Soil-atmosphere N$_2$O exchange in natural savannah, non-fertilized and fertilized agricultural land in Burkina Faso (W. Africa)

Brüggemann N, Brümmer C, Butterbach-Bahl K, Wassmann R, Papen H

Forschungszentrum Karlsruhe
Institute for Meteorology and Climate Research
Atmospheric Environmental Research (IMK-IFU)
Kreuzeckbahnstraße 19
82467 Garmisch-Partenkirchen, Germany
Location of study area

Climate
Mean annual air temperature: 29.5 °C
Mean annual precipitation: 926 mm
Rainy season: May to October

Dano
Bontioli
Ouagadougou

Burkina Faso

0 100 200 Kilometers
Field sites

Bontioli

Natural savannah - dry

Bontioli Reserve
nature park, no farming, no tillage, no livestock

Sorghum – Bontioli

used for agriculture since 15 years

Natural savannah - wet

Dano

Sorghum – Dano

used for agriculture since several decades

Cotton – Dano

Peanut – Dano

Bontioli Reserve
nature park, no farming, no tillage, no livestock

Reserve

used for agriculture since several decades

used for agriculture since 15 years

Reserve

Reserve

Reserve
## Site characteristics

<table>
<thead>
<tr>
<th></th>
<th>I Bontioli Reserve</th>
<th>II Sorghum Bontioli</th>
<th>III Sorghum Dano</th>
<th>IV Cotton Dano</th>
<th>V Peanut Dano</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>10° 51’ 55.8” N</td>
<td>10° 52’ 18.1” N</td>
<td>11° 09’ 52.9” N</td>
<td>11° 09’ 53.2” N</td>
<td>11° 09’ 53.6” N</td>
</tr>
<tr>
<td></td>
<td>3° 04’ 21.5” W</td>
<td>3° 03’ 59.0” W</td>
<td>3° 05’ 03.0” W</td>
<td>3° 05’ 01.4” W</td>
<td>3° 05’ 02.7” W</td>
</tr>
<tr>
<td>Altitude [m a.s.l.]</td>
<td>293</td>
<td>295</td>
<td>318</td>
<td>322</td>
<td>322</td>
</tr>
<tr>
<td>Slope [°]</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Management</td>
<td>Natural reserve, no farming, no tillage</td>
<td>Agriculture since 15 years</td>
<td>Agriculture since several decades</td>
<td>Agriculture since several decades</td>
<td>Agriculture since several decades</td>
</tr>
<tr>
<td>Sampling Frequency</td>
<td>1-3 week⁻¹</td>
<td>1-3 week⁻¹</td>
<td>1-3 week⁻¹ / 10 d⁻¹</td>
<td>1-3 week⁻¹</td>
<td>1-3 week⁻¹</td>
</tr>
<tr>
<td>Bulk density [g cm⁻³]</td>
<td>1.43 ± 0.01</td>
<td>1.44 ± 0.01</td>
<td>1.58 ± 0.02</td>
<td>1.47 ± 0.03</td>
<td>1.59 ± 0.04</td>
</tr>
<tr>
<td>pH</td>
<td>4.9 ± 0.2</td>
<td>6.0 ± 0.1</td>
<td>5.9 ± 0.1</td>
<td>5.9 ± 0.1</td>
<td>5.9 ± 0.1</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>11.08 ± 0.15</td>
<td>11.08 ± 0.18</td>
<td>11.80 ± 0.30</td>
<td>11.09 ± 0.33</td>
<td>11.78 ± 0.24</td>
</tr>
<tr>
<td>Cₜₐ₉ [%]</td>
<td>0.56 ± 0.06</td>
<td>0.66 ± 0.04</td>
<td>0.86 ± 0.12</td>
<td>0.85 ± 0.09</td>
<td>0.89 ± 0.11</td>
</tr>
<tr>
<td>Nₜₒ₉ [%]</td>
<td>0.05 ± 0.01</td>
<td>0.06 ± 0.01</td>
<td>0.07 ± 0.01</td>
<td>0.07 ± 0.01</td>
<td>0.07 ± 0.01</td>
</tr>
<tr>
<td>Soil texture</td>
<td>sandy loam</td>
<td>loamy sand</td>
<td>loam</td>
<td>loam</td>
<td>loam</td>
</tr>
<tr>
<td>sand [%]</td>
<td>65.1</td>
<td>80.6</td>
<td>42.3</td>
<td>47.0</td>
<td>32.6</td>
</tr>
<tr>
<td>silt [%]</td>
<td>27.2</td>
<td>13.4</td>
<td>35.4</td>
<td>30.5</td>
<td>46.3</td>
</tr>
<tr>
<td>clay [%]</td>
<td>7.7</td>
<td>6.0</td>
<td>22.3</td>
<td>22.5</td>
<td>21.1</td>
</tr>
<tr>
<td>Stone fraction [%]</td>
<td>35.3</td>
<td>37.8</td>
<td>75.2</td>
<td>54.2</td>
<td>75.0</td>
</tr>
</tbody>
</table>

### Agricultural practice

Seeds sown in May, no fertilizer application (except fertilizer experiment), topsoil aerated with hoes every 2 to 4 weeks after sowing, harvest in October.
Experiments

Experiment A
N₂O fluxes from natural savannah and sorghum in Bontioli, and from sorghum, cotton & peanut in Dano using manual chamber sampling 1-3 times per week in 2005 and 2006

Experiment B
Effect of NPK-fertilizer addition to 3 plots of a sorghum field in Dano (plot A: 140 kg N ha⁻¹; plot B: 52.5 kg N ha⁻¹; plot C: control) on N₂O fluxes using automated chamber sampling over several weeks in 2006

Experiment C
Laboratory study on potential N₂O efflux from soils of the Bontioli natural savannah and Bontioli sorghum under different soil moisture conditions
Manual and automated chamber measurements

Manual:
4 chambers at each site, measured 1-3 times per week

Automated:
3 chambers at each plot, measured continuously (10 values per day)

Sampling with syringes in the field

Manual: GC analysis at the same day

Automated: On-line GC analysis in the field

Pneumatically operated chambers
No fertilization, manual measurements

- air temperature
- soil temperature
- Bontioli Reserve
- Sorghum Bontioli
- Sorghum Dano
- Cotton Dano
- Peanut Dano

Brümmer et al., *Ecosystems*, submitted
No fertilization, manual measurements – mean fluxes

![Graph showing mean fluxes of N2O-N m^{-2} h^{-1} for different crops and years.](image)

- Bontioli Reserve
- Sorghum Bontioli
- Sorghum Dano
- Cotton Dano
- Peanut Dano

Legend:
- bC
- aA
- aB

- 2005
- 2006

- n = 79-162, ± SE;
- lowercase letters = significant differences (p < 0.05) between years;
- uppercase letters = between sites

Brümmer et al., *Ecosystems*, submitted
Fertilization, automated measurements

Brümmer et al., *Ecosystems*, submitted

Plot A - high N-fertiliser addition (140 kg per ha)  
Plot B - ordinary N-fertiliser addition (52.5 kg per ha)  
Plot C - no N-fertiliser addition

Fertilization, automated measurements

- soil temperature
- soil moisture
- precipitation
- WFPS [%]

N$_2$O flux [µg N$_2$O-N m$^{-2}$ h$^{-1}$]

- plot A [140 kg N ha$^{-1}$]
- plot B [52.5 kg N ha$^{-1}$]

plot A:
$y = 1.64 + 3.47 \times e^{0.07x}$  
$R^2 = 0.90$

plot B:
$y = 1.13 + 6.40 \times e^{0.02x}$  
$R^2 = 0.34$
No fertilization, diurnal cycles of N$_2$O fluxes

Mean diurnal N$_2$O fluxes at the unfertilized Sorghum field in Dano from June 26 to August 17, 2006 (n = 42, ± SE).

Brümmer et al., Ecosystems, submitted
Effect of single and repeated watering on N$_2$O fluxes

- Figure A: Soil moisture - dry up
- Figure B: Soil moisture - constant
- Figure C: Soil moisture - dry up
- Figure D: Soil moisture - constant

**N$_2$O flux [µg N$_2$O-N m$^{-2}$ h$^{-1}$]**

*Time since wetting [d]*

**N$_2$O flux Bontioli Reserve**
**N$_2$O flux Bontioli Sorghum**

% WHC$_{max}$

Medium water content

High water content

(n = 3, ± SE)

Brümmer et al., *Ecosystems*, subm.
Conclusions

- Very low N₂O emission rates from rain-fed and non-fertilized agricultural fields during both wet and dry season
- No significant differences in N₂O exchange between the most typical crops of Burkina Faso, i.e. sorghum, cotton, and peanut in 2005, however in 2006
- N₂O emissions from a natural savannah site in 2005 slightly, but not significantly higher than from the agricultural fields, in 2006 significantly higher
- No significant difference of time of conversion of savannah to agriculture on N₂O emissions
- Application of N fertilizer led to a gradual, but significant increase of N₂O emissions
- N₂O emissions were highest at medium soil water content, especially after single wetting events with subsequent dry up
Thank you,

and many thanks also to “the team”!

Funding for this research work was provided by the Helmholtz Association of German Research Centres (Virtual Institute, VH-VI-001).