UNIVERZA V LJUBLJANI | BF Biotehniška fakulteta

REPUBLIKA SLOVENIJA
MINISTRSTVO ZA NARAVNE VIRE IN PROSTOR

REPUBLIKA SLOVENIJA
MINISTRSTVO ZA KMETIJSTVO, GOZDARSTVO IN PREHRANO

aris

Evaluation of Agricultural Measures to Safeguard the Vulnerable Karst Groundwater Habitat of the Black Olm (*Proteus anguinus parkelj*) from Nitrate Pollution

Assist. Prof. **Matjaž Glavan, PhD,** *Environmental planning*

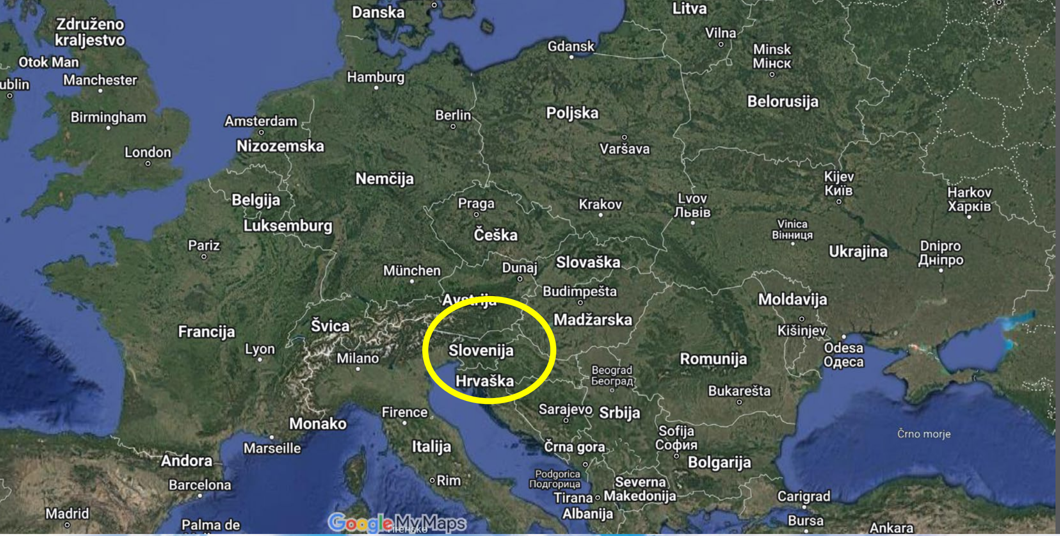
Mitja Prelovšek, PhD, ZRC SAZU – Academy of Science and Art

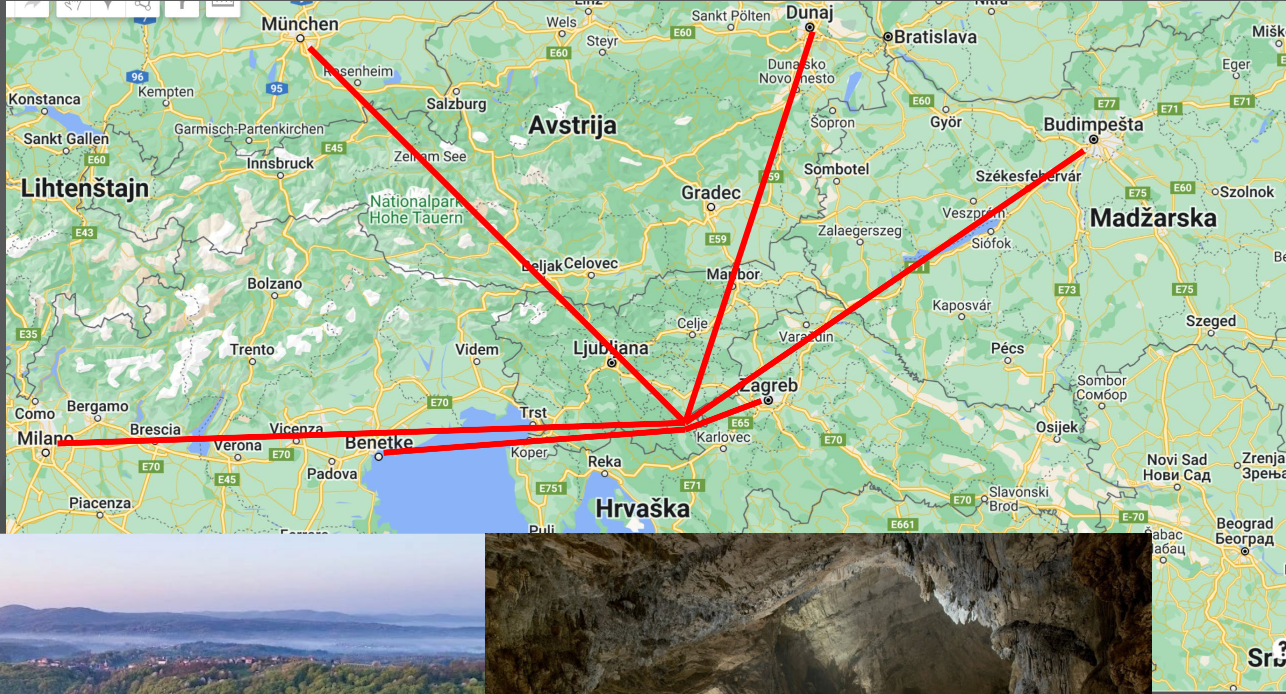
Nina Mali, PhD, Geological Survey of Slovenia

SWAT international Conference

Jeju, South Korea

23-27 June, 2025


Združeno kraljestvo
Otok Man
Manchester
Birmingham
London
Amsterdam
Nizozemska
Danska
Hamburg
Gdansk
Berlin
Poljska
Varšava
Litva
Vilna
Minsk
Belorusija
Belgija
Luksemburg
Nemčija
Praga
Češka
Krakov
Lvov
Kijev
Harkov
Pariz
Francija
München
Dunaj
Slovaška
Ukrajina
Dnipro
Avstrija
Budimpešta
Madžarska
Moldavija
Kišinjev
Odesa
Švica
Lyon
Milano
Slovenija
Hrvaška
Beograd
Romunija
Monako
Marseille
Firence
Sarajevo
Srbija
Bukarešta
Andora
Barcelona
Italija
Črna gora
Sofija
Bolgarija
Rim
Podgorica
Tirana
Albanija
Severna Makedonija
Carigrad
Madrid
Palma de
Burgas
Ankara
Črno morje
Google My Maps


München
Rosenheim
Kempten
Salzburg
Konstanca
Sankt Gallen
Garmisch-Partenkirchen
Innsbruck
Zell am See
Lihtenštajn
Nationalpark Hohe Tauern
Avstrija
Dunaj
Bratislava
Sankt Pölten
Wels
Steyr
Sopron
Győr
Budimpešta
Gradec
Sombotel
Székesfehérvár
Madžarska
Szolnok
Veszprém
Siófok
Zalaegerszeg
Beljak
Celovec
Maribor
Bolzano
Kaposvár
Szeged
Trento
Videm
Ljubljana
Celje
Varaždin
Pécs
Como
Bergamo
Zagreb
Milano
Brescia
Vicenza
Trst
Verona
Benetke
Karlovec
Padova
Koper
Osijek
Reka
Piacenza
Hrvaška
Novi Sad
Beograd

Proteus anguinus - *Olm*

Black olm
Proteus anguinus parkelj
Arntzen, 1994
- first found in 1986

White olm
Proteus anguinus anguinus
Laurenti, 1768
- first written mention in 1689 as a baby dragon.

- It is entirely aquatic, eating, sleeping, and breeding underwater.
- Living in caves found in the Dinaric Alps.
- It is endemic to the waters that flow underground through the extensive limestone bedrock of the karst of Central and Southeastern Europe
- Adaptated to a life of complete darkness in its underground habitat.
- The olm's eyes are undevel while its other senses, part and hearing, are acutely de
- Longevity up to 100 years

1 Aim

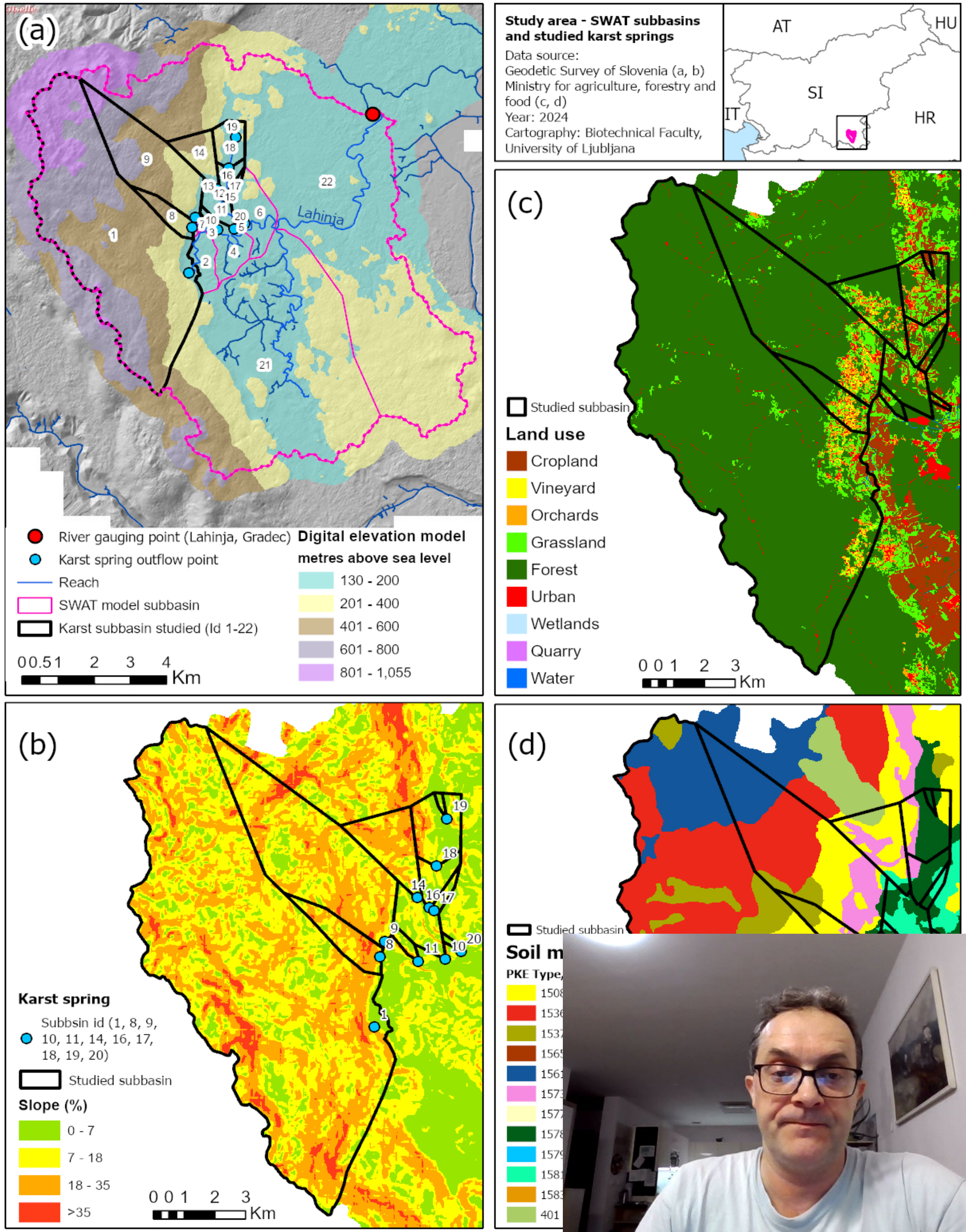
1. Identify **nitrate leaching hotspots** in the vulnerable Dobličica River aquifer and assess nitrate leaching by modeling different adaptation scenarios:

- crop rotations and agricultural practices,

- land use.

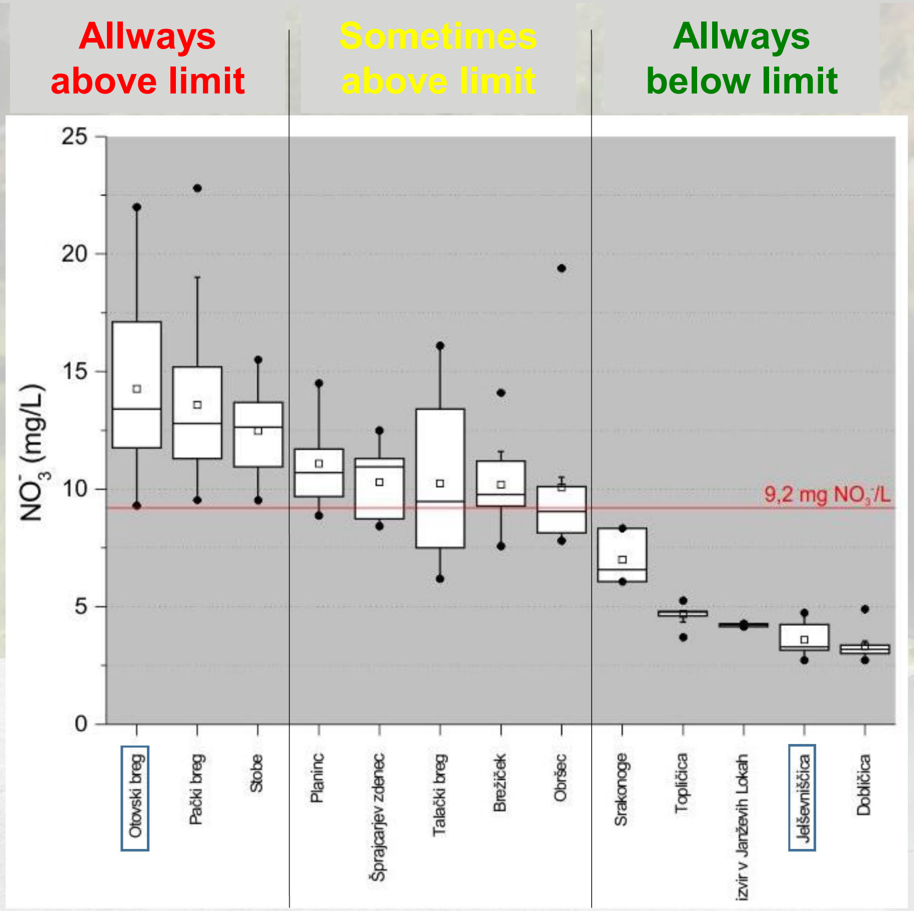
2. Determine **agricultural measures** that will lead to the **protection of the black olm habitat** from nitrate pollution.

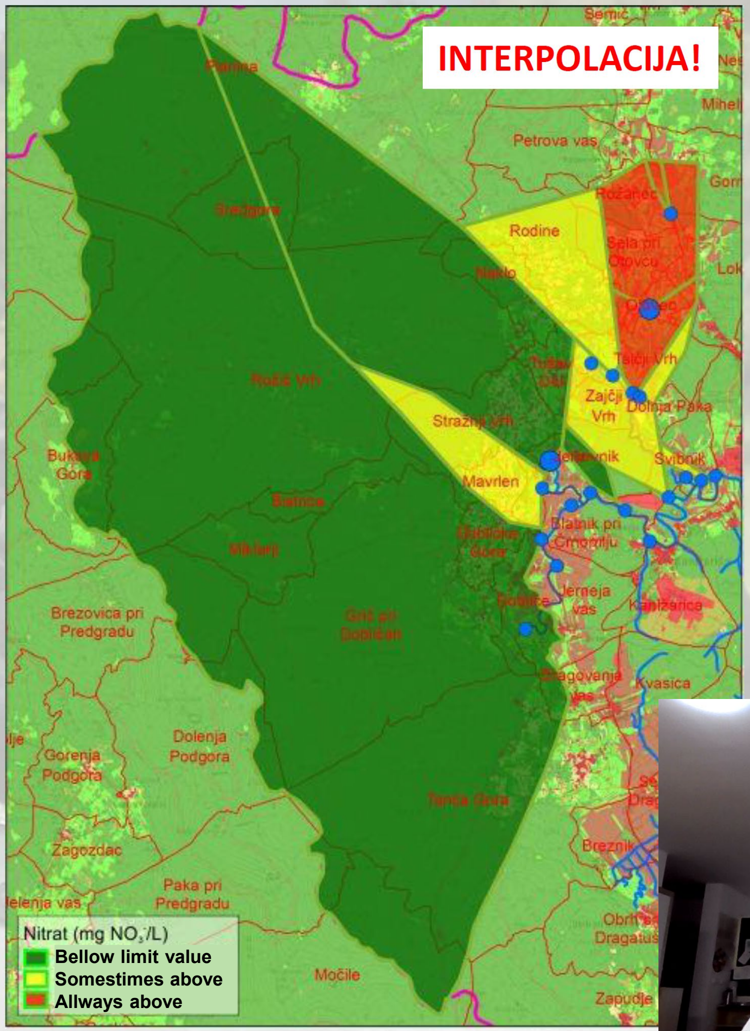
2 Study Area - Landscape



2 Study Area – Nitrate concentration

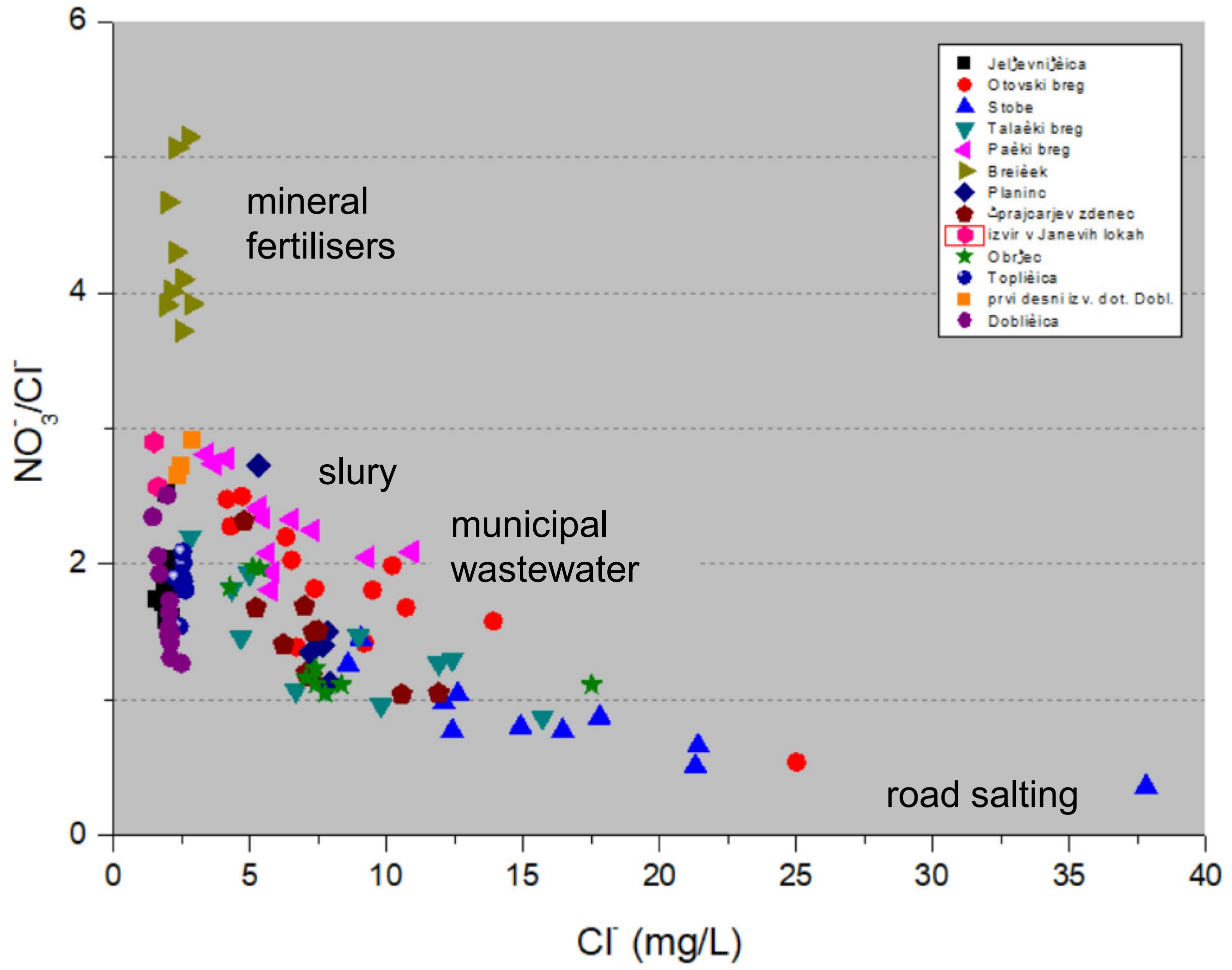
Characteristic of nitrate in karst springs

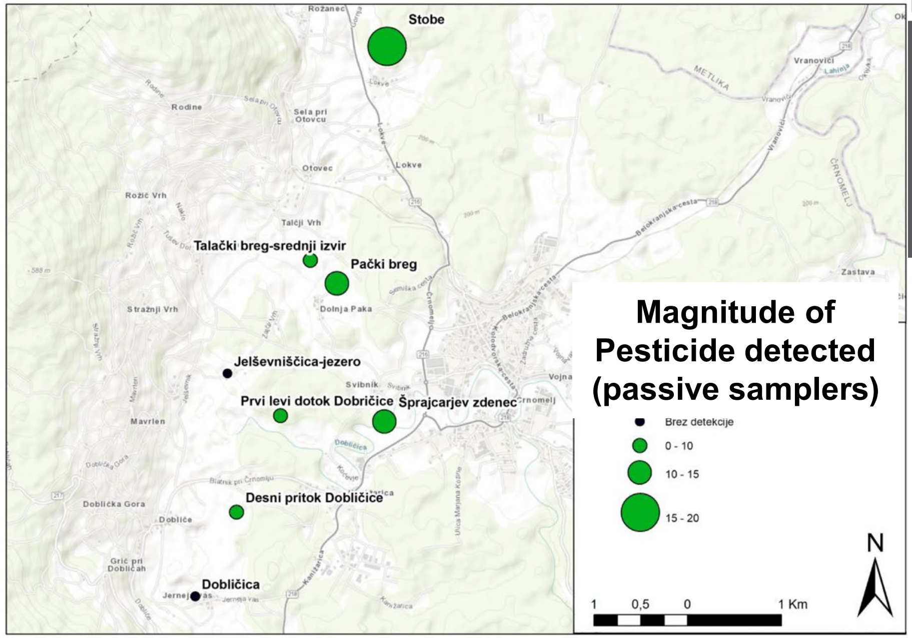


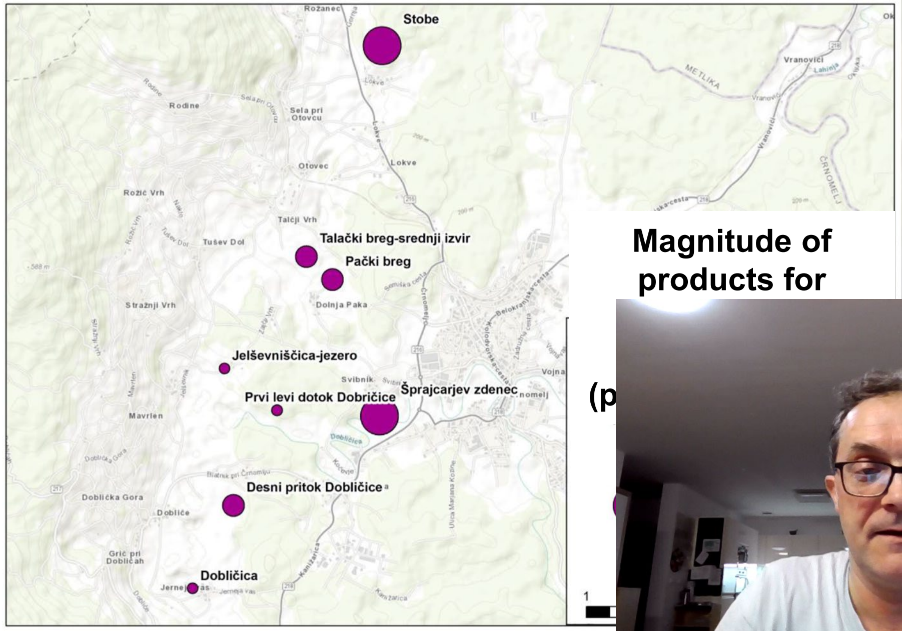


UL | BF

2 Study Area – Nitrate source







3 Data collection

Weather	Unit	Data source
precipitation	mm day^{-1}	Slovenian Environmental Agency (ARSO) Gauging stations Dobliče (precipitation, temperature, wind, relative humidity), Novo mesto (sun)
min. in mxs. temperature	°C day^{-1}	
relative humidity	fraction	
global radiation energy (sun hours)	(h day^{-1})	
average wind speed	km day^{-1}	
Soil		
digital soil map, soil horizons, colour	.shp	Ministry of Agriculture, Forestry and Food of the Republic of Slovenia (MKGP)
soil depth, roth depth	cm	
texture (clay, silt, sand), organic matter	mass %	
soil density	cm^3 cm^{-3}	Calculation of pedotransfer functions based on digital spil map data (MKGP)
field capacity, wilting point	cm cm^{-1}	
saturated hydraulic conductivity	cm h^{-1}	
soil erosivity - MUSLE		calculation
Crop production techniques		
crop type and rotation, sowing/planting/harvesting time		Farmers Agricultural advisory service (KGZ Novo mesto)
fertiliser type and method of application, equipment use scheduler, depth of cultivation		
Land		
actual land use	.shp	MKGP
digital elevation model	raster	Geodetic Survey RS (GU
Water		
river flow - Lahinja gauging station Gradac (1992-2022)	m^3/s	ARSO
karst springs (2021-2022)		Institute for Karst Research (Z
nitrate content - Lahinja gauging station Gradac (2021-2022)	(mg/l NO_3^-)	ARSO
monthly nitrate content (09/2021 – 11/2022)		ZRC SAZU
karst springs subbasins	.shp	ZRC SAZU

4 Arable crop rotation

- 40% maize
- 30% cereals
- 30% clover-grass mix

Year	Crop	Datum	Opravilo	Količina	N:P:K (kg)
1	Clover-grass mix	20. apr.	Košnja		
	Silage maize	22. apr.	Gnojenje	25 m^3	100:50:140
		23. apr.	Oranje		
		24. apr.	Predsetvena priprava		
		25. apr.	Gnojenje (ob setvi)	250 kg/ha	38:38:38
		25. apr.	Setev		
		10. jun.	Gnojenje	200 kg/ha	92
		15. sept.	Žetev		
	Winter wheat	15. okt.	Gnojenje	15 m^3	60:30:85
		16. okt.	Oranje		
		17. okt.	Predsetvena priprava		
		18. okt.	Gnojenje (ob setvi)	200 kg/ha	14:40:60
		18. okt.	Setev		
2		20. feb	Gnojenje	200 kg/ha	54
		25. mar.	Gnojenje	200 kg/ha	54
		16. jul	Žetev		
	barre	17. jul	začetek		
3		11. apr	konec		
	Silage maize	12. apr.	Gnojenje	25 m^3	100:50:140
		13. apr.	Oranje		
		14. apr.	Predsetvena priprava		
		15. apr.	Gnojenje (ob setvi)	250 kg/ha	38:38:38
		15. apr.	Setev		
		10. jun.	Gnojenje	200 kg/ha	92
		15. sept.	Žetev		
	Winter barley	10. okt.	Gnojenje		
		11. okt.	Oranje		
		12. okt.	Predsetvena priprava		
		13. okt.	Gnojenje (ob setvi)		
		13. okt.	Setev		
4		15. mar.	Gnojenje		
		25. jun.	Žetev		
	Clover-grass mix	1. jul.	Predsetvena priprava		
		2. jul.	Setev		
		30. sept.	Košnja		

5 Scenarios

Scenarios			
No.	Name	Description	
		Arable land	Grassland
0	BASE (B)	4-year rotation, no greening in 2nd year after winter wheat maize/wheat+no greening/maize/barley+clover-rass mix	3 cuts
AGRICULTURAL CROP ROTATION CHANGE			
1	ROTATION (R1)	2-year rotation maise/winter barley+summer maize+clover-grass mix (CGM)	3 cuts
2	ROTATION 1 (R2)	B + CGM in 2nd year (maize/wheat+CGM/maize/barley+CGM)	3 cuts
3	ROTATION 2 (R3)	R2 + 20% decrease in fertilisation (maize/wheat+CGM/maize/barley+CGM)	3 cuts
4	ROTATION 3 (R4)	6-year rotation R3 + additional 2 years of CGM (maize/wheat+CGM/maize/barley+CGM/CGM/CGM	3 cuts
5	ROTATION 4 (R5)	6-year rotation R4 + winter fodder peas (WFP) replaced winter wheat (maize/WFP+CGM/maize/barley+CGM/CGM/CGM	3 cuts
AGRICULTURAL LAND USE CHANGE			
6	EXTENSIVE 1 (E1)	B + selected fields into grassland (3 cuts) (slope > 7%, Soil PKE type: 1508, 1536, 1537, 1561, 1573)	3 cuts
7	EXTENSIVE 2 (E2)	B + all fields into grassland (3 cuts)	
8	EXTENSIVE 3 (E3)	B + selected fields into unfertilised grassland (1 cut) (slope > 7%, Soil PKE type: 1508, 1536, 1537, 1561, 1573)	
9	EXTENSIVE 4 (E4)	B + all fields into unfertilised grassland (1 cut)	
10	EXTENSIVE 5 (E5)	B + E4 + all grassland into forest	
11	EXTENSIVE 6 (E6)	R5 + selected grasslands into fields (slope <7, Soil PKE type: 1578, 1579, 1583)	

6 Results CROPLAND

Comparison of results between baseline and alternative **scenarios of agricultural** crop rotation

change for

- **nitrate transported into the main channel in the groundwater loading from the HRU** (NO3GW) (kg N/ha year),
- **nitrate leached from the soil profile** (NO3L) (kg N/ha year)
- **total plant biomass** (BIOM) (metric tons/ha year)

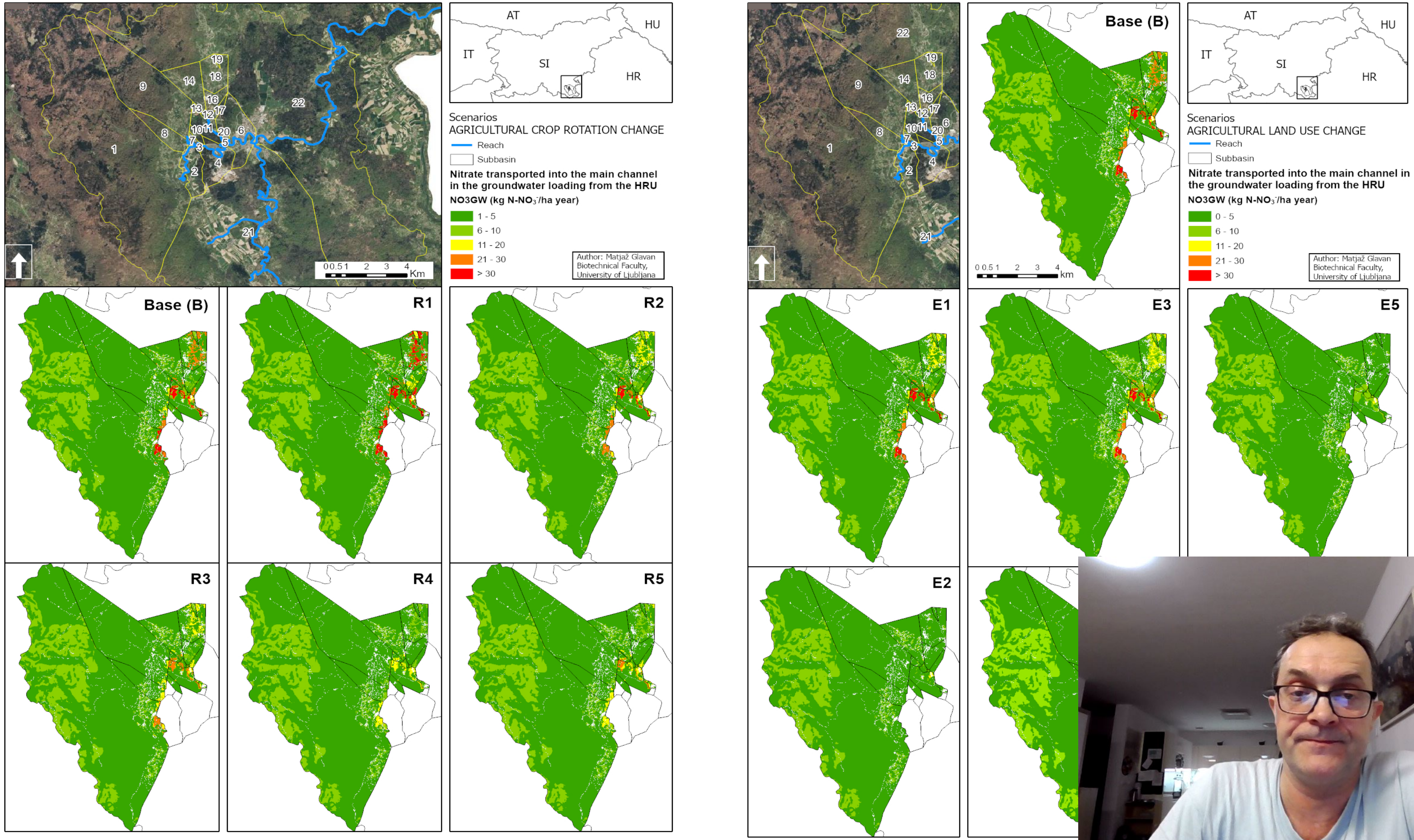
Simulated Annual Averages (1998-2022)	CROPLAND										
	Subbasin Name and Number										
	Dobličica	Obršec	Jelševnik	Janževe loke	Šprajcarjev zdenec	Talački breg	Pački breg	Brežiček	Otovski breg	Stobe	Planinc
	1	8	9	10	11	14	16	17	18	19	20
Nitrate transported into the main channel in the groundwater loading from the HRU (NO3GW) (kg N/ha year)											
BASE model (kg N/ha year)	23	21	15	8	32	25	7	18	16	8	22
StDv	17	16	12	7	21	18	7	14	13	7	15
SCENARIOS	Change (%) in the amount of nitrate nitrogen (N-NO_3^-)										
R1	67	64	63	70	68	69	70	66	66	69	62
R2	-16	-15	-12	-18	-16	-17	-17	-18	-18	-17	-16
R3	-38	-38	-35	-39	-37	-39	-40	-39	-40	-36	-36
R4	-68	-68	-66	-67	-66	-68	-68	-67	-68	-65	-66
R5	-52	-52	-50	-50	-51	-52	-52	-51	-52	-48	-49
Nitrate leached from the soil profile (NO3L) (kg N/ha year)											
BASE model (kg N/ha year)	61	65	73	66	64	60	66	68	61	72	75
StDv	46	48	58	45	44	44	47	46	45	46	47
SCENARIOS	Change (%) in the amount of nitrate nitrogen (N-NO_3^-)										
R1	70	68	64	69	70	72	70	70	71	66	64
R2	-13	-12	-8	-13	-14	-15	-14	-13	-14	-12	-11
R3	-35	-35	-31	-34	-35	-37	-36	-34	-36	-32	-31
R4	-66	-65	-62	-64	-64	-66	-66	-64	-65	-62	-62
R5	-50	-49	-47	-48	-48	-50	-50	-48	-49	-46	-46
Total plant biomass (BIOM) (metric tons/ha year)											
BASE model (kg N/ha year)	25	25	24	26	26	26	26	26	26	26	26
StDv	13	13	13	13	13	13	13	13	13	[illegible]	[illegible]
SCENARIOS	Change (%) in the amount of biomass (dry matter)										
R1	16	16	16	17	17	17	17	17	16	[illegible]	[illegible]
R2	18	18	18	19	19	18	18	19	18	[illegible]	[illegible]
R3	14	14	15	15	15	15	15	15	14	[illegible]	[illegible]
R4	-5	-4	-3	-4	-4	-4	-4	-4	-5	[illegible]	[illegible]
R5	-1	0	1	-1	-1	-1	0	-1	-1	[illegible]	[illegible]

* Scenario descriptions and abbreviations are explained in Table 2; red – increase in N leaching, blue - decreas
green – increase in biomass, yellow – decrease in biomass

7 Results – Spatial representation

Average nitrate-nitrogen transported ($kg\ N\text{-}NO_3^-/ha$ per year) from HRU in the groundwater flow to the surface water flow

(a) agricultural crop rotations change (R) (b) agricultural land use change (E)



8 Results – Cocentration at karst springs

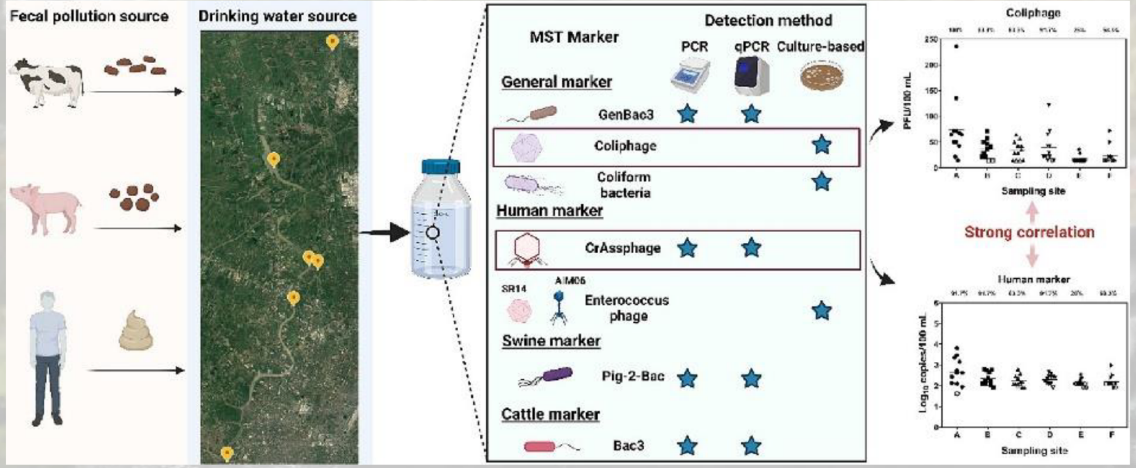
Evaluating the potential for improving black olm habitat by adapting agricultural practices - limit value of 9.2 mg NO_3^-/l

UL | BF

	Nitrate concentration in the reach at karst springs subbasin outflow (mg NO_3^-/l)										
	Karst springs subbasin name and No.										
	Dobličica	Obršec	Jelševnik	Janževe loke	Šprajcarjev zdenec	Talački breg	Pački breg	Brežiček	Otovski breg	Stobe	Planinc
	1	8	9	10	11	14	16	17	18	19	20
Average observed (ZRC SAZU) (9/2021-11/2022)	3.3	10.1	3.6	4.2	10.3	10.3	13.6	10.2	14.3	12.5	11.1
Target value for the black olm habitat	**9.2 mg NO_3^-/l**										
Required reduction	**-**	**1.1**	**-**	**-**	**1.3**	**1.3**	**4.6**	**1.2**	**5.3**	**3.5**	**2.1**
Scenario	***Potential nitrate concentration upon implementation of the scenarios***										
R1 (2-year maize rotation)	3.4	10.7	3.7	4.6	12.2	10.5	15.5	12.2	16.6	16.9	14.2
R2 (winter greening)	3.3	10.0	3.6	4.1	9.9	10.2	13.2	9.7	13.7	11.5	10.3
R3 (-20% fertilizer)	3.3	9.8	3.6	4.0	9.3	10.2	12.5	9.1	13.0	10.4	9.3
R4 (6-year rotation)	3.2	9.5	3.5	3.9	8.4	10.1	11.7	8.1	12.0	8.5	7.9
R5 (fodder peas)	3.3	9.7	3.5	3.9	8.9	10.1	12.2	8.7	[illegible]	[illegible]	[illegible]
E1 (selected fields → grass)	3.3	10.1	3.6	4.2	10.3	10.2	13.5	10.2	[illegible]	[illegible]	[illegible]
E2 (all fields → grass)	3.2	9.3	3.5	3.7	7.6	10.0	11.0	7.2	[illegible]	[illegible]	[illegible]
E3 (selected fields → grass no-fert)	3.3	10.3	3.6	4.4	10.6	10.5	14.0	10.5	[illegible]	[illegible]	[illegible]
E4 (all fields → grass)	3.3	9.6	3.6	3.9	8.2	10.4	11.7	8.0	[illegible]	[illegible]	[illegible]
E5 (E4 + grass → forest)	3.2	9.4	3.5	3.8	8.0	10.1	11.4	7.7	[illegible]	[illegible]	[illegible]
E6 (selected grass → cropland)	3.3	9.8	3.6	4.1	9.6	10.2	13.6	9.5	[illegible]	[illegible]	[illegible]

9. Results – Microbial source tracking

The real source of nitrate pollution



Sresung M. et al. 2023. Microbial source tracking using molecular and cultivable methods in a tropical mixed-use drinking water source to support water safety plans. Science ot The Total Environment, vol. 876.

The real source of nitrate originates in untreated wastewaters from individual houses septic tanks.

	Jelševniščica			Otovski breg			Obršec			Stobe		
	5.07.2023	23.11.2023	27.05.2024	5.07.2023	23.11.2023	27.05.2024	5.07.2023	23.11.2023	27.05.2024	5.07.2023	23.11.2023	27.05.2024
Koliformi (CFU/100 mL)	610	/	/	24.000	/	/	/	/	/	4.400	/	/
E. coli (CFU/100 mL)	56	52	93	220	420	920	/	580	860	73	82	110
Clostridium perfringens (CFU/100 mL)	1	3	4	26	67	39	/	53	184	[illegible]	[illegible]	[illegible]
Enterokoki (CFU/100 mL)	18	60	150	150	384	960	/	640	980	[illegible]	[illegible]	[illegible]
Molekularni označevalec fekalnega onesnaženja GenBac3 (#kopij/100 mL)	9.300	9.700	12.000	11.000	120.000	10.000	/	30.000	12.000	[illegible]	[illegible]	[illegible]
Marker – human BacH (#kopij/100 mL)	230	450	560	510	1.100	180	/	3.400	1.800	[illegible]	[illegible]	[illegible]
Marker – human crAssphage (#kopij/100 mL)	<150	<150	230	600	600	<150	/	450	1.300	[illegible]	[illegible]	[illegible]
Marker – human BacHum (#kopij/100 mL)	200	450	680	830	1.600	350	/	4.200	2.300	[illegible]	[illegible]	[illegible]
Marker – ruminants Rum-2-Bac (#kopij/100 mL)	<150	<150	<150	<150	1.400	750	/	<200	<188	[illegible]	[illegible]	[illegible]
Marker – cattle CowM3 (#kopij/100 mL)	<150	<150	<150	<150	<300	<150	/	<200	<188	[illegible]	[illegible]	[illegible]
Marker – pigs Pig2Bac (#kopij/100 mL)	<150	<150	<150	<150	510	<150	/	<200	<188	[illegible]	[illegible]	[illegible]
Marker – birds AV4143 (#kopij/100 mL)	<150	<150	<150	<150	<300	<150	/	<200	<188	[illegible]	[illegible]	[illegible]

UL | BF

10. Conclusion

MODELING RESULTS and their interpretation by researchers should serve as a **STARTING POINT FOR CONSTRUCTIVE DISCUSSION,** aimed at achieving and maintaining good water quality in the research area, which is also the goal of the Water Directive and legislation related to the protection of water resources.

REPUBLIKA SLOVENIJA
MINISTRSTVO ZA NARAVNE VIRE IN PROSTOR

REPUBLIKA SLOVENIJA
MINISTRSTVO ZA KMETIJSTVO, GOZDARSTVO IN PREHRANO

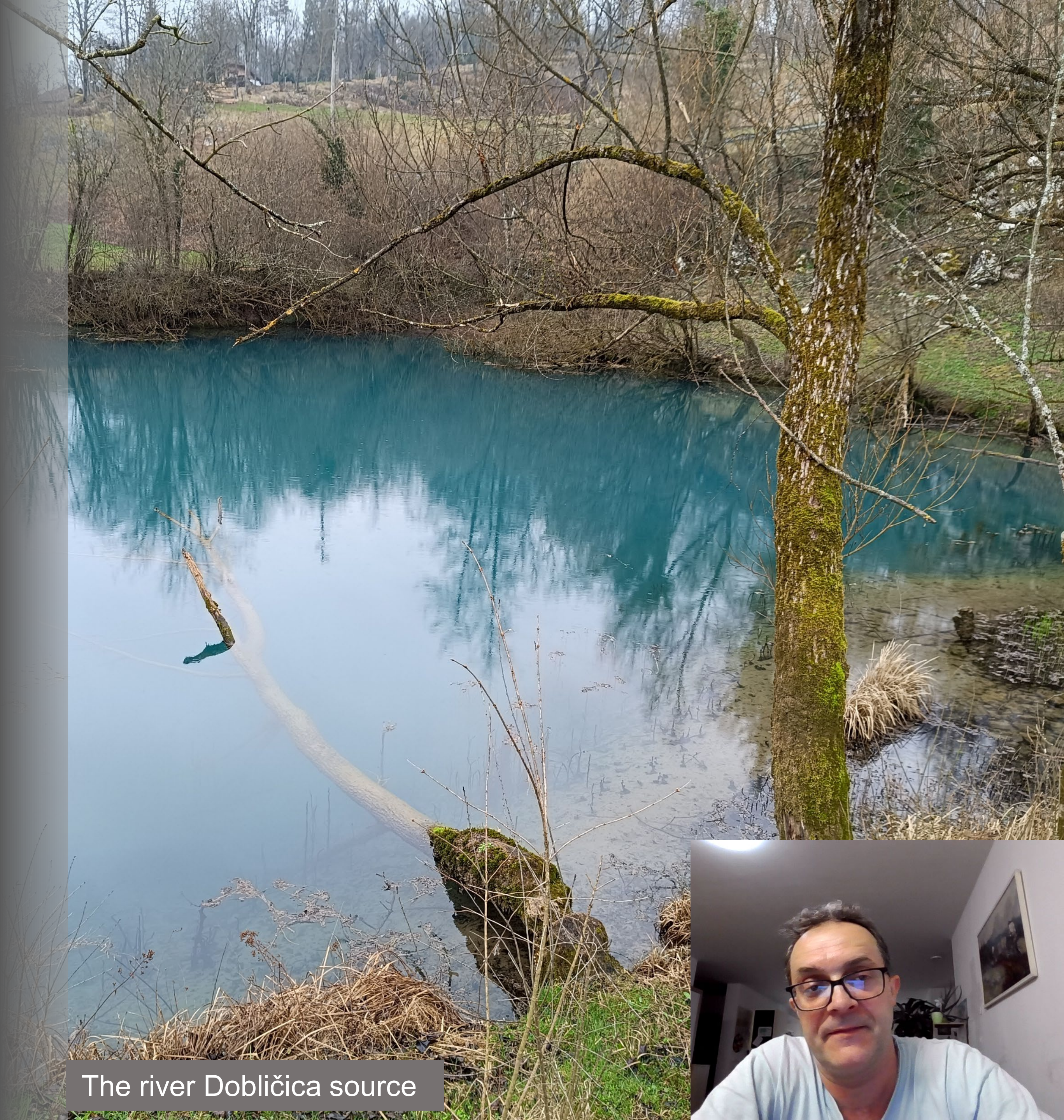
UNIVERZA V LJUBLJANI | BF Biotehniška fakulteta

ARIS

Thank you for your attention.

Matjaž Glavan, University of Ljubljana, Slovenia

Matjaz.Glavan@bf.uni-lj.si



The river Dobličica source