Evaluation of Adaptive Measures to Reduce Climate Change Impact on Soil Organic Carbon Stock on Danubian Lowland

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Motivation

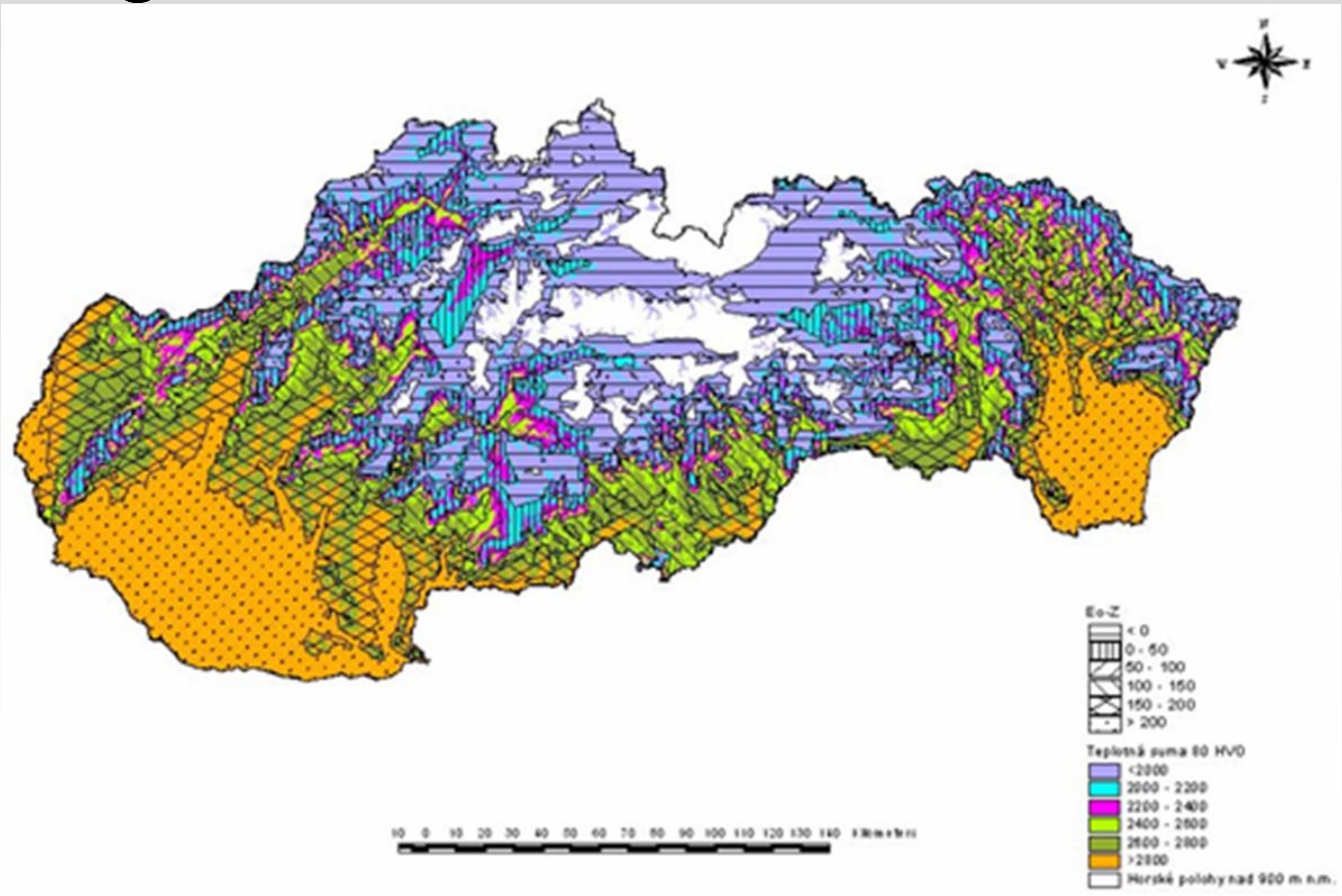
We have:

- validated crop yield models
- GCM outputs
- → simulated crop yield (in large scale in dependence upon SRES, agricultural practices etc.)
- → adaptive measures

But:

- Are our management practices sustainable in future climate from the point of view of soil fertility?

Regional and/or local conditions

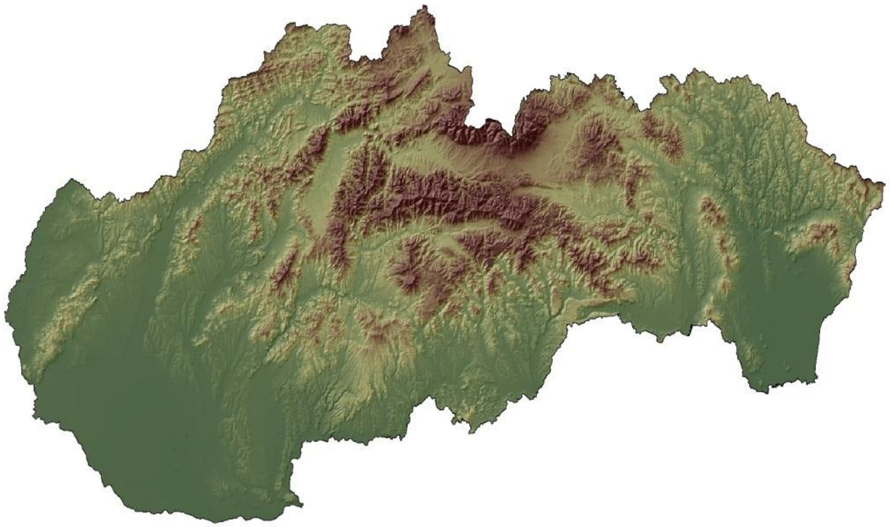


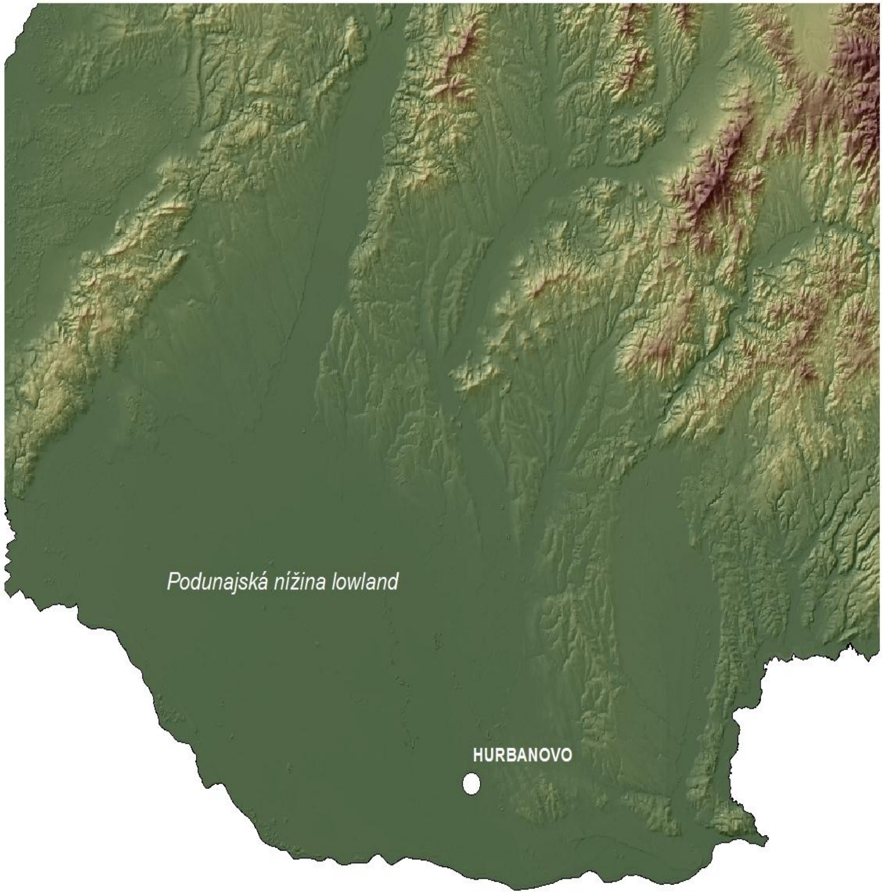
Regional and/or local conditions

Agroclimatic classification of Slovak republic

Region	**Subregion**	***TS10***	***E_0-R***	**Agroregion**
Cold	Wet	< 2000	< 0	**Mountainous**
Moderately warm	Normal	2000 – 2400	0 – 50	**Potato**
Warm	Semi Dry	2400 -2600	50 – 150	**Sugar beet**
	Dry	> 3000	> 150	**Maize**

Material and methods





- Region: Danubian Lowland
- Meteorological Station: Hurbanovo (observations since 1871)

Climate data

- Reference period: 1961-1990
- Emission scenarios: SRES A2 and SRES B1 – gradual increase of CO_2 concentration
- Daily meteorological data (global radiation, temperature, precipitation) generated according to the outputs of GCM CGCM3.1 (Canadian Climate Centre) up to 2100
- Downscaling by Lapin et al., 2006

Climate scenarios

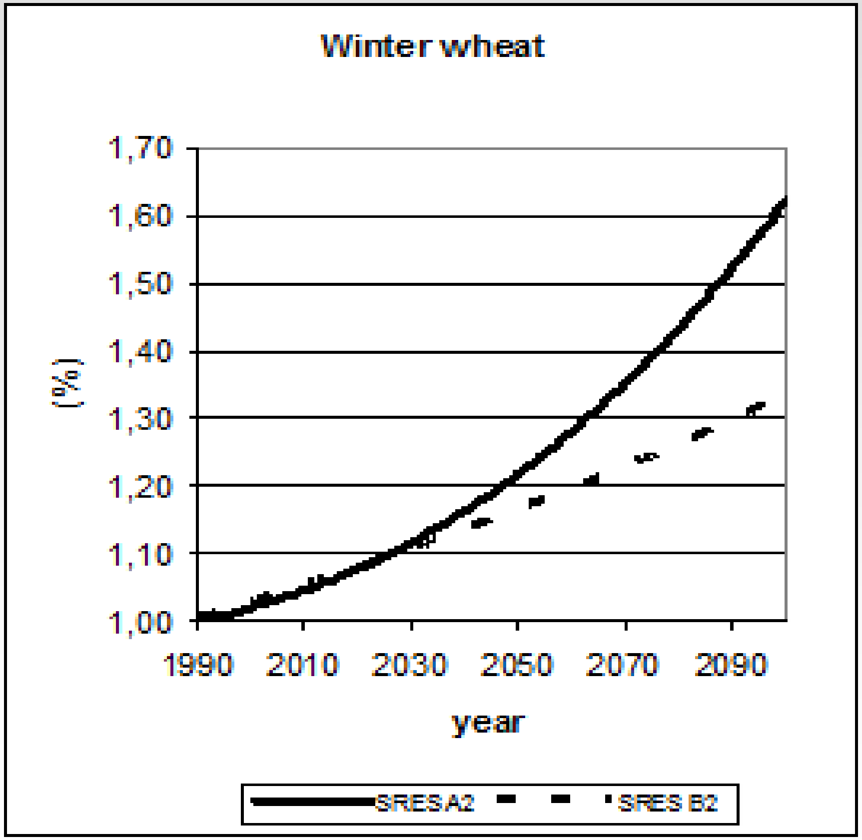
- 1961-1990

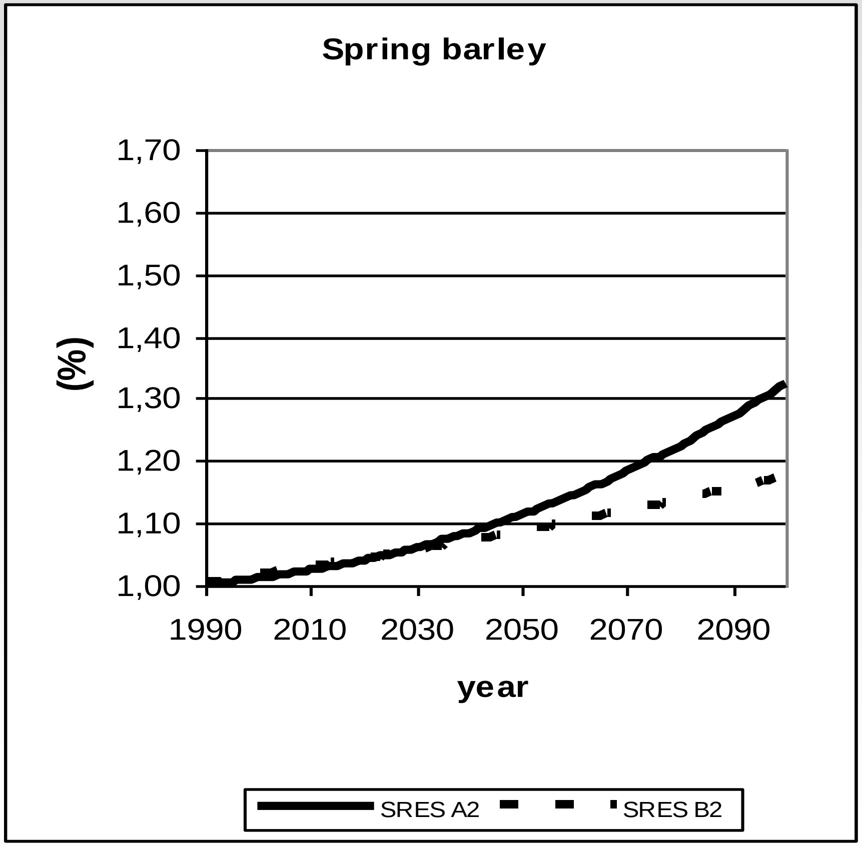
Annual mean temperature: 10.0 °C
April – September: 16.7 °C
Mean annual precipitation total : 523 mm
April – September: 303 mm

- Climate scenarios

		2011-2040		2041-2070		2071-2100	
		Temp	**Prec**	**Temp**	**Prec**	**Temp**	**Prec**
SRES A2	**Year**	11.6	603	12.6	665	14.2	712
	IV-IX	18.2	349	19.1	372	20.7	377
SRES B1	**Year**	11.6	621	12.2	642	12.4	656
	IV-IX	18.0	380	18.5	364	18.9	369

Efficiency of photosyntheticaly active radiation as influenced by CO2 concentration in winter wheat and spring barley crops up to year 2100 – emission scenarios SRES A2 and SRES B1





CO_2 concentration in atmosphere and radiation efficiency (coefficients) for different crops in time slices according to SRES A2 and SRES B1

Year	Concentration CO_2 [ppm]		Potato		Winter wheat		Spring barley		Corn maize	
	A2	B1	A2	B1	A2	B1	A2	B1	A2	B1
2000	369	369	1,01	1,01	1,03	1,03	1,02	1,02	1,00	1,00
2010	391	393	1,02	1,02	1,05	1,05	1,03	1,03	1,01	1,01
2020	419	416	1,03	1,03	1,07	1,07	1,04	1,04	1,01	1,01
2030	451	441	1,04	1,03	1,10	1,09	1,05	1,05	1,01	1,01
2040	493	465	1,05	1,04	1,13	1,11	1,07	1,06	1,02	1,02
2050	538	489	1,06	1,05	1,17	1,13	1,09	1,07	1,03	1,02
2060	589	510	1,08	1,05	1,21	1,15	1,11	1,08	1,03	1,02
2070	646	527	1,10	1,06	1,26	1,16	1,13	1,08	1,04	1,02
2080	708	541	1,11	1,06	1,31	1,17	1,16	1,09	1,05	1,03
2090	776	549	1,14	1,07	1,37	1,18	1,19	1,09	1,05	1,03
2100	850	551	1,16	1,07	1,43	1,18	1,22	1,09	1,06	1,03

Soil and management data

- Soil

  Medium textured chernozem, 3.5 % humus in topsoil
- Cropping pattern

  8 crops (winter wheat, spring barley, winter rape, maize, sugar beet, potato, pea, alfalfa) in four 10-year crop rotations
- Management setup

1. rainfed (M0)
2. irrigated (M1)
3. spring crops rainfed, summer crops irrigated, residuals incorporated (M2)

- Simulation model: Daisy (Hansen et al., 1990)

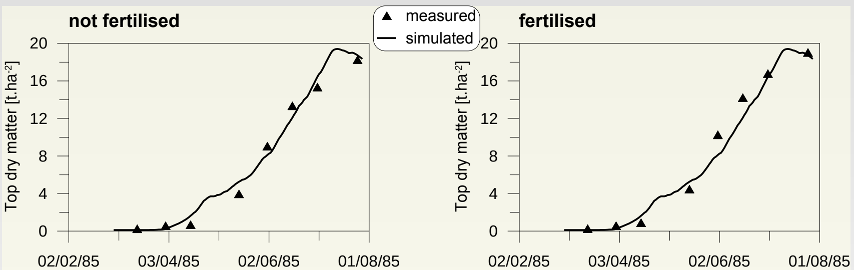
Dozens of mineral nitrogen for DAISY model simulation

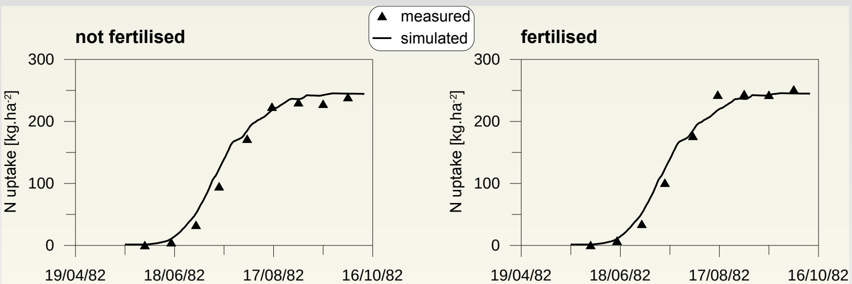
Crop	Before season $[kg\ N.ha^{-1}]$	During growing season $[kg\ N.ha^{-1}]$	Total $[kg\ N.ha^{-1}]$
Winter wheat	40	80	120
Spring barley	40	20	60
Oil seed rape	50	70	120
Corn maize	120	0	120
Sugar beet	40	60	100
Alfalfa	30	0	30
Potato	80	20	100
Pea	30	0	30

Crop rotation schedule for DAISY model simulation

year	CR1	CR2	CR3	CR4
1	Alfalfa	Wheat	Sugar beat	Corn
2	Alfalfa	Rape	Wheat	Corn
3	Alfalfa	Wheat	Rape	Barley
4	Wheat	Corn	Barley	Rape
5	Rape	Wheat	Corn	Barley
6	Wheat	Sugar beat	Barley	Peas
7	Rape	Barley	Peas	Wheat
8	Corn	Potato	Wheat	Rape
9	Potato	Barley	Rape	Wheat
10	Barley	Peas	Wheat	Potato

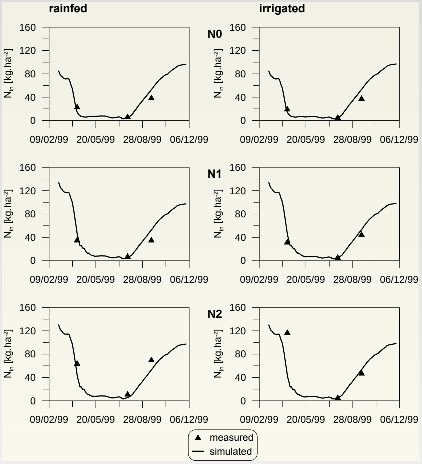
Model calibration

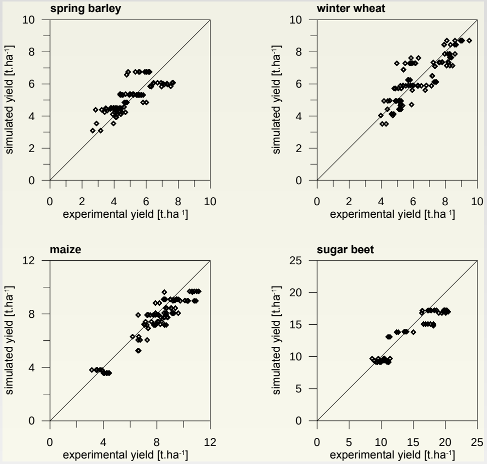




- Crop parameters of spring barley, winter wheat, maize and sugar beet were calibrated
- Field experimental station of Research Institute of Irrigation in Most near Bratislava
- Experimental data from the period 1983 – 1987 were used
- Fertilised as well as not fertilised crops
- Available data on harvested yield, top dry matter, crop N uptake, N in soil
- Figure (left): Simulated and measured top dry matter of winter wheat
- Figure (right): Simulated and measured maize N uptake

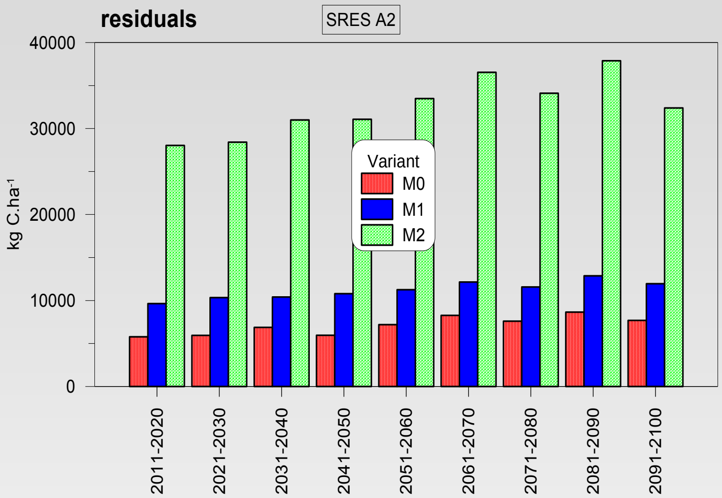
Model validation



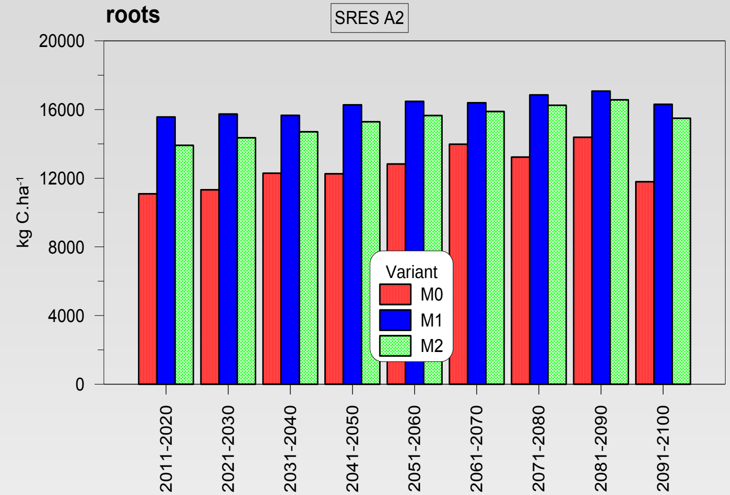


- Yields from the Farm Lehnice 1992 - 1995
- Field experimental station of Research Institute of Irrigation in Most near Bratislava
- Experimental data from the stationary experiment 1973 – 2006
- Fertilised (6 variants) and not fertilised crops, rainfed and irrigated
- Experimental data from the experiment 1999-2002
- Fertilised and/or residuals incorporated (3 variants), rainfed and irrigated
- Figure (left): Simulated and measured yield
- Figure (right): Simulated and measured inorganic N in soil (winter wheat)

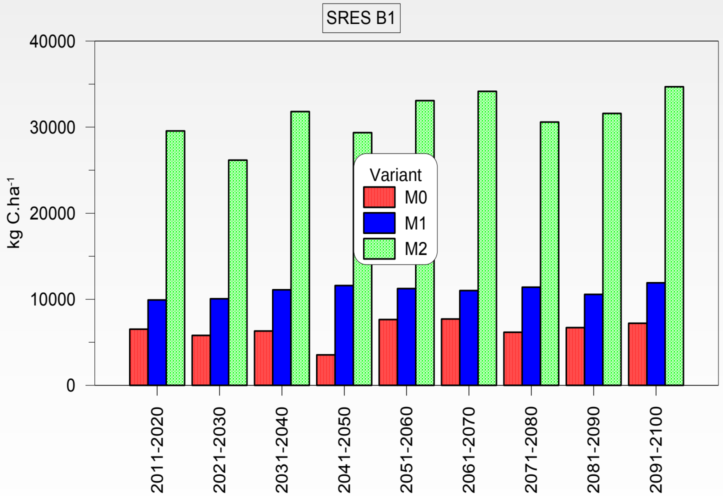
Results



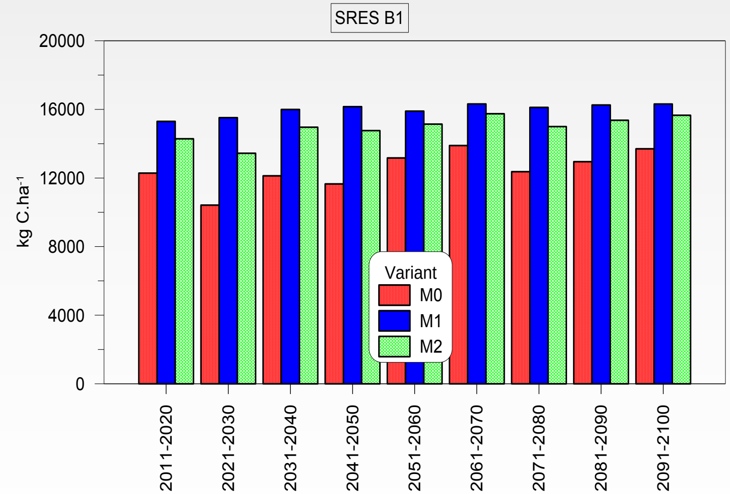
residuals
SRES A2
kg C.ha-1
Variant
M0
M1
M2



roots
SRES A2
kg C.ha-1
Variant
M0
M1
M2

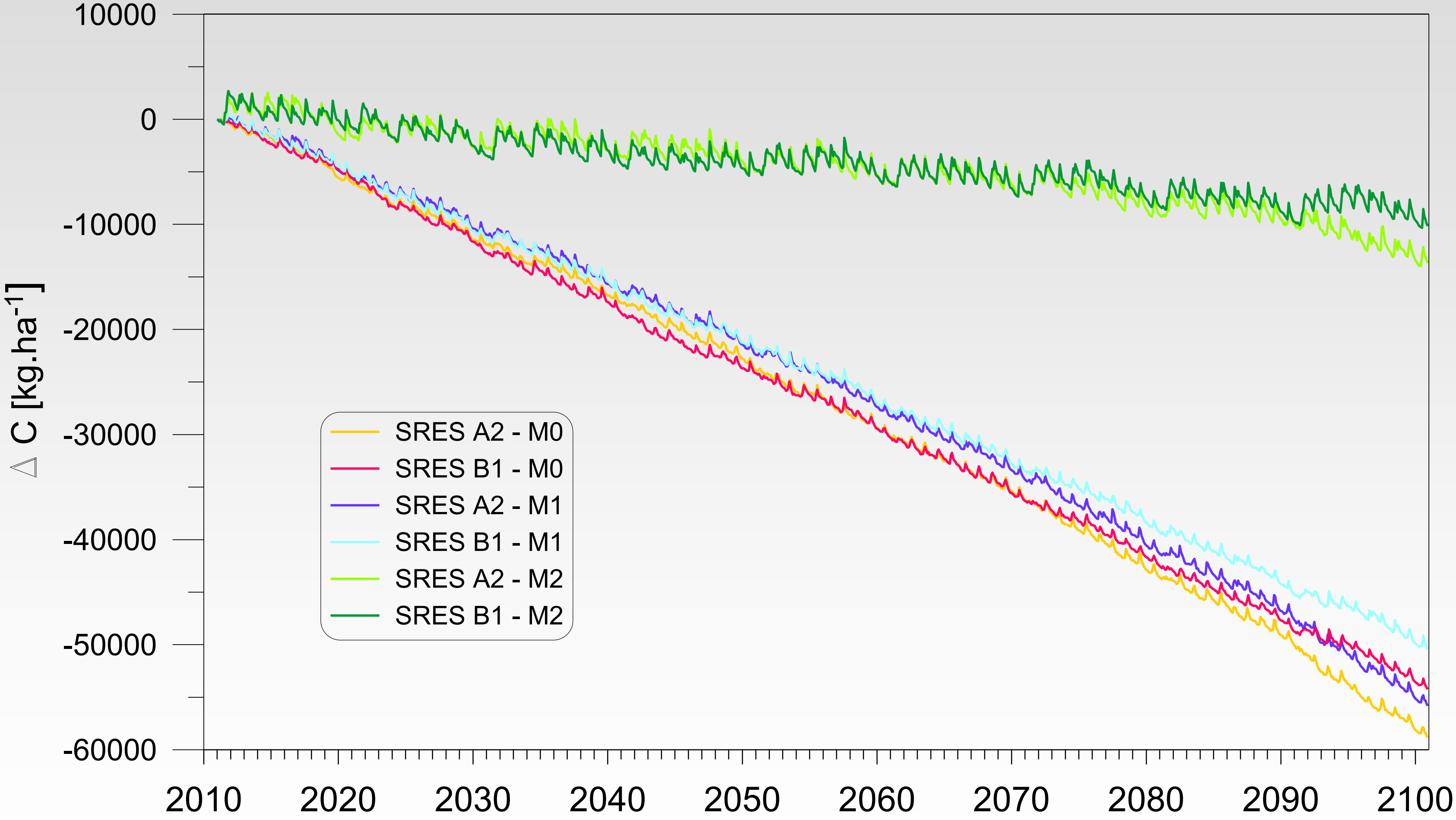


SRES B1
kg C.ha-1
Variant
M0
M1
M2



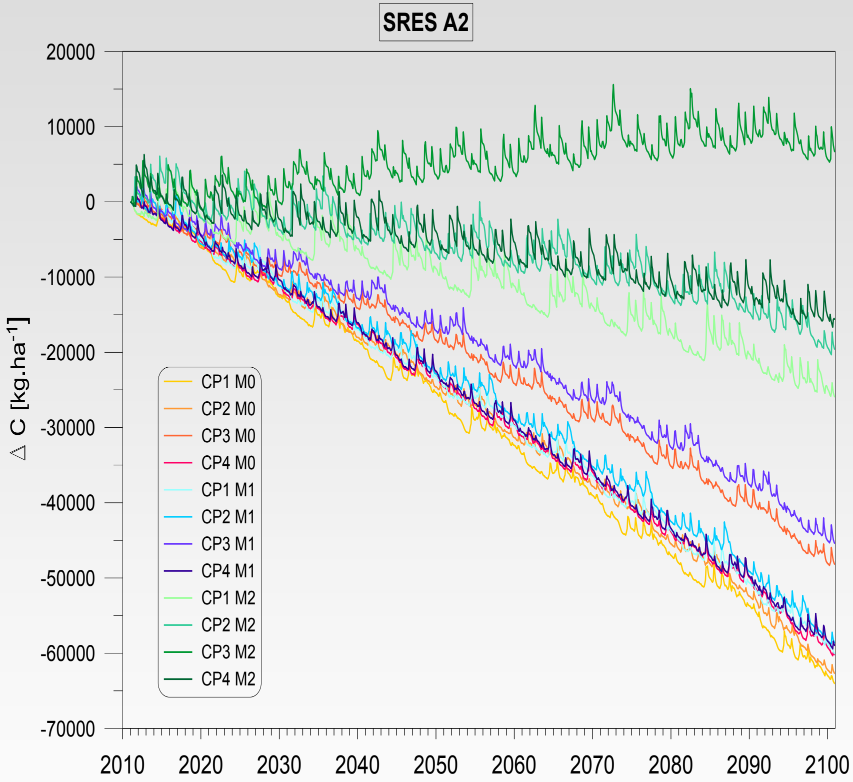
SRES B1
kg C.ha-1
Variant
M0
M1
M2

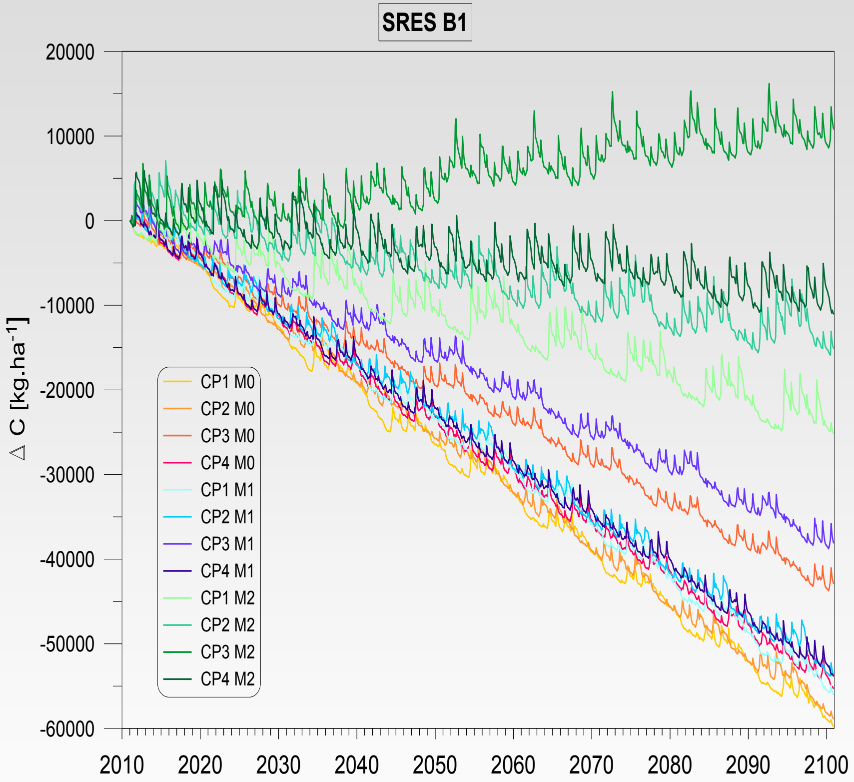
Results



10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Δ C [kg.ha-1]
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
SRES A2 - M0
SRES B1 - M0
SRES A2 - M1
SRES B1 - M1
SRES A2 - M2
SRES B1 - M2

Results


SRES A2
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
Δ C [kg.ha-1]
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
CP1 M0
CP2 M0
CP3 M0
CP4 M0
CP1 M1
CP2 M1
CP3 M1
CP4 M1
CP1 M2
CP2 M2
CP3 M2
CP4 M2


SRES B1
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Δ C [kg.ha-1]
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
CP1 M0
CP2 M0
CP3 M0
CP4 M0
CP1 M1
CP2 M1
CP3 M1
CP4 M1
CP1 M2
CP2 M2
CP3 M2
CP4 M2

Conclusions

- According to DAISY simulation the significant carbon stock decreases can be expected as a result of climate change scenarios (SREA A2, SRES B1) impacts in variant of conventional rainfed management without incorporation of crop residuals into the soil. Little bit better results but still decrease of carbon stock was found if irrigation is applied. Only the combination of the incorporation of crop residuals into the soil with irrigation can save carbon in soil or the carbon lost is very small.
- Global warming without a proposal and the consequent application of the effective adaptive measures (especially irrigation) can lead to significant carbon stock lost in conditions of Slovak republic: from **-14 to -20%** in time slice 2070 and from **-19 to -32%** in time slice 2100.
- We can conclude on the base of DAISY as well as DNDC modeling that soil fertility (including steady level of carbon stock) in climate change conditions require to adopt complex of measures. Except for crop rotations the irrigation will play important role. Combination of both measures can accelerate carbon stock by 4 - 5 % in conditions of future climate

THANK YOU FOR ATTENTION