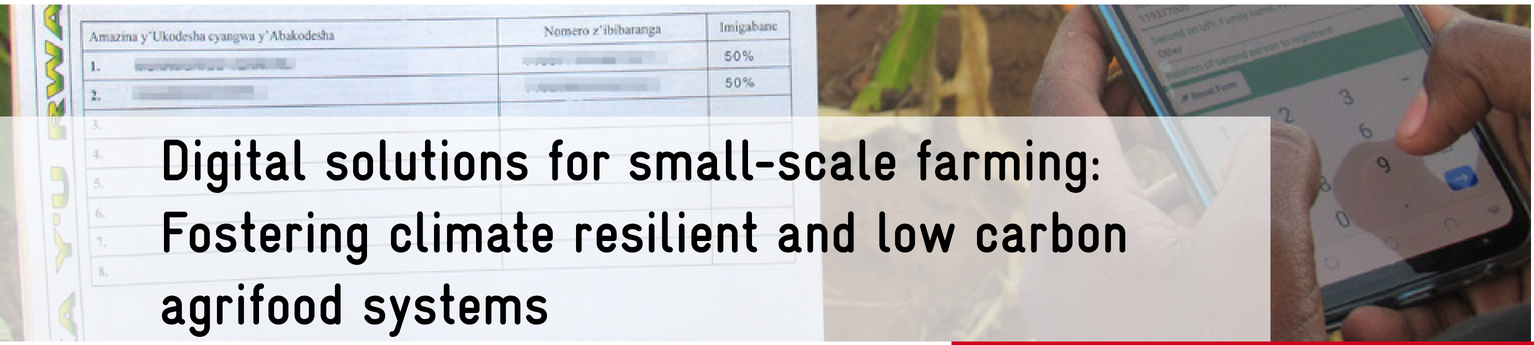


# Digital solutions for small-scale farming: Fostering climate resilient and low carbon agrifood systems

**A focus brief on alignment between digital technology providers and small-scale farming**

## 1. Key Messages

- Promoting and steering the digital transformation in climate and development co-operation projects provides opportunities for small-scale farming in the agrifood system: Digital technologies can decrease information asymmetry and lower transaction costs, which could lead to rapid adoption of climate-smart agriculture and improved access to value chains or markets for ecosystem services.
- User-centered software design helps to develop the most suitable technologies for small-scale farmers in their specific farming context. The triple 'D' can be used to characterize the context: digital literacy, digital access, and decent internet.
- Digital platforms combining digital services (e.g. knowledge sharing + social interaction + business models) are most promising, but they require a supportive institutional framework and capacity development of end-users. Such digital platforms can bundle virtual marketplaces, online extension services or e-government services.
- Climate and development projects can support a digital transformation for small-scale farmers in agrifood systems by identifying appropriate digital technologies and intervention areas at farm, community and value chain levels.
- Advisory and financial services, input and output markets and machinery rental services are promising areas for supporting (rural) entrepreneurs, in particular youth and women, to transform climate-smart business cases along the agrifood value chain. For example, digital technologies can enable education as a COVID-19 response measure or support rural financial institutions to make use of remote sensing technology to deliver green recovery loans.
- Collaboration with digital partners working at the interface of software development and technical expertise in the land use sector can help to foster the dialogue between small-scale farmers and the software community to develop context specific digital solutions and use cases.

## 2. The Benefits of Digitalization for Small-Scale Farming

A rapid adoption of climate-smart agriculture is needed to nourish a growing population within the sustainability limits of planetary boundaries. A lack of information and high transaction costs for small farmers to access information, coupled with information asymmetries, are key transformation barriers that digitalization can address.

Even though small-scale farmers are not a homogenous group , they are important actors for achieving the UN Sustainable Development Goals (SDGs). Studies estimate that small-scale farms (<2 hectare) contribute 28 to 31 percent of total global crop production, amounting to roughly four-fifths of food production in developing countries (Fan & Rue, 2020; FAO, 2011; Ricciardi et al., 2018). Small-scale farmers can also play a key role in the sustainable use of biodiversity and the provision of ecosystem services, e.g. pollination services or water provisioning. However, unsustainable resource management can also contribute to deforestation and the loss of biodiversity. Digitalization can inform and improve the sustainable use of biodiversity and detect and help enforce zero-deforestation.

Digital solutions are particularly relevant for providing the information required to improve the implementation of the various agricultural development activities (Fan & Rue, 2020; IFC, 2013):

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- securing land rights
- creating safety nets against price spikes and volatility
- improving access to financial services
- developing and leveraging cultivation strategies/technologies regarding climate change impacts and tackle poor soil fertility and limited water access
- establishing direct access to modern markets for women and men
- establishing cooperatives and farmer groups
- providing inclusive strategies for farmers with low literacy and numeracy
- motivating a young generation to engage in farming.

Digital solutions can also help small-scale farmers to narrow the information asymmetry related to improved cultivation practices, weather forecasts, post-harvest management and market prices. Providing this information cost effectively, by reducing the transaction costs that are often prohibitive for small-scale farmers, is the key to narrowing information asymmetry.

Small-scale farmers can have a higher per-unit farm output than larger farms (Heltberg, 1998) whereas larger commercial farms have an advantage in terms of finance, technology, and logistics (Fan & Rue, 2020). Digital services could reduce this discrepancy in transaction costs by improving access to financial markets and providing access to machinery and farm inputs – a set of practices which serve both climate change adaptation and mitigation.

To grasp the opportunities provided by digital solutions, policy makers require first a well-structured and action-oriented overview of current developments in the field of digitalization, and second an understanding of the measures required to successfully support the development of digital technologies.

Chapter 3 provides an overview of how digital technologies can be categorized and examples of the main categories are presented. Chapter 4 presents digital solutions along the agricultural value chain and their key functionalities. Chapter 5 explains practical entry points for digitalization activities and key pitfalls to avoid. Finally, conclusions are presented in Chapter 6.

## 3. Digital Solutions for Small-Scale Farmers – a Categorization

Different terms and concepts are used describing the digital key technologies. By 'digital solutions', we refer to the functions and applications summarized by the German Advisory Council on Global Change (WBGU, 2019) in their report Towards our Common Digital Future. The report names four main digital areas (see lower row in Figure 1 below) which are closely interlinked, and five key technologies for sustainability (upper row in Figure 1). The four main digital areas can promote and accelerate agricultural transformation. These include the use of 'big data' which leads to qualitatively new results by relying on artificial intelligence. Big data is in turn based on increased

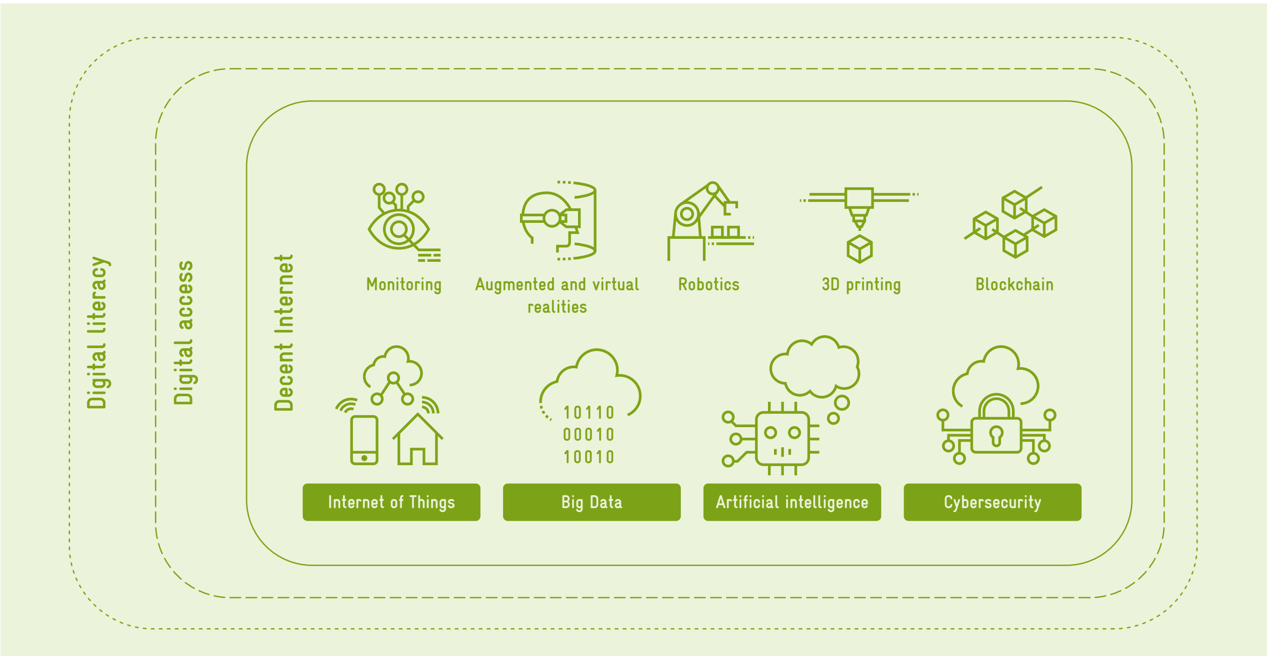


**Figure 1: Main digital solutions in the sustainability context** (based on WBGU, 2019)

computing, storage, and transmission capacities. For every digital solution, trustworthiness, reliability and cybersecurity to protect crucial systems and critical information from digital attacks, are central.

Digital solutions are embedded in a context defined by the triple 'Ds': digital literacy of the included actors, digital access and decent internet.

- **Digital literacy** – describes the standardized operational skills and the applications used by actors, such as cell phones, smartphones, apps, browsers and digital platforms. Further, it describes the capacity to critically assess a virtual reality, the algorithm applied by an app or the monitored indicator on a web dashboard, all of which may be produced by artificial intelligence.
- **Digital access** – is the possibility of an actor to connect to the internet (fixed vs. mobile connection) and the kinds of devices and software available
- **Decent Internet** – mainly refers to the connectivity in terms of speed and capacity that can be provided to the users.

The context-specific levels of the triple D factors shape the possible degree of implementation of digital solutions for small-scale farmers.

All four main digital areas and the five key technologies for sustainability can be translated into concrete digital solutions with transformative potential for small-scale farmers (see also Figure 2):

### Internet of Things

The Internet of Things refers to the networking or integration of different digital solutions and technologies, integrating data collection, agricultural information systems and analytical and visualization tools for spatial information and dashboards where key performance information is readily available. Digital platforms play an increasing role, giving small-scale farmers access to financial services, machinery, inputs or training modules.

### Big Data

Big data is the basis of many digital solutions. There is increasingly big data available to inform farming and market access, but small-scale farmers often lack the capacity to access data and extract relevant information for decision making. The latter refers to the datafication process whereby data related to field cultivation strategies, market activities and social interactions turns into machine readable and quantifiable information. Big data exchanged in real time creates extensive amounts of data, which can be evaluated for example for control and optimization purposes. However, big data is demanding to generate, process and to store and requires clear rules governing data ownership and security (see also cyber security). Weather forecasts are a good example in which massive amounts of data are transformed into real time information to improve planning and risk management by small-scale farmers.

### Artificial Intelligence

Artificial intelligence enables development of smart algorithms that analyse the big data. Access to data describing the planning behaviour of small-scale farmers can, for example, support improved and optimized farm management decisions. Apps can make the analysis in real time, based on pictures of crop pests, diseases, or other data inputs.

### Cybersecurity

Cybersecurity is central to every digital solution. It is the practice of protecting crucial systems and critical information from digital attacks. Data protection and protecting privacy are key. In the EU, the General Data Protection Regulation (GDPR) addresses some of these concerns and the digital dividends for the poor in developing countries will strongly depend on the protection of their data ownership and privacy. This can be especially important in countries that do not have democratic systems in place.

### Blockchain

Blockchain technology is a decentralized and distributed ledger. Various actors can input, receive and retrieve the same information. Based on this technology smart contracts can be defined among actors. This makes it an effective tool for verifying proof of existence, ownership, or origin of exchanged information. The challenge with blockchain solutions is to transfer physical assets into digital proofs in a verifiable way and at the same time to address the increasing power and energy demand of such systems. In the field of agriculture, blockchain is gaining momentum in traceability along the value chain and for certification bodies.

### Augmented and Virtual Reality

This digital technology refers to a world simulated by computers and corresponding programs and devices. In agriculture, such technology is increasingly used for simulation training related to field-based machinery techniques,

**Box 1: Twiga Foods**

Founded in 2014, Twiga Foods connects small fruit and vegetable farmers in Kenya to small and medium-sized vendors. Through its mobile-based platform, Twiga offers attractive prices and a guaranteed market to farmers. At the same time, vendors benefit from attractive prices and reliable supply. Consumers also benefit by paying 10 – 15 percent less than at traditional wholesale markets. Blockchain technology is used to keep track of all transactions, and payment processes are carried out using M-Pesa (twiga.com). This overall helps to avoid food waste, one of the main drivers of GHG emissions in the agri-food sector.

for example in the field of precision farming that uses large machines. By improving access to machinery for small-scale farmers via digital platforms, augmented and virtual reality could also benefit small-scale farmers.

### Monitoring

The use of remote sensing data is progressing, with more and more data available at a higher resolution and, therefore, useful to use on smaller scale farming operations. Together with drones or activity-based reports based on SMS or apps, remote sensing can provide important information to monitor farming activities and improve sustainability- and productivity-enhancing agricultural practices and ecosystem services.

### Robotics

Robots are increasingly used on large scale farms. The main applications are related to commercial cultivation systems. Nevertheless, machinery sharing could also allow small-scale farmers to access advanced technology and improve management in their fields and release them from exhausting physical work such as weeding. Improved access to robot services for soil sampling and site assessment could also be relevant for small-scale farmers.

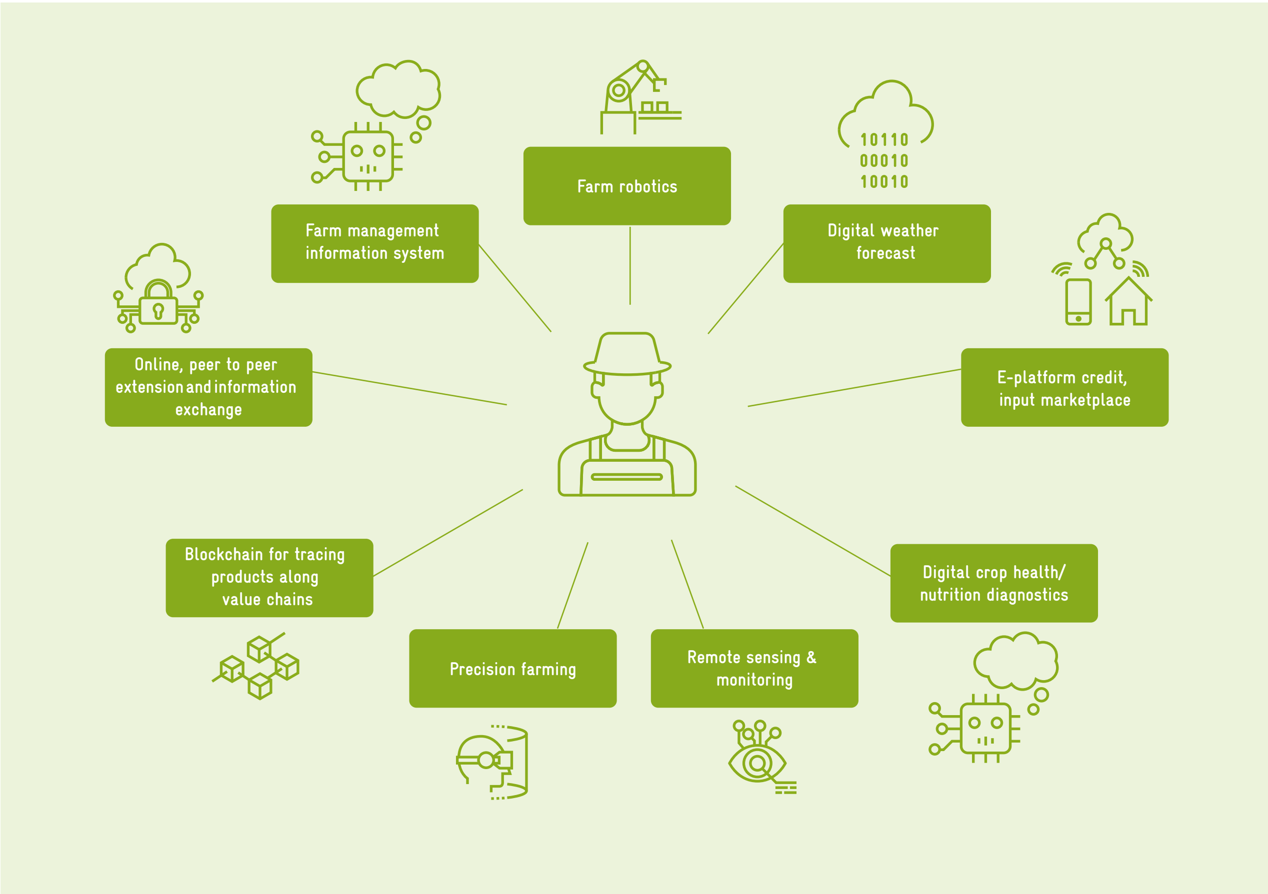


**Figure 2: Digital Solutions with transformative potential for small-scale farmers**

## 4. A Value Chain Perspective

The following summary table highlights intervention levels along the value chain and describes related digital solutions and their key functionalities. Not all climate and development projects follow a value chain approach, but an insight into the possibilities of digital solutions at different levels along the value chain helps create an understanding of their potential.

### Table: Value chain area-specific digital solutions and possible wins.

| Intervention level along the value chain | Optional digital solutions | Key functionalities |
|---|---|---|
| **Planning: Land tenure security and weather forecasting** | • GPS data, smartphones and drones are useful tools for land mapping<br>• Blockchain technology allows the creation of a transparent land registry for tenure security (currently in proof-of-concept phase)<br>• Digital weather stations and improved weather forecasting can enable farmers to make better decisions about when to plough, sow, and harvest and, hence, to better adapt to climate change<br>• Mobile or online services provided to small-scale farmers in a timely, location-specific, and user-friendly way (e.g. CropManager, provided by the International Rice Research Institute) | • Secure land tenure is often a precondition for farmers to adopt investments in land productivity (e.g. soil conservation, agroforestry, micro-irrigation). Many such practices have both adaptation and mitigation benefits. Proof of land ownership is also often used as collateral for credit.<br>• Climate resilient planning by small-scale farmers no longer depends only on traditional knowledge and experience about the weather and seasons. Farmers can react to scientific forecasts reflecting change in climate variability due to climate change (e.g. delayed on-set of the rainy season, drought spells, extreme rainfall events) |
| **Access to inputs such as mechanization and finance** | • ICTs and GPS-tracking of machinery ('Uberization') enhance the efficiency and transparency of services, further reducing costs for customers and enhancing the business case for service providers (e.g. Hello Tractor, Trringo)<br>• Simple ICTs can be used to create mobile payment and banking services (e.g. M-Pesa in Kenya)<br>• Various marketplace platforms (e.g. Jumia) offer much more comprehensive financial services, including short-term loans and crop insurance | • Custom-hiring services allow small-scale farmers to access modern mechanization technology without steep investment costs. This includes specialized equipment for direct seeding under conservation agriculture, proven to have both adaptation and mitigation benefits. At the same time, mechanization services provide new business opportunities for larger farmers (who own machinery but do not utilize it to full extent) and specialized service providers.<br>• Improved financial environment improves investments into enhanced cultivation schemes with higher productivity and modern risk reducing inputs.<br>• Reduction of bank-related due diligence costs.<br>• Access to finance, e.g. through digital platforms. |

| | | |
|---|---|---|
| **Production: Advisory services, production monitoring (incl. carbon monitoring) and precision farming** | • Digital advisory services can be especially powerful if they convey content through pictures, videos or voice messages (e.g. Digital Green)<br>• Numerous marketplace platforms (e.g. lersha, wefarm, Jumia) offer advisory services to farmers<br>• Digital monitoring and reporting is crucial for farmers to learn and for projects to demonstrate (real-time) impacts<br>• This requires digital tools to collect data (e.g. Apps), analyse data (e.g. dashboards linked to a cloud data-base, Web-GIS), and models to support decision making or impact reporting<br>• Decision support tools often use artificial intelligence, e.g. to learn from best performing farmers and then advise others how to improve their crop and livestock production<br>• An example is digital carbon monitoring (see Box 2), which is used for third-party verification<br>• Digital hardware for agriculture in the form of sensors, drones and smart irrigation powered by the Internet of Things (IoT)<br>• Apps allow an automated identification of weeds, pests and diseases; due to a likely increase in disease and pest pressure with climate change (e.g. xarvio)<br>• Remote and real-time monitoring of crops and livestock allows farmers to identify and manage potential problems effectively and in a timely manner | • Providing information at the right time and at scale facilitates the adoption of sustainable practices that serve both adaptation and mitigation purposes and overcomes the lack of access to appropriate agricultural training or extension services<br>• Supporting adoption of sustainability and productivity enhancing agricultural practices and ecosystem services (e.g. conservation agriculture and climate-smart agriculture), which tend to be knowledge-intensive<br>• Sustainably maximizing agricultural productivity through the targeted use of inputs, such as fertilizer and water, as well as the reduction of GHG emissions |
| **Postharvest Management: Reduce post-harvest losses and increase traceability** | • Providing access to real-time information on market prices can enable small-scale farmers to make sound decisions on when and where to sell their crops and at what prices.<br>• ICT reduces search costs for price information and can strengthen farmers' negotiating power, reducing the risk of selling produce under value<br>• Blockchain technology can be used to link farmers to guaranteed markets and realize prices that are attractive to both farmers and consumers (see Box 1: Twiga Foods)<br>• By assigning a digital identity to a product, blockchain technology allows actors to trace how and into what the product was processed<br>• Traceability facilitates product certification according to quality, environmental and/or social standards (e.g. Rainforest Alliance, UTZ, Fairtrade) | • Reduce post-harvest losses and related GHG emissions; it further increases farmer incomes, facilitating investments in sustainable agricultural practices<br>• Attention to the high incidence of food-related health hazards and increasing concerns about the environmental and social impacts of global agrifood supply chains have led to a proliferation of certification standards and the wish to trace food from farmers to end-users<br>• Farmers who produce according to such standards can access higher-value (export) markets<br>• Higher farmer incomes in combination with adherence to sustainable agricultural practices can serve both adaptation and mitigation purposes |

| | | |
|---|---|---|
| **Consumption: Improved and climate-smart nutrition** | • ICT can play an important role in raising consumer awareness and promoting best nutrition practices and nutrition-sensitive agriculture; apart from health benefits (and related cost savings to society), such activities could also aim to shift diets towards climate-smart, low-emission nutrition<br>• The active commercial promotion of climate-smart substitutes for meat (esp. beef) is gaining traction (e.g. IMPOSSIBLE foods) | • Start to solve the challenges whereby 820 million people are currently undernourished, 2 billion people are micronutrient deficient, and 2.1 billion adults are overweight<br>• Hence, while increasing food production for a growing population is a must, enhancing the diversity and quality of the food consumed is just as important |

Mainly based on (BMZ, 2019; Montpellier Panel, 2019; Saiz-Rubio & Rovira-Más, 2020; Trendov et al., 2019; World Bank, 2019)

## 5. Practical Entry Points for Projects

Like in any climate and development project, robust planning, and adaptive management with regard to digitalization are crucial to ensure climate and livelihoods impacts. The following four key design principles can be iteratively applied to help practitioners to succeed.

**Principle 1: Identify intervention areas and digital solution host and users** – Based on the intervention levels defined in the table in Chapter 4 an actor mapping is required to understand who will benefit from which information and which actor has the capacity to implement and maintain the desired digital solution. For example, developing a digital platform providing training material for small-scale farmers would need an actor who is interested to keep the digital platform updated with new and revised training material. Additionally, maintenance costs of the software or server hosting requires a business model beyond the project. Engaging small-scale farmers and key actors in their support network is crucial to precisely understand their context specific needs (see Box 3: Demand oriented software adoption cycle).

**Principle 2: Assess the digital context** – Any digitalization effort must use the triple 'Ds': **digital literacy** of the included actors, **digital access** and **decent internet**. A related assessment will help to develop the framework of a digital strategy related to a project.

**Principle 3: Describe the requirements for a digital key technology with a focus on quick wins** – Digitalization projects should start with rather simple digital solutions with high impact on information asymmetry or transaction costs. Such quick wins could be achieved for example by disseminating training material or price information in the form of digital workshops, given the digital access of small-scale farmers. In some areas this might still involve support from rural radio stations, while in other areas this can be managed by a digital platform cooperating with a private business. More complex projects with a higher

**Box 2: Ecosystem Services – Linking small-scale farming projects with the voluntary carbon market**

Irrespective of whether in Kenya, India or Indonesia, small-scale farmers benefit from the adoption of improved Sustainable Agricultural Land-use Management (SALM) practices. They can achieve a triple-win: Enhancing resilience, reducing emissions and sequestering greenhouse gas emissions, and improving livelihoods through higher climate risk adjusted returns. With the help of digital solutions, the impact of SALM practices can be measured, reported and verified (MRV) following internationally recognized carbon monitoring standards, such as the Verified Carbon Standard or the Gold Standard. Soil organic carbon (SOC) is the foundation of the triple win, and SOC is strongly affected by climate-smart agricultural practices. The main components of applied digital solutions are data collection tools (Excel sheets, SMS-based or customized Apps) and a web-dashboard for monitoring at project level (https://digital.unique-landuse.de/themes/co2/). Such digital management information systems allow projects to bundle thousands of small-scale farmers, involving them in carbon smart practices and letting them participate in ecosystem-based payment schemes.

**Box 3: Demand oriented software adoption cycle**

**1.) Requirements analysis and specification:** Farms and value chains are analyzed to understand information demands for decision making and optimization. Simultaneously, technology is developed for other applications that can be used or modified to benefit small-scale farmers. A framework is crucial to align and structure the two sources of information to define the software application demand. Well known methodologies for this process are: Agile development, Scaled Agile Framework, DevOps, Waterfall and Rapid Application Development. Flexible building architecture for the software to operate should be considered.

**2.) Design and development:** Based on the requirements documented, a design is developed and presented. This can include process models and storyboards. Based on these, the code is constructed using an appropriate programming language. Writing code and testing to eliminate errors is an iterative process.

**3.) Testing:** Project relevant scenarios are tested as part of software design and coding. This will include performance testing to simulate load testing on the application. Further quality assurance will be established as well as priorities and release criteria to address and track defects. A beta-version of the software can be already used and tested by the client.

**4.) Deployment:** The final version of the software will be released for the user. Data from existing data sources or software can be migrated if necessary.

**5.) Maintenance and support:** Maintain the quality level and adjusting to updates in the programming environment and delivery over the application lifecycle. Sometimes this also includes hosting the software on a server.

digital disruptive momentum should always build on trust from quick win projects and a good understanding of the capacity of the key actors involved.

**Principle 4: Develop and execute the digital use case (partnerships and scaling)** – Compared to social media where applications can be used instantly by millions of users, digital technology and software for small-scale farmers often do not reach commercially viable scale, especially if the user is not expected to pay for the service. Therefore, numerous digital solutions exist that lack funding or further development. Partnerships between software developers and large user networks can ensure high user numbers and the ability to secure funding from public and private sources. Digital service providers are often crucial intermediaries adopting the digital technology and providing the services to small-scale farmers. They require business incubation support and often the costs for their services initially need to be covered by development partners until the services achieve economy of scale and farmers are certain about the benefits and become willing to cover the costs. The digital solutions introduced by climate and development projects often offer customized solutions. However, this requires that a business model is developed to ensure continuation beyond the project lifespan.

## 6. Conclusions

This brief presented digital solutions and practical guidance for adopting digital technologies that support small-scale farming as a pillar of the agrifood system. For small-scale farming and related agrifood systems, focusing on enhancing climate resilience and low carbon development is a great opportunity to reduce the barriers preventing farmers from accessing information.

At this early stage of the digital disruption in small-scale agriculture, learning and feedback loops are crucial. Open sharing of successes and failures can help to accelerate learning.

The difficulty of providing financially sustainable digital solutions for small-scale farming requires a smart approach. With a focus on quick wins, for example to overcome the barriers that cause information asymmetry, straightforward success can be achieved. This means, for example, digitizing existing data and learning materials. Small applications, e.g. Apps for data collection, can generate quick time- and cost-savings related to baseline and impact monitoring tasks.

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