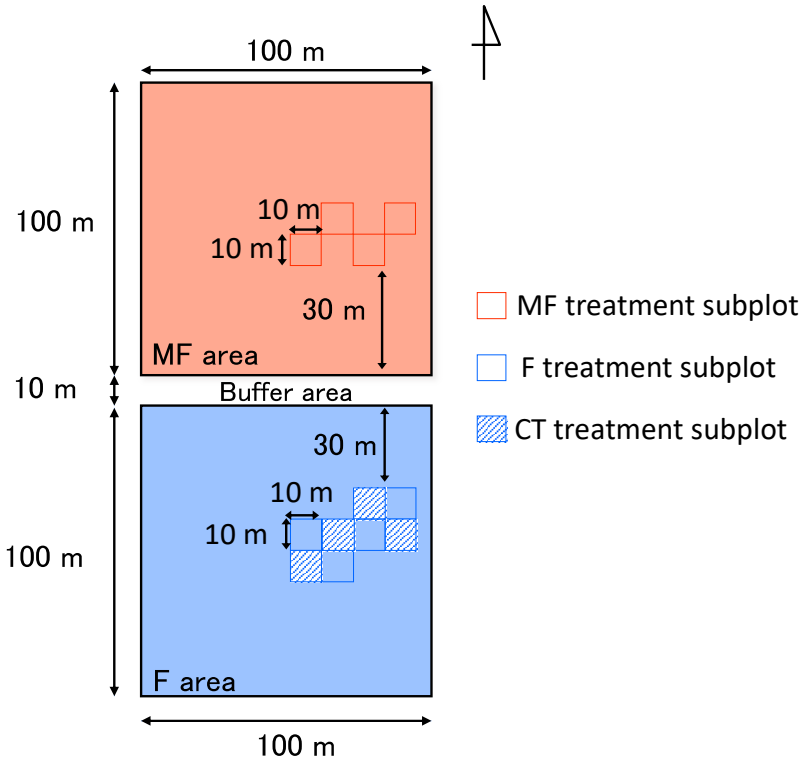

Figure S1 Layout of the treatment subplots in the field sampling. The gas, water, soil samples were taken around the center of each subplot. F area had been managed with only chemical fertilizer, and MF area had been managed with combined application of chemical fertilizer and beef cattle manure. These nutrient management were kept for 8 years before this study since 2005 and it continued during this study until 2016.

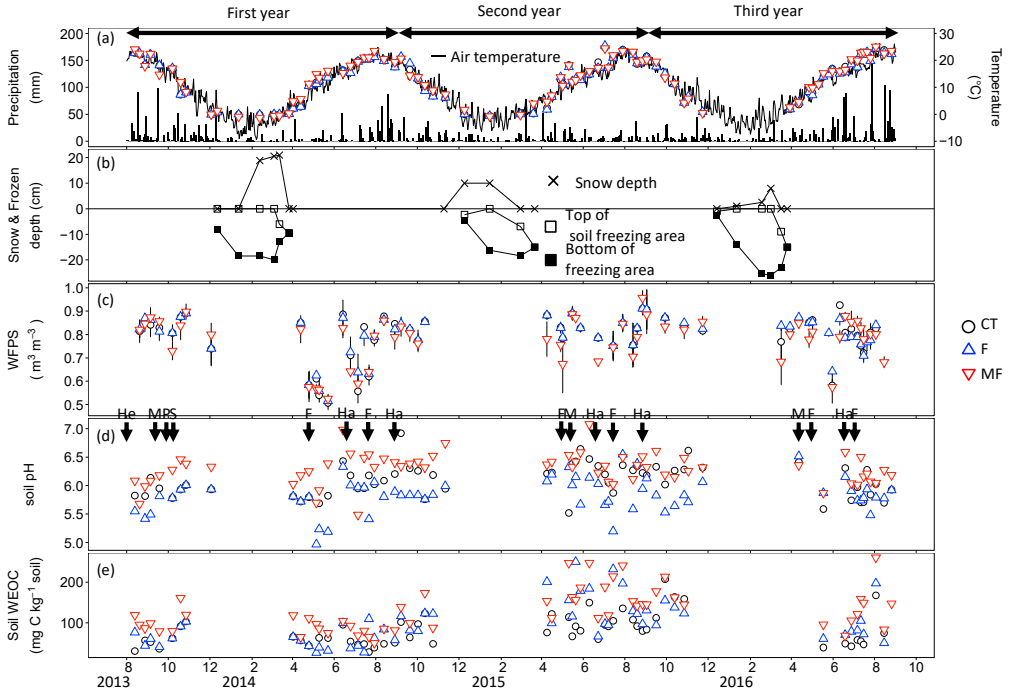

Figure S2 Daily change of precipitation, air and soil temperature depth (**a**), snow and soil freezing depth (**b**), water-filled pore space (WFPS) (**c**), soil pH (**d**), soil water extractable organic carbon (WEOC) concentration (**e**). Error bar show standard deviation. CT is unfertilized control plots (○); F is chemical fertilizer plots (△); MF is combined manure and chemical fertilizer plots (▽). Black allows for letters indicates the timing of management as He: Herbicide application, P: Plowing, S: Seeding, F: Chemical fertilizer application, M: Manure application, Ha: Harvest.

Table S1 Seasonal cumulative N_2O emission and NO_3^--N leaching and their contribution to annual cumulative value (%).

Variety		N_2O Emission (kg N_2O–N ha^{-1})						Nitrate Nitrogen Leaching (kg NO_3^-–N ha^{-1} $year^{-1}$)					
		CT		F		MF		CT		F		MF	
First year	Renovation	3.77	(57.9%)	4.35	(54.5%)	10.58	(80.7%)	2.03	(31.2%)	2.03	(31.2%)	10.81	(62.6%)
	G3	0.25	(3.9%)	0.25	(3.2%)	0.19	(1.5%)	1.59	(24.4%)	1.59	(24.4%)	2.77	(16.0%)
	Winter	0.04	(0.7%)	0.04	(0.5%)	-0.10	-(0.8%)	0.00	(0.0%)	0.00	(0.0%)	0.00	(0.0%)
	Thawing	1.67	(25.6%)	1.67	(20.9%)	0.86	(6.6%)	2.86	(43.8%)	2.86	(43.8%)	3.49	(20.2%)
	G1	0.83	(12.7%)	0.50	(6.3%)	1.54	(11.8%)	0.02	(0.3%)	0.02	(0.3%)	0.17	(1.0%)
	G2	–0.05	(–0.7%)	1.17	(14.6%)	0.04	(0.3%)	0.02	(0.3%)	0.02	(0.3%)	0.02	(0.1%)
Second year	G3	0.21	(21.3%)	0.49	(21.5%)	0.25	(9.8%)	0.00	(1.1%)	0.00	(1.1%)	0.00	(0.0%)
	Winter	0.04	(3.6%)	–0.17	(–7.3%)	0.52	(20.7%)	0.00	(0.0%)	0.00	(0.0%)	0.00	(0.0%)
	Thawing	0.21	(21.3%)	0.76	(33.2%)	0.13	(5.1%)	0.15	(86.7%)	0.15	(86.7%)	0.16	(31.5%)
	G1	0.33	(32.7%)	0.35	(15.4%)	0.90	(35.7%)	0.00	(0.0%)	0.00	(0.0%)	0.02	(3.3%)
	G2	0.21	(21.1%)	0.85	(37.2%)	0.72	(28.7%)	0.02	(12.2%)	0.02	(12.2%)	0.33	(65.2%)
Third year	G3	0.54	(9.3%)	0.49	(3.6%)	0.47	(13.6%)	0.00	(0.0%)	0.00	(0.0%)	0.00	(0.0%)
	Winter	1.57	(27.0%)	1.35	(10.0%)	0.28	(7.9%)	0.00	(0.0%)	0.00	(0.0%)	0.00	(0.0%)
	Thawing	0.58	(9.9%)	0.33	(2.5%)	0.52	(14.9%)	0.27	(24.8%)	0.27	(24.8%)	0.09	(4.0%)
	G1	2.68	(46.0%)	2.51	(18.5%)	0.83	(23.8%)	0.74	(67.6%)	0.74	(67.6%)	0.41	(18.0%)
	G2	0.45	(7.7%)	8.88	(65.5%)	1.39	(39.8%)	0.08	(7.6%)	0.08	(7.6%)	1.77	(78.1%)

The definition of each season:.Renovation: The period from when the herbicide was applied (13 August) to the first sampling date after re-seeding (7 October) The crop growing season is the period of time with 7 days moving average of daily air temperature above 5℃. And the growing season was divided into 3 periods as below. G1: The period from the beginning of the growing season to the first crop harvest. G2: The period from the first harvest to the second harvest G3: The period from the second harvest to the end of the growing season. The non-growing season was divided into 2 periods as winter and thawing period. Winter: The period from the end of G3 to the end of February when maximum temperatures recorded reached 0 °C. Thawing: The period from when minimum daily temperatures reached 0 °C, to the time when soils were completely melted (minimum soil temperatures ~5 °C).

Table S2 Annual heterotrophic respiration (RH) in unfertilized control treatment (CT), chemical fertilizer treatment (F) and combined manure and chemical fertilizer treatment (MF). Values are mean ± standard deviation. Values with the same letters are not significantly different ($p < 0.05$).

Treatment	RH (Mg C ha^{-1} $year^{-1}$)		
	First Year (2013–2014)	Second Year (2014–2015)	Third Year (2015–2016)
CT	5.56 ± 0.76 cde	4.65 ± 0.63 e	7.21 ± 0.77 abc
F	5.79 ± 0.67 bcde	5.03 ± 0.42 de	7.62 ± 1.41 ab
MF	8.55 ± 0.56 a	6.69 ± 0.98 bcd	8.84 ± 0.37 ab
ANOVA	df	F value	p-value
Treatment (T)	2	28.2	< 0.001
Year (Y)	2	26	< 0.001
T × Y	4	1.15	0.36