Geophysical Research Abstracts
Vol. 12, EGU2010-4243-1, 2010
EGU General Assembly 2010

Understanding the potential impact of climate change on long term soil carbon dynamics in tropical cropping systems - evidence from West Africa

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Long term experiments offer a unique opportunity to assess sustainability and temporal dynamics of biogeochemical cycles in agriculture, as well as the gradual impact on these of relatively slow processes such as climate change. Two long term experiments on annual cropping systems representing locally common crop rotations and cultural practices were established on two contrasting agroecological zones in Ivory Coast (in 1971) and in Mali (in 1965). These experiments were designed to assess the long-term productivity of these systems under different organic matter and nutrient management regimes, applying organic and mineral soil amendments alone or in combination. Organic soil amendments - such as animal manure, compost or plant material collected from the surroundings - were included in the experiments with the double purpose of adding nutrients for immediate crop production and adding organic matter inputs to the soil to restore (or maintain) its organic C content. Here, we provide an overview of the major trends in crop productivity and soil organic C observed in these experiments that illustrates the potential impact of climate change on the effectiveness of different measures to sustain agricultural productivity.

Materials and methods
Both experiments compared crop productivity on control plots without any soil amendment versus plots receiving organic matter, mineral fertilisers or both combined. The experiment at Gagnoa (southern Ivory Coast) was conducted during 23 years in a zone characterised by a bimodal rainfall regime (c. 1300 mm year-1) that allows two cropping seasons per year (Alfisols 15% clay). Every year maize was planted during the first rainy season. Organic matter was added as compost at a rate of 10 t ha-1 year-1, with or without application of 160 kg N ha-1 year-1 in mineral fertiliser (Chabalier, 1986). The experiment at N'Tarla (southern Mali) was conducted during 24 years in a zone of mono-modal rainfall (c. 900 mm year-1); Alfisols 5% clay), and consisted of quadrennial/triennial rotations of cotton (2x), sorghum and groundnuts. Organic matter was added as straw collected from adjacent fallow fields at a rate of 15 t ha-1 every three years, with and without application of N-P-K mineral fertilisers at an average rate of 30, 20 and 40 kg ha-1 year-1, respectively (Kone, 1989). In both experiments crop residues were incorporated in the soil every year.

Results
At both sites yields of the main crops were larger than the control on plots receiving organic and/or mineral soil amendments, and in both experiments crop yields were comparable when either organic or mineral fertilisers were applied. In the case of maize, partial additive effects of organic and mineral fertilisers applied in combination were observed. In the case of cotton, plots receiving only mineral fertilisers tended to yield less than those receiving organic amendments during the second half of the experiment. Soil organic C declined in control plots and in those receiving only mineral fertilisers in Gagnoa (Ivory Coast), and less markedly also in N'Tarla (Mali). Addition of 10 t ha-1 year-1 of organic matter with or without addition of mineral N led to greater soil C contents in Gagnoa, but yet a decline was observed over the 23 years. Addition of 15 t ha-1 year-1 of organic matter with or without fertilisers in N'Tarla had only a marginal effect on soil C content. In spite of the observed decline in soil C contents, maize yields tended to increase in Gagnoa in the last years of the experiment.

Discussion
Important differences were observed between sites in the size of the stocks and flows of carbon in and through the cropping system, which were the result of a different agroecological potential. Maize is a C4 species that produces

large amounts of biomass; two cropping seasons per year allow fixing greater amounts of C from the atmosphere through photosynthesis. Although soil C inputs via crop residues were thus larger in Gagnoa, climatic conditions at this site favoured also a faster mineralisation of soil organic matter. The addition of organic matter, alone or in combination with mineral fertilisers, had a direct positive impact on the size of the stable soil C pool, as evidenced by the greater soil C contents in plots receiving compost. In the case of Mali, with a long dry season between crops, soil organic C did not increase substantially with addition of (15 t dm ha-1 year-1 of) straw.

Plausible scenarios of climate change envisaged for West Africa include greater rainfall variability (a delay in the offset and a shortening in the length of the cropping season) and increased air temperatures. These translate into less inputs of C to the soil (poorer crop productivity) and faster mineralisation rates (higher temperatures), leading to undesirable positive feedbacks. Since fast mineralisation rates under tropical conditions do not allow substantial increases in organic C contents in soils receiving regular organic matter inputs, measures to reduce mineralisation (e.g., no tillage) are necessary to propend to agricultural sustainability in the region.