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Impacts of historically changed land use on the water quality of the rivers Reka and Dragonja, Slovenia

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1. Introduction

Agricultural land has always been the foundation of human existence.

Their use has changed greatly throughout the history including abandonment, reclamation, intesification, agromeliorations and urban development
(Lisec and Prosen, 2008).

Differences in shares between land use categories and land managements of the crops between past and present situation are not negligible, but important as they can change hydrological characteristics of soils and have influence on the rivers ecosystems.



1. Introduction

The aim of the research was to examine the impacts of the historically changed land use in the rivers Reka in Goriška Brda (30 km^2) and Dragonja in Istria (100 km^2).

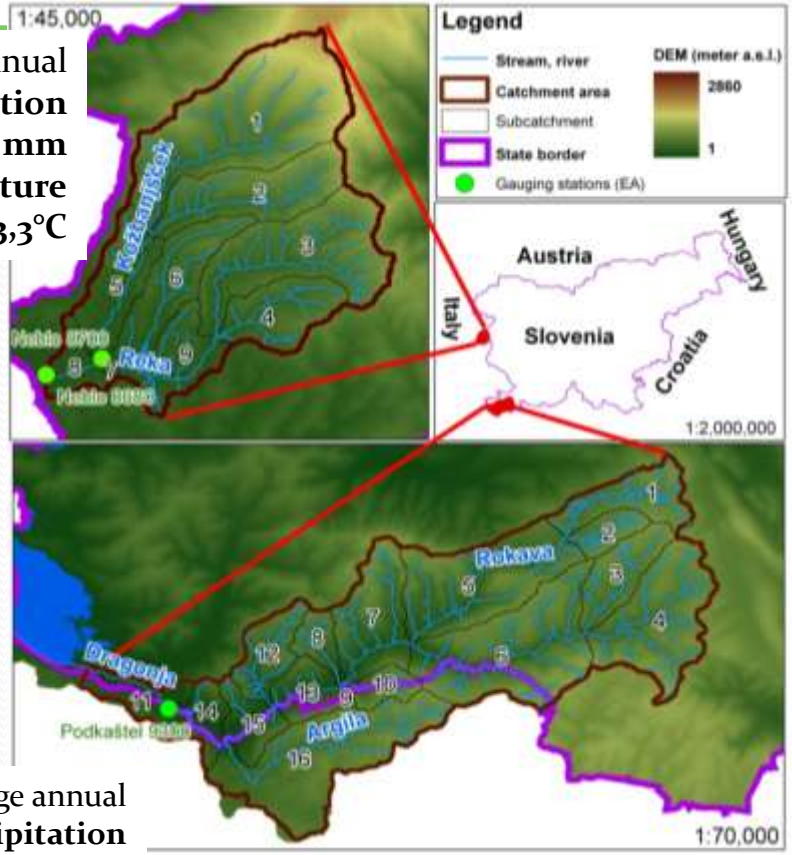
And further, how is this reflected on the quality of surface waters through soil erosion and transport of nitrogen and phosphorus in to the watercourses.

The SWAT model was used for the first time in Slovenia.

2. Materials and methods

Research areas

Average annual
precipitation
1397 mm
temperature
13,3°C



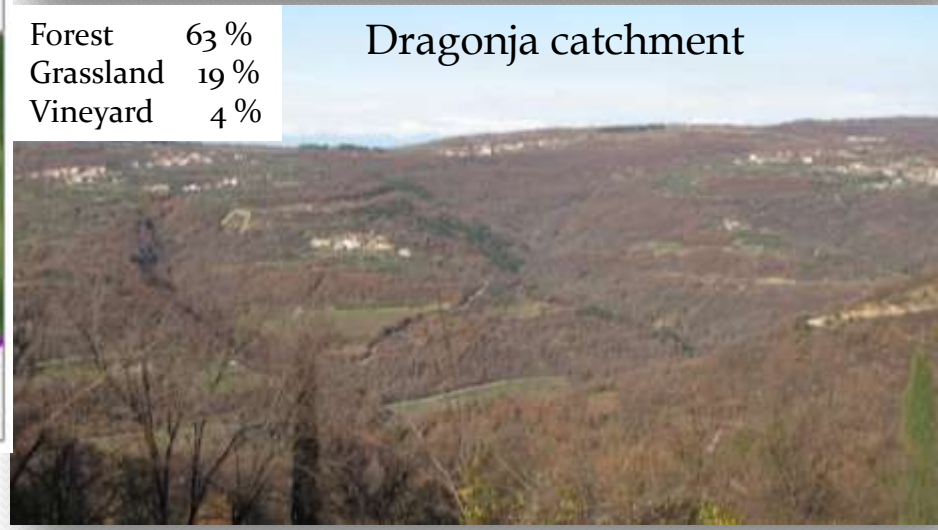
Average annual
precipitation
930 mm
temperature
14,1°C

Reka catchment

Forest 56 %
Grassland 8 %
Vineyards 23 %

Dragonja catchment

Forest 63 %
Grassland 19 %
Vineyard 4 %

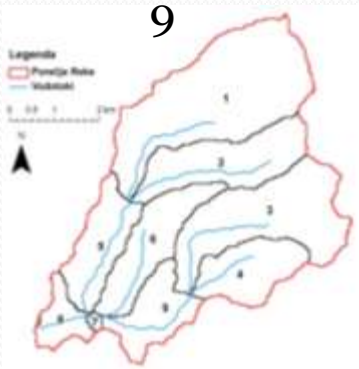


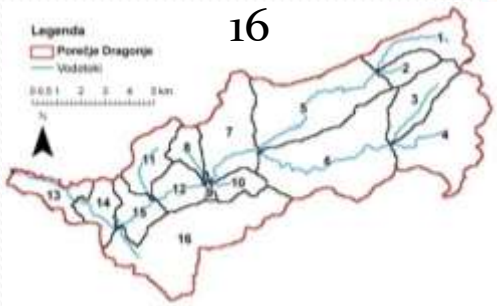
2. Materiali in metode - Flysch

- Flysch bedrock in Slovenia mostly consists from alternating layers of sediments with predominating marl and sandstone with silt and clay texture.
- Flysch is highly erodible material and decomposes fast under wet warm and moist climatic conditions, which can be accelerated with agricultural activities

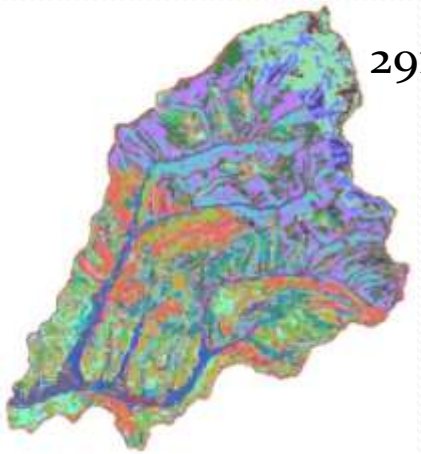
3. Model run

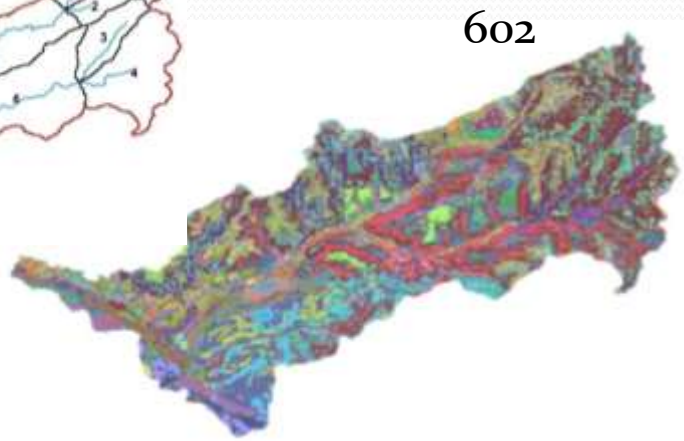
Subcatchments





Hydrological respont units - HRU





Data type	Scale	Source
Topography	25m×25m	The Surveying and Mapping Authority of the Republic of Slovenia
Soils	Slovenia: 1:25,000 Croatia: 1:50,000	Ministry or Agriculture, Forestry and Food Biotechnical Faculty (University of Ljubljana) University of Zagreb (Faculty of Agriculture)
Land use Present	Slovenia: 1m×1m (Graphical Units of Agricultural Land) Croatia: 100m×100m (CORINE)	Ministry or Agriculture, Forestry and Food European Environment Agency
Land use Historic		Slovenia Forest Service The Archives of the Republic of Slovenia Archivio di Stato di Trieste, Italy Biotechnical Faculty (University of Ljubljana) Municipality of Nova Gorica Slovenian Academy of Sciences and Arts
Land management	/	Chamber of Agriculture and Forestry Guidelines for expert justified fertilization (Mihelič et al., 2009) Interviews with farmers
Weather	Reka: 2 precipitation stations, 1 temperature, wind, humidity and solar radiation station Dragonja: 3 precipitation stations, 1 temperature, wind, humidity and solar radiation station	Environment Agency of Republic of Slovenia
Water abstraction	46 abstraction permits (136 abstraction points)	Environment Agency of Republic of Slovenia
Waste water discharges	Reka: 2 points Dragonja: 1 point	Environment Agency of Republic of Slovenia
River discharge	Reka: 2 stations Dragonja 1 station	Environment Agency of Republic of Slovenia
River quality	Reka: 0 monitoring station Dragonja: 1 monitoring station approx. monthly data	Environment Agency of Republic of Slovenia

3. Model run

Calibration and validation data

River **Parameter**		***Calibration/ Sensitivity Analysis***		***Validation***	
		period	***source***	***period***	***source***
Reka					
Flow (m^3s^{-1})	FLOW_OUT	1998–2005	ARSO	1993–97, 2006–08	ARSO
Kožbanjšček Reka tributary					
Flow (m^3s^{-1})	FLOW_OUT	1998–2005	ARSO	1992–94, 2006–08	ARSO
Sediment (t day^{-1})	SED_OUT	1.7.2008–30.6.2009	Field work	/	/
Nitrate (NO_3^-)	NO3_OUT	1.7.2008–30.6.2009	Field work	/	/
Total P	MINP, ORGP	1.7.2008–30.6.2009	Field work	/	/
ortho-P (PO_4^{3-})	MINP_OUT	1.7.2008–30.6.2009	Field work	/	/
Dragonja					
Flow (m^3s^{-1})	FLOW_OUT	1998–2005	ARSO	1994–96, 2006–08	ARSO
Sediment (t $daay^1$)	SED_OUT	1994–2008	ARSO	/	/
Nitrate (NO_3^-)	NO3_OUT	1994–2008	ARSO	/	/
Total P	MINP, ORGP	1994–2008	ARSO	/	/
ortho-P (PO_4^{3-})	MINP_OUT	1994–2008	ARSO	/	/

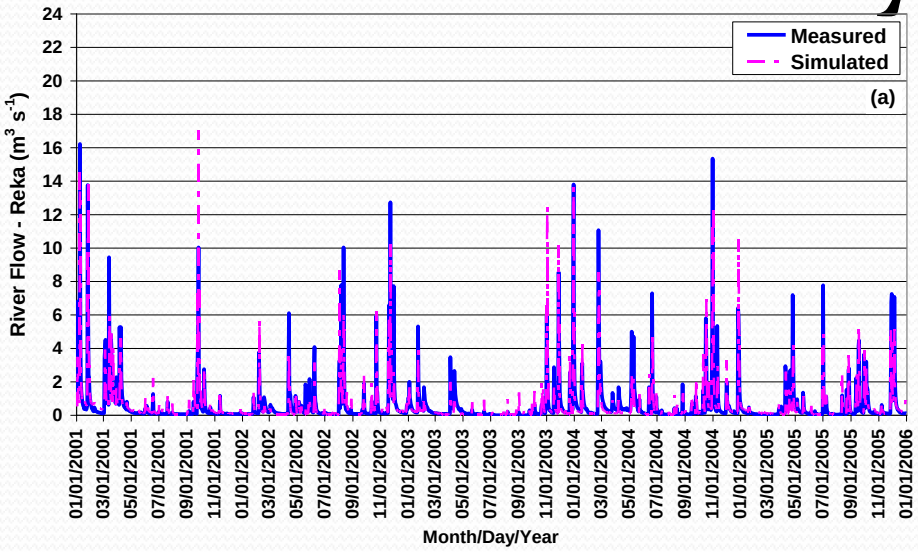
4. Sensitivity Analysis

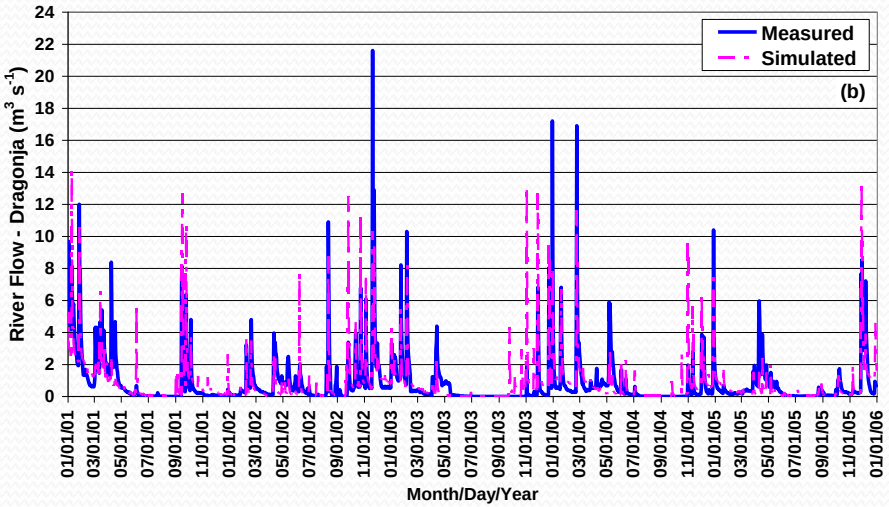
Objective function (SSQR)								**Sensitivity category**
RekaBase				DragonjaBase				
Flow	**Sediment**	**NO_3^{-1}-N**	**Total-P**	**Flow**	**Sediment**	**NO_3^{-1}-N**	**Total-P**	
Surlag	Spcon	Cn2	Usle_P	Cn2	Spcon	Blai	Canmx	Very important
Alpha_Bf	Ch_N	Revapmin	Cn2	Alpha_Bf	Ch_Erod	Sol_Awc	Alpha_Bf	Important (2-6)
Cn2	Surlag	Alpha_Bf	Alpha_Bf	Ch_K2	Ch_Cov	Cn2	Blai	
Ch_K2	Spexp	Esco	Surlag	Rchrg_Dp	Ch_N	Revapmin	Surlag	
Esco	Cn2	Rchrg_Dp	Ch_K2	Esco	Spexp	Rchrg_Dp	Cn2	
Ch_N	Alpha_Bf	Sol_Awc	Slope	Surlag	Surlag	Sol_Z	Sol_Z	

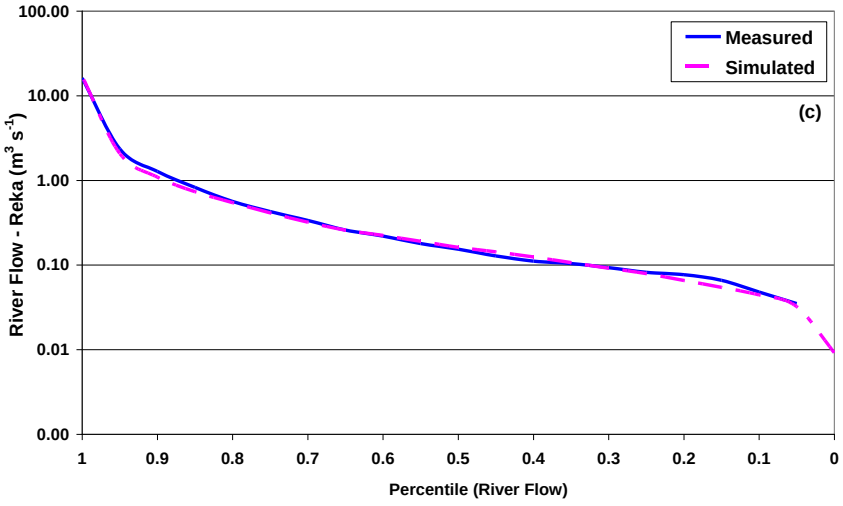
5. Calibration and validation Hydrology

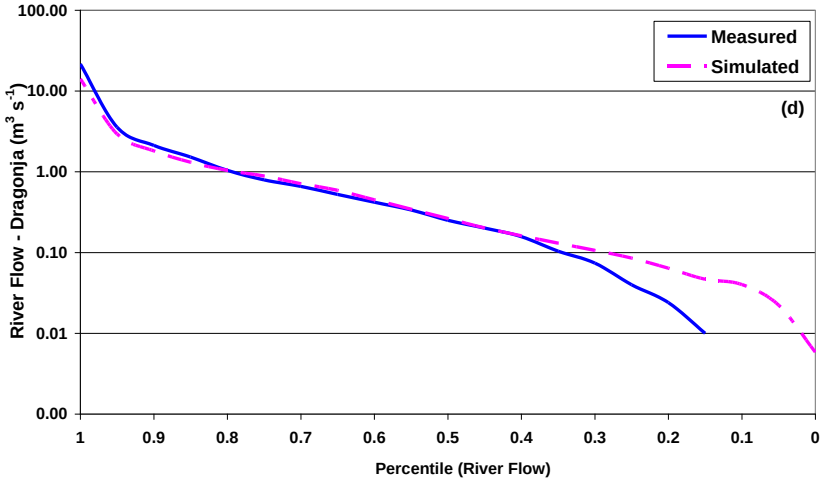
	Reka				**Dragonja**			
	Calibration		Validation (Total Flow)		Calibration		Validation (Total Flow)	
Statistical test	Base Flow	Total Flow	1993 - 1997	2006 - 2008	Base Flow	Total Flow	1994 - 1996	2006 - 2008
E_{NS}	0.61	0.61	0.39	0.69	0.55	0.57	0.45	0.42
R^2	0.72	0.64	0.57	0.70	0.66	0.59	0.49	0.49
RMSE	0.13	0.82	1.21	0.74	0.35	1.06	1.98	1.50
PBIAS	-12.79	7.04	-14.19	19.40	1.49	4.69	23.15	-3.31

5. Calibration and validation Hydrology









5. Calibration and validation - pollutants

				Reka - Kožbanjšček	*Dragonja*
Parameter		**Default**	**Range**	**Calibrated values**	**Calibrated values**
Sediment					
1	SpCon	0.0001	0.0001-0.01	0.002	0,002
2	SpExp	1	1-1.5	1.3	1
3	Ch_Erod	0	0-1	0.092	0,06
4	Ch_Cov	0	0.05-0.6	0.1	0,1
5	USLE_P	1	0-1	slope dependent	slope dependent
		E_{NS}		**0.23**	**0.70**
		E_{NS} percentile		**0.83**	**0.73**
Nitrogen (NO_3-N)					
1	Nperco	0.2	0.01-1	1	0,2
2	Al1	0.08	0.07-0.09	0.071	0,08
3	CMN	0.0003	0.0001-0.001	0.0003	0,0001
4	HLIFE_NGW	0	0-200	0	0,02
5	FRT_surface	0.2	0-1	management dependent	management dependent
		E_{NS}		**0.40**	**0.10**
		E_{NS} percentile		**0.72**	**0.78**
Phosphorus					
1	Pperco	10	10-17.5	15	10
2	Phoskd	175	100-200	175	200
3	Al2	0.015	0.01-0.02	0.003	0,001
4	PSP	0.4	0.01-0.7	0.22	0,04
5	ERORGP	0	0.001-5	0	0,003
6	BC4	0.35	0.01-0.7	0.1	0,1
7	RS2	0.05	0.001-0.1	0.1	0,1
8	RS5	0.05	0.001-0.9	0.08	0,001
9	FRT_surface	0.2	0-1	management dependent	management dependent
orto P		**E_{NS}**		**0.16**	**0.22**
		E_{NS} percentile		**0.92**	**0.65**
Total P		**E_{NS}**		**-0.05**	**0.36**
		E_{NS} percentile		**0.95**	**0.85**

6. Scenarios - Reka

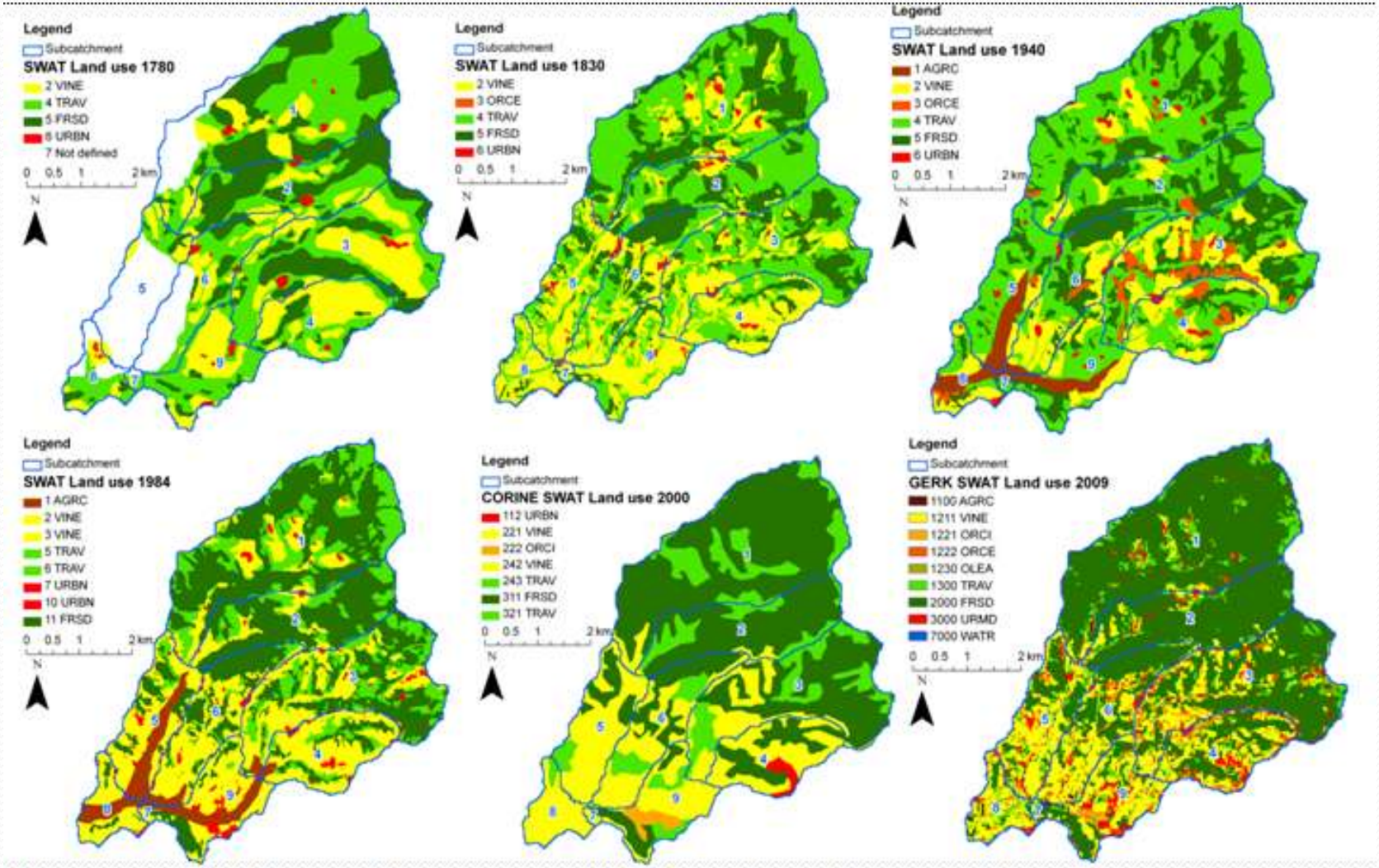


Figure 4: The river Reka catchment maps: (1780) Emperor Joseph II, Austro-Hungary military map; (1830) Map of Austro-Hungary Franciscan cadastre; (1940) Map of Catasto Forestale - Italy; (1984) Agro map - Yugoslavia; (2000) CORINE land use map – EU; (2009) Graphical Units of Land Use - Slovenia

6. Scenarios - Dragonja

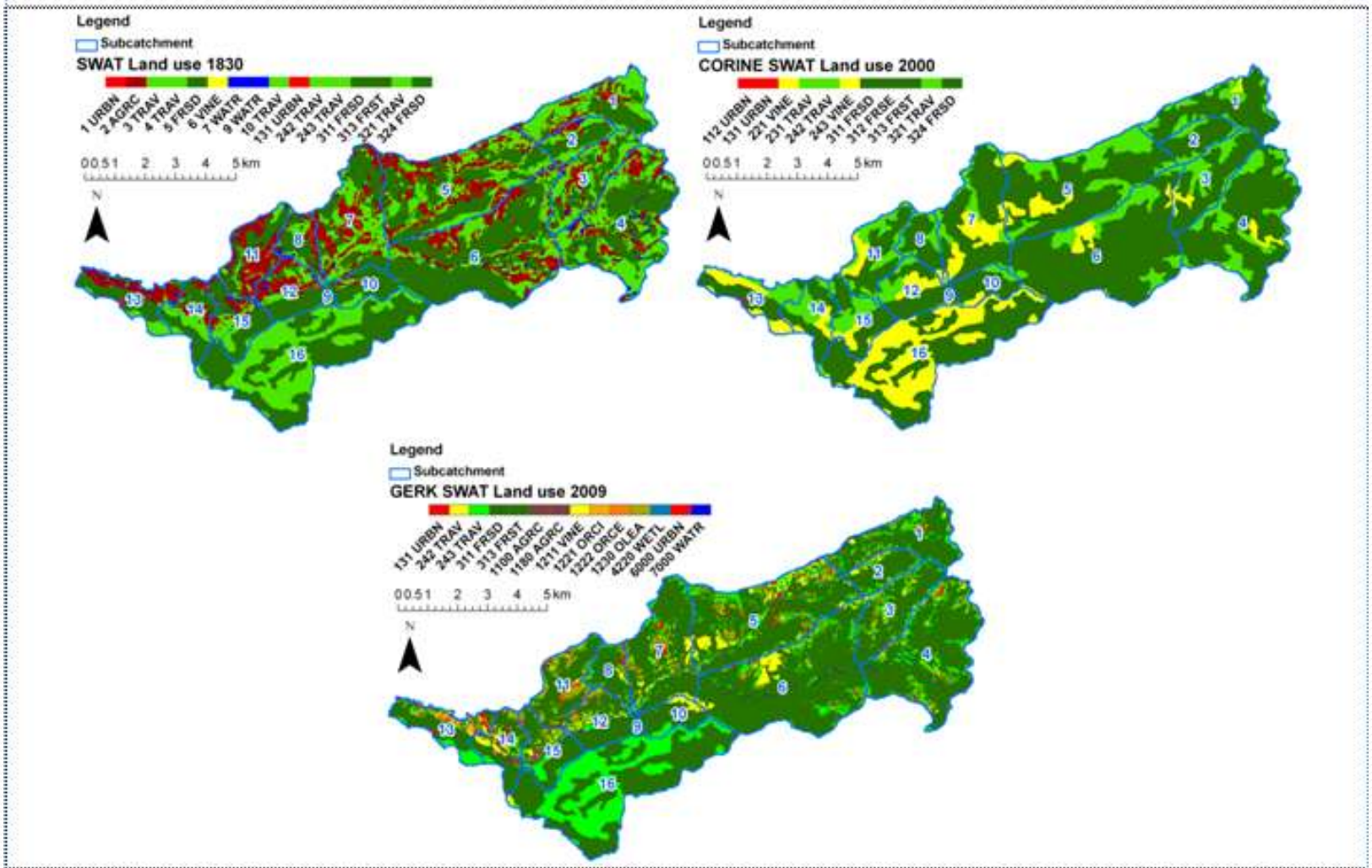


Figure 5: The river Dragonja catchment maps: (1830) Map of Austro-Hungary Franciscan cadastre; (2000) CORINE land use map - EU; (2009) Graphical Units of Land Use – Slovenia.

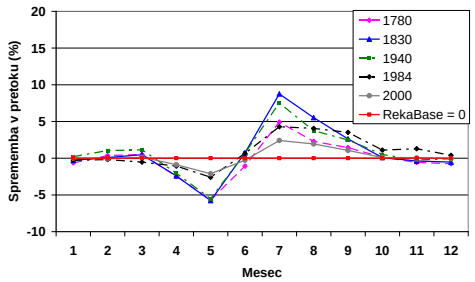
7. Results

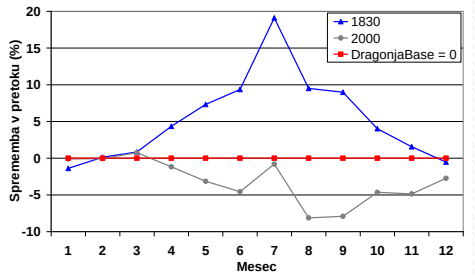
Change in **flow** (%)					
Catchment (subcatchment)	**1780**	**1830**	**1940**	**1984**	**2000 CORINE**
Reka (8)	-	–0,23	0,53	0,24	–0,68
R-Vedrijanščcek (9)	–0,31	0,28	0,45	0,82	0,10
Dragonja (14)	-	-	-	-	–2,38
D-Rokava (7)	-	2,61	-	-	–2,68

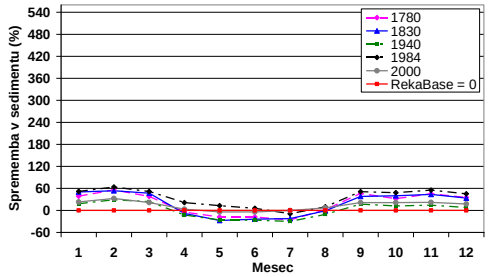
Change in **sediment** load (%)					
Catchment (subcatchment)	**1780**	**1830**	**1940**	**1984**	**2000 CORINE**
Reka (8)	-	43	39	45	13
R-Vedrijanščcek (9)	30	30	8	43	17
R-Kožbanjščcek (5)	-	93	94	75	15
Dragonja (14)	-	-	-	-	–10
D-Rokava (7)	-	294	-	-	–18

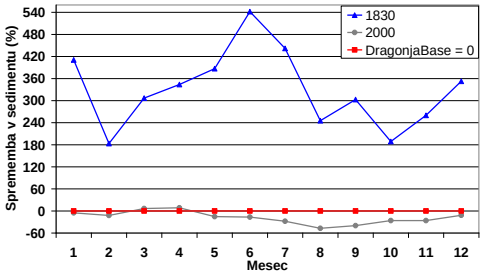
Change in **Total N** load (%)					
Catchment (subcatchment)	**1780**	**1830**	**1940**	**1984**	**2000 CORINE**
Reka (8)	-	2	–8	8	–9
R-Vedrijanščcek (9)	20	4	–9	19	–0,3
Dragonja (14)	-	-	-	-	–5
D-Rokava (7)	-	72	-	-	–7

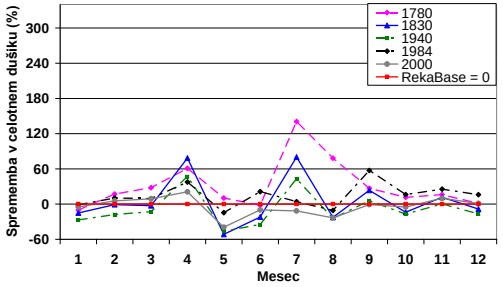
Change in **Total P** load (%)					
Porečje/ rečni odsek	**1780**	**1830**	**1940**	**1984**	**2000 CORINE**
Reka (8)	-	23	14	30	–6
R-Vedrijanščcek (9)	37	2	–13	29	–8
Dragonja (14)	-	-	-	-	–7
D-Rokava (7)	-	68	-	-	–9

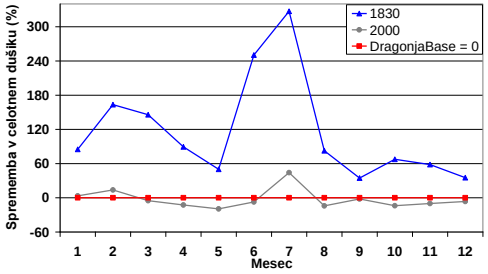


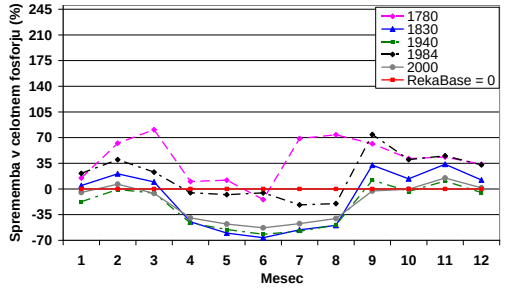


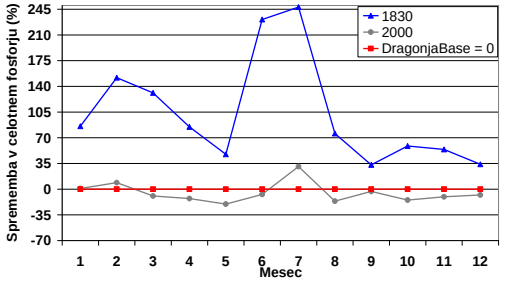












8. Scenario evaluation

	Concentration (mg l^{-1})		
	Sediment (SS)	Nitrate (NO_3^-)	Total phosphorus (TP)
DRAGONJA - subcatchment 14 (cyprinid waters)			
Observed - Podkaštel	**29,3**	**2,7**	**0,043**
1830	66,7	4,2	0,064
2000	26,5	2,3	0,040
REKA - subcatchment 5 (salmonid waters)			
Observed –Kožbanjšček (Neblo)	**32,6**	**2,7**	**0,109**
1780	-	-	-
1830	62,9	5,5	0,149
1940	63,2	4,6	0,142
1984	57,1	4,8	0,135
2000	37,1	3,8	0,090

Limit and guide levels

		Concentration (mg l^{-1})
Sediment		25
Nitrate (NO_3^-)	drinking water	50
	very good state	14,08 - 30,8
	good state	28,6 - 41,8
Total phosphorus (P)	salmonid waters	0,2
	cyprinid waters	0,4

9. Conclusions

(1) Within the Reka catchment share of vineyard land use remains relatively constant for over 200 years. But due to the technological revolution (tractors), the amount of domestic animals decreased, which resulted in reforestration of grassland and vineyards planting in the flatlands.

(2) In the Reka catchment, historic land use scenarios would not have beneficial impact on modelled catchment response due to decreasing percentage of forest and increasing percentage of grassland in the past.

(3) Majority of the Dragonja catchment has been in the past under agricultural cultivation, but with the emigration and the development of industry and tourism on the coast, has the proportion of the reforestation expanded, which finally reflected in the changed ecological and hydrological conditions in the catchment

(4) Scenarios results for the Dragonja catchment indicate that past shift from arable land use to forest decreased annual loads of sediment and nutrients.

(5)Modelling scenarios of the historical agricultural land use change showed that their preservation or realization in present climatic conditions is likely to lead to increased levels of sediment, nitrate and total phosphorus in the rivers, exceeding current average annual measured sediment concentrations and by the legislation recommended guide levels (25 mg l^{-1}).

Acknowledgment: Financial support for this study was provided by the Slovenian Research Agency founded by the Government of the Republic of Slovenia.


Thank you. Questions?