Geological Survey of Slovenia

University of Ljubljana. Biotechnical faculty

Chamber of Agriculture and Forestry of Slovenia. Institute Maribor

REPUBLIC OF SLOVENIA
MINISTRY OF AGRICULTURE AND THE ENVIRONMENT

Influence of different agricultural practices on nitrate–nitrogen (NO_3-N) leaching

Experiences in the Drava catchment, Slovenia

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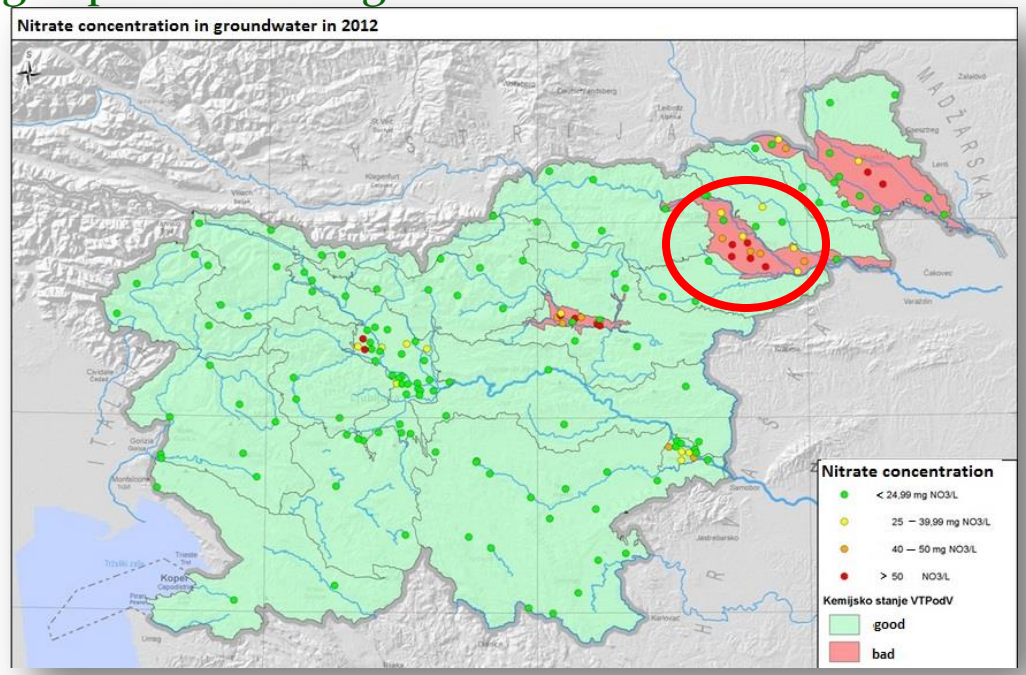
SWAT 2013, Toulouse, France, 17. 7. 2013

1. Introduction

Underground water is for more than 95% of Slovenian population main source of drinking water.



Especially vulnerable to nitrate-nitrogen pollution are groundwaters in alluvial aquifers with porous media.



<u>High concentrations are combination of:</u>

Intensive agriculture (dairy and pig farms).
Untreated domestic waste water.

Alluvial bedrock.
Shallow upper soil profile.
Sandy soil texture.

1. Introduction

The aim of research was to determine how changes in the management of agricultural land (cultivation technics, fertilisation, type of crop, crop rotation) and type of soils influence on the nitrogen leaching from the soil profile to the groundwater in the Drava river plain, Slovenia.

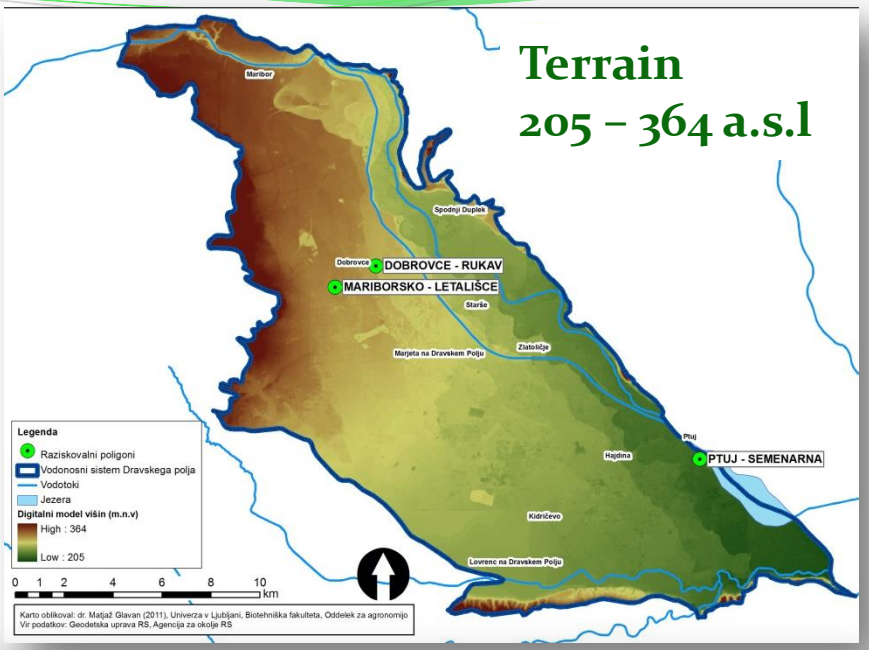
Research was located on the shallow alluvial bedrock with carbonate and silicate layers, which is the main source of drinking water in the area.

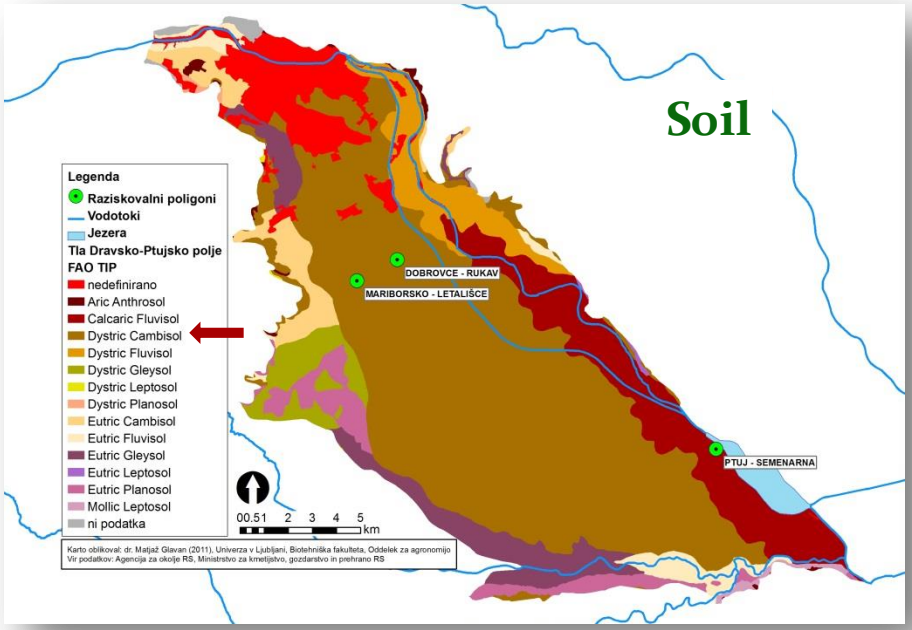
The SWAT 2009 model (ArcSWAT version 2009.10.1) was used.

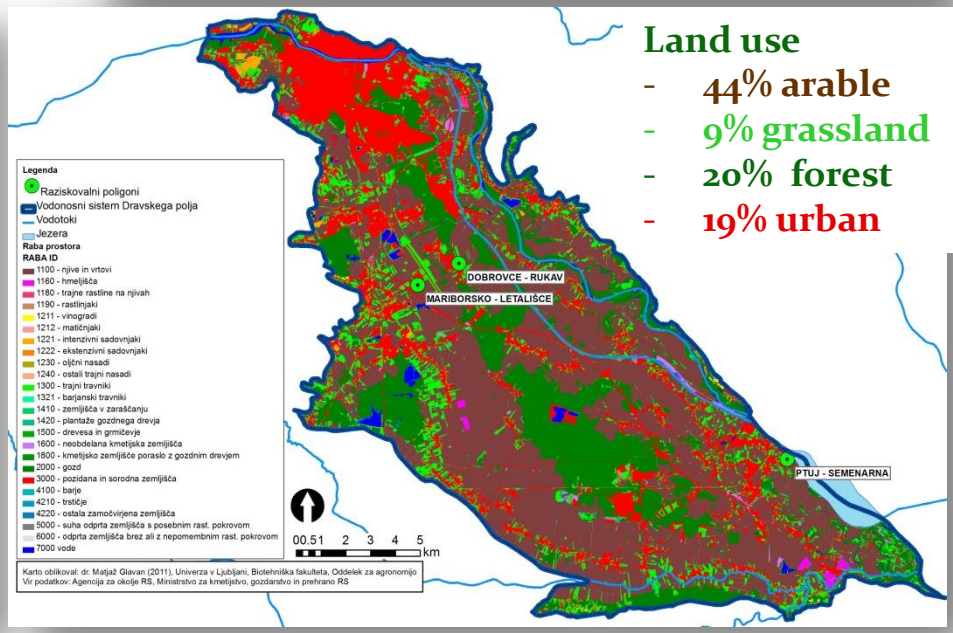
2. Study area

Three reserch polygons:
Ptuj – 218 a.s.l.
Dobrovce – 253 a.s.l.
Maribor – 262 a.s.l.

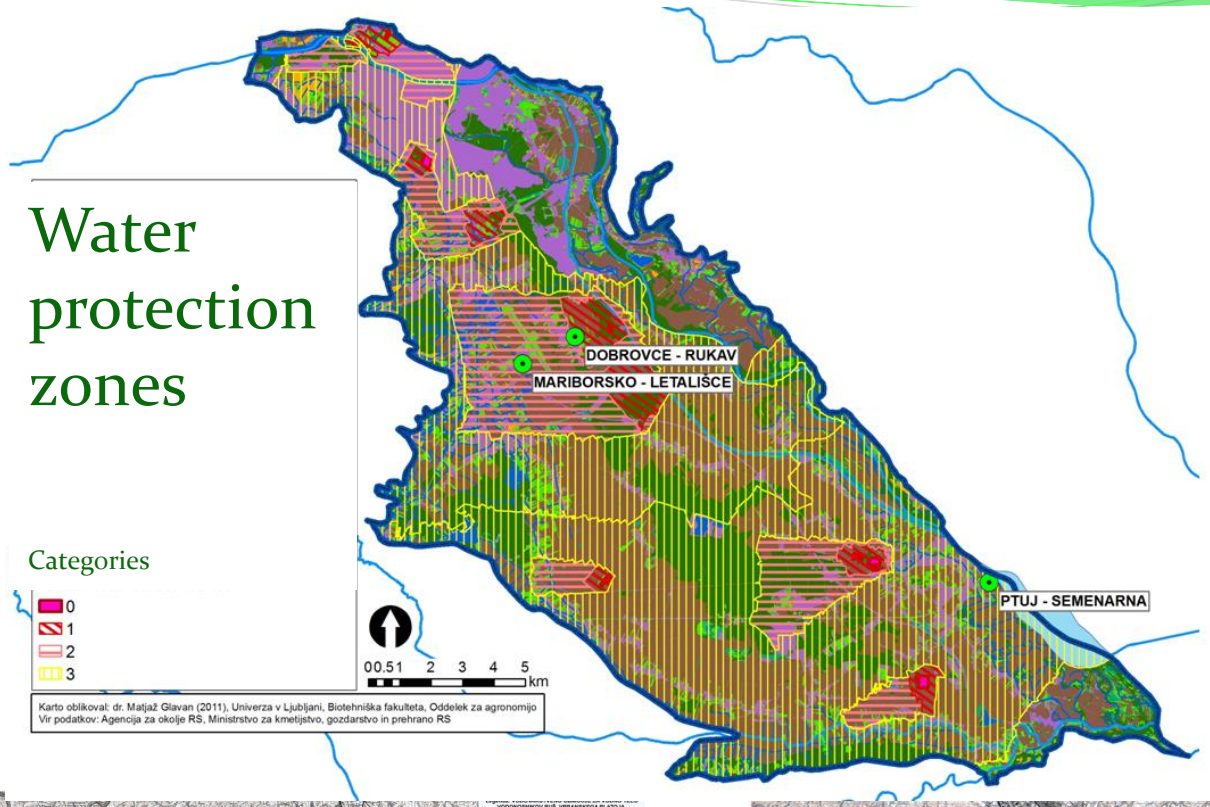
Sub-Panonnian continental climate
Precipitation: 959 mm/year
Average yearly temperature
Min: 5.3°
Max: 15.3°

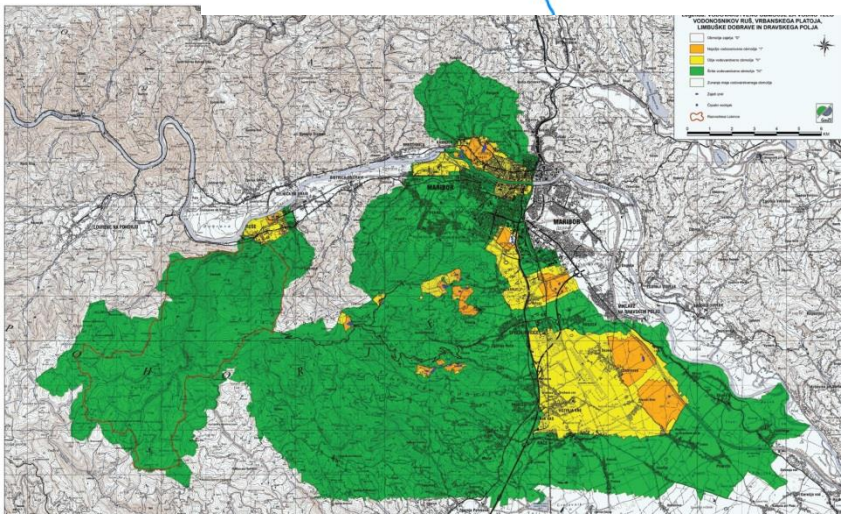


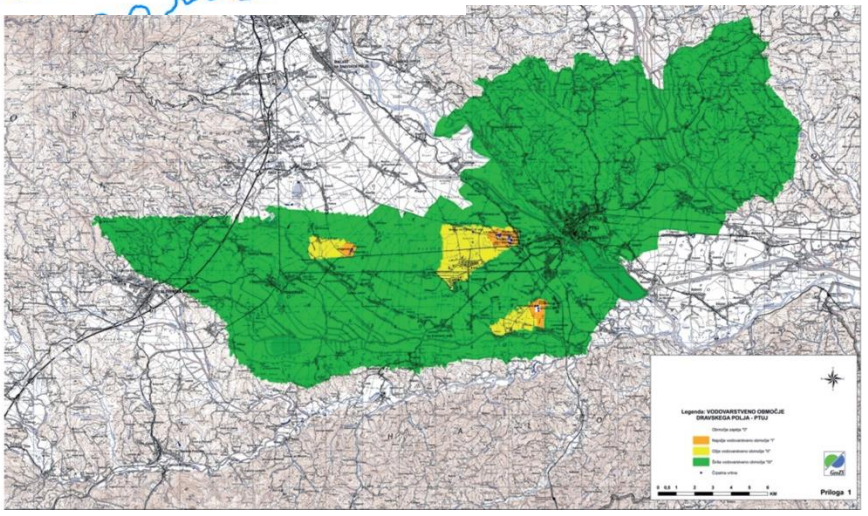




2. Study area


Water protection zones
Categories
0
1
2
3
DOBROVCE - RUKAV
MARIBORSKO - LETALIŠČE
PTUJ - SEMENARNA
0 0.5 1 2 3 4 5 km
Karto oblikoval: dr. Matjaž Glavan (2011), Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za agronomijo
Vir podatkov: Agencija za okolje RS, Ministrstvo za kmetijstvo, gozdarstvo in prehrano RS

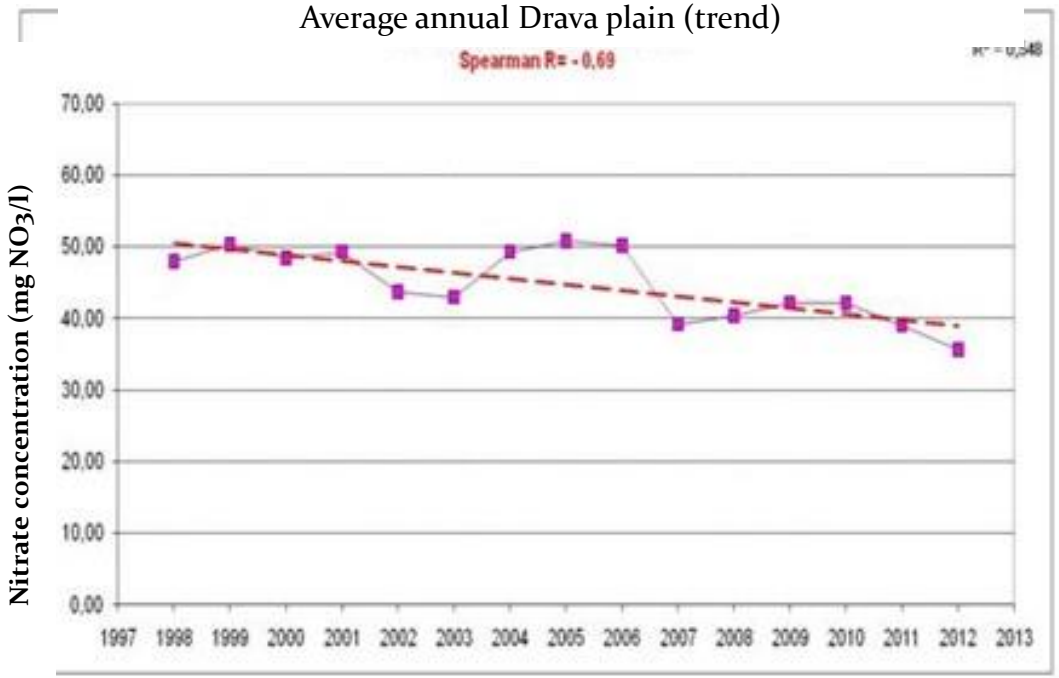




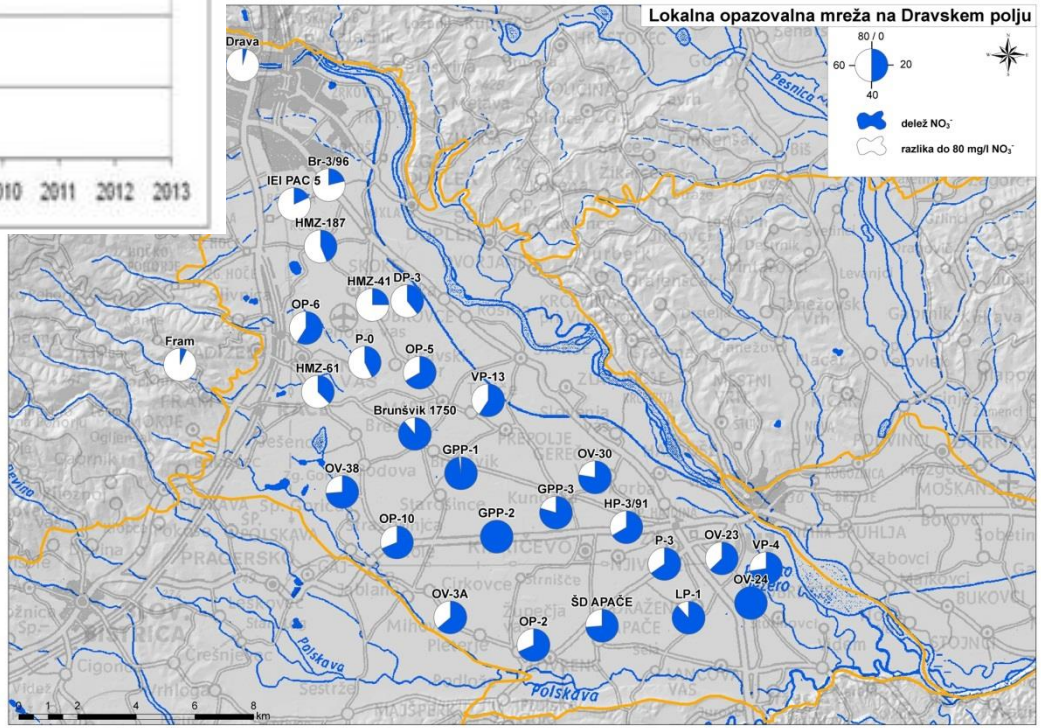
2. Study area

Nitrate concentration

Average annual Drava plain (trend)



Measurements at certain points exceed 50 mg NO_3/l and reach up to 80 mg/l (full blue circles).



Water framework directive target value for drinking water is 50 mg/l.

3. Calibration – base land managment scenarios

Maribor

Leto	Kultura	Datum	Operacija	Tip operacije	Količina gnojila v elementalni obliki (kg/ha)
1	oljna ogrščica	10.mar	Fertilizer application 27:00:00 250kg	KAN	80
		15.apr	Fertilizer application 27:00:00 250kg	KAN	50
		30.jun	Harvest and kill	spravilo pridelka	
	detelja	9.avg	Tillage operation	Field Cultivator 15cm	
		10.avg	Plant/begin growing season		
		23.apr	Kill operation		
2	koruza za zrnje	24.apr	Fertilizer application 15:15:15=350 kg	NPK	53:53:53
		24.apr	Tillage operation	Field Cultivator 22cm	
		25.apr	Plant/begin growing season		
		30.maj	Fertilizer application 27:00:00=200kg	KAN	54
		15.jun	Fertilizer application 27:00:00=200kg	KAN	54
		12.sep	Harvest and kill	spravilo pridelka	
	pšenica	2.okt	Fertilizer application 6:12:24=250 kg	N P K	15:30:60
		2.okt	Tillage operation	Field Cultivator 15cm	
		3.okt	Plant/begin growing season		
3	pšenica	15.mar	Fertilizer application 27:00:00=130kg	KAN	35
		20.apr	Fertilizer application 27:00:00=120kg	KAN	32
		1.jun	Fertilizer application 27:00:00=100kg	KAN	27
		15.jul	Harvest and kill	spravilo pridelka	
	detelja	9.avg	Tillage operation	Field Cultivator 15cm	
		10.avg	Plant/begin growing season		
		20.apr	Kill operation		
4	koruza za zrnje	21.apr	Fertilizer application 15:15:15=350 kg	N P K	53:53:53
		21.apr	Tillage operation	Field Cultivator 22cm	
		22.apr	Plant/begin growing season		
		30.maj	Fertilizer application 27:00:00=200kg	KAN	54
		15.jun	Fertilizer application 27:00:00=200kg	KAN	54
		4.okt	Harvest and kill	spravilo pridelka	
	ječmen	8.okt	Fertilizer application 6:12:24=250 kg	N P K	15:30:60
		8.okt	Tillage operation	Field Cultivator 15cm	
		9.okt	Plant/begin growing season		
5	ječmen	15.mar	Fertilizer application 27:00:00=130kg	KAN	35
		20.apr	Fertilizer application 27:00:00=120kg	KAN	32
		1.jun	Fertilizer application 27:00:00=100kg	KAN	27
		22.jun	Harvest and kill	spravilo pridelka	
	detelja	9.avg	Tillage operation	Field Cultivator 15cm	
		10.avg	Plant/begin growing season		
		21.apr	Kill operation		
6	koruza za zrnje	22.apr	Fertilizer application 15:15:15=350 kg	N P K	53:53:53
		22.apr	Tillage operation	Field Cultivator 22cm	
		23.apr	Plant/begin growing season		
		30.maj	Fertilizer application 27:00:00=200kg	KAN	54
		15.jun	Fertilizer application 27:00:00=200kg	KAN	54
		20.sep	Harvest and kill	spravilo pridelka	
	pšenica	2.okt	Fertilizer application 6:12:24=250 kg	N P K	15:30:60
		2.okt	Tillage operation	Field Cultivator 15cm	
		3.okt	Plant/begin growing season		
7	pšenica	15.mar	Fertilizer application 27:00:00=130kg	KAN	35
		20.apr	Fertilizer application 27:00:00=120kg	KAN	32
		1.jun	Fertilizer application 27:00:00=100kg	KAN	27
		15.jul	Harvest and kill	spravilo pridelka	
	oljna ogrščica	25.avg	Tillage operation	Field Cultivator 15cm	
		25.avg	Fertilizer application 6:12:24	NPK 333 kg	20:40:80
		26.avg	Plant/begin growing season		

Dobrovce

Leto	Kultura	Datum	Operacija	Tip operacije	Količina gnojila v elementalni obliki (kg/ha)	Harvest efficiency HARVEFF	Harvest index override HI_OVR
1	zelje	25. maj	Fertilizer application 15:15:15=500kg	NPK	75:75:75		
		25. maj	Tillage operation	Field Cultivator 15cm			
		26. maj	Plant/begin growing season				
		10. jun	Tillage operation	Cultiweeder 36 Ft - 10cm			
		20. jun	Tillage operation	Cultiweeder 36 Ft - 10cm			
			Fertilizer application	Listno gnojenje ni vpliva na tla			
		1. jul	Harvest only operation	spravilo pridelka		1	0.85
		2. jul	Harvest and kill operation				
	repa	9. jul	Tillage operation	Field Cultivator 15cm			
		10. jul	Plant/begin growing season				
		1. sep	Tillage operation	Cultiweeder 36 Ft - 10cm			
		19. okt	Harvest only operation	spravilo pridelka		1	0.9
		1. nov	Harvest and kill operation				
2	čebula	5. nov	Tillage operation	Generic Fall Plowing Opr25cm			
		13. apr	Tillage operation	Field Cultivator 15cm			
		14. apr	Plant/begin growing season				
		23. maj	Fertilizer application 27:00:00=100kg	KAN	27		
		23. maj	Tillage operation	Cultiweeder 36 Ft - 10cm			
		1. avg	Harvest only operation	spravilo pridelka		1	0.85
		2. avg	Harvest and kill operation				
3	krompir	27. okt	Fertilizer application 25 t/ha	hlevski gnoj	118:75:128		
		28. okt	Tillage operation	Generic Fall Plowing Opr25cm			
		31. mar	Tillage operation	Field Cultivator 15cm			
		1. apr	Plant/begin growing season				
			Fertilizer application	Listno gnojenje ni vpliva na tla			
		5. maj	Tillage operation	Cultiweeder 36 Ft - 10cm			
		23. maj	Tillage operation	Cultiweeder 36 Ft - 10cm			
		10. sep	Harvest only operation	spravilo pridelka		1	0.9
		15. sep	Harvest and kill operation				
4	paprika	28. okt	Tillage operation	Generic Fall Plowing Opr25cm			
		14. maj	Fertilizer application 15:15:15=500kg	NPK	75:75:75		
		14. maj	Tillage operation	Field Cultivator 15cm			
		21. maj	Plant/begin growing season				
			Fertilizer application	Listno gnojenje ni vpliva na tla			
		10. jul	Harvest only operation	spravilo pridelka		1	0.2
		25. jul	Harvest only operation	spravilo pridelka		1	0.2
		10. avg	Harvest only operation	spravilo pridelka		1	0.2
		25. avg	Harvest only operation	spravilo pridelka		1	0.2
		20. sep	Harvest only operation	spravilo pridelka		1	0.2
		20. okt	Harvest only operation	spravilo pridelka		1	0.2
		1. nov	Harvest and kill operation				
5	krompir	5. nov	Tillage operation	Generic Fall Plowing Opr25cm			
		31. mar	Fertilizer application 15:15:15=800kg		120:120:120		
		31. mar	Tillage operation	Field Cultivator 15cm			
		1. apr	Plant/begin growing season				
		5. maj	Fertilizer application 27:00:00=200kg	KAN	54		
		5. maj	Tillage operation	Cultiweeder 36 Ft - 10cm			
		23. maj	Tillage operation	Cultiweeder 36 Ft - 10cm			
		15. sep	Harvest only operation	spravilo pridelka		1	0.9
	zelje	16. sep	Harvest and kill operation				
		27. okt	Fertilizer application 30 t/ha	hlevski gnoj	141:90:153		
		28. okt	Tillage operation	Generic Fall Plowing Opr25cm			

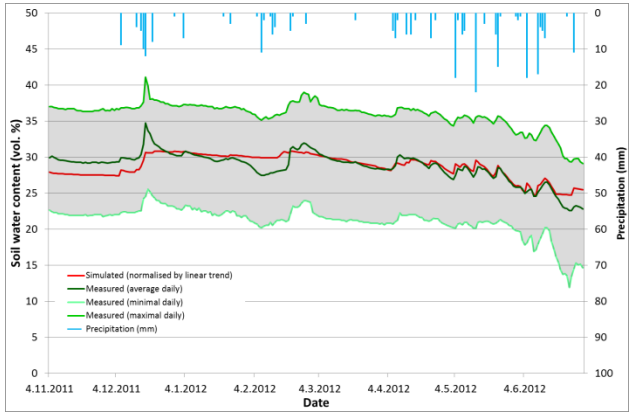
3. Calibration

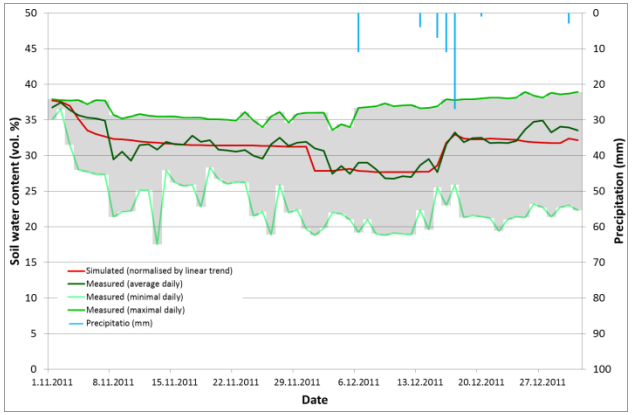
Calibration
at research polygons
was done by comparing
daily soil water content (SWC)
between measured and
simulated data at field
scale/HRU level.

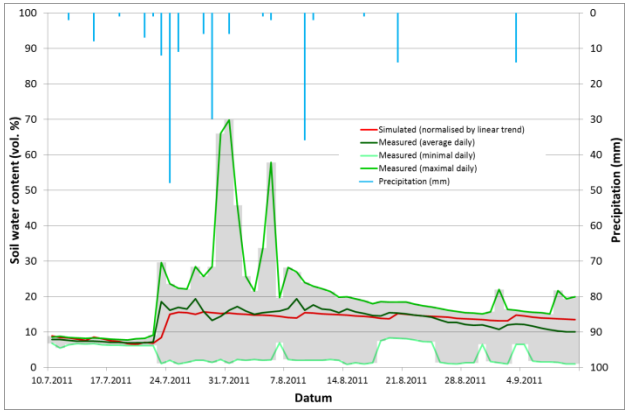
Time Domain Reflectometry probes (TDR)

3. Calibration

Calibration statistics for **soil water content**					
Objective function	unit	Optimal values	Soil water content		
			Ptuj	**Maribor**	**Dobrovce**
E_{NS}	-	1	0.65	0.72	0.64
E_{NS} cumulative distribution	-	1	0.82	0.90	0.84
R^2	-	1	0.65	0.72	0.64
PBIAS	%	0 (+ values = underestomate; – valuesi = overestimeta)	-0.01	0.76	0.01





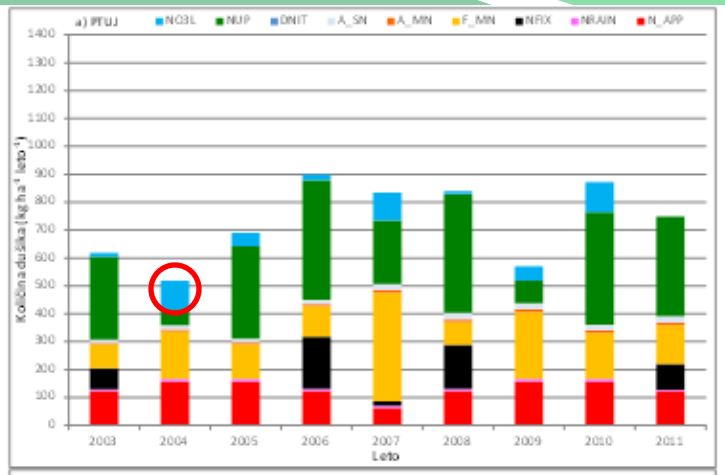


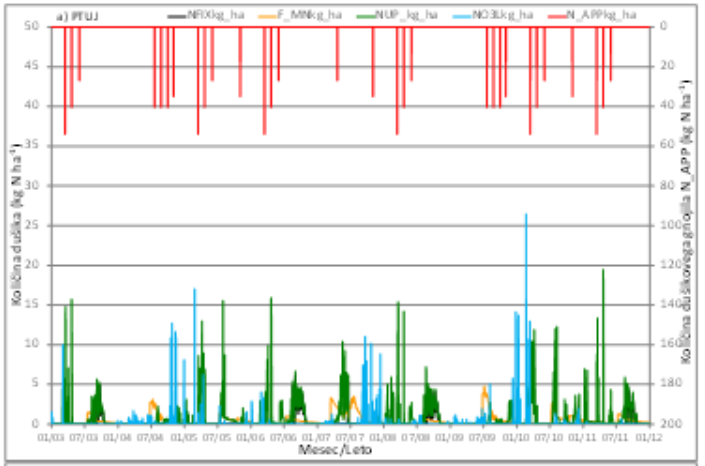
4. Results

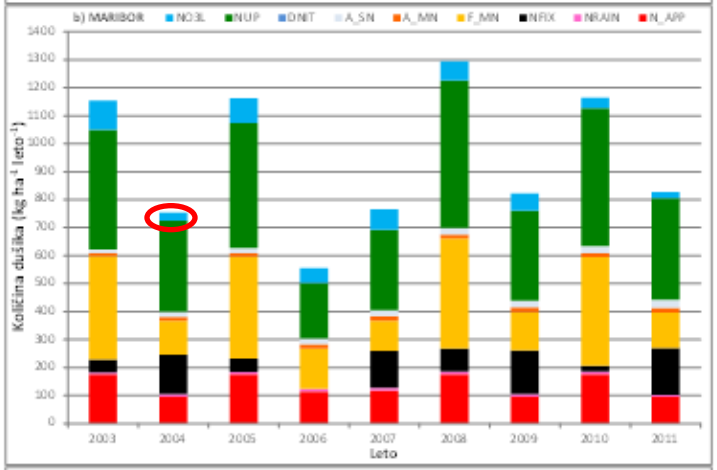
Ptuj

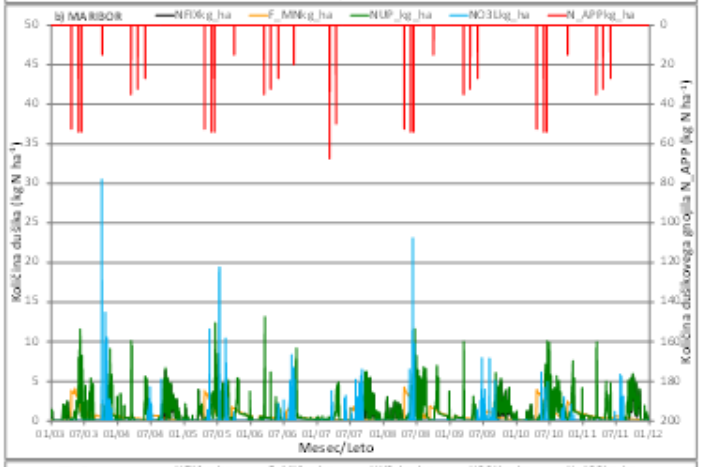
Maribor

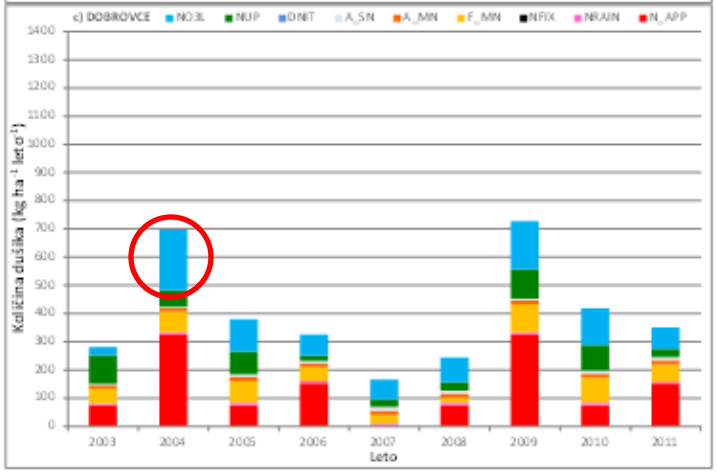
Dobrovce

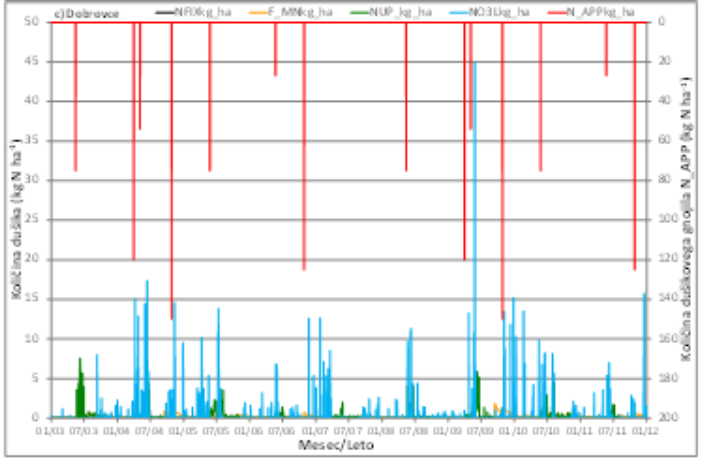












4. Results

Average annual nitrogen leaching (2003-2011)

Soil type	Nitrogen leaching(kg N ha^{-1} year)											
	BASE Rotation											
	Ptuj				Maribor				Dobrovce			
	avg.	st.dv.	min.	max.	avg.	st.dv.	min.	max.	avg.	st.dv.	min.	max.
Ptuj	51.3	43.4	1.2	109.1	32.4	17.5	0.7	56.2	71.4	50.1	13.2	152.8
Maribor	71.1	76.0	4.0	180.9	59.9	27.5	22.2	103.9	85.5	49.7	8.8	159.0
Dobrovce	91.5	105.5	6.0	267.6	97.5	62.3	12.3	208.4	91.1	56.1	4.9	188.3

avg. - average; St.dv. – standard deviation; min. – minimal; max. - maksimal

Rotational schemes have important influence on N leaching.

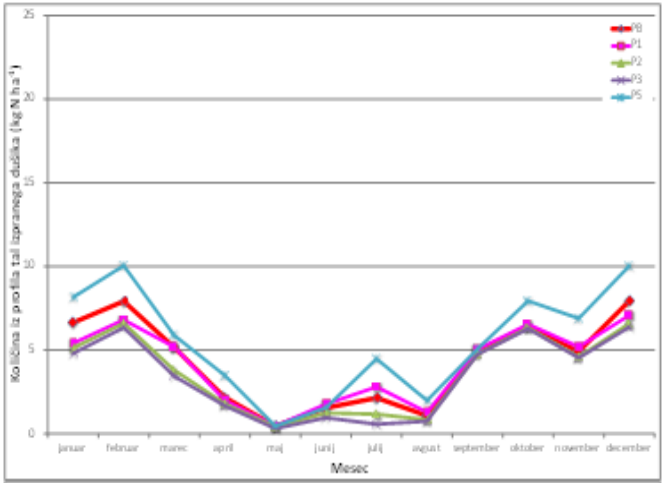
They should be adjusted also based on soil type not only by undergound hydrogeology and spatial position of water abstraction points.

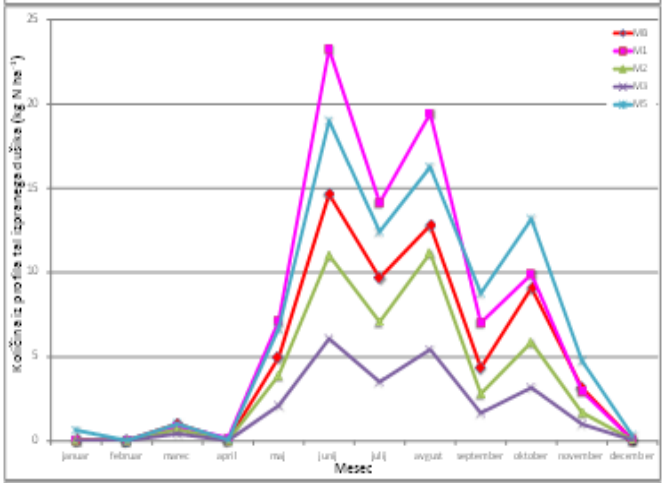
4. Results Scenarios

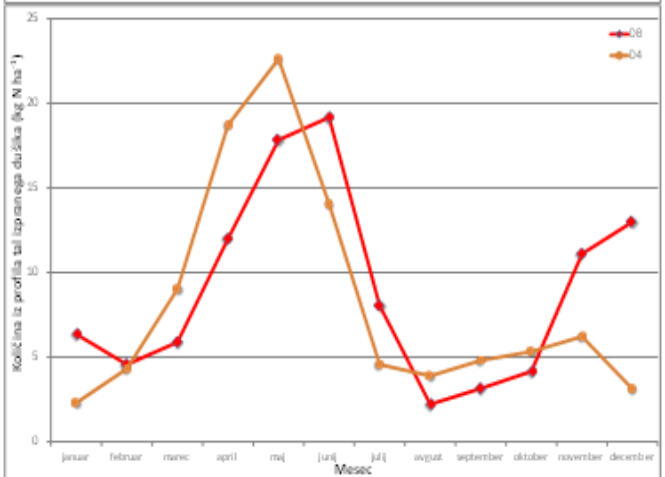
1. We created thirty-one (31) different scenarios of potential agri-environmental measures and agricultural technologies (rotational schemes, fertilisation, etc.) for all of the three research polygons to test the influence on nitrate leaching.

2. We created two (2) spatial scenarios for the whole Drava Plain research area to test the influence of water protection zones on nitrate leaching.

Scenarios 1-5 – modifications in fertilisation



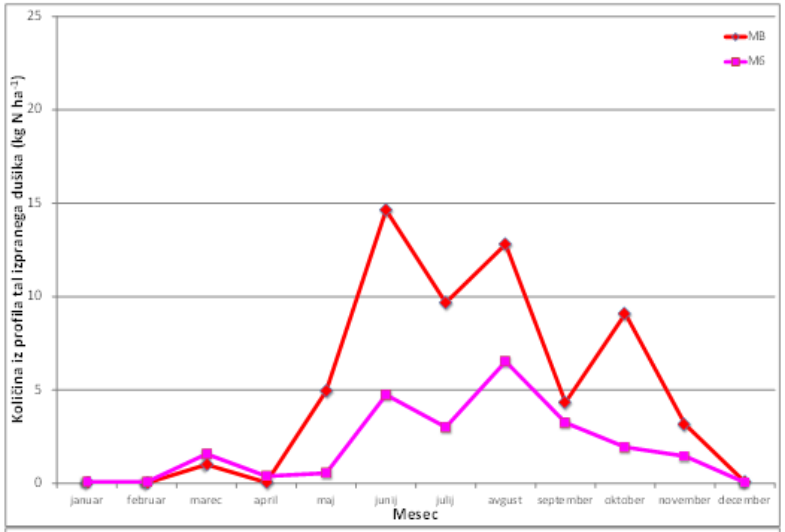


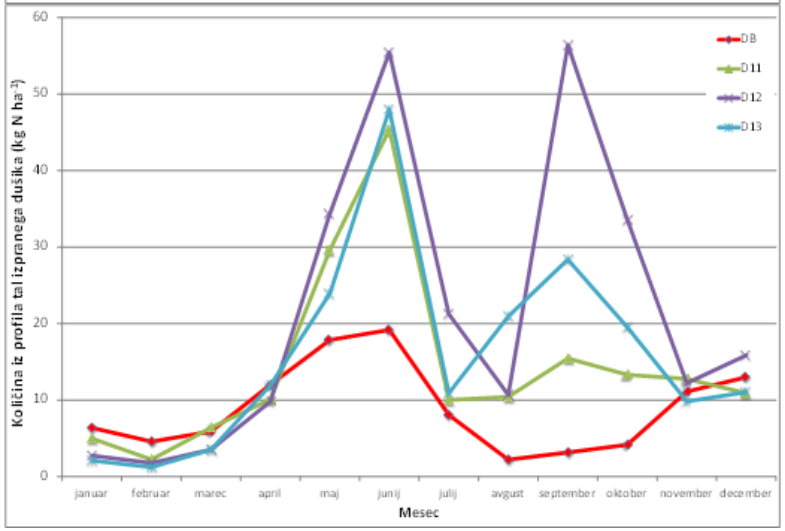


	Scenarios					
	Base	Scenario 1 Max fertilisation	Scenario 2 Medium fertilisation	Scenario 3 Min fertilisation	Scenario 4 No organic fertiliastion	Scenario 5 With organic fertilisation
Ptuj						
Average (kg ha^{-1} year^{-1})	51.3	49.6	43.3	40.8	/	66.0
Standard deviation (sd)	43.4	42.2	41.8	41.3	/	58.0
t-test		-0.124	-0.577	-0.766	/	0.759
Confidence interval(l)	33.3	32.4	32.1	31.7	/	44.6
Change (kg ha^{-1} year^{-1})		-1.7	-8.0	-10.5		14.7
Change (%)		-3.4	-15.7	-20.5	/	28.6
Maribor						
Average (kg ha^{-1} year^{-1})	59.9	85.0	44.4	23.5	/	83.1
Standard deviation (sd)	27.5	32.3	21.8	12.4	/	39.7
t-test		**2.333**	**-2.142**	**-8.787**	/	1.758
Confidence interval(l)	21.1	24.9	16.7	9.5	/	30.5
Change (kg ha^{-1} year^{-1})		25.1	-15.5	-36.4		23.2
Change (%)		42.0	-25.9	-60.7	/	38.8
Dobrovce						
Average (kg ha^{-1} year^{-1})	91.1	/	/	/	87.4	/
Standard deviation (sd)	56.1	/	/	/	46.5	/
t-test		/	/	/	-0.239	/
Confidence interval(l)	43.1	/	/	/	35.8	/
Change (kg ha^{-1} year^{-1})		/	/	/	-3.7	/
Change (%)		/	/	/	-4.1	/

Scenarios 6. 11-13

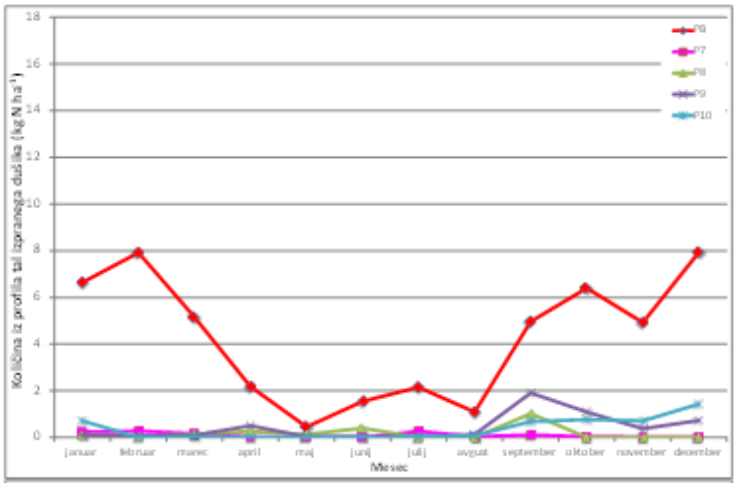
– new plants – Soya crop. 6
- vegetable integrated rotational schemes. 11-13

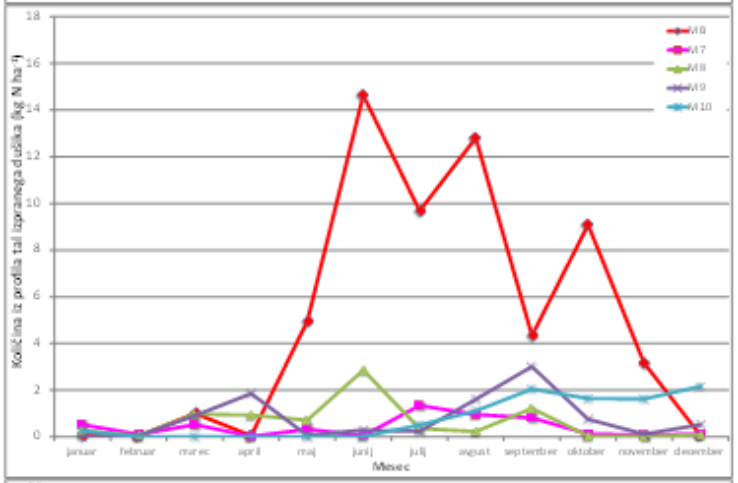


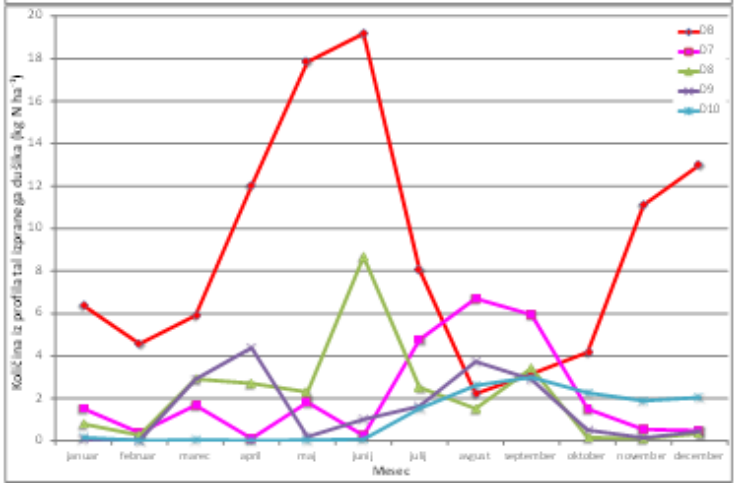


	Scenarios				
	Base	Scenario 6 soya	Scenario 11 Integrated I	Scenario 12 Integrated II	Scenario 13 Integrated III
Maribor					
Average (kg ha^{-1} year^{-1})	59.9	23.7	/	/	/
Standard deviation (sd)	27.5	23.0	/	/	/
t-test		-4.727	/	/	/
Confidence interval(l)	21.1	17.6	/	/	/
Change (kg ha^{-1} year^{-1})		-36.2	/	/	/
Change (%)		-60.4	/	/	/
Dobrovce					
Average (kg ha^{-1} year^{-1})	91.1	/	158.7	237.0	179.8
Standard deviation (sd)	56.1	/	48.7	132.2	94.0
t-test		/	4.162	3.309	2.831
Confidence interval(l)	43.1	/	37.4	101.6	72.3
Change (kg ha^{-1} year^{-1})		/	67.6	145.9	88.7
Change (%)		/	74.2	160.1	97.4

Scenarios 7-10 – grass cutting schemes

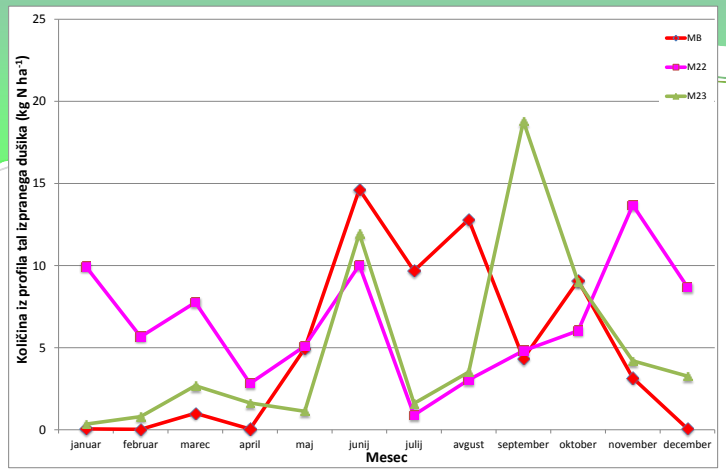


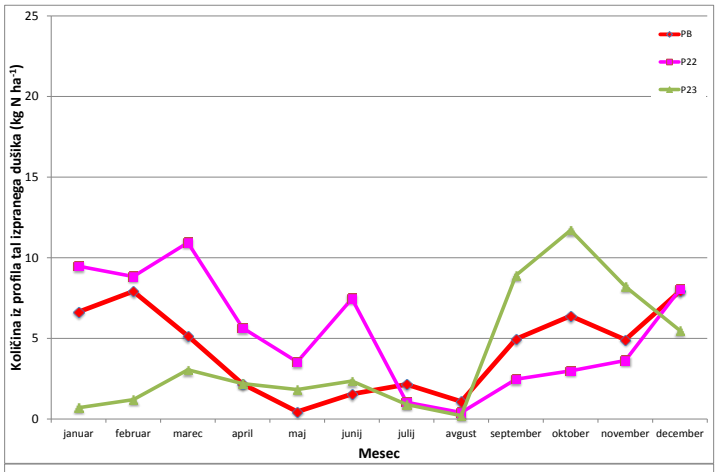


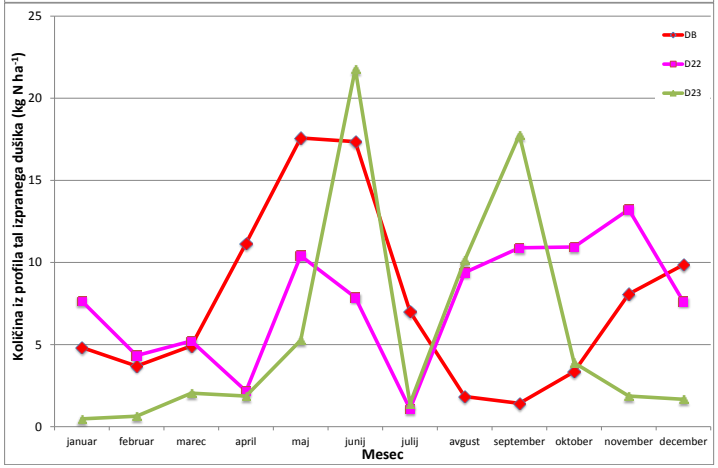


	Scenarios				
	Base	Scenario 7 4 cuts	Scenario 8 3 cuts	Scenario 9 2 cuts	Scenario 10 1 cut
Ptuj					
Average (kg ha^{-1} year^{-1})	51.3	1.2	2.1	5.1	4.4
Standard deviation (sd)	43.4	0.8	2.6	12.4	3.9
t-test		-179.153	-56.758	-11.238	-36.036
Confidence interval(l)	33.3	0.6	2.0	9.5	3.0
Change (kg ha^{-1} year^{-1})		-50.1	-49.2	-46.3	-46.9
Change (%)		-97.7	-95.9	-90.2	-91.4
Maribor					
Average (kg ha^{-1} year^{-1})	59.9	5.0	7.8	9.4	9.4
Standard deviation (sd)	27.5	3.8	5.0	17.0	7.3
t-test		-43.407	-31.276	-8.881	-20.791
Confidence interval(l)	21.1	2.9	3.8	13.1	5.6
Change (kg ha^{-1} year^{-1})		-54.9	-52.1	-50.4	-50.5
Change (%)		-91.6	-87.1	-84.2	-84.3
Dobrovce					
Average (kg ha^{-1} year^{-1})	91.1	25.7	25.7	17.9	13.7
Standard deviation (sd)	56.1	13.1	10.1	21.7	9.9
t-test		-15.006	-19.478	-10.119	-23.500
Confidence interval(l)	43.1	10.1	7.7	16.7	7.6
Change (kg ha^{-1} year^{-1})		-65.4	-65.4	-73.2	-77.4
Change (%)		-71.8	-71.8	-80.3	-85.0

Scenarios 22-23 – organic rotational schemes

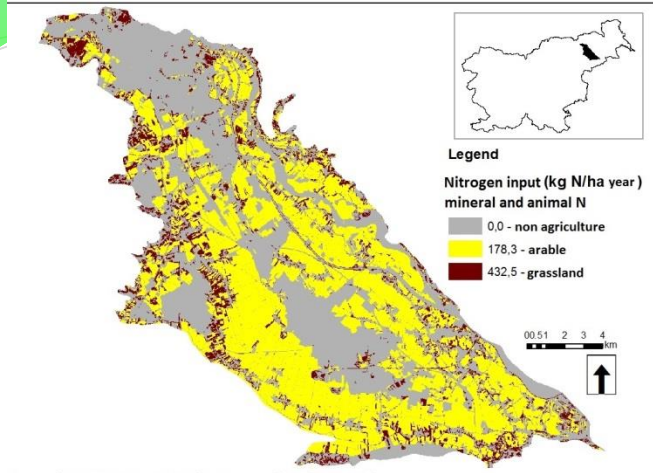




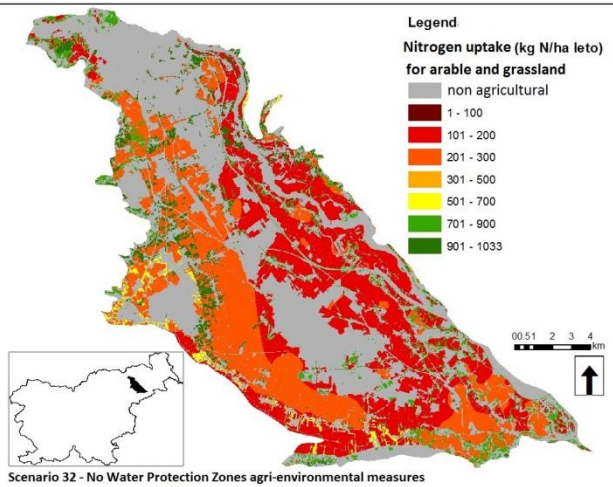


	Scenarios		
	Base	Scenario 22 Organic vegetable	Scenario 23 Organic field crops
Ptuj			
Average (kg ha^{-1} year^{-1})	51.3	64.5	46.8
Standard deviation (sd)	43.4	59.6	52.3
t-test		0.661	-0.262
Confidence interval(l)	33.3	45.8	40.2
Change (kg ha^{-1} year^{-1})		13.1	-4.6
Change (%)		25.6	-8.9
Maribor			
Average (kg ha^{-1} year^{-1})	59.9	78.5	58.9
Standard deviation (sd)	27.5	52.5	74.8
t-test		1.061	-0.039
Confidence interval(l)	21.1	40.4	57.5
Change (kg ha^{-1} year^{-1})		18.6	-1.0
Change (%)		31.0	-1.6
Dobrovce			
Average (kg ha^{-1} year^{-1})	91.1	90.8	68.8
Standard deviation (sd)	56.1	78.8	88.2
t-test		-0.012	-0.758
Confidence interval(l)	43.1	60.6	67.8
Change (kg ha^{-1} year^{-1})		-0.3	-22.3
Change (%)		-0.3	-24.4

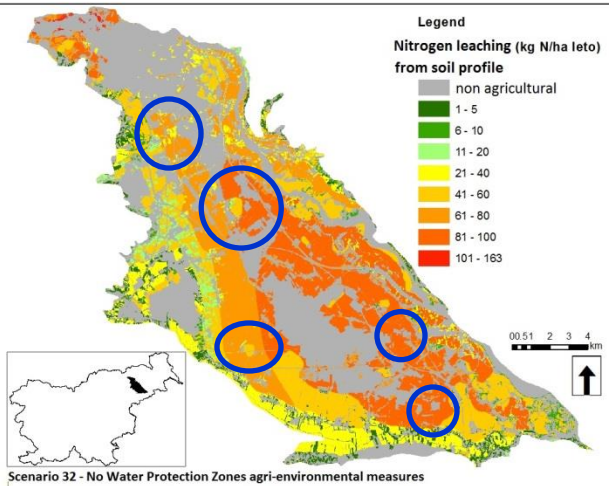
4. Results Spatial Scenarios



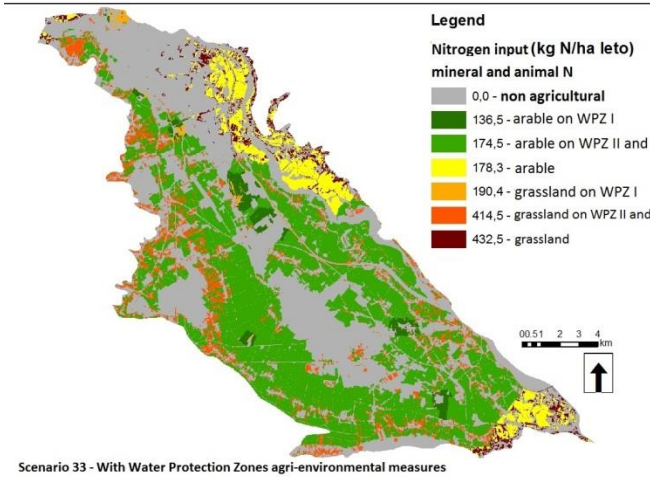
Sceanario 32 - No Water Protection Zones agri-environmnetal measures



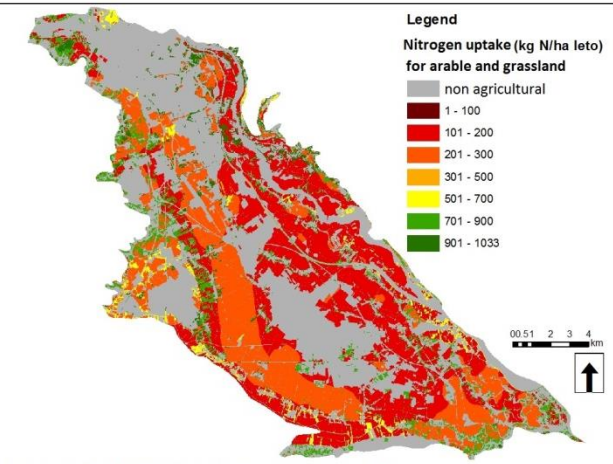
Scenario 32 - No Water Protection Zones agri-environmental measures



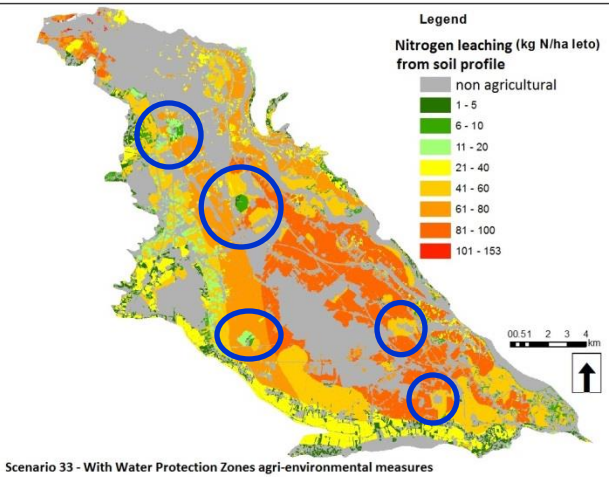
Scenario 32 - No Water Protection Zones agri-environmental measures



Scenario 33 - With Water Protection Zones agri-environmental measures



Scenario 33 - With Water Protection Zones agri-environmental measures



Scenario 33 - With Water Protection Zones agri-environmental measures

5. Conclusions

Results of the SWAT model version 2009 showed that magnitude of nitrogen leaching from the soil profile is influenced by soil properties and type of agricultural land management.

The most drastic effect on the increase of nitrogen leaching showed vegetable production technology, followed by cereals (corn, wheat, barley).

Effects of grassland production may lead to 76 to 98% reduction in nitrogen loss from soil profile in comparison to current practices.

Rotations adapted to the measures of WPZ I scheme considerably reduce N leaching however crop biomass and yield are not reduced.

Rotations adapted to the measures of WPZ II and III scheme have minimal influences on arable crop production and N leaching. This means that farming takes place in this areas without any serious constrains.

We suggest that agri-environmental measures of WPZ schemes should be formed also based on soil characteristic and not only on ground water flow direction and spatial position of water abstraction points. New soil map with more precise spatial scale will be required as it is obvious that the existent one (1:25.000) is not optimal.

Thank you.