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Urbanization enhances stocks of P fractions in strongly weathered arable soils of Kumasi (Ghana), West Africa

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Urban farming is common and pivotal to the sustainable development of West African cities. Naturally, tropical soils have low contents of soil organic matter (SOM) and plant-available nutrients such as P. In addition, they are characterized by high contents of Fe oxides and mobile Al that easily form stable P compounds, thus leading to P fixation. The effects of urbanization on P fractions in tropical arable soils of West African cities are largely unknown. Thus, we investigated the effects of urbanization on four relevant P fractions for urban arable soils of Kumasi (Ghana).

In 2016, we sampled topsoils (0-10 cm) from 206 maize fields on Acrisols of the same local soil series, thereby keeping land use and soil series constant. Based on historical satellite images, we included (a) long-term urban soils, i.e., the core Kumasi area that was urban already in 1986, and (b) short-term urban soils, i.e., the periphery that became urban after 1986. We subjected the soil samples to sequential P extraction, including 1) plant-available P (P_{pa}; reagents= $NaHCO_3$, NaOH, at pH 8.5), 2) SOM-bound P (P_{SOM}; reagents= 30% H_2O_2, Na acetate), 3) Ca-bound P (P_{Ca}; reagents= 10% HCl, Na acetate), and 4) P occluded in pedogenic oxides (P_{occ}; reagents= $NaHCO_3$,Na dithionite, Na acetate). We determined P_{pa} and P_{Ca} concentrations in the extracts colorimetrically, and those of P_{SOM} and P_{occ} with an ICP-OES. We transformed all P contents to P stocks per m^2.

Stocks and contents of all P fractions were significantly ($p<0.005$) greater in the long-term urban soils compared to the short-term urban soils. The P_{Ca} fraction is naturally absent in most tropical soils, yet 75 out of the 206 maize fields in this study had quantifiable contents of this fraction. This finding was consistent with the enhanced soil pH and carbonate contents in the urban arable soils of Kumasi. The mean P_{Ca} stocks of those 75 samples exceeded the stocks of all other P fractions in both the long-term (231.1 g m^{-2}) and short-term (63.7 g m^{-2}) urban soils.

Apart from this, P stocks decreased in the following sequence:

1) P_{pa} (long-term= 54.8 g m^{-2}, short-term= 14.7 g m^{-2}),

2) P_{occ} (long-term= 16.5 g m^{-2}, short-term= 12.2 g m^{-2}),

3) P_{SOM} (long-term= 2.3 g m^{-2}, short-term= 1.5 g m^{-2}).

Thus, P_{SOM} stocks were the lowest of all the fractions. Further, stocks of all P fractions were significantly ($p<0.005$) related to SOM stocks. This relationship suggests that urbanization enhances P mineralization from SOM. Key sources of SOM and carbonates are from household and construction waste that accumulate in the arable soils of Kumasi under long-term urbanization. The findings in this work suggest that it will be beneficial for urban farmers in Kumasi and other West African cities, to engage actively in composting urban household waste for the enhancement of soil P stocks. This is a highly relevant issue, as peak P exploitation will be reached in the next decade, thereby initiating an increase in global P fertilizer prices, which is already unaffordable for many West African farmers.