Agroecological TRANSITIONS Programme

Global digital tool review for agroecological transitions

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Correct citation
Burns, S., Dittmer K.M., Shelton S.W., Wollenberg E. 2022. Global digital tool review for agroecological transitions. Agroecological TRANSITIONS: *Inclusive Digital Tools to Enable Climate-informed Agroecological Transitions* (ATDT). Cali, Colombia: Alliance of Bioversity & CIAT.

Project Donor Acknowledgement
The *Agroecological transitions for building resilient and inclusive agricultural and food systems (*TRANSITIONS) programme is funded by the European Union through its DeSIRA initiative and managed by the International Fund for Agricultural Development (IFAD). This publication was produced by the *Inclusive Digital Tools to Enable Climate-informed Agroecological Transitions* (ATDT) Project under the European Commission grant agreement No. 2000003773.

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Cover photo*:* © 2013 JP Sinohin (IRRI). Depicts Joan Villoria, an agricultural extension agent, and farmer Angel Bautista using the Rice Crop Manager in Los Banos, Philippines.
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Acknowledgements

The Agroecological Transitions for Building Resilient, Inclusive, Agricultural and Food Systems (TRANSITIONS) Program aims to enable agroecological. This report was produced by the TRANSITION'S Inclusive Digital Tools (ATDT) project, which 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. The TRANSITIONS programme is funded by the European Union through its DeSIRA initiative and managed by the International Fund for Agricultural Development (IFAD). The contents and opinions expressed in this publication are not peer reviewed and are the sole responsibility of the authors. They do not necessarily reflect the views of the European Union, IFAD or affiliated organizations.

Keywords

Climate Change, Digital Extension Tools, Agriculture, Agroecology, Farmers, Social Inclusion, Climate Change Mitigation, Performance Assessment.

Contents

Why digital tools for an agroecological transition?

Agroecological transitions are increasingly seen as a means for improving the sustainability of food systems by applying ecological principles to agriculture and generating ecosystem services while also improving socially equitable decision-making. At the same time, climate change adaptation and mitigation are increasingly being integrated into agroecological transitions to meet the goals of the Paris Agreement. In low- and middle-income countries (LMICs) agricultural investment remains a priority for economic development. Agroecological transitions in these contexts involve supporting farmers to shift to more climate-resilient and intensive production systems while minimizing negative ecological and human impacts, for example from greenhouse gas emissions, toxic pesticides, or inefficient nutrient use. Social movements for agroecology and donor funding have been the primary drivers of agroecology to date.

As advocates and donors seek to scale up agroecological transitions, digital tools can help rapidly provide technical support and performance assessment for large numbers of farmers. Yet digital tools for scaling up practices or assessing outcomes have not been widely used by smallholders, women, the rural poor and other marginalized groups in LMIC due to a lack of digital literacy or access to digital infrastructure. Involving farmers in the co-creation of knowledge is a key principle of agroecology. If digital platforms are to be a major driver for scaling up agroecology, it is essential to support more inclusive use of tools and co-design of practices by farmers to address needs in LMICs.

In addition, technical guidance for agroecology in tools is often weak and climate change adaptation and mitigation are not regularly integrated into practices.

To support scaling of agroecology, the Socially Inclusive Digital Tools Project (ATDT) of the Agroecological TRANSITIONS Program aims to support use of digital resources and citizen science to empower farmers to co-create, adapt and innovate practices for climate-informed agroecological outcomes at large scales. The project is one component of the CGIAR's Program on Agroecological Transitions for Building Resilient, Inclusive, Agricultural and Food Systems (TRANSITIONS), which aims to enable climate-informed agroecological transitions through the development and adoption of holistic

metrics for food and agricultural systems performance, inclusive digital tools and transparent private sector engagement.

Purpose of this report

This report summarizes a global review of digital resources relevant to climate change-informed agroecological transitions.

The goal of the review was to identify exemplary features of digital tools for socially inclusive and climate-informed agroecological transitions. We cataloged digital resources available globally that provided either technical advisory services or performance assessment, as functions that directly support scaling up new practices. We reviewed the tools' functions (i.e., the purpose of using a tool) against indicators for exemplary features (i.e., the channels through which a user can engage with the tool). To address social inclusion, we gave special attention to farmers' co-creation of knowledge for on-the-ground practices.

Methods

We defined digital tools as programs or applications used primarily on devices such as cell phones, computers, or tablets, and that that allow users to engage in defined target activities, in this case agro-advisory and performance assessment. We did not include analog tools with a digital component, such as in-person extensions services with follow-up via SMS. We also did not include digital platforms or processes.

We selected tools with either agro-advisory or performance assessment functions and that had agroecological or climate change content or features. Tools were classified as technical advisory resources if they delivered any recommendations regarding farming practices and as performance assessment resources if they included assessment of farm outcomes, status or operations.

Exemplariness was defined as tool features that best fit the requirements of the target users and best addressed agroecological and climate change mitigation or adaption outcomes. We developed 87 indicators to characterize tools and their exemplary features for the following functional or content areas: technical advisory, performance assessment, agroecology, climate change adaptation and mitigation, social inclusion and co-design, and scaling (see Annex 1). These indicators provided a

framework to identify and evaluate exemplary features of digital tools that could support socially inclusive agroecological transitions.

The 12 agroecological indicators (i.e., principles) were adopted and refined from the FAO 10 Elements of Agroecology (FAO, 2018), HLPE (HLPE, 2019), and TAPE (FAO, 2019) reports, resulting in 12 agroecological indicators (Annex 1, Agroecological Principles). Indicators for climate change were determined for adaptation and mitigation based on Snapp et al. 2021. Greenhouse gas sources included trees on farm, land use change, livestock and pasture, soil and nutrient management, paddy rice, food loss and waste, energy (on-farm), and burning. All indicators in Categories i-v in Annex 1 were developed and validated via several rounds of internal reviews and expert consultations.

We conducted three stages of selection and analysis of tools for review: (1) collection of candidate tools, (2) selection of the tools with the strongest exemplary features selection, and (3) analysis of exemplary features of tools for agroecology and tools for climate change. Tools were identified via Google searches, expert interviews and recommendations, and platforms such as the CGIAR Evidence Clearing House and Digital Agri Hub.

More than 244 candidate tools were identified. Sixty-one (61) tools were then selected for a full review against the 87 indicators, based on inclusion and exclusion criteria.

The inclusion criteria required that the tool:

- Provided farming technical advice or performance assessment for agroecology or climate change mitigation or adaption outcomes,
- Applied, or could be applied, to smallholder farmers,
- Applied, or could be applied, in low- and middle-income countries, and
- Was consistently mentioned during expert interviews and other discussions.

The exclusion criteria eliminated tools that:

- Solely related to precision agriculture (e.g., agricultural drones, in-field sensors, variable rate input application technology, etc.),
- Solely related to market access or digital finance, and

- Did not provide enough information online.

Each tool was reviewed by one analyst by accessing the tool, when available, or by reviewing materials online. A second analyst validated individual indicator responses when subjectivity in responses was an issue. Indicators were marked as 'unknown' when subjectivity in responses persisted or when information was not available. The results are publicly available in a published database (Dittmer et al. 2022a).

The tools for agroecology and tools for climate change were then analyzed and results published in separate policy briefs (Burns, et al. 2022; Dittmer et al. 2022b). The climate change policy brief examined the intersection between agroecology and climate change functions. These results are shared below. The statistical analyses for these briefs are provided in Annex 2 and Annex 3 respectively.

Exemplary features for agroecology

Many digital tools are available to provide farmers agricultural advice and assessment of their farm performance. Increasing interest in agroecology has created a demand for digital tools that can include agroecological principles such as farmer co-design, diversity, and whole farming system transitions. Digital tools can also be a means of rapidly scaling up agroecological practices. Our analysis aimed to answer two questions:

- How well do available digital tool features in agriculture support agroecology practices?
- To what extent do these digital tools' features also support farmer co-creation and smallholder farmer inclusion?

To answer these questions, we identified existing digital tools that provided agro-advisory services or performance assessment and reviewed their features against indicators for socially inclusive, agroecological transitions relevant to smallholder farmers in LMIC.

Of the 61 tools that we assessed, 43 included agroecological components, including 37 that provided agro-advisory services and 14 that provided performance assessment. While productivity is an

agroecology principle, we did not consider tools that only addressed productivity as having an agroecological component.

This analysis covered tools for a wide range of geographical areas, target users, and intervention strategies. Analysis across tools was complicated by differences in what was exemplary for different target users and contexts – a smallholder farmer often has different literacy requirements, incentives, and training needs compared to a researcher. The transition of industrial agriculture to agroecological practices requires different approaches than a smallholder farmer seeking to improve their livelihood. Reaching smallholders may include more than just one tool, and appropriate implementation of tools may depend on the broader digital ecosystem of enabling conditions and combined use of other tools such as FarmStack for secure data transfer, Amplio talking book for e-extension, and FarmOS for farm management. Tools that are geospatially enabled, provide local environmental data, or connect to local weather information services are key features for supporting contextually relevant solutions.

We explored three exemplary features or functions of digital tools for agroecology in our review: (1) the extent to which tools comprehensively addressed agroecological principles, (2) features for technical agro-advisories and performance assessment, and (3) how well tools supported farmer communication and access to tool content. A summary of the tools and their features may be found in Table 1.

1) Agroecological completeness

We considered tools more exemplary to the extent they reflected a more complete set of agroecological principles. We defined agroecological completeness as the degree to which tools addressed 12 agroecological principles, based on Barrios et al. 2020 and HLPE 2019 (Figure 1). Tools were classified as agroecological if they included four or more agroecological principles and complete if they included all twelve. A tool was counted as addressing a principle if it included content or features related to agro-advisories or performance assessment related to this principle. Examples include sending short message service (SMS) messages on how to apply fertilizer appropriately (agro-advisory for efficiency/input reduction) or collecting information in an app about gender representation in farm roles (performance assessment for gender and youth).

Agroecological completeness was weak among the tools reviewed. Most tools (65%) addressed four or fewer agroecological principles. Only three tools in our sample were complete: F-ACT: Farm-Level

Agroecology Criteria Tool, Tool for Agroecology Performance Evaluation (TAPE), and Access Agriculture. Most tools addressed sustainability issues at levels of granularity that did not capture the nuances or multiple scales of agroecology. Use of agroecological principles at social scales, such as culture and food traditions or governance were rare for the types of tools we reviewed. Productivity was the primary principle covered by most tools.

The most frequently represented agroecological principles among the 43 tools reviewed were productivity, income, and their stability over time (81%), co-creation and sharing of knowledge (58%), and efficiency/input reduction (56%). Agro-advisory tools reflected a similar pattern, while performance assessment tools included productivity, income, and their stability over time (93%), followed by efficiency/input reduction (64%), with co-creation and sharing of knowledge in under half of the tools (43%). All four tools with only one principle included co-creation and sharing of knowledge, farmer-relevant content (67%).

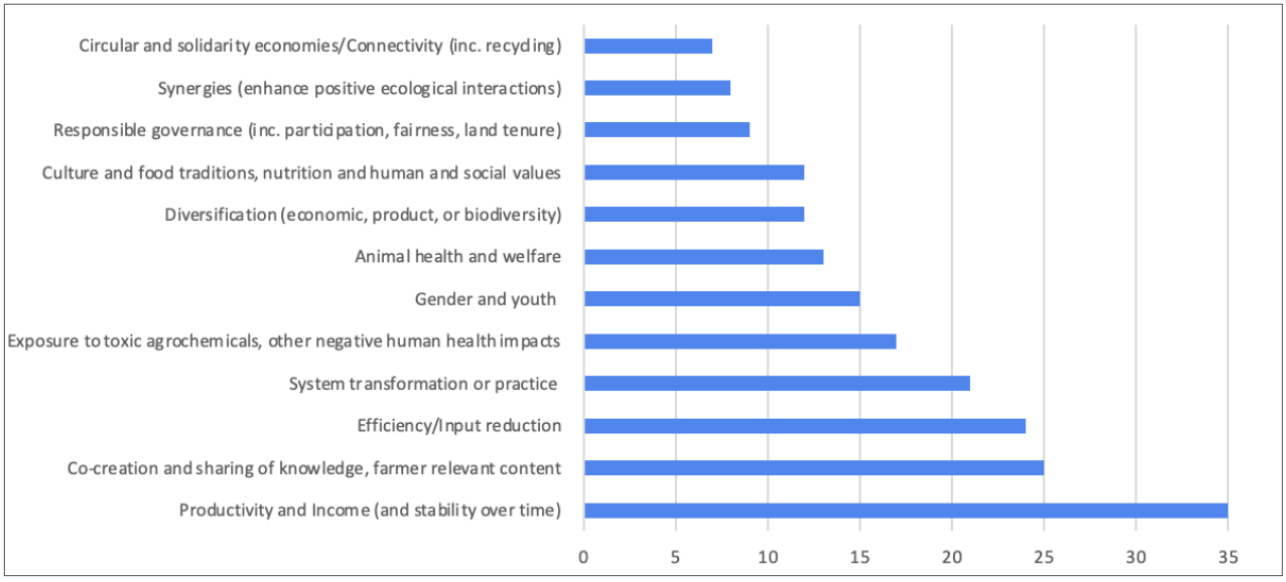

Figure 1. Number of tools per agroecological principle

Tools that were agroecological (four or more principles) did not include communication features that can enhance access or usability for smallholder farmers in LMICs. Such features include interactive voice response (IVR), audio or video text messages, and iconography as an alternative to text-based communication. Tools that did have these features only addressed up to three agroecological principles, indicating a gap.

Given the low number of tools available for agroecology, one approach for tool implementers is to identify the priority agroecological principles for application in each community or region to guide selection of tools, or use a combination of tools, rather than seek a single tool. For example, overuse of toxic agrochemical inputs may be an issue requiring urgent attention in some places and tools could be selected that address this content.

Tool developers that want to improve the agroecological completeness of an existing tool should look to see which principles are included in the tool as it exists and which agroecological principles are most appropriate for improving the tool. They can then work to pilot and test modifications that include those principles. We suggest that, in this process, agroecological completeness should be flexibly defined according to the tool's objectives and local contexts for its application. Advocates for agroecological principles should be considered another "stakeholder" and their interests weighed carefully against those of targeted tool users and farmers.

2) Exemplary features for agro-advisories and performance assessment

Exemplary features of the 37 agroecological agro-advisory tools included context-specific technical options, use of videos, integration with people-based support systems that included coaching and hotlines for questions, and two-way communication. Agro-advisories require accessibility and actionability of information at the farmer-level. The goal of co-creation requires farmer input into the development of these advisories.

Exemplary features of the 14 performance assessment tools included collaborative definition of indicators with farmers and other stakeholders; distinguishing between characterizing agroecological transitions and farm performance according to the United Nations Sustainable Development Goals (SDGs); options for use of multiple languages; options to modify tools to fit users' needs; easy to use spreadsheets (for researchers) and easily digestible, quick view reporting such as pie charts. Spreadsheet tools can provide meaningful evidence for policymakers and other decision makers, collecting data across the agroecological principles. An exemplary feature such as a spreadsheet, while suitable for researchers or farmers in wealthy countries, could be a prohibitive feature for a smallholder, marginalized farmer who usually would not have access to a computer.

Data privacy issues of farmers should be considered with digital tool design and implementation. This information was not readily available for each tool reviewed, but experts interviewed noted this concern.

3) Smallholder farmer inclusion and co-creation

Features that improved farmer communication such as targeting farmer subgroups, farmer-driven content, and use of human intermediaries were exemplary features for socially just inclusion of farmers and farmer co-creation of farming solutions. Both social inclusion and farmer co-creation are core tenants of agroecology. Social inclusion is defined here as "the process of improving the terms on which individuals and groups take part in society—improving the ability, opportunity, and dignity of those disadvantaged on the basis of their identity" (World Bank 2013). We use co-creation to mean the collaborative process of developing and implementing knowledge about farm practices among farmers, advisors, and researchers.

Communication features of the 43 agroecology tools reviewed that supported inclusion and co-design enabled farmers to provide input, feedback, direct the type of information they received, or enabled two-way communication. Features included IVR, SMS, and sometimes audio and video (Table 2). SMS and video or non IVR-audio were most common. Tools with these features also included the most agroecological content. Only 21% of tools offered more than one way of communicating. Other exemplary features for communication were use of local language, tailored recommendations, and group chats and SMS messages.

Few tools were designed to target specific sub-groups such as women or youth (19%) or include citizen science (16%). Farmer-driven content was possible in 26% of the tools.

Many smallholder farmers, women, and other marginalized groups in LMICs have limited literacy and access to technology, which often requires the role of an intermediary to facilitate their access to digitally available information. The enabling environment and how a tool is used to support inclusion and co-design is as important as digital tool features. For example, the lack of wireless internet access, digital literacy, and access to devices are major barriers to social inclusiveness. Some experts told us they were better able to reach smallholder farmers when tools were designed for intermediaries rather than farmers themselves.

Many tools in this review were primarily used by farmers' support organizations such as farmer unions, extension agents, or community NGOs. As a trusted intermediary, these organizational agents around the farmer provide opportunities for use of technologies that farmers may not have access to or the capacity to use. For example, Digital Green partnered with the Andhra Pradesh Department of Agriculture and Cooperation to facilitate the production of farmer videos. The community video framework is an important innovation, and the collaboration with the state government, and the focus on the Andhra Pradesh Community Natural Farming (APCNF) practices, allowed them to reach 300,000 smallholder farmer households with climate-resilient agronomic practices.

As with any user, tools that have farmers as the target user should add value for the farmer to use them and reflect a strong understanding of the context in which the farmer is working. Value-for-farmer examples include improved income, digital inputs layaway, e-extension services through video recordings, and e-extension via web and smartphone applications.

Recommendations for agroecology features

There is an opportunity to improve the agroecological completeness of digital tools and the inclusion and co-design features of digital tools for smallholder farmers in LMICs. Increasing farmers' use of tools will also require finding ways to make tools compelling to use and financially or culturally meaningful. Our recommendations include:

- Identify how a digital tool is intended to support agroecology before evaluating which tool to use or feature to improve. Is it a priority of the project to address all agroecology principles? Recognize that more than one tool may be needed.
- Work with a trusted intermediary to connect to pre-existing groups of farmers, such as farmer unions, trade groups, or established governmental and nongovernmental organizations.
- Review existing tools and their use to identify exemplary features that might be relevant to the project's objectives and local context.
- Improve the number of performance assessment tools by improving existing tools or adding agroecology components to performance assessment tools.
- In existing tools, incrementally build up agroecological completeness. If currently 3 or 4 principles are covered, see how to make it to 5 or 6 as opposed to unreasonably stretching to cover all 12.

- Create digital tool features related to social-scale agroecological principles such as governance or culture and traditions. Agro-advisories and performance assessment tools currently focus on on-farm aspects of agroecology such as productivity and input reduction.
- Include multiple and innovative ways of engaging the farmer or end user such as SMS, IVR, mobile app, or other.
- Consider the appropriateness of replacing existing in-person interactions such as extension work with digital options, which may not always be appropriate or best for the farmer.

Table 1. Exemplary features of 43 digital tools for agroecology

GHG = greenhouse gas. SDGs = Sustainable Development Goals. AFOLU = agriculture, forestry and other land use. IVR = interactive voice response. IVR = interactive voice response. SMS = short messaging service. AI = artificial intelligence.

Digital Tool	Functions & exemplary features
3S Management Information System	Farm crop management, full chain traceability, analytics and business intelligence. Measure the impact and progress made on the sustainability goals in the cashew supply chain.
Access Agriculture	Farmer-to-farmer training videos with agroecological principles applied. Enables global and local access to open-access training videos in local languages. Combines scientific and indigenous knowledge. Multiple ways to access content: website, app and audio podcasts.
AgriApp	Crop advisory, soil testing, drone services, crop practice advice, market access and information. Farmer-to-farmer videos on smart farming practices, organic farming, managing against diseases, weeds and pests, etc. Hotline or SMS to chat with experts.
AgriExt App	Information and advice on crop or livestock management, good agricultural practices, sanitary and phytosanitary measures. Exchanges between farmers or with extension workers can be done with messages, photos and videos
Agrinapsis	Virtual training courses and technical assistance. Collective knowledge sharing platform and app. Farmer videos and community forum.
Agrisuite NEO	Decision support information system for crop and livestock production, market information. Adapts seamlessly to the smaller displays of multiple devices.
Agroecology Criteria Tool (ACT)	Assesses a project's alignment with agroecological principles. Provides a structured and graphically intuitive way to identify the focus and agroecological character of an initiative.
Agroecomakers	Traceability system applied to agroecological systems. Developed via participatory research and citizen science. Strengthens a circular economy by committing to products at fair prices that provide quality of life to all those involved.
AtSource	Traceability, carbon and water footprint calculator. Monitors nine core sustainability topics related to 12 SDGs. Strong focus on women and youth.
BharatAgri	Personalized crop calendar, weather based advisory, crop advisory. Soil health reports printed and sent to farmers. Timely notifications on the preventive steps to be taken at the farm based on the weather conditions. Video and chat/call support.

Clima y cafe - Cafenica Prognostico	Early warning system, decision support, farm data collection. Focus on family inclusion and protagonism of young people and women.
Climate FarmRise	Agronomic information and advice for smallholder farmers. Farmer-to-farmer chat. Agricultural news and event information to educate farmers on industry developments and opportunities. Information available in multiple languages.
CubicA	Agricultural advisory via free hotline or IVR. Field-level human-centered design. Advisory in local languages and on any mobile device. Internet connection not required.
DigiFarm	Access to quality farm inputs, input loans, learning content (crop and livestock), market access. Insurance yield cover and extension services through remote agronomists (call center or on ground advisors). Learning content available via app or SMS.
Digital Green (Community Videos)	Community videos made by the community to share knowledge with one another. Illiteracy sensitive. Option to provide feedback about videos.
EcoFarmer SMS Advisory Tips	Subscription based SMS advisory service offering tips on maize, groundnuts, tobacco, cattle, goats, bees, and sorghum.
Esoko	Weather information, early warning systems, climate-smart agronomic advice and crop protocols, market price information, market linkages and insurance coverage. Customizable announcements and reminders. Content delivered via SMS, voice SMS, IVR or call center.
EX-Ante Carbon-balance Tool for value chains (EX-ACT VC)	Environmental and socio-economic performance assessment of value chains. Additional analysis opportunities on gender and youth employment engagement. Makes direct links to six SDGs indicators.
Extension Solution	Field activity monitoring and management, individual farmer workplan, certification and verification. Integrated with WhatsApp for direct communication.
Farm-Level Agroecology Criteria Tool (F-ACT)	Holistic farm assessment to identify agroecological development and areas for further development relative to a farm's unique context and objectives. Generates automatic bar charts that provide qualitative indicators of a farm's strengths and areas for further agroecological development.
Farm(x)	Crop management system for tree crops. IVR and mobile app interface. Machine learning platform suggests irrigation schedule, optimizes water and fertilizer use, and helps predict crop yield.
FarmBetter	Tailored land management recommendations to farmers based on their location, practices, and goals. Linked to the Carbon Benefits project and connected to WOCAT Sustainable Land Management Database.
Farming Solution	Decision support and technical assistance on diverse crops and livestock. Illiteracy sensitive (information delivered via iconography, video, and audio for agricultural management practices).
Farmshine	Market access, traceability, technical advice. Technical field agents provide farmers with advice and support throughout the growing season and help them aggregate crops for sale to large buyers.
Haller Farmers App	Open access to farming techniques and agricultural information. Supported by Swahili audio to allow for wide access. Visually based.

iCow	Information dissemination aimed at improving extension services. iCow library consists of over 30,000 SMS categories across all practices of smallholder production systems.
iShamba	Call center for farming tips on crop and livestock, market prices and weather updates. SMS alerts for famer trainings in the user's area.
Mergdata	Farm data collection integrated with IVR agro-advisory (weather, farming tips and market prices. Offline mode. Voice surveys. Inbuilt features that ensure data accuracy and reduce human error. GPS enabled.
mFarmer	Farm management recommendations, farm data collection, certification. Available on Facebook's Free Basics or as a browser based mobile website. Multiple languages.
miCampoApp	Participatory research for decision support combined with a certification for market differentiation. The farmer collects information using simple icons and produces traceability pages for research or certification purposes.
Mobile Kilimo (M-Kilimo)	Market access and consulting service. SMS-based, where farmers can text in specific inquiries to be answered by extension agents.
mooOn	Herd management app that provides recommendations to optimize herd performance. Aims to improve animal health and welfare and animal productivity.
MyAgro	Input access, agricultural training, harvest-improving agricultural techniques tailored to specific regions and crops, mobile layaway.
Plantvillage Nuru	Mobile AI assistant, with human agents available, capable of diagnosing cassava diseases.
Premium Hortus	Market access, e-commerce of organic and agroecological products. Connects consumers to smallholder produce markets.
RiceAdvice	Farm-specific advice on rice management practices, crop calendar, fertilizer plan. Offline mode. Face-to-face training.
Shade Tree Advice	Decision-support for selecting tree species in agroforestry systems. Developed via participatory approach.
SmartFarm	Farm data management, crop advisory via SMS, certification. Customizable business intelligence dashboard and reporting.
Sowing App	Insights around soil health, fertilizer recommendations and seven-day weather forecasts using AI and crop modelling tools.
Stepwise	Helps farmers adopt best farming practices in small increments and decreases investment burden.
Tool for Agroecology Performance Evaluation (TAPE)	Participatory tool to assess the multidimensional performance of agroecology. Informs various dimensions of sustainability: land tenure, productivity, income, added value, exposure to pesticides, dietary diversity, women's empowerment, youth employment, biodiversity, and soil health.
WADI Virtual Assistant	Chatbot that serves as a nexus between farmer and extension officers. Integrated thorough WhatsApp. Enables the farmer and extensionist to interact and access information from multiple sources (satellites, weather services, soil testing and logistics).
xarvio FIELD MANAGER	Farm management recommendations, farm data collection, independent field-zone specific agronomic advice. Map generation for multiple assessments (soil conditions, seeding, fertilization, crop protection, growth regulator and yield).

Table 2. Digital tool innovations for farmer communication

All tools (total of 43 tools)	Feature	Innovations	Tool Example	Drawbacks	High agroecology content (total of 15 tools)
4	IVR	Delivers tailored recommendations in an accessible way with option for farmer to engage. Allows a call center to triage calls.	DigiFarm[1]	Limited to the logic of the menu	0
9	Iconography	Provides opportunity for interaction and conveying information about a practice or idea where farmer literacy is limited.	miCampoApp[2]	Smartphones usually require a level of literacy	2
11	Video/ non-IVR audio	Brings video capabilities to exchange among farmer peers. Delivers recommendations to farmers in a local language. WhatsApp application allows farmers to use video clips, instead of requiring text literacy.	Access Agriculture[3]	One-way or slow two-way communication	4
13	SMS	Cheap and widely accessible text communication that farmers can read any time. Farmers can subscribe to tool's advice via SMS. Advice can be distributed to many farmers at once.	myAgro[4]	Dependent on literacy	4

** High content reflects tools with content or features reflecting 5-12 agroecology principles*

Exemplary features for climate change adaptation and mitigation

Digital tools to support farmer innovation are becoming more widespread. At the same time, farmers are increasingly feeling the effects of climate change and the demand for climate change adaptation and mitigation in agriculture is growing. Digital tools can play a role in scaling up practices, yet digital tools for agriculture often lack the technical content needed to support practices related to climate change. In addition, many smallholder farmers lack access to digital technology, electricity, or mobile networks in LMICs, limiting digital tool's impacts. For example, only 28% of the population in Sub-Saharan Africa use mobile internet (GSMA, 2021). Smallholders generally have slower internet services than larger farms even when they do have access (Mehrabi et al., 2021).

To gain insight on the state of digital tools for scaling up climate-resilient and low-emissions agriculture, our analysis aimed to answer two questions:

- How well do available digital tools for agriculture support climate change mitigation or adaptation functions?
- To what extent do digital tool features support inclusion for smallholder farmers by enabling farmers' input and communication about climate change practices in agriculture?

To answer these questions, we identified digital tools that provide technical advice and performance assessment and reviewed their features related to climate change adaptation and mitigation in agriculture and food systems. We identified 39 tools based on web searches, expert interviews and platforms such as the CGIAR Evidence Clearing House and Digital Agri Hub. We relied primarily on information available online. Tools were classified as technical advisory resources if their primary function was to deliver recommendations regarding farming practices and as performance assessment if their primary function was to report on farm outcomes, status or operations. See Dittmer et al. (2022a) for an in-depth description of the methodology.

How well do digital tools support climate change adaptation or mitigation functions?

Our review identified 39 digital tools that addressed climate change mitigation or adaptation related to technical advice or on-farm performance assessment (Table 3). Although we included all relevant tools identified in our search and interviews, this set of tools should be considered as a sample, since some tools are not publicly available online.

Among the 39 digital tools reviewed in this study, 24 provided technical advice, 11 provided on-farm performance assessment and four provided both technical advice and performance assessment on climate change adaptation or mitigation. Twenty-three (59%) were initiatives of private companies. Over two-thirds of the tools were free or had free versions available.

Technical advisory digital tools for climate change

Tools for technical advice more commonly supported climate change adaptation than mitigation. The most common tool function related to climate change was providing access to weather or climate information, or early warning systems for hazardous weather-related events (58%). Farmer information exchange (46%) was the second most common function for technical advisory tools, followed by water conservation or use efficiency (33%). Our review did not find any technical advisory tools related to

emergency relief and only two tools that provided access to crop insurance (Figure 2), which suggests a gap in climate change safety net functions in digital tools. Technical advisory tools did not necessarily inform users about priority actions for scaling impacts or the significance of the level of mitigation and adaptation impacts.

Only one technical advisory tool (FarmBetter) addressed climate change mitigation (Figure 2), indicating another major gap. Mitigation functions were more commonly found in performance assessment tools (See *Performance assessment digital tools for climate change* below).

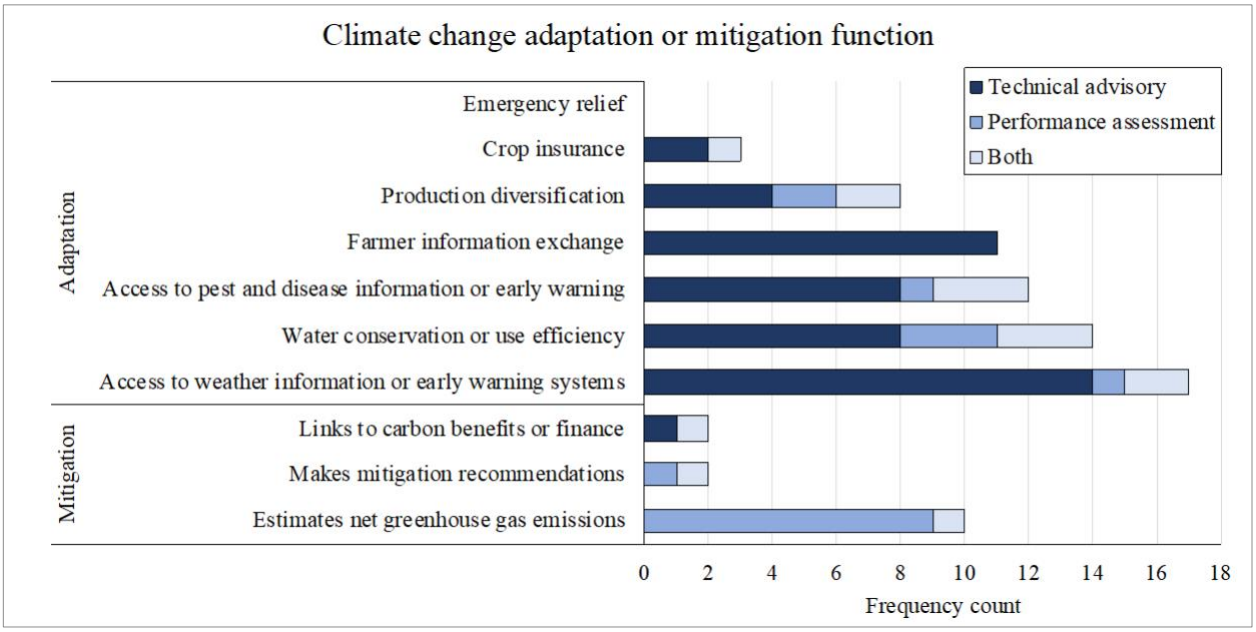

Figure 2. Number of digital tools that provide climate change mitigation or adaptation technical advice, on-farm performance assessment, or both (n=39).

Examples of exemplary features for tools that provided technical advice for climate change adaptation included delivering advisories through SMS in local languages (Sowing App); artificial intelligence providing agroclimatic forecasts via WhatsApp, Facebook and Telegram (Melisa chatbot); or automated 24/7 hotlines and call centers (DigiFarm, Ushari) for farmers to receive timely and tailored advice regarding specific topics. It was also common for digital technical advisories to accommodate farmers with limited literacy by incorporating features such as iconography (Plantvillage Nuru, Esoko, Farming Solution, FarmBetter, iShamba, Climate FarmRise), or videos or audio messages (Digital Green, Esoko, AgriApp, Plantvillage Nuru, Farming Solution, AgriExt App, Access Agriculture).

Tools that allowed farmers to exchange information were also exemplary as they enabled peer-to-peer learning, exchange of context-specific information and knowledge sharing. Examples of such tools included community videos where the production and dissemination of videos made by the community allowed farmers to share knowledge with one another in local languages (Digital Green and Access Agriculture), two-way communication between farmers and extension services via voice messages (Ushari), or a free hotline that leveraged previous farmer-caller data (customer journey, location, agronomic context as well as their profile including gender) to provide timely information for farmers (CubicA).

Performance assessment digital tools for climate change

The most common performance assessment tools related to climate change were calculators for greenhouse gas (GHG) emissions. Calculators varied in the sources of emissions they covered. The most common sources of emissions covered among calculators were rice production, land use change and energy use. Only one tool calculated GHG emissions for food loss and waste (ACE). Calculators were almost evenly split between estimating emissions at the farm or landscape level and the value chain. One performance assessment tool provided mitigation recommendations, assessed water conservation or use efficiency and pest or disease outbreaks, and will link users to carbon payments in future development (Extension Solution). Performance assessment tools did not necessarily inform users about priority actions for scaling impacts or the significance of the level of mitigation and adaptation impacts.

Exemplary features for GHG calculators included the ability for users to input their own emission factors (i.e., Tier 2 or 3); comprehensive Scope 1, 2 and 3 reporting for value chain products; complete accounting of significant GHG sources and sinks; minimized data needs for estimating GHG emissions; bundling of technical advice with performance assessment, data visualization in the tool or a downloadable report (Cool Farm Tool, CF-Rice, geoFootprint, Terra-I, EX-ACT, EX-ACT VC); and modeling different interventions to reduce adverse environmental footprints (geoFootprint). Only two tools (EX-ACT VC, AtSource) included analysis of multiple indicators related to environmental and social sustainability. More than half of the calculators determined a change in emissions based on comparison with a reference scenario.

Exemplary features for performance assessment tools that might be improved and used in digital tools more often in the future are (1) comprehensive assessment of food security and sustainability indicators, (2) agri-intelligence services or "watch dog" functions to alert decision makers about deforestation or other negative impacts, (3) functions for linking payments or finance to assessment of avoided emissions or sequestered carbon, and (4) recommendations for mitigation practices in performance assessment tools.

We found only four performance assessment tools with climate change adaptation functions (Mergdata, Carbon Benefits Project Toolkit, Extension Solution, AtSource). Three tools assessed water conservation or use efficiency (27%), two tools assessed product diversification (18%) and one tool had pest and disease information or early warning systems for pest and disease outbreaks (9%).

Technical advisory and performance assessment digital tools for climate change

Most tools that provided both technical advisory and performance assessment covered a wider range of climate change adaptation functions. One tool (SmartFarm) covered five of the seven adaptation functions (access to weather information or early warning systems, production diversification, crop insurance, water conservation or use efficiency, access to pest and disease information or early warning) and one mitigation function (linking to carbon benefits or finance). Other tools (Cool Farm Tool, DataGreen, Sustainable Coffee Verification) covered two to three adaptation functions and up to one mitigation function.

The Cool Farm Tool was exemplary for its farmer and sustainability focus, orientation towards action, and interaction functions. The tool began as an on-farm Excel-based GHG calculator but was adapted to the web to include modules for measuring water footprint, soil carbon and biodiversity management using robust quantification methods responsive to farm- and field-scale management decisions. The tool enables minimal data entry and supports farmers, the primary user, to plug in their farm characteristics and get immediate results and feedback on the impact of different farm management decisions using "what-if" scenarios. This was one of two tools that explicitly stated that users retain ownership of their assessment and personal data.

What climate information are farmers receiving?

Twenty-five of the 39 tools (65%) identified farmers as either the sole end-user or as one of the end-users; most were technical advice tools (22). Only three provided farmer-facing performance assessment. The primary function of most (17) of the twenty-five tools was weather information or early warning systems for hazardous weather-related events. Gaining access to reliable and localized weather information has become increasingly important for smallholders in LMICs given the unpredictability of weather events due to climate change. A study in Colombia, for example, found that SMS weather information services enabled smallholders to reduce crop losses by 11-14% (Camacho and Conover, 2019). In Ghana, a digital agronomy and weather advisory service providing time-sensitive information helped farmers adapt to changing rainfall patterns (Barnett et al., 2019).

Aside from access to weather information or early warning systems, farmers were also using digital tools that provided functions related to agro-advisory services, farmer learning, and farm management. Such services included climate-related agronomic advice (e.g., diagnosing crop diseases, information on optimal use of fertilizers, water harvesting techniques, etc.), market price information, market linkages, and insurance coverage through local languages and features including SMS, voice SMS, IVR, call centers, and community videos.

Farmers are more likely to use tools that provide clear benefits and reflect a strong understanding of the context in which they are working (Rose et al., 2016). Digital tool functions that provide value to farmers included improved income, digital inputs layaway, e-extension services through video recordings, and e-extension via web and smartphone applications. Tools that reflect a strong understanding of local context often involve farmers' peers or trusted contacts. For example, Digital Green Community Videos have been highly successful in part because of the inclusion of local farmers and extension officers in the instructional videos, which creates a sense of trust and familiarity in the delivered content. Involving human intermediaries such as hotlines and coaching services linked to tools provide opportunities for farmers and experts to interact and design solutions best suited to farmers' needs.

Climate change tools and agroecological principles

Climate change tools generally did not support functions related to agroecology, as indicated by the Food and Agriculture Organization's Ten Elements of Agroecology. Only one tool (Access Agriculture)

captured a substantial number of agroecology functions (12). Ten tools did not cover any agroecological functions. The most common adaptation function for tools that included agroecology practices was information or assessment on water conservation or use efficiency, followed by production diversification and pest and disease information or early warning. About half of these tools have farmers as the primary end-user.

Productivity, income, and their stability over time were the most frequently represented function (60%), followed by efficiency or input reduction (43%), co-creation and sharing of knowledge or farmer relevant content (40%), and system transformation or practice (35%). Synergies (i.e., enhancing positive ecological interactions), circular and solidarity economies, and responsible governance were the least represented agroecological function (13%, respectively).

Recommendations for climate change features

There is an opportunity to improve climate change digital tools and to enhance the access and usability features of these tools for smallholder farmers in LMICs. Based on this review, we suggest to:

- Support exemplary features for climate change adaptation and mitigation in digital tool development for agriculture and food systems, considering the tools' objectives and the contextual needs of farmers.
- Address gaps by improving the number of digital tools that provide technical advice for safety nets and climate change mitigation, and farmer-facing performance assessment tools.
- Bundle technical advice and performance assessment to encourage farmer action and adaptive management. For example, bundle functions that provide recommendations for farmer action with weather information, early warning systems, or GHG estimates.
- Localize technical advice or performance assessment through farmer input.
- Provide "coaching" tools so farmers can weigh the trade-offs of their decisions and add context on how to achieve and sustain change.
- Design digital tools for scale. Achieving scale for climate-informed digital tools does not just mean increasing farmers' access to tools, but also supporting action recommendations in tools and identifying priority, large-scale impacts in terms of the level of climate risk mitigated and resilience built, or climate change mitigation achieved.

Digital tools for climate change are in an early stage of development. This analysis has identified exemplary features of climate change tools that should be considered in future tool development. For digital tools to help scale up resilience to climate change—especially among smallholder farmers—and reduce emissions from agriculture, a wider understanding of potential exemplary features can enable farmers to get the technical information they need and demonstrate performance that can enable learning and access to additional benefits.

Table 3. Selected digital tools with climate change adaptation or mitigation outcomes and their function.

GHG = greenhouse gas. SDGs = Sustainable Development Goals. AFOLU = agriculture, forestry and other land use. IVR = interactive voice response. SMS = short messaging service. AI = artificial intelligence.

Digital Tool	Function(s) & Exemplary feature(s)
Access Agriculture	Farmer-to-farmer training videos with agroecological principles applied. Translation of videos to local languages upon request. Farmer information exchange on topics such as production diversification, water conservation and pest/disease management.
ACE	Pre- and post-harvest GHG calculator for estimating emissions associated to a food product. Combines a calculation framework with datasets containing crops GHG intensities and food loss factors along the value chain.
AgriApp	Crop advisory, soil testing, drone services, crop practice advice, market access. Expert hotline for crop production, yield protection and climate-smart farming.
AgriExt App	Information and advice on crop or livestock management, good agricultural practices, sanitary and phytosanitary measures. Online assistance for locally adapted agricultural advice or extension services on demand.
AtSource	Traceability, carbon, and water footprint calculator. Environmental footprint calculator is founded on Life Cycle Assessment methodology. Monitors nine core sustainability topics related to 12 SDGs.
BharatAgri	Personalized crop calendar, weather based advisory, crop advisory. Soil health reports printed and sent to farmers. Timely notifications on the preventive steps to be taken at the farm based on the weather conditions.
Carbon Benefits Project ToolKit	AFOLU carbon stock and GHG emission assessment. Simple (minimal data requirements) or detailed assessment.
CF-Rice	Calculator for carbon footprints of rice products. Comprehensive breakdown of emissions by cultivation and harvest & post-harvest. Excel or web based.
Clima y cafe - Cafenica Prognostico	Early warning system, decision support, farm data collection. Alerts and recommendations on crop management, pest and disease prevention/control. Focus on family inclusion and protagonism of young people and women.
Climate FarmRise	Agronomic information and advice relevant to smallholder farmers. Farmer-to-farmer chat. Agricultural news and event information to educate farmers on industry developments and opportunities.
Cool Farm Tool	Online GHG, biodiversity and water calculator for farmers. Provides growers the ability to plug in their farm characteristics and get immediate results and feedback on the

	impact of different farming management options. Crop-specific or whole-farm assessment. Downloadable assessment results as a PDF.
CubicA	Agricultural advisory via free hotline or IVR. Field-level human-centered design. Advisory in local languages and on any mobile device. Internet connection not required.
DataGreen	Traceability, farm data management, certification, and monitoring and evaluation. Farmer advisory services via audio or SMS. Offline mode. Geo-referencing capability. Customizable for unique needs.
DigiFarm	Access to quality farm inputs, input loans, learning content (crop and livestock), market access. Insurance yield cover and extension services through remote agronomists (call center or on ground advisors). Learning content available via app or SMS.
Digital Green (Community Videos)	Farming videos made by the community to share knowledge with one another. Illiteracy sensitive. Option to provide feedback about videos.
Sustainable Coffee Verification	Sustainability practice assessment (social, environmental, and economic) and technical assistance for the coffee value chain. Provides producers with free verification of their sustainability practices.
Esoko	Weather information, early warning systems, climate-smart agronomic advice and crop protocols, market price information, market linkages and insurance coverage. Customizable announcements and reminders. Content delivered via SMS, voice SMS, IVR or call center.
Ex-Ante Carbon-balance Tool (EX-ACT)	AFOLU GHG emissions assessment including agricultural inputs, energy, infrastructure, management of organic soils and coastal wetlands. Flexibility in input data. Well known amongst scientific communities.
Extension Solution	Field activity monitoring and management, individual farmer workplan, certification and verification. Integrated with WhatsApp for direct communication.
EX-Ante Carbon-balance Tool for value chains (EX-ACT VC)	Environmental and socio-economic performance assessment of value chains. Additional analysis opportunities on gender and youth employment engagement. Makes direct links to six SDGs indicators.
FarmBetter	Tailored farm management recommendations. Strong focus on building climate change resilience. Linked to the Carbon Benefits project and connected to WOCAT Sustainable Land Management Database.
Farming Solution	Decision support and technical assistance on diverse crops and livestock. Illiteracy sensitive (information delivered via iconography, video, and audio for agricultural management practices).
geoFootprint	Geospatial analysis and interactive visualization of supply chain environmental footprints. Combines data from satellite imagery with environmental metrics. Granular visibility down to 10×10 km.
iCow	Information disseminating aimed at improving extension services. iCow library consists of over 30,000 SMS categories across all practices of smallholder production systems.
iShamba	Call center for farming tips on crop and livestock, market prices and weather updates. SMS alerts for famer trainings in the user's area.
Kenya Agricultural Observatory Platform (KAOP)	Weather forecasts, agronomic advisory, agricultural insights. Integrated advisories available via SMS or online.

Melisa chatbot	AI system providing information on agroclimatic forecasts. Available across multiple platforms (Facebook, WhatsApp, Telegram).
Mergdata	Farm data collection integrated with IVR agro-advisory (weather, farming tips, and market prices. Offline mode. Voice surveys. Inbuilt features that ensure data accuracy and reduce human error. GPS enabled.
mFarmer	Farm management recommendations, farm data collection, certification. Available on Facebook's Free Basics or as a browser based mobile website. Multiple languages.
Mozare3	Reports, recommendations, market access, field visits and training programs for capacity building of small farmers. Connects small farmers to agricultural export companies via contracts.
MyAgro	Input access, agricultural training, harvest-improving agricultural techniques tailored to specific regions and crops, mobile layaway.
Plantvillage Nuru	Mobile AI assistant, with human agents available, capable of diagnosing cassava diseases.
Premium Hortus	Market access, e-commerce of organic and agroecological products. Connects consumers to smallholder produce markets.
SECTOR	GHG calculator for rice production. Flexibility in emissions- and scaling factors. Based on the IPCC Tier 2 approach
Shade Tree Advice	Decision-support for selecting tree species in agroforestry systems. Developed via participatory approach. Focus on on-farm advice regarding climate change adaptation and mitigation.
SmartFarm	Farm data management, crop advisory via SMS, certification. Customizable business intelligence dashboard and reporting.
Sowing App	Insights around soil health, fertilizer recommendations and seven-day weather forecasts using AI and crop modelling tools.
Terra-I	Near-real time monitoring system for natural vegetation conversion at pan-tropical scale. Uses satellite data and computational neural networks to detect anthropogenic changes in the vegetation cover every 16 days.
Ushauri	Agricultural advice via automated 24/7 hotline or audio content, online platform for extension agents. Two-way communication. Developed via participatory approach.

Annex 1. Indicators used to assess tools for agroecology and climate change

Field Category	Field
Basic Information	Name of tool
	Brief description of tool
	Website or other locating information
	Creator of tool
	Name of underlying technology
	Underlying technology creator
Categorization	Does this tool provide technical assistance on agroecology?
	Does this tool provide technical assistance on climate change?
	Does this tool provide performance assessment on agroecology?
	Does this tool provide performance assessment on climate change?
Performance Assessment Purpose	Does this tool support certification or labelling?
	Does this tool provide reports or monitoring?
	Does this tool support payments for ecosystem services or finance?
	What traceability functions are part of the tool?
	Identification number/code provided
	Triangulation with other forms of data
	Provenance (documentation of origin)
	Solutions available on a clearinghouse/platform or linked to other digital tools
	Record keeping (inc. GIS compatible)
	What other performance assessment functions are part of this tool?
Tech Specs	Does the solution require phone?
	Does the solution require smartphone/tablet?
	Does the solution require internet connection?
	Does the solution require computer?
	Does the solution use interactive voice response (IVR)?
	Does the tool use short message service (SMS)?
	Does the tool use video or (non-IVR) audio recordings?
	Does the tool use iconography?
	Can you engage in more than one way with the tool? (e.g., IVR and SMS)
	What hardware is required beyond phone, smartphone/tablet, or a computer?
	Does the tool allow for integration with other tools?
	Assuming that the user is familiar with the hardware, do they need to be trained to use this tool?
	Is the tool built on open source software?
	What language(s) is/are the tool available in?
	What is the primary incentive for the user of this tool?
	How much does this tool cost?
	Is the cost transparent?
	Who pays the cost of the tool?

Social Inclusion & Co-design	Is the technical assistance informed by citizen science?
	Who is contributing to the information provided by the technical assistance?
	Does this tool allow for direct farmer-driven content, aside from user information?
	Was a user design or participatory approach employed during tool development?
	Is this tool designed for any sub-group? (e.g., for women farmers)
	Does this tool have features or content that accommodate sub-groups?
	Who is the primary end user of this tool?
	Who is the primary beneficiary of this tool?
	Is the underlying technology proprietary?
	Is there two-way communication?
	Do farmers control their own information? (e.g., data privacy, IPR)
	In what ways could this tool be extractive of farmer participation or information?
	Is the tool a stand-alone solution or does it contain bundled services?
	Is the tool time efficient for the user?
	Does the tool ensure user security, especially amongst women?
Scaling	Was the tool developed for a specific project/program?
	Who is responsible for the improvement or maintenance of this tool?
	How local or generalizable is the tool?
Climate Change	*What climate change resilience functions are part of the tool?*
	Access to weather information or early warning systems
	Production diversification (e.g., multi-cropping/livestock/forestry)
	Crop insurance
	Water conservation/use efficiency
	Emergency relief
	Access to pest and disease information and/or early warning
	Farmer information exchange
	What climate change mitigation functions are part of the tool?
	Linking to carbon benefits / finance
	Making mitigation recommendations
Climate Change - GHG Estimates	Does this tool estimate net greenhouse gas emissions?
	Which sub-sectors are covered by this GHG analysis?
	Trees on farm (e.g., agroforestry)
	Land use change
	Livestock & pasture
	Soil & nutrient management
	Rice
	Food loss & waste
	Energy
	Burning
	What is the scale/boundaries of analysis of GHG emission estimates?
	Does the tool calculate a change in emissions based on comparison with a reference (compare two practices)?
	What tier emission factors (EFs) are used?

Agroecological Principles	*Which of the following agroecological principles are addressed by the implementation of this tool?*
	System transformation or practice
	Diversification (economic, product, or biodiversity)
	Efficiency/Input reduction
	Exposure to toxic agrochemicals, other negative human health impacts
	Animal health and welfare
	Synergies (enhance positive ecological interactions)
	Productivity and Income (and stability over time)
	Co-creation and sharing of knowledge, farmer relevant content
	Gender and youth
	Circular and solidarity economies/Connectivity (inc. recycling)
	Culture and food traditions, nutrition and human and social values
	Responsible governance (inc. participation, fairness, land tenure)
Preliminary Assessment	What are the strengths of this tool?
	What are the weaknesses of this tool?
	Identify any unique or special features that make this tool exemplary
	Other notes
	Sources

Annex 2. Summary statistics for agroecology digital tools

Agroecological principle count

# of Principles	# of Tools	Cumulative %
1	4	9%
2	8	28%
3	8	47%
4	8	65%
5	4	74%
6	1	77%
7	2	81%
8	2	86%
9	1	88%
10	1	91%
11	1	93%
12	3	100%

All tools with TA or PA for agroecology

Category	Indicator	All (n=43)	All (%)	TA (n=37)	TA (%)	PA (n=14)	PA (%)
Agroecology	Productivity and Income (and stability over time)	35	81%	29	78%	13	93%
	Co-creation and sharing of knowledge, farmer relevant content	25	58%	22	59%	6	43%
	Efficiency/Input reduction	24	56%	20	54%	9	64%
	System transformation or practice	21	49%	17	46%	8	57%
	Exposure to toxic agrochemicals, other negative human health impacts	17	40%	14	38%	6	43%
	Gender and youth	15	35%	10	27%	6	43%
	Animal health and welfare	13	30%	11	30%	4	29%
	Diversification (economic, product, or biodiversity)	12	28%	7	19%	8	57%
	Culture and food traditions, nutrition and human and social values	12	28%	7	19%	5	36%
	Responsible governance (inc. participation, fairness, land tenure)	9	21%	5	14%	5	36%
	Synergies (enhance positive ecological interactions)	8	19%	5	14%	5	36%
	Circular and solidarity economies/Connectivity (inc. recycling)	7	16%	4	11%	3	21%
Tech Specs	SMS	13	30%	12	32%	3	21%
	Video and non-IVR audio recordings	11	26%	10	27%	2	14%
	Multiple specs (e.g., IVR+SMS)	9	21%	8	22%	2	14%

Tech Specs	Iconography	9	21%	9	24%	2	14%
	IVR	4	9%	4	11%	0	0%
Social Inclusion	Two-way communication	18	42%	17	46%	3	21%
	Bundled services	14	33%	13	35%	4	29%
	Feature/content to accommodate sub-group	17	40%	15	41%	5	36%
	Participatory approach	14	33%	11	30%	6	43%
	Farmer-driven content	11	26%	11	30%	1	7%
	Designed for sub-group	8	19%	6	16%	2	14%
	Citizen science	7	16%	6	16%	2	14%

Tools with >4 agroecological principles

Category	Indicator	All (n=15)	All (%)
Agroecology	Productivity and Income (and stability over time)	14	93%
	Efficiency/Input reduction	13	87%
	Co-creation and sharing of knowledge, farmer relevant content	13	87%
	System transformation or practice	12	80%
	Diversification (economic, product, or biodiversity)	11	73%
	Gender and youth	11	73%
	Culture and food traditions, nutrition and human and social values	10	67%
	Exposure to toxic agrochemicals, other negative human health impacts	9	60%
	Animal health and welfare	8	53%
	Responsible governance (inc. participation, fairness, land tenure)	8	53%
	Synergies (enhance positive ecological interactions)	7	47%
	Circular and solidarity economies/Connectivity (inc. recycling)	6	40%
Tech Specs	Multiple specs (e.g., IVR+SMS)	4	27%
	SMS	4	27%
	Video and non-IVR audio recordings	4	27%
	Iconography	2	13%
	IVR	0	0%
Social Inclusion	Feature/content to accommodate sub-group	10	67%
	Participatory approach	7	47%
	Farmer-driven content	5	33%
	Two-way communication	5	33%
	Bundled services	4	27%
	Designed for sub-group	4	27%
	Citizen science	3	20%
TA/PA	TA	11	73%
	PA	7	47%

Annex 3. Summary statistics for climate change digital tools

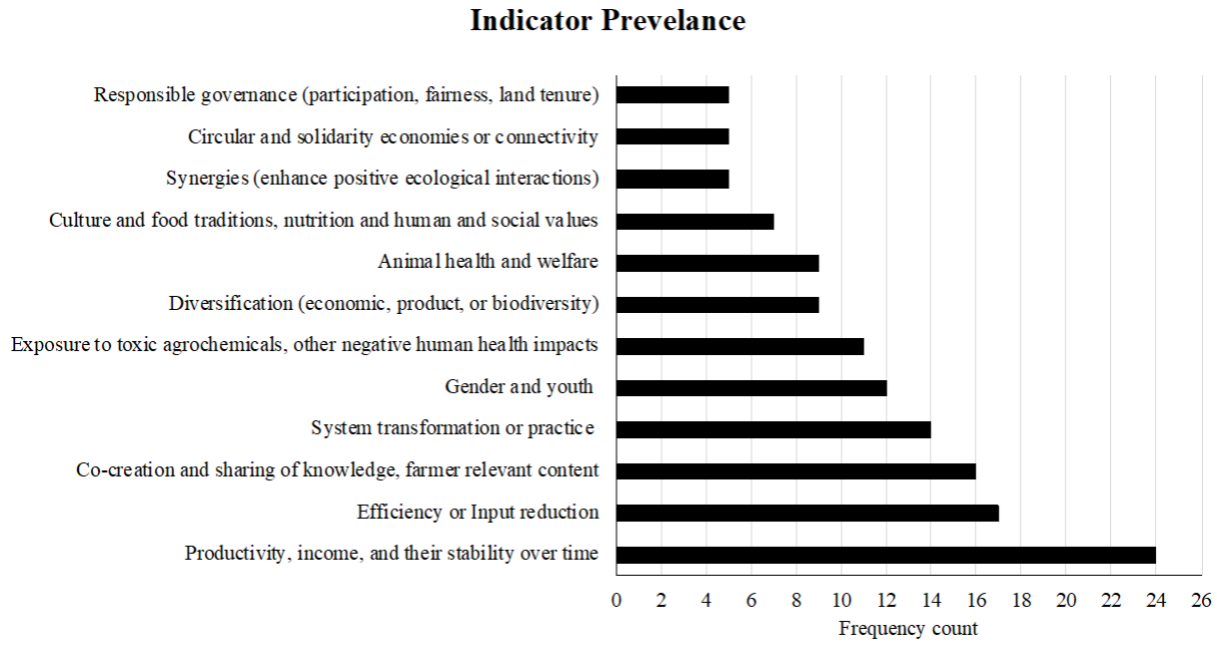

Figure A1. Number of agroecological principles addressed for tools with climate change mitigation or adaptation functions (n=39).

Table A2. Summary statistics for all tools providing technical advisory (TA), performance assessment (PA) or both (TA&PA) with climate change mitigation and/or adaptation functions (*n=40*).

Category	Indicator	TA (n=24)	TA *(%)*	PA (n=11)	PA *(%)*	TA&PA (n=4)	TA&PA *(%)*
Climate change adaptation	Access to weather information or early warning systems	14	58%	1	8%	2	50%
	Product diversification	4	17%	2	18%	2	50%
	Crop insurance	2	8%	0	0%	1	25%
	Water conservation or use efficiency	8	33%	3	27%	3	75%
	Emergency relief	0	0%	0	0%	0	0%
	Access to pest and disease information and/or early warning	8	33%	1	9%	3	75%
	Farmer information exchange	11	46%	0	0%	0	0%
Climate change mitigation	Links to carbon benefits or finance	1	4%	0	0%	1	25%
	Makes mitigation recommendations	0	0%	1	9%	1	25%
	Estimates net greenhouse gas emissions	0	0%	9	75%	1	25%

Category	Indicator	TA (n=24)	TA *(%)*	PA (n=11)	PA *(%)*	TA&PA (n=4)	TA&PA *(%)*
Tech features	Interactive voice response (IVR)	5	21%	0	0%	0	0%
	Short messaging service (SMS)	8	33%	2	17%	2	50%
	Video or audio recordings	7	29%	3	25%	1	25%
	Iconography	6	25%	0	0%	0	0%
	Multiple features (e.g., IVR+SMS)	10	42%	1	8%	2	50%
Social inclusion	Informed by citizen science	4	16%	2	17%	0	0%
	Farmer-driven content	8	32%	0	0%	1	25%
	User design or participatory approach during tool development	9	36%	2	18%	0	0%
	Designed for sub-group	5	20%	1	9%	0	0%
	Feature/content to accommodate sub-group	9	36%	2	18%	0	0%
	Two-way communication	13	52%	2	17%	1	25%
	Bundled services	7	28%	2	17%	2	50%
	Farmers control their own information (e.g., data privacy, IPR)	0	0%	1	9%	1	25%

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Agroecological TRANSITIONS Programme

The Program on Agroecological Transitions for Building Resilient, Inclusive, Agricultural and Food Systems (TRANSITIONS) aims to enable climate-informed agroecological transitions by farmers in low- and middle-income countries through the development and adoption of holistic metrics for food and agricultural systems performance, inclusive digital tools, and transparent private sector engagement. The *Inclusive Digital Tools to Enable Climate-informed Agroecological Transitions* (ATDT) aims to scale agroecological practices by enabling smallholder farmers to participate in co-design of digital tools and farming practices. Learn more about ATDT here.

It is led by:

TRANSITIONS is financed by:

And managed by: