Supplementary materials for the Chapter " Towards carbon neutrality : cost-effectiveness of targetting GHG emissions vs. carbon sequestration in agricultural sector"

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These supplementary materials contain the input data for the static inter-temporal model on the supply side of the chapter entitled "Towards carbon neutrality : cost-effectiveness of targetting GHG emissions vs. carbon sequestration in agricultural sector".

List of Tables

1 Farm groups

Farm group	Sub region	TF	ES	Sampled	Number represented	UAA (ha)	UAA total (ha)
1	Champagne	Cereals	1	27.20	1662.42	57.52	95617.58
2		Cereals	2	55.80	2267.69	132.64	300781.41
3		Cereals	3	8.40	363.26	292.86	106384.54
4		General cropping	1	9.60	459.39	42.85	19684.77
5		General cropping	2	44.40	1433.06	92.28	132240.34
6		General cropping	3	20.20	768.65	178.31	137054.14
7		Dairy cattle	1	5.80	137.22	60.16	8255.05
8		Dairy cattle	2	28.20	477.28	112.15	53525.09
9		Dairy cattle	3	6.60	167.82	215.51	36166.13
10		Rearing-fattening cattle	1	3.75	163.20	100.09	16333.92
11		Mixed livestock	1	5.20	65.35	84.37	5513.35
12		Mixed livestock	2	14.60	314.40	127.91	40214.31
13		Mixed livestock	3	4.40	143.49	230.81	33118.86
14		Mixed crop-livestock	2	14.80	780.93	134.97	105400.72
15		Mixed crop-livestock	3	23.20	635.75	288.45	183381.26
16	Lorraine	Cereals	1	8	906.60	82.84	75104.01
17		Cereals	2	37.80	1000.15	185.65	185677.25
18		Cereals	3	6.60	185.69	393.52	73073.32
19		Dairy cattle	1	7.60	378.55	59.41	22489.84
20		Dairy cattle	2	36.80	1264.87	115.29	145831.42
21		Dairy cattle	3	13.40	259.90	202.32	52583.15
22		Rearing-fattening cattle	1	8.80	527.32	74.49	39282.39
23		Rearing-fattening cattle	2	3.40	107.40	189.50	20351.96
24		Mixed livestock	2	18.80	476.71	133.89	63828.85
25		Mixed livestock	3	10	248.75	238.05	59214.64
26		Mixed crop-livestock	1	6.60	414.03	99.37	41140.34
27		Mixed crop-livestock	2	36.40	1037.88	161.05	167155.66
28		Mixed crop-livestock	3	24.80	556.85	297.17	165480.56
29	Alsace	Cereals	1	23.60	1560.15	39.80	62096.62

30	Cereals	2	17.80	427.76	96.51	41284.49
31	Cereals	3	2.40	34.10	191.13	6517.70
32	General cropping	1	4.80	178.33	32.44	5785.54
33	General cropping	2	12.40	190.29	52.17	9926.52
34	Dairy cattle	1	6	151.07	52.20	7885.23
35	Dairy cattle	2	23	303.58	77.18	23429.97
36	Dairy cattle	3	5.40	80.72	130.89	10565.19
37	Rearing-fattening cattle	1	2.40	77.93	70.72	5511.02
38	Mixed crop-livestock	1	8	382.46	40.97	15670
39	Mixed crop-livestock	2	13.20	327.78	81.93	26853.51
40	Mixed crop-livestock	3	8.40	155.89	178.10	27763.45

Table 1: Farm groups characteristics. TF = Type of farming. ES = Economic size : 1 if 25000 €$<$ Standard gross production $<$ 100000 €, 2 if 100000 €$<$ SGP $<$ 250000 €, 3 if SGP $>$ 250000 €. "Sampled" = the number of farms sampled. "Represented" = number of farms represented by the farm group. "UAA" = average utilized agricultural area per farm in the farm group. "UAA total" = total UAA represented by the farm group, i.e., UAA * number of farms represented. Data source: FADN individual farm data by former administrative region (before 2015), technico-economic orientation, and economic size, average over 2009-2013.

2 Crop areas

Farm group	Wheat	Grain Maize	Barley	Rapeseed	Rotation	Permanent Grassland	Fodder maize
1	22.08	1.73	20.93	11.79	56.53	0.99	0.00
2	49.72	5.49	40.77	31.98	127.95	4.53	0.16
3	87.52	5.94	90.94	75.81	260.21	29.89	2.76
4	19.80	0.37	16.08	6.51	42.76	0.09	0.00
5	40.79	1.68	33.14	15.65	91.27	0.99	0.03
6	79.99	3.65	61.75	30.34	175.74	2.46	0.11
7	5.92	2.39	2.30	0.47	11.07	46.52	2.57
8	12.60	0.40	5.65	2.36	21.00	79.24	11.91
9	28.16	14.87	10.41	5.27	58.71	128.44	28.35
10	4.39	0.06	1.22	0.48	6.15	90.28	3.65
11	5.31	2.10	1.83	1.03	10.27	70.14	3.96
12	15.32	0.85	3.69	2.27	22.14	94.05	11.73
13	24.68	7.47	9.17	6.17	47.48	146.14	37.19
14	33.55	3.56	23.79	19.89	80.79	47.79	6.38
15	72.86	3.00	61.43	48.26	185.54	79.42	23.48
16	21.65	1.35	23.70	16.96	63.66	18.65	0.53
17	56.36	5.64	45.01	41.86	148.87	34.62	2.15
18	138.68	2.53	84.70	109.40	335.31	56.89	1.32
19	4.90	0.18	6.14	0.76	11.98	43.60	3.82
20	15.71	1.05	7.35	3.71	27.81	72.95	14.53
21	32.62	0.42	17.64	12.02	62.70	114.69	24.93
22	2.75	0.33	2.98	1.39	7.46	65.41	1.63
23	17.88	2.05	2.15	3.10	25.19	142.80	21.51
24	13.48	0.69	6.80	2.47	23.45	92.90	17.55
25	40.31	0.76	17.84	11.21	70.12	134.72	33.21
26	18.88	1.55	10.82	14.24	45.50	50.99	2.88
27	39.07	1.75	26.39	24.61	91.82	58.10	11.13
28	72.69	8.76	46.07	42.80	170.31	96.67	30.19
29	7.96	26.17	0.34	0.71	35.18	4.56	0.06
30	11.91	80.44	0.41	0.90	93.66	2.80	0.05
31	38.24	141.97	0.00	9.88	190.09	1.04	0.00
32	4.92	22.35	0.47	0.04	27.78	3.71	0.95
33	8.83	39.75	0.67	0.43	49.68	2.33	0.15
34	0.73	0.46	0.07	0.00	1.25	50.38	0.57
35	14.44	11.11	2.48	0.33	28.37	33.96	14.85
36	30.45	19.48	4.06	0.71	54.71	48.50	27.68
37	3.00	0.87	0.33	0.00	4.20	65.83	0.68
38	7.10	15.57	0.75	0.77	24.19	14.89	1.89
39	15.86	30.57	2.11	2.35	50.89	20.59	10.45
40	35.60	53.41	5.20	7.32	101.53	58.47	18.09

Table 2: Average initial area of each crop in each farm group, in hectare per farm. Data source: FADN individual farm data by former administrative region (before 2015), technico-economic orientation, and economic size, average over 2009-2013.

Farm group	Wheat	Grain maize	Rapeseed	Barley
1	39.10	3.10	20.90	37.00
2	38.90	4.30	25.00	31.90
3	33.60	2.30	29.10	34.90
4	46.30	0.90	15.20	37.60
5	44.70	1.80	17.10	36.30
6	45.50	2.10	17.30	35.10
7	53.50	21.60	4.20	20.80
8	60.00	1.90	11.20	26.90
9	48.00	25.30	9.00	17.70
10	71.40	1.00	7.80	19.80
11	51.70	20.50	10.00	17.80
12	69.20	3.80	10.30	16.70
13	52.00	15.70	13.00	19.30
14	41.50	4.40	24.60	29.40
15	39.30	1.60	26.00	33.10
16	34.00	2.10	26.60	37.20
17	37.90	3.80	28.10	30.20
18	41.40	0.80	32.60	25.30
19	40.90	1.50	6.40	51.20
20	56.50	3.80	13.30	26.40
21	52.00	0.70	19.20	28.10
22	36.90	4.50	18.60	40.00
23	71.00	8.10	12.30	8.60
24	57.50	3.00	10.50	29.00
25	57.50	1.10	16.00	25.40
26	41.50	3.40	31.30	23.80
27	42.60	1.90	26.80	28.70
28	42.70	5.10	25.10	27.00
29	22.60	74.40	2.00	1.00
30	12.70	85.90	1.00	0.40
31	20.10	74.70	5.20	0.00
32	17.70	80.40	0.20	1.70
33	17.80	80.00	0.90	1.30
34	58.30	36.40	0.00	5.30
35	50.90	39.20	1.20	8.70
36	55.70	35.60	1.30	7.40
37	71.30	20.80	0.00	7.90
38	29.40	64.40	3.20	3.10
39	31.20	60.10	4.60	4.10
40	35.10	52.60	7.20	5.10

Table 3: Share of each activity in the crop rotation (in % of 1 of rotation), for each farm group. Data source: FADN average over 2009-2013 from individual farm data cross-referenced by pre-2015 administrative regions, technico-economic orientation and economic size. These shares are estimated by dividing the initial area for each of the 4 activities by the sum of theareas of these 4 activities.

3 Interactions between mitigation practices and applicability to crop activites

	Area share on which (combined) practices are applicable	
Mitigation practice(s)	Fodder maize baseline	Rotation baseline
Nitrification inhibitors	Applicable on 100%	Applicable on 100%
Including legumes in the rotation	Not applicable	$\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively
Including legumes in the rotation +Nitrification inhibitors	Not applicable	$\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively and inhibitors on 100% of surface area
Agroforestry	Reduces cultivated area by 12.5%	reduces cultivated area by 12.5%
Hedges	Reduces cultivated area by approx. 3% (depends of regions)	reduces cultivated area by approx. 3% (depends of regions)
Inserting temporary grassland into fodder maize	50% of maize fodder and 50% of temporary grassland	Not applicable
Agroforestry + Hedges	Cumulative reduction in surface area for both practices (Intra-plot tree lines + hedges) 12.5% + approx. 3% less cultivated surface area.	Cumulative reduction in surface area for both practices (Intra-plot tree lines + hedges) : 12.5% + approx. 3% less cultivated surface area.
Hedges + Nitrification inhibitors	Reduce the cultivated area by approx. 3%, apply nitrification inhibitors to the remaining.	Reduce the cultivated area by approx. 3%, apply nitrification inhibitors to the remaining.

Agroforestry + Nitrification inhibitors	Reduce the cultivated area by 12.5%, apply nitrification inhibitors to the remaining.	Reduce the cultivated area by 12.5%, apply nitrification inhibitors to the remaining.
Agroforestry + Hedges + Nitrification inhibitors	Reduce the cultivated area by 12.5% + approx 3%, apply nitrification inhibitors to the remaining	Reduce the cultivated area by 12.5% + approx 3%, apply nitrification inhibitors to the remaining
Including legumes in the rotation + Agroforestry	Not applicable	Reduce the cultivated area by 12.5% and $\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively to the remaining
Including legumes in the rotation + Hedges	Not applicable	Reduce the cultivated area by approx 3% and $\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively to the remaining
Including legumes in the rotation + Hedges + Agroforestry	Not applicable	Reduce the cultivated area by 12.5% and on the remaining :$\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively
Including legumes in the rotation + Nitrification inhibitors +Hedges	Not applicable	Reduce the cultivated area by approx 3%, and on the remaining : $\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively + inhibitors on 100%
Including legumes in the rotation + Nitrification inhibitors + Agroforestry	Not applicable	Reduce the cultivated area by 12.5%, and on the remaining : $\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively + inhibitors on 100%
Including legumes in the rotation + Nitrification inhibitors +Hedges + Agroforestry	Not applicable	Reduce the cultivated area by 12.5%+approx 3%, and on the remaining : $\frac{1}{6}^{th}$ of legumes in the rotation area, divided into $\frac{1}{6}^{th}$, $\frac{2}{3}^{rd}$, and $\frac{1}{6}^{th}$ on wheat, barley, and rapeseed, respectively + inhibitors on 100%

Inserting temporary grassland into fodder maize + Nitrification inhibitors	Inhibitor only on the 50% share of fodder maize	Not applicable
Inserting temporary grassland into fodder maize + Nitrification inhibitors + Hedges	Reduce the cultivated area by approx 3% and in the remaining : Inhibitor only on the 50% share of fodder maize	Not applicable
Inserting temporary grassland into fodder maize + Nitrification inhibitors + Agroforestry	Reduce the cultivated area by 12.5% and in the remaining : Inhibitor only on the 50% share of fodder maize	Not applicable
Inserting temporary grassland into fodder maize + Nitrification inhibitors + Agroforestry + Hedges	Reduce the cultivated area by 12.5% + approx. 3% and in the remaining : Inhibitor only on the 50% share of fodder maize	Not applicable
Inserting temporary grassland into fodder maize + Agroforestry	Reduce the cultivated area by 12.5% and in the remaining : 50% of fodder maize and 50% of temporary grassland	Not applicable
Inserting temporary grassland into fodder maize + Hedges	Reduce the cultivated area by approx. 3% and in the remaining : 50% of fodder maize and 50% of temporary grassland	Not applicable
Inserting temporary grassland into fodder maize + Hedges + Agroforestry	Reduce the cultivated area by 12.5% + approx. 3% and in the remaining : 50% of fodder maize and 50% of temporary grassland	Not applicable

Table 4: Interactions between mitigation practices and applicability to crop activities. Describes how (combined) mitigation practices can be implemented in terms of surface area on fodder maize and wheat-barley-rapeseed-grain maize rotation, according to the assumptions made in the [Pellerin et al., 2017] for nitrification inhibitors and introduction of legumes in the rotation, and in [Pellerin et al., 2019] and [Bamière et al., 2021b] for the other mitigation practices. The area taken up by the introduction of hedges around plots is estimated in [Bamière et al., 2023] according to sub-region: 2.9% in Champagne, 3% in Lorraine and 3.4% in Alsace.

4 Yields of each agricultural product from crop activities - mitigation practice(s)

Farm group	BAU	NI	Leg	Hedg	AF	NI+ Leg	NI+ AF	NI+ Hedg	NI+ Hedg +Agro	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg + AF
1	3.23	3.23	3.14	3.14	2.70	3.14	2.70	3.14	2.86	2.63	3.05	2.77	2.86	2.63	3.05	2.77
2	3.09	3.09	3.00	3.00	2.58	3.00	2.58	3.00	2.73	2.51	2.91	2.65	2.73	2.51	2.91	2.65
3	2.38	2.38	2.32	2.31	1.99	2.32	1.99	2.31	2.11	1.93	2.25	2.04	2.11	1.93	2.25	2.04
4	4.03	4.03	3.92	3.91	3.37	3.92	3.37	3.91	3.57	3.27	3.80	3.46	3.57	3.27	3.80	3.46
5	3.92	3.92	3.81	3.81	3.28	3.81	3.28	3.81	3.47	3.19	3.70	3.37	3.47	3.19	3.70	3.37
6	4.13	4.13	4.02	4.01	3.45	4.02	3.45	4.01	3.66	3.36	3.90	3.55	3.66	3.36	3.90	3.55
7	3.50	3.50	3.40	3.40	2.92	3.40	2.92	3.40	3.10	2.84	3.30	3.00	3.10	2.84	3.30	3.00
8	3.89	3.89	3.78	3.77	3.25	3.78	3.25	3.77	3.44	3.16	3.67	3.33	3.44	3.16	3.67	3.33
9	3.24	3.24	3.15	3.14	2.70	3.15	2.70	3.14	2.87	2.63	3.05	2.78	2.87	2.63	3.05	2.78
10	4.17	4.17	4.05	4.05	3.48	4.05	3.48	4.05	3.69	3.38	3.93	3.58	3.69	3.38	3.93	3.58
11	2.79	2.79	2.71	2.71	2.33	2.71	2.33	2.71	2.47	2.26	2.63	2.39	2.47	2.26	2.63	2.39
12	4.53	4.53	4.41	4.40	3.79	4.41	3.79	4.40	4.01	3.68	4.27	3.89	4.01	3.68	4.27	3.89
13	3.19	3.19	3.11	3.10	2.67	3.11	2.67	3.10	2.83	2.59	3.01	2.74	2.83	2.59	3.01	2.74
14	2.76	2.76	2.68	2.68	2.30	2.68	2.30	2.68	2.44	2.24	2.60	2.36	2.44	2.24	2.60	2.36
15	2.68	2.68	2.61	2.60	2.24	2.61	2.24	2.60	2.38	2.18	2.53	2.30	2.38	2.18	2.53	2.30
16	2.09	2.09	2.04	2.03	1.75	2.04	1.75	2.03	1.85	1.70	1.97	1.79	1.85	1.70	1.97	1.79
17	2.78	2.78	2.70	2.69	2.32	2.70	2.32	2.69	2.46	2.26	2.62	2.38	2.46	2.26	2.62	2.38
18	2.84	2.84	2.76	2.75	2.37	2.76	2.37	2.75	2.51	2.30	2.67	2.43	2.51	2.30	2.67	2.43
19	2.51	2.51	2.45	2.44	2.10	2.45	2.10	2.44	2.22	2.04	2.37	2.16	2.22	2.04	2.37	2.16
20	3.45	3.45	3.36	3.35	2.89	3.36	2.89	3.35	3.06	2.81	3.26	2.96	3.06	2.81	3.26	2.96
21	3.51	3.51	3.41	3.41	2.93	3.41	2.93	3.41	3.11	2.85	3.31	3.01	3.11	2.85	3.31	3.01
22	2.01	2.01	1.95	1.95	1.68	1.95	1.68	1.95	1.78	1.63	1.89	1.72	1.78	1.63	1.89	1.72
23	4.16	4.16	4.05	4.04	3.48	4.05	3.48	4.04	3.68	3.38	3.92	3.57	3.68	3.38	3.92	3.57
24	3.57	3.57	3.47	3.46	2.98	3.47	2.98	3.46	3.16	2.90	3.36	3.06	3.16	2.90	3.36	3.06

25	3.78	3.78	3.68	3.67	3.16	3.68	3.16	3.67	3.35	3.07	3.56	3.24	3.35	3.07	3.56	3.24
26	2.87	2.87	2.79	2.78	2.39	2.79	2.39	2.78	2.54	2.33	2.70	2.46	2.54	2.33	2.70	2.46
27	2.88	2.88	2.80	2.80	2.41	2.80	2.41	2.80	2.55	2.34	2.72	2.47	2.55	2.34	2.72	2.47
28	3.00	3.00	2.92	2.91	2.50	2.92	2.50	2.91	2.65	2.44	2.83	2.57	2.65	2.44	2.83	2.57
29	1.63	1.63	1.59	1.58	1.36	1.59	1.36	1.58	1.44	1.33	1.53	1.39	1.44	1.33	1.53	1.39
30	0.98	0.98	0.95	0.95	0.82	0.95	0.82	0.95	0.86	0.79	0.92	0.83	0.86	0.79	0.92	0.83
31	1.35	1.35	1.31	1.30	1.13	1.31	1.13	1.30	1.19	1.10	1.27	1.15	1.19	1.10	1.27	1.15
32	1.20	1.20	1.17	1.16	1.01	1.17	1.01	1.16	1.06	0.98	1.13	1.03	1.06	0.98	1.13	1.03
33	1.36	1.36	1.32	1.32	1.14	1.32	1.14	1.32	1.20	1.11	1.28	1.16	1.20	1.11	1.28	1.16
34	3.30	3.30	3.21	3.19	2.76	3.21	2.76	3.19	2.91	2.68	3.10	2.82	2.91	2.68	3.10	2.82
35	3.73	3.73	3.63	3.60	3.12	3.63	3.12	3.60	3.28	3.03	3.50	3.18	3.28	3.03	3.50	3.18
36	3.98	3.98	3.87	3.85	3.33	3.87	3.33	3.85	3.51	3.23	3.74	3.40	3.51	3.23	3.74	3.40
37	4.50	4.50	4.38	4.35	3.76	4.38	3.76	4.35	3.96	3.66	4.22	3.84	3.96	3.66	4.22	3.84
38	1.89	1.89	1.84	1.82	1.58	1.84	1.58	1.82	1.66	1.53	1.77	1.61	1.66	1.53	1.77	1.61
39	2.35	2.35	2.28	2.27	1.96	2.28	1.96	2.27	2.07	1.91	2.20	2.00	2.07	1.91	2.20	2.00
40	2.59	2.59	2.52	2.50	2.16	2.52	2.16	2.50	2.28	2.10	2.43	2.21	2.28	2.10	2.43	2.21

Table 5: Wheat yield per ha of rotation (wheat-barley-rapeseed -grain maize) with mitigation practice(s) in $t.ha^{-1}$. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; Leg= including legumes in the rotation; AF= Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. To estimate these parameters, we use the wheat yield per farm group from the 2009-2013 FADN data, and apply the previously estimated share of wheat in the crop rotation (refer to Table 3). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the wheat or cultivated area, as assumed by [Pellerin et al., 2017] for legumes and based on [Bamière et al., 2023] for the two other practices (see Table 4).

Farm group	BAU	NI	Leg	Hedg	AF	NI+ Leg	NI+ AF	NI+ Hedg	NI+ Hedg +AF	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg + AF
1	2.63	2.63	2.48	2.55	2.20	2.48	2.20	2.55	2.33	2.07	2.41	2.18	2.33	2.07	2.41	2.18
2	2.15	2.15	2.03	2.09	1.80	2.03	1.80	2.09	1.90	1.70	1.97	1.78	1.90	1.70	1.97	1.78
3	2.02	2.02	1.91	1.97	1.69	1.91	1.69	1.97	1.79	1.60	1.85	1.68	1.79	1.60	1.85	1.68
4	2.57	2.57	2.43	2.50	2.15	2.43	2.15	2.50	2.28	2.03	2.36	2.14	2.28	2.03	2.36	2.14
5	2.60	2.60	2.45	2.52	2.17	2.45	2.17	2.52	2.30	2.05	2.38	2.16	2.30	2.05	2.38	2.16
6	2.71	2.71	2.56	2.63	2.26	2.56	2.26	2.63	2.40	2.14	2.48	2.25	2.40	2.14	2.48	2.25
7	1.12	1.12	1.06	1.09	0.94	1.06	0.94	1.09	0.99	0.89	1.03	0.93	0.99	0.89	1.03	0.93
8	1.48	1.48	1.40	1.43	1.23	1.40	1.23	1.43	1.31	1.17	1.35	1.23	1.31	1.17	1.35	1.23
9	1.10	1.10	1.04	1.07	0.92	1.04	0.92	1.07	0.97	0.87	1.01	0.91	0.97	0.87	1.01	0.91
10	0.44	0.44	0.42	0.43	0.37	0.42	0.37	0.43	0.39	0.35	0.41	0.37	0.39	0.35	0.41	0.37
11	0.78	0.78	0.74	0.76	0.66	0.74	0.66	0.76	0.70	0.62	0.72	0.65	0.70	0.62	0.72	0.65
12	1.04	1.04	0.98	1.01	0.87	0.98	0.87	1.01	0.92	0.82	0.95	0.86	0.92	0.82	0.95	0.86
13	1.19	1.19	1.13	1.16	1.00	1.13	1.00	1.16	1.06	0.94	1.09	0.99	1.06	0.94	1.09	0.99
14	1.74	1.74	1.64	1.69	1.45	1.64	1.45	1.69	1.54	1.37	1.59	1.45	1.54	1.37	1.59	1.45
15	1.87	1.87	1.77	1.82	1.56	1.77	1.56	1.82	1.66	1.47	1.71	1.55	1.66	1.47	1.71	1.55
16	2.07	2.07	1.96	2.01	1.73	1.96	1.73	2.01	1.83	1.63	1.89	1.72	1.83	1.63	1.89	1.72
17	1.90	1.90	1.80	1.84	1.59	1.80	1.59	1.84	1.68	1.50	1.74	1.58	1.68	1.50	1.74	1.58
18	1.47	1.47	1.39	1.43	1.23	1.39	1.23	1.43	1.30	1.16	1.35	1.22	1.30	1.16	1.35	1.22
19	2.56	2.56	2.42	2.49	2.14	2.42	2.14	2.49	2.27	2.02	2.34	2.12	2.27	2.02	2.34	2.12
20	1.50	1.50	1.42	1.46	1.26	1.42	1.26	1.46	1.33	1.19	1.37	1.25	1.33	1.19	1.37	1.25
21	1.70	1.70	1.60	1.64	1.42	1.60	1.42	1.64	1.50	1.34	1.55	1.41	1.50	1.34	1.55	1.41
22	1.90	1.90	1.79	1.84	1.59	1.79	1.59	1.84	1.68	1.50	1.74	1.57	1.68	1.50	1.74	1.57
23	0.51	0.51	0.48	0.49	0.43	0.48	0.43	0.49	0.45	0.40	0.47	0.42	0.45	0.40	0.47	0.42
24	1.67	1.67	1.57	1.62	1.39	1.57	1.39	1.62	1.47	1.31	1.52	1.38	1.47	1.31	1.52	1.38
25	1.52	1.52	1.44	1.48	1.27	1.44	1.27	1.48	1.35	1.20	1.39	1.26	1.35	1.20	1.39	1.26

26	1.71	1.71	1.61	1.66	1.43	1.61	1.43	1.66	1.51	1.35	1.56	1.42	1.51	1.35	1.56	1.42
27	1.75	1.75	1.65	1.70	1.46	1.65	1.46	1.70	1.55	1.38	1.60	1.45	1.55	1.38	1.60	1.45
28	1.64	1.64	1.55	1.59	1.37	1.55	1.37	1.59	1.45	1.29	1.50	1.36	1.45	1.29	1.50	1.36
29	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
30	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.08	0.08	0.07	0.08	0.06	0.07	0.06	0.08	0.07	0.06	0.07	0.06	0.07	0.06	0.07	0.06
33	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
34	0.32	0.32	0.30	0.31	0.26	0.30	0.26	0.31	0.28	0.25	0.29	0.26	0.28	0.25	0.29	0.26
35	0.55	0.55	0.52	0.53	0.46	0.52	0.46	0.53	0.48	0.43	0.50	0.45	0.48	0.43	0.50	0.45
36	0.42	0.42	0.40	0.41	0.35	0.40	0.35	0.41	0.37	0.33	0.39	0.35	0.37	0.33	0.39	0.35
37	0.42	0.42	0.39	0.40	0.35	0.39	0.35	0.40	0.37	0.33	0.38	0.35	0.37	0.33	0.38	0.35
38	0.18	0.18	0.17	0.17	0.15	0.17	0.15	0.17	0.16	0.14	0.16	0.15	0.16	0.14	0.16	0.15
39	0.27	0.27	0.26	0.26	0.23	0.26	0.23	0.26	0.24	0.21	0.25	0.22	0.24	0.21	0.25	0.22
40	0.31	0.31	0.30	0.30	0.26	0.30	0.26	0.30	0.28	0.25	0.29	0.26	0.28	0.25	0.29	0.26

Table 6: Barley yields per ha of rotation (wheat-barley-rapeseed-grain maize) with mitigation practice(s) in $t.ha^{-1}$. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; Leg= including legumes in the rotation; AF = Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. To estimate these parameters, we use the barley yield per farm group from the 2009-2013 FADN data, and apply the previously estimated share of barley in the crop rotation (refer to Table 3). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the barley or cultivated area, as assumed by [Pellerin et al., 2017] for legumes and based on [Bamière et al., 2023] for the two other practices (see Table 4).

Farm group	BAU	NI	Leg	Hedg	AF	Leg + NI	NI+ AF	NI+ Hedg	NI+ Hedg+ AF	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg+ AF
1	0.73	0.73	0.71	0.71	0.61	0.71	0.61	0.71	0.65	0.59	0.69	0.63	0.65	0.59	0.69	0.63
2	0.85	0.85	0.83	0.83	0.71	0.83	0.71	0.83	0.76	0.69	0.80	0.73	0.76	0.69	0.80	0.73
3	0.89	0.89	0.87	0.87	0.74	0.87	0.74	0.87	0.79	0.72	0.84	0.77	0.79	0.72	0.84	0.77
4	0.58	0.58	0.56	0.56	0.48	0.56	0.48	0.56	0.51	0.47	0.55	0.50	0.51	0.47	0.55	0.50
5	0.66	0.66	0.64	0.64	0.55	0.64	0.55	0.64	0.59	0.54	0.62	0.57	0.59	0.54	0.62	0.57
6	0.66	0.66	0.64	0.64	0.55	0.64	0.55	0.64	0.58	0.53	0.62	0.56	0.58	0.53	0.62	0.56
7	0.14	0.14	0.14	0.14	0.12	0.14	0.12	0.14	0.12	0.11	0.13	0.12	0.12	0.11	0.13	0.12
8	0.40	0.40	0.39	0.38	0.33	0.39	0.33	0.38	0.35	0.32	0.37	0.34	0.35	0.32	0.37	0.34
9	0.30	0.30	0.29	0.29	0.25	0.29	0.25	0.29	0.26	0.24	0.28	0.26	0.26	0.24	0.28	0.26
10	0.12	0.12	0.12	0.12	0.10	0.12	0.10	0.12	0.11	0.10	0.11	0.10	0.11	0.10	0.11	0.10
11	0.27	0.27	0.27	0.27	0.23	0.27	0.23	0.27	0.24	0.22	0.26	0.24	0.24	0.22	0.26	0.24
12	0.31	0.31	0.30	0.30	0.25	0.30	0.25	0.30	0.27	0.25	0.29	0.26	0.27	0.25	0.29	0.26
13	0.44	0.44	0.43	0.43	0.37	0.43	0.37	0.43	0.39	0.36	0.42	0.38	0.39	0.36	0.42	0.38
14	0.70	0.70	0.68	0.68	0.59	0.68	0.59	0.68	0.62	0.57	0.66	0.60	0.62	0.57	0.66	0.60
15	0.78	0.78	0.76	0.76	0.65	0.76	0.65	0.76	0.69	0.63	0.74	0.67	0.69	0.63	0.74	0.67
16	0.70	0.70	0.68	0.68	0.59	0.68	0.59	0.68	0.62	0.57	0.66	0.60	0.62	0.57	0.66	0.60
17	0.92	0.92	0.89	0.89	0.77	0.89	0.77	0.89	0.81	0.74	0.86	0.79	0.81	0.74	0.86	0.79
18	0.92	0.92	0.89	0.89	0.76	0.89	0.76	0.89	0.81	0.74	0.86	0.78	0.81	0.74	0.86	0.78
19	0.15	0.15	0.15	0.15	0.12	0.15	0.12	0.15	0.13	0.12	0.14	0.13	0.13	0.12	0.14	0.13
20	0.42	0.42	0.40	0.40	0.35	0.40	0.35	0.40	0.37	0.34	0.39	0.36	0.37	0.34	0.39	0.36
21	0.64	0.64	0.62	0.62	0.54	0.62	0.54	0.62	0.57	0.52	0.60	0.55	0.57	0.52	0.60	0.55
22	0.52	0.52	0.50	0.50	0.43	0.50	0.43	0.50	0.46	0.42	0.49	0.44	0.46	0.42	0.49	0.44
23	0.34	0.34	0.33	0.33	0.28	0.33	0.28	0.33	0.30	0.27	0.32	0.29	0.30	0.27	0.32	0.29
24	0.34	0.34	0.33	0.33	0.28	0.33	0.28	0.33	0.30	0.28	0.32	0.29	0.30	0.28	0.32	0.29
25	0.50	0.50	0.49	0.49	0.42	0.49	0.42	0.49	0.44	0.41	0.47	0.43	0.44	0.41	0.47	0.43

26	0.97	0.97	0.95	0.94	0.81	0.95	0.81	0.94	0.86	0.79	0.92	0.83	0.86	0.79	0.92	0.83
27	0.87	0.87	0.85	0.85	0.73	0.85	0.73	0.85	0.77	0.71	0.82	0.75	0.77	0.71	0.82	0.75
28	0.80	0.80	0.78	0.77	0.67	0.78	0.67	0.77	0.71	0.65	0.75	0.68	0.71	0.65	0.75	0.68
29	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
30	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
31	0.17	0.17	0.17	0.16	0.14	0.17	0.14	0.16	0.15	0.14	0.16	0.15	0.15	0.14	0.16	0.15
32	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.03
36	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.10	0.10	0.10	0.10	0.08	0.10	0.08	0.10	0.09	0.08	0.09	0.08	0.09	0.08	0.09	0.08
39	0.17	0.17	0.17	0.16	0.14	0.17	0.14	0.16	0.15	0.14	0.16	0.15	0.15	0.14	0.16	0.15
40	0.24	0.24	0.23	0.23	0.20	0.23	0.20	0.23	0.21	0.19	0.22	0.20	0.21	0.19	0.22	0.20

Table 7: Rapeseed yields per ha of rotation (wheat-barley-rapeseed-grain maize) with mitigation practice(s) in $t.ha^{-1}$. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; Leg= including legumes in the rotation; AF = Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. To estimate these parameters, we use the rapeseed yield per farm group from the 2009-2013 FADN data, and apply the previously estimated share of rapeseed in the crop rotation (refer to Table 3). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the rapeseed or cultivated area, as assumed by [Pellerin et al., 2017] for legumes and based on [Bamière et al., 2023] for the two other practices (see Table 4).

Farm group	BAU	NI	Leg	Hedg	AF	Leg + NI	NI+ AF	NI+ Hedg	NI+ Hedg+ AF	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg+ AF
1	0.27	0.27	0.27	0.26	0.23	0.27	0.23	0.26	0.24	0.23	0.26	0.24	0.24	0.23	0.26	0.24
2	0.38	0.38	0.38	0.37	0.32	0.38	0.32	0.37	0.33	0.32	0.37	0.33	0.33	0.32	0.37	0.33
3	0.15	0.15	0.15	0.14	0.12	0.15	0.12	0.14	0.13	0.12	0.14	0.13	0.13	0.12	0.14	0.13
4	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.06	0.07	0.07
5	0.15	0.15	0.15	0.15	0.13	0.15	0.13	0.15	0.13	0.13	0.15	0.13	0.13	0.13	0.15	0.13
6	0.18	0.18	0.18	0.18	0.15	0.18	0.15	0.18	0.16	0.15	0.18	0.16	0.16	0.15	0.18	0.16
7	2.06	2.06	2.06	2.00	1.72	2.06	1.72	2.00	1.82	1.72	2.00	1.82	1.82	1.72	2.00	1.82
8	0.15	0.15	0.15	0.14	0.12	0.15	0.12	0.14	0.13	0.12	0.14	0.13	0.13	0.12	0.14	0.13
9	2.23	2.23	2.23	2.17	1.87	2.23	1.87	2.17	1.98	1.87	2.17	1.98	1.98	1.87	2.17	1.98
10	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.07	0.07	0.08	0.07
11	1.85	1.85	1.85	1.80	1.55	1.85	1.55	1.80	1.64	1.55	1.80	1.64	1.64	1.55	1.80	1.64
12	0.32	0.32	0.32	0.31	0.27	0.32	0.27	0.31	0.28	0.27	0.31	0.28	0.28	0.27	0.31	0.28
13	1.19	1.19	1.19	1.16	1.00	1.19	1.00	1.16	1.06	1.00	1.16	1.06	1.06	1.00	1.16	1.06
14	0.41	0.41	0.41	0.39	0.34	0.41	0.34	0.39	0.36	0.34	0.39	0.36	0.36	0.34	0.39	0.36
15	0.12	0.12	0.12	0.12	0.10	0.12	0.10	0.12	0.11	0.10	0.12	0.11	0.11	0.10	0.12	0.11
16	0.12	0.12	0.12	0.12	0.10	0.12	0.10	0.12	0.11	0.10	0.12	0.11	0.11	0.10	0.12	0.11
17	0.31	0.31	0.31	0.30	0.26	0.31	0.26	0.30	0.27	0.26	0.30	0.27	0.27	0.26	0.30	0.27
18	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
19	0.11	0.11	0.11	0.10	0.09	0.11	0.09	0.10	0.09	0.09	0.10	0.09	0.09	0.09	0.10	0.09
20	0.32	0.32	0.32	0.31	0.27	0.32	0.27	0.31	0.29	0.27	0.31	0.29	0.29	0.27	0.31	0.29
21	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.05
22	0.37	0.37	0.37	0.36	0.31	0.37	0.31	0.36	0.33	0.31	0.36	0.33	0.33	0.31	0.36	0.33
23	0.50	0.50	0.50	0.49	0.42	0.50	0.42	0.49	0.44	0.42	0.49	0.44	0.44	0.42	0.49	0.44
24	0.24	0.24	0.24	0.23	0.20	0.24	0.20	0.23	0.21	0.20	0.23	0.21	0.21	0.20	0.23	0.21
25	0.09	0.09	0.09	0.09	0.07	0.09	0.07	0.09	0.08	0.07	0.09	0.08	0.08	0.07	0.09	0.08

26	0.25	0.25	0.25	0.25	0.21	0.25	0.21	0.25	0.23	0.21	0.25	0.23	0.23	0.21	0.25	0.23
27	0.13	0.13	0.13	0.13	0.11	0.13	0.11	0.13	0.12	0.11	0.13	0.12	0.12	0.11	0.13	0.12
28	0.42	0.42	0.42	0.41	0.35	0.42	0.35	0.41	0.37	0.35	0.41	0.37	0.37	0.35	0.41	0.37
29	8.63	8.63	8.63	8.34	7.21	8.63	7.21	8.34	7.60	7.21	8.34	7.60	7.60	7.21	8.34	7.60
30	10.43	10.43	10.43	10.07	8.71	10.43	8.71	10.07	9.18	8.71	10.07	9.18	9.18	8.71	10.07	9.18
31	7.29	7.29	7.29	7.04	6.09	7.29	6.09	7.04	6.42	6.09	7.04	6.42	6.42	6.09	7.04	6.42
32	9.40	9.40	9.40	9.08	7.85	9.40	7.85	9.08	8.28	7.85	9.08	8.28	8.28	7.85	9.08	8.28
33	9.45	9.45	9.45	9.13	7.89	9.45	7.89	9.13	8.32	7.89	9.13	8.32	8.32	7.89	9.13	8.32
34	2.81	2.81	2.81	2.71	2.35	2.81	2.35	2.71	2.47	2.35	2.71	2.47	2.47	2.35	2.71	2.47
35	4.32	4.32	4.32	4.17	3.61	4.32	3.61	4.17	3.81	3.61	4.17	3.81	3.81	3.61	4.17	3.81
36	3.52	3.52	3.52	3.40	2.94	3.52	2.94	3.40	3.10	2.94	3.40	3.10	3.10	2.94	3.40	3.10
37	2.22	2.22	2.22	2.14	1.85	2.22	1.85	2.14	1.95	1.85	2.14	1.95	1.95	1.85	2.14	1.95
38	5.63	5.63	5.63	5.44	4.70	5.63	4.70	5.44	4.96	4.70	5.44	4.96	4.96	4.70	5.44	4.96
39	6.69	6.69	6.69	6.46	5.59	6.69	5.59	6.46	5.89	5.59	6.46	5.89	5.89	5.59	6.46	5.89
40	5.34	5.34	5.34	5.16	4.46	5.34	4.46	5.16	4.70	4.46	5.16	4.70	4.70	4.46	5.16	4.70

Table 8: Grain maize yields per ha of rotation (wheat-barley-rapeseed-grain maize) with mitigation practice(s) in $t.ha^{-1}$. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; Leg= including legumes in the rotation; AF = Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. To estimate these parameters, we use the grain maize yield per farm group from the 2009-2013 FADN data, and apply the previously estimated share of grain maize in the crop rotation (refer to Table 3). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the cultivated area, as assumed by [Pellerin et al., 2017] for legumes and based on [Bamière et al., 2023] for the two other practices (see Table 4).

	Champagne	Lorraine	Alsace
BAU	13.30	12.27	15.60
NI	13.30	12.27	15.60
AF	11.11	10.25	13.03
NI+ Hedg	12.91	11.90	15.07
Hedg	12.91	11.90	15.07
NI+ AF	11.11	10.25	13.03
NI+ Hedg+ AF	11.78	10.86	13.74
AF+ Hedg	11.78	10.86	13.74
TempG	6.65	6.13	7.80
TempG + AF	5.55	5.12	6.52
TempG + Hedg	6.46	5.95	7.53
TempG + Hedg+ AF	5.89	5.43	6.87
TempG + NI	6.65	6.13	7.80
TempG + NI+ AF	5.55	5.12	6.52
TempG + Hedg + NI	6.46	5.95	7.53
TempG + Hedg+ NI+ AF	5.89	5.43	6.87

Table 9: Yields of fodder maize in the different combinations of crop activities and mitigation practices in tons of dry matter per ha. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; TempG=Introduction of temporary grassland; AF = Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. To estimate these parameters, we use fodder maize yields by sub-region (Alsace, Lorraine and Champagne) estimated by [Pellerin et al., 2019] using FADN data for the reference year 2009-2013. For introduction of temporary grassland, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the cultivated area as assumed by [Bamière et al., 2023] (see Table 4).

	Champagne	Lorraine	Alsace
Perm Grass	5.64	6.14	5.12
TempG	2.98	3.60	4.03
TempG + AF	2.49	3.01	3.37
TempG + Hedg	2.89	3.49	3.90
TempG + Hedg+ AF	2.64	3.19	3.55
TempG + NI	2.98	3.60	4.03
TempG + NI+ AF	2.49	3.01	3.37
TempG + Hedg + NI	2.49	3.01	3.37
TempG + Hedg+ NI+ AF	2.89	3.49	3.90

Table 10: Yields of permanent grassland and temporary grassland in the different combinations of crop activities and mitigation practice(s) in tons of dry matter per ha. Perm Grass= permanent grassland; NI = Nitrification inhibitors; TempG=Introduction of temporary grassland; AF = Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges.

We use permanent and temporary grassland yields by sub-region (Alsace, Lorraine and Champagne) estimated by [Bamière et al., 2023] using FADN data for the reference years 2009-2013, in $q.ha^{-1}$. For introduction of temporary grassland, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the cultivated area as assumed by [Bamière et al., 2023] (see Table 4).

Farm group	BAU	NI	Leg	Hedg	AF	NI+ Leg	NI+ AF	NI+ Hedg	NI+ Hedg +AF	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg + AF
1	1.33	1.33	0.95	1.29	1.11	0.95	1.11	1.29	1.18	0.79	1.24	1.12	1.18	0.79	1.24	1.12
2	1.24	1.24	0.95	1.20	1.03	0.95	1.03	1.20	1.10	0.79	1.15	1.05	1.10	0.79	1.15	1.05
3	1.20	1.20	0.95	1.17	1.00	0.95	1.00	1.17	1.06	0.79	1.12	1.01	1.06	0.79	1.12	1.01
4	1.47	1.47	0.94	1.43	1.23	0.94	1.23	1.43	1.30	0.79	1.37	1.24	1.30	0.79	1.37	1.24
5	1.42	1.42	0.94	1.38	1.18	0.94	1.18	1.38	1.26	0.79	1.32	1.20	1.26	0.79	1.32	1.20
6	1.41	1.41	0.94	1.37	1.18	0.94	1.18	1.37	1.25	0.79	1.31	1.19	1.25	0.79	1.31	1.19
7	1.30	1.30	0.95	1.26	1.09	0.95	1.09	1.26	1.15	0.80	1.22	1.10	1.15	0.80	1.22	1.10
8	1.52	1.52	0.94	1.48	1.27	0.94	1.27	1.48	1.35	0.79	1.42	1.29	1.35	0.79	1.42	1.29
9	1.15	1.15	0.96	1.12	0.96	0.96	0.96	1.12	1.02	0.80	1.08	0.98	1.02	0.80	1.08	0.98
10	1.60	1.60	0.95	1.55	1.33	0.95	1.33	1.55	1.41	0.79	1.50	1.36	1.41	0.79	1.50	1.36
11	1.22	1.22	0.96	1.18	1.02	0.96	1.02	1.18	1.08	0.80	1.14	1.04	1.08	0.80	1.14	1.04
12	1.50	1.50	0.95	1.46	1.26	0.95	1.26	1.46	1.33	0.79	1.41	1.28	1.33	0.79	1.41	1.28
13	1.25	1.25	0.96	1.21	1.04	0.96	1.04	1.21	1.10	0.80	1.17	1.06	1.10	0.80	1.17	1.06
14	1.24	1.24	0.95	1.21	1.04	0.95	1.04	1.21	1.10	0.79	1.16	1.05	1.10	0.79	1.16	1.05
15	1.27	1.27	0.95	1.23	1.06	0.95	1.06	1.23	1.12	0.79	1.18	1.07	1.12	0.79	1.18	1.07
16	1.25	1.25	0.95	1.21	1.04	0.95	1.04	1.21	1.10	0.79	1.16	1.05	1.10	0.79	1.16	1.05
17	1.19	1.19	0.95	1.16	1.00	0.95	1.00	1.16	1.05	0.80	1.11	1.01	1.05	0.80	1.11	1.01
18	1.17	1.17	0.96	1.13	0.97	0.96	0.97	1.13	1.03	0.80	1.09	0.99	1.03	0.80	1.09	0.99
19	1.61	1.61	0.93	1.56	1.35	0.93	1.35	1.56	1.43	0.78	1.49	1.36	1.43	0.78	1.49	1.36
20	1.45	1.45	0.95	1.41	1.21	0.95	1.21	1.41	1.28	0.79	1.35	1.23	1.28	0.79	1.35	1.23
21	1.40	1.40	0.95	1.36	1.17	0.95	1.17	1.36	1.24	0.79	1.31	1.19	1.24	0.79	1.31	1.19
22	1.35	1.35	0.94	1.31	1.12	0.94	1.12	1.31	1.19	0.79	1.25	1.13	1.19	0.79	1.25	1.13
23	1.39	1.39	0.96	1.35	1.16	0.96	1.16	1.35	1.23	0.80	1.31	1.19	1.23	0.80	1.31	1.19
24	1.51	1.51	0.94	1.47	1.26	0.94	1.26	1.47	1.34	0.79	1.41	1.28	1.34	0.79	1.41	1.28
25	1.45	1.45	0.95	1.41	1.21	0.95	1.21	1.41	1.28	0.79	1.36	1.23	1.28	0.79	1.36	1.23

26	1.14	1.14	0.96	1.11	0.95	0.96	0.95	1.11	1.01	0.80	1.06	0.97	1.01	0.80	1.06	0.97
27	1.25	1.25	0.95	1.21	1.04	0.95	1.04	1.21	1.10	0.79	1.16	1.06	1.10	0.79	1.16	1.06
28	1.22	1.22	0.95	1.18	1.02	0.95	1.02	1.18	1.08	0.80	1.14	1.03	1.08	0.80	1.14	1.03
29	0.41	0.41	0.99	0.40	0.34	0.99	0.34	0.40	0.36	0.83	0.39	0.35	0.36	0.83	0.39	0.35
30	0.23	0.23	0.99	0.22	0.19	0.99	0.19	0.22	0.20	0.83	0.22	0.20	0.20	0.83	0.22	0.20
31	0.35	0.35	0.99	0.34	0.29	0.99	0.29	0.34	0.31	0.83	0.33	0.30	0.31	0.83	0.33	0.30
32	0.34	0.34	0.99	0.33	0.28	0.99	0.28	0.33	0.30	0.83	0.32	0.29	0.30	0.83	0.32	0.29
33	0.33	0.33	0.99	0.32	0.28	0.99	0.28	0.32	0.29	0.83	0.31	0.28	0.29	0.83	0.31	0.28
34	1.11	1.11	0.97	1.08	0.93	0.97	0.93	1.08	0.98	0.81	1.04	0.95	0.98	0.81	1.04	0.95
35	1.04	1.04	0.97	1.01	0.87	0.97	0.87	1.01	0.92	0.81	0.98	0.89	0.92	0.81	0.98	0.89
36	1.10	1.10	0.97	1.07	0.92	0.97	0.92	1.07	0.97	0.81	1.03	0.94	0.97	0.81	1.03	0.94
37	1.39	1.39	0.96	1.34	1.16	0.96	1.16	1.34	1.22	0.80	1.30	1.18	1.22	0.80	1.30	1.18
38	0.57	0.57	0.98	0.55	0.47	0.98	0.47	0.55	0.50	0.82	0.53	0.48	0.50	0.82	0.53	0.48
39	0.62	0.62	0.98	0.60	0.52	0.98	0.52	0.60	0.54	0.82	0.58	0.53	0.54	0.82	0.58	0.53
40	0.70	0.70	0.98	0.68	0.59	0.98	0.59	0.68	0.62	0.82	0.66	0.60	0.62	0.82	0.66	0.60

Table 11: Straw yield per ha of rotation (wheat-barley-rapeseed -grain maize) with mitigation practice(s) in $t.ha^{-1}$. BAU = rotation baseline, without mitigation practice; NI = Nitrification inhibitors; Leg= including legumes in the rotation; AF= Intra-plot agroforestry; Hedg = Insertion of hedges along plot edges. The crops on which straw is harvested are wheat and barley, so the straw yields estimated here depend on the share of each of these crops in the rotation of each farm group (refer to Table 3). To estimate this parameter, we use the hypothesis used in [Bamière et al., 2023]: we consider that 50% of the straw can be harvested without damaging the soil, with a straw yield of 3.5 $tDM.ha^{-1}$ (Data source [Bamière et al., 2021b]). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the yield based on the decrease in the wheat and barley area as assumed by [Pellerin et al., 2017] for legumes and based on [Bamière et al., 2023] for the two other practices (see Table 4).

Mitigation practice(s)	Yields
Leg	0.40
Leg+NI	0.40
Leg+AF	0.34
Leg+Hedg	0.39
Leg+Hedg+AF	0.33
Leg+NI+AF	0.34
Leg+NI+Hedg	0.39
Leg+NI+Hedg+AF	0.33

Table 12: Legumes yield per ha of rotation (wheat-barley-rapeseed -grain maize) with mitigation practice(s), in $t.ha^{-1}$, for the sub-regions Champagne and Lorraine. Legumes yields in Alsace are considered to be zero. NI = Nitrification inhibitors, Leg= including legumes in the rotation, AF= Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges.

5 Crop prices

Crop product	Sale Price
Wheat	175
Grain maize	162.00
Barley	158.00
Rapeseed	385.40
Legumes	213.5
Straw	25
	Purchase Price
Straw	29.3

Table 13: Crop prices for the application, in €.t^{-1}. These parameters are estimated at the French-scale by [Bamière et al., 2023] using FADN data for the reference years 2009-2013, and from IDELE's 2015 dairy cattle standard cases for straw sale price. The purchase price of the straw corresponds to the selling price, to which is added a transportation cost estimated from a formula on the website of the National Road Committee (We have rounded these data to the cent in this table.

Crop product	Sale Price
Wheat	160,615
Grain maize	138,413
Barley	152,955
Rapeseed	364,522
Legumes	222,645

Table 14: 2015 Crop prices for validation, in €.t^{-1}, these parameters are estimated at the French-scale using FADN data for the reference year 2015

6 Crop activities production cost

Farm group	BAU	NI	Leg	AF	Hedg	Leg + NI	NI+ AF	NI+ Hedg	NI+ Hedg+ AF	Leg+ AF	Leg+ Hedg	Leg+ Hedg+ AF	AF+ Hedg	Leg+ NI+ AF	Leg+ NI+ Hedg	Leg+ NI+ Hedg+ AF
1	294.60	346.19	343.09	338.41	323.16	394.68	383.55	373.25	390.30	362.34	370.24	387.68	346.66	407.47	420.33	431.33
2	297.10	349.09	346.65	340.59	325.58	398.65	386.08	376.07	392.76	365.45	373.70	390.69	348.77	410.94	424.18	434.68
3	289.26	340.64	338.23	333.73	317.97	389.61	378.69	367.86	385.61	358.08	365.52	383.57	342.14	403.04	415.41	427.04
4	299.42	351.77	347.44	342.62	327.84	399.79	388.43	378.67	395.02	366.14	374.47	391.37	350.74	411.95	425.30	435.65
5	299.17	351.43	347.55	342.40	327.59	399.81	388.13	378.34	394.74	366.24	374.58	391.46	350.53	411.96	425.32	435.67
6	300.53	352.96	349.13	343.60	328.92	401.56	389.47	379.83	396.04	367.62	376.11	392.79	351.68	413.50	427.02	437.15
7	330.47	383.49	382.99	369.80	357.99	436.00	416.18	409.46	421.86	397.25	408.98	421.44	377.01	443.63	460.46	466.28
8	316.87	371.44	366.61	357.89	344.78	421.18	405.64	397.77	411.66	382.92	393.08	407.58	365.50	430.66	446.06	453.75
9	329.50	382.03	383.01	368.95	357.05	435.54	414.90	408.05	420.62	397.27	409.01	421.46	376.19	443.22	460.01	465.89
10	329.25	385.62	379.95	368.73	356.80	436.32	418.05	411.54	423.67	394.59	406.03	418.87	375.98	443.91	460.77	466.56
11	328.61	381.85	381.64	368.16	356.18	434.88	414.75	407.88	420.47	396.07	407.67	420.30	375.43	442.65	459.37	465.34
12	330.68	386.94	382.23	369.97	358.19	438.49	419.20	412.82	424.78	396.58	408.24	420.79	377.18	445.81	462.88	468.39
13	324.11	377.61	376.51	364.22	351.81	430.01	411.04	403.76	416.88	391.57	402.69	415.95	371.62	438.39	454.64	461.21
14	300.52	352.99	350.46	343.58	328.90	402.93	389.49	379.85	396.06	368.79	377.40	393.92	351.67	414.70	428.35	438.31
15	294.66	346.78	343.77	338.46	323.21	395.89	384.06	373.82	390.80	362.93	370.90	388.26	346.71	408.54	421.51	432.35
16	291.23	338.99	344.07	335.46	318.82	391.82	377.25	365.15	383.04	363.19	370.07	387.33	342.69	404.98	416.40	427.69
17	289.28	337.52	344.18	333.75	316.93	392.42	375.96	363.72	381.80	363.29	370.18	387.43	341.04	405.49	416.97	428.19
18	285.03	333.88	341.05	330.03	312.81	389.91	372.78	360.20	378.73	360.55	367.15	384.78	337.44	403.30	414.54	426.07
19	289.25	336.03	338.40	333.73	316.91	385.18	374.65	362.28	380.54	358.23	364.58	382.55	341.02	399.16	409.95	422.07
20	279.18	327.90	335.36	324.91	307.13	384.08	367.54	354.39	373.67	355.57	361.63	379.97	332.50	398.20	408.89	421.15
21	279.88	328.62	335.27	325.52	307.81	384.02	368.18	355.10	374.28	355.50	361.55	379.90	333.09	398.15	408.83	421.09
22	291.52	338.93	343.85	335.71	319.10	391.27	377.20	365.10	383.00	363.00	369.86	387.15	342.93	404.49	415.86	427.22
23	271.85	321.84	333.38	318.50	300.03	383.37	362.24	348.52	368.55	353.84	359.71	378.30	326.31	397.58	408.20	420.54

24	278.52	327.11	333.96	324.34	306.50	382.55	366.85	353.63	373.00	354.35	360.27	378.79	331.95	396.86	407.40	419.85
25	276.95	325.94	333.18	322.96	304.97	382.17	365.83	352.49	372.01	353.67	359.52	378.14	330.62	396.53	407.04	419.53
26	286.31	335.12	342.96	331.15	314.05	391.76	373.86	361.39	379.77	362.22	369.00	386.39	338.53	404.92	416.34	427.63
27	285.56	334.09	340.77	330.50	313.33	389.29	372.96	360.39	378.90	360.30	366.88	384.55	337.90	402.76	413.94	425.55
28	287.16	335.61	343.09	331.90	314.88	391.54	374.29	361.87	380.19	362.34	369.13	386.51	339.25	404.73	416.13	427.45
29	395.90	445.44	463.85	427.04	423.61	513.39	470.39	471.46	475.80	468.00	489.25	491.29	434.14	511.35	537.11	532.95
30	412.79	462.74	481.96	441.82	439.92	531.91	485.52	488.17	490.35	483.85	506.74	506.52	448.34	527.55	555.00	548.52
31	397.52	447.23	466.02	428.46	425.17	515.73	471.95	473.19	477.31	469.90	491.34	493.11	435.50	513.39	539.36	534.91
32	406.91	456.58	474.88	436.68	434.25	524.54	480.14	482.22	485.17	477.65	499.90	500.56	443.40	521.11	547.88	542.33
33	405.79	455.48	473.94	435.69	433.16	523.63	479.17	481.16	484.24	476.83	498.99	499.77	442.46	520.31	547.00	541.56
34	341.79	389.66	404.22	379.70	371.34	452.09	421.58	417.58	428.89	415.83	431.65	441.14	388.63	457.71	477.89	481.40
35	363.66	411.54	423.85	398.84	392.47	471.72	440.73	438.72	447.29	433.00	450.61	457.65	407.03	474.89	496.85	497.91
36	351.74	399.54	412.58	388.41	380.95	460.38	430.23	427.13	437.20	423.14	439.72	448.17	397.00	464.96	485.89	488.36
37	324.76	371.94	384.28	364.80	354.89	431.45	406.08	400.46	413.99	398.37	412.38	424.36	374.31	439.65	457.95	464.04
38	388.63	437.75	454.38	420.68	416.59	503.50	463.66	464.04	469.34	459.71	480.10	483.32	428.03	502.69	527.55	524.63
39	387.72	436.69	452.37	419.89	415.71	501.34	462.73	463.01	468.44	457.95	478.16	481.63	427.26	500.80	525.46	522.81
40	382.59	431.34	445.93	415.40	410.76	494.68	458.06	457.85	463.95	452.32	471.94	476.21	422.95	494.97	519.03	517.21

Table 15: Combination crop rotation (wheat-barley-rapeseed- grain maize) and mitigation practice(s) production costs in €$.ha^{-1}$. BAU = rotation baseline, without mitigation pratice, NI = Nitrification inhibitors, Leg= including legumes in the rotation, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges.

To estimate these parameters, we use the production cost per activity per region (Champagne, Lorraine, Alsace) estimated by [Pellerin et al., 2019] from the FADN database 2009-2013, and apply the previously estimated share of each activity in the crop rotation (refer to Table 3). For introduction of legumes, hedgerows, and agroforestry practices, we reduce the costs based on the decrease in the cultivated area, as assumed by [Pellerin et al., 2017] for legumes and based on [Pellerin et al., 2019] for the two other practices (see Table 4). The other additional costs of implementing the practices (hedges and trees maintenance, costs of purchasing nitrification inhibitors, etc.) are those estimated by [Pellerin et al., 2017] for Leg and NI practices, and those estimated by [Pellerin et al., 2019] for AF and Hedg practices. These additional costs are listed in the practice description table (table 45).

	Champagne	Lorraine	Alsace
Perm Grass	52.76	45.07	57.95
Fodder maize BAU	448.00	529.59	498.94
Fodder maize NI	453.17	534.22	500.40
Fodder maize TempG	231.29	308.55	311.29
Fodder maize AF	472.63	544.02	517.20
Fodder maize Hedg	472.11	550.03	523.15
Fodder maize NI+ AF	477.15	548.07	518.48
Fodder maize NI+ Hedg	477.13	554.52	524.56
Fodder maize NI+ Hedg+ AF	480.81	548.01	522.02
Fodder maize AF+ Hedg	476.43	544.10	520.80
Fodder maize TempG+ AF	264.51	332.11	334.51
Fodder maize TempG+ Hedg	261.68	335.62	341.88
Fodder maize TempG+ Hedg+ AF	293.10	357.32	362.98
Fodder maize TempG+ NI	236.46	313.17	312.75
Fodder maize TempG+ NI+ AF	269.03	336.16	335.79
Fodder maize TempG+ NI+ Hedg	266.70	340.11	343.29
Fodder maize TempG+ NI+ Hedg+ AF	297.47	361.23	364.21

Table 16: Combination fodder maize and mitigation practice(s), and permanent grassland production costs in €$.ha^{-1}$. Perm Grass= permanent grassland, BAU = fodder maize, without mitigation pratice, NI = Nitrification inhibitors, TempG=Introduction of temporary grassland, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges.

To estimate these parameters, we use the production cost per activity per region (Champagne, Lorraine, Alsace) estimated by [Pellerin et al., 2019] from the FADN database 2009-2013. For introduction of hedgerows, and agroforestry practices, we reduce the costs based on the decrease in the cultivated area, as assumed by [Pellerin et al., 2019] for these two practices (see Table 4). The other additional costs of implementing the practices (hedges and trees maintenance, costs of purchasing nitrification inhibitors, etc.) are those estimated by [Pellerin et al., 2017] for NI practice, and those estimated by [Pellerin et al., 2019] for AF and Hedg practices. These additional costs are listed in the practice description table (see table 45).

7 Fertilizer requirement by combination of activity and mitigation practice(s)

Farm group	BAU	NI	Leg	AF	Hedg	NI+ Leg	NI+ AF	NI+ Hedg	NI + Hedg + AF	Leg + AF	Leg + Hedg	NI+ Hedg + AF	AF+ Hedg	NI+ Leg + AF	NI+ Leg + Hedg	NI+ Leg + Hedg + AF
1	0.164	0.162	0.151	0.144	0.160	0.149	0.142	0.157	0.137	0.132	0.147	0.128	0.139	0.130	0.147	0.128
2	0.166	0.163	0.153	0.145	0.161	0.151	0.143	0.159	0.138	0.134	0.149	0.130	0.140	0.132	0.149	0.130
3	0.164	0.162	0.151	0.144	0.159	0.149	0.141	0.157	0.137	0.132	0.147	0.128	0.139	0.130	0.147	0.128
4	0.166	0.164	0.153	0.145	0.161	0.150	0.143	0.159	0.139	0.134	0.148	0.129	0.141	0.132	0.148	0.130
5	0.166	0.164	0.153	0.145	0.161	0.150	0.143	0.159	0.138	0.134	0.148	0.129	0.141	0.132	0.148	0.130
6	0.167	0.164	0.154	0.146	0.162	0.151	0.144	0.159	0.139	0.134	0.149	0.130	0.141	0.132	0.149	0.130
7	0.169	0.167	0.159	0.148	0.164	0.156	0.146	0.162	0.141	0.139	0.154	0.134	0.143	0.137	0.154	0.134
8	0.173	0.170	0.160	0.151	0.168	0.158	0.149	0.165	0.144	0.140	0.156	0.136	0.146	0.138	0.156	0.136
9	0.168	0.166	0.158	0.147	0.164	0.156	0.145	0.161	0.141	0.138	0.153	0.134	0.143	0.136	0.153	0.134
10	0.178	0.175	0.166	0.156	0.173	0.163	0.153	0.170	0.148	0.145	0.161	0.141	0.150	0.143	0.161	0.141
11	0.170	0.168	0.160	0.149	0.165	0.157	0.147	0.163	0.142	0.140	0.155	0.135	0.144	0.138	0.155	0.135
12	0.178	0.175	0.167	0.156	0.173	0.164	0.153	0.170	0.148	0.146	0.162	0.141	0.150	0.143	0.162	0.141
13	0.171	0.168	0.160	0.149	0.166	0.157	0.147	0.163	0.142	0.140	0.155	0.135	0.144	0.138	0.155	0.135
14	0.167	0.165	0.155	0.146	0.162	0.152	0.144	0.160	0.139	0.135	0.150	0.131	0.141	0.133	0.150	0.131
15	0.166	0.164	0.153	0.145	0.161	0.151	0.143	0.159	0.138	0.134	0.149	0.130	0.140	0.132	0.149	0.130
16	0.153	0.151	0.140	0.134	0.149	0.138	0.132	0.147	0.128	0.122	0.136	0.118	0.130	0.121	0.136	0.119
17	0.155	0.153	0.142	0.136	0.150	0.140	0.134	0.148	0.129	0.125	0.138	0.120	0.131	0.123	0.138	0.121
18	0.157	0.154	0.144	0.137	0.152	0.142	0.135	0.150	0.131	0.126	0.140	0.122	0.132	0.124	0.140	0.122
19	0.150	0.147	0.135	0.131	0.145	0.133	0.129	0.143	0.125	0.118	0.131	0.114	0.126	0.116	0.131	0.114
20	0.156	0.154	0.144	0.136	0.151	0.141	0.134	0.149	0.130	0.126	0.139	0.121	0.132	0.124	0.139	0.122
21	0.156	0.154	0.143	0.136	0.151	0.141	0.134	0.149	0.130	0.125	0.139	0.121	0.132	0.123	0.139	0.121
22	0.152	0.150	0.139	0.133	0.148	0.137	0.131	0.146	0.127	0.121	0.134	0.117	0.129	0.119	0.134	0.117
23	0.160	0.157	0.150	0.140	0.155	0.147	0.138	0.153	0.133	0.131	0.145	0.126	0.135	0.129	0.145	0.127

24	0.155	0.153	0.143	0.136	0.150	0.140	0.134	0.148	0.129	0.125	0.138	0.121	0.131	0.123	0.138	0.121
25	0.156	0.154	0.144	0.137	0.152	0.142	0.135	0.150	0.130	0.126	0.140	0.122	0.132	0.124	0.140	0.122
26	0.157	0.154	0.145	0.137	0.152	0.142	0.135	0.150	0.131	0.127	0.140	0.122	0.132	0.125	0.140	0.123
27	0.156	0.153	0.143	0.136	0.151	0.141	0.134	0.149	0.130	0.125	0.139	0.121	0.131	0.123	0.139	0.121
28	0.155	0.153	0.143	0.136	0.151	0.141	0.134	0.149	0.130	0.125	0.139	0.121	0.131	0.123	0.139	0.121
29	0.163	0.161	0.157	0.143	0.158	0.155	0.141	0.156	0.136	0.137	0.151	0.132	0.137	0.135	0.150	0.130
30	0.165	0.164	0.159	0.145	0.160	0.157	0.143	0.158	0.138	0.139	0.154	0.134	0.139	0.138	0.152	0.132
31	0.164	0.162	0.157	0.143	0.158	0.156	0.142	0.157	0.136	0.138	0.152	0.132	0.138	0.136	0.150	0.131
32	0.164	0.162	0.158	0.144	0.159	0.156	0.142	0.157	0.136	0.138	0.152	0.133	0.138	0.136	0.150	0.131
33	0.164	0.162	0.158	0.144	0.159	0.156	0.142	0.157	0.137	0.138	0.152	0.133	0.138	0.136	0.151	0.131
34	0.155	0.153	0.147	0.136	0.150	0.145	0.134	0.148	0.129	0.128	0.142	0.123	0.131	0.127	0.140	0.122
35	0.156	0.154	0.147	0.136	0.150	0.145	0.134	0.148	0.129	0.128	0.142	0.123	0.131	0.127	0.140	0.122
36	0.155	0.153	0.146	0.136	0.150	0.144	0.134	0.148	0.129	0.128	0.141	0.123	0.130	0.126	0.139	0.121
37	0.152	0.150	0.142	0.133	0.147	0.140	0.131	0.145	0.126	0.125	0.138	0.120	0.128	0.123	0.136	0.118
38	0.161	0.159	0.154	0.141	0.156	0.152	0.140	0.154	0.134	0.135	0.149	0.130	0.136	0.133	0.147	0.128
39	0.161	0.159	0.153	0.141	0.155	0.151	0.139	0.153	0.133	0.134	0.148	0.129	0.135	0.132	0.146	0.127
40	0.159	0.158	0.151	0.140	0.154	0.150	0.138	0.152	0.132	0.133	0.146	0.127	0.134	0.131	0.144	0.126

Table 17: Fertilizer requirements for crop rotation wheat- barley- rapeseed- grain maize, combined with one or more mitigation practice(s)in $tN.ha^{-1}$. BAU = rotation baseline, without mitigation pratice, NI = Nitrification inhibitors, Leg= including legumes in the rotation, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges. To determine these parameters, we use the individual proportions of each activity in the rotation, which are derived from FADN data for standard groups (refer to table 3). These proportions are then multiplied by the average nitrogen requirement in $tN.ha^{-1}$ for each region and activity, as provided by the ADEME carbon base. For rapeseed and barley in Alsace and grain maize in Lorraine, data on nitrogen requirements are unavailable. Therefore, we assume that the nitrogen requirements are similar to those of corresponding activities in Lorraine and Champagne, respectively. For NI and Leg practices, we integrate a reduction in nitrogen dose based on regional results obtained as part of the [Pellerin et al., 2017] expertise. We assume that if these practices are implemented together, their effect results in a cumulative nitrogen reduction. For hedgerow and agroforestry practices, we reduce nitrogen requirements on the basis of the reduction in cultivated area according to [Pellerin et al., 2019] expertise (see Table 4). The coefficients shown in the table below are rounded to the cent.

		Champagne	Lorraine	Alsace
Perm Grass		0.046	0.046	0.046
Maize fodder	BAU	0.124	0.116	0.069
	NI	0.122	0.114	0.069
	TempG	0.082	0.081	0.064
	AF	0.108	0.102	0.061
	Hedg	0.120	0.113	0.067
	NI+ AF	0.107	0.100	0.060
	NI+ Hedg	0.119	0.111	0.066
	AF+ Hedg	0.105	0.098	0.058
	NI+ Hedg+ AF	0.103	0.097	0.058
	TempG+ AF	0.072	0.071	0.056
	TempG+ Hedg	0.080	0.078	0.061
	TempG+ Hedg+ AF	0.070	0.068	0.053
	TempG+ NI	0.081	0.080	0.063
	TempG+ NI+ AF	0.071	0.070	0.055
	TempG+ NI+ Hedg	0.079	0.078	0.061
	TempG+ NI+ Hedg+ AF	0.069	0.068	0.053

Table 18: Fertilizer requirements for permanent grassland and fodder maize combined with one or more mitigation practice(s) in $tN.ha^{-1}$. Perm Grass = permanent grassland, BAU = fodder maize baseline, without mitigation pratice, NI = Nitrification inhibitors, TempG=Inserting temporary grassland into fodder maize, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges. To determine these parameters, we use the average nitrogen requirement in $tN.ha^{-1}$ for each region and activity, as provided by the ADEME carbon base based on the 2006 cultivation practice surveys. Since the requirements for permanent grassland are not available at sub-regional level, we assume that the nitrogen requirement for this activity corresponds to the average requirement for France. For NI practice, we integrate a reduction in nitrogen dose based on regional results obtained as part of the [Pellerin et al., 2017] expertise. For hedges and agroforestry practices, we reduce nitrogen requirements compared with the baseline situation, depending on the reduction in cultivated area, according to [Pellerin et al., 2019] expertise (see Table 4). The parameters shown in this table are rounded to the cent.

8 GHG emission factors for combinations of cropping activities and mitigation practices

Rotation activity	Champagne	Lorraine	Alsace
BAU	0.406	0.406	0.406
NI	0.403	0.403	0.403
Leg	0.347	0.347	0.347
AF	0.235	0.235	0.235
Hedg	0.274	0.274	0.272
Leg+ NI	0.344	0.344	0.344
NI+ AF	0.232	0.232	0.232
NI+ Hedg	0.271	0.271	0.269
NI+ Hedg+ Agro	0.101	0.100	0.099
Leg+ AF	0.184	0.184	0.184
Leg+ Hedg	0.217	0.216	0.215
Leg+ Hedg+ AF	0.053	0.053	0.052
AF+ Hedg	0.103	0.103	0.101
Leg+ NI+ AF	0.181	0.181	0.181
Leg+ NI+ Hedg	0.217	0.216	0.212
Leg+ NI+ Hedg+ AF	0.054	0.054	0.049

Table 19: GHG emission factors for combinations of crop rotation (wheat- rapeseed- barley-grain maize) and mitigation practice(s) in $tCO_2e.ha^{-1}$.BAU = rotation baseline, without mitigation pratice, NI = Nitrification inhibitors, Leg= including legumes in the rotation, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges. To determine these parameters, we use the individual proportions of each activity in the rotation, which are derived from FADN data for standard groups (refer to table 3). These proportions are then multiplied by the average emissions factors in France, by activity, provided by the ADEME carbon base. These emission factors by activity include CO_2 emissions linked to fuel combustion, and upstream emissions linked to fuel and farm machinery production. For NI and Leg we consider the additional mitigation potential estimated by the expertise [Pellerin et al., 2017]. For NI, the reduction in GHG emissions compared with the baseline comes from the reduction in direct and upstream fuel emissions linked to the reduction in nitrogen spreading. For Leg: lower N_2O emissions due to the introduction of legumes, and lower CO_2 emissions linked to fuel use due to the change in technical itinerary concerning the proportion of legumes. For AF and Hedg, the additional mitigation potential is the one estimated by the expertise [Pellerin et al., 2019]. For these two practices, we consider a decrease in CO_2 emissions due to the reduction in the area under crop and also a decrease in emissions due to energy substitution with pruning wood. When practices are cumulated, the parameters are calculated according to the surface areas on which they can be applied, as specified in the table 4. Parameters in this table are rounded to the cent.

		Champagne	Lorraine	Alsace
Perm Grass		0.217	0.217	0.217
Maize fodder	BAU	0.406	0.406	0.406
	NI	0.403	0.403	0.403
	TempG	0.311	0.311	0.311
	AF	0.235	0.235	0.235
	Hedg	0.274	0.274	0.272
	NI+ AF	0.232	0.232	0.232
	NI+ Hedg	0.271	0.271	0.269
	NI+ Hedg+ AF	0.101	0.100	0.099
	AF+ Hedg	0.103	0.103	0.101
	TempG+ AF	0.152	0.152	0.152
	TempG+ Hedg	0.182	0.182	0.181
	TempG+ Hedg+ AF	0.023	0.023	0.022
	TempG+ NI	0.294	0.295	0.299
	TempG+ NI+ AF	0.138	0.138	0.142
	TempG+ NI+ Hedg	0.166	0.166	0.169
	TempG+ NI+ Hedg+ AF	0.009	0.010	0.011

Table 20: GHG emission factors for combinations of fodder maize and mitigation practice(s), and permanent grassland in $tCO_2e.ha^{-1}$. Perm Grass = permanent grassland, BAU = fodder maize baseline, without mitigation pratice, NI = Nitrification inhibitors, TempG=Inserting temporary grassland into fodder maize, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges. To determine these parameters, we use the average emissions factors in France, by activity, provided by the ADEME carbon base. These emission factors by activity include CO_2 emissions linked to fuel combustion, and upstream emissions linked to fuel and farm machinery production. For NI we consider the additional mitigation potential estimated by the expertise [Pellerin et al., 2017] and the reduction in GHG emissions compared with the baseline comes from the reduction in direct and upstream fuel emissions linked to the reduction in nitrogen spreading. For TempG, AF and Hedg, the additional mitigation potential is the one estimated by the expertise [Pellerin et al., 2019]. For AF and Hedg, we consider a decrease in CO_2 emissions due to the reduction in the area under crop and also a decrease in emissions due to energy substitution with pruning wood. When practices are cumulated, the parameters are calculated according to the surface areas on which they can be applied, as specified in the table 4. Parameters in this table are rounded to the cent.

8.1 Initial carbon stocks

	Crop	Permanent grassland
Champagne	206.43	318.26
Lorraine	224	334.77
Alsace	202.40	286

Table 21: Initial carbon stocks in t$CO_2e.ha^{-1}$. Average data by land use in the 3 regions. Data source : Statistics on carbon stocks (0-30 cm) in RMQS (The soil quality measurement network in France) network soils, [Martin et al., 2019]

9 Maximum carbon stock

Crop activity	Mitigation practice(s)	Champagne	Lorraine	Alsace
Rotation	BAU	178.00	208.14	202.57
	NI	178.00	208.14	202.57
	Leg	178.00	208.14	202.57
	NI+Leg	178.00	208.14	202.57
	Hedg	208.53	226.15	204.76
	NI+ Hedg	208.53	226.15	204.76
	Leg+NI+Hedg	208.53	226.15	204.76
	AF	233.94	251.51	228.80
	NI+AF	233.94	251.51	228.80
	Leg+AF	233.94	251.51	228.80
	Leg+NI+AF	233.94	251.51	228.80
	AF+Hedg	235.24	252.83	230.27
	NI+Hedg+AF	235.24	252.83	230.27
	Leg+Hedg	208.53	226.15	204.76
	Leg+Hedg+AF	235.24	252.83	230.27
	Leg+ NI+ Hedg+ AF	235.24	252.83	230.27
Perm Grass	BAU	318.72	334.50	285.49
Fodder maize	BAU	178.00	208.14	202.57
	NI	178.00	208.14	202.57
	Hedg	208.53	226.15	204.76
	NI+ Hedg	208.53	226.15	204.76
	AF	233.94	251.51	228.80
	NI+ AF	233.94	251.51	228.80
	TempG	241.47	258.44	207.20
	NI+ TempG	241.47	258.44	207.20
	AF+ Hedg	235.24	252.83	230.27
	NI+ Hedg+ AF	235.24	252.83	230.27
	TempG+ AF	237.81	254.86	206.77
	TempG+ AF+ NI	237.81	254.86	206.77
	TempG+ Hedg	241.85	258.84	208.62
	TempG+ Hedg+ NI	241.85	258.84	208.62
	TempG+ AF+ Hedg	238.30	255.40	208.21
	TempG+ Hedg+ NI+ AF	238.30	255.40	208.21
Fallow bare	BAU	134	164.14	158.57

Table 23: Maximum carbon stock for each combination crop activity - mitigation practice(s) in $tCO_2e.ha^{-1}$. Perm Grass = permanent grassland, BAU = baseline, crop activity without mitigation pratice, NI = Nitrification inhibitors, TempG=Inserting temporary grassland into fodder maize, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges, Leg= including legumes in the rotation. Maximum baseline stock parameters are derived from STICS simulations of the expertise [Pellerin et al., 2019]. For the maximum stocks of carbon-sequestering practices (AF, Hedge and TempG), they are calculated by multiplying the annual additional carbon potential for each practice from [Pellerin et al., 2019] (also estimated with STICS), by 30 (the time horizon of expertise [Pellerin et al., 2019]), then adding this additional potential over 30 years to the initial carbon stock (see table 21). Annual additional potential data are from [Bamière et al., 2021b].

For combinations of carbon-sequestering practices, we have followed the cumulation assumptions made by [Pellerin et al., 2019], namely: agroforestry has an additional potential per ha that decreases by approximately 3% (depending on the region) when cumulated with hedgerow insertion (see table 4). The same applies to temporary grassland when combined with hedgerows insertion. For the combination of agroforestry and temporary grassland insertion, we add up the two additional potentials, from which we subtract: the additional stokage on the inter-row of agroforestry (considered as null), and the additional sequestration potential of temporary grassland insertion at tree line level, i.e. on 12.5% of the surface. For the cumulation of the 3 carbon-sequestering activities, we take the additional potential of the cumulation of agroforestry with the insertion of temporary grassland reduced by approximately 3% (see table 4) to which we add the additional potential of the insertion of hedgerows. Finally, for fallow bare, we consider a 20-year average annual carbon increment from the literature, which [Arrouays et al., 2002] used as data for the fallow bare. We add this increment, multiplied by 31, to the initial carbon stock of the crops to obtain the maximum carbon stock associated with fallow bare.

10 Sequestration rate/ mineralization coefficient

	Champagne	Lorraine	Alsace
Perm Grass	0.025000	0.025000	0.025000
Rotation and Fodder maize BAU	0.025000	0.025000	0.025000
AF	0.024063	0.024063	0.024063
Hedg	0.025000	0.025000	0.025000
TempG	0.025000	0.025000	0.025000
Hedg+ TempG	0.025000	0.025000	0.025000
AF+ TempG	0.024063	0.024063	0.024063
AF+ Hedg	0.024090	0.024091	0.024094
Fallow bare	0.025000	0.025000	0.025000

Table 24: Sequestration rate/ mineralization coefficient (or coefficient of destruction of organic matter, K2), in $year^{-1}$. Perm Grass = permanent grassland, BAU = baseline, crop activity without mitigation pratice(s), TempG=Inserting temporary grassland into fodder maize, AF = Intra-plot agroforestry, Hedg = Insertion of hedges along plot edges. The rate is the same whether the mitigation practice(s) are applied to rotation or fodder maize. For these parameters we use the coefficients considered in [Arrouays et al., 2002], based on a literature review. For the practices Perm Grass, Hedg, and TempG, all rates are 0.025 $year^{-1}$. The rate for the change from cultivation to afforestation is 0.0175 $year^{-1}$. We therefore apply this coefficient to the surface area of the tree line in the agroforestry practice (i.e. 12.5%) based on the hypothesis of [Pellerin et al., 2019]. For the accumulation between practices, we use the same assumptions as for the accumulation of surfaces in [Pellerin et al., 2019](see table 4).

11 Additional sequestration in above-ground biomass

	Champagne	Lorraine	Alsace
Hedg	0.858	0.877	0.995
Agro	3.30	3.30	3.30

Table 25: Annual additional sequestration in above-ground biomass in $tCO_2e.ha^{-1}.year^{-1}$. The source of this data is expertise [Pellerin et al., 2019, Bamière et al., 2021b]

12 Fixed cost for implementing agroforestry and hedges

	Agroforestry	Hedgerows
Champagne		631
Lorraine	1007	646
Alsace		732

Table 26: Fixed cost for implementing agroforestry and hedges in €$.ha^{-1}$. Includes costs of advice, planting, for both. For agroforestry in addition : soil preparation, protection and mulching and sowing under the trees. Data Source : [Pellerin et al., 2019, Bamière et al., 2021a].

13 Composition of composite cattle

Farm group	Region	TEO	Dairy cow		Suckler cow	
			Share less than 1 year	Share others	Share less than 1 year	Share others
7	Champagne	Dairy cattle	0.77	1.15	*N.A*	*N.A*
8	Champagne	Dairy cattle	0.76	1.02	*N.A*	*N.A*
9	Champagne	Dairy cattle	0.82	0.94	*N.A*	*N.A*
10	Champagne	Rearing-fattening cattle	*N.A*	*N.A*	0.82	0.69
11	Champagne	Mixed livestock	0.78	1.03	1.06	1.64
12	Champagne	Mixed livestock	0.78	1.03	0.98	1.43
13	Champagne	Mixed livestock	0.78	1.03	1.60	2.20
14	Champagne	Mixed crop-livestock	0.78	1.03	0.45	0.10
15	Champagne	Mixed crop-livestock	0.78	1.03	0.78	*N.A*
19	Lorraine	Dairy cattle	0.50	0.60	*N.A*	*N.A*
20	Lorraine	Dairy cattle	0.75	0.79	*N.A*	*N.A*
21	Lorraine	Dairy cattle	0.86	0.90	*N.A*	*N.A*
22	Lorraine	earing-fattening cattle	*N.A*	*N.A*	0.83	0.57
23	Lorraine	Rearing-fattening cattle	*N.A*	*N.A*	1.00	1.01
24	Lorraine	Mixed livestock	0.70	0.76	1.38	1.63
25	Lorraine	Mixed livestock	0.70	0.76	1.98	2.15
26	Lorraine	Mixed crop-livestock	0.70	0.76	0.80	0.66
27	Lorraine	Mixed crop-livestock	0.70	0.76	0.91	0.78

28	Lorraine	Mixed crop-livestock	0.70	0.76	1.19	1.55
34	Alsace	Dairy cattle	0.40	0.32	*N.A*	*N.A*
35	Alsace	Dairy cattle	0.52	0.47	*N.A*	*N.A*
36	Alsace	Dairy cattle	0.50	0.42	*N.A*	*N.A*
37	Alsace	Rearing-fattening cattle	*N.A*	*N.A*	0.81	0.73
38	Alsace	Mixed crop-livestock	0.47	0.40	0.76	0.66
39	Alsace	Mixed crop-livestock	0.47	0.40	2.80	6.83
40	Alsace	Mixed crop-livestock	0.47	0.40	1.37	1.25

To create the composite animals, we start by considering farm groups that specialize in dairy and rearing-fattening cattle. We estimate the proportion of head in each category (under one year and other) per main cow (dairy and suckler cow). Composite animals for these farming types coorespond to one main animal head + the proportion of each other category.
For farm groups classified as Mixed livestock or mixed crop-livestock, where both dairy and suckler cows coexist, we assume that the number of cows in each category per dairy cow aligns with the average number of cows found in dairy cattle farm groups within the same region. The remaining number of cows not assigned to dairy cows is regarded as part of the suckler cow herd. Using this information, we can calculate the number of cows in each category per suckler cow for both Mixed livestock and multi-crop, mixed livestock farms. However, it should be noted that this approach to estimate composite animals for mixed livestock and mixed crop-livestock farms is an estimation based on a simplified assumption and does not take into account specific variations in each operation. As a result, the results may be approximate and subject to a certain margin of error.

14 Initial herd size , LU per composite animal, the number of LU per ha of grassland and purchase price of a composite animal

Farm group	Dairy cows	Suckler cows	Initial menu
7	27.44	*N.A*	Grass
8	54.98	*N.A*	Grass- maize fodder
9	101.70	*N.A*	Grass- maize fodder
10	*N.A*	74.93	Grass- maize fodder
11	20.66	14.34	Grass
12	40.67	24.18	Grass- maize fodder
13	76.63	35.68	Maize fodder
14	23.02	15.27	Grass
15	64.48	17.65	Grass- maize fodder
19	28.07	*N.A*	Grass
20	55.25	*N.A*	Grass- maize fodder
21	93.28	*N.A*	Grass- maize fodder
22	*N.A*	51.74	Grass- maize fodder
23	*N.A*	119.89	Maize fodder
24	44.94	23.67	Grass- maize fodder
25	87.27	30.98	Grass- maize fodder
26	0.59	41.54	Grass
27	20.68	30.14	Grass- maize fodder
28	72.54	19.20	Maize fodder
34	26.06	*N.A*	Grass
35	55.46	*N.A*	Maize fodder
36	104.51	*N.A*	Maize fodder
37	*N.A*	40.79	Grass
38	2.60	6.00	Grass
39	31.11	1.69	Maize fodder
40	66.64	11.44	Maize fodder

Table 28: Number of composite dairy and suckler cows per farm group in initial state. Data source : FADN data 2009-2013 by farm group. A description of how menus are allocated in the initial state is available in the 17 section of the appendix.

According to the FADN (reference year 2010), both a suckler cow and a dairy cow are each counted as 1 Livestock Unit (LU) per head. A bovine under one year old (calf) is counted as 0.3 LU per head. Other non-dairy bovines, including bovines one year old and older that do not produce milk, are counted as 0.7 LU per head. These coefficients are used to calculate the number of Livestock Units associated with each composite animal per farm, considering the proportions of each bovine category per main bovine group (dairy cows and suckler cows).

Farm group	LU per composite dairy cow	LU per composite suckler cow
7	2.04	*N.A*
8	1.94	*N.A*
9	1.90	*N.A*
10	*N.A*	1.73
11	1.96	2.47
12	1.96	2.29
13	1.96	3.02
14	1.96	1.21
15	1.96	1.23
19	1.57	*N.A*
20	1.78	*N.A*
21	1.89	*N.A*
22	*N.A*	1.65
23	*N.A*	2.01
24	1.74	2.55
25	1.74	3.10
26	1.74	1.70
27	1.74	1.82
28	1.74	2.44
34	1.34	*N.A*
35	1.48	*N.A*
36	1.44	*N.A*
37	*N.A*	1.75
38	1.42	1.69
39	1.42	6.62
40	1.42	2.29

Table 29: LU per composite animal per farm group

Farm group	Head per ha
7	0.56
8	0.60
9	0.65
10	0.80
11	0.47
12	0.61
13	0.61
14	0.71
15	0.80
19	0.59
20	0.63
21	0.67
22	0.77
23	0.73
24	0.62
25	0.70
26	0.78
27	0.73
28	0.72
34	0.51
35	1.14
36	1.37
37	0.61
38	0.51
39	1.06
40	1.02

Table 30: Number of head of composite cattle per ha of main forage area (fodder maize + permanent grassland). Estimate by adding up the number of dairy and suckler cows (if any on the farm) and dividing by the number of ha of forage maize and permanent grassland.

Farm group	Dairy cow price	Suckler cow price
7	4160.73	*N.A*
8	3803.95	*N.A*
9	3607.51	*N.A*
10	*N.A*	3085.18
11	3855.50	4578.09
12	3855.50	4217.06
13	3855.50	5922.18
14	3855.50	1922.93
15	3855.50	2170.26
19	2721.06	*N.A*
20	3225.65	*N.A*
21	3511.36	*N.A*
22	*N.A*	2958.16
23	*N.A*	3710.01
24	3137.30	4931.24
25	3137.30	6280.31
26	3137.30	3039.89
27	3137.30	3313.42
28	3137.30	4618.47
34	1974.32	*N.A*
35	2375.24	*N.A*
36	2243.98	*N.A*
37	*N.A*	3134.69
38	2192.10	2988.29
39	2192.10	13191.42
40	2192.10	4445.29

Table 31: Purchase price of a composite animal to increase the herd in €.$head^{-1}$. This price is calculated on the basis of IDELE case type data for dairy and suckler cattle in the Grand Est (reference years 2015 and 2011 respectively), and is an average of the 3 menus for each type of cattle.

15 Feed requirement per composite bovine

Farm group	Fodder maize					Grass			Fodder maize - Grass				
	Conc	Milk powder	Straw	Fodder maize	Grass	Conc	Straw	Grass	Fodder maize	Conc	Milk powder	Straw	Grass
7	2.82	0.03	2.12	3.60	8.29	2.18	2.10	11.67	2.14	1.78	0.03	2.04	9.90
8	2.70	0.03	2.02	3.60	7.74	2.13	2.00	11.01	2.14	1.73	0.03	1.94	9.36
9	2.64	0.04	1.98	3.60	7.54	2.12	1.96	10.77	2.14	1.70	0.04	1.90	9.16
11	2.72	0.04	2.04	3.60	7.85	2.14	2.02	11.14	2.14	1.73	0.04	1.96	9.46
12	2.72	0.04	2.04	3.60	7.85	2.14	2.02	11.14	2.14	1.73	0.04	1.96	9.46
13	2.72	0.04	2.04	3.60	7.85	2.14	2.02	11.14	2.14	1.73	0.04	1.96	9.46
14	2.72	0.04	2.04	3.60	7.85	2.14	2.02	11.14	2.14	1.73	0.04	1.96	9.46
15	2.72	0.04	2.04	3.60	7.85	2.14	2.02	11.14	2.14	1.73	0.04	1.96	9.46
19	2.36	0.02	1.63	3.60	5.98	1.85	1.62	9.05	2.14	1.57	0.02	1.57	7.75
20	2.52	0.03	1.85	3.60	7.20	2.04	1.83	10.49	2.14	1.64	0.03	1.78	8.95
21	2.61	0.04	1.96	3.60	7.84	2.13	1.95	11.26	2.14	1.68	0.04	1.89	9.59
24	2.49	0.03	1.81	3.60	6.98	2.00	1.79	10.23	2.14	1.63	0.03	1.74	8.74
25	2.49	0.03	1.81	3.60	6.98	2.00	1.79	10.23	2.14	1.63	0.03	1.74	8.74
26	2.49	0.03	1.81	3.60	6.98	2.00	1.79	10.23	2.14	1.63	0.03	1.74	8.74
27	2.49	0.03	1.81	3.60	6.98	2.00	1.79	10.23	2.14	1.63	0.03	1.74	8.74
28	2.49	0.03	1.81	3.60	6.98	2.00	1.79	10.23	2.14	1.63	0.03	1.74	8.74
34	2.12	0.02	1.40	3.60	4.24	1.70	1.38	6.71	2.14	1.47	0.02	1.34	5.76
35	2.24	0.02	1.54	3.60	4.98	1.81	1.53	7.59	2.14	1.52	0.02	1.48	6.48
36	2.20	0.02	1.50	3.60	4.77	1.78	1.49	7.34	2.14	1.51	0.02	1.44	6.28
38	2.19	0.02	1.48	3.60	4.65	1.76	1.46	7.20	2.14	1.50	0.02	1.42	6.16
39	2.19	0.02	1.48	3.60	4.65	1.76	1.46	7.20	2.14	1.50	0.02	1.42	6.16
40	2.19	0.02	1.48	3.60	4.65	1.76	1.46	7.20	2.14	1.50	0.02	1.42	6.16

Table 32: Feed requirement per composite dairy cow in t.$head^{-1}.year.{-1}$. Con=Concentrate. Grass represents the sum of grass requirements in all forms (grazing, hay, silage, etc.). The calculation of these requirements is based on IDELE's Grand Est dairy cattle case types (reference year 2015) and varies according to the composition of the composite dairy cow within the group type. The different menus come from the following case types: Fodder maize = case type 6, Grass= case type 2, Corn-fodder-grass = case type 5. The categories of feed vary depending on the menu, as certain products are excluded from menus (for example the milk powder in the Grass menu).

Farm group	Fodder maize				Grass			Fodder maize - Grass			
	Fodder maize	Grass	Conc	Straw	Grass	Conc	Straw	Fodder maize	Grass	Conc	Straw
10	1.55	5.76	0.85	0.40	6.87	0.52	1.60	1.27	4.23	0.91	0.29
11	2.07	9.32	1.13	0.59	10.28	0.66	2.38	1.90	9.46	1.21	0.43
12	1.92	8.50	1.06	0.54	9.49	0.63	2.20	1.74	9.46	1.14	0.40
13	2.98	11.79	1.34	0.73	12.71	0.77	2.96	2.70	9.46	1.44	0.54
14	0.91	3.38	0.65	0.26	4.56	0.43	1.06	0.66	9.46	0.70	0.19
15	1.39	3.32	0.66	0.27	4.58	0.43	1.09	0.97	9.46	0.71	0.20
22	1.56	5.70	0.82	0.38	6.94	0.51	1.52	1.25	4.44	0.88	0.28
23	1.89	7.47	0.95	0.47	8.65	0.58	1.90	1.60	4.44	1.02	0.34
24	2.54	10.11	1.16	0.61	11.26	0.68	2.47	2.24	8.74	1.25	0.45
25	3.52	12.60	1.36	0.75	13.76	0.78	3.04	3.07	8.74	1.47	0.55
26	1.53	6.00	0.84	0.39	7.22	0.52	1.58	1.25	8.74	0.90	0.29
27	1.71	6.54	0.88	0.42	7.75	0.54	1.70	1.41	8.74	0.95	0.31
28	2.26	9.64	1.12	0.58	10.77	0.66	2.36	2.01	8.74	1.20	0.43
37	1.55	5.53	0.86	0.40	6.54	0.53	1.63	1.29	4.00	0.92	0.30
38	1.47	5.25	0.83	0.39	6.27	0.52	1.56	1.21	6.16	0.89	0.28
39	5.52	27.56	2.70	1.67	27.29	1.45	6.74	5.78	6.16	2.90	1.22
40	2.47	7.74	1.06	0.54	8.70	0.63	2.19	2.08	6.16	1.14	0.40

Table 34: Feed requirement per composite suckler cow in t.$head^{-1}.year.-1$. Con=Concentrate. Grass represents the sum of grass requirements in all forms (grazing, hay, silage, etc.). The calculation of these requirements is based on IDELE's Grand Est rearing-fattening cattle case types (reference year 2011) and varies according to the composition of the composite dairy cow within the group type. The different menus come from the following case types: Fodder maize = HIV2, Grass= HEVI, Corn-fodder-grass = CVGS4. The feed categories vary depending on the menu, as certain products are excluded from menus (for example the Fodder maize in the Grass menu).

16 Cost per composite cattle

Farm group	BAU			Add Nit		
	Grass	Fodder maize	Grass-Fodder maize	Grass	Fodder maize	Grass-Fodder maize
7	272.00	412.00	332.00	288.84	428.84	348.84
8	272.00	412.00	332.00	288.77	428.77	348.77
9	272.00	412.00	332.00	289.15	429.15	349.15
11	272.00	412.00	332.00	288.90	428.90	348.90
12	272.00	412.00	332.00	288.90	428.90	348.90
13	272.00	412.00	332.00	288.90	428.90	348.90
14	272.00	412.00	332.00	288.90	428.90	348.90
15	272.00	412.00	332.00	288.90	428.90	348.90
19	272.00	412.00	332.00	286.99	426.99	346.99
20	272.00	412.00	332.00	288.67	428.67	348.67
21	272.00	412.00	332.00	289.44	429.44	349.44
24	272.00	412.00	332.00	288.36	428.36	348.36
25	272.00	412.00	332.00	288.36	428.36	348.36
26	272.00	412.00	332.00	288.36	428.36	348.36
27	272.00	412.00	332.00	288.36	428.36	348.36
28	272.00	412.00	332.00	288.36	428.36	348.36
34	272.00	412.00	332.00	286.32	426.32	346.32
35	272.00	412.00	332.00	287.12	427.12	347.12
36	272.00	412.00	332.00	287.00	427.00	347.00
38	272.00	412.00	332.00	286.80	426.80	346.80
39	272.00	412.00	332.00	286.80	426.80	346.80
40	272.00	412.00	332.00	286.80	426.80	346.80

Table 35: Cost per composite dairy cow per €$.head^{-1}.year^{-1}$. BAU=Baseline as usual, without mitigation practice, Add Nit = practice addition of 1 % nitrate in the ration of ruminants.

These costs differ according to the composite dairy cow's feed menu and the mitigation practices that the farmer applies to its feed. BAU costs are taken from IDELE case types for dairy cattle in the Grand Est region (reference year 2015), where Fodder maize = case type 6, Grass= case type 2, Corn-fodder-grass = case type 5. These costs include artificial insemination, milk control, veterinary expenses and other breeding costs. For costs with mitigation practices, these are the BAU costs added to the additional costs of implementing these practices on a French scale estimated by [Pellerin et al., 2017].

Farm group	BAU			Add Nit		
	Grass	Fodder maize	Grass-Fodder maize	Grass	Fodder maize	Grass-Fodder maize
10	91.00	84.00	79.00	95.65	88.65	83.65
11	91.00	84.00	79.00	97.02	90.02	85.02
12	91.00	84.00	79.00	96.58	89.58	84.58
13	91.00	84.00	79.00	100.15	93.15	88.15
14	91.00	84.00	79.00	93.57	86.57	81.57
15	91.00	84.00	79.00	95.45	88.45	83.45
22	91.00	84.00	79.00	95.74	88.74	83.74
23	91.00	84.00	79.00	96.73	89.73	84.73
24	91.00	84.00	79.00	98.85	91.85	86.85
25	91.00	84.00	79.00	102.29	95.29	90.29
26	91.00	84.00	79.00	95.59	88.59	83.59
27	91.00	84.00	79.00	96.20	89.20	84.20
28	91.00	84.00	79.00	97.80	90.80	85.80
37	91.00	84.00	79.00	95.63	88.63	83.63
38	91.00	84.00	79.00	95.36	88.36	83.36
39	91.00	84.00	79.00	106.95	99.95	94.95
40	91.00	84.00	79.00	98.83	91.83	86.83

Table 36: Cost per composite suckler cow per €$.head^{-1}.year^{-1}$. BAU=Baseline as usual, without mitigation practice, Add Nit = practice addition of 1 % nitrate in the ration of ruminants

These costs differ according to the composite suckler cow's feed menu and the mitigation practices that the farmer applies to its feed. BAU costs are taken from IDELE case types for suckler cattle in the Grand Est region (reference year 2011), where Fodder maize = HIV2, Grass= HEVI, Corn-fodder-grass = CVGS4. These costs include various breeding expenses of which veterinary expenses. For cost with mitigation practice, there is the BAU costs added to the additional costs of implementing this practice on a French scale estimated by [Pellerin et al., 2017].

Farm group	Dairy cow			Suckler cow		
	Grass	Grass-Fodder maize	Fodder maize	Grass	Grass-Fodder maize	Fodder maize
7	260.61	122.71	103.33	*N.A*	*N.A*	*N.A*
8	247.94	116.74	98.31	*N.A*	*N.A*	*N.A*
9	243.24	114.53	96.45	*N.A*	*N.A*	*N.A*
10	*N.A*	*N.A*	*N.A*	67.64	20.34	87.43
11	250.45	117.92	99.30	102.81	33.29	167.37
12	250.45	117.92	99.30	94.86	30.39	149.31
13	250.45	117.92	99.30	124.55	40.90	216.79
14	250.45	117.92	99.30	45.57	12.43	37.27
15	250.45	117.92	99.30	42.73	11.04	30.82
19	201.00	94.64	79.70	*N.A*	*N.A*	*N.A*
20	227.49	107.11	90.20	*N.A*	*N.A*	*N.A*
21	241.52	113.72	95.76	*N.A*	*N.A*	*N.A*
22	*N.A*	*N.A*	*N.A*	63.54	18.79	78.12
23	*N.A*	*N.A*	*N.A*	79.72	24.69	114.90
24	222.77	104.89	88.33	103.22	33.13	168.32
25	222.77	104.89	88.33	123.53	40.14	214.47
26	222.77	104.89	88.33	66.68	20.00	85.27
27	222.77	104.89	88.33	71.22	21.59	95.58
28	222.77	104.89	88.33	99.86	32.05	160.68
34	171.65	80.82	68.06	*N.A*	*N.A*	*N.A*
35	189.80	89.36	75.26	*N.A*	*N.A*	*N.A*
36	184.63	86.93	73.21	*N.A*	*N.A*	*N.A*
37	*N.A*	*N.A*	*N.A*	69.14	20.91	90.85
38	181.72	85.56	72.05	66.40	19.93	84.63
39	181.72	85.56	72.05	295.04	103.65	604.33
40	181.72	85.56	72.05	89.56	28.01	137.26

Table 38: Cost per composite cattle for grass transformation into hay, silage, and baling in €$.head^{-1}$. Hay costs include baling, storage and transport, and are estimated at 41 €$.tDM^{-1}$. For grass silage: transport and storage, at 10.8 €$.tDM^{-1}$, and wrapping: baling, wrapping and transport at 88.32 €$.tDM^{-1}$. These costs come from [Bamière et al., 2021a]. We then relate these costs to the requirements for each type of forage on the IDELE standard menu and to the composition of composite cattle per farm group to obtain a grass processing cost per composite cattle (IDELE case types for dairy cattle in the Grand Est region (reference year 2015), where Fodder maize = case type 6, Grass= case type 2, Corn-fodder-grass = case type 5, and IDELE case types for suckler cattle in the Grand Est region (reference year 2011), where Fodder maize = HIV2, Grass= HEVI, Corn-fodder-grass = CVGS4.).

17 Income per composite cow

Farm group	Grass	Grass-Fodder maize	Fodder maize
7	2015.21	2519.01	2760.84
8	1545.05	2060.07	2389.68
9	1590.75	2121	2460.36
11	1969.06	2461.32	2697.61
12	1625.56	2167.41	2514.20
13	1507.33	2009.77	2392.58
14	2094.70	2618.37	2869.74
15	1774.76	2366.35	2744.97
19	1906.62	2383.28	2612.07
20	1593	2124	2463.84
21	1710.91	2281.21	2646.20
24	1656.15	2208.20	2561.51
25	1757.42	2343.23	2718.15
26	2134.86	2668.57	2924.75
27	1780.20	2373.60	2753.38
28	1572.11	2096.14	2495.40
34	1778.45	2223.06	2436.48
35	1486.32	1981.76	2359.24
36	1517.08	2022.77	2408.06
38	2284.41	2855.51	3129.64
39	1550.13	2066.84	2460.53
40	1601.99	2135.99	2542.84

Table 39: Income from milk production per composite dairy cow in €$.head^{-1}.year^{-1}$.

Farm group	Dairy cow			Suckler cow		
	Grass	Grass-Fodder maize	Fodder maize	Grass	Grass-Fodder maize	Fodder maize
7	585.26	702.31	702.31	*N.A*	*N.A*	*N.A*
8	503.98	629.97	629.97	*N.A*	*N.A*	*N.A*
9	512.71	640.89	640.89	*N.A*	*N.A*	*N.A*
10	*N.A*	*N.A*	*N.A*	787.47	984.34	984.34
11	624.47	749.37	749.37	1089.97	1307.96	1307.96
12	499.58	624.47	624.47	882.38	1102.97	1102.97
13	499.58	624.47	624.47	1432.67	1790.84	1790.84
14	624.47	749.37	749.37	790.06	948.07	948.07
15	499.58	624.47	624.47	1227.53	1534.41	1534.41
19	360.03	432.04	432.04	*N.A*	*N.A*	*N.A*
20	507.30	634.13	634.13	*N.A*	*N.A*	*N.A*
21	644.67	805.84	805.84	*N.A*	*N.A*	*N.A*
22	*N.A*	*N.A*	*N.A*	879.24	1099.06	1099.06
23	*N.A*	*N.A*	*N.A*	1041.16	1301.45	1301.45
24	482.45	603.06	603.06	1400.25	1750.31	1750.31
25	482.45	603.06	603.06	2447.00	3058.75	3058.75
26	603.06	723.67	723.67	1154.09	1384.91	1384.91
27	482.45	603.06	603.06	1011.95	1264.93	1264.93
28	482.45	603.06	603.06	1808.86	2261.08	2261.08
34	335.49	402.59	402.59	*N.A*	*N.A*	*N.A*
35	325.93	407.41	407.41	*N.A*	*N.A*	*N.A*
36	322.41	403.01	403.01	*N.A*	*N.A*	*N.A*
37	*N.A*	*N.A*	*N.A*	1008.83	1210.60	1210.60
38	386.45	463.74	463.74	1080.31	1296.38	1296.38
39	309.16	386.45	386.45	5021.56	6276.95	6276.95
40	309.16	386.45	386.45	1377.68	1722.10	1722.10

Table 40: Income from sale of cattle and related products (meat, hides, etc.) per composite dairy and suckler cow in €$.head^{-1}.year^{-1}$.

Income per composite animal and per diet is estimated using income data by animal type from 2009-2013 FADN data on farm groups. Income from the sale of cattle and derived products (meat, hides, etc.) per composite dairy cow for mixed livestock and mixed crop-livestock farms is determined from the average non-dairy income per dairy cow for specialist dairy farms in the same region, taking into account the weighting by number of farms represented. The remainder of the non-dairy income on mixed livestock and mixed crop-livestock farms is then allocated to suckler cows.

The initial diet for each farm group is estimated based on the proportion of fodder maize in the main forage area, using the IDELE case studies (dairy cattle : reference year 2015 ,where Fodder maize = case type 6, Grass= case type 2, Corn-fodder-grass = case type 5, and suckler cattle : reference year 2011, Fodder maize = HIV2, Grass= HEVI, Corn-fodder-grass = CVGS4) . For farms specializing in dairy, Mixed livestock and mixed crop-livestock, the initial diet based on the proportion of fodder maize is determined by the following levels :

- < 10 %: grass menu

- $> 10\ \% < 20\ \%$: fodder maize-grass menu
- $> 20\ \%$: fodder maize menu

For beef farms, the initial diet based on the proportion of fodder maize is determined by the following levels :

- $< 1\%$: grass diet
- $> 1\% < 7\%$: fodder maize- grass diet
- $> 7\%$: fodder maize diet

Once the initial diet is determined, we apply yield increase or decrease coefficients, previously deducted from the variations in yields between the IDELE typical cases, to estimate the yields of the other diets.

18 Nitrogen produced per composite cow

Farm group	Dairy cow						Suckler cow					
	Manure			Grazing			Grazing			Manure		
	Grass	Grass-Fodder maize	Fodder maize	Grass	Grass-Fodder maize	Fodder maize	Grass	Grass-Fodder maize	Fodder maize	Grass	Grass-Fodder maize	Fodder maize
7	0.08	0.09	0.08	0.16	0.15	0.02	0.09	0.07	0.06	0.04	0.05	0.05
8	0.08	0.09	0.08	0.15	0.14	0.02	0.09	0.07	0.06	0.04	0.05	0.05
9	0.08	0.08	0.08	0.15	0.14	0.01	0.09	0.07	0.06	0.04	0.05	0.05
10	0.05	0.05	0.05	0.07	0.06	0.01	0.13	0.10	0.09	0.05	0.07	0.07
11	0.08	0.09	0.08	0.15	0.14	0.02	0.18	0.14	0.13	0.06	0.08	0.09
12	0.08	0.09	0.08	0.15	0.14	0.02	0.17	0.13	0.12	0.06	0.08	0.08
13	0.08	0.09	0.08	0.15	0.14	0.02	0.22	0.17	0.15	0.07	0.09	0.10
14	0.08	0.09	0.08	0.15	0.14	0.02	0.10	0.08	0.07	0.04	0.05	0.06
15	0.08	0.09	0.08	0.15	0.14	0.02	0.10	0.08	0.07	0.04	0.06	0.06
19	0.07	0.07	0.07	0.12	0.11	0.01	0.09	0.07	0.06	0.04	0.05	0.05
20	0.08	0.08	0.08	0.14	0.13	0.01	0.09	0.07	0.06	0.04	0.05	0.05
21	0.08	0.09	0.08	0.15	0.14	0.02	0.09	0.07	0.06	0.04	0.05	0.05
22	0.05	0.05	0.05	0.07	0.06	0.01	0.13	0.10	0.09	0.05	0.06	0.07
23	0.05	0.05	0.05	0.07	0.06	0.01	0.15	0.12	0.11	0.05	0.07	0.08
24	0.07	0.08	0.07	0.14	0.13	0.01	0.19	0.14	0.13	0.06	0.08	0.09
25	0.07	0.08	0.07	0.14	0.13	0.01	0.22	0.17	0.16	0.07	0.10	0.10
26	0.07	0.08	0.07	0.14	0.13	0.01	0.13	0.10	0.09	0.05	0.07	0.07
27	0.07	0.08	0.07	0.14	0.13	0.01	0.14	0.11	0.10	0.05	0.07	0.07
28	0.07	0.08	0.07	0.14	0.13	0.01	0.18	0.14	0.13	0.06	0.08	0.09
34	0.06	0.06	0.06	0.10	0.10	0.01	0.09	0.07	0.06	0.04	0.05	0.05
35	0.07	0.07	0.07	0.11	0.11	0.01	0.09	0.07	0.06	0.04	0.05	0.05

36	0.06	0.07	0.06	0.11	0.10	0.01	0.09	0.07	0.06	0.04	0.05	0.05
37	0.05	0.05	0.05	0.07	0.06	0.01	0.14	0.10	0.10	0.05	0.07	0.07
38	0.06	0.07	0.06	0.11	0.10	0.01	0.13	0.10	0.09	0.05	0.06	0.07
39	0.06	0.07	0.06	0.11	0.10	0.01	0.44	0.34	0.31	0.12	0.17	0.18
40	0.06	0.07	0.06	0.11	0.10	0.01	0.17	0.13	0.12	0.06	0.08	0.08

Table 41: Nitrogen produced per composite cow in t.$head^{-1}.year^{-1}$, in meadows and in the barn in the form of manure. Quantities are calculated using OMINEA data from CITEPA (reference year 2013), which gives the weight of N per day spent grazing and in the barn. (We took the data for manure concerning effluent in buildings, but these data are very close to the data for slurry, to within 0.1g per day). Then we use the number of days spent grazing and in the barn given by IDELE's case studies for cattle in Grand Est for dairy cattle (reference year 2015 ,where Fodder maize = case type 6, Grass= case type 2, Corn-fodder-grass = case type 5) and suckler cattle (reference year 2011, Fodder maize = HIV2, Grass= HEVI, Corn-fodder-grass = CVGS4).

19 GHG emissions per composite cattle

Farm group	Dairy cow		Suckler cow	
	BAU	Add Nit	BAU	Add Nit
7	7.18	6.74	2.37	2.37
8	6.94	6.49	2.37	2.37
9	6.90	6.45	2.37	2.37
10	3.98	3.69	4.88	4.71
11	7.00	6.56	6.87	6.66
12	7.00	6.56	6.39	6.19
13	7.00	6.56	8.72	8.40
14	7.00	6.56	3.29	3.20
15	7.00	6.56	3.68	3.52
19	5.81	5.42	2.37	2.37
20	6.54	6.10	2.37	2.37
21	6.91	6.45	2.37	2.37
22	3.98	3.69	4.71	4.55
23	3.98	3.69	5.73	5.52
24	6.41	5.98	7.39	7.11
25	6.41	5.98	9.26	8.86
26	6.41	5.98	4.82	4.65
27	6.41	5.98	5.19	5.01
28	6.41	5.98	6.95	6.71
34	5.17	4.80	2.37	2.37
35	5.62	5.23	2.37	2.37
36	5.51	5.12	2.37	2.37
37	3.98	3.69	4.94	4.78
38	5.43	5.04	4.74	4.59
39	5.43	5.04	18.43	17.87
40	5.43	5.04	6.75	6.47

Table 42: GHG emission factor per composite cattle in $tCO_2e.head^{-1}.year^{-1}$. BAU=Baseline as usual, without mitigation practice, Add Nit = practice addition of 1 % nitrate in the ration of ruminants. BAU coefficients are estimated from OMINAE database (reference year 2013) from CITEPA and include enteric fermentation emissions (CH_4) and effluent management emissions (CH_4 and N_2O, storage and production of effluent in farm buildings without spreading). Conversions to CO_2e are based on IPCC GWP assumptions over a 100-year period (28 for CH_4 and 274 for N_2O). For the other coefficients, the mitigation potential of practices, estimated [Pellerin et al., 2017], is deducted from the BAU coefficients.

20 Prices of feed purchased and mineral nitrogen fertilizer

Parameter	Data	Source
Milk powder	2140 €.t^{-1}	average of IDELE dairy case studies number 2 and 5 (reference year 2015)
Dairy cow concentrate	276.30 €.t^{-1}	average of IDELE dairy case studies number 2, 5 and 6 (reference year 2015)
Suckler cow concentrate	251.30 €.t^{-1}	average of IDELE rearing-fattening cattle case studies HIV2, HEVI and CVGS4 (reference year 2011)
Straw	25 €.t^{-1}	average of IDELE dairy case studies number 2, 5 and 6 (reference year 2015)
Mineral nitrogen fertilizer	911 €.tN^{-1}	same data as in [Pellerin et al., 2017] report, sourced from Eurostat

Table 43: Prices of feed purchased and mineral nitrogen fertilizer

21 GHG emissions factor for livestock feed purchase and nitrogen purchase/spreading

Parameter	Data	Details	Source
EF for an average mineral nitrogen fertilizer	10,1 t$CO_2e.tN^{-1}$	4,267t $CO_2e.tN^{-1}$ for upstream GHGs (linked to production) and 5.754 t$CO_2e.tN^{-1}$ for spreading (direct N_2O emissions,volatilization and livixation)	IPCC GHG emissions factor, [Eggleston et al., 2006]
EF for spreading organic cattle manure	6.028 t$CO_2e.tN^{-1}$	Direct N_2O emissions, volatilization and livixation	IPCC GHG emissions factor, [Eggleston et al., 2006]
EF for cattle effluents released to meadows	10,4 t$CO_2e.tN^{-1}$	Direct N_2O emissions, volatilization and livixation	IPCC GHG emissions factor, [Eggleston et al., 2006]
EF Milk powder	17tCO_2e/t		Database Base Carbone, ADEME
EF Concentrate for cattle	0.468 t$CO_2e.t^{-1}$	Purchase category for cereal-type cattle feed	Database Base Carbone, ADEME

Table 44: GHG Emissions factor for livestock feed purchases and nitrogen purchases/spreading. Conversions to CO_2e are based on IPCC GWP assumptions over a 100-year period (28 for CH_4 and 274 for N_2O).

22 Additional cost, yields nitrogen requirement and mitigation potential for each practice

Practices	Effects on GHGs	Parameters variation (yields, production costs, ..)	Variation in GHG emissions	SOC sequestration (0-30 cm) ($tCO2e.ha^{-1}.year^{-1}$)	Above-ground biomass sequestration ($tCO2e.ha^{-1}.year^{-1}$)	Scale of costs and mitigation potential	Source
Use of nitrification inhibitors	N_2O, CO_2	Application of inhibitors 1 year in 5, -6,1 €$.ha^{-1}.year^{-1}$ fuel savings during spreading, +0,34 €$.kgN^{-1}$ purchasing inhibitors, 10% reduction in the reducible nitrogen dose per crop the year of application	-0.003 $tCO_2e.ha^{-1}.year^{-1}$ due to fuel combustion, -0.0001584 $tCO_2e.ha^{-1}.year^{-1}$of upstream emissions linked to fuel use	0	0	Farm group for crop rotation (different share of crop activities), Sub-region for fodder maize	[Pellerin et al., 2017, Bamière et al., 2021b]
Introduction of 1/6 ha of legumes in the rotation (on 1/6 ha of soft wheat, 1/6 ha of rapeseed, and 2/3 ha of barley)	N_2O, CO_2	Yield reductions on areas where legumes are introduced, crop production costs on $1/6$ of the ha replaced by those of legumes , suppression of nitrogen input : -0.033 $tN.ha^{-1}.year^{-1}$ per ha of legumes introduced	+0.077 $tCO_2e.ha^{-1}.year^{-1}$ per ha of legumes due to symbiotic nitrogen fixation, -0.021 $tCO_2e.ha^{-1}.year^{-1}$ and - 0.00465 per ha of legume for respectively direct and indirect CO_2 emissions linked to the use of fuel (reduction in nitrogen spreading)	0	0	Farm group (different share of crop activities)	[Pellerin et al., 2017, Bamière et al., 2021b]

Temporary grassland insertion (in a fodder maize mono culture)	SOC, N_2O, CO_2	Variation in production (yields, nitrogen and production costs) due to reallocation of surface : 50% fodder maize, 50% temporary grassland, reduced nitrogen dosage on the crop following the grassland (fodder maize) (in $tN.ha^{-1}.year^{-1}$): Champagne 0.017, Lorraine 0.012, and Alsace 0	Variation in GHG emissions due to reallocation of surface	Champagne : 1.168, Lorraine 1.148, Alsace 0.160	0	Sub-region	[Pellerin et al., 2019, Bamière et al., 2021a, Bamière et al., 2021b]
Intra-plot agroforestry	SOC, biomass, N_2O, CO_2	Variation in production (yield loss, reduction of production costs and nitrogen) on 12.5% of the surface due to tree planting, yield loss on the inter-row after 16 years of implementation, assuming annualization of this loss over 30 years: additional annual loss of 3.97%, Tree maintenance costs : 95.33 €$.ha^{-1}.year^{-1}$, Sale of pruning wood: 14.7 €$.ha^{-1}.year^{-1}$, Fixed installation costs (due to tree planting): 1007 €$.ha^{-1}$	12.5% reduction in GHG emissions per ha of crops, -0.12 $tCO_2e.ha^{-1}.year^{-1}$ substitution effect due to the use of thinning wood (energy)	Champagne 0.917, Lorraine 0.917, Alsace 0.88 (In the case of combination with the insertion of temporary grassland in fodder maize : Champagne and Lorraine 0.5692, Alsace 0.550)	3.3	Farm group for rotation (different share of crop activities) and Sub-regional for fodder maize	[Pellerin et al., 2019, Bamière et al., 2021a, Bamière et al., 2021b]

Planting hedges along plot edges	SOC, biomass, N_2O, CO_2	Decrease in yields, production costs and nitrogen inputs due to variation in crop area per ha (For Champagne -2.9%, Lorraine -3%, Alsace -3.4%), Maintenance costs (€$.ha^{-1}.year^{-1}$) : Champagne 62 , Lorraine 61.83, Alsace 70.1, Wood sales (€$.ha^{-1}.year^{-1}$) : Champagne -24.9, Lorraine -25.5, Alsace -28.93, Fixes implementation cost (€$.ha^{-1}$) : Champagne 631, Lorraine 646, Alsace 732	Reduction in GHG emissions due to variation in crop area, -0.12 $tCO_2e.ha^{-1}.year^{-1}$ substitution effect due to the use of thinning wood (energy)	On crop : Champagne 0.07, Lorraine 0.071, Alsace 0.078; On temporary grassland : Champagne 0.023, Lorraine 0.024, Alsace 0.027	Champagne : 0.858 Lorraine 0.877, Alsace 0.995	Farm group for rotation and sub-regional for fodder maize	[Pellerin et al., 2019, Bamière et al., 2021a, Bamière et al., 2021b]

Addition of 1 % nitrate in ruminants ration	CH_4	-11.6 €$.head^{-1}.year^{-1}$ for dairy cow and 6.8 for young dairy cattle, 5.7 for young suckler cattle from nitrate purchases and urea savings	-0.289 $tCO_2e.head^{-1}.year^{-1}$ for dairy cow and -0.203 for young cattle	0	0	Farm group (different composition of composite cattle)	[Pellerin et al., 2017, Bamière et al., 2021b]

Table 45: Additional mitigation potential and variation in parameters (yields, costs, nitrogen application, etc.) per mitigation practice. The SOC is provided here as a yearly constant parameter, but it is only indicative since we consider carbon sequestration in the soil dynamically. The parameters associated with this dynamic process, such as the sequestration rate, initial carbon stock, and maximum stock, are represented in Tables 21, 23 and 24 in the appendix. Moreover, these data are additional to the baseline practice, but total costs, total yields, GHG emissions and other parameters are available for each combination of mitigation practice(s) - crop activity and livestock activity- mitigation practice(s), in the appendix (tables 5, 7, 6, 8 9,10, 13, 15,16, 17, 18, 19, 20 for crop activities and 35, 36, 42 for livestock activities).

References

[Arrouays et al., 2002] Arrouays, D., Balesdent, J., Germon, J., Jayet, P., Soussana, J., and Stengel, P. (2002). Stocker du carbone dans les sols agricoles de france? expertise scientifique collective. rapport d'expertise réalisé par inra à la demande du ministère de l'ecologie et du développement durable. *Contribution à la lutte contre l'effet de serre. Paris, France: INRA (in French)*.

[Bamière et al., 2023] Bamière, L., Bellassen, V., Angers, D., Cardinael, R., Ceschia, E., Chenu, C., Constantin, J., Delame, N., Diallo, A., Graux, A.-I., Houot, S., Klumpp, K., Launay, C., Letort, E., Martin, R., Mézière, D., Mosnier, C., Réchauchère, O., Schiavo, M., Thérond, O., and Pellerin, S. (2023). A marginal abatement cost curve for climate change mitigation by additional carbon storage in french agricultural land. *Journal of Cleaner Production*, 383:135423.

[Bamière et al., 2021a] Bamière, L., Mosnier, C., Bellassen, V., Schiavo, M., Delame, N., Letort, E., Cardinael, R., and Meziere, D. (2021a). Etude 4pour1000 : Données économiques.

[Bamière et al., 2021b] Bamière, L., Schiavo, M., Bellassen, V., Letort, E., Mosnier, C., and Delame, N. (2021b). Etude 4pour1000 : Données modèle BANCO.

[Eggleston et al., 2006] Eggleston, H., Buendia, L., Miwa, K., Ngara, T., and Tanabe, K., editors (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change (IPCC). IGES, Japan.

[Martin et al., 2019] Martin, M., Saby, N., Toutain, B., Chenu, J.-p., Ratié, C., and Boulonne, L. (2019). Statistiques sur les stocks de carbone (0-30 cm) des sols du réseau RMQS.

[Pellerin et al., 2019] Pellerin, S., Bamière, L., Launay, C., Martin, R., Schiavo, M., Angers, D., Augusto, L., Balesdent, J., Doelsch, I. B., Bellassen, V., et al. (2019). Stocker du carbone dans les sols français, quel potentiel au regard de l'objectif 4 pour 1000 et à quel coût?

[Pellerin et al., 2017] Pellerin, S., Bamière, L., Angers, D., Béline, F., Benoit, M., Butault, J.-P., Chenu, C., Colnenne-David, C., De Cara, S., Delame, N., Doreau, M., Dupraz, P., Faverdin, P., Garcia-Launay, F., Hassouna, M., Hénault, C., Jeuffroy, M.-H., Klumpp, K., Metay, A., Moran, D., Recous, S., Samson, E., Savini, I., Pardon, L., and Chemineau, P. (2017). Identifying cost-competitive greenhouse gas mitigation potential of french agriculture. *Environmental Science & Policy*, 77:130–139.