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Realizing soil health for food security in Africa

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Dramatic improvements in soil health are necessary to increase agricultural production and reduce crop failures. We provide recommendations for scaling of soil health and fertility management in Africa through practical approaches to prioritization, evidence-based policy and effective extension.

There is a growing recognition of the critical importance of investment in soil health on farms across Africa as a core strategic element of efforts to realize sustainable development goals. The fragmented nature of cultivated areas across the continent is coupled with weak infrastructure, variable policies and disparate efforts. All of these challenge efforts to bridge the 'last mile' and realize soil health on farmer fields. The heterogeneity of local contexts has consequences, as soil health solutions vary by location and social, economic and market context. This context requires targeted efforts, which are inherently challenging to scale. Fortunately, new technological advances are lowering the costs of delivering solution options. However, embracing new technologies is only one part of the solution: to fully capitalize we need coordinated efforts involving public–private partnerships that integrate soil health information with behavioural change.

This Comment outlines a framework for prioritization and operationalization of a coherent soil health investment agenda. We propose three guiding principles. 1) Prioritize investments based on expected returns. Targeting soil amelioration to soil that is not highly degraded will help to maintain productivity where it is most needed and where benefit–cost ratios are generally high. 2) Use simple, quantifiable indicators for systematic assessments. This evidence base can provide feedback on how well policies are working. Soil productivity and buffering capacity is proposed as the lens, with indicators such as soil organic carbon (SOC), pH, yield response to fertilizer and yield stability. 3) Invest in effective extension. Public, private and civil society actors engaged in extension are needed to leverage innovations in communication technologies and promote a learning agenda at the farm and community level.

It is important to target efforts to maximize farm-level investment returns, with the understanding that costs and benefits will vary by location[1]. We acknowledge that there are management and methodological challenges to assessing returns on farms and at regional scales. At the same time, this is a key guiding principle, one that conserves scarce resources. Farmers value their labour inputs differently, as well as the perceived and real costs of depreciation, working capital and opportunity costs. Real and perceived benefits of improved soil health vary widely. One of the most significant benefits – reduced risk of crop failure – can be difficult to quantify. Efforts to promote soil investments where they are agronomically and economically effective will support sustained farm managerial changes.

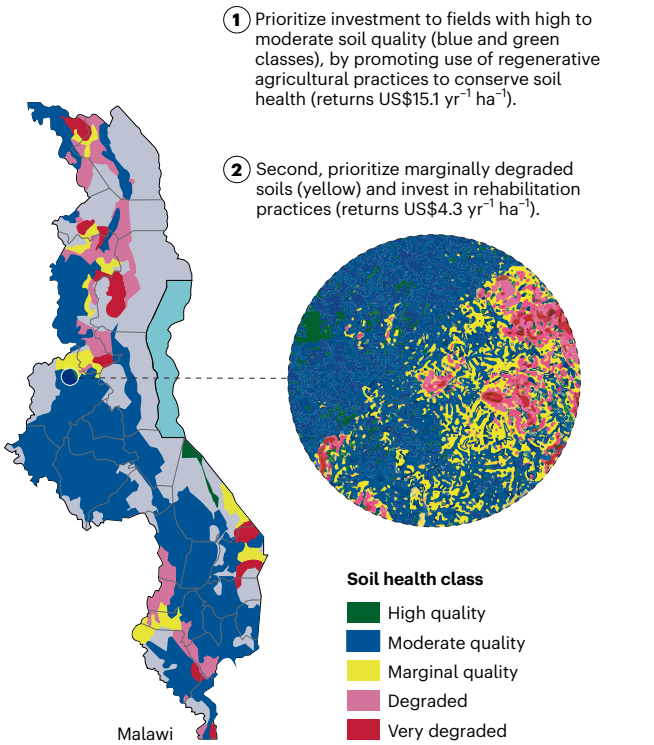

Fig. 1 | Soil health class status in Malawi. Blue and green sites are moderate to high soil health status; these classes are targeted for conservation and sustainable intensification practices to support crop productivity gains and profitable returns to investment. Adapted from ref. 4, CC BY 4.0.

Given the heterogeneity of soil resources, we recommend fine-tuned and localized recommendations. Prescriptive recommendations over large areas are useful only as a starting point. This leads us to propose the following. First, prioritize investments in areas with responsive plots and with farmers willing and able to implement soil conservation practices. Research shows that non-responsive soils are often highly degraded, with depleted SOC stocks and/or chemical deficiencies (such as soil acidity), with water constraints or with innately high fertility[2]. The largest crop productivity and economic returns are thus likely for intermediate status soils[3]. An example of this approach is shown in Fig. 1, which illustrates such targeting in the context of a specific use case, that of Malawi[4]. This is not to minimize the importance of rehabilitating degraded soils, which require investment as a global good. Rather, we seek to highlight the importance of conserving and enhancing the health of moderate quality soils.

Second, prioritization efforts should recognize that even where agronomic responses are high, they may not be profitable. Recent work has highlighted the marked heterogeneity in the profitability of fertilizer and other soil investments across Africa's varied agricultural landscapes[5]. At current prices and fertilizer response rates, short-term policy options may include smart subsidies or ecosystem service payment interventions for otherwise unprofitable contexts. Extension advisory investments are discussed below, as raising fertilizer efficiency and soil health through sustainable practices will improve profitability and investment incentives in the long term.

Finally, addressing riskiness of farm-level investments is critical. African smallholders are known to be risk-averse and yet operate in rainfed systems with considerable uncertainty in seasonal production outcomes[6]. Using modelling approaches to identify where expected returns on fertilizer and soil health are high but uncertain, for example, may help to target input promotion efforts or ecosystem service payments, which are bundled with risk-reducing instruments, such as crop insurance or risk-contingent credit[7].

Indicators for monitoring progress

Evidence-based decision-making on policies and investments in soil health requires indicators that are readily measurable and enable cross-site and inter-temporal comparisons. Spatially explicit indicator measurements provide context-specific soil health management advice and enable the tracking of soil status over time. We propose indicators that meet the criteria of feasibility, affordability, scalability and predictive power. These include two direct measures of soil health properties (SOC and pH), as well as indirect measures, cereal yield response to fertilizer and yield stability.

SOC status is closely related to regulation of soil moisture and nutrient cycling and is often predictive of crop establishment, growth and yield potential[3]. Soil pH is a common constraint, as both acidic and alkaline soils present barriers to agricultural production. These indicators can be the basis of spatial assessments using low-cost proximal devices for field diagnostics[8], including innovations in reflectance spectroscopy to inform predictive maps[9].

Yield response of maize to fertilizer is a useful indicator that connects soil health to productivity[4,10]. Furthermore, yield stability is a measure of resilience to weather extremes, where reduction in downside risk of yield loss is the recommended indicator of stability. Recent advances in soil and land surveillance from reflectance-corrected satellite imagery and field-sampled spectral libraries are paving the way for biophysical characterization of the land surface. Spectral monitoring can provide insights into crop productivity, stability of yield response and extent of land degradation[9].

These advances are opportunities to revolutionize the way in which spatial resources are monitored, analysed and predicted, when ground-truthed with observations in smallholder farms and communities. Efforts need to be mobilized around a core set of consistently measured indicators. This constitutes an inexpensive monitoring approach that can generate the evidence for effective, timely soil health investments.

Innovations for inclusive extension

Pluralistic extension institutions and approaches are urgently needed to realize improvement in soil health management on smallholder farms in Africa. Progress has been hampered by extension that does not invest sufficiently in a learning agenda, leading to limited local agency and a lack of adaptation or localization of solutions[11]. To correct this, investments should include improving the competencies of extension workers (including digital competencies) and access to information and communication technologies and developing farmer-centric and fit-for-purpose solution options. Farmer-centred approaches are a critical enabler of behavioural change[12]. Farmer adopters act as effective change agents and extension messengers as they adapt recommendations, the key to scaling out soil health.

The fundamental shift in extension proposed is to develop human capital, in support of harnessing indigenous knowledge (forged through millennia of experience) and scientific information generated through the rigours of empiricism. Our role is not technology development per se, but rather socioeconomic development. The latter is essentially a social process. This requires enhancing social capital, norms of trust, reciprocity and collective action. All of this will, likely, require investments in pluralistic extension systems. This will inevitably include public extension, private sector entities, and civil society and community organizations to achieve broader and more significant impacts[13].

Strategic investments are required to sustain soil health across the smallholder-dominated farming systems of Africa. In this Comment, we have advocated for three pillars of such an investment strategy. To begin with, targeting efforts to areas where field-level soil health investments offer the highest returns will maximize aggregate impacts and benefits. However, effective geo-targeting requires an evidence base. Recent developments in proximal and remote-sensing-based indicators provide affordable means to assess soil health at scale but require coordinated investments. Finally, extension efforts are needed to support farmer learning. This is important, as soil amelioration often involves knowledge-intensive approaches such as agroforestry, conservation agriculture and agroecology. In combination, such investments have the scope to enable adaptive extension systems, guided by evidence and an active learning agenda, to tackle the urgent challenge of scaling locally adapted soil health solutions across the heterogeneous challenges faced by African farming systems.

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Author contributions

S.S., J.C. and L.W. developed the ideas for the Comment jointly. S.S. wrote the initial draft. S.S., J.C., L.W., T.A., E.B., S.G., J.E.H., R.L., P.M., L.N., Z.S. and T.V contributed to subsequent revisions.

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