Climate change increases soil carbon loss and CO₂ 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 CO₂ release to the atmosphere.

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 calibrate a version of the Roth-C model written as an Excel worksheet. The model parameterised and tested was used for exploration of climatic scenarios.

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). The average rate of C-CO₂ 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-CO₂ released of 3.4 t ha⁻¹. When plots were not vegetated until April-May, soil C mineralization and C-CO₂ emission increased in 1.0 t ha⁻¹ year⁻¹.

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) unchains positive feedback loops in terms of C losses and CO₂ 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.

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.