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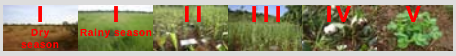
Soil-atmosphere exchange of N_2O, NO, CH_4 and CO_2 in natural savannah and savannah converted to agricultural land in Burkina Faso (W. Africa)

Introduction

Approximately 65% of the African continent could be considered as native savannah in the past, but large portions of this area have been converted to agricultural land, namely rangeland and low intensity cropping systems. Land conversion triggers mineralization processes and a rapid reduction of soil carbon and nitrogen. It can be hypothesized that the conversion is accompanied by an increased loss of gaseous C and N compounds, which could in turn affect the carbon and nitrogen balance from the landscape to sub-continental scale.

Site characteristics



I *Bontioli Réserve* - natural park, no farming, no tillage, subtropical brown soil, rich of nutrients, on clayey base material

II *Sorghum Bontioli* - agriculturally used since 15 years, subtropical ferruginous soil, partly leached, on sandy base material

III *Sorghum Dano*, *IV* *Cotton Dano*, *V* *Peanut Dano* - agriculturally used since several decades, subtropical ferruginous soil, leached, on sandy base material

Materials and methods

For determination of the soil-atmosphere exchange of N_2O, CH_4 and CO_2 the static chamber technique was used. Two major field campaigns were carried out during the vegetation periods in 2005 and 2006. Air samples (15 ml) were taken every 10 min and analysed afterwards by a gas chromatography system (see Butterbach-Bahl et al. 1997).

Additionally a fertiliser experiment on the Dano sorghum site was set up using an automated chamber system (Breuer et al. 2000). The sorghum field was divided into three square plots with a side length of 10 m each. The amount of added inorganic fertiliser (NPK) ought to represent realistic scenarios of farmers who have access and financial support for (i) high (1000 kg per ha) and (ii) ordinary (375 kg per ha) fertiliser applications.

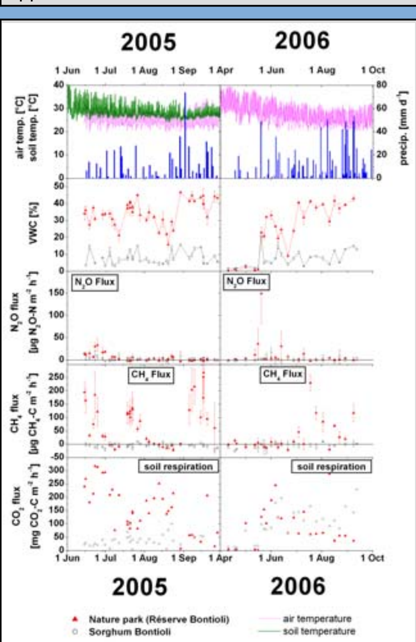


Fig.1: Seasonal courses of N_2O, CH_4 and CO_2 exchange, precipitation, VWC and air temperature on a near-natural savannah site and a sorghum site in Bontioli.

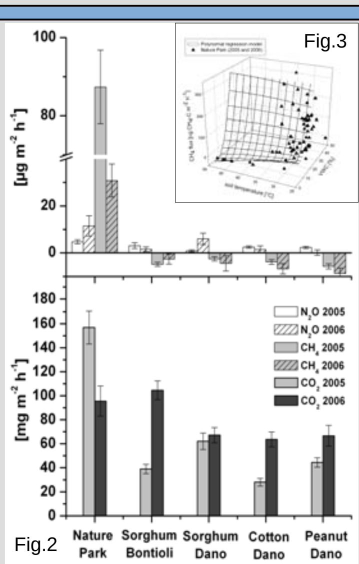


Fig.2: Mean N_2O, CH_4 and CO_2 flux rates of all investigated land use types of field campaigns 2005 and 2006.

Fig.3: Impact of soil moisture and soil temperature on CH_4 exchange in the nature park Bontioli.

Results and discussion (1) –

Impact of soil moisture and soil temperature on trace gas exchange

While the savannah soil showed consistently higher water contents resulting in higher respiration rates, differences among the sorghum, cotton and peanut fields were marginal (Fig.2). Average N_2O fluxes were very low (3-10 µg N_2O-N m^{-2} h^{-1}), whereas the highest flux rates in each year were measured in June which coincided with the onset of the rainy season. While on the agriculturally used fields mean CH_4 uptake rates of 3-8 µg CH_4-C m^{-2} h^{-1} were observed, average CH_4 emissions of 80 µg CH_4-C m^{-2} h^{-1} were measured in the nature park during the rainy season in 2005 (Fig.2). CH_4 uptake was observed at high soil temperature and low water content levels, while highest emissions occurred at soil moisture values above 20 % (Fig.3). Fig.4 and 5 show the time course of N_2O and NO fluxes after wetting. Both, N_2O and NO fluxes were highest at medium water contents between 15-20 %. Soil dry up resulted in a longer lasting decline of fluxes, while constantly high water contents led to relatively low N_2O and NO emissions.

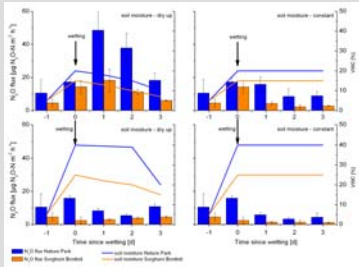


Fig.4: Time courses of N_2O fluxes after wetting. Left charts show a singular wetting event with a subsequent dry up; right charts show permanent wetting events with constant water content.

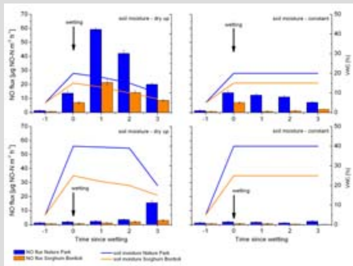


Fig.5: Time courses of NO fluxes after wetting. Left charts show a singular wetting event with a subsequent dry up; right charts show permanent wetting events with constant water content.

Results and discussion (2) -

Effect of N fertiliser application on N_2O exchange

Before adding inorganic fertiliser on the sorghum field, fluxes ranged from low release rates (1-10 µg N_2O-N m^{-2} h^{-1}) to even lower uptake rates (1-8 µg N_2O-N m^{-2} h^{-1}) on all three untreated fields (Fig.6). After the application of fertiliser, there was no abrupt increase of fluxes, but a constant rise on the two treated plots to values up to 30 µg N_2O-N m^{-2} h^{-1} (plot B) and 120 µg N_2O-N m^{-2} h^{-1} (plot A).

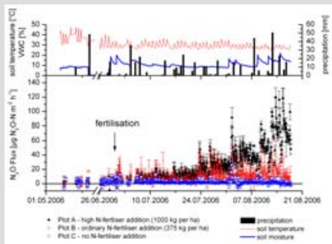


Fig.6: Effect of N-fertiliser application on N_2O exchange on a sorghum site in Dano.

Conclusion

On the agricultural fields, the flux rates and directions of N_2O and CH_4 indicate very low input and turnover of N. In the near-natural savannah park, however, CH_4 emissions are among the highest ever observed in a 'dryland' ecosystem. This CH_4 source strength is normally a characteristic trait of a wetland and is even amplified by enormous CH_4 release of insular termite nests (data not shown). Highest CH_4 fluxes in the park could be explained by the assumption that the input of organic material into the soil decreases rapidly after conversion to cropland, leading to significantly decreased C and N availability and turnover.

References

Breuer L, Papen H, Butterbach-Bahl K (2000): N_2O emission from tropical forest soils of Australia. *J Geophys Res* 105:26353-26367

Butterbach-Bahl K, Gasche R, Breuer L, Papen H (1997): Fluxes of NO and N_2O from temperate forest soils: impact of forest type, N deposition and of liming on the NO and N_2O emissions. *Nutr Cycl Agroecosys* 48:79-90

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