Modelling the effects of vegetation and soil moisture on biogenic nitrogen oxide emissions from Sahelian soils

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NO emissions from soils

- NO is one of the most important precursor for tropospheric ozone.
- NOx are involved in the abundance of OH which determines the lifetime of greenhouse gases.
- Below canopy emissions: 21 TgN/yr (Davidson & Kingerlee, 1991) at the global scale.
- Above canopy emissions: 5-10 TgN/yr (YL95, Hudman et al., 2012) at the global scale.
- Sahel: 0.5 TgN/yr (Delon et al., 2010), 5 to 10% of the global budget, a large part being emitted during pulse events at the beginning of the rain season.

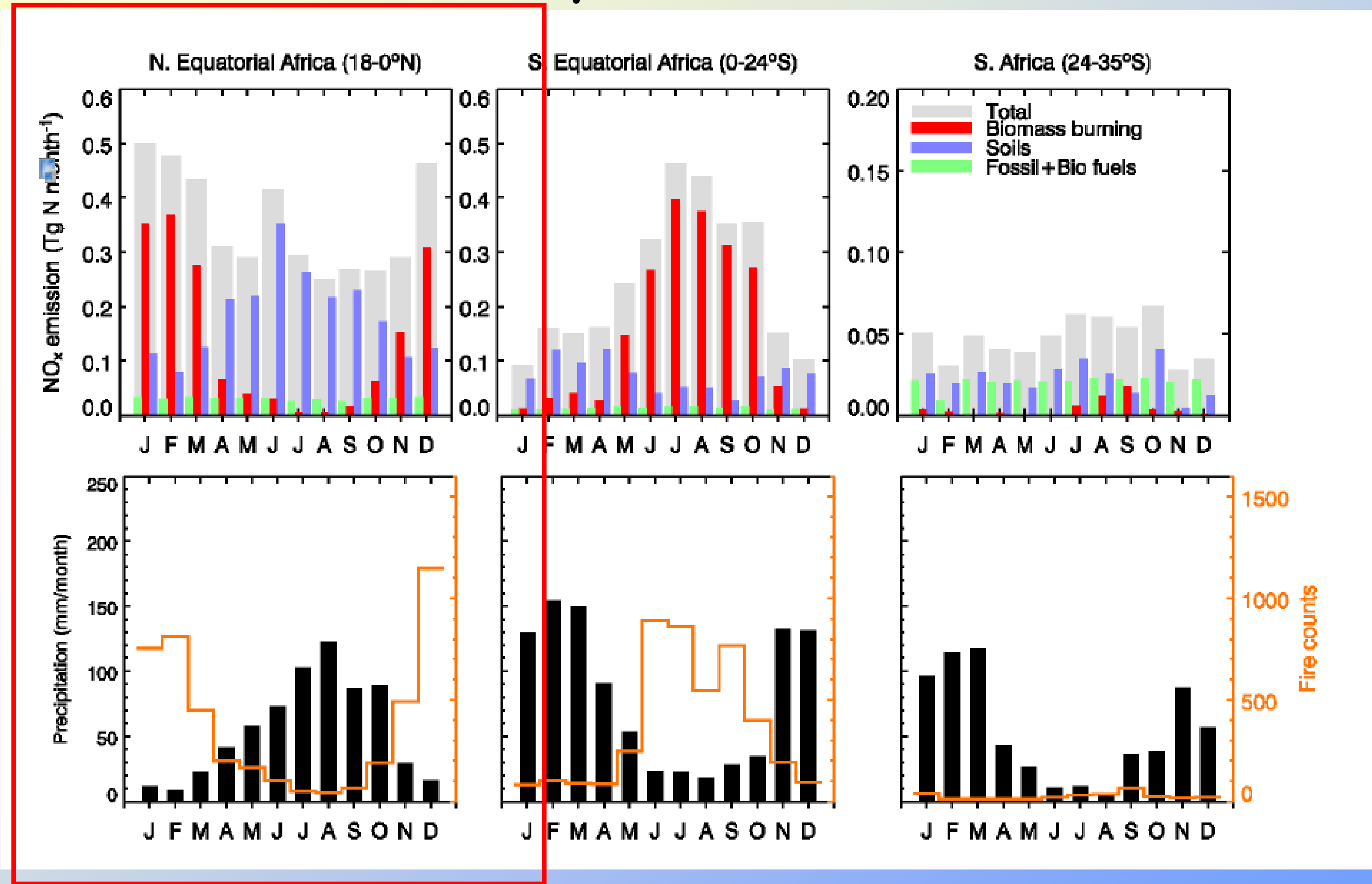
Outline

- Objective: understand the links between soil and atmosphere leading to NO emissions.
- Importance and origin of pulse events in Sahel
- Scheme of the reactive nitrogen cycle between soil and atmosphere
- Modelling approach to connect processes in the soil and emission to the atmosphere
- Simulations at a sahelian site in Mali for the years 2006, 2007, 2008.
- Limitations, conclusions, perspectives

NO emissions in semi arid regions

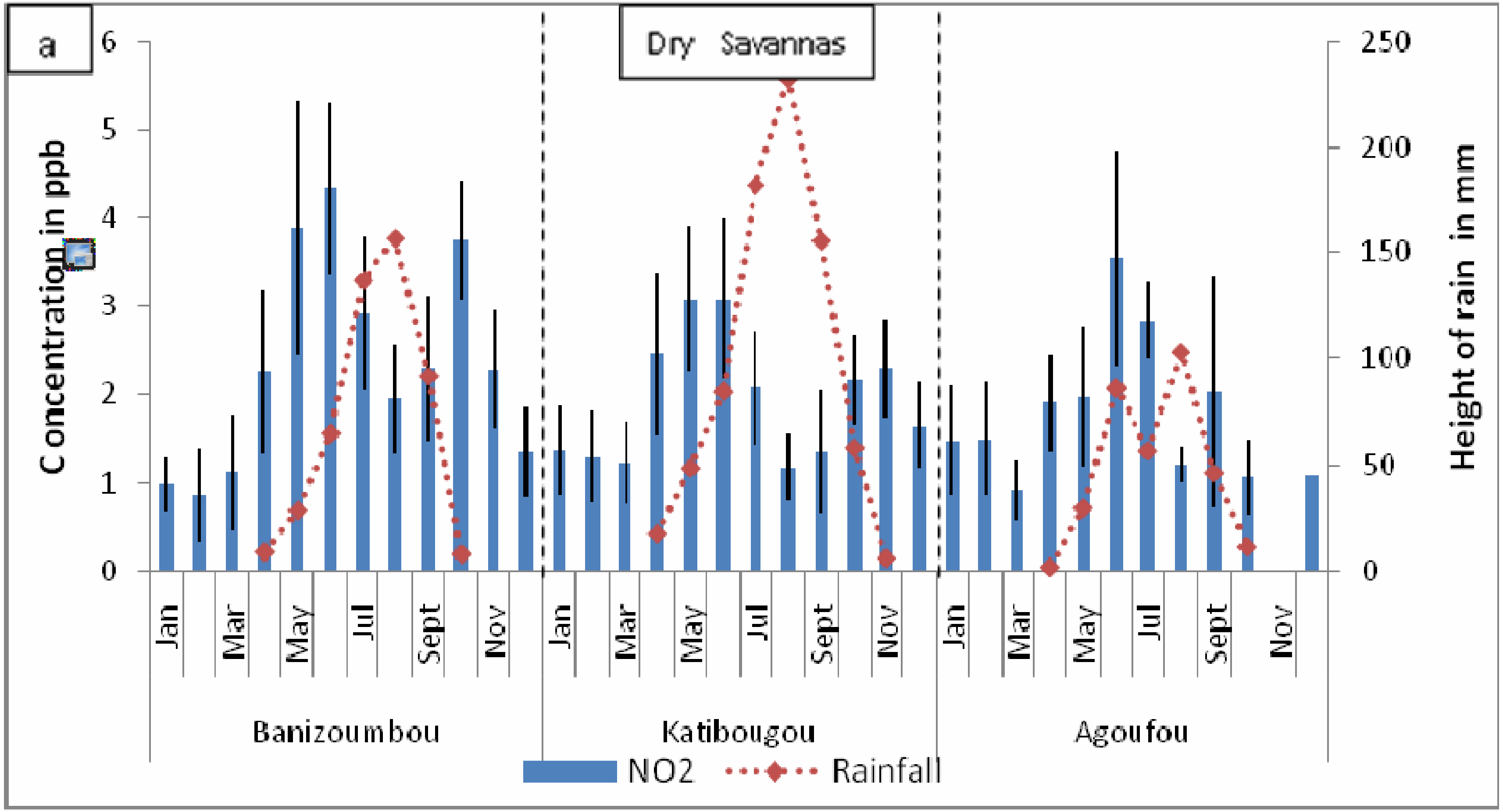
- Pulse events: effect of substrate and moisture.
  - mineral and organic substrates accumulate during dry periods (8 months in Sahel)
  - excess of mineralisation during the early phases of the wet cycle
  - Pulses occur when very dry soils are suddenly wetted. Above a certain threshold (when soil moisture is more constant in time), NO emissions decrease.
  - pulse emissions of NO contribute strongly to the total emission

NO emissions in sahelian regions during pulse events



Jaeglé et al., 2004: Monthly NOx emissions, fires and rainfall over North Equatorial Africa (18-0N),

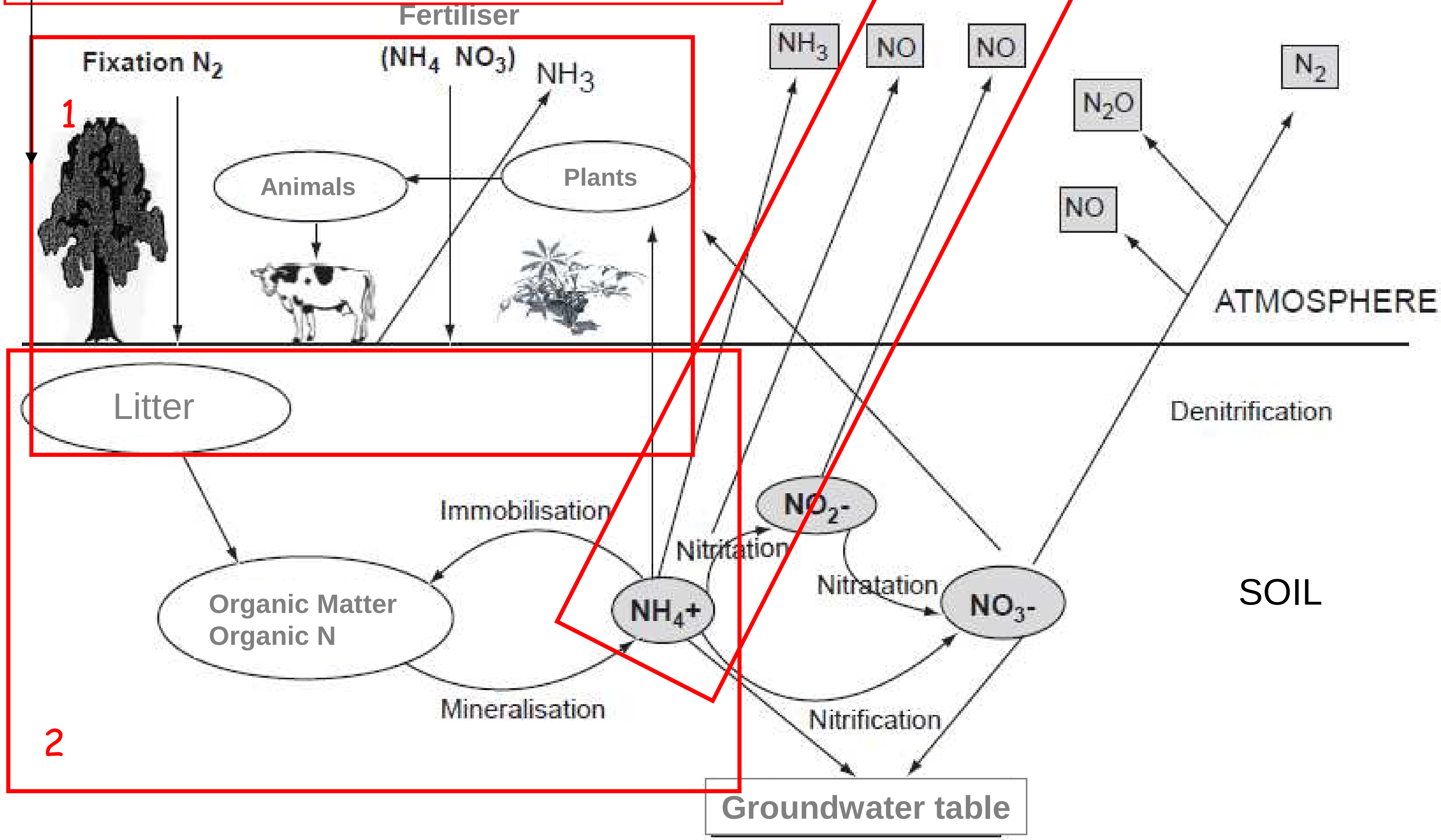
NO_2 concentrations at sahelian sites



Evolution of monthly concentrations in dry savannas. Adon et al., 2010.

Reactive Nitrogen cycle soil-atmosphere

Atmospheric inputs: wet and dry deposition
N_2 fixation

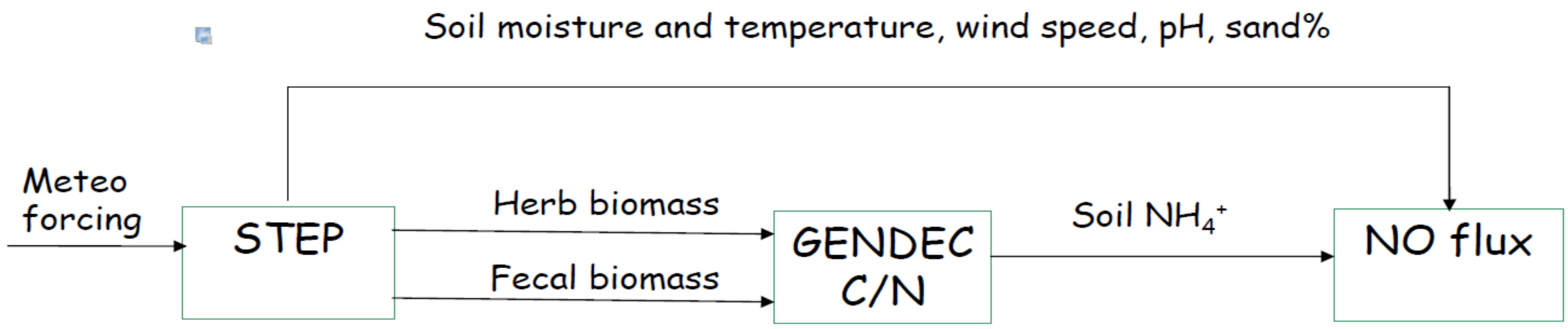


Modelling approach

1: STEP model (Mougin et al., 1995): Sahelian Transpiration Evaporation and Productivity. Ecosystem process model for sahelian herbaceous vegetation. Simulates the temporal variation of the main parameters and processes (livestock included) associated with vegetation functioning in arid countries.

2: GENDEC model (Moorhead & Reynolds, 1991): GENeral DEComposition is a general, synthetic model, which aim is to examine the interactions between litter, decomposer microorganisms, and C and N pools, and to explore the mechanisms underlying observed patterns of decomposition in arid ecosystems.

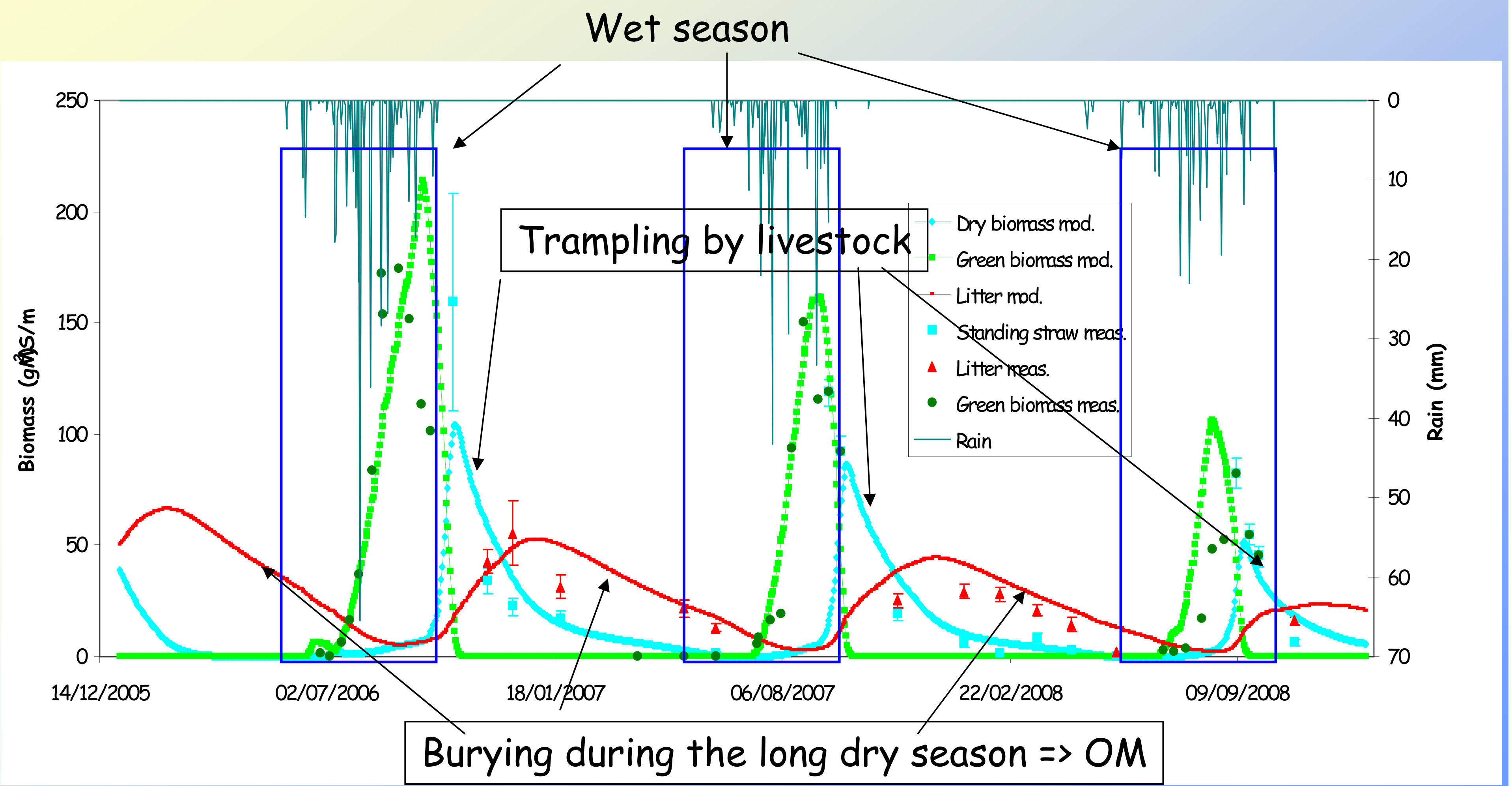
3: NO flux (Delon et al., 2007): An emission algorithm, derived from a neural network, has been developed for the calculation of NO biogenic emissions from soils in West Africa.



Schematic representation of NO flux modeling coupled to STEP-GENDEC

Simulations made at Agoufou, Mali, 15.3°N, 1.7°W, agro pastoral region

Modelling approach: STEP (Mougin et al., 1995)



Herbaceous layer for the years 2006, 2007, 2008, lines for simulated results, points for measurements made at Agoufou.

Modelling approach: GENDEC (Moorhead & Reynolds, 1991)

- Litter decomposition depending on C/N ratio, for different compartments.
- Microbial biomass dynamics: estimates the mineralization supposing a total consumption of C.
- Output: NH_4^+

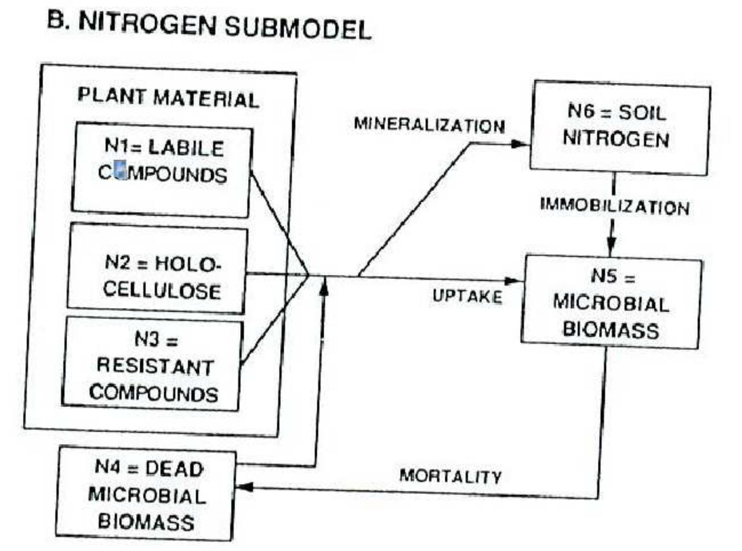


Fig. 1. Model flow diagram: A. carbon; B. nitrogen.

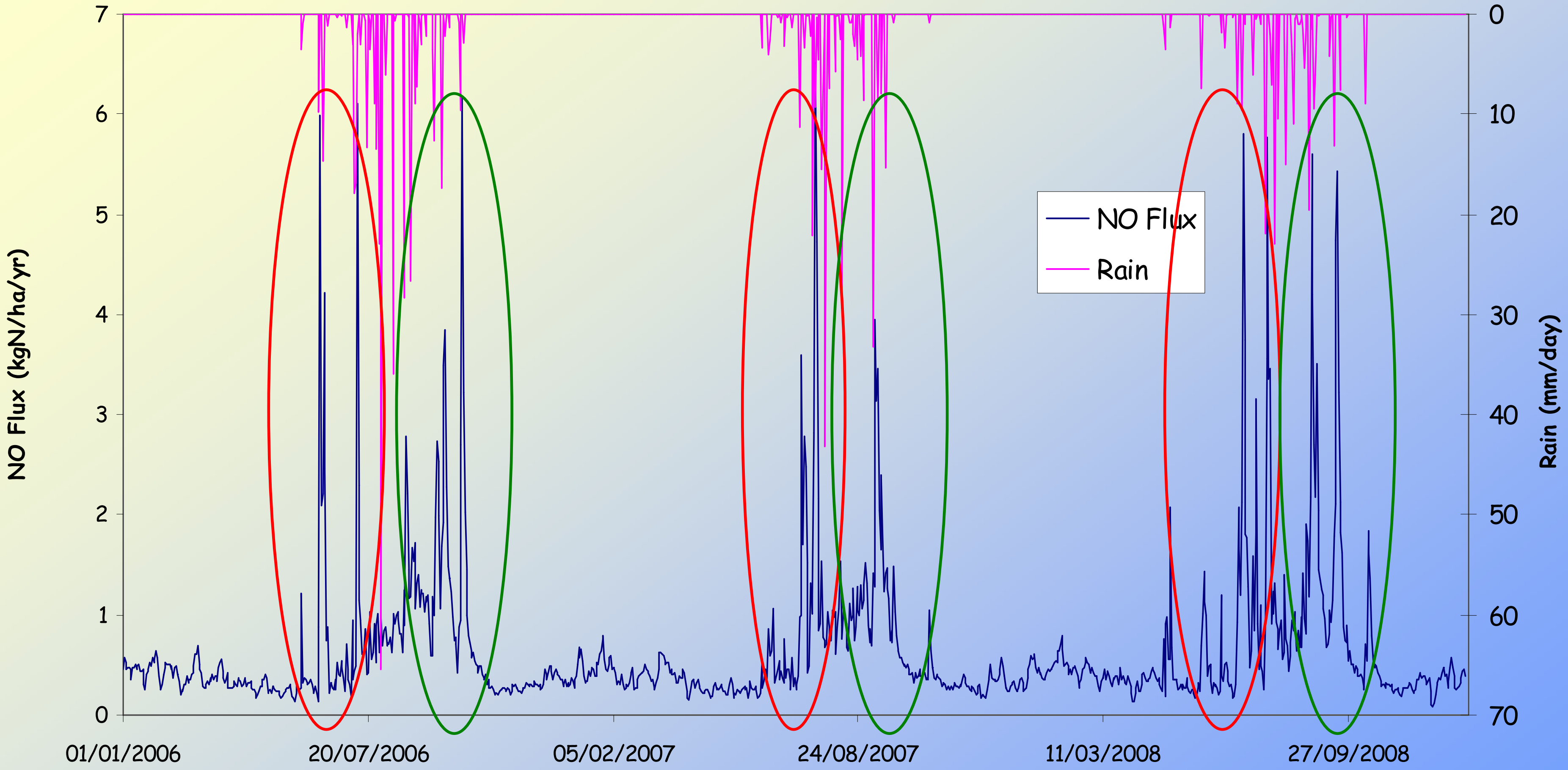
Modelling approach: NO flux

- NO flux = f

» (Surface soil moisture,	STEP
» Surface soil temperature,	STEP
» Deep soil temperature (30 cm),	STEP
» Wind speed,	Meteo forcing
» Sand percentage,	Initial param.
» pH,	Initial param.
» 2% NH_4^+)	GENDEC

- 2% of the NH_4^+ = N input from the surface (except atmospheric deposition), depends on vegetation and livestock. Based on Potter et al., (1996).

NO flux from soil at Agoufou (Sahel, Mali)



Pulse emission at the beginning of the wet season when the first rains fall : rapid decomposition of the OM from litter buried during the dry season.

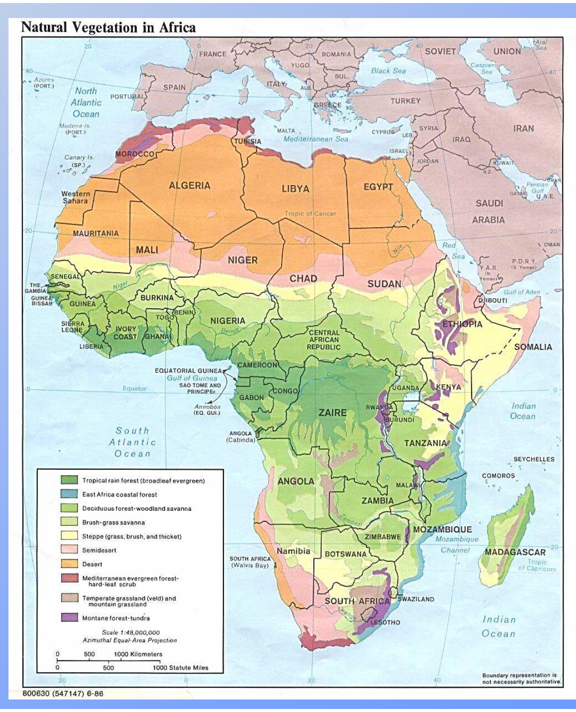
During the wet season, N is mobilized by the growing of the vegetation, soil moisture is above the pulse threshold => emission is reduced

Second peak at the end of the wet season: the soil moisture is still sufficient to allow decomposition of the fresh OM.

NO flux in dry savannas

- Comparison with measurements in dry savanna sites at the beginning of the wet season.
- Simulations are in the range of what has been measured

Site name	NO flux (kgN.ha^{-1}.yr^{-1})	Period	Reference
Banizoumbou	1.92±0.83	Wet season 1992	Le Roux et al. (1995)
Agoufou	2.58±3.86	Wet season 2004	Delon et al. (2007)
Agoufou	0.81±0.51	Wet season 2005	Unpublished
South Africa	1.7-2.5	Wet season 1993	Otter et al. (1999)
Agoufou (STEP)	1.00±0.88	Wet season 2006	This work
Agoufou (STEP)	1.23±1.03	Wet season 2007	This work
Agoufou (STEP)	1.39±1.32	Wet season 2008	This work
Agoufou (ISBA)	2.52±1.14	Wet season 2006	Delon et al. (2010)



Limitations and uncertainties

- Missing:
  - input from symbiotic fixation by plants and crusts (large uncertainty)
  - Input from atmospheric deposition (wet + dry). Total deposition = 8 $kg.ha^{-1}.yr^{-1}$ (Delon et al., 2010), but what is the proportion fixed by the vegetation which returns to the soil?
  - Interannual variation of the N content in the soil?
  - Dry season mineral N and NO emissions?

Conclusion and perspectives

- This work is an attempt to represent the annual cycle of NO emissions from soils in a semi arid site in Sahel.
- Vegetation quantity, soil moisture and temperature dynamics, N content in the soil are well reproduced by the model (when measurements are available for comparison)
- NO flux is mainly dependent on soil moisture and mineral N (2% of this pool is used as input to calculate the flux).
- Annual budget dominated by wet season emissions (pulses contribute to 60 to 65% of the annual budget)
- Further measurements needed => field campaigns organized in Sénégal (dry savanna, similar ecosystem as Agoufou), to follow up our studies in reactive N cycle between soil and atmosphere