19*[10,b]
Coarse silt 0.063-0.02mm (%)	22	*14.28*[10]	*3.09*[10]	*21.62*[10]	*16.19*[10]	*12.88*[10]	*13.7*[10]	*14.10*[10,b]

[10] Sample data for upper 10 cm soil layer.

Table 1. Basic statistics for soil organic carbon stock (t/ha/40 cm), SOC concentration (g/kg), total nitrogen (TN), C/N ratio, soil reaction and fine soil fractions in dolines bottom compared with available reference data for forest soils sampled outside of dolines

	Specific land-use type coverage (ha) in years 2002 and 2012		
LAND-USE TYPE	2002	2012	Difference 2002/2012
forest	1,645.21	1,776.18	130.97
permanent meadow	719.01	600.69	-118.33
succession	190.43	183.15	-7.29
cultivated land	65.57	34.26	-31.31
urban area	33.67	45.81	12.14
vineyard	18.54	19.22	0.67
abandoned	0.00	15.53	15.53
orchard	2.12	4.46	2.34
other	5.88	1.40	-4.48

Table 2: Trend in /and-use changes in over 14,000 dolines of Kras Plateau between 2002/2012

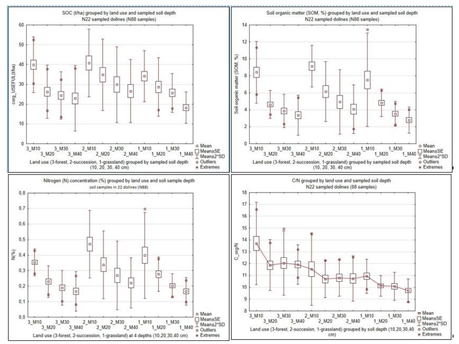
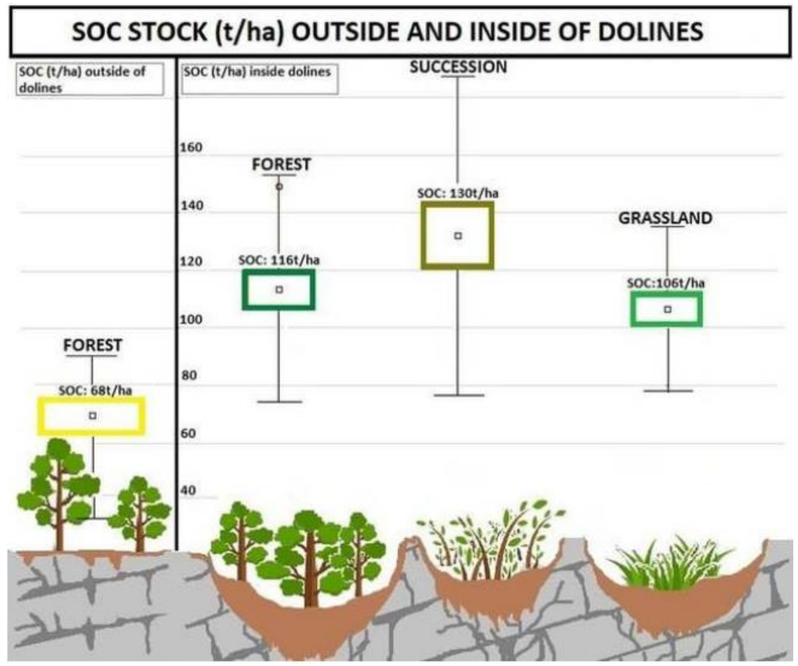


Figure 1: Distribution of SOC stock (t/ha), SOM (%), soil nitrogen (N), C/N ratio along soil profile between 0-40 cm, in dolines grouped by land use.



CONCLUSIONS

- Thick clay-silty Luvisols in the bottom of dolines have high SOC storage capacity
- Past agricultural land-use presents long-term impact on SOC stock in dolines
- Succession plots in dolines show the highest SOC storage capacity (130 t/ha)
- Soil organic carbon stock in dolines was double the amount nothe levelled plateau
- With reforestation process the amout of soil organic carbon will increase

REFERENCES

Braun-Blanquet, J., 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde, 3rd ed.; Springer Verlag: Wien, A, 1964; 631 pp

Breg Valjavec, M., Zorn, M., Čarni, A., 2018. Human-induced land degradation and biodiversity of Classical Karst landscape: On the example of enclosed karst depressions (dolines). Land Degradation & Development 29, 3823–3835.

Cools N, De Vos, B., 2016. Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part X: Sampling and Analysis of Soil. Thünen Institute of Forest Ecosystems, Eberswalde.

Mali, B., Marinšek, A., Voglar, G.E., Kozamernik, E., Železnik, P., Žlindra, D., Simončič, P., Sinkovec, M., Bergant, J., Vrščaj, B., 2018. Soil sampling for the assessment of carbon stock on agricultural land in 2018: Report nothe implementation of the public procurement task. Slovenian Forestry Institute, Agricultural Institute of Slovenia, University of Ljubljana, Ljubljana.

Mihevc, A., Mihevc, R., 2021. Morphological characterostics and distribution of dolines in Slovenia, a study of a Lidar-based doline map of Slovenia. Acta Carsologica 50(11), 11-36.

MKGP, 2020. Agricultural land-use maps. Ministry of Agriculture, Forestry and Food of Republic Slovenia. Ljubljana.

Ogrinc, N., Kanduc, A., Krajnc, B., Vilhar, U., Simončič, P., Jin, L., 2016. Inorganic and organic carbon dynamics in forested soils developed no contrasting geology in Slovenia - a stable isotope approach. Journal of soils and sediments 16, 382-395.

ACKNOWLEDGEMENTS

The research was funded by Slovenian Reseach Agency (ARRS) through research programs Geography of Slovenia" (P6-0101), Biodiversity: patterns, processes, predictions and conservation (P1-0236) and Forest biology, ecology and technology (P4-0107), as well as through research project Connectivity concept in karst: the doline-cave coupling in the context of human impacts (J6-2592).

CONTACT INFORMATION

Andraž Čarni, Research Center of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI – 1000 Ljubljana, Slovenia, e-mail: carni@zrc-sazu.si