Impacts of climate change alone, and with agricultural land use change, on surface water quality (NO_3^-N, TP)

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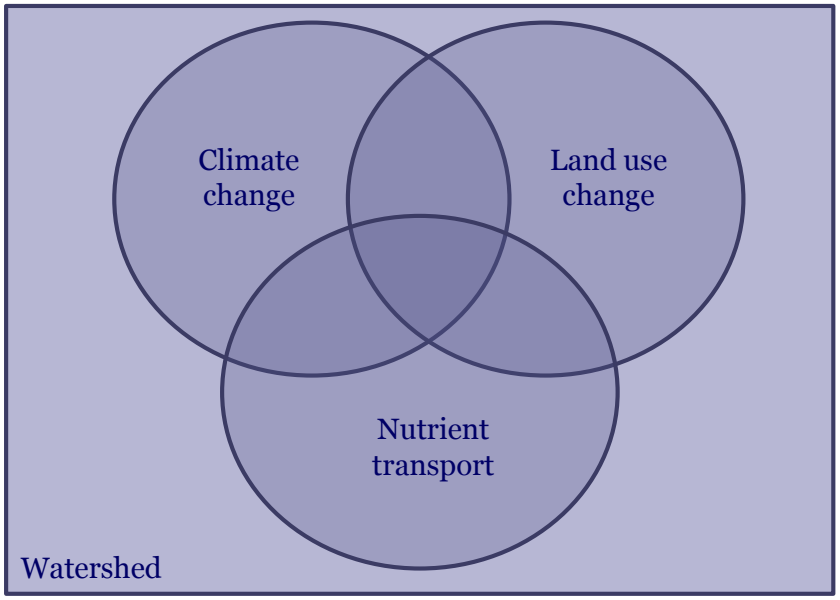
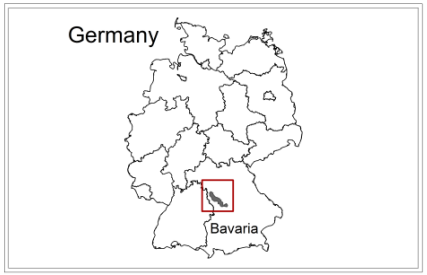
Introduction

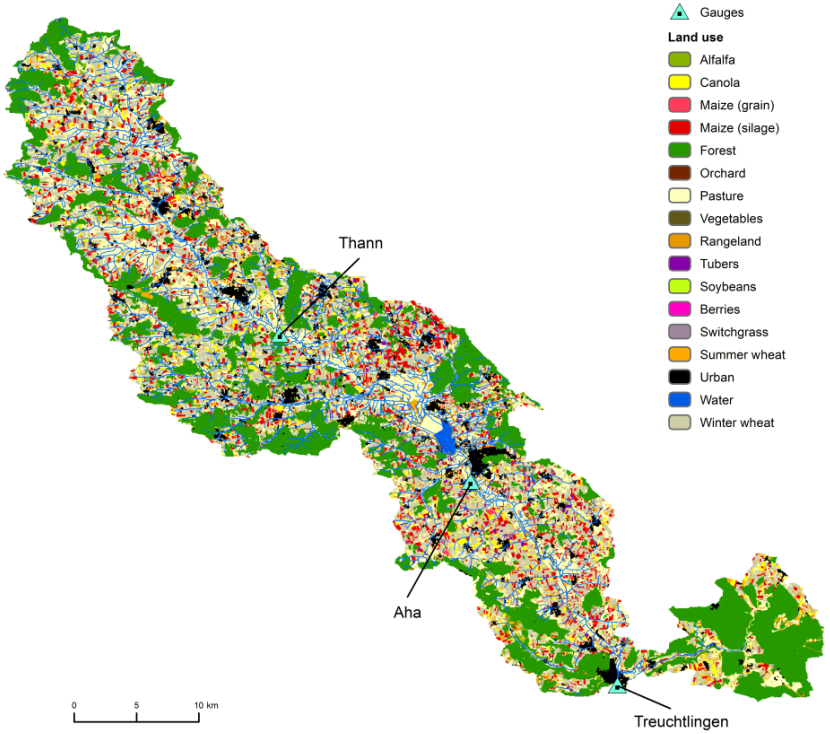
- WFD aims to maintain & improve the aquatic environment by ensuring a good water quality status to 2027 at latest
- Agricultural land use is not static (rotations, transitions, changes)
- Climate change is a threat to water quality
- Agriculture can affect non-point source pollution, but how can this be considered for policies



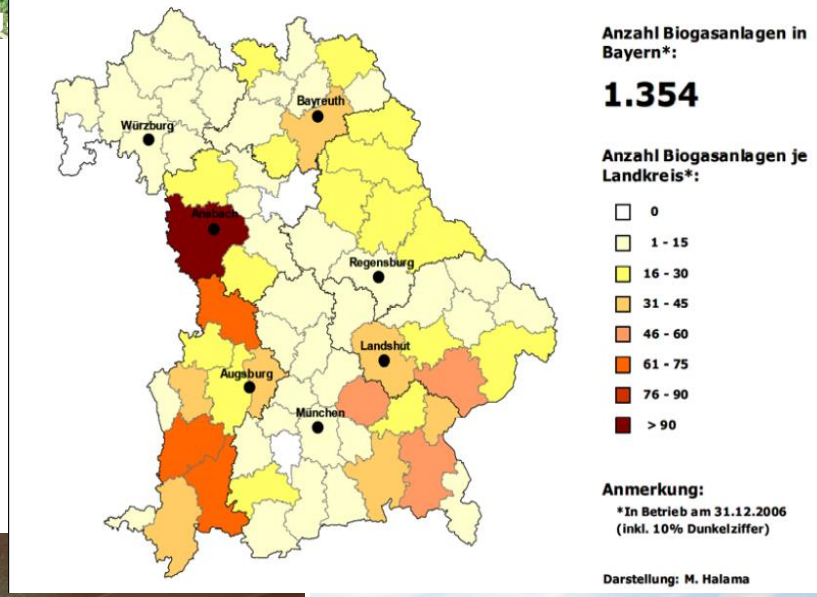
Quantify the changes to water quality (NO_3^-, TP) due to future climates, and also concurrent changes of climate and land use to 2050

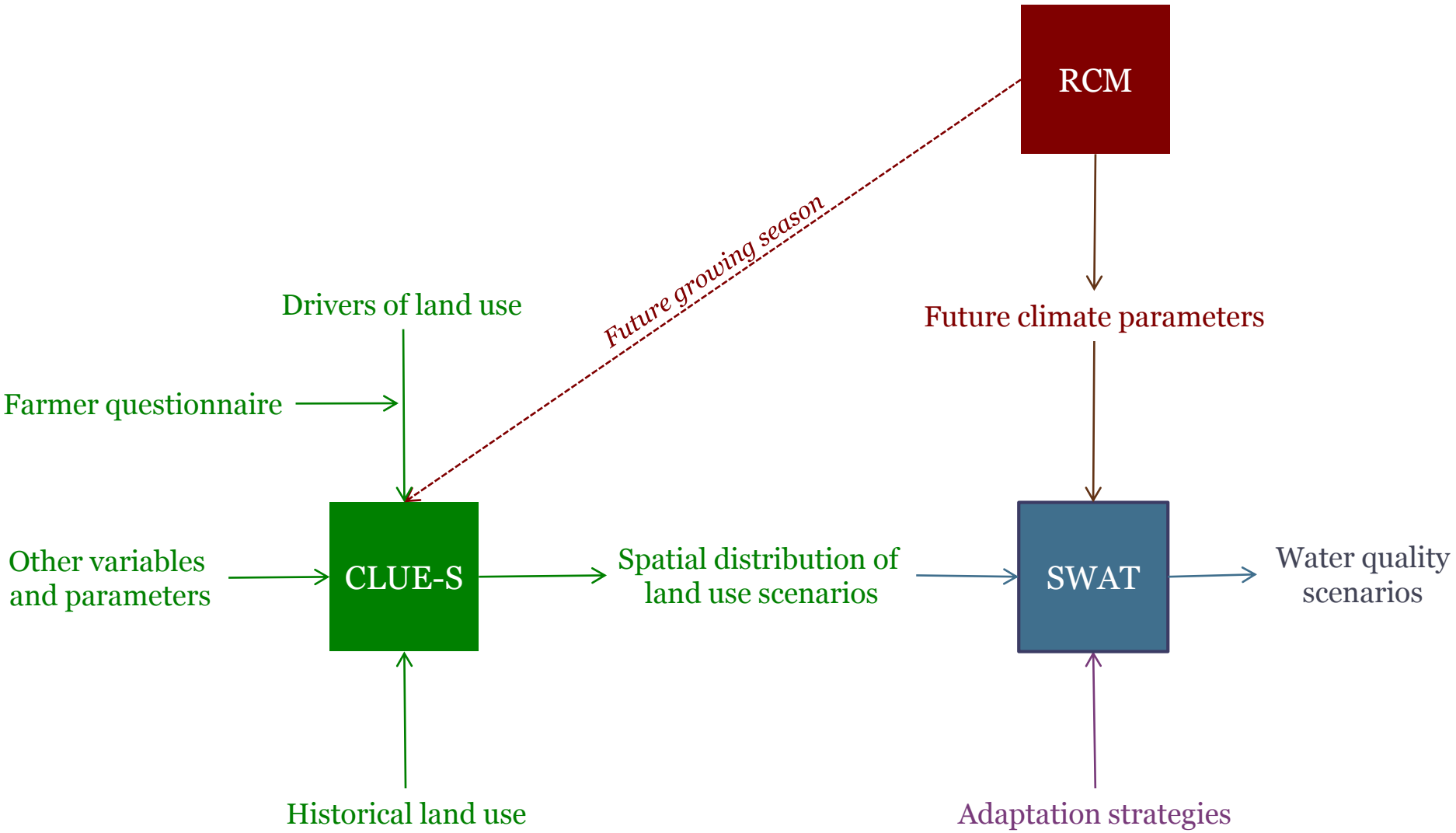
The Altmühl watershed





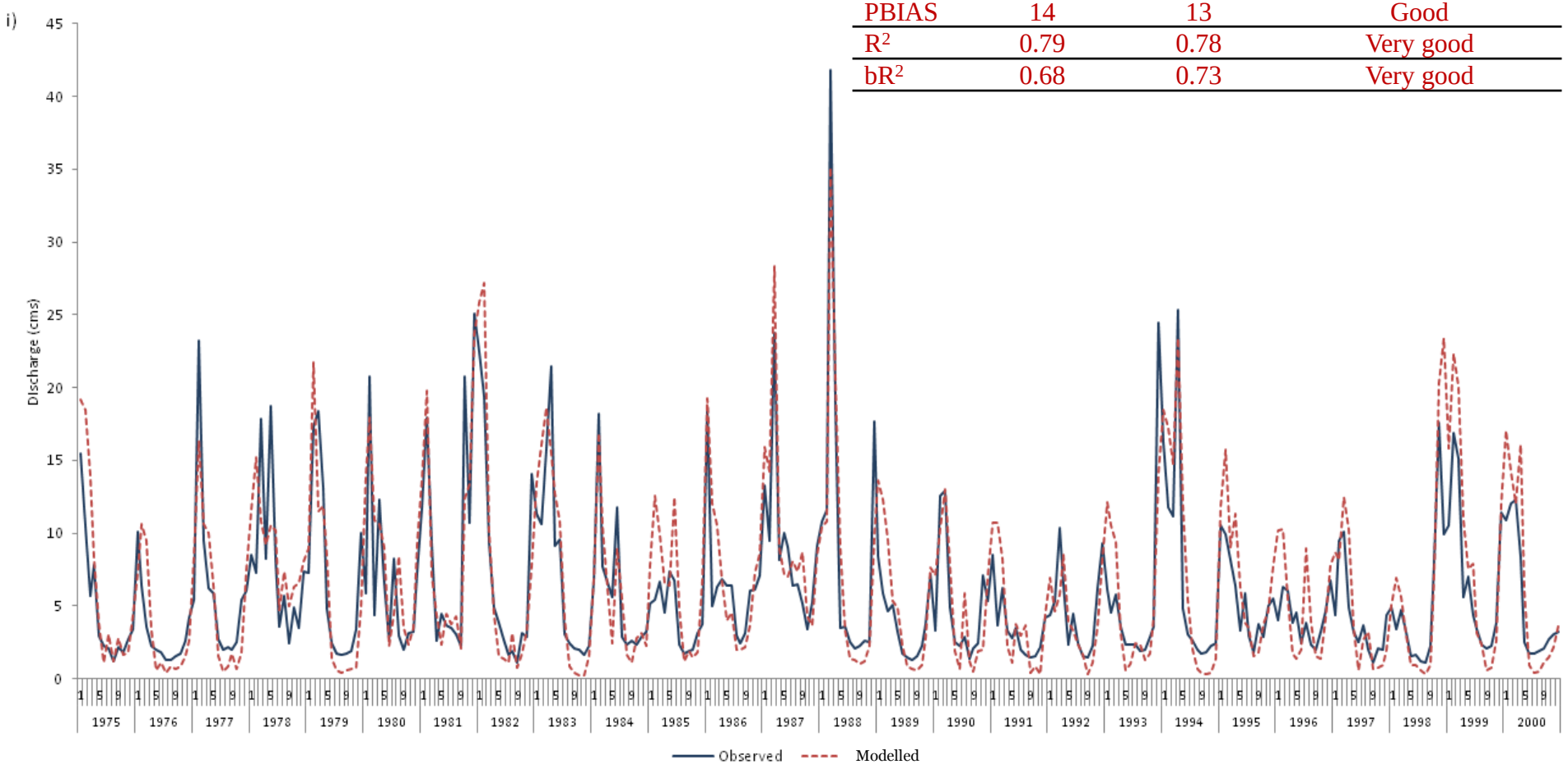
Data Sources:
Agricultural land use 2008: Bavarian State Office for Agriculture, www.lfl.bayern.de
Forested areas: Bavarian State Office for Forest, www.lwf.bayern.de; and CORINE Land Cover 2006 (50
River network: Bavarian State Office for the Environment, www.lfu.bayern.de
Urban areas: VEKTOR 500, Bavarian Surveying Administration, www.lvg.bayern.de




RCM
Future growing season
Drivers of land use
Future climate parameters
Farmer questionnaire
Other variables
and parameters
CLUE-S
Spatial distribution of
land use scenarios
SWAT
Water quality
scenarios
Historical land use
Adaptation strategies

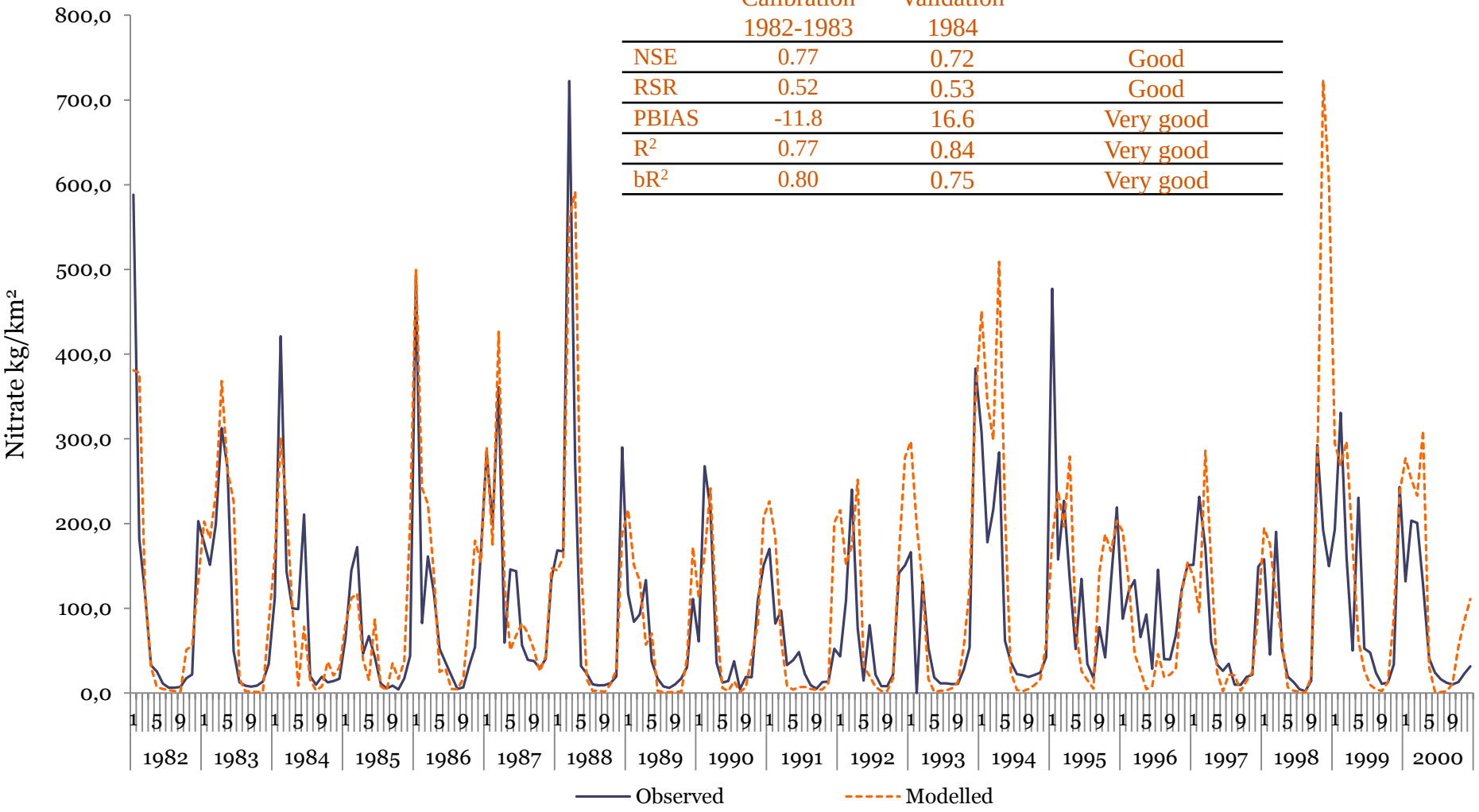
SWAT simulated monthly discharge

	Calibration 1964-1974	Validation 1975-1984	
NSE	0.78	0.75	Very good
RSR	5.2	5.9	Very good / Good
PBIAS	14	13	Good
R^2	0.79	0.78	Very good
bR^2	0.68	0.73	Very good



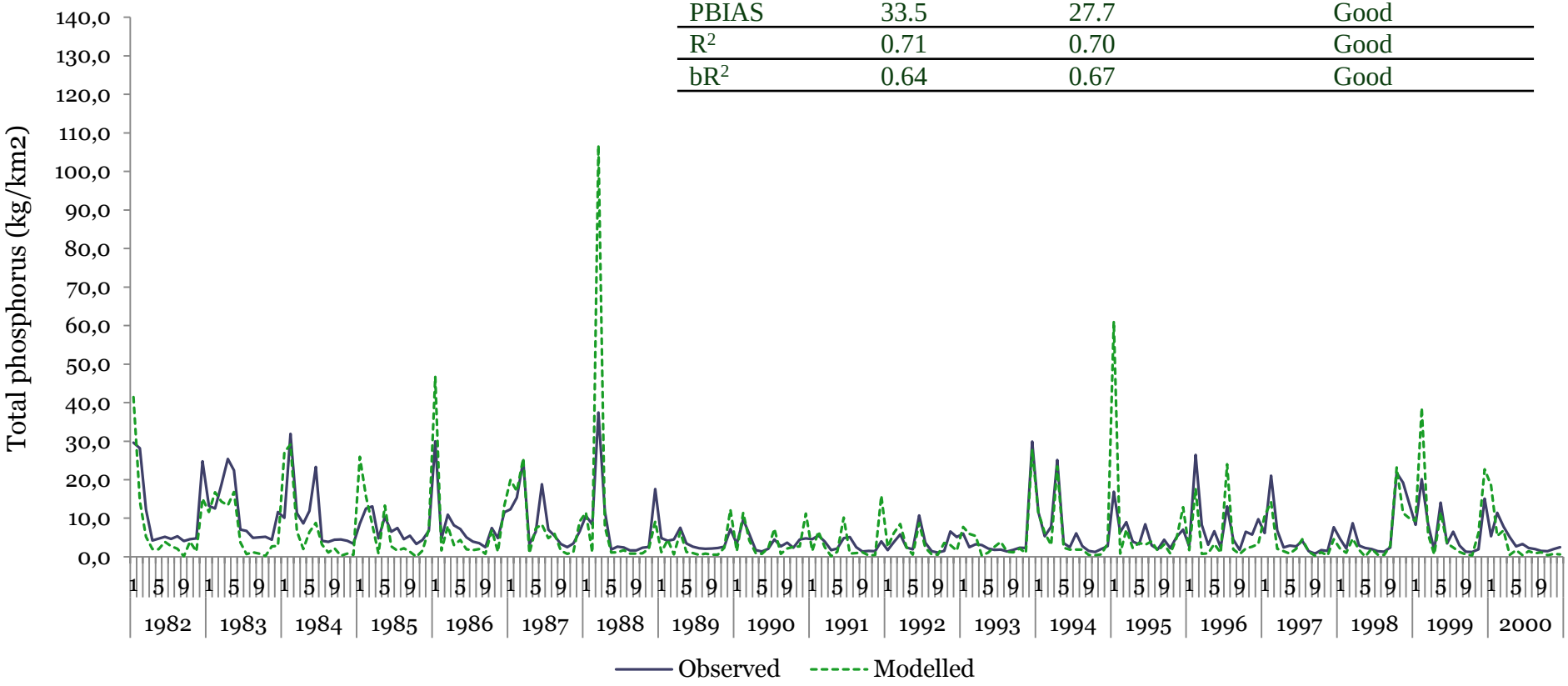
SWAT simulated monthly nitrate

	Calibration 1982-1983	Validation 1984	
NSE	0.77	0.72	Good
RSR	0.52	0.53	Good
PBIAS	-11.8	16.6	Very good
R^2	0.77	0.84	Very good
bR^2	0.80	0.75	Very good

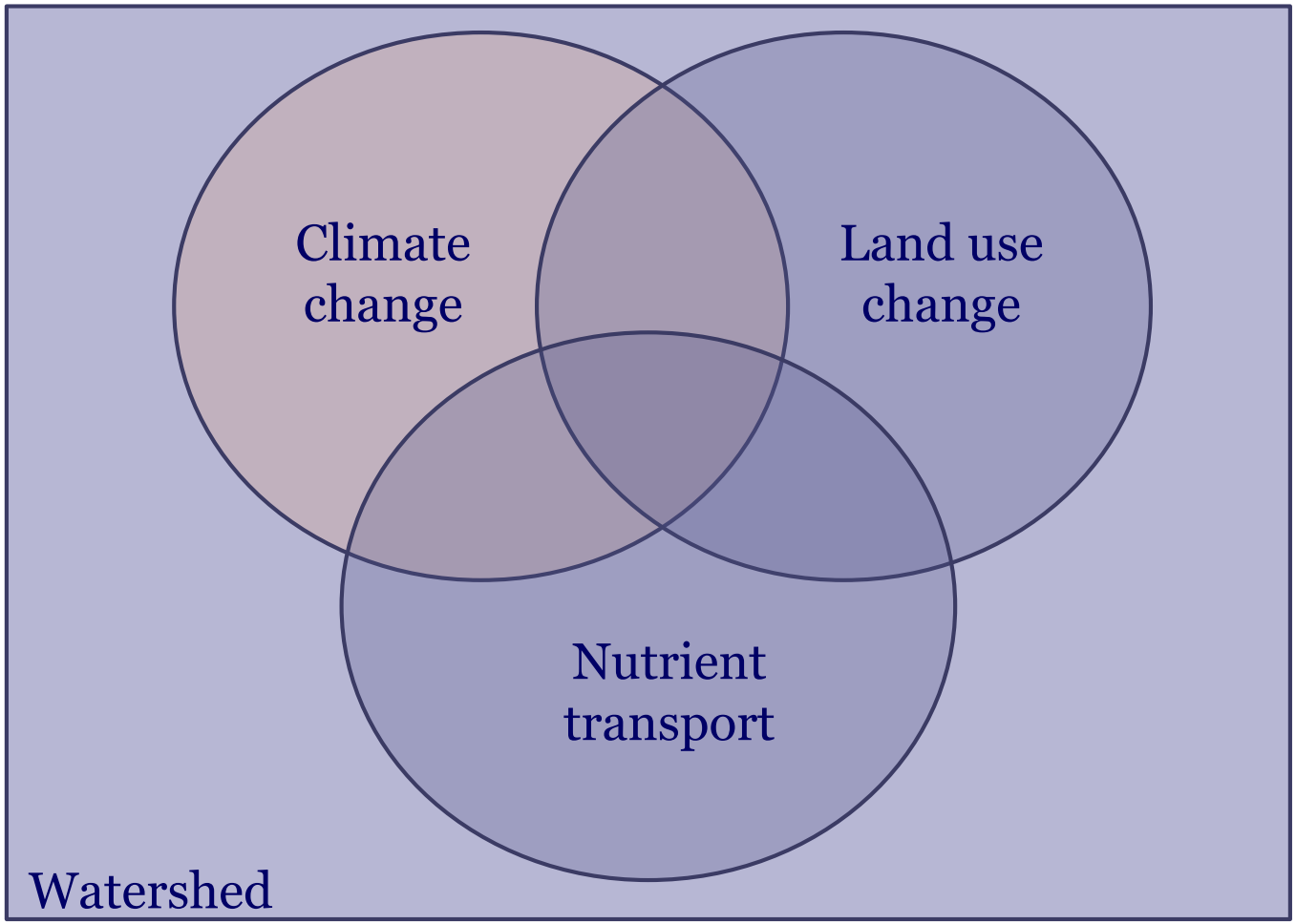


SWAT simulated monthly total P

	Calibration 1982-1983	Validation 1984	
NSE	0.47	0.52	unsatisfactory/ satisfactory
RSR	0.70	0.83	satisfactory/ unsatisfactory
PBIAS	33.5	27.7	Good
R^2	0.71	0.70	Good
bR^2	0.64	0.67	Good



Climate change scenarios

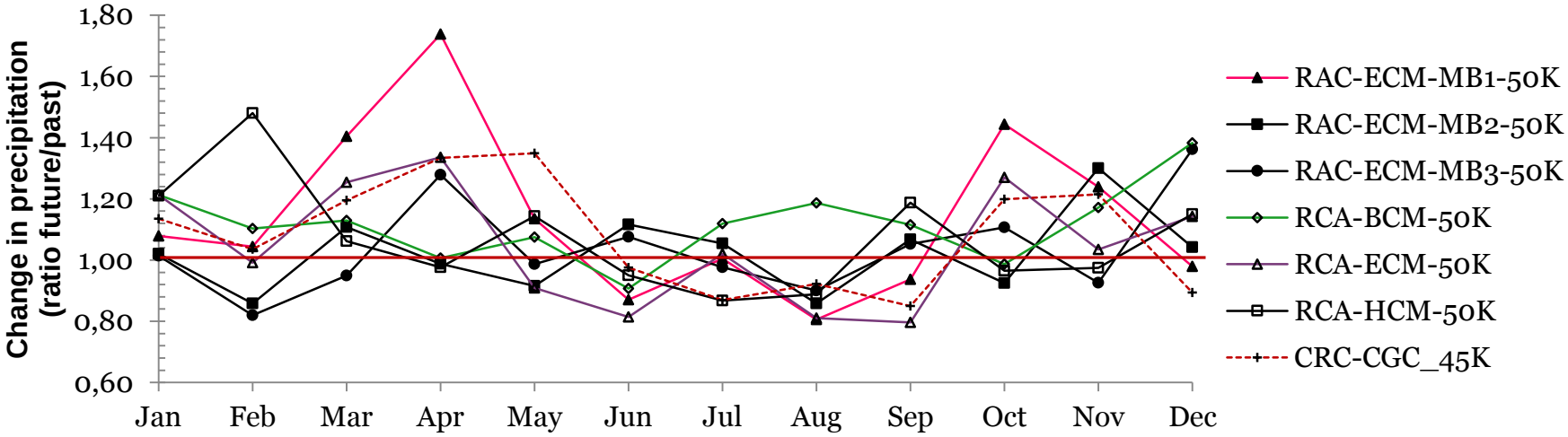


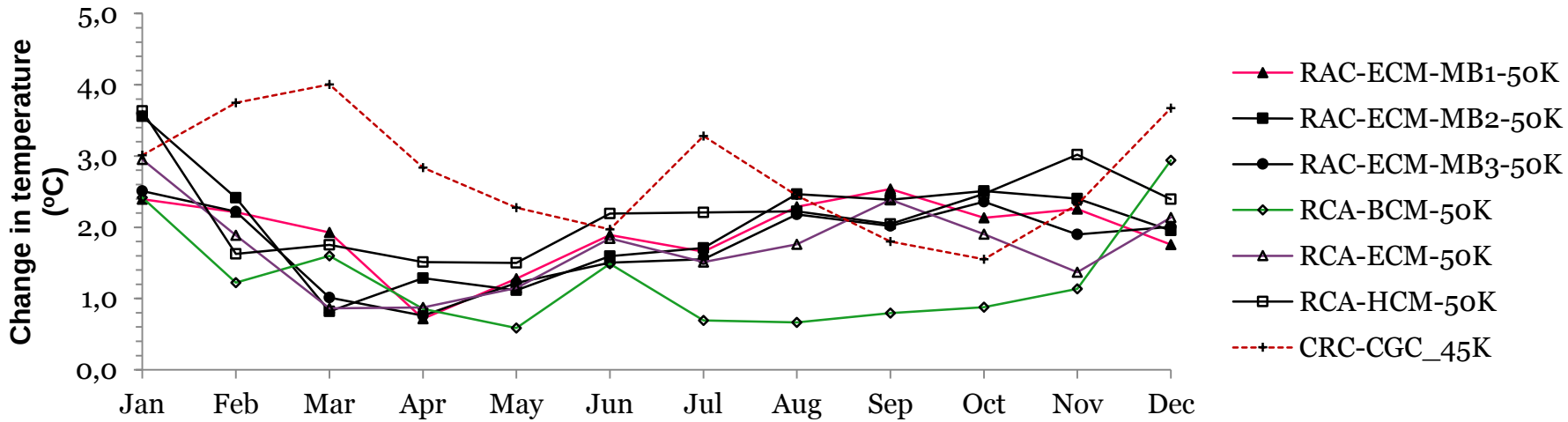
Regional climate models

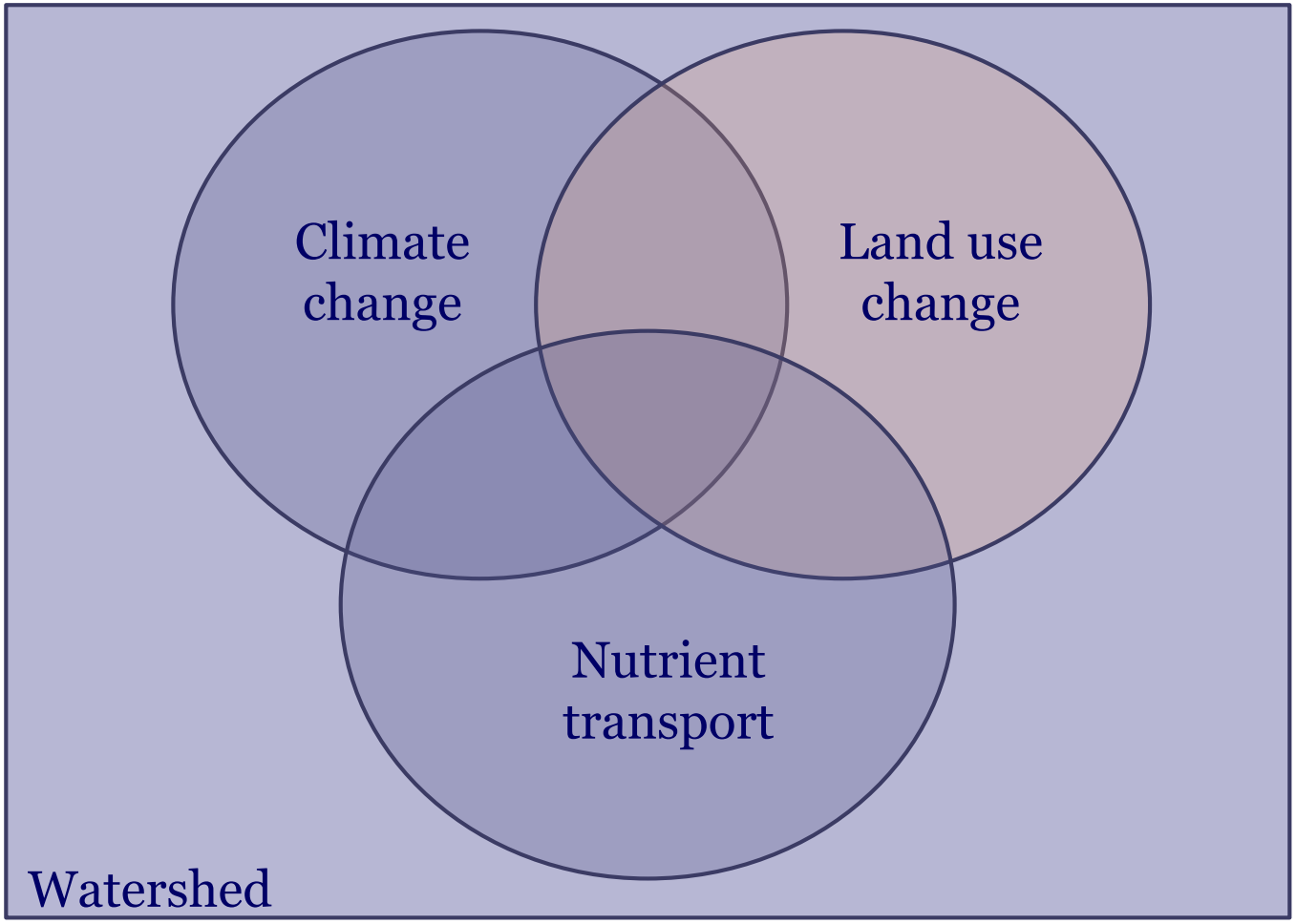
- Ensemble of 7 climate simulations from 2040-2070

RCM[a]	Driving GCM[b]	SRES	Grid size (km)	Name of simulation
RCA	BCM	A1B	50	RCA-BCM-50K
RCA	ECHAM5-r3	A1B	50	RCA-ECM-50K
RCA	HadCM3Q3	A1B	50	RCA-HCM-50K
RACMO2	ECHAM5-r1	A1B	50	RAC-ECM-MB1-50K
RACMO2	ECHAM5-r2	A1B	50	RAC-ECM-MB2-50K
RACMO2	ECHAM5-r3	A1B	50	RAC-ECM-MB3-50K
CRCM 4.2.3	CGCM3	A2	45	CRC-CGC-45K

Climate simulations (2041-2070) minus the reference period (1971-2000)






Climate change
Land use change
Nutrient transport
Watershed

Development of future land use scenarios

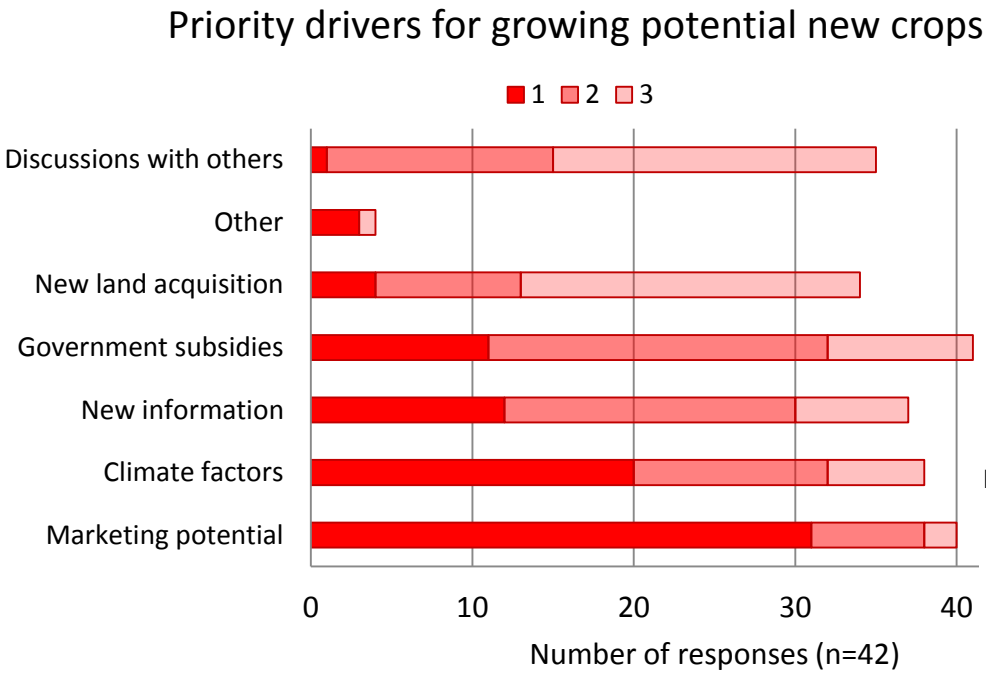
A. Current land use change trends are continued (BAU)
   - Examination of geospatial & statistical data
   - Biophysical and socio-economic factors

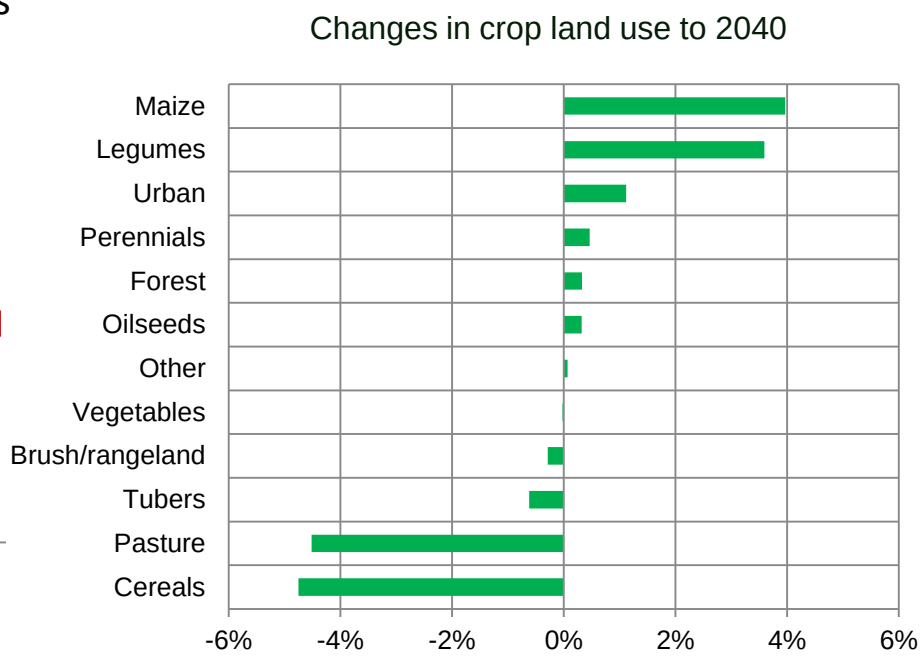
B. Farmer decisions dominate (FARM)
   - Questionnaires determined drivers of crop changes
   - Decision making factors important to farmers

C. Common Agricultural Policy 2003 (CAP)
   - Literature review for market drivers to calculate yearly crop amounts
   - Based heavily on agricultural policies

B. Farmer decisions dominate (FARM)

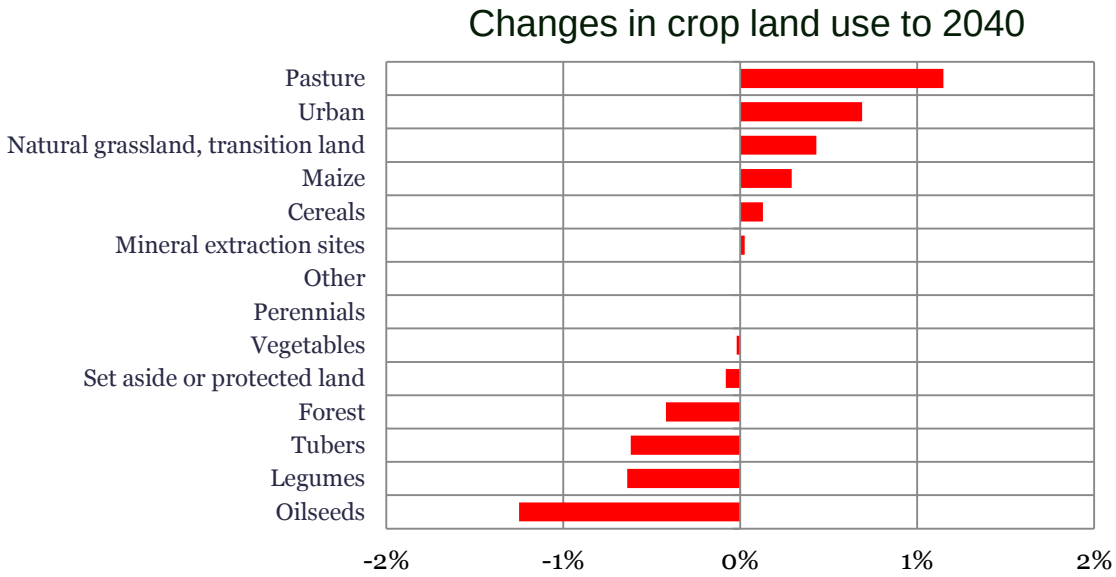
- Decision factors that lead to crop changes: marketing potential, climate factors, new information and subsidies
- More biofuel crops will be planted, entailing a consequent reduction in the area of pasture, cereals and tubers (not cost efficient)
- Farmers will seed new crops such as soybeans, lupin, sorghum, miscanthus, sudangrass

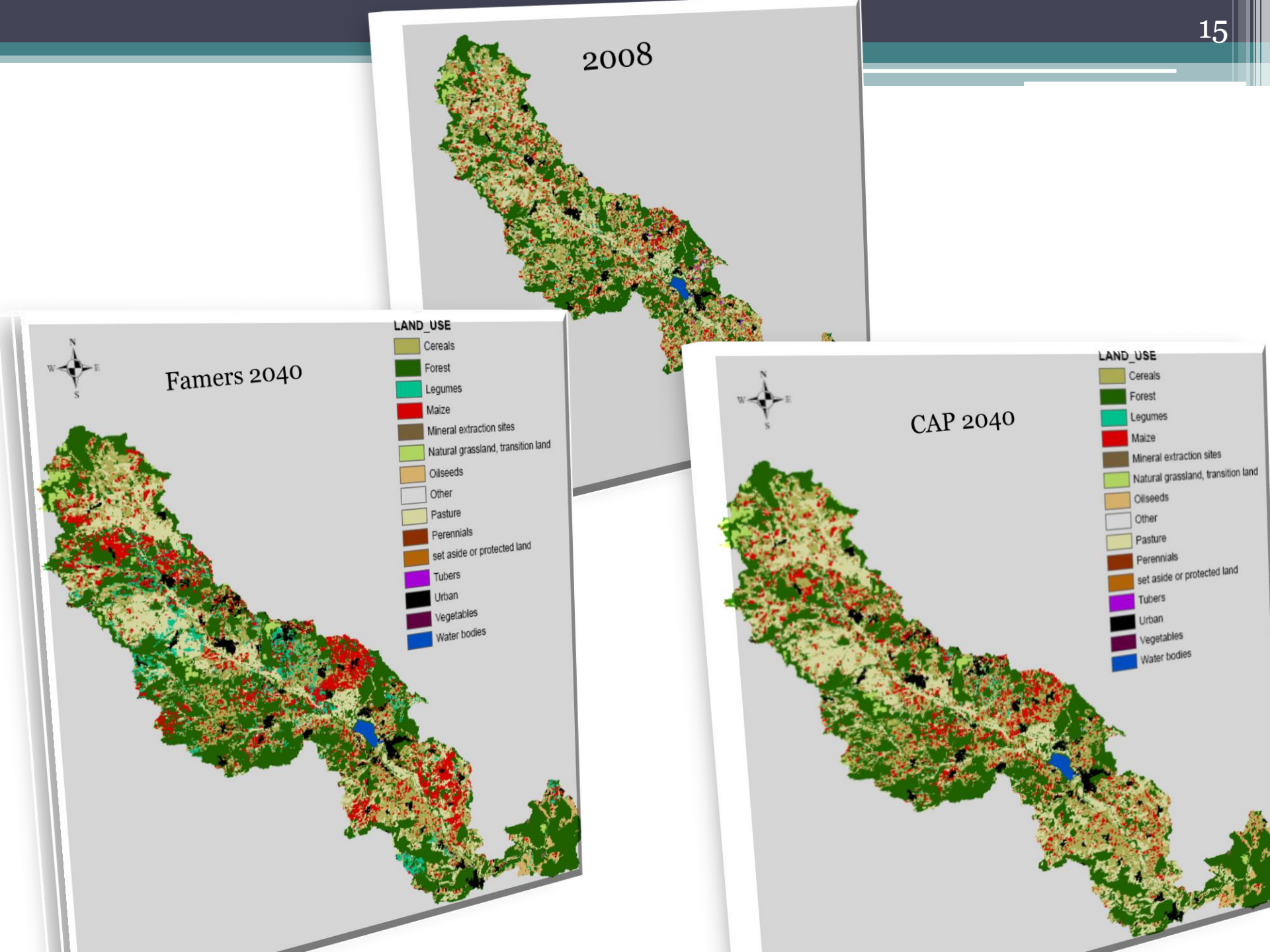




C. CAP 2003 is continued (CAP)

- Market forces determine the agricultural land use
- Decoupling of agricultural production from direct payments allow farmers to maintain land stewardship practices
- Sustainable land use policies (income stabilisation) bring about an extensification of the agricultural lands
- Maintenance of permanent pastures, natural pastures and set-aside land is encouraged to increase the biodiversity
- Lower population, and less economic growth, as well as a lower meat consumption will lead to less demand for animal products and crops for animal feed.

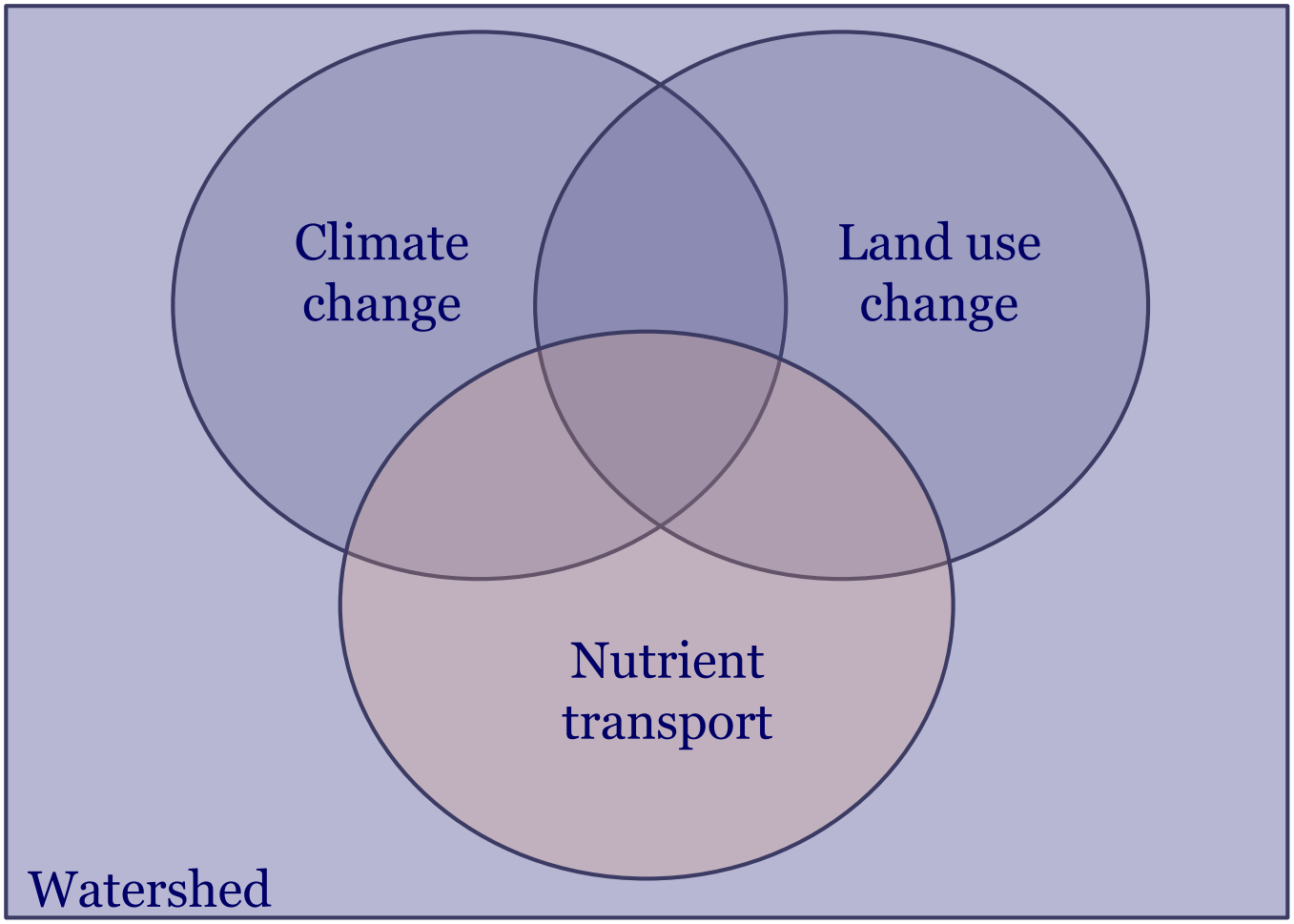



2008
Famers 2040
CAP 2040
LAND_USE
Cereals
Forest
Legumes
Maize
Mineral extraction sites
Natural grassland, transition land
Oilseeds
Other
Pasture
Perennials
set aside or protected land
Tubers
Urban
Vegetables
Water bodies

Impact of climate change alone and with land use change scenarios on water quality

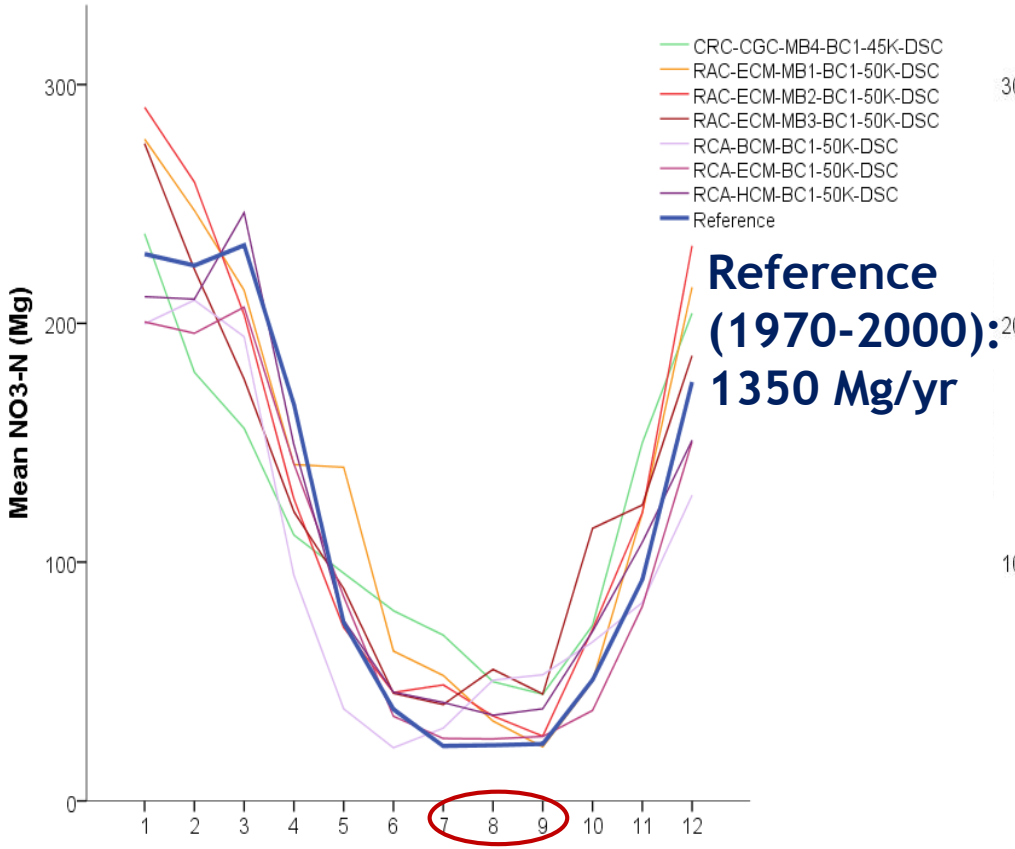
- Each of 3 land use scenarios was applied in SWAT with each of the 7 climate scenarios in turn
  - land use dynamic for the run time 2041-2070.
- 3 land use scenarios * 7 climate simulations = 21

- Adjusted planting and harvesting dates for crops
- Additional fertilizer for maize (65 kg N/ha & 25 kg P/ha), pasture & hay had an extra cut (with application of 200 kg/ha manure)


Climate change
Land use change
Nutrient transport
Watershed

Simulated mean monthly NO_3^--N loads

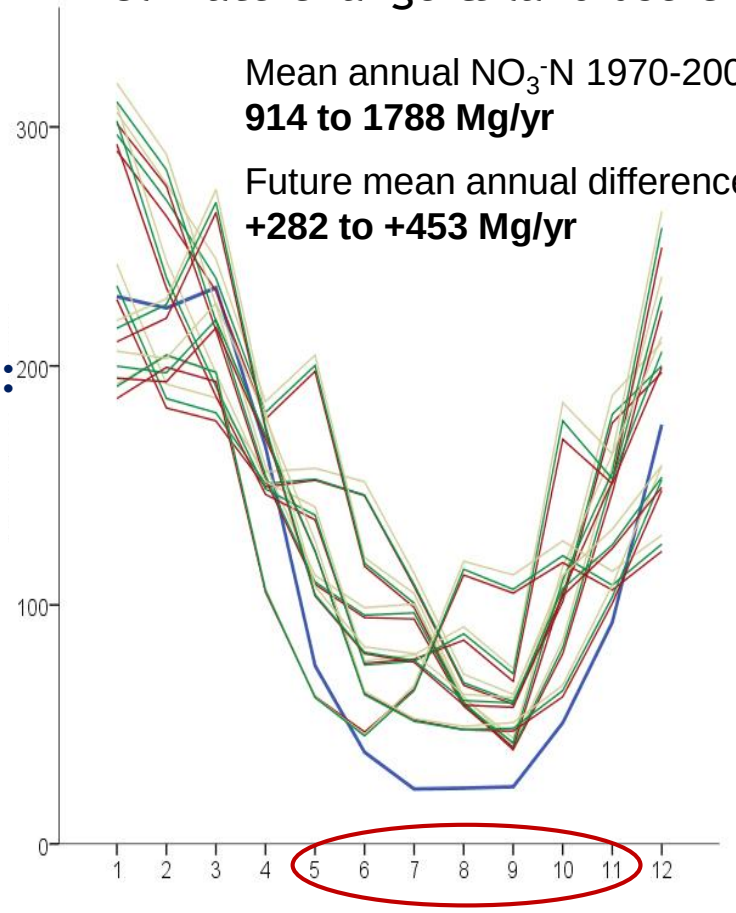
Climate change



Reference (1970-2000): 1350 Mg/yr

Mean average annual load:
1400 Mg/yr
+4%

Climate change & land use change



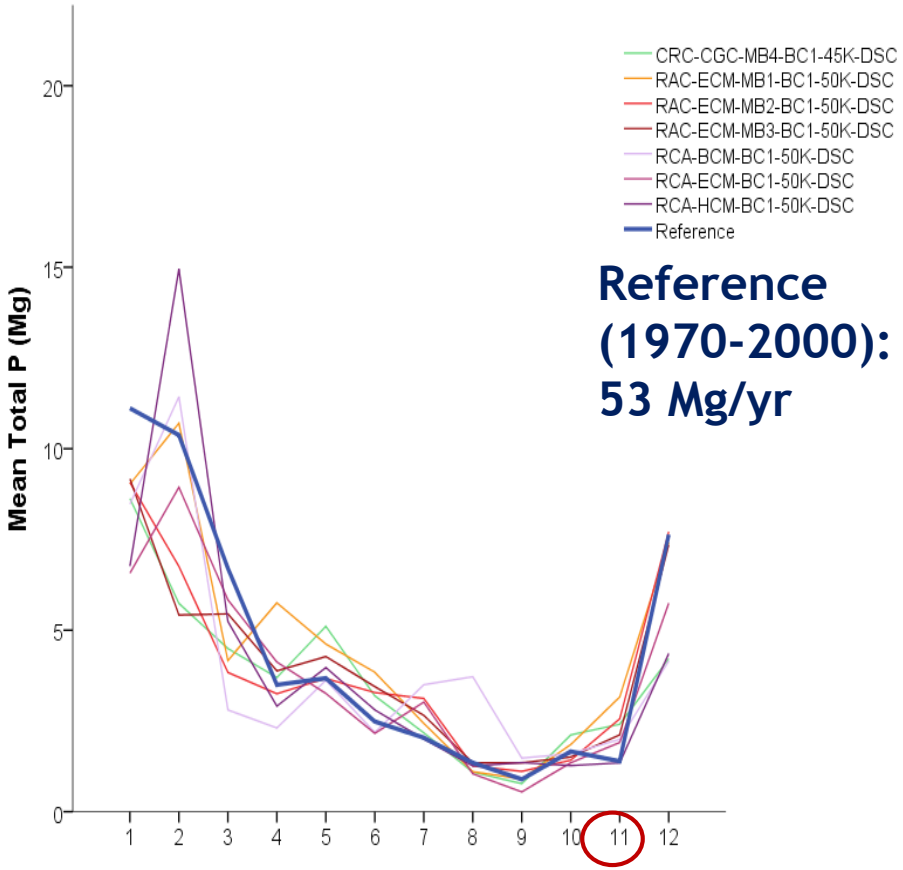
Mean annual NO_3^-N 1970-2000
914 to 1788 Mg/yr

Future mean annual difference
+282 to +453 Mg/yr

Mean average annual load:
1700 Mg/yr
+27%

Simulated mean monthly TP loads

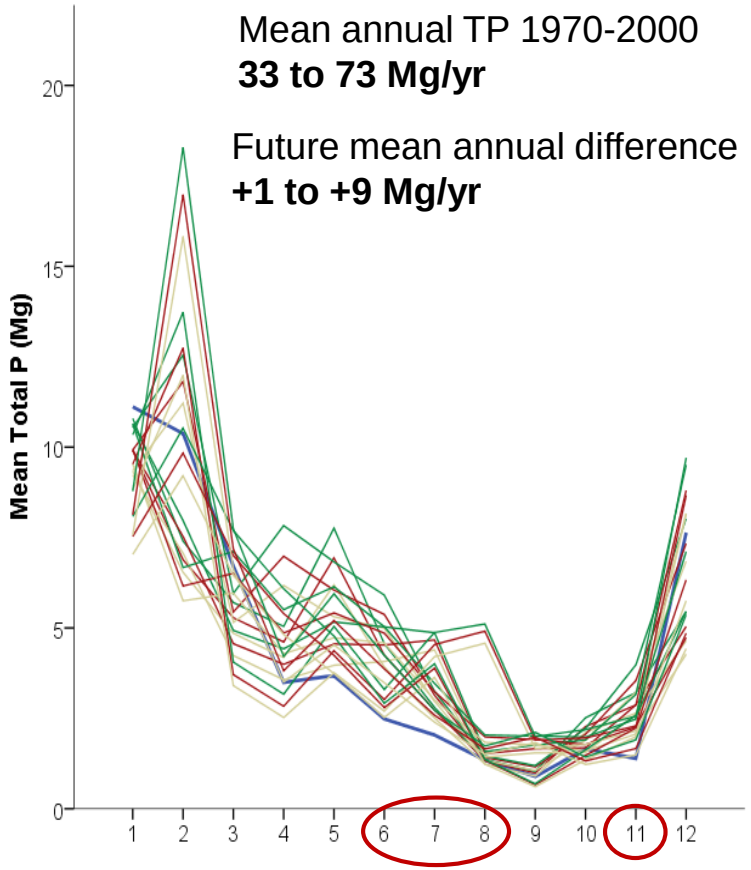
Climate change



Reference (1970-2000): 53 Mg/yr

Mean average annual load:
48 Mg/yr
-10%

Climate change & land use change



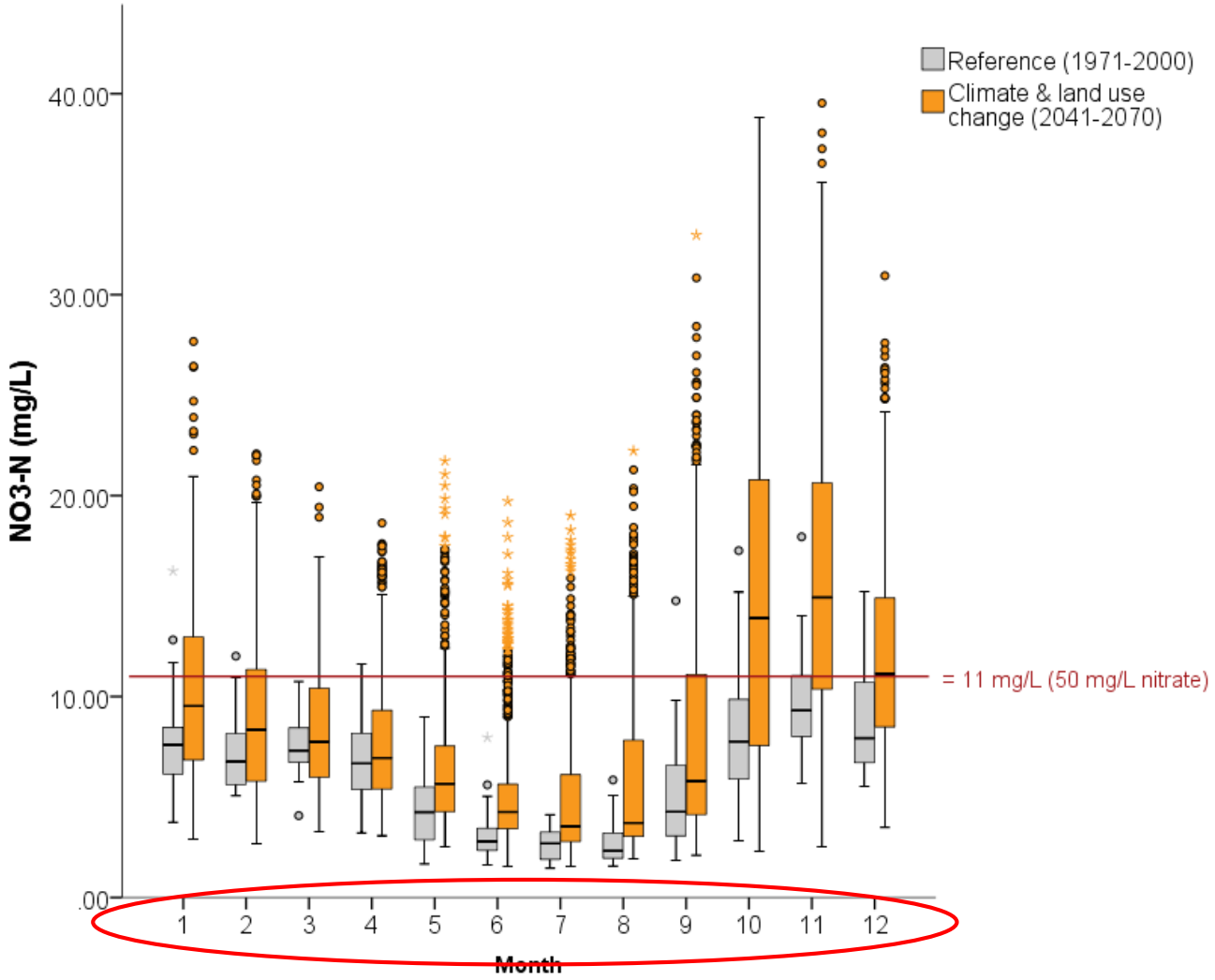
Mean annual TP 1970-2000
33 to 73 Mg/yr

Future mean annual difference
+1 to +9 Mg/yr

Mean average annual load:
57 Mg/yr
+8%

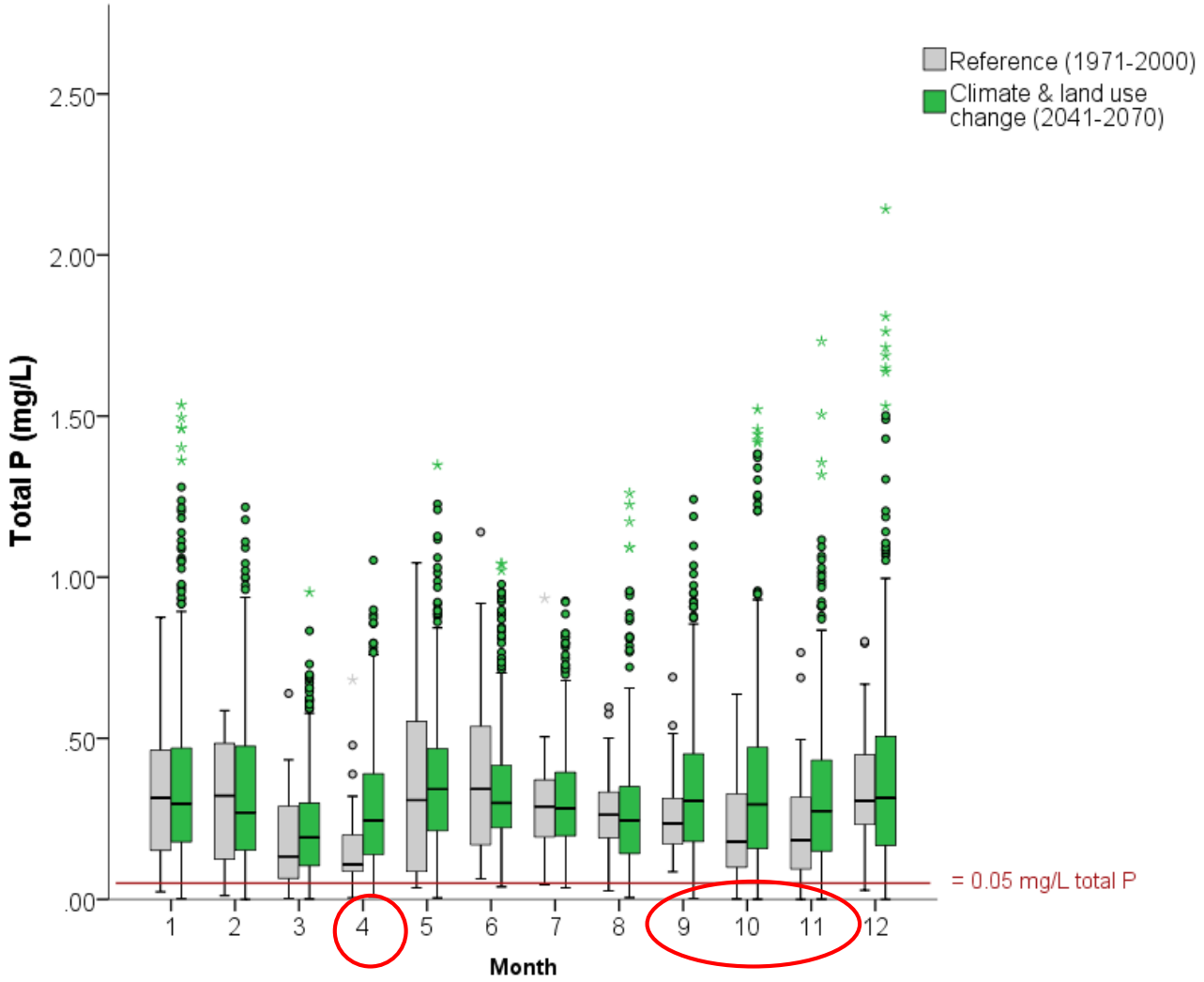
Impacts on water quality and policies?

NO_3^--N concentrations for climate combined with land use change to 2050



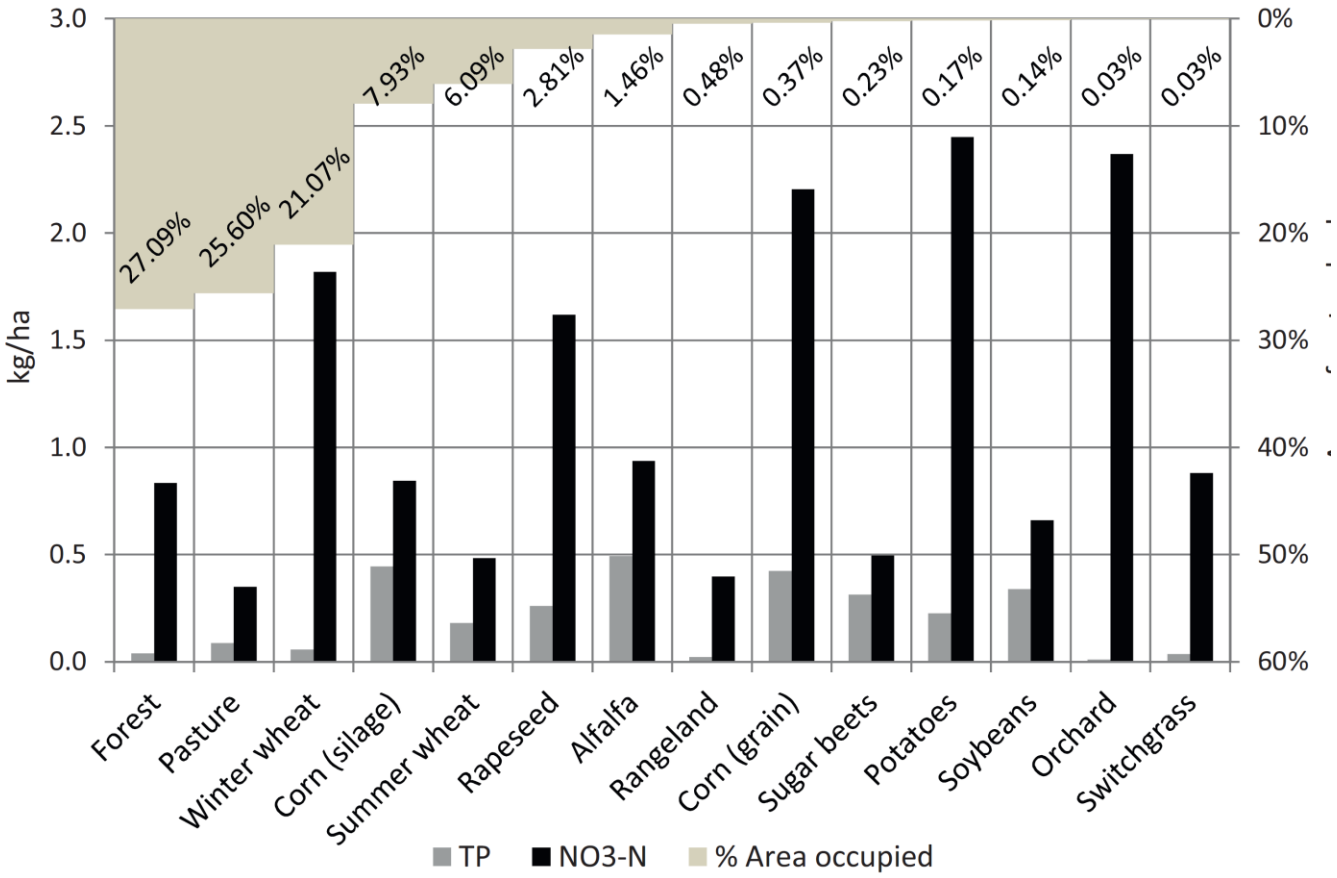
p<0.05

TP concentrations for climate combined with land use change to 2050

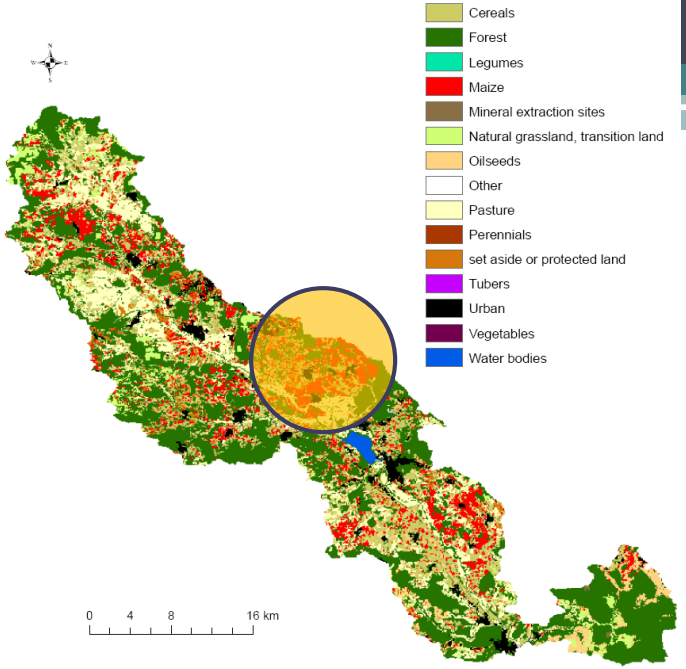


p<0.05

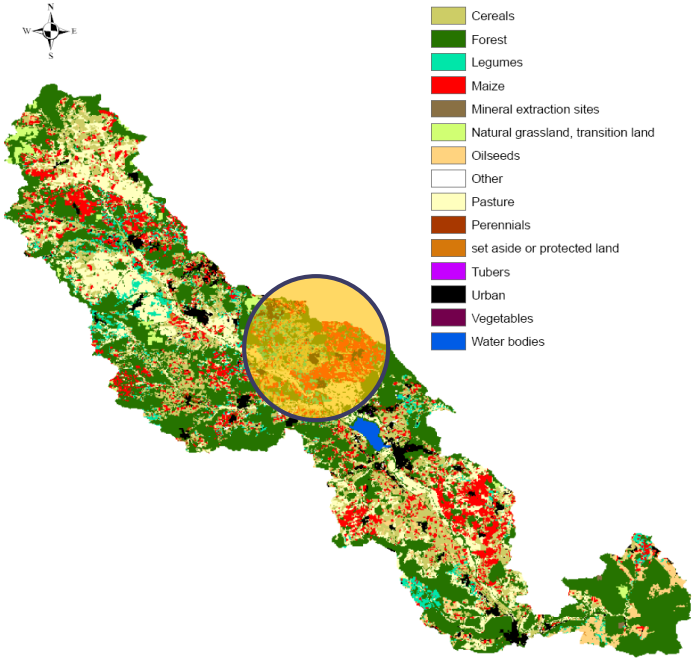
Contributions of crops to mean monthly P and N loads (kg/ha) into the river, as simulated by SWAT using the land use from 2008 and the climate from 1975-1980, but applying future seeding, fertilizer and tillage management practices.



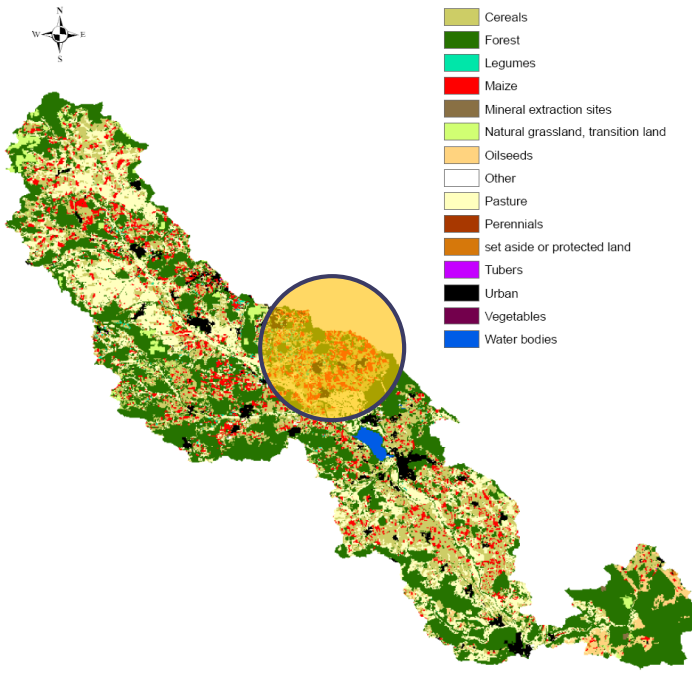
BAU scenario in 2040



FARM driven scenario in 2040



CAP driven scenario in 2040



Conclusion

- When climate change simulations were combined with land use changes, mean annual NO_3^--N loads increased 3-fold, and TP loads 8-fold, compared to the climate change simulations alone

- Challenge will be to maintain and to improve NO_3^--N and TP concentrations in the future (to 2050)

Research Support

NSERC
McGill University
Ludwig Maximilians Universität
Québec ministère du Développement économique, Innovation & Exportation
GEC^3