Agroecological TRANSITIONS Programme

POLICY BRIEF

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Socially inclusive decision support tool for smallholder sustainable intensification and soil health

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KEY MESSAGES

- Decision support tools for sustainable intensification to enhance soil health are needed to supplement extension services in sub-Saharan Africa, yet many remain inaccessible or irrelevant to smallholders.
- These tools should consider both GIS and place-based solutions or elements, such as onsite measurements. The *Space to Place* method was used as a case analysis to enhance localization of improved fertilizer and soil health practices at scale.
- A roadmap was developed to support the creation of socially inclusive, agency-enhancing decision support tools aimed at promoting sustainable intensification in smallholder farming systems.
- We conclude with recommendations on the best combination of tools to achieve the needs of sustainable intensification, co-creation of knowledge and social inclusion, namely, the GeoFarmer application (Space) and onsite spectrometers (Place).

Digital tools for smallholder decision support

Decision support tools (DSTs) are essential for smallholder farmers in sub-Saharan Africa (SSA) as unprecedented changes to the agricultural landscape persist. Climate change is manifesting through erratic weather patterns, shifting growing seasons, and an increased frequency of extreme weather events while market dynamics are evolving to offer opportunities and challenges alike. Extension services remain unable to address these compounding challenges at the necessary scale. To navigate these complexities, DSTs are a vital component in providing sound agronomic advice when tailored to local contexts, thus enabling the development of solutions that address these multifaceted challenges. Yet DSTs remain inaccessible or irrelevant to smallholders for several reasons (Shelton et al., 2022), including:

- Top-down technical assistance approaches.
- Lack of representation, context-specificity, digital skills, or trust in recommendations.
- Inability to access the necessary infrastructure (e.g., digital devices, internet, cost of digital services).
- Marginalized groups are often the last to benefit from new technology or are at the greatest risk of data and privacy rights violations.

At the same time, increased attention to soil health under agronomic conditions of intensification has become a policy priority. Smallholders often face issues such as soil nutrient depletion, erosion, and declining organic matter, which undermine productivity and resilience. Soil degradation exacerbates the challenges posed by climate change, reducing the effectiveness of agronomic interventions (Pozza and Field, 2020). Moreover, inadequate access to appropriate soil testing tools and tailored fertility management recommendations limits the ability of farmers to improve soil health sustainably (Hou et al., 2020).

Against this background, the purpose of this brief is to (1) understand how DSTs can support sustainable intensification (SI) in a way that serves the most marginalized (e.g., gender, class, race, ability, etc.) smallholders and recognizes and enhances their agency; and (2) provide a roadmap for research organizations, development entities, and private sector stakeholders to implement a socially inclusive DST related to SI for enhancing soil health. The goal is to reduce fertilizer wastage for optimal economic returns with better soil fertility management

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practices and technologies by expanding on the menu of agronomic innovations related to SI. Such innovations encompass a wide range of practices, including organic and inorganic nutrient management, cropping systems technologies, and agronomic decision making (Sileshi et al., *under review*). This multifaceted approach will empower smallholders with a versatile arsenal of options, enabling them to respond proactively to the intricate challenges they encounter.

Below we synthesize the current state of DSTs regarding their applicability to support inclusive and agency-enhancing scaling of SI and soil health. We use this synthesis to guide research organizations, development entities, and private sector stakeholders on implementing a DST to support best bet SI options, by context.

How DSTs can promote SI and foster social inclusion

Digital dissemination of information can promote SI, reach diverse farmers with personalized information, and foster knowledge sharing among farmers and agricultural advisors. Further, establishing digital knowledge channels with farmers opens the opportunity to collect their feedback, enabling demand-driven agricultural advisory.

Site-specific SI approaches are needed to address poor soil health, including soil organic carbon depletion, and declining crop productivity in SSA. DSTs that leverage cutting-edge innovation, such as digital sensors and data analytics that harness the wealth of empirical evidence drawn from extensive long-term research and on-farm experimentation, offering a new-generation approach for empowering smallholders to address these challenges. When digital sensors are integrated with empirical evidence, they provide locally informed advice on the most suitable agronomic practices for specific contexts. This approach enhances the precision of agronomic advice and ensures that recommendations are grounded in scientific rigor.

Importantly, digital technologies offer the possibility to reach those with limited literacy, disproportionately women and other marginalized groups, through voice-based messaging and feedback in local languages and preferred tones (e.g., formal/informal, male/female). In addition, digital extension allows users to access information and provide feedback from the convenience of their home or farm while performing daily activities, which helps alleviate women's time and mobility constraints (Pierotti et al., 2022). Furthermore, providing women with access to large virtual networks can help compensate for the information disadvantages they face from having smaller social networks with less geographic coverage and are less diverse than men's social networks.

Optimism about inclusive digital advisories is tempered by persistent digital divides based on gender (GSMA, 2024) and other social identities (e.g., age, income, education, ability, sexuality). The main proximate factors contributing to the social digital divide in SSA are unaffordability of mobile phones and SIM cards, irrelevant information content, and the illiteracy and limited digital skills of many potential users (Coggins et al., 2022; Roberts and Hernandez, 2019), which are rooted in social norms (Sterling et al., 2020). These factors, existing social norms, and the common practice of targeting male progressive farmers in agricultural information channels (BMGF, *n.d.*), can exclude many farmers from the potential benefits of digital extension (e.g., information access, higher productivity and farm income, and greater agency) and exacerbate social inequality. Thus, only carefully tailored multi-dimensional interventions that address the immediate proximate causes of digital exclusion and tackle systemic inequality hold promise for ensuring women and men are equally positioned to benefit from digitalization.

Roadmap for inclusive DSTs

Here, we provided a roadmap for research organizations, development entities, and private sector stakeholders to support socially inclusive, agency-enhancing DSTs in promoting SI in smallholder systems, given the constraints and opportunities discussed above. We use the Space to Place method as a case study. This method aims to localize improved fertilizer and soil health practices at scale. It is motivated by two observations: First, blanket and soil map-based recommendations are not specific enough to be useful to farmers. Second, while farmers need site-specific recommendations (i.e., soil analyses, extension advisor), development is costly and hard to scale. By combining GIS based (Space) and user sourced (Place) information, Space to Place will enable the scaling of fertilizer and soil health recommendations tailored to the objectives, circumstances, and needs of diverse smallholders.

We draw upon existing principles related to the development and implementation of socially inclusive digital tools for smallholder farmers (Dittmer & Burns et al., 2024) and the *Principles for Digital Development*. We assume that smallholders or extensionists are the DST end-user and smallholders are the primary beneficiary. Figure 1 provides a visual summary of the roadmap.

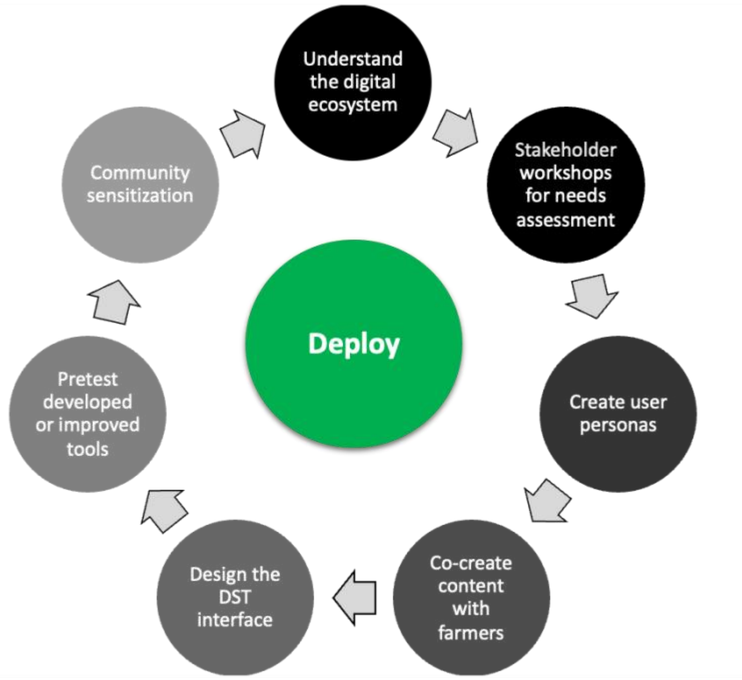

Figure 1 Summary of the recommended steps for the design and implementation of socially inclusive decision support tools (DSTs).

1. Understand the digital ecosystem

Understanding the digital ecosystem requires allocating time and resources for a comprehensive analysis of cultural, social, economic, political, and technological factors within which a digital development initiative operates. The analysis should be conducted through desk research, expert interviews and focus groups with relevant stakeholders. This understanding is vital for the success of design, implementation, and sustainability of digital projects. It helps in ensuring that digital initiatives are relevant and capable of achieving the intended impact.

Creating a new digital tool does not inherently equate to innovation. Several options currently exist regarding DSTs for SI (Dittmer et al., 2022), each with their own strengths and weaknesses in terms of accessibility and relevance. Building on existing solutions ensures the selected digital tool is relevant and eliminates duplication of effort, resources, and time. Partnering with others who have done similar projects provides opportunities to learn about challenges, opportunities and areas to collaborate to create a resource that best serves the intended target group.

2. Hold stakeholder workshops for needs assessment

Stakeholder workshops offer a space for inclusive understanding by bringing together a diverse array of smallholders, agricultural experts or extensionists, local authorities, and tool developers. By involving these key players, the development process gains access to a comprehensive range of perspectives, ensuring a holistic understanding of smallholders' unique challenges and needs for adopting SI practices. This approach is fundamental to designing DSTs that resonate with and effectively address the specific challenges experienced by smallholder farmers.

Workshops provide a forum for farmers to articulate their requirements, express their preferences, and convey their real-world challenges. This direct engagement ensures that DSTs are crafted with a deep understanding of the farmers' contexts, fostering the creation of solutions that are not only technically robust but also culturally and contextually relevant (e.g., local language/dialect, pictures that reflect them and provide a sense of familiarity). Consider having an even balance between all stakeholders, meaning smallholders are equally represented for fair and comfortable participation amongst researchers and tool developers. Compensate farmers for their time, whenever possible.

3. Create user personas

User personas relate to fictional yet realistic representations of the characteristics of real users or beneficiaries. Based on stakeholder workshops and needs assessment with target users, create these personas to reflect the lived experiences, needs, risks and frustrations they might face when engaging with a digital tool. Purposes of user personas include:

- **User-centered design**: Serve as a reference point during the design and development of digital tools. Designers, developers and tool implementers can consider the personas' needs and preferences to create user-friendly experiences.
- **Digital tool development**: Guide digital tool managers and developers in prioritizing features and functionalities that align with user needs and goals.

- **User testing**: Smallholders are not a homogenized group. Personas can inform the selection of participants for user testing, ensuring that testing reflects the diversity of the target audience.
- **Alignment across organizations**: Provide a shared understanding of the target users across different organizations, fostering alignment and collaboration.

4. Co-create SI content with smallholder farmers

Farmers are experts over their own lived experiences and abilities, and co-creating content and solutions with them will enrich their digital experience. Co-creation is an iterative, collaborative process among farmers, researchers, agricultural extensionists, and other relevant stakeholders, especially important when creating SI content. The co-creation process begins with stakeholder workshops, followed by the development of *initial* SI content by a team of agricultural researchers. This SI content, differentiated to the various farmer personas, is then made available to agricultural extension officers and a diverse group of farmers in targeted communities who evaluate the information content for its relevance and utility to the socio-economic circumstances, priorities, and existing knowledge of farmers. Feedback from farmers and agricultural extension agents will regularly be solicited to keep information content current with farmers' changing circumstances and needs.

5. Design the DST interface

To operationalize the concepts of social inclusion, farmer agency, and informed soil health decisions, the DST interface can incorporate features such as:

- **Customized recommendations**: Tailored advice based on user input and local context to ensure inclusivity and relevance.
- **Interactive features**: Engagement features like chatbots, two-way communication channels, or interactive tutorials to empower farmers and promote a bottom-up approach.
- **Data collection mechanisms**: Tools to collect user feedback and data on soil health, enabling informed decision-making.
- **Training and capacity building**: Resources to enhance farmers' knowledge and skills, fostering their agency in adopting sustainable practices.

By incorporating these elements, the DST interface can address the specific needs of farmers, promote social inclusivity, and empower users to make informed decisions regarding soil health management.

6. Pretest developed or improved tools

Pretesting developed or improved digital tools involves a structured plan that outlines the steps and activities required to assess the tools' functionality, usability, and effectiveness before wider deployment. It serves as a strategic guide to ensure that the tool aligns with the needs and expectations of smallholders and is refined based on feedback. Based on farmer feedback, note how the current design could exclude individuals, and identify those individuals or groups. Following this, iterative cycles of refinement and retesting are carried out until the digital tool demonstrates robustness, user-friendliness, and effectiveness in meeting the needs of smallholders.

Receiving farmer feedback does not end at the testing phase. Prioritize farmer feedback during each step of the design and implementation phase and incorporate feedback mechanisms in the tool. It is crucial to maintain open channels of communication for farmer-to-farmer exchange, farmer-to-advisor, advisor-to-famer, and farmer-to-developer feedback.

7. Community sensitization

Meaningful involvement of farmers and community engagement are crucial elements in ensuring the success and sustainability of agricultural interventions. In the context of deploying a digital tool, it is essential to conduct pre-implementation meetings with and in intervention communities. During these meetings, extension agents and community leaders play a vital role in informing and getting input from community members about the digital application's purpose, functionality, and potential benefits. This helps to build legitimacy and gain community buy-in, as community members can understand how the tool can directly benefit them.

Furthermore, these meetings provide a platform for community members to voice their concerns, ask questions, and provide feedback. This participatory approach ensures that the tool is designed and implemented in a way that is sensitive to the needs and realities of the community, emphasizing:

- **Inclusivity**: By emphasizing equal opportunity, the aim is to ensure that marginalized or disadvantaged groups within the community, including the "last mile population," are not left behind.
- **Equity**: Equal opportunity emphasizes fairness and justice in access to resources and benefits. It aims to level the playing field so that all farmers, regardless of their background, social identities, or resources, have a fair chance to benefit from the tool.
- **Maximizing impact**: By ensuring that the tool is accessible to all members of the community, its potential impact can be maximized.
- **Sustainability**: Building a sense of inclusivity and equal opportunity can lead to greater community ownership and support for the tool. This, can contribute to the tool's long-term sustainability as community members are more likely to continue using and supporting the tool over time.
- **Social cohesion**: Promoting equal opportunity can also foster social cohesion within the community by reducing inequalities and promoting a sense of unity and shared purpose.

It is important to hold these community meetings at a time and location that maximizes attendance, particularly by women and men from diverse backgrounds. This inclusive approach ensures that the voices and perspectives of all community members are heard and considered in the implementation process.

8. Deploy

Deploying a digital tool should only occur after thorough consideration and execution of the preceding steps. Deployment is not the end of the development process but rather the beginning of a new phase where the tool is used, adjustments are made to the design based on user feedback, and impact is assessed (Figure 1).

During deployment, the safety and protection of the most vulnerable user groups must be prioritized. This includes implementing safeguards for privacy and ensuring the confidentiality of data. Providing these individuals with the option to opt out of the service is essential for respecting their autonomy and rights. It is also important to recognize that deployment is not a static process. The digital ecosystem is constantly evolving, and user needs and preferences may change over time. As such, ongoing adjustments and improvements to the tool based on feedback and evolving needs are necessary to ensure its continued relevance and effectiveness.

Deployment should be approached as a dynamic and iterative process. Continuous monitoring and evaluation are essential during the deployment phase. These activities assess the tool's impact and identify areas for improvement, which optimizes efficient and effective use of resources for maximum impact. Interface and content updates should be continuous during development, informed by iterative user feedback and the latest science, respectively, to ensure the tool remains user-friendly and scientifically rigorous during implementation and provide essential lessons for the tool's sustainability beyond the project.

Recommendations

To develop a farmer-centered and socially inclusive soil health DST, guided by the principles above, we recommend bundling several existing digital resources to provide the following services:

1. provide farmers with high-quality and science-based technical options for improving their soil health;
2. allow farmers to measure and subsequently improve soil health at their farm;
3. allow farmers to provide feedback to scientists, agricultural extension officers, and developers; and
4. enhance opportunities for farmers to collaborate (peer-to-peer knowledge sharing).

Currently there is no single tool that can deliver these four services. Based on the need for these services and to achieve socially inclusive DSTs, we recommend bundling the GeoFarmer application (Space) with the use of onsite soil spectroscopy (Place). This recommendation is based on a global review of technical advisory or performance assessment tools (Dittmer et al., 2022), review of platforms such as the CGIAR Evidence Clearing House and Digital Agri Hub, and consultations with agricultural scientists with knowledge or experience using different tools and approaches for soil health interventions in SSA.

Below we describe the tools recommended for the soil health advisory system and highlight how they provide the necessary services and promote social inclusion.

The GeoFarmer application

GeoFarmer serves as a supplementary tool to digital extension services that can also be used by the community. The concept behind GeoFarmer is to establish a versatile communication channel connecting farmers, researchers, and farmer groups. It presents a cost-effective information and communication technology-based platform for monitoring agricultural production systems, enabling interactive feedback among users within predefined geographical domains (“channels”). Inputs to the system can be entered online, a smartphone application, or through an interactive voice response (IVR) service. These elements facilitate information collection and sharing during project interventions involving community workers and smallholders. For instance, development entities have the flexibility to customize the tool, creating a new communication channel to gather valuable feedback and address the evolving needs of their beneficiaries. Through the same communication channel, farmers can access information and best practices shared by peers or extension workers. GeoFarmer facilitates near real-time, bidirectional data flows that support co-innovation processes in agricultural development projects. See Eitzinger et al. (2019) for a comprehensive description of the GeoFarmer application.

GeoFarmer was developed as a subsystem of GeoCitizen. The GeoCitizen framework provides several modules such as georeferenced surveys, geolocation of context-relevant information and structured and transparent discussion and feedback loops. In turn, GeoFarmer integrates various data layers, including maps, satellite imagery, and geospatial datasets. These layers may encompass information such as topography, land cover, soil types, weather patterns, and crop health. By combining these layers, the application creates a multidimensional and low-cost representation of the agricultural environment.

Onsite spectrometer readings

The use of onsite spectrometers in agriculture is not a new concept (Ahmadi et al., 2021; Monteiro et al., 2021; Rodríguez-Pérez et al., 2021; Shafi et al., 2019). Notable applications include quality control in fruit production, soil characteristic analysis for sustainable farming, and disease detection in livestock farming. Spectrometers are also employed in cereals production to assess the nutritional status of crops, identifying deficiencies in macro- and micronutrients, thus playing a crucial role in timely fertilizer recommendations. Overall, the appeal of onsite spectrometers lies in being cost-effective, fast, environmentally friendly, and providing reproducible results without the burden of high technical literacy in using the device (Ahmadi et al., 2021; Monteiro et al., 2021; Rodríguez-Pérez et al., 2021). The ability to measure soil characteristics imperceptible to the naked eye enhances farmers' understanding and encourages the adoption of best soil management practices.

For SI to improve soil health through improved nutrient management and enhanced soil organic matter, we suggest the employment of spectrometers for qualitative soil property analysis and associated recommendations. The use of spectrometers in this context further promotes discussions about soil health and farm management, particularly for smallholders unfamiliar with data-driven tools. The spectrometer-generated, plot-specific soil property information becomes the foundation for tailored extension advice on soil fertility management and related topics. The advice is then customized based on the organic composition of the soil.

Bundling GeoFarmer with onsite spectroscopy

To bundle the GeoFarmer application with onsite spectrometer readings to support SI in SSA, the tool implementor will need to integrate the spectrometer data seamlessly into the existing framework while maintaining the application’s core functionalities. Here is how this can be achieved:

1. **Integration of spectrometer data module**: Develop a module within the GeoFarmer application to capture, store, and process onsite spectrometer readings. This module should allow users to input spectrometer data directly through the smartphone application or online interface.
2. **Data visualization and analysis**: Implement tools within GeoFarmer to visualize and analyze spectrometer data alongside existing georeferenced surveys, maps, and other geospatial datasets. This integration will provide farmers and researchers with a comprehensive view of soil health parameters such as nutrient levels, organic matter content, and soil moisture.
3. **Interactive feedback loop**: Enhance the feedback loop functionality of GeoFarmer to enable users to provide feedback based on the analyzed spectrometer data. This feedback should include actionable recommendations for soil amendments, crop selection, or irrigation practices to improve soil health and optimize production. It should also allow users to report issues (e.g., privacy concerns, critical updates, software defects, etc.) within the application itself and have those issues quickly addressed.
4. **Customization and adaptation**: Ensure that the GeoFarmer application remains customizable to meet the specific needs of different farms and communities. The tool implementor should have the flexibility to

tailor the spectrometer data module according to the requirements of their beneficiaries across demographics.

5. **Capacity building and training**: Provide training and capacity building support to farmers, extension workers, and other stakeholders on how to effectively use spectrometer data within the GeoFarmer application. This includes training on data collection, interpretation, and decision-making based on the insights derived from spectrometer readings.
6. **Collaborative knowledge sharing**: Facilitate collaborative knowledge sharing and co-innovation processes by integrating spectrometer data sharing capabilities into GeoFarmer. This will enable farmers, researchers, and extension workers to exchange insights, best practices, and innovative solutions for SI.
7. **Accessibility and usability**: Ensure that the spectrometer data module is accessible and user-friendly, especially in regions with limited internet connectivity or smartphone usage. Consider alternative data input methods such as SMS or IVR services in local languages to accommodate users with different technological capabilities.

By integrating onsite spectrometer readings into the GeoFarmer application and aligning it with the existing framework for SI, research organizations, development entities, and private sector stakeholders can enhance the capacity of smallholder farmers in SSA to make informed decisions and improve soil health management practices.

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The Agroecological Transitions for Building Resilient, Inclusive, Agricultural and Food Systems (TRANSITIONS) Program aims to enable agroecological transitions. The TRANSITIONS Inclusive Digital Tools (ATDT) project aims to support the use of digital resources and citizen science to empower farmers to co-create, adapt, and innovate practices for climate-resilient and low-emission agroecological outcomes at large scales.

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