Characterization of Soil Mineralogy in Relation to Soil Fertility Functional Properties for Selected Countries in Africa

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Abstract:

Africa's development depends heavily on soil ecosystem services. However current soil degradation coupled with increasing pressure on land is threatening the soil resource base. There is an urgent need to establish soil health surveillance systems to guide investments and monitor trends in soil health status and impacts of interventions. Surveillance systems require appropriate and rapid, low cost methods that directly measure soil functional properties and can be applied at larger scale. Spectroscopic methods that directly measure organic and mineral composition hold promise for fulfilling this role. Infrared molecular spectroscopy (IR) is one method that has shown promise for predicting many soil functional properties. Xray diffraction spectroscopy (XRD) is another promising method, which directly determines soil mineral composition, but has been little researched as a tool for quantitative prediction of soil functional properties. However a comprehensive knowledge of soil mineralogy in Africa is lacking due to poorly and fragmentally coordinated scientific investigations coupled with the limitations in the traditional analytical techniques. The aim of this study was to develop a rapid XRD measurement protocol and evaluate the ability of X-ray diffraction technique to rapidly predict soil functional properties based on mineral composition. Geo-referenced samples associated with the Africa Soil Information Service (AfSIS), taken from a set of 10 sentinel sites randomized over sub-Saharan Africa, were used for characterization. A total of 160 topsoil samples taken from 16 randomized points of ten 100-km2 sites: Tanzania (3 sites), Malawi (2 sites), Mali (1 site), Burkina Faso (1 site), Kenya (2 sites) and Ghana (1 site) were characterized for chemical properties, particle size distribution, engineering properties and bulk mineralogy. Variation of the mineralogy within and between sites was explored using principal component analysis using the R statistical software, as a precursor to exploring relationships with directly measured soil properties and soil fertility diagnostics. The clustering of individual minerals and the distributions of the soil fertility variables identified across the sites appeared to relate to differences in mineralogical functional groups, supporting the hypothesis that mineralogical data could be used to predict functional properties. The findings therefore suggest opportunity for improving soil assessment using information on soil mineralogy. For instance XRD information on mineralogy can be combined with information from soil physico-chemical properties, to provide powerful diagnostic capabilities, for low cost and rapid prediction of soil functional properties. Further work should aim to develop direct quantitative predictive relationships between soil functional properties and mineralogical composition using the full set of AfSIS reference samples.