Modeling Impact of Climate Change and Managament Practices on Greenhouse Gas Emissions from Arable Solis

Alina Syp, Antoni Faber, Jerzy Kozyra,
Robert Borek, Rafał Pudełko,
Magdalena Borzęcka-Walker, Zuzanna Jarosz

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IUNG Institute of Soil Science and Plant Cultivation
State Research Institute

Background:

- Agricultural lands occupy about 40-50% of the Earth's land surface. Agriculture, in 2005, accounted for 10-12% of total global anthropogenic emissions of GHGs (IPPC, 2007).
- Globally, agricultural CH_4 and N_2O emissions have incresed by nearly 17% from 1990 to 2005. (IPPC, 2007). According to FAO, agricultural N_2O emissions are projected to rise by 35-60% to 2030 due to increse of nitrogen fertilizer use and animal manure production.

- Tillage systems affects crop yields and GHG emisions (Lal, 2007; West and Point, 2002).

- There is a gowing concern about soil productivity and influence of management pracitces on the enviroment.

Aim of the study:

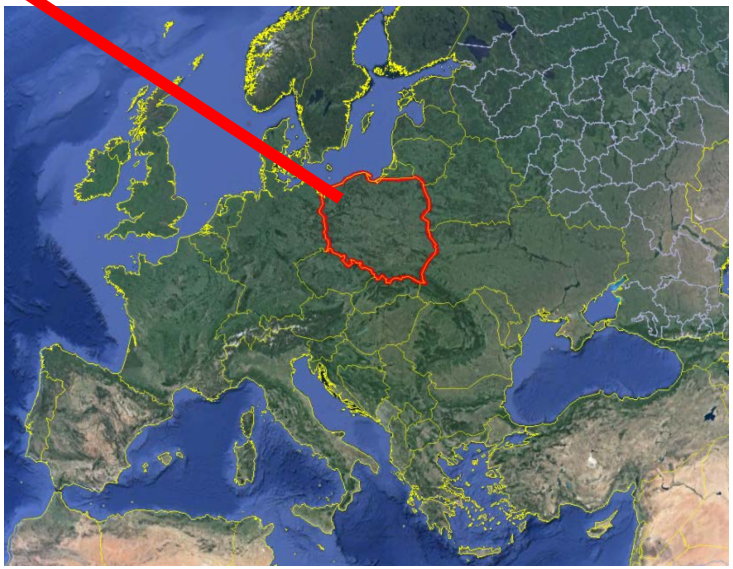
- Estimation of impact of climate change on GHG emissions under different management practices using the DNDC model.

- Comparison of DNDC model outputs for baseline (1971-2000) and future climate scenarios for 2030 and 2050.

Pilot area - Grabów Experimental Station of IUNG-PIB

Localization of pilot area (51°21´N, 21°40´E and 167 m above sea level)

- soil type - loamy sand,
- soil pH - 7
- clay fraction - 0.09%
- bulk density - 1.5 g cm^{-3}
- initial value of SOC – 0.01 kg C kg^{-1} of soil
- continental climate
- average annual temperature (1971-2000) - 8.1°C
- annual precipitation - 631.6 mm



Experimental Design

Crop rotations and quantity of fertilizer applied

Crop_type:	Corn	Spring wheat	Rapeseeds	Winter wheat
Manure_amended (kg C ha^{-1} yr^{-1})	0	0	2000	0
Fertilizer_N (kg N $ha^{-1}yr^{-1}$) – Urea	120	120	180	140
Manure_N (kg N $ha^{-1}yr^{-1}$)	0	0	40	0
Planting time	1.05.	1.04.	15.08.	15.09.
Harvesting time	20.10.	3.08.	20.07.	3.08.

Management pracitces:

- Conventional tillage (tillage)- mouldboard plowing
- Conservation tillage (reduced tillage) - chisel plowing

Climate model simulations

- The climate model simulations for the baseline period (1971-2000) and for the future climate (2030 and 2050) were prepared as a part of activity COST 734 Action: Impacts of Climate Change and Variability on European Agriculture - CLIVAGRI, particularly as special activity of WG4 Risk Assessment and Foreseen Impacts on Agriculture (www.cost734.eu).

- The data from Grabów Weather Station (1971-2000) were used to train the stochastic weather generator to calculate 100-year stochastic weather series of daily sum of global radiation, maximum and minimum temperatures, sum of precipitation, daily mean air humidity and wind speed.

- The data were assumed for baseline climate scenario called C2000. The weather generator parameters for the future climate (2030 – scenario C2030 and 2050 - scenario C2050) were modified according to the ECHAM5/MPI-OM GCM, with the SRES-A2 emissions scenario for the Fourth Assessment Report of IPPC.

Climate Change Projections

Month	1971-2000		2030		2050	
	Baseline climate		Deviation from baseline		Deviation from baseline	
	T_{mean} (ºC)	Precipitation (mm)	T_{mean} (ΔºC)	Precipitation (% change)	T_{mean} (ΔºC)	Precipitation (% change)
1	-2.9	30.4	1.6	5.0	2.8	4.7
2	-1.0	26.2	1.2	7.3	2.1	5.7
3	3.1	35	0.9	6.0	1.6	4.9
4	8.0	40.3	0.6	12.9	1.2	10.8
5	13.4	63.8	0.5	3.6	0.9	2.6
6	16.3	82.4	0.7	-0.7	1.3	-0.2
7	18.0	82.5	0.8	-6.1	1.5	-4.6
8	17.7	72.4	1.0	-10.9	1.8	-9.0
9	13.3	70.8	0.9	-8.6	1.7	-6.8
10	8.6	50	1.2	-0.8	2.1	-0.8
11	2.6	41	0.9	-4.1	1.6	-3.1
12	-0.5	36.9	1.3	6.0	2.4	4.3
Annual mean	8.1	631.6*	1.0	-1.0	1.7	-0.4

*Annual total

Validation of DNDC model

The DNDC model validation was carried out comparing the measured and modelled values on the basis of real data from Grabów Experimental Station. The relative root mean squared error (RRMSE) was 15%. In our research we used DNDC model (version 9.2).

Results

Estimated average annual N_20, CH_4 and CO_2 emissions (or uptake) for 4-year complete crop rotation cycle for different climates scenarios and management practices

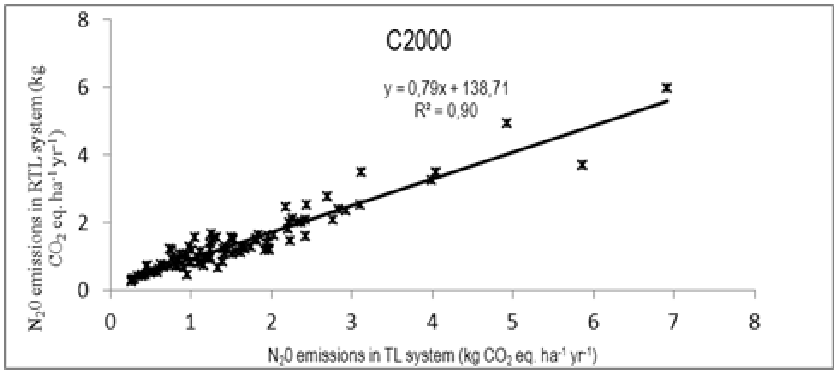
	N_20 - N (kg N ha$^{-1)*}$		CH_4-C (kg C ha$^{-1)*}$		CO_2 - C (kg C ha$^{-1)*}$	
Scenario	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage
C2000	3.18±2.3a	2.80±1.9a	-0.73±0.05e	-0.81±0.07c	-140±2264a	-278±1923a
C2030	3.00±2.2a	2.65±1.9a	-0.78±0.05 d	-0.87±0.07b	-120±2386a	-255±2041a
C2050	2.86±2.1a	2.48±1.7a	-0.82±0.05c	-0.92±0.07a	-110±2488a	-244±2143a

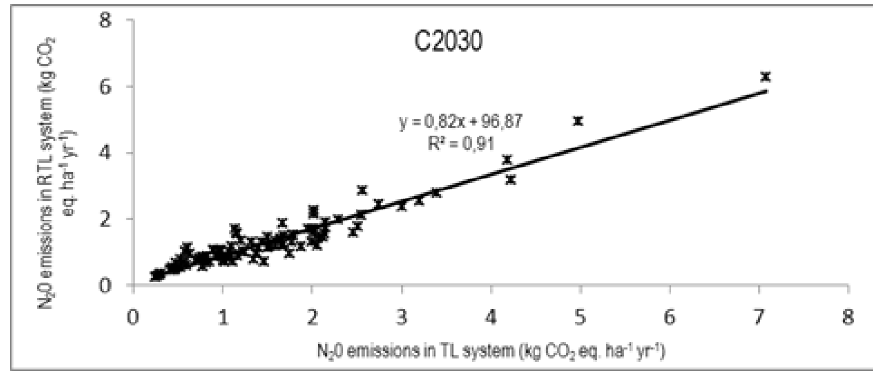
*Within each column crop, scenario and management practices followed by the same letter are not significantly different at $P<0.05$ (Tukey HSD test)

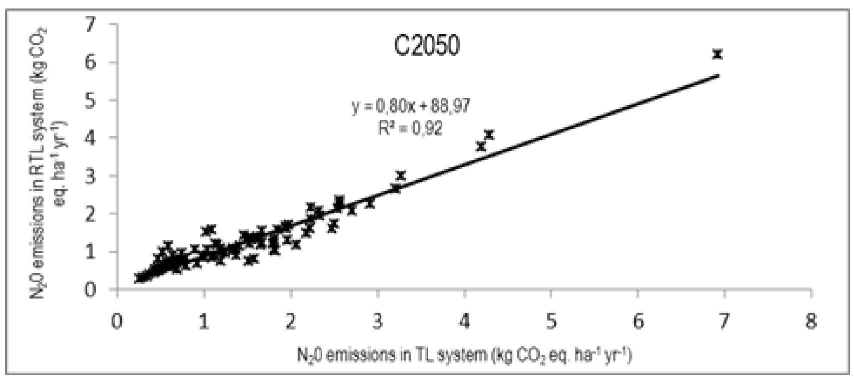
Results

Comparison of N_20 emissions between tillage and reduced tillage in scenarios: C2000(a), C2030(b) and C2050(c)

Abbreviations: TL- tillage system; RTL –reduced tillage system







Results

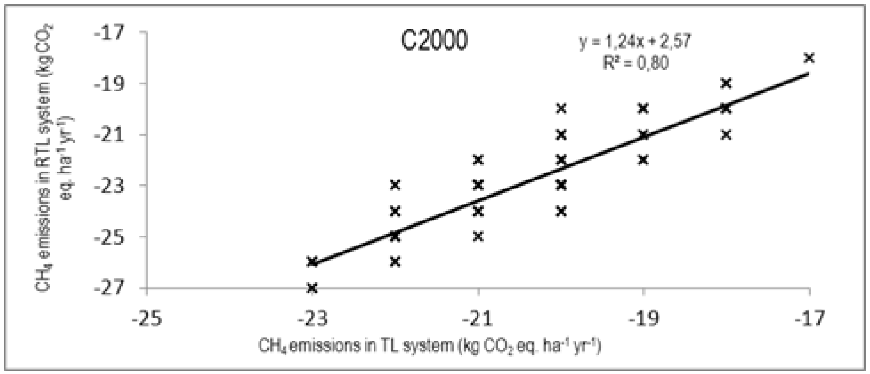
Estimated average annual N_2O (kg N ha^{-1}) emissions in 4-year cropping systems for different climate scenarios and management practices

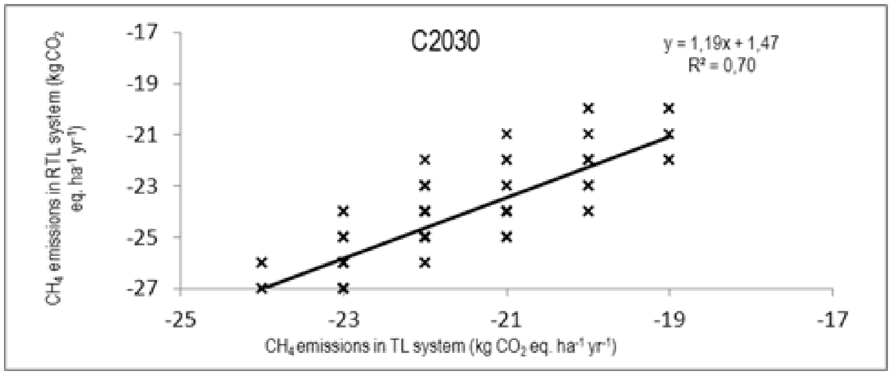
	Corn		Rapeseed		Spring wheat		Winter wheat	
Scenario	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage
C2000	5.48±2.5a	4.51±2.4a	20.89±20.2abc	32.86±18.9c	3.16±0.9bc	2.51±1.0ab	1.59±1.29a	1.63±1.35a
C2030	5.39±2.5a	4.48±2.5a	16.78±20.2ab	30.56±17.6bc	3.16±0.7bc	2.44±0.8a	1.35±0.81a	1.41±0.82a
C2050	5.2±2.4a	4.28±2.3a	14.48±20.4a	29.86±17.3abc	3.2±0.7c	2.39±0.7a	1.20±0.46a	1.24±0.39a

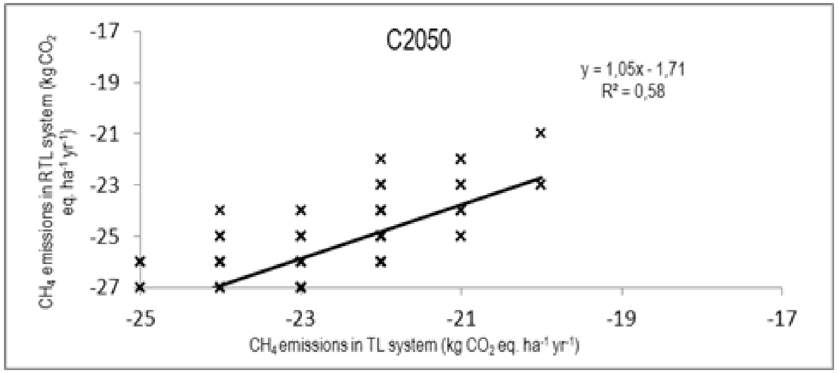
*Within each column crop, scenario and management practices followed by the same letter are not significantly different at $P<0.05$ (Tukey HSD test)

Results

Comparison of CH_4 uptake between tillage and reduced tillage in scenarios: C2000(a), C2030(b) and C2050(c).







Results

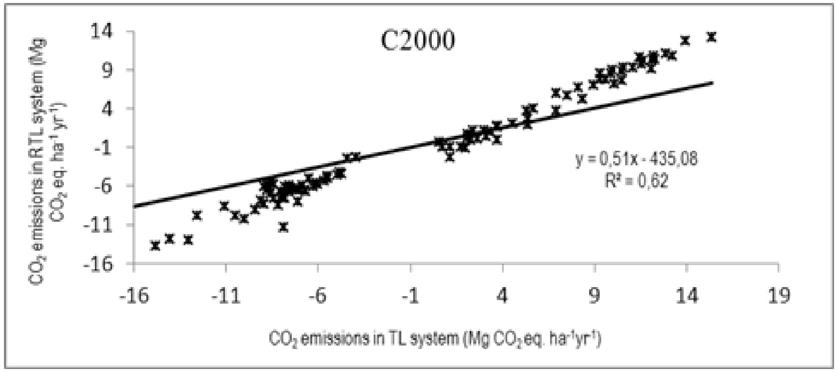
Estimated average annual CH_4 (kg C ha^{-1}) uptake in 4-year cropping systems for different climate scenarios and management practices

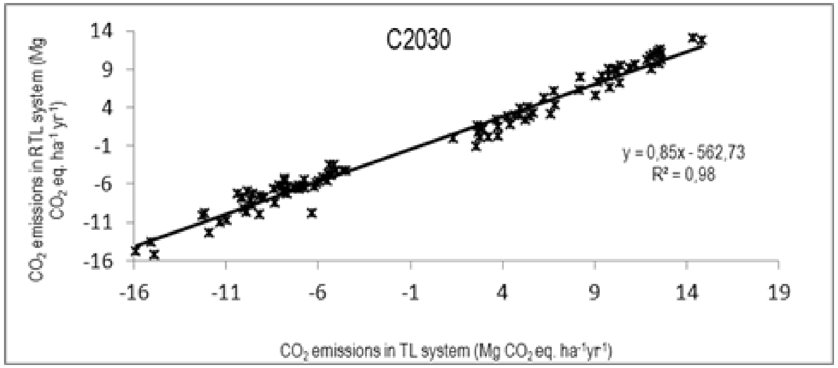
	Corn		Rapeseed		Spring wheat		Winter wheat	
Scenario	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage
C2000	-0.73±0.04e	-0.81±0.06cd	-0.73±0.04e	-0.82±0.07cd	-0.71±0.05c	-0.8±0.07b	-0.73±0.05e	-0.82±0.07cd
C2030	-0.78±0.04 d	-0.87±0.06b	-0.78±0.04d	-0.88±0.06b	-0.76±0.05bc	-0.86±0.07a	-0.78±0.05d	-0.87±0.07b
C2050	-0.83±0.04 bc	-0.93±0.06 a	-0.82±0.04c	-0.93±0.06a	-0.81±0.05b	-0.91±0.08a	-0.83±0.05 bc	-0.93±0.07a

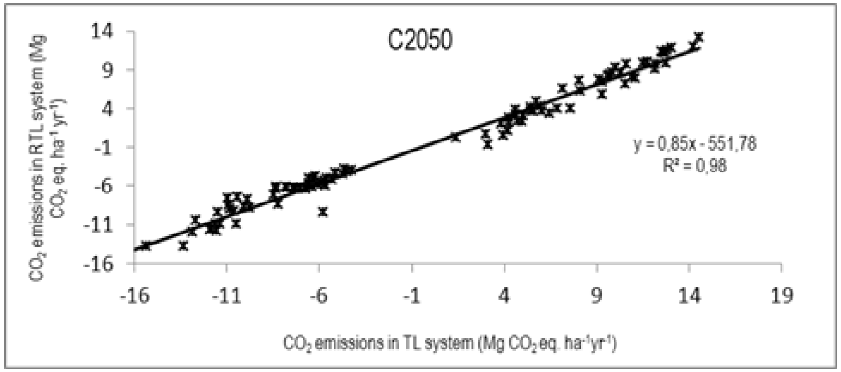
*Within each column crop, scenario and management practices followed by the same letter are not significantly different at $P<0.05$ (Tukey HSD test)

Results

Comparison of CO_2 emissions between tillage and reduced tillage in scenarios: C2000(a), C2030(b) and C2050(c)







Results

Estimated average annual CO_2 (kg C ha^{-1}) emissions in 4-year cropping systems for different climate scenarios and management practices

	Corn		Rapeseed		Spring wheat		Winter wheat	
Scenario	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage
C2000	933±937abc	286±956c	-2447±713abc	-2022±804a	2824±795a	2704±827a	-1868±328b	-1725±314ab
C2030	1321±921ab	673±941bc	-2781±703bc	-2440±837ab	2786±8425a	2349±866a	-1807±344b	-1642±307ab
C2050	1551±949a	905±961abc	-3054±689c	-2704±827bc	2783±847a	2363±860a	-1721±324ab	-1541±285a

*Within each column crop, scenario and management practices followed by the same letter are not significantly different at P<0.05 (Tukey HSD test)

Results

Estimated average annual biomass crop (kg C ha^{-1}) in 4-year cropping systems for different climate scenarios and management practices

	Corn		Rapeseed		Spring wheat		Winter wheat	
Scenario	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage	Tillage	Reduced tillage
C2000	7249±988a	7249±988a	6125±710ab	5929±649a	5000±749bcd	4378±551a	4686±709a	4541±681a
C2030	7049±960a	7049±960a	6407±667ab	6137±593ab	5151±747cd	4542±563ab	4564±744a	4375±660a
C2050	6925±921a	6925±921a	6583±633b	6247±549ab	5278±740d	4678±571abc	4383±699a	4161±604a

*Within each column crop, scenario and management practices followed by the same letter are not significantly different at $P<0.05$ (Tukey HSD test)

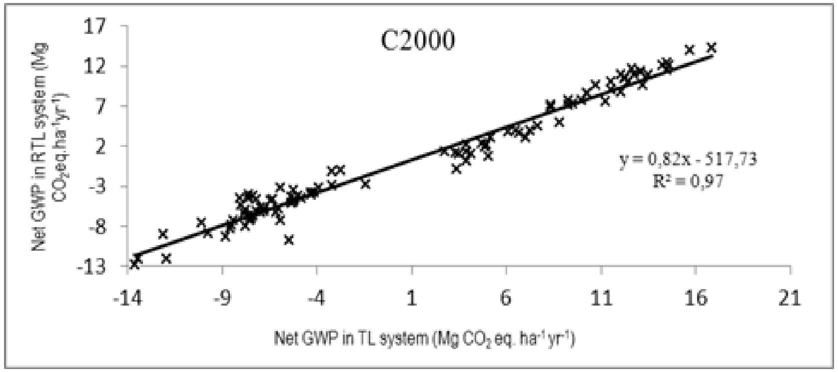
Results

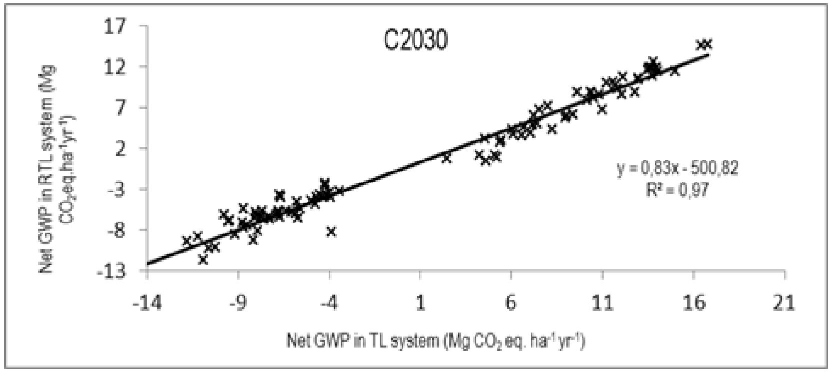
Estimated net Global Warming Potential (GWP) for 4 year complete crop rotation cycle for different climate scenarios and management practices

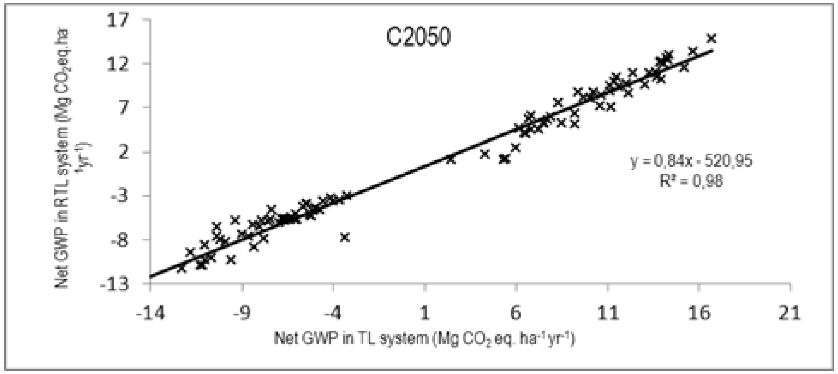
GWP (kg CO_2 eq. $ha^{-1}yr^{-1}$)		
Scenario	Tillage	Reduced tillage
C2000	954±8758	265±7315
C2030	936±9282	273±7806
C2050	909±9698	237±8187

Results

Comparison of GWP between tillage and reduced tillage in scenarios: C2000(a), C2030(b) and C2050(c)







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Conclusions:

1. Emissions of N_2O, CH_4 and CO_2 were affected by all assumed climate scenarios and managements tillage practices.
2. The use of reduced tillage has decreased the N_2O emissions by 21% in the C2000 scenario, 18% in the C2030 scenario, and 20% in the C2050 scenario. Increase of temperature and decrease of precipitation has reduced N_2O emissions in both conventional and conservative systems by 6% (C2030 scenario) and by 12% (C2050 scenario).
3. The highest carbon accumulation rates were found in conservation tillage. The differences were 49% in C2000 scenario, 25% in C2030 and C2050 compared to the tillage system.
4. An increase of temperature and decrease of precipitation can reduce GWP by 2% in the 2030 climate scenario, and by 5% in the 2050 scenario in conventional tillage with reference to baseline scenario. In the case of conservation tillage, a reduction of GWP by 5% and by 10% was estimated, respectively.
5. Reduced tillage has negative effect on corn and winter wheat biomass crop. Therefore, in the future, more land area could be required for crops to maintain production at the same level.

Thank you for your attention

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