Nutri2Cycle

Transition towards a more carbon and nutrient efficient agriculture in Europe

Field trial with recycling-derived fertilizers

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- Animal manure = unpredictable N mineralisation kinetics
- Legal constraints on animal manure application (170 kg N/ha, total N)
- Crop N demand exceeds organic N supply → Mineral top dressings
- Surplus animal manure in Flanders → Manure processing (€, CO_2↑)
- Mineral (N) fertilizer production (€, CO_2↑)

- Solution = processed animal manure (predictable mineralisation kinetics)
- Legal constraints: processed animal manure has the same legal status as animal manure
- Thorough evaluation of agricultural value and environmental impact of processed animal manure requested by the legislator.

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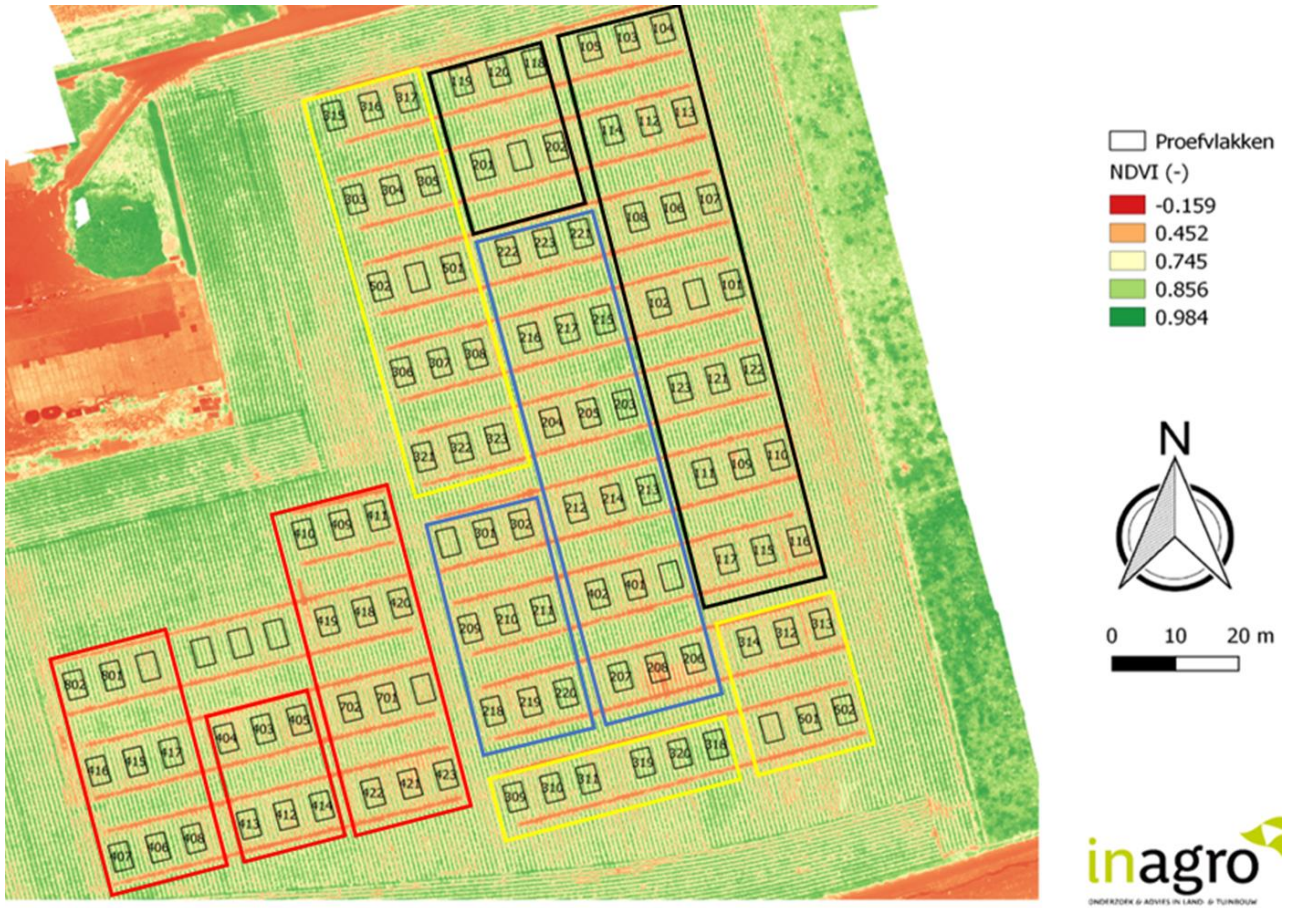
RDF	Source	N – total (g kg -1)	NO_3-N (g kg -1)	NH_4-N (g kg -1)	P – total (g kg -1)	K – total (g kg -1)	S – total (g kg -1)
Ammonium-nitrate*	Stripping/scrubbing installation	86-198	43-89	43-109	-	-	-
Ammonium-sulphate*	Air scrubber	30-86	-	30-86	-	-	60-100
Pig urine**	Primary separation in the stable	3,3 - 6,2	-	3,0 – 5,1	0,01-1,0	3,2-4,7	0,25-0,76
Liquid fraction digestate *	Solid/liquid separation	3,67 – 6,0	2,54 – 3,9	2,5-4,5	1,17 – 3,50	2,5 – 3,2	0,2 - 1
Digestate**	Anaerobic digestion	4 - 9	-	3,5-5	4 - 6	2 - 5	0,5 – 1,5

*https://systemicproject.eu/
**Harms et, al., 2021 : Handbook of best practice example fertilizer plans andrecommendations (Interreg NWE Renu2farm)

Nr	RDF/fertilizer (N)	Dose (X = N –advice)	RDF/fertilizer (P, K, S)	Dose (Y = P, K, S advice of highest dose applied via RDF's)	# parallells
1	-	0	0	0	8
2	-	0	Mineral fertilizer	Y	8
3	Mineral fertilizer	X – 60%	Mineral fertilizer	Y	4
4	Mineral fertilizer	X - 40%	Mineral fertilizer	Y	4
5	Mineral fertilizer	X	Mineral fertilizer	Y	4
6	Pig slurry	X – 60%	Pig slurry + mineral fertilizer	Y – plant available PKS applied via pig slurry	4
7	Pig slurry	X - 40%	Pig slurry + mineral fertilizer	Y – plant available PKS applied via pig slurry	4
8	Pig slurry	X	Pig slurry + mineral fertilizer	Y – plant available PKS applied via pig slurry	4
9	Product 1	X – 60%	Product 1 + mineral fertilizer	Y – plant available PKS applied via product 1	4
10	Product 1	X - 40%	Product 1 + mineral fertilizer	Y – plant available PKS applied via product 1	4
11	Product 1	X	Product 1 + mineral fertilizer	Y – plant available PKS applied via product 1	4
	…	…	…	…	…
23	Product 5	X	Product 5 + mineral fertilizer	Y – plant available PKS applied via product 5	4

Field trial design :

- Random variability linked to soil conditions
- Randomized block trial (4 parallels/ object, 8 parallels for the negative references
- Split plot design
- Preliminary screening
  - NDVI preceding catch crop
  - Chemical analysis of soil parameters
  - Penetration resistance measurement
- Divergent sectors were omitted
- Choice of blocks based upon measured soil characteristics



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Timeline

- Winter 2018 – 2019 : Italian ryegrass
- Spring 2019 : Screening
- 2019 : Maize (silage) after ploughing
  - N advice (100%) = 151 kg N/ha
- 2020 : Spinach after non inversing soil tillage
  - N advice (100%) = 210 kg N/ha
- 2020 : Maize (silage) after ploughing
- 2021 : Early potatoes after ploughing
  - N advice (100%) = 140 kg N/ha
- 2021 – 2022 : Italian ryegrass

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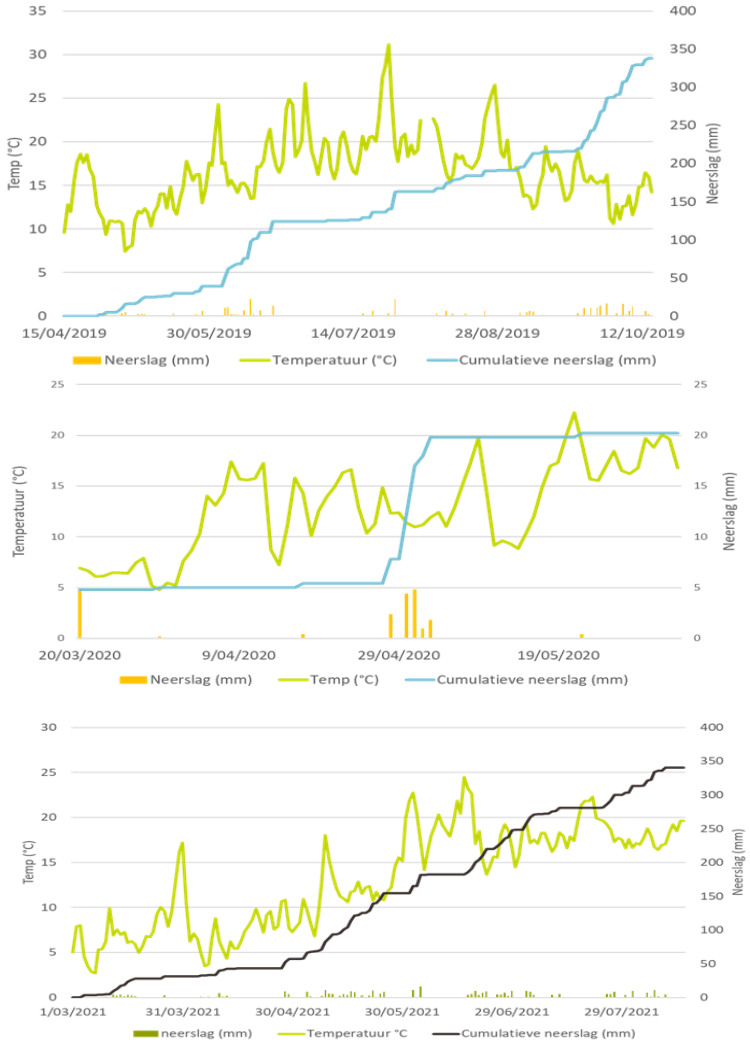
Weather

- 2019 : Maize (silage)
  - Drought stress during vegetative stage
  - Reduced growth and N uptake in all plots
- 2020 : spinach
  - Dryest spring recorded -> irrigation
  - ‘Dust storm’ – shortly after germination (sandy soil)
  - Block 4 excluded from processed data
- 2021: Early potatoes
  - Verry wet season
  - Partial leaching of applied nitrogen (application before ploughing)



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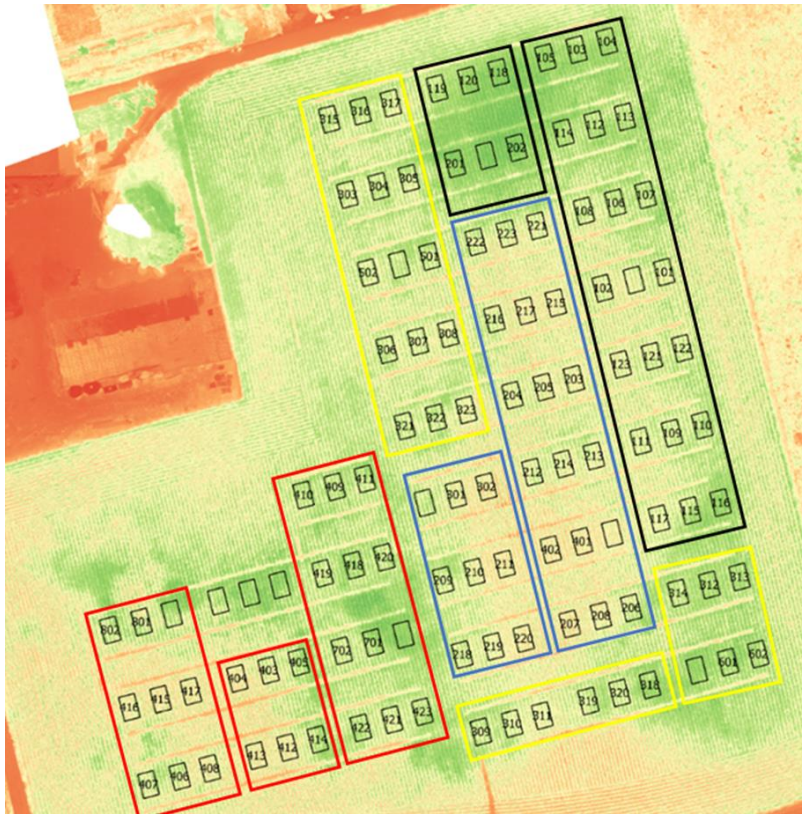
Results 2019 crop

RDF applied	Fresh yield (tons/ha)		Dry yield (tons/ha)		N uptake in aboveground biomass (kg/ha)	
No fertiliser	31.69	a	13.37	a	150.63	a
Mineral PK	30.17	a	12.24	a	140.61	a
Mineral NPK	34.27	a	12.17	a	179.97	a
Pig slurry	30.06	a	10.85	a	159.16	a
Ammonium nitrate	31.66	a	11.62	a	171.94	a
Ammonium sulphate	32.73	a	11.44	a	170.38	a
Pig urine	30.02	a	10.76	a	160.22	a
Liquid fraction from digestate separation	32.86	a	13.24	a	157.33	a
Digestate	31.66	a	11.03	a	166.29	a

N dose applied	Fresh yield (tons/ha)		Dry yield (tons/ha)		N uptake in aboveground biomass (kg/ha)	
0% of advisory N dose	30.93	a	12.80	a	145.62	a
40% of advisory N dose	33.54	a	12.67	a	172.53	a
70 % of advisory N dose	30.34	a	11.00	ab	158.34	a
100 % of advisory N dose	30.72	a	10.70	ab	168.54	a



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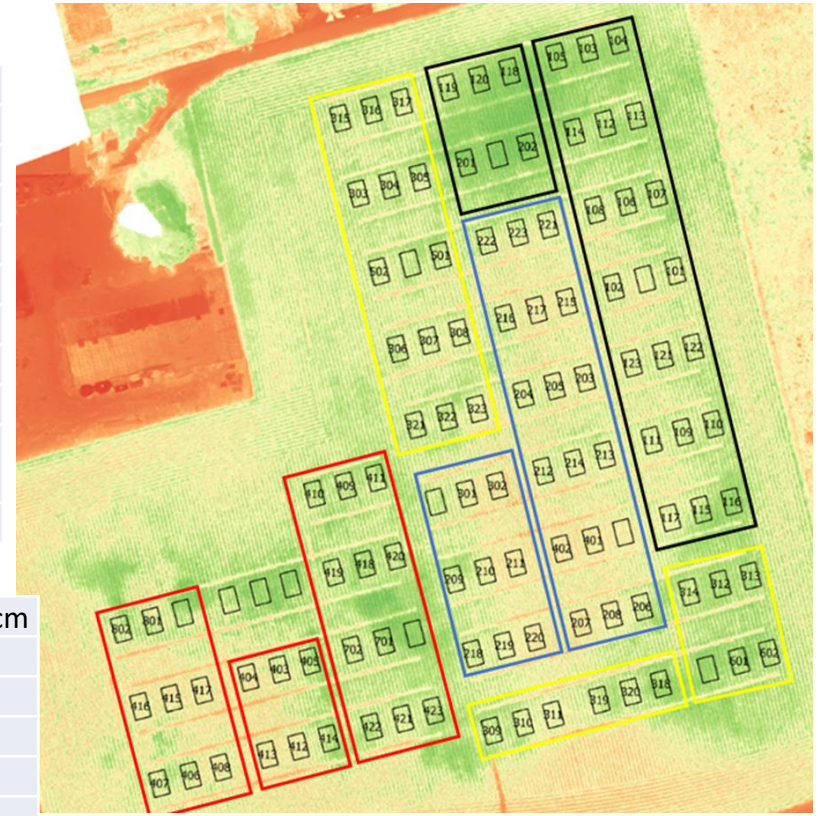
Results 2019 soil

	Residual nitrate 0-30 cm	Residual nitrate 30-60 cm	Residual nitrate 60-90 cm	residual nitrate 0-90 cm
RDF applied	kg NO_3-N/ha	kg NO3-N/ha	kg NO3-N/ha	kg NO3-N/ha
No fertilizer	12 a	22 b	30 a	64 a
Mineral PK	12 a	24 ab	25 a	61 a
Mineral NPK	19 a	41 ab	44 a	104 a
Pig slurry	15 a	42 ab	33 a	90 a
Ammonium nitrate	13 a	43 ab	35 a	91 a
Ammonium sulphate	15 a	40 ab	46 a	100 a
Pig urine	15 a	37 ab	34 a	86 a
Liquid fraction from digestate separation	15 a	36 ab	27 a	78 a
Digestate	17 a	46 a	41 a	104 a

N dose applied	Residual nitrate 0-30 cm	Residual nitrate 30-60 cm	Residual nitrate 60-90 cm	residual nitrate 0-90 cm
	kg NO_3-N/ha	kg NO3-N/ha	kg NO3-N/ha	kg NO3-N/ha
0% of advisory N dose	12 a	23 b	27 a	63 b
40% of advisory N dose	15 a	39 a	35 a	88 a
70 % of advisory N dose	15 a	37 a	39 a	92 a
100 % of advisory N dose	17 a	45 a	38 a	100 a



Results 2020 crop

RDF applied	Fresh yield (ton/ha)	Dry Yield (kg/ha)	N uptake (kg/ha)
No fertilizer	3,45 c	465 c	13.10 cd
Mineral PK	2,35 c	319 c	8.37 d
Mineral NPK	15,18 ab	1712 ab	52.54 abcd
Pig slurry	18,16 a	2170 a	64,64 ab
Ammonium nitrate	**7,81 bc**	**749 bc**	**24.06 bcd**
Ammonium sulphate	17,47 ab	1857 a	74.06 a
Pig urine	15,42 ab	1687 ab	55.48 abc
Liquid fraction from digestate separation	16,54 ab	1759 ab	59.47 ab
Digestate	15,86 ab	1687 ab	63.81 ab

N dose applied	Fresh yield (ton/ha)	Dry Yield (kg/ha)	N uptake (kg/ha)
0% of advisory N dose	2,9 c	393 c	10.74 c
40% of advisory N dose	10,42 b	1147 b	40.06 b
70 % of advisory N dose	15,72 ab	1863 a	54.08 ab
100 % of advisory N dose	19,48 a	2017 a	74.74 a

Results 2020 soil

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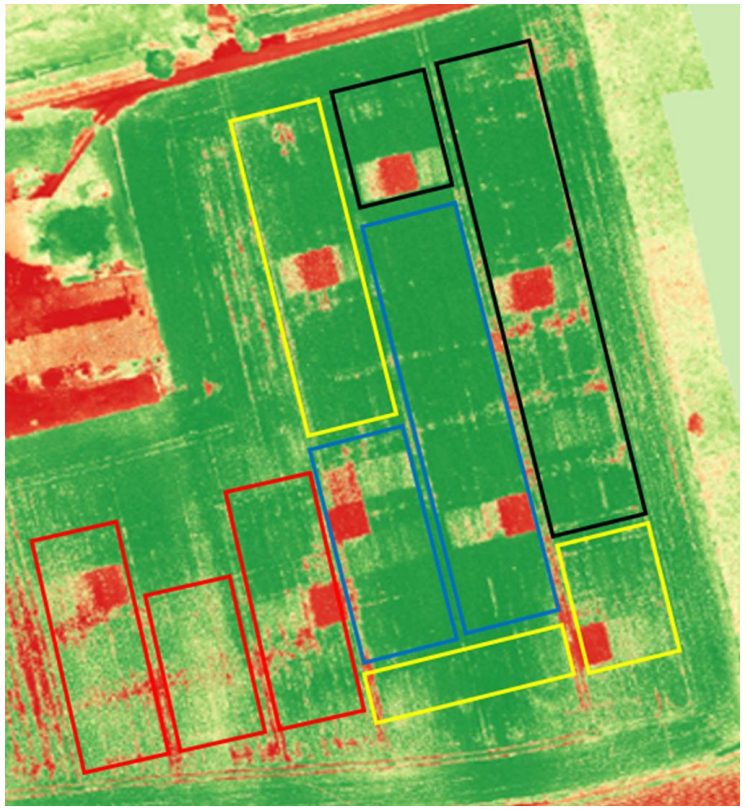
40% of advisory N dose				
RDF	Nitrate 0-30 cm (kg NO_3-N/ha)	Nitrate 30-60cm (kg NO_3-N/ha)	Nitrate 60-90 cm (kg NO_3-N/ha)	Nitrate 0-90 cm (kg NO_3-N/ha)
Ammoniumnitrate	43 a	12 a	9 a	64 a
Ammoniumsulfate	40 a	10 a	7 a	56 a
Digestate	20 a	6 a	12 a	37 a
Liquid fraction	49 a	9 a	8 a	67 a
NPK mineral	63 a	8 a	7 a	79 a
Pig slurry	47 a	15 a	17 a	78 a
Pig urine	40 a	8 a	10 a	58 a

70% of advisory N-dose				
RDF	Nitrate 0-30 cm (kg NO_3-N/ha)	Nitrate 30-60cm (kg NO_3-N/ha)	Nitrate 60-90 cm (kg NO_3-N/ha)	Nitrate 0-90 cm (kg NO_3-N/ha)
Ammoniumnitrate	38 bc	22 a	7 a	67 b
Ammoniumsulfate	102 ab	14 a	7 a	123 ab
Digestate	47 bc	23 a	8 a	78 b
Liquid fraction	18 c	8 a	9 a	35 b
NPK mineral	16 c	4 a	13 a	34 b
Pig slurry	13 c	4 a	12 a	29 b
Pig urine	152 a	21 a	7 a	180 a

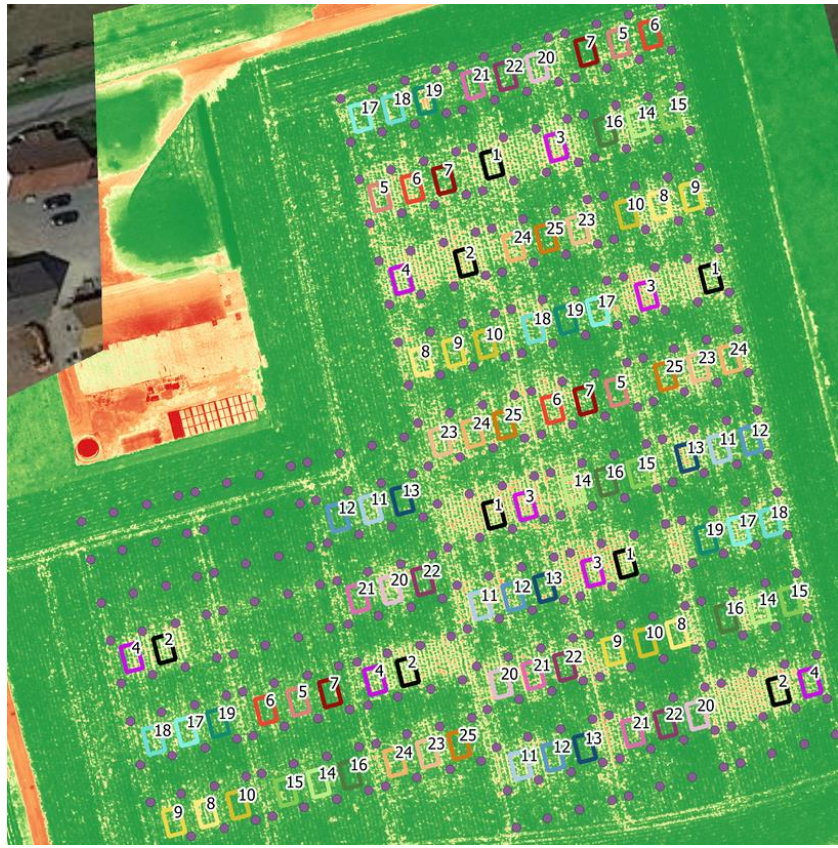
100 % of advisory N-dose				
RDF	Nitrate 0-30 cm (kg NO3-N/ha)	Nitrate 30-60cm (kg NO3-N/ha)	Nitrate 60-90 cm (kg NO3-N/ha)	Nitrate 0-90 cm (kg NO3-N/ha)
Ammoniumnitrate	25 a	8 a	8 a	42 a
Ammoniumsulfate	26 a	13 a	10 a	49 a
Digestate	36 a	11 a	9 a	55 a
Liquid fraction	31 a	9 a	8 a	49 a
NPK mineral	48 a	13 a	9 a	70 a
Pig slurry	26 a	6 a	9 a	41 a
Pig urine	24 a	9 a	8 a	41 a



Results 2021 crop

	Fresh Yield	Dry yield	Marketable Fresh Yield
RDF Applied	Kg/ha	Kg/ha	Kg/ha
No fertilizer	14272 b	3792 b	10696 b
Mineral PK	14649 b	3764 b	11146 b
Mineral NPK	24927 a	6046 a	19753 a
Pig slurry	26376 a	6221 a	21581 a
Ammonium nitrate	23697 a	5828 a	19119 a
Ammonium sulphate	25860 a	6242 a	21197 a
Pig urine	24056 a	5808 a	19700 a
Liquid fraction from digestate separation	24065 a	5811 a	18703 a
Digestate	21623 ab	5272 ab	16619 ab

	Fresh Yield	Dry yield	Marketable Fresh Yield
N dose applied	Kg/ha	Kg/ha	Kg/ha
0%	14460 c	3778 b	10921 c
40%	19391 b	4783 b	15594 b
70%	25756 a	6235 a	20738 a
100%	27970 a	6651 a	22242 a



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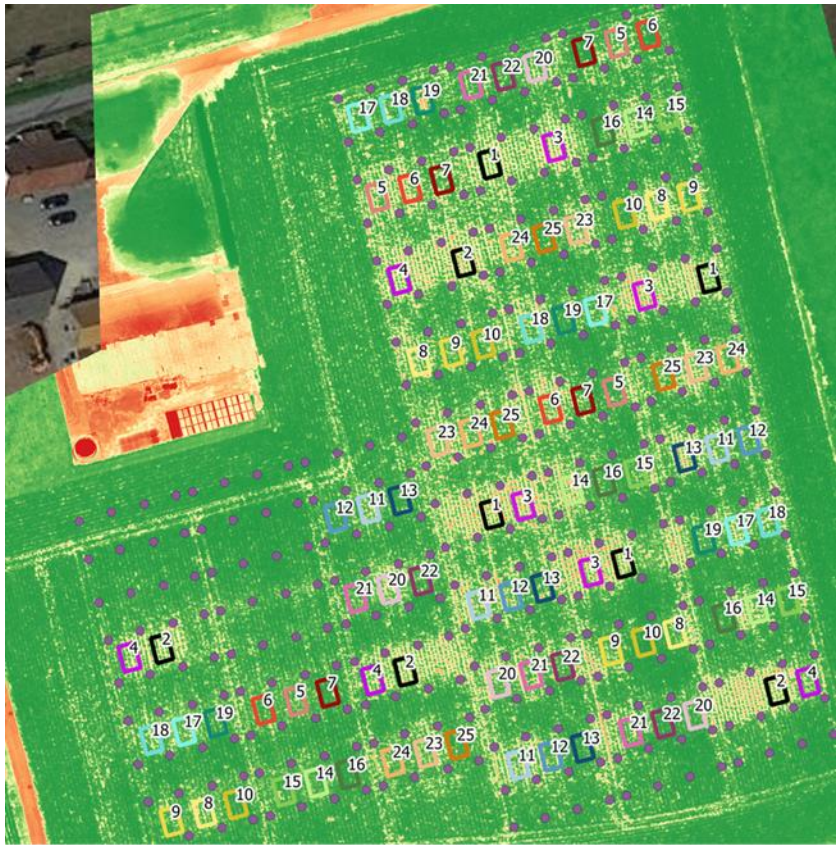
Results 2021 soil

	Residual nitrate 0-30 cm	Residual nitrate 30-60 cm	Residual nitrate 60-90 cm	Residual nitrate 0-90 cm
RDF - applied	kg NO_3-N/ha	kg NO_3-N/ha	kg NO_3-N/ha	kg NO_3-N/ha
No fertilizer	43 a	27 a	25 c	95 ab
Mineral PK	39 a	25 a	26 bc	89 b
Mineral NPK	42 a	41 a	40 a	123 a
Pig slurry	42 a	39 a	40 a	121 ab
Ammonium nitrate	41 a	40 a	42 a	123 a
Ammonium sulphate	40 a	33 a	38 abc	111 ab
Pig urine	44 a	37 a	38 abc	119 ab
Liquid fraction digestate	38 a	34 a	39 ab	112 ab
Digestate	44 a	43 a	42 a	128 a

	Residual nitrate 0-30 cm	Residual nitrate 30-60 cm	Residual nitrate 60-90 cm	Residual nitrate 0-90 cm
N- dose applied	kg NO_3-N/ha	kg NO_3-N/ha	kg NO_3-N/ha	kg NO_3-N/ha
0%	41 a	26 b	26 c	92 b
40%	43 a	41 a	43 a	126 a
70%	42 a	38 a	43 a	123 a
100%	40 a	35 ab	34 b	110 ab



General conclusions

- Only minor differences (crop yield/residual nitrate) could be observed between RDF's applied.
- The effect of weather conditions on crop yield was larger than the product/RDF, and even the N - dose applied.
- Preliminary screening of the field insufficiently considers effects of drought stress.
- In 2020, the use of ammonium nitrate, applied close to the seeds (non inversing tillage) and in extremely dry conditions led to a yield reduction in spinach.
- Top dressings with RDF's are technically not possible yet and field trial application must be done before ploughingg/deep tillage (soil structure). In wet years this may cause nitrate leaching (for all N fertilizers).

Thank you for your attention

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