"*Faidherbia*-Flux": a collaborative observatory for Ecosystem Services and GHG in a semi-arid agro-silvo-pastoral system (Senegal)

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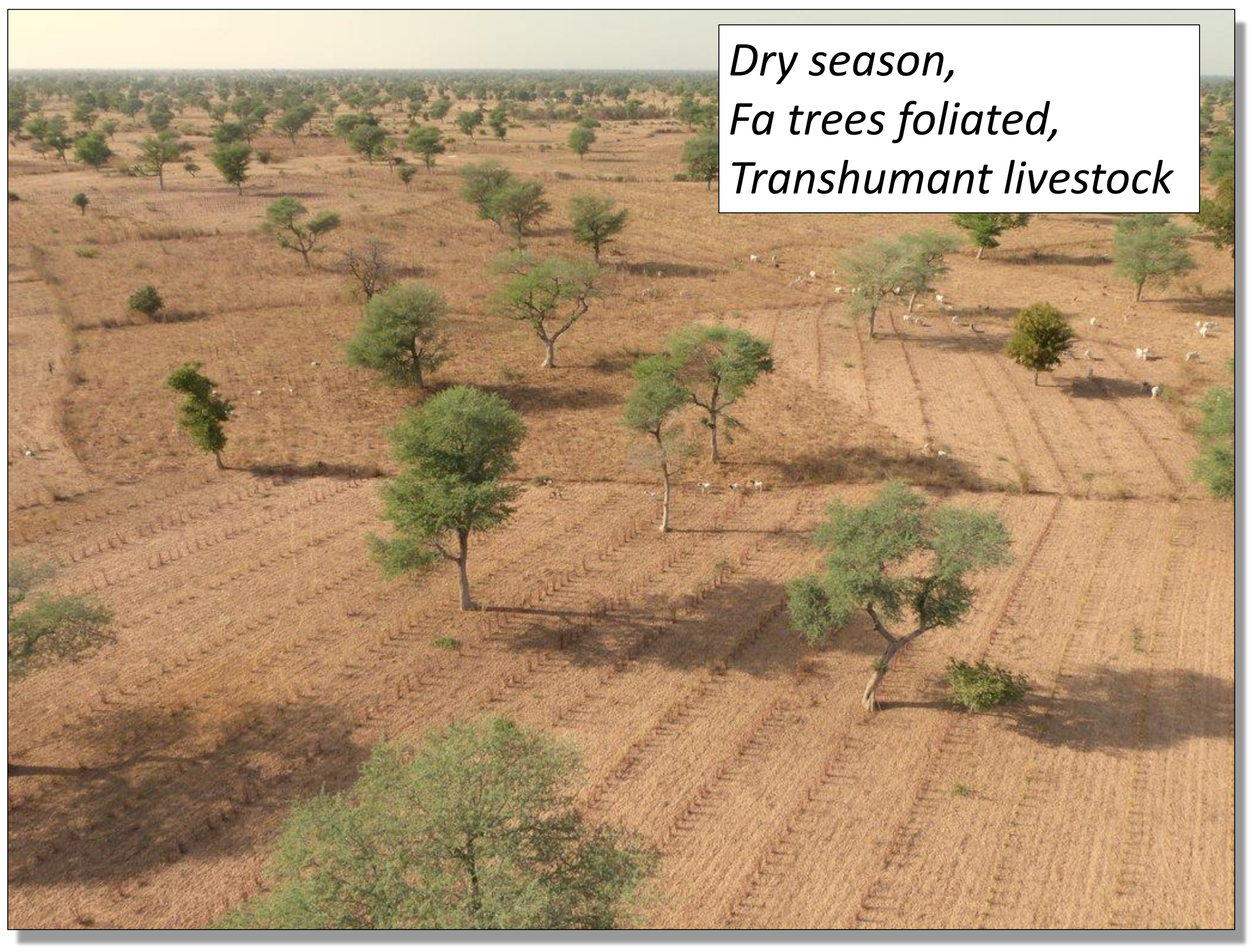
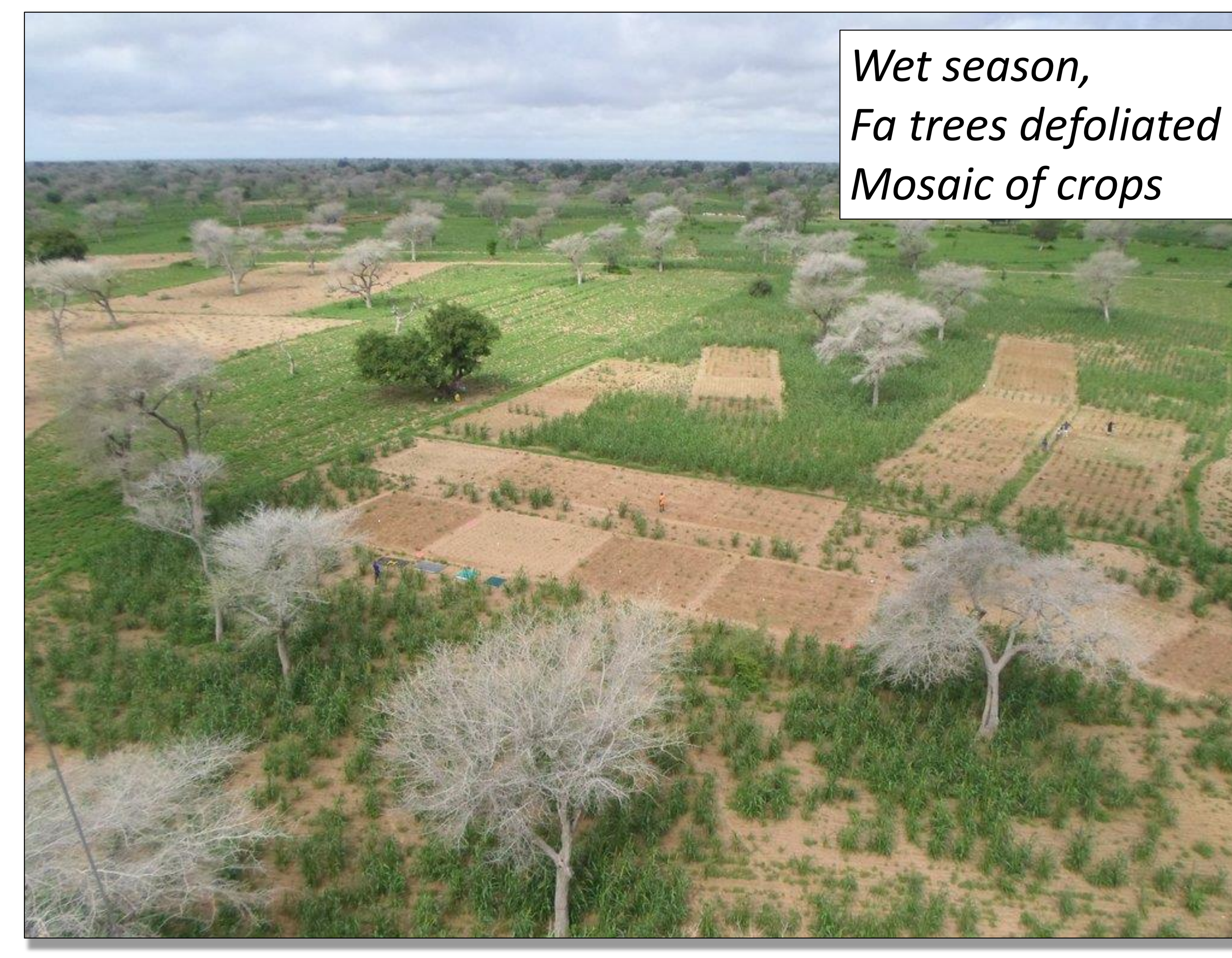
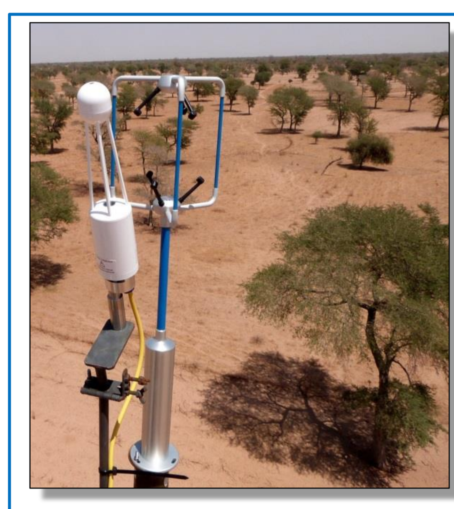
Rationale: The ecosystem services provided by agro-silvo-pastoral systems are complex to assess or model, owing to high spatial and temporal heterogeneities. In 2018, we set up a new long-term observatory , open to collaboration, for the monitoring and modelling of ecosystem services, GHG, hydrology and deep SOC in a semi-arid agro-silvo-pastoral system (Niakhar, Sénégal). The system is dominated by the multipurpose and reverse phenology tree *Faidherbia albida* (Fa). Crops are mainly millet and peanut (annual rotation). Transhumant livestock contributes to manure (see Dry Season picture below), SOM and soil fertility and is fed by the tree fodder pruned at that time. The positive effect of *Faidherbia* on crop yield is under scrutiny (see Wet Season picture below, trees are defoliated).





Eddy Covariance for CO_2, H_2O and energy balances:

Early 2018, we set up 3 eddy-covariance towers above (i) the whole mosaic ecosystem (20m), (ii) millet (3m) and (iii) peanut (3m) and monitored energy, CO_2 balance and evapotranspiration for one full year. The ecosystem displayed low but significant CO_2 and H_2O fluxes during the dry season, owing to *Faidherbia* in leaf (Fig. 1). When rains resumed, the soil bursted a large amount of CO_2. Just after the growth of millet, CO_2 uptake by photosynthesis increased dramatically, then stabilized before harvest. However, this was compensated by large ecosystem respiration. The annual ecosystem CO_2 balance was a slight C uptake.



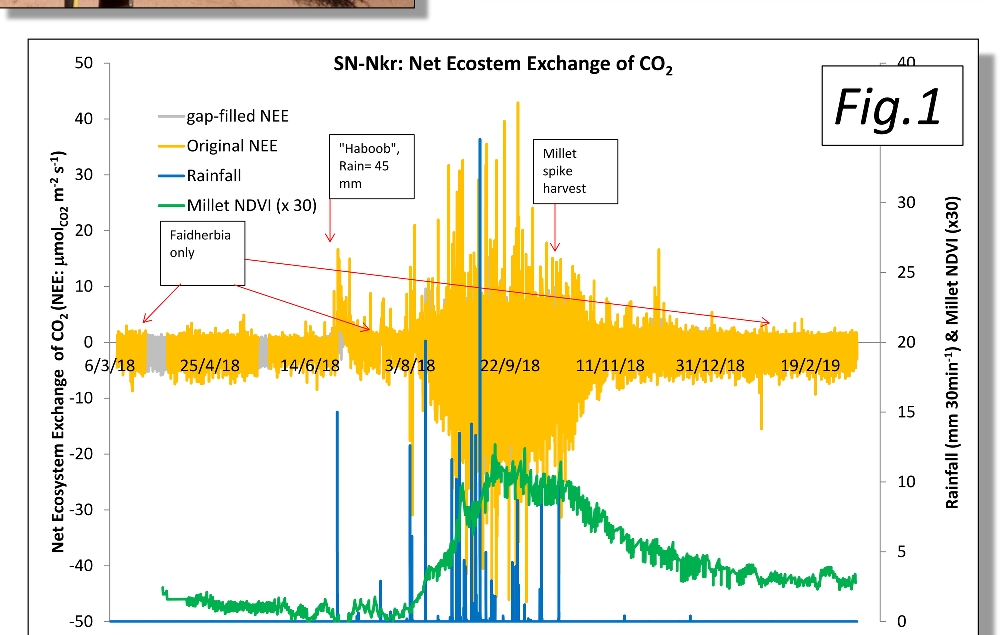


Fig.1

Drone (UAV) & Agronomy:

At harvest, we collected 12 subplots of 15 millet holes each, distributed either below the crown of *Faidherbia*, at 2.5 x crown radius, or at 5 x crown radius. Millet yield was about 3 times higher below Fa than in full sun (Fig. 2). We noted higher soil humidity and SOC close to the Fa trunks.

We scanned the 1.24 ha millet plot with VHR drone flights in visible, multispectral and thermal IR bands at 5 dates. Drone images confirm higher yield below or close to Fa trees, with at least 30m of influence (semivariogram). A simple model based on NDVI allowed to draw a plot yield map (g m^{-2}) and to estimate the plot yield within 15% of the actual plot harvest (Fig. 3)

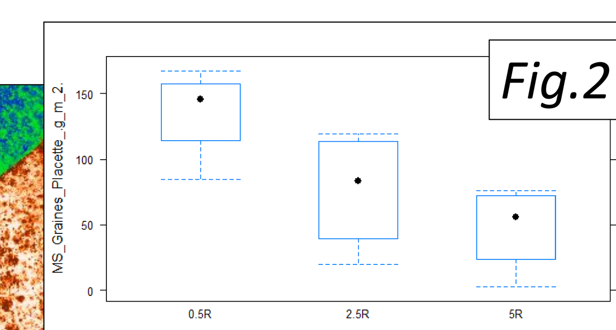


Fig.2

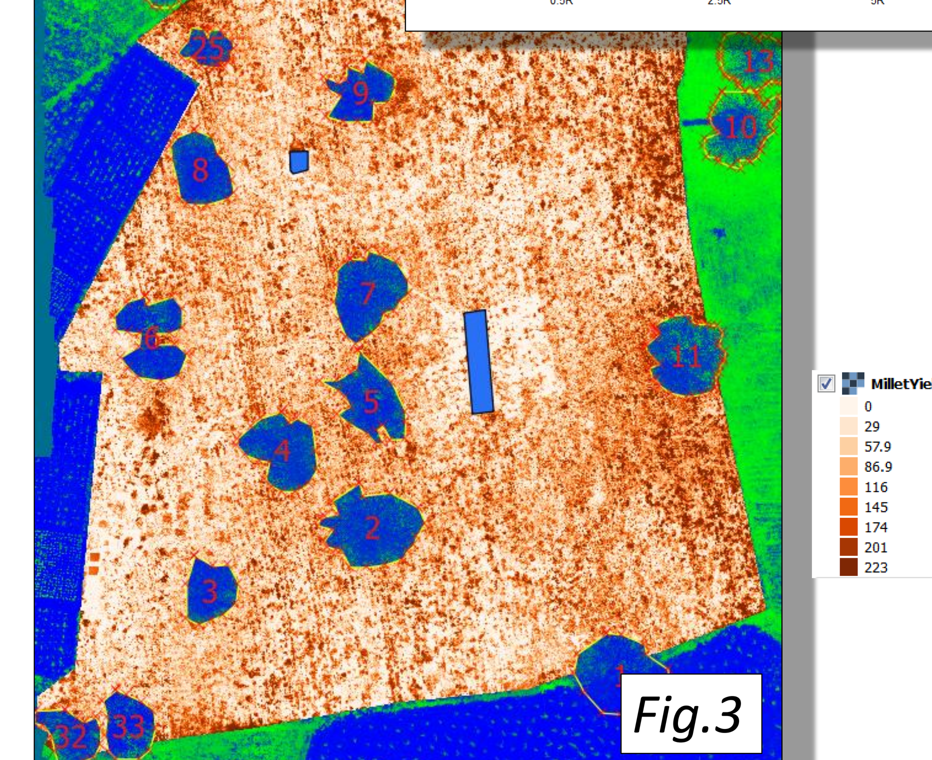
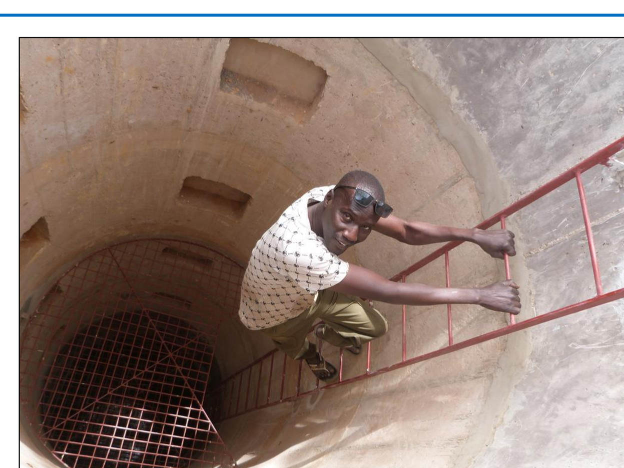


Fig.3

Deep roots & Hydraulic Redistributions:

Six deep (8m) pits were dug down to the water table and equipped with automatic scanners and minirhizotrons to monitor the tree and crop root growth, according to soil depth and distance to trees. In parallel, 5 Fa trees (in a range of sizes) were equipped with 57 TTD sap flow systems in the trunk (azimuthal and radial sampling), the tap and lateral roots and 20 pairs of thermocouples for direction and zero flow assessment. The goal is to study hydraulic distributions, from the soil water table to the superficial layers and assess if trees uplift deep water and nutrients for the crops. In Fig. 4, nocturnal sap flows were not nil in the tap roots.



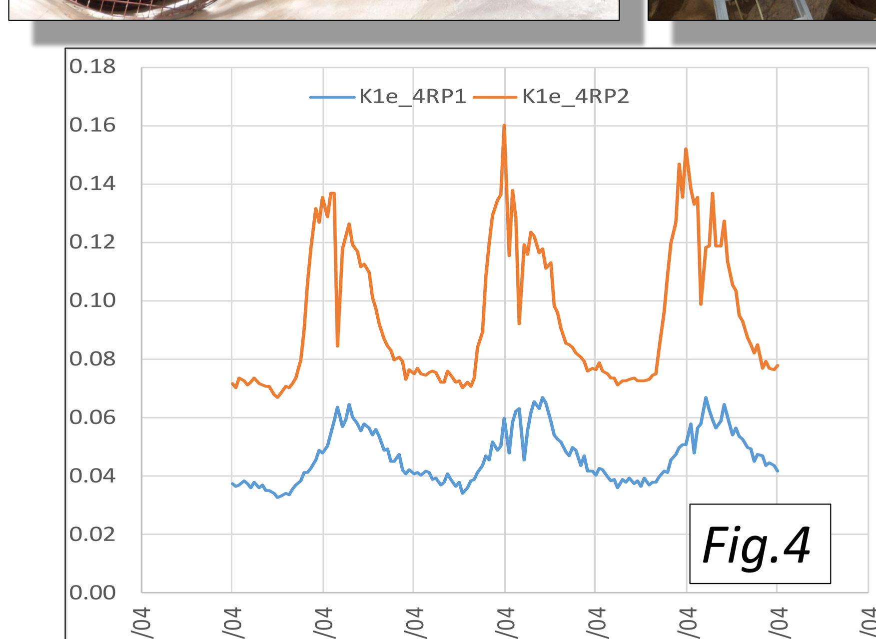


Fig.4

Soil respiration and GHG exchanges with automatic chambers:

Home-made automatic soil respiration chambers were installed in the field under Fa tree (photo) and in full sun. Just before closing (every 30 min), each chamber measures ambient [CO2] nearby the soil level. After closing, [CO2] raises much faster under the tree (pink) than in full sun (white). Rsoil is computed from the slope. Full GHG assessment (CO_2, N_2O, CH_4) balance are planned.

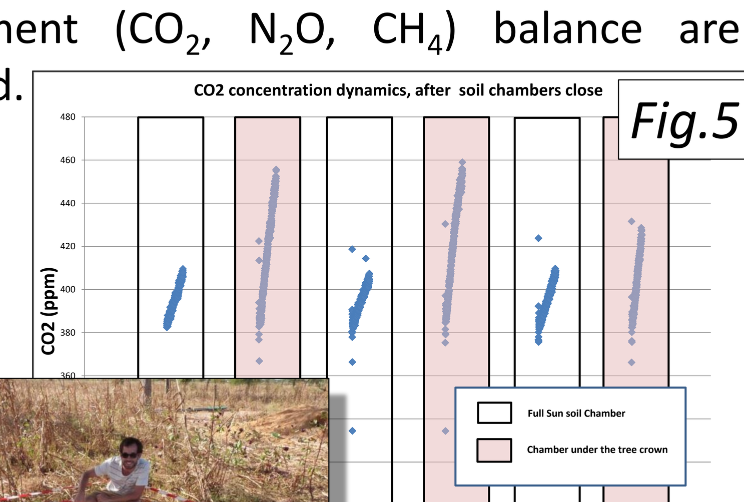
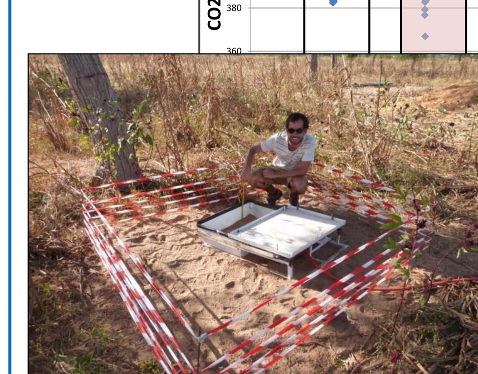


Fig.5



Infiltration, vegetation cover and ecohydrology :

The impact of woody species distribution on local water redistribution is questioned to assess the resilience of the ecosystem and to test innovative water management strategies in agroforestry. 20 PVC tubes of 6 m depth have been set up into the soil along a toposéquence of 250 m according to the micro-topography and the Faidherbia distribution (Fig. 6): 10 piezometers follow hourly the static level of the phreatic aquifer (range -5 to -3m) and 10 tubes for the soil humidity survey are scanned by a TDR IPH44. The soil infiltration is measured with the automatic BEST method.

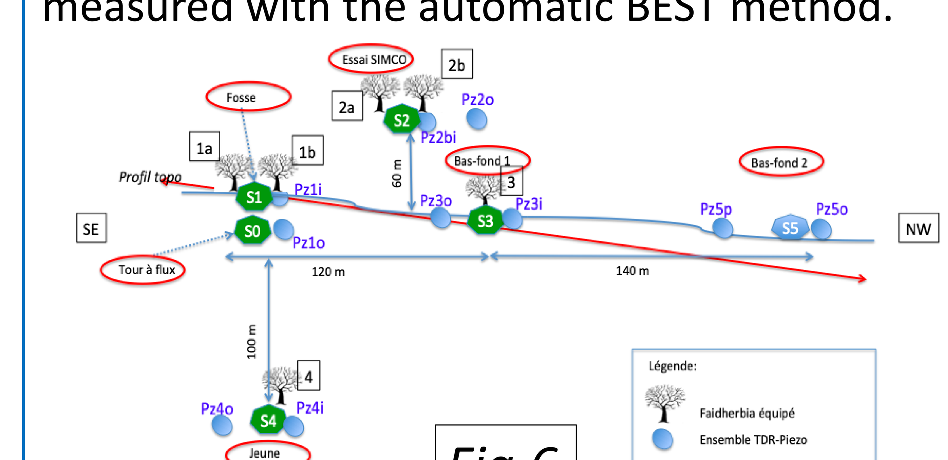


Fig.6

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