Table S1. Weather data during the cropping period of spring barley from 1990 to 2020 recorded at the Normandin and the Saint-Prime weather station of Environment Canada, the closest of the studied field experiment.

Year	**Precipitations** [mm]		**Mean temperature** [°C]		**GDD*** [°C-d]	**Sum Radiation** [MJ m^{-2}]
	From early May to harvest	**Annual**	**From sowing to harvest**	**Annual**	**From sowing to harvest**	
1990	338	858	15.8	3.0	1641	1912
1991	245	717	17.0	2.6	1597	1931
1992	402	839	14.9	1.5	1699	1944
1993	387	867	17.0	1.9	1715	1845
1994	371	814	16.1	2.1	1639	1960
1995	230	790	18.4	2.9	1492	1866
1996	379	1134	16.4	2.9	1607	1921
1997	315	733	15.4	1.9	1744	2067
1998	310	732	15.4	3.4	1775	2166
1999	371	875	15.7	2.7	1510	1840
2000	260	702	14.4	1.5	1456	1840
2001	325	832	16.1	2.6	1605	1828
2002	263	779	15.8	0.9	1553	1928
2003	262	805	16.1	1.3	1597	1819
2004	311	785	14.3	0.1	1497	1804
2005	176	702	16.3	2.0	1431	1821
2006	297	1033	16.0	2.8	1555	1839
2007	292	697	14.3	1.4	1635	2259
2008	324	800	15.5	1.2	1438	1543
2009	311	683	14.8	1.2	1674	2008
2010	179	758	16.4	3.8	1550	1891
2011	402	890	16.4	2.4	1540	1859
2012	298	804	16.4	3.1	1609	1989
2013	296	965	16.1	1.9	1463	1813
2014	340	982	16.9	1.4	1610	1895
2015	349	958	16.0	1.7	1644	1910
2016	417	1291	16.3	2.0	1598	1854
2017	498	1117	14.9	1.6	1687	2157
2018	269	843	17.4	1.6	1722	1962
2019	249	742	15.8	0.7	1591	1980
2020	355	838	18.1	2.8	1663	1823
Average	317	850	16.0	2.0	1598	1912

*Sum of growing degree-days on 0°C basis

Table S2. Key cropping practices (date of N application, seeding, harvest, and soil tillage) and measurements at harvest of the 'Chapais' (1990-2014) and 'Alyssa' (2015-2020) spring barley cultivars.

Year	Fertilization date	Seeding date	Harvest date	Fall tillage date	N total LDM [kg N ha^{-1}]
1990	8/05	9/05	20/08	21/09	73
1991	20/05	21/05	22/08	16/10	121
1992	23/05	25/05	15/09	15/10	79
1993	30/05	30/05	7/09	13/10	90
1994	20/05	20/05	29/08	27/09	89
1995	26/05	26/05	14/08	28/09	77
1996	17/05	17/05	22/08	25/09	75
1997	15/05	15/05	4/09	25/09	110
1998	11/05	12/05	3/09	25/09	79
1999	16/05	17/05	20/08	25/09	79
2000	23/05	23/05	31/08	25/09	110
2001	22/05	23/05	30/08	25/09	141
2002	28/05	29/05	3/09	25/09	105
2003	26/05	27/05	2/09	17/09	115
2004	27/05	27/05	8/09	22/10	105
2005	19/05	20/05	15/08	20/09	120
2006	19/05	19/05	23/08	12/09	120
2007	14/05	14/05	4/09	24/09	142
2008	19/05	20/05	20/08	18/09	75
2009	21/05	21/05	10/09	24/09	153
2010	20/05	21/05	23/08	4/10	87
2011	25/05	25/05	26/08	28/09	103
2012	14/05	15/05	20/08	27/09	134
2013	27/05	28/05	26/08	16/10	138
2014	27/05	27/05	29/08	15/10	123
2015	21/05	22/05	1/09	28/09	134
2016	26/05	26/05	31/08	5/10	84
2017	31/05	31/05	20/09	4/10	118
2018	28/05	29/05	4/09	1/10	138
2019	28/05	28/05	5/09	2/10	85
2020	22/05	25/05	24/08	24/09	110

Table S3. Performance of STICS with defaults parameters (Scarlett cultivar) and newly calibrated parameters to predict spring barley aboveground biomass (AGB), grain yield (GY), N concentration in AGB (NCAGB) and in grain (NCG), plant shoot N uptake (NU) and N amount in grain (NAG).

Variables	n	Mean Obs	Mean Pred	NME (%)	NRMSE (%)	EF
With defaults parameters (Scarlett cultivar)						
AGB (Mg DM ha^{-1})	28	4.5(0.8)	6.4(1.0)	-42	50	-7.9
GY (Mg DM ha^{-1})	28	2.8(0.6)	2.4(0.7)	16	29	-0.8
NCAGB (g kg^{-1} DM)	28	16(2)	9(1)	47	48	-14.4
NCG (g kg^{-1} DM)	28	19(3)	12(2)	38	41	-7.2
NU (kg N ha^{-1})	28	71.8(9.3)	55.2(12.3)	23	32	-5.2
NAG (kg N ha^{-1})	28	54.3(9.1)	44.2(16.3)	19	39	-4.7
With newly calibrated parameters (Chapais cultivar)						
AGB (Mg DM ha^{-1})	28	4.5(0.8)	4.4(0.3)	3	14	0.3
GY (Mg DM ha^{-1})	28	2.8(0.6)	2.8(0.2)	0	16	0.4
NCAGB (g kg^{-1} DM)	28	16(2)	16(2)	0	6	0.8
NCG (g kg^{-1} DM)	28	19(3)	20(2)	-4	9	0.6
NU (kg N ha^{-1})	28	71.8(9.3)	70.4(4.4)	2	13	0.0
NAG (kg N ha^{-1})	28	54.3(9.1)	56.1(3.5)	-3	17	-0.1

n: Number of predicted/observed data pairs, Mean Obs: mean of observed values, Mean Pred: mean of predicted values, NME; normalized mean error, NRMSE: normalized root mean square error, EF: model efficiency

Table S4. Mean of field-observed and STICS-predicted values for aboveground biomass (AGB), grain yield (GY), N concentration in aboveground biomass (NCAGB) and in grain (NCG), N uptake by plant (NU), and N amount in grain (NAG) as affected by N source type and tillage system. LDM: liquid dairy manure; MIN: ammonium nitrate; MP: moldboard plow; CP: chisel plow.

Source	AGB (Mg DM ha^{-1})	GY (Mg DM ha^{-1})	NCAGB (g kg^{-1} DM)	NCG (g kg^{-1} DM)	NU (kg N ha^{-1})	NAG (kg N ha^{-1})
Mean of field-observed values						
N source type						
MIN	4.7	3.0	16.1	19.8	73.2	57.1
LDM	3.9	2.4	16.6	20.2	62.0	45.7
Tillage system						
MP	4.3	2.8	16.6	20.1	67.2	52.2
CP	4.3	2.6	16.2	20.0	68.0	50.6
Mean of STICS-predicted values						
N source type						
MIN	4.5	2.9	16.1	19.8	72.1	57.4
LDM	4.1	2.6	16.9	20.8	69.8	55.6
Tillage system						
MP	4.3	2.8	16.5	20.3	71.2	56.7
CP	4.3	2.8	16.4	20.3	70.7	56.3

Figure S1. Aboveground biomass (AGB), grain yield (GY), N concentration in aboveground biomass (NCAGB), N uptake by plant (NU), and N amount in grain (NAG) as affected by N source type (a, b, c, d, e) or tillage system (f, g, h, i, j). Dots represent the means. Bars on dots are standard error of the mean (n=4). LDM: liquid dairy manure; MIN: ammonium nitrate; MP: moldboard plow; CP: chisel plow.

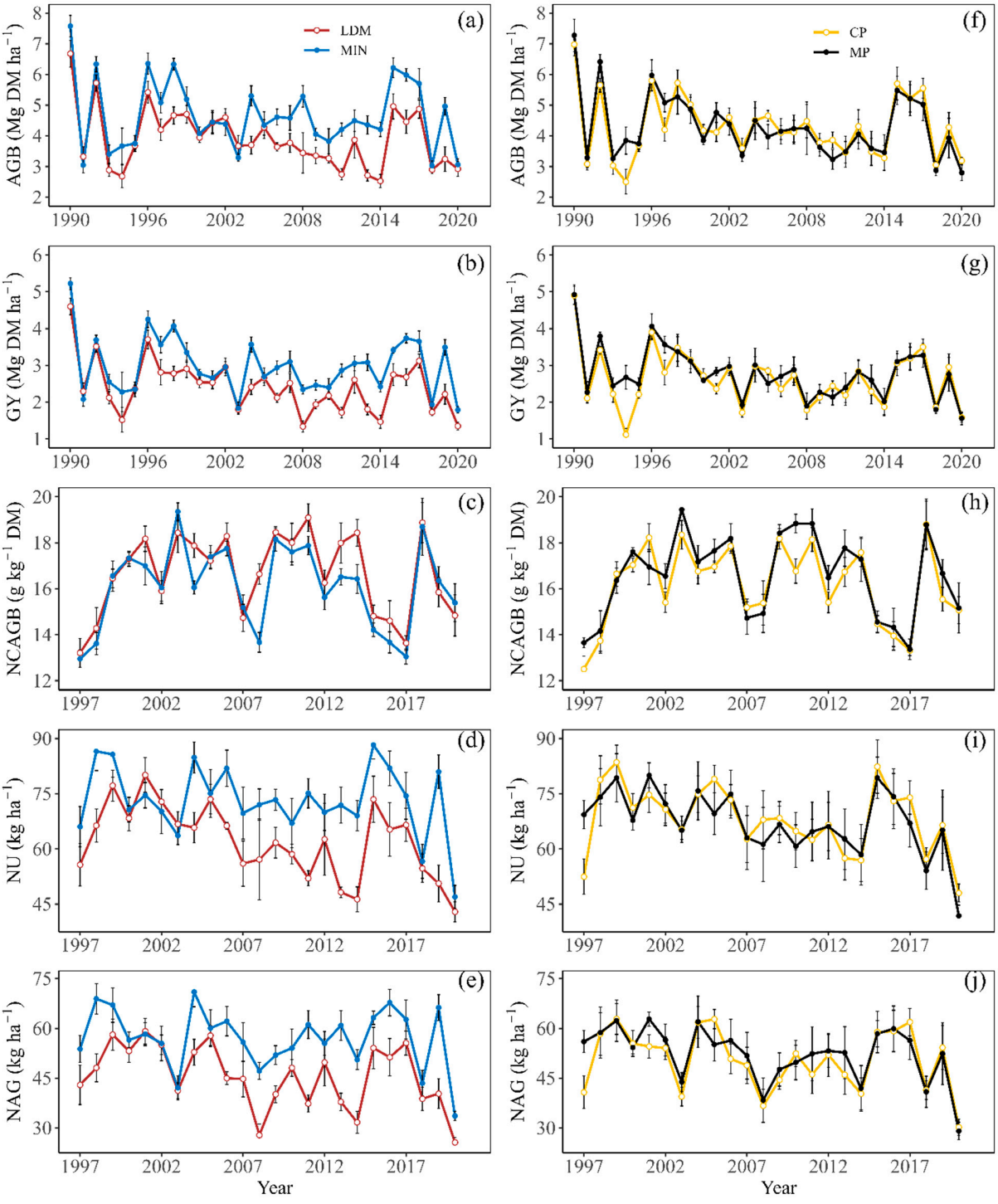

Figure S2. Scatterplots showing the trend in field-observed spring barley AGB and GY as a function of N source type (a, b), and tillage system (c, d) between 1993 and 2020. LDM: liquid dairy manure; MIN: ammonium nitrate.

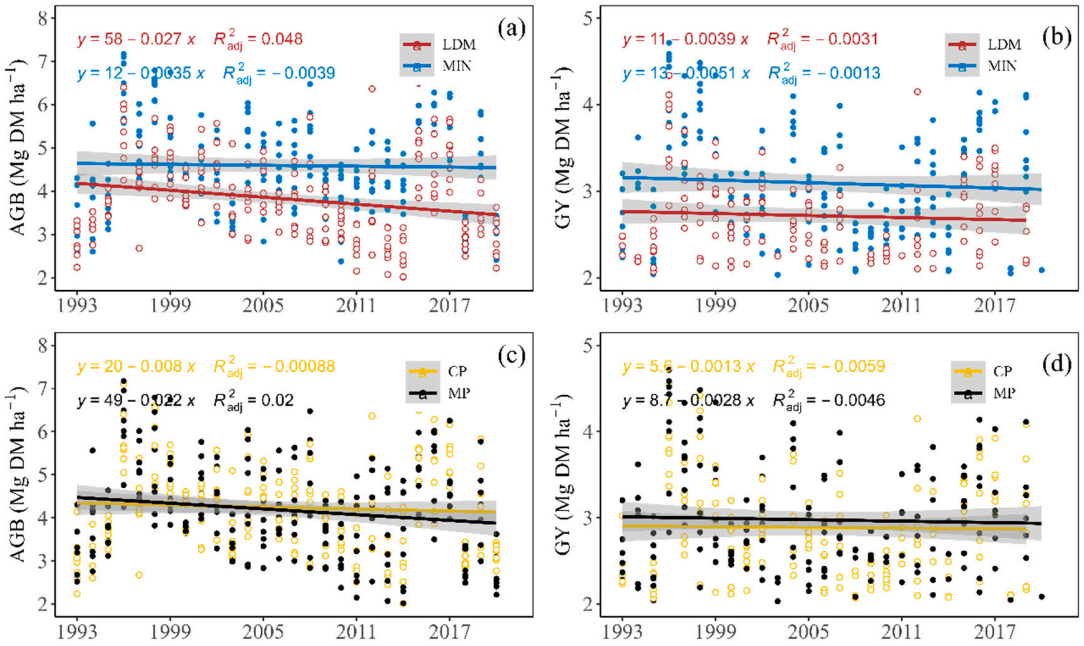

Figure S3. STICS-predicted soil mineral N content (kg ha^{-1}) down to 100 cm depth over 31 years according to management system. LDM: liquid dairy manure; MIN: ammonium nitrate; MP: moldboard plow; CP: chisel plow