

# Surface atmosphere exchange of NO and CO<sub>2</sub> in a grazed semi-arid ecosystem: comparison of measurements and model predictions

Claire Delon, Corinne Galy-Lacaux, Dominique Serça, Ndiobo Camara, Eric Gardrat, Idrissa Saneh, Rasmus Fensholt, Torbern Tagesson, Valérie Le Dantec, Bienvenu Sambou, Cheikh Diop, Manuela Grippa, Eric Mougin

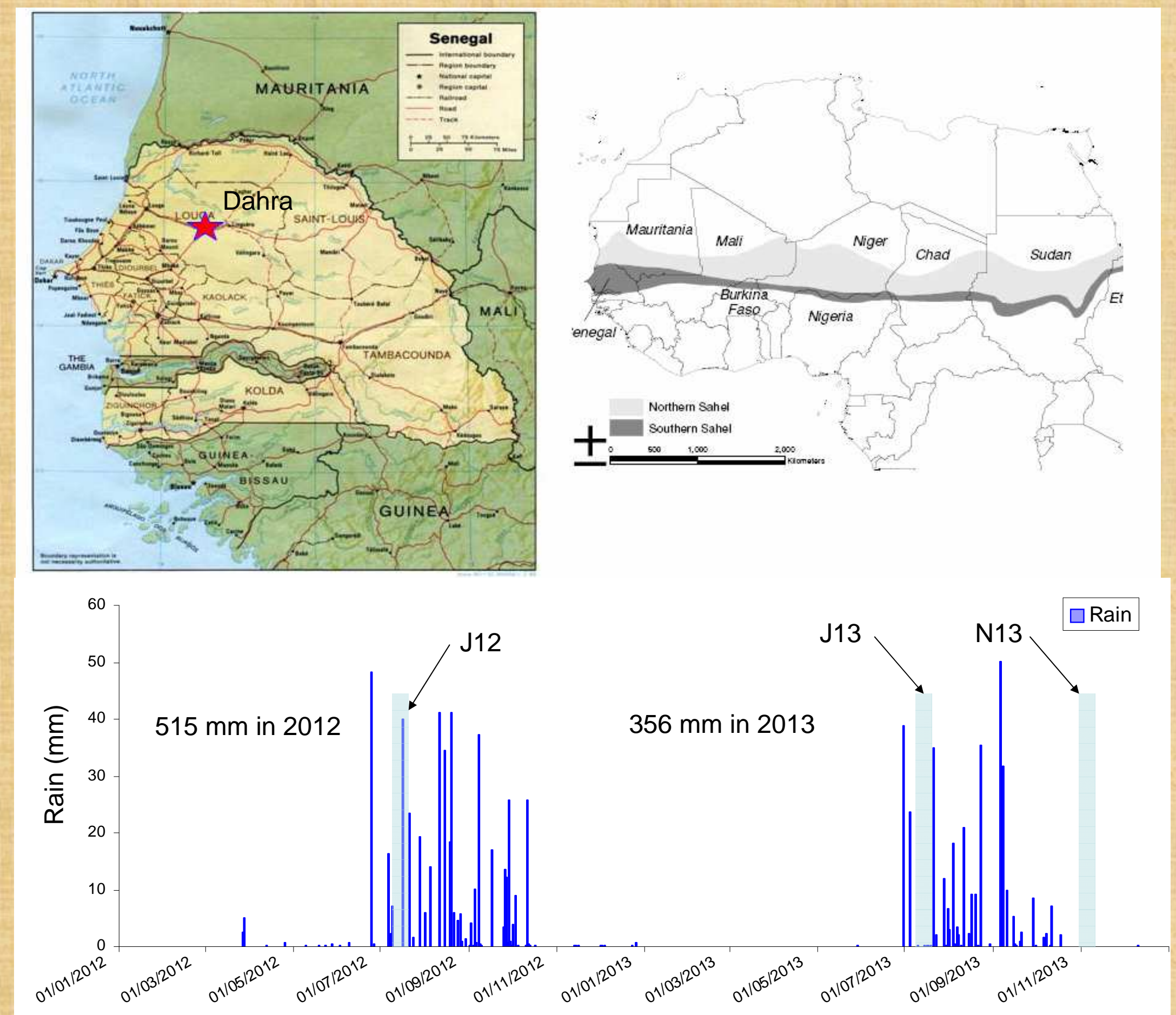
**Introduction:** Semi arid lands are submitted to **drastic changes in water availability at the transition between dry and wet seasons**. Changes in soil water are recognized as drivers of **microbial and biogeochemical processes**. In the **Sahel** the first rainfalls after the long dry season (8 months) have significant impacts on nitrogen production and consumption processes in the soils, and on **nitrogen and carbon exchange fluxes** with the atmosphere, leading to **strong pulses of CO<sub>2</sub> and NO**. NO contributes to the formation of tropospheric ozone and play an essential role in regional atmospheric chemistry, and soil respiration (CO<sub>2</sub> fluxes) accounts for an important part in the global carbon cycle.

**Context:** Three field campaigns were carried out in a semi-arid **Sahelian rangeland in Dahra** (Ferlo, Senegal), two at the beginning of the wet season in July 2012 (J12) and July 2013 (J13), and one in November 2013 (N13) at the end of the wet season. **NO and CO<sub>2</sub> (respiration) fluxes** from soils were measured by **dynamic chambers**. A **one dimensional coupled model** (STEP-GENDEC-NOFlux) was used to **simulate NO and CO<sub>2</sub> fluxes from soils in Dahra** at the daily scale for the years 2012 and 2013. Modeling results and measurements are compared, and **processes of emission are investigated**, especially at the beginning and end of the wet seasons (**transition dry/wet and wet/dry**).

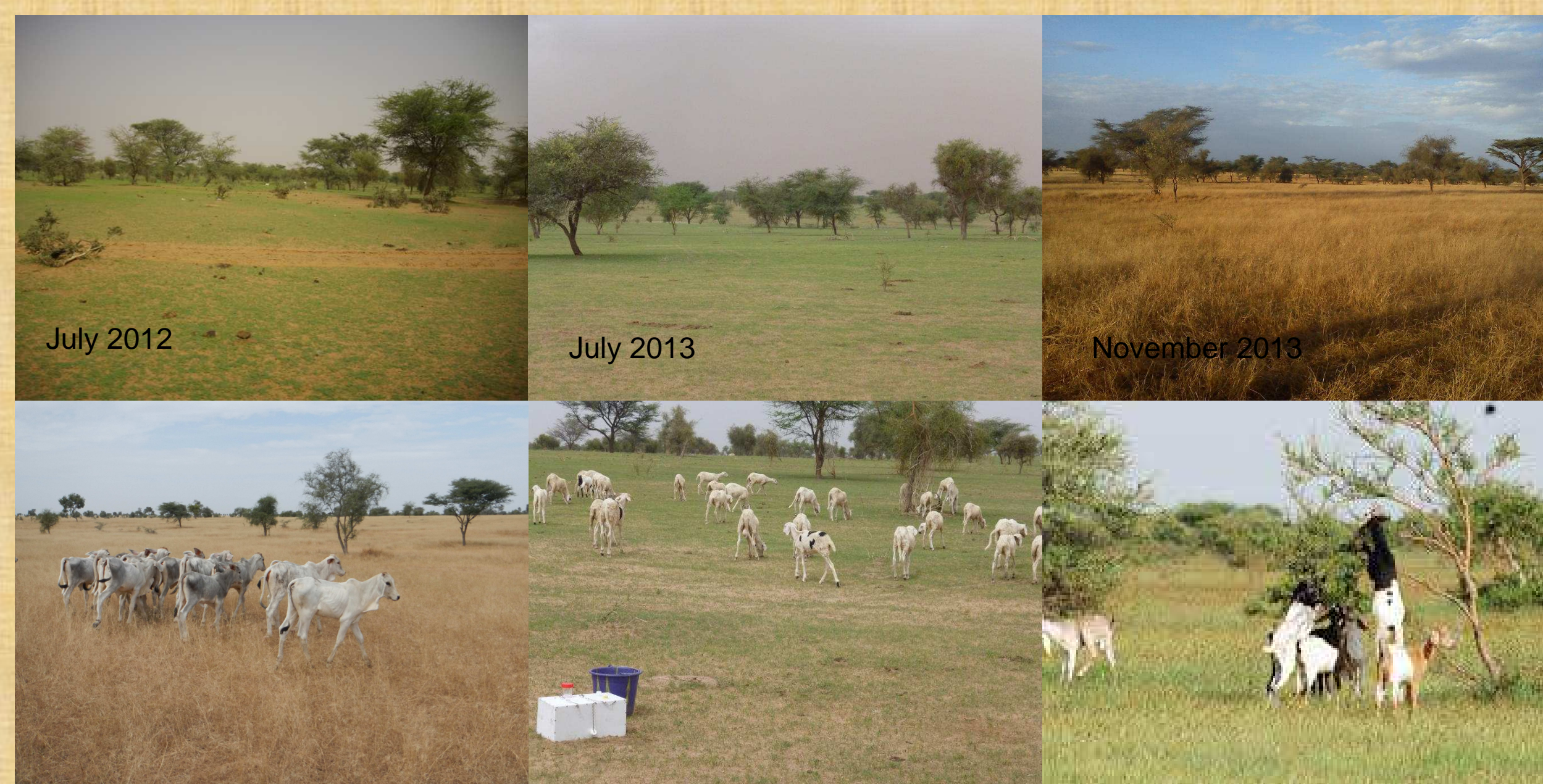
**Research question:** understanding the **underlying biogeochemical processes** in the soil in a **semi-arid region** and the influence of **environmental parameters leading to NO and CO<sub>2</sub> fluxes** when the soil experiences drastic soil water content variations.

This research is a collaborative work between Laboratoire d'Aérodologie (Toulouse, **France**), Géosciences Environnement Toulouse (France), Centre d'Etudes Spatiales de la Biosphère (Toulouse, France), Institut des Sciences de l'Environnement, Université Cheikh Anta Diop (Dakar **Senegal**), Institut Sénégalais de Recherche Agronomique (Dakar, Senegal), Centre de Recherche Zootechnique (Dahra, Senegal) and Institut Géographique de l'Université de Copenhague (**Denmark**).

Geographical position of the semi arid site of Dahra (Sahel, Ferlo, Senegal).



Rain distribution during years 2012 and 2013. In light blue: periods of the three field campaigns.



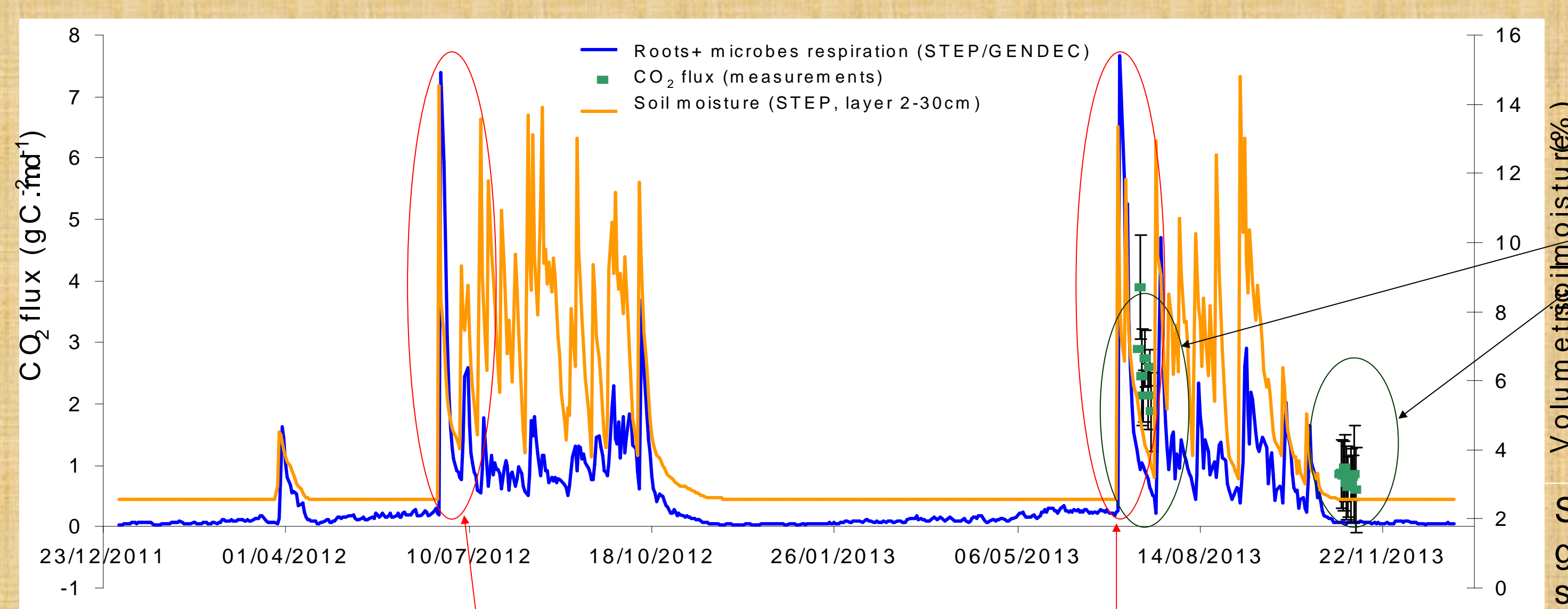
Dahra is a grazed semi arid savannain the Sahel (15°24'10"N, 15°25'56"W), tree species are *Balanites aegyptiaca* and *Acacia tortilis*, and the ground vegetation is dominated by annual C4 grasses.

Livestock is mainly composed of cows, sheep, and goats, and grazing occurs permanently all year-round.

C & N contents are low (resp. 5 g/kg and 0.4 g/kg).

Model forcing comes from local meteorological data.

**The organic matter input in the model has several origins: roots, buried litter and animal faeces** (resp. 35%, 25%, 40% in annual mean with large seasonal variations)



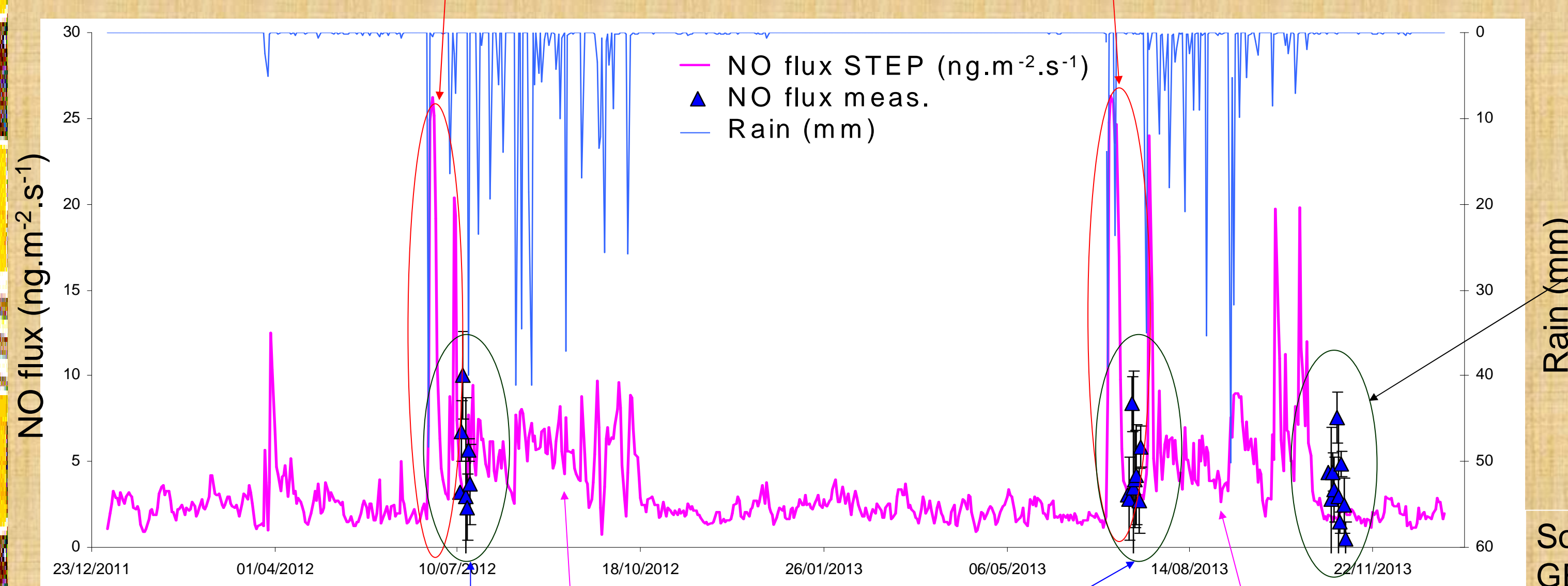
The model overestimates the death rate of microbes: respiration is underestimated when the rain stops for several days and after the end of the wet season.

Measurements show a persistent soil respiration highlighting a persistant microbial activity and the presence of root residues despite low soil moisture.

**Mean annual CO<sub>2</sub> flux: 0.18±0.25 kgC.m<sup>-2</sup>.yr<sup>-1</sup>** (0.07±0.22 kgC.m<sup>-2</sup>.yr<sup>-1</sup> in dry season, 0.40±0.22 kgC.m<sup>-2</sup>.yr<sup>-1</sup> in wet season). **In the lower range of global estimates for grasslands or deserts partially vegetated**, where measurements are sparse.

Soil respiration (CO<sub>2</sub> fluxes) of roots and microbes in 2012 and 2013 in gC.m<sup>-2</sup>.d<sup>-1</sup>, simulated by STEP-GENDEC-NOFlux (in blue). Simulated soil moisture in % in the layer between 2 and 30 cm in STEP.

At the beginning of the wet season (June-July), the rapid response of the soil decomposers to the increase in soil moisture leads to a **rapid decomposition of the litter buried during the preceding dry season** which involves **pulses of NO and CO<sub>2</sub>**. The same microbes are involved in both processes of **nitrification and respiration**.



End of dry season fluxes are underestimated in the model: N may be emitted by litter and straw (senescent vegetation) in addition to soil emissions due to the degradation of fresh organic matter, not accounted for in the model because litter is not yet buried. There is a large spatial heterogeneity in measurements explained by variations in soil pH, texture, and livestock trampling and grazing.

**Mean annual NO flux: 1.29±1.32 kgN.ha<sup>-1</sup>.yr<sup>-1</sup>** (0.94±1.04 kgN.ha<sup>-1</sup>.yr<sup>-1</sup> in dry season, 2.27±1.48 kgN.ha<sup>-1</sup>.yr<sup>-1</sup> in wet season). **In the range of previous estimates in drylands.**

Soil NO fluxes in 2012 and 2013 in ngN.m<sup>-2</sup>.s<sup>-1</sup>, simulated by STEP-GENDEC-NOFlux (in pink). Rain in mm (in blue).

Model results are in the range of measured fluxes with a 20-30% underestimate.

N uptake by plants in the wet season: mineral N is less available for nitrification and release to the atmosphere.

**Abiotic factors influence:** Both CO<sub>2</sub> and NO fluxes are significantly correlated with soil moisture. The correlation with soil temperature appears for NO fluxes only during the wet season. Soil respiration is not affected by soil temperature variations. **Soil moisture overrides temperature effects in water limited conditions**. Soil pH, soil texture, N input are driving parameters for NO emissions. CO<sub>2</sub> and NO fluxes are significantly correlated in the model (R<sup>2</sup>=0.7). In J13 measurements, CO<sub>2</sub> and NO fluxes are correlated (R<sup>2</sup>=0.6) if CO<sub>2</sub> is one day in advance, *i.e.* there is a lag appearing between respiration and nitrification processes. This correlation is retrieved in the model also with a one day shift. This « one day » lag is subject to variations and has to be verified with other data sets.

**Conclusion:** Soil **respiration and nitrification** processes (causing CO<sub>2</sub> and NO release) **are closely linked by microbial processes**: soil microorganisms trigger soil respiration and decomposition of soil organic matter. CO<sub>2</sub> and NO pulses are explained by the **rapid response of the soil decomposers to the soil moisture increase**. The microbial activity remains active even when soil moisture is low. The threshold under which microbes become inactive is difficult to determine and depends on physical, biological and chemical connected parameters. The transition between seasons in semi arid ecosystems leads to strong changes in water availability and to large pulses of N and C compounds. This is important to study and quantify in a context of climate change and demographic pressure to understand possible **changes in N and C cycles in semi arid regions**.