Climate change increases soil carbon loss and CO_2 emission in cultivated Alfisols: calibration and application of the model Roth-C in Togo

During the last years in West Africa, the effects of climate change have manifested through an increase in air temperatures and a delay/irregularity of the first rains, which contribute to keeping agricultural land without vegetation cover during several months of the year. Using a modeling approach we explored the impacts of this climatic change on soil C dynamics and on CO_2 release to the atmosphere.

Plot without vegetation cover until March

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Materials and methods

Data from a 30-year experiment on annual crop rotations and mineral fertilizer use conducted at Elavagnon (N 7° 58′, E 1° 21′) in Togo were used to callibrate a version of the Roth-C model written as an Excel worksheet. The model parameterised and tested was used for exploration of climatic scenarios.

Farm plots with low yields and symptoms of mineral deficiency after long-term cultivation (village Manga, Togo)

Results

Topsoil C (20 cm) decreased in 3.2 t ha^{-1} on average over the 30 years, in spite of incorporation to the soil of c. 1.2 t C ha^{-1} $year^{-1}$ through crop residue biomass. The model Roth-C described satisfactorily the observed long-term changes in soil C (r^2=0.8, RMSE= 0.8 t C ha^{-1} - **Fig. 2).** The average rate of C-CO_2 release to the atmosphere was c. 1.3 t ha^{-1} $year^{-1}$. Explorations revealed that an increase of 1°C in monthly temperatures reduced in 27% the equilibrium soil C levels after 60 years, with an extra C-CO_2 released of 3.4 t ha^{-1}. When plots were not vegetated until April-May, soil C mineralization and C-CO_2 emission increased in 1.0 t ha^{-1} $year^{-1}$ **(Fig.3).**

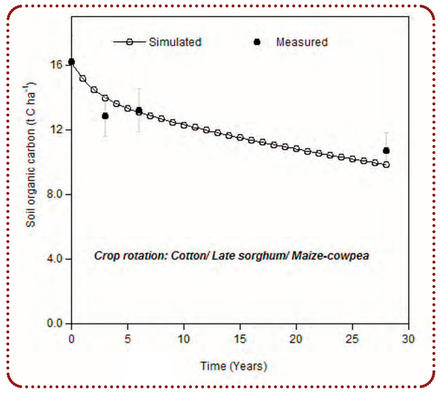

Fig. 1 Observed and Roth-C model simulated long-term changes in soil C at Elavagnon, Togo

Spectrometer for C, N and isotopic analysis at laboratory of UMR Biogéoscience, Dijon, France

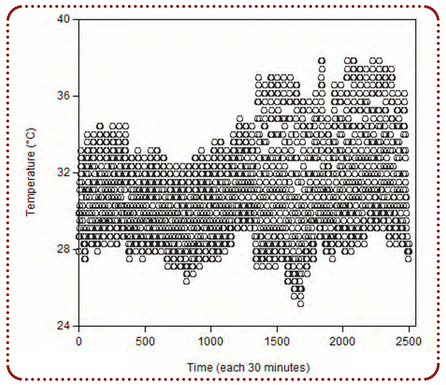

Fig. 3. Temperature changes in topsoil (10 cm) registered each 30 minutes between November and December 2009

Discussion

Replacement of the natural vegetation by annual crops that provide easily decomposable C inputs and soil disturbance through tillage under torrid temperature **(Fig. 1)** unchaine positive feedback loops in terms of C losses and CO_2 release in these sandy soils with only 5% clay contents (Eswaran et al., 1993; Jacinthe et al., 2002). Heavy rains after long periods of drought impact on denudated soils, leading to severe soil losses by erosion (Roose and Barthes, 2001). A practice of mulch that may reduce soil temperatures and limit erosion may be an alternative for soil C protection in this region.

Partnership ITRA/CRA-SH and CIRAD at Kolokopé station (Togo)

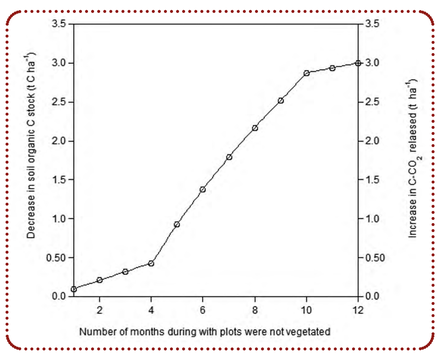

Fig. 2. Decrease in soil C stocks and increase in C-CO2 releases as a function of the duration of the period of soil uncovered

Conclusion

An increase in air temperatures and a delay of the first rains such as recently observed in West Africa increased soil C mineralization and CO2 emission substantially.

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