Land use change from an annual maize cropping systems to a perennial *Silphium perfoliatum* crop has unused potential to reduce GHG emissions in biomass production

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Project: BESTLAND

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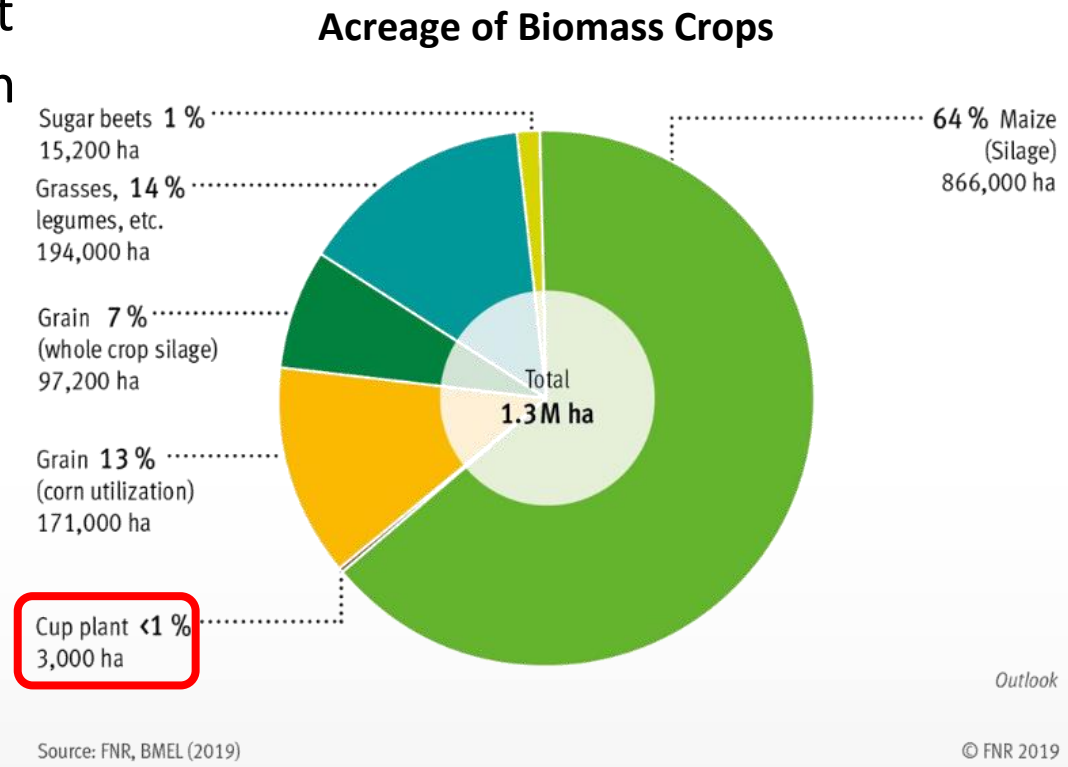
Biogas from biomass
a renewable energy source for base load energy demand

There are more than 9500 biogas plants in Germany. About 850,000 ha agricultural land are used to produce their main feedstock, silage maize.

Other feedstocks only have a small share in comparison.

Intensive maize production may lead to environmental issues:

- Loss of SOM
- Soil compaction
- Soil erosion
- Loss of biodiversity



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Cup plant: an alternative to maize?

Maize (*Z. mays*):

- Dry matter yield: 14-16 t ha^{-1} yr^{-1}
- Annual spring crop
- Intermediate intensity / tillage
- C4 plant
- High N and water use efficiency
- High energy substrate (starch)
- Harvest: mid September - October

Cup plant (*S. perfoliatum*):

- Dry matter yield: 11-17 t ha^{-1} yr^{-1}
- Perennial crop (up to 15 years)
- Low input / no tillage
- C3 plant
- Good winter hardiness
- Attractive for insects (pollinators)
- Harvest: end August- mid September

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Site description

4 paired study sites each with one cup plant and one maize field

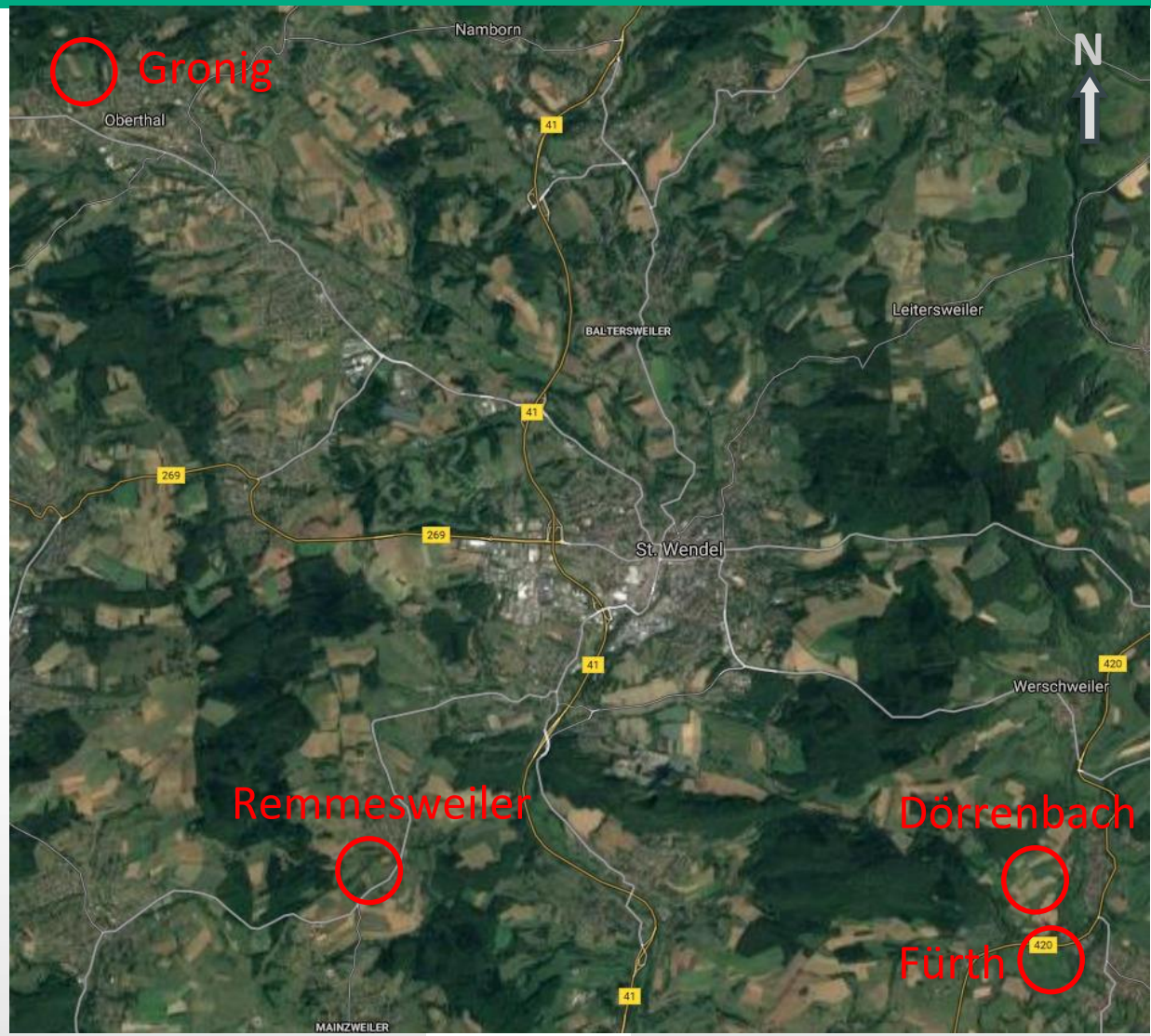
- Located in the Saar-Nahe mountain range, Saarland, Germany
- 280-380 m above sea level
- 3-9° slope
- >950 mm precipitation
- 8.75°C mean annual temperature

Soil characteristics

- Stagnosols and Planosols
- Fine textured: pseudogleyic
- pH 4.1 – 6.5

Fields were managed according to site-specific best management practices by the farmers.

Sites are prone for temporal waterlogging, compaction and erosion!



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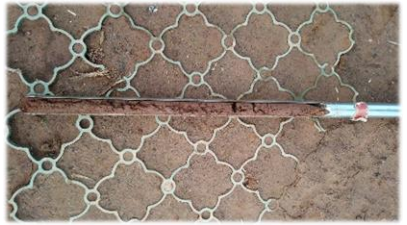
Experimental setup and management

Weekly GHG measurements
- Closed chamber technique
- n=4 per field

Soil mineral nitrogen (N_{min})
- 0-30 cm (weekly)
- 0-90 cm (2 x year)



Soil parameters
- Data logger (7.5, 17.5 cm): Temperature and vol. water content
- Bulk density (7.5, 17.5 cm) 2 x year

Table: applied nitrogen fertilizer

	Fertilizer N (kg N ha^{-1})	
	Cup plant	**Maize**
Gronig	170[1]	213.5[1,2]
Remmesweiler	110[2]	147.5[1]
Dörrenbach	192[1]	192[1]
Fürth	192[1]	192[1]

1 Slurry, manure, digestate
2 Synthetic fertilizer

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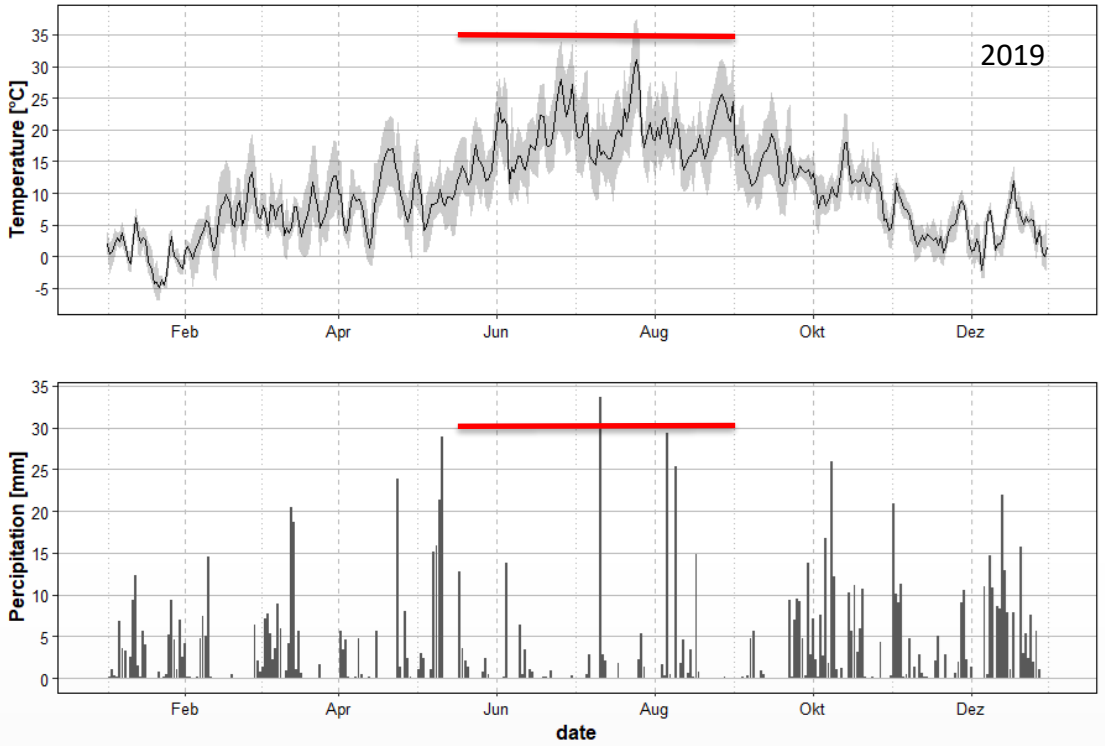
Weather 2019

	2019		Long-term mean
Mean temperature (°C)	10.7	>>	8.7
Mean temperature 15.05 – 01.09 (°C)	18.7	>>	15.3
Total precipitation (mm)	1005.8	>	973.1
Precipitation 15.05 – 01.09 (mm)	187.2	<<	297.5



→ The spring was cold and wet, summer above average warm and dry and the autumn was very rainy

Would results be the same in a growing season with average weather conditions?

Measurements in 2020 already started

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N_{min} dynamics in 2019

→ Nmin content in maize was substantial higher between May and September

→ Quick depletion of N_{min} after fertilizer application in cup plant relative to maize

→ Comparable N_{min} levels at the end of the year

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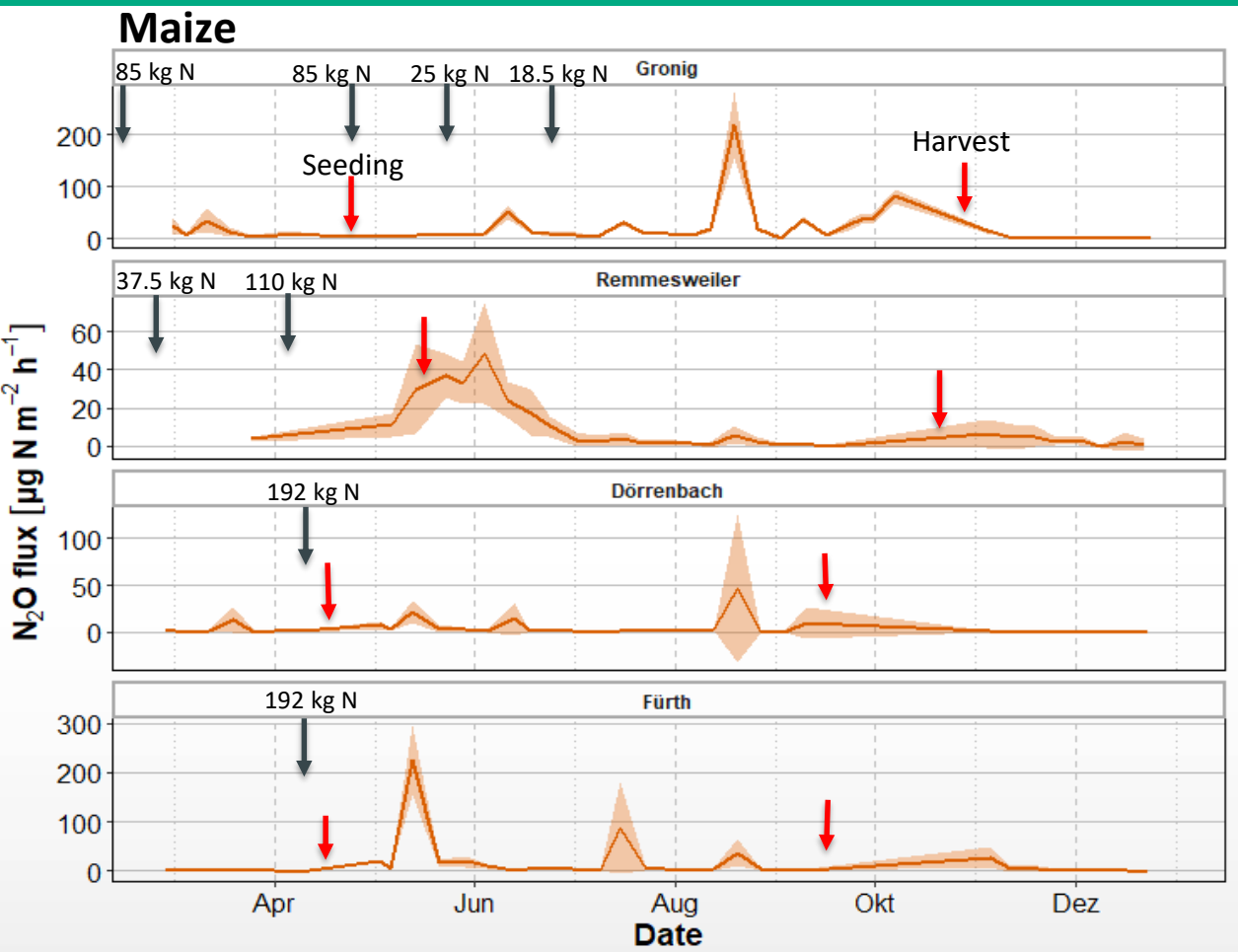
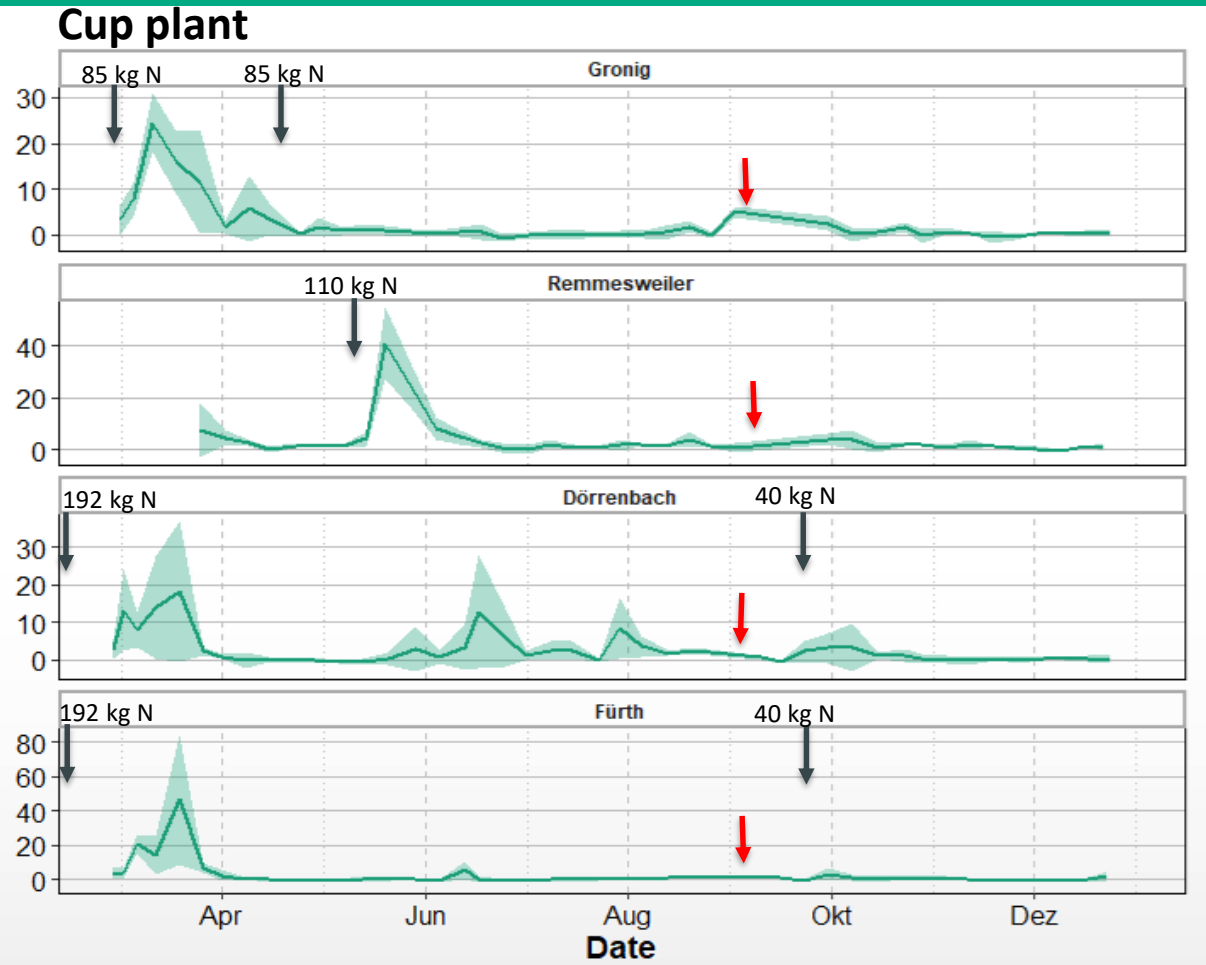
N_2O flux 2019





→ Emission peaks in silage maize were higher and mainly between May and October

→ Lower emissions peaks in cup plant mainly between March and July

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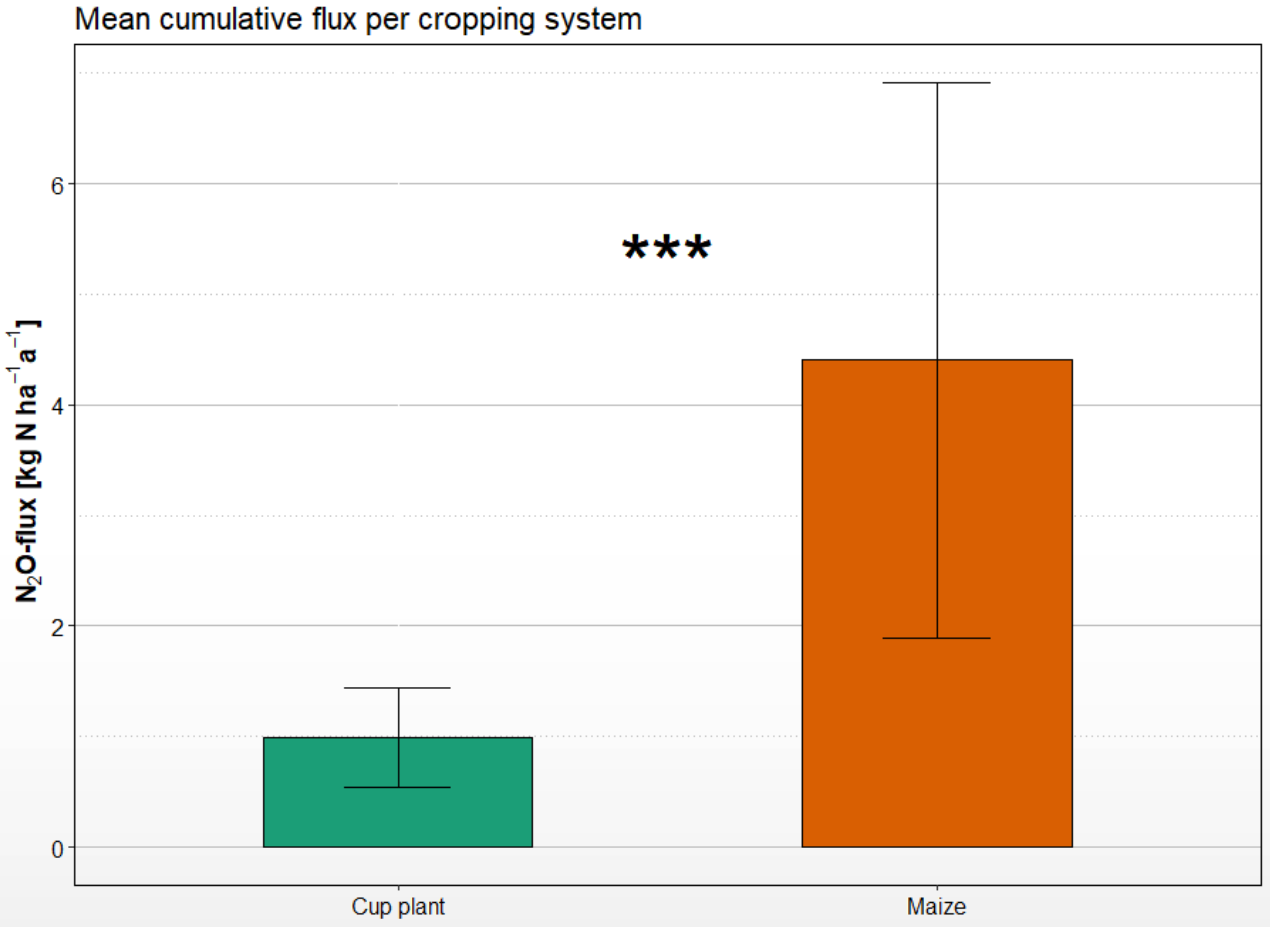
Mean N_2O flux during growing season 2019



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Comparison of key facts

Table 4: mean yield, N_2O emission, in-/ output related emissions with standard deviation (n=4) in 2019

	Crop	Yield (t DM ha^{-1})	Emitted N_2O-N (kg N ha^{-1})	N_2O-N / applied N (%)	Electric power yield* (MWh ha^{-1})	Emitted N_2O-N/ MWh (kg $CO_{2\text{-eq}}$ MWh^{-1})
Gronig	Cup plant	14.2 ±1.6	0.9 ±0.3	0.5	18.3	19.1 ±6.9
	Maize	16.3 ±0.2	7.4 ±0.7	3.5	25.4	118.9 ±11.0
Remmesweiler	Cup plant	18.9 ±2.5	1.3 ±0.4	1.2	17.4	30.9 ±8.1
	Maize	17.9 ±4.0	3.1 ±0.2	2.1	25.3	49.3 ±2.8
Dörrenbach	Cup plant	11.5 ±0.5	0.9 ±0.6	0.5	13.0	27.3 ±19.5
	Maize	15.3 ±3.6	1.6 ±1.7	0.8	22.2	28.9 ±31.8
Fürth	Cup plant	17.6 ±2.7	0.9 ±0.4	0.5	19.1	19.1 ±9.4
	Maize	16.7 ±1.9	5.5 ±1.0	2.9	22.7	98.9 ±18.3

*Methane ha yield * 9.97 kWh * 0.38 (efficiency cogeneration plant)

→Maize is superior regarding yields (DM, CH_4)

→Cup plant emit less N_2O per area and produced electrical power

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Conclusions

Pros and cons of Cup plant:

- less DM yield (-6.1 %) organic dry matter yield (-12.2%)
- less Electric power per ha (-29 %)

+ 77.5 % less emitted N_2O per ha

+ 71.6 % less N_2O emission per applied N

+ For the generation of 1 MWh,
  67.5% less N_2O is emitted in the field.

→ **To generate the same electric power as from 1 ha of maize, cup plant acreage has to be larger by 40 %.**

→ **Total N_2O (kg a^{-1}) emissions from 1.4 ha cup plant are 68.6 % lower than from 1 ha maize.**

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Conclusions

→ The early harvest of cup plant may protect the vulnerable soil from compaction.

→ Cup plants provide due to the long flowering period a longer lasting food source for insects.

→ Especially in the spring, cup plant as a perennial crop may protect the soil against erosion.

In 2019 where maize could not exploit its potential due to the weather, cup plant was more environmentally friendly.

On sites that have a high N_2O emission potential due to their hydrology, cultivation of cup plant can mitigate soil borne N_2O emission in biomass production.

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