

Supplementary materials for manuscript entitled: Methane Emissions Associated with the Conversion of Marshland to Cropland and Climate Change on the Sanjiang Plain of Northeast China from 1950 to 2100

Authors: Tingting Li, Yao Huang, Wen Zhang, Yongqiang Yu

Supplementary material A: Information of the counties and administrative farms on the Sanjiang Plain.

The Sanjiang Plain of northeast China covers 23 counties: Baoqing, Boli, Fujin, Fuyuan, Hegang, Huachuan, Huanan, Hulin, Jiamusi, Jidong, Jixi, Jixian, Luobei, Mishan, Muling, Qitaihe, Raohe, Shuangyashan, Suibin, Tangyuan, Tongjiang, Yilan and Youyi counties as well as three administrative farms: Baoquanling, Hongxinglong, and Jiansanjiang administrative farms (Fig. 1). The Baoquanling and Hongxinglong administrative farms were founded in 1949 and are located on the northwest and central parts of the Sanjiang Plain, respectively. The Jiansanjiang administrative farm was founded in 1956 and is located on the northeast part of the area.

During the 1950s and 1960s, the administrative divisions in some counties changed. These changes included: Jixi and Jidong counties; Jixian, Shuangyashan and Youyi counties; Huanan, Huachuan and Qitaihe counties; Fujin, Fuyuan, Suibin and Tongjiang counties. To isolate the influence of administrative division change in the area or CH₄ emission, the related counties were grouped together when analyzing the change in the area or CH₄ emission of marshland/rice paddies.

Supplementary material B: Parameter values for the main kinds of marshland in the Sanjiang Plain

Table B1 Parameter values for *Deyeuxia angustifolia* and *Carex lasiocarpa* marshland sites

Marshland Type	α_0	a_1	a_2	D ₁ (cm)	D ₂ (cm)
<i>Deyeuxia angustifolia</i>	1.1	0.012	0.02	0	-15
<i>Carex lasiocarpa</i>	1.25	0.011	0.005	0	-15

Supplementary material C: Description of the RCP scenarios for AR5

A set of new scenarios referred as “Representative Concentration Pathways (RCPs)” were identified for the fifth IPCC assessment report (AR5) (Moss et al., 2008). Four RCP scenarios have been derived from integrated assessment models (IAM) (Bernie, 2010). RCP 8.5 is a “high pathway” for which radiative forcing reaches $>8.5 \text{ W m}^{-2}$ by 2100 and continues to rise for some amount of time. It has an approximate CO_2 equivalent concentration of 1370 ppm in 2100. RCP 6.0 and RCP 4.5 are two intermediate “stabilization pathways” in which radiative forcing is stabilized at approximately 6 W m^{-2} and 4.5 W m^{-2} after 2100. The approximate CO_2 equivalent concentrations are 850 ppm and 650 ppm, representatively. RCP 2.6 is a pathway where radiative forcing peaks at approximately 3 W m^{-2} before 2100 and then declines 2.6 W m^{-2} in 2100. The peak approximate CO_2 equivalent concentration reaches 490 ppm before 2100 under RCP 2.6. These scenarios include time paths for emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. Those scenarios were reported in the IPCC expert meeting report (Moss et al., 2008) (<http://www.ipcc.ch/ipccreports/supporting-material.htm>).

Supplementary material D: The spatial pattern of the area variation in marshland and irrigated rice due to the conversion of marshland to cropland.

Table D1 shows the change of the marshland area and irrigated rice cultivation area for a county or at the scale of an administrative farm due to the conversion of marshland to cropland from 1960s-2000s relative to the 1950s. During this period, the marshland area decreased by 1031.9×10^3 ha in the 23 counties, and 1150.0×10^3 ha in the 3 administrative farms relative to the 1950s.

Among the counties, the conversion of marshland to cropland mainly happened on the northeast and east of the Sanjiang Plain (Table D1). The marshland loss amounted to 375.4×10^3 ha in the northeast counties, including Fujin, Fuyuan, Raohe, Suibin and Tongjiang over the past 6 decades, accounting for ~36% of the 23 counties. Marshland in Baoqing and Hulin counties, which are located in the eastern part of the area decreased by 87.9×10^3 ha and 74.8×10^3 ha, respectively, occupying 16% of the total marshland area lost in the 23 counties. Among the administrative farms, marshland loss amounted to 293.1×10^3 , 384.2×10^3 , and 472.7×10^3 ha, on Baoquanling, Hongxinglong and Jiansanjiang administrative farm, respectively, accounting for 13.4%, 17.6% and 21.7% of the total decrease in marshland area from 1960s-2000s relative to the 1950s, respectively.

The irrigated rice area mainly increased on the administrative farms; they accounted for 61% of the total increase in irrigated rice area on the Sanjiang Plain over the past 6 decades. The increases were 95.3×10^3 ha, 145.7×10^3 ha and 292.7×10^3 ha on Baoquanling, Hongxinglong and Jiansanjiang administrative farms, respectively (Table D1).

Table D1 Change of marshland and irrigated rice area (1000 ha yr⁻¹) for a county or an administrative farm due to the conversion of marshland to cropland on the Sanjiang Plain

County (Farm)	1960s		1970s		1980s		1990s		2000s	
	Marsh	Rice	Marsh	Rice	Marsh	Rice	Marsh	Rice	Marsh	Rice
Baoqing	-43.9	-0.7	-21.8	-0.9	-32.6	2.4	-37.6	7.5	-87.9	11.4
Boli	-5.9	-2.8	13.8	-2.4	10.6	-2.4	9.5	-1.5	-6.2	-1.5
Fujin	-269.6	-0.6	-293.4	-0.4	-341.9	3.7	-355.6	19.7	-413.9	33.8
Fuyuan	96.9	-0.1	-28.4	-0.1	-45.2	0.3	-54.3	1.7	-100.8	5.8
Hegang	11.7	1.3	34.9	0.4	28.8	4.3	28.7	14.4	19.9	20.6
Huachuan	42.3	-1.2	20.6	-2.4	20.5	9.2	13.7	16.5	-13.3	35.1
Huanan	-63.6	1.4	-55.6	2.3	-66.7	7.6	-76.9	14.9	-88.4	22.4
Hulin	-21.0	-1.9	-4.5	-2.1	-22.0	3.5	-29.0	15.8	-74.8	43.6
Jiamusi	-63.7	3.0	-64.6	0.7	-64.9	1.4	-65.3	8.2	-65.6	21.9
Jidong	3.5	3.2	16.6	7.6	15.1	10.0	11.5	16.3	0.2	26.7
Jixi	-11.0	0.3	-14.3	0.1	-16.6	0.0	-16.6	0.7	-20.3	2.7
Jixian	-88.2	-2.1	-80.6	-1.3	-97.2	-6.0	-116.0	1.0	-135.4	3.6
Luobei	-40.8	-0.2	-2.7	-0.2	-13.4	2.5	-16.3	8.3	-33.6	8.2
Mishan	-21.2	-7.3	0.7	-7.5	-10.9	-1.5	-13.2	3.1	-49.0	19.4
Muling	0.2	-0.4	-3.9	-0.3	-9.1	0.0	-15.7	0.9	-41.7	0.9
Qitaihe	8.7	0.1	14.7	0.2	11.1	3.0	6.9	5.1	1.7	6.3
Raohe	-13.4	-0.5	-9.3	-0.5	-22.2	1.4	-26.7	4.1	-55.4	6.2
Shuangyashan	30.7	1.2	3.7	0.1	1.5	0.1	-1.6	0.3	-5.7	0.6
Suibin	15.2	0.4	43.0	5.2	29.6	5.2	31.1	7.5	23.4	16.1
Tangyuan	-11.3	2.7	4.1	-1.2	2.8	5.9	5.9	7.2	-12.2	15.4
Tongjiang	125.6	0.0	244.8	0.2	209.6	1.7	207.4	4.7	171.3	14.9
Yilan	-7.8	-2.1	1.3	-1.3	-9.3	0.9	-13.6	13.0	-44.2	20.5
Youyi	34.7	0.6	46.1	0.8	26.6	0.9	0.0	0.0	0.0	0.0
(Baoquanling)	-150.6	3.6	-238.1	1.5	-293.1	6.5	-293.1	43.6	-293.1	95.3
(Hongxinglong)	-142.1	1.8	-234.7	1.7	-324.4	7.4	-358.6	64.3	-384.2	145.7
(Jiansanjiang)	-29.0	0.0	-171.3	-0.1	-280.9	5.9	-361.2	76.9	-472.7	292.7
Total (Mha)	-0.61	0.00	-0.78	0.00	-1.29	0.07	-1.54	0.35	-2.18	0.87

* relative to the average 1950s

Supplementary material E: The spatial pattern of the CH₄ variation from the marshland and irrigated rice cultivation due to the conversion of marshland to cropland.

Based on CH₄MOD_{wetland} and CH₄MOD, Table E1 gives an overview of the CH₄ variation from 1960s-2000s relative to 1950s for a county or at the scale of an administrative farm due to the conversion of marshland to cropland.

For the marshland, the reductions in mean annual amount of CH₄ emissions during the past 6 decades were 166.5×10^3 t, 218.4×10^3 t and 323.0×10^3 t due to the conversion of marshland to cropland on the Baoquanling, Hongxinglong and Jiansanjiang administrative farms, respectively (Table E1). Among the 23 counties, the northeastern and central counties were the main contributors of CH₄ reduction from the marshland (Table E1). The mean annual amount of CH₄ emissions decreased at a rate of 275.9×10^3 t yr⁻¹ in Fujin, Fuyuan, Suibin and Tongjiang counties, followed by 80.0×10^3 t yr⁻¹ in Jixian, Shuangyashan and Youyi counties, 59.2×10^3 t yr⁻¹ in Huanan, Huachuan and Qitaihe counties, and 47.0×10^3 t yr⁻¹ in Baoqing county during the past 6 decades.

From the rice paddies, the mean annual amount of CH₄ emissions increased by 28.2×10^3 t, 35.6×10^3 t and 66.0×10^3 t on the Baoquanling, Hongxinglong and Jiansanjiang administrative farms, respectively, from the 1950s to the 2000s (Table E1). A higher increase in the mean annual amount of CH₄ emissions, over 10000 t during the past 6 decades, occurred in the four northeastern counties (Fujin, Fuyuan, Suibin and Tongjiang counties) and in the three western counties (Huachuan, Huanan and Qitaihe counties) (Table E1). The temporal trend in CH₄ emissions for each county/farm was similar to the whole region (Fig. 5c), which has shown a rapid increase since the 1980s (Table E1).

Table E1 CH₄ variation (1000 t yr⁻¹) from marshland and rice fields for a county or an administrative farm due to the conversion of marshland to cropland and climate change on the Sanjiang Plain

County (Farm)	1960s		1970s		1980s		1990s		2000s	
	Marsh	Rice	Marsh	Rice	Marsh	Rice	Marsh	Rice	Marsh	Rice
Baoqing	-27.3	-0.07	-18.3	-0.06	-23.6	0.43	-21.5	1.70	-47.0	3.28
Boli	-3.0	-0.33	5.3	-0.19	6.2	0.04	6.8	1.34	-4.2	3.08
Fujin	-151.8	-0.05	-197.0	-0.01	-185.1	0.63	-176.4	3.69	-243.0	7.38
Fuyuan	41.6	0.00	-61.1	0.00	-32.3	0.03	-17.8	0.27	-85.2	1.28
Hegang	6.9	0.12	18.2	0.06	18.8	0.63	21.1	3.00	14.3	6.08
Huachuan	19.9	-0.26	-3.2	0.03	8.1	1.08	12.6	3.95	-11.6	9.23
Huanan	-34.6	0.12	-33.2	0.26	-36.2	0.97	-40.8	2.45	-48.3	5.18
Hulin	-11.1	-0.16	-6.7	-0.16	-1.2	0.54	13.6	3.11	-22.6	9.65
Jiamusi	-35.3	0.24	-36.2	0.10	-36.2	0.23	-36.4	1.65	-36.5	5.62
Jidong	1.8	0.32	6.3	1.05	9.5	1.52	7.3	3.30	0.1	7.25
Jixi	-5.6	0.06	-7.9	0.22	-7.5	0.32	-7.8	0.58	-10.2	1.23
Jixian	-51.9	-0.12	-56.6	-0.23	-57.3	-0.06	-64.4	1.50	-77.6	2.80
Luobei	-22.9	-0.05	-5.4	-0.02	-2.1	0.42	1.6	1.59	-12.3	2.27
Mishan	-11.5	-0.65	-1.4	-0.49	-3.0	0.62	1.4	2.17	-24.6	6.10
Muling	-0.8	-0.02	-6.5	0.08	0.3	0.33	-3.9	0.59	-20.3	0.70
Qitaihe	3.4	0.01	7.3	0.03	5.6	0.50	3.7	1.00	0.8	1.70
Raohe	-9.8	-0.05	-17.7	-0.04	-12.9	0.14	-10.0	0.90	-35.8	1.60
Shuangyashan	19.8	0.14	2.7	0.02	1.3	0.02	0.3	0.08	-2.3	0.19
Suibin	8.0	0.00	18.2	0.05	16.3	0.75	18.7	1.27	10.5	3.85
Tangyuan	-6.9	0.25	-5.0	0.07	0.4	1.51	7.0	2.66	-9.3	5.91
Tongjiang	59.3	0.00	105.1	0.02	113.5	0.18	125.1	0.81	77.5	3.35
Yilan	-2.7	-0.18	-2.7	-0.04	-2.0	0.45	-1.8	2.94	-25.4	5.79
Youyi	17.0	0.06	23.2	0.10	14.1	0.11	0.0	0.00	0.0	0.00
(Baoquanling)	-86.3	0.35	-135.0	0.38	-166.5	1.56	-166.5	10.63	-166.5	28.16
(Hongxinglong)	-84.5	0.14	-164.4	0.21	-178.1	1.14	-186.6	12.62	-218.4	35.59
(Jiansanjiang)	-46.7	0.00	-215.1	0.00	-158.7	0.89	-155.8	14.78	-323.0	65.96
Total (Tg yr ⁻¹)	-0.41	0.00	-0.79	0.00	-0.71	0.01	-0.67	0.08	-1.32	0.22

* relative to the average 1950s

Supplementary material F: Projected change in climate and CH₄ flux on the Sanjiang Plain for the RCP scenarios

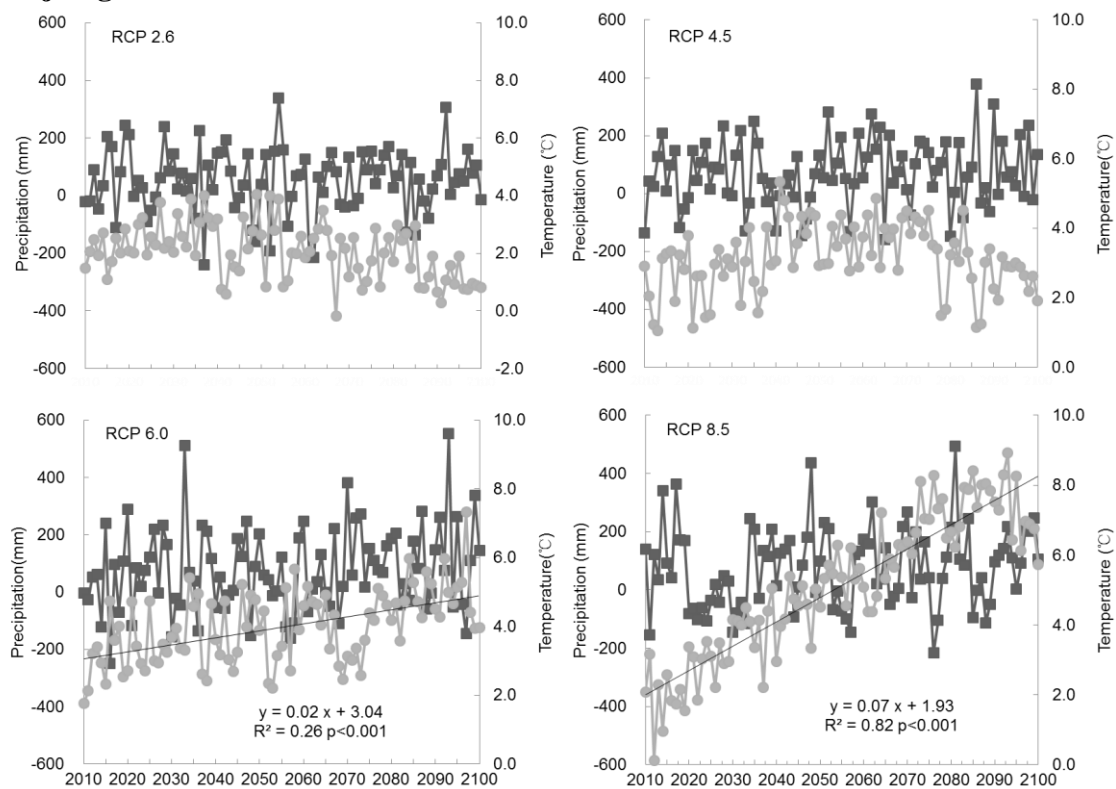


Figure F1 Projected climate change by FGOALS on the Sanjiang Plain for the RCP scenarios. The squares and the circles represent the area-weighted annual mean precipitation and the air temperature relative to the average 1961-1990, respectively.

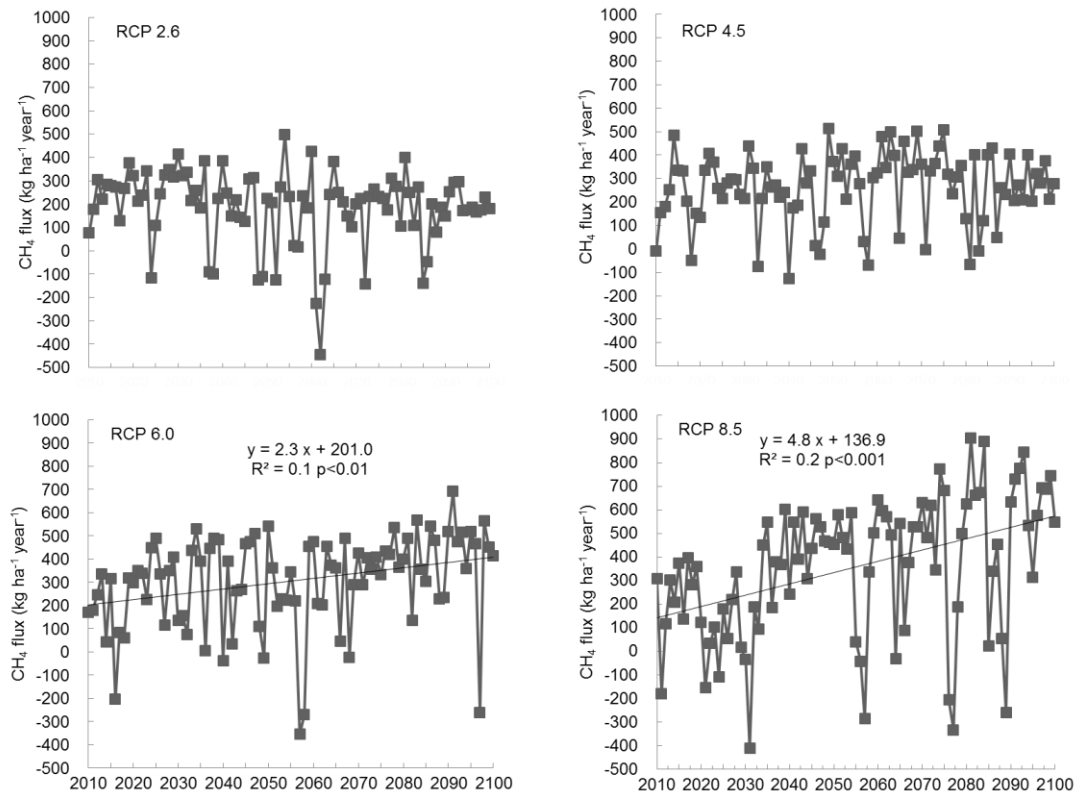


Figure F2 Projected change in CH₄ flux relative to 1961-1990 on the Sanjiang Plain for the RCP scenarios.

Reference

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