African Union

AU Digital Agriculture Strategy (DAS) and Implementation Plan 2024 – 2030

October 2023

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Abbreviations

Term	Description
A4AI	Alliance for Affordable Internet
AAIP	African Agribusiness Incubation Programme
ACB	African Central Bank
ACET	African Centre for Economic Transformation
ACP	African, Caribbean and Pacific
AFCAS	African Commission on Agricultural Statistics
AfCFTA	African Continental Free Trade Area
AFD	Agence Française de Développement
AfDB	African Development Bank
AfSIS	Africa Soil Information Service
AGOA	African Growth and Opportunity Act
AGRA	Alliance for Green Revolution in Africa
AgTech	Agricultural Technology
AI	Artificial Intelligence
AMF	African Monetary Fund
AMIS	Agricultural Monitoring Information System
ARBE	Department of Agriculture, Rural Development, Blue Economy, and Sustainable Environment
ASTA	Academy of Science and Technology for Africa
ATU	African Telecommunications Union
AU	African Union
AUC	African Union Commission
AUDA	African Union Development Agency
BDT	Telecommunication Development Bureau
CAADP	Comprehensive African Agricultural Development Programme
CAPI	Computer Aided Personal Interview
CATI	Computer Assisted Telephone Interviewing
CAWI	CAWI - Computer Assisted Web Interviewing
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CEMAC	Communauté Économique et Monétaire de l'Afrique Centrale
CGIAR	Consultative Group on International Agricultural Research
CHIRPS	Climate Hazards Group Infrared Precipitation with Station Data
CORS	Continually Operating Reference Stations
COVID-19	Coronavirus disease
CTA	Technical Centre for Agricultural and Rural Cooperation ACP-EU
DARBE	Department of Agriculture, Rural Development, Blue Economy and Sustainable Environment
DFS	Digital Financial Services
DIE	Department of Infrastructure and Energy
DMS	Database Management System

DSS	Decision Support System
DTS	Digital Transformation Strategy
EA	Enterprise Architecture
EAC	East African Community
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EEA	European Economic Area
EOI	Expression of Interest
ESA	European Space Agency
EU	European Union
FAO	Food and Agricultural Organisation
G2P	Government to Person Payment
GAP	Global Agricultural Productivity
GDP	Gross Domestic Product
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring Initiative
GFAR	Global Forum on Agricultural Research and Innovation
GII	Global Innovation Index
GIS	Geoinformation systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GNI	Gross National Income
GODAN	Global Open Data for Agriculture
GSARS	Global Strategy to Improve Agriculture and Rural Statistics
GSM	Global System for Mobile Communication
GSMA	GSM Association
HDI	Human Development Index
IBEF	India Brand Equity Foundation
ICT	Information and Communications Technology
IDB	Inter-American Development Bank
IEA	International Energy Agency
IED	Department for Infrastructure & Energy
IFPRI	International Food Policy Research Institute
IMD	Institute for Management Development
IoT	Internet of Things
IPDM	Integrated Pest and Disease Management
ISRIC	International Soil Reference and Information Centre
ITA	International Trade Administration
ITA	International Trade Administration
ITU	International Telecommunications Union
IVR	Interactive Voice Response
LAC	Latin America and the Caribbean
LAN	Local Area Networks
MAMOPANEL	Malabo Montpellier Panel
ML	Machine Learning
MNO	Mobile Network Operators

MS	Member State(s)
NASA	National Aeronautics and Space Administration
NEPAD	New Partnership for Africa's Development
NFC	Near Field Communication
OACPS	Organisation of African, Caribbean and Pacific States (OACPS)
OBD	Outbound Voice Messaging
OECD	Organisation for Economic Cooperation and Development
P2G	Person to Government
P2P	Peer-to-Peer Transaction
PaaS	Platform-as-a-Service-Technology
PDA	Personal Digital Assistant
PRIDA	Policy and Regulation Initiative for Digital Africa
REC	Regional Economic Community
RFID	Radio frequency Identification
SDG	Sustainable Development Goals
SMS	Short Message Service
STC	Specialised Technical Committee
TOR	Terms of Reference
UAA	Utilized Agricultural Area
UAV	Unmanned Ariel Vehicles
UMA	Union du Maghreb Arabe
UN	United Nations
UNDP	United Nations Development Program
UNESCO	United Nationals Educational Scientific and Cultural Organisation
USAID	U.S. Agency for International Development
USF	Universal Service Fund
USSD	Unstructured Supplementary Service Data
WAN	Wide Area Networks
WIPO	World Intellectual Property Organisation
WLAN	Wireless Local Area Network

The AU Digital Agriculture Strategy – The Documents

AU Digital Agriculture Strategy (DAS) and Implementation Plan 2024 – 2030

The African Union Digital Agriculture Strategy and its Implementation Plan 2024 to 2030.

THIS DOCUMENT

Full version, 146 pages

AU Digital Agriculture Strategy Abridged Version (AU DAS Abridged Version),

The African Union Digital Agriculture Strategy and its Implementation Plan 2024 to 2030.

Abridged version, *22 pages*

AU Digital Agriculture Strategy Fact Sheet (AU DAS Fact Sheet)

The African Union Digital Agriculture Strategy and its Implementation Plan 2024 to 2030.

Fact Sheet, *3 pages*

AU DAS – Situation Analysis Report,

Introduction to Digital Agriculture. Information about enabling environments, technologies, trends.

113 pages

AU DAS – Situation Analysis - Country Profiles

Country profiles of the 55 AU member states with indicators for agriculture, ICT, financial inclusion and others.

110 pages

Acknowledgements

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The Digital Agricultural Strategy was developed under the auspices of H.E. Josefa Leonel Correia Sacko, Commissioner for Agriculture, Rural Development, Blue Economy, and Sustainable Environment (ARBE) of the African Union. The formulation and development were guided by a multi-stakeholder taskforce created in August 2021 and involved exchanges with different stakeholders. The Strategy benefited from multiple consultations with the members of the taskforce, staff from the Department of Agriculture, Rural Development, Blue Economy, and Sustainable Environment (ARBE) and the Infrastructure and Energy Department (IED), stakeholders from the European Commission, UN organisations (FAO, IFAD, ITU, DEC), development banks (World Bank, African Development Bank), development agencies (GIZ, ENABEL, USAID), research centres (AGRA), farmer representatives as well as private sector organisations.

The analysis was carried out through the Policy and Regulation Initiative for Digital Africa (PRIDA) project led by Mr Sandro Bazzanello and Dr. Linda Kleeman. Dr Ralph Elsaesser, senior Digital Agricultural consultant and Emilly Ongus, ICT in agriculture consultant conducted the analysis and report writing. Cristina de la Maza and her team from CARSA and Research ICT Africa contributed to the situation analysis report as well as to the strategy. Mrs. Revi Sterling, Ph.D. Gender, Technology and Development Consultant, provided chapter A4.1 “Gender Inclusion”.

Executive Summary

The **African Union (AU) Digital Agriculture Strategy (DAS) and Implementation Plan** establish a framework for the digital transformation of African agriculture and cover the period from **2024 to 2030**. The strategy builds on the goals and priority areas of **Agenda 2063** and shares the goals for modern agriculture for increased productivity and production (goal 5) for a high standard of living, quality of life, and well-being for all citizens (goal 1). Technology is seen as a driver for the transformation of economies, including agriculture, and economies must be environmentally sustainable and resilient to climate change (goal 7). One of the AU's flagship projects, the **African Continental Free Trade Area (AfCFTA)**, signed by 55 AU member states, targets the establishment of regional value chains, and the DAS can help to build the required digital environments. The DAS promotes digital agriculture to achieve "Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods" in line with the **2014 Malabo Declaration** which was recalled at the 2022 AU assembly.

The **Vision of the Strategy** is a **digitally** facilitated/ enabled, socio-economically and environmentally sustainable agriculture that contributes to the **Comprehensive African Agricultural Development Programme's (CAADP)** vision of **"eliminating hunger and reducing poverty by raising economic growth through agriculture-led development as well as promoting increased national budget provision to the agriculture sector."** Digital agriculture will contribute to these targets by improving the efficiency and effectiveness of African agricultural systems; making African agricultural systems more resilient and climate-smart; attracting youth to agriculture, creating jobs in modern agriculture; and by making agriculture inclusive. An average agricultural growth rate target of 6% was formulated, and other targets were defined for food security, the reduction of poverty and malnutrition, and improvements in the sustainability of agricultural production and use of natural resources.

A comprehensive situation analysis on digital agriculture in all 55 AU member states, carried out in 2021 in the frame of the DAS, revealed that a uniform approach to the digitalisation of agriculture in the member countries is not possible. This is because climate, soils, water availability, type of agricultural production system, level of mechanisation and digital skills of the population significantly differ across member states. A regional approach would, in turn, disregard the fact that countries in different regions may well have similar problems.

Therefore, the strategy prioritises the **development of national digital agriculture/e-agriculture strategies** that are in line with the respective national development plans for agriculture. An important recommendation for all member states is the joint development of the strategies by the Ministries of Agriculture and the Ministries of Infrastructure or Information and Communications Technologies (ICT) and other key stakeholder ministries such as Trade, Foreign Affairs, Livestock, Fisheries, and Environment.

The AU Commission (AUC) and the Regional Economic Communities (RECs) have a **coordination role** and need instruments to promote and monitor the transformation process. They support the 55 member states in successfully transforming their agricultural sectors. Respective indicators are proposed by the DAS indicator framework.

Most of the digitalisation of agriculture is driven by the **private sector**. Here, governments must ensure the enabling environment by leveraging digital infrastructure, policies, regulatory environments, business environments, broadband and energy prices. Policy frameworks should also promote energy-efficient/green ICT and circular solutions and ensure that large-scale investments do not harm the small-scale business models of eco-agriculture. Financial inclusion and access in rural areas as well as early exposure to digital education are other success factors. The promotion of digital skills in schools, the visibility of digital agriculture at tertiary levels of education, and room for digital agriculture innovations to help attract the youth to agriculture. The smallholder producer is the foundation of

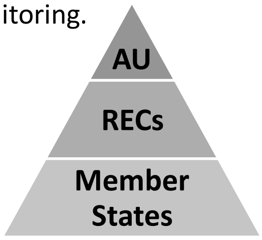
agricultural production within the continent and the first point of contact for many digital agriculture solutions and incentives. Therefore, increasing the digital literacy of smallholder producers, their adoption and use of digital tools and improving extension and advisory services to them should be a priority. The knowledge generated within this foundational level of the value chain will greatly enhance the transformation of the agricultural sector. The attractiveness of the agricultural sector for innovative digital solutions is often underestimated. Creating networking opportunities for ICT service providers with agricultural businesses through conferences, trade fairs, and innovation centres can make the sector's potential more visible. The DAS, together with the AU digitalisation strategies for the education and health sectors, consider these intersectoral interactions and dependencies critical for successful digital transformation. An additional AU Artificial Intelligence (AI) for Agriculture Strategy has been developed under the auspices of the PRIDA project, providing information on the state of development of the most innovative technologies serving agriculture.

Core framework conditions for digital agriculture are:

- **Accessibility layer:** Access to electricity, Internet, technology, digital skills, information, finance.
- **Network layer:** Reliable, performant, and affordable networks.
- **Technology layer:** Traceability of products, remote sensing, AI, Machine Learning (ML), Unstructured Supplementary Service Data (USSD), Interactive Voice Response (IVR) etc.
- **Business layer:** Investment ecosystem, incubation system, doing-business environment, and human capital.
- **Policy layer:** Data privacy and security, climate governance, and compliance monitoring.

The DAS proposes actions on three levels:

- The **continental** level – the AUC.
- The **regional** level – the African RECs.
- The **national** level – the AU member states.



For these three levels, the strategy defines mission objectives and areas of focus:

- Build accessible shared **knowledge platforms** for AUC, RECs, and member states.
- Promote **hi-end smart technologies** such as AI, blockchain technology, Internet of Things (IoTs), ML and Big Data and present potentials for their use in the various African agricultural contexts.
- Conduct a **situational analysis study** of the AU member states to show an estimate of standardised data on their readiness for the digitalisation of their agri-food systems.
- Understand, prioritise, and **consolidate relevant stakeholder achievements** and identify the best ways to **strategize** and **synergize** for the digital agricultural transformation of the continent.
- Aid in **defining** explicitly **the role that the AUC, RECs, and member states** can play in ensuring the digital agricultural transformation.
- Introduce and ensure **data privacy** and **security standards** through policies and regulations.
- Ensure that cross-cutting issues such as **gender inclusiveness**, **climate resilience, youth employment**, and **rural financial inclusion** are fostered and respected at any point.
- Foster specific initiatives such as **e-identity**, **traceability**, **integrated pest and disease monitoring**, and **index-based insurance**.
- Avoid and **mitigate digital divides** between regions, businesses, and population groups.

Many stakeholders are currently engaged in digital agriculture projects and initiatives. The DAS lists and clusters these stakeholders, their information products, and identifies synergies and potentials for collaboration.

Chapter 6 presents the **implementation plan** together with an **investment plan** and suggestions for a

monitoring system. Detailed actions, structured for the three levels, define the DAS implementation plan, and can be found in Annex A.

At **AUC level**, the DAS suggests leveraging multi-lingual digital agriculture knowledge platforms and digital agriculture forums. The development and free provision of an e-advice software platform can be a direct intervention with a high impact for the AUC member states.

At **REC level**, capacity building is essential to enable RECs to support their member countries in developing national digital agriculture/e-agricultural strategies.

At the **AU member state level**, the DAS provides recommendations for the elaboration of national digital agriculture/e-agriculture strategies. The DAS lists the required core elements for national strategies and provides additional resources for various use cases. National agricultural ministries can select from this portfolio depending on their development priorities. The 55 member countries were clustered for each of the use cases depending on use-case-specific enablers and obstacles. That way, the DAS helps AU member countries to prioritise the sub-sectors for digital transformation according to their national development plans for agriculture.

Other recommendations and elements for implementation concern stakeholders at different governance levels along the agri-food value chain, such as multilateral organisations, development agencies, donors, non-governmental organisations (NGOs), the private sector, and the smallholder producers.

The implementation of the DAS is from 2024 to 2030, in line with the performance and speed at which the agriculture sector is developing. Given the speed at which technologies evolve, longer implementation planning is impracticable. It is estimated that the implementation of the DAS requires around 165 million USD on continental level. Besides that, huge investments will be required at national levels and the private sector will invest manifoldly.

The DAS was developed between May 2021 and June 2022, under the guidance of a multi-stakeholder task force. The Strategy and Implementation Plan have benefited from eight consultations with the members of this ICT Task Force hosted by the AU's Department of Agriculture, Rural Development, Blue Economy, and Sustainable Environment (ARBE) and the Infrastructure and Energy Department (IED), which included stakeholders from the European Commission, UN organisations (FAO, IFAD, ITU, DEC), development banks (World Bank, African Development Bank), development agencies (GIZ, ENABEL, USAID), research centres (AGRA), farmer representatives and private sector organisations.

The DAS is based on an extensive situation assessment of agriculture and digital technology application on a continental scale which reviewed all layers of the digitalisation for agriculture (D4Ag) ecosystem including existing infrastructure, platforms, business environments, policies and regulations, data sources, data availability, data management practices, digital skills, and linkages with other sectors such as water, health, education, and trade. The DAS will be completed by a monitoring and evaluation system, that targets the overall AU Digitalisation Transformation Strategy (DTS) and all its sector strategies.

The Policy and Regulatory Initiative for Digital Africa (PRIDA), funded by the European Union, provided technical assistance and analysis for the development of this strategy and its implementation plan.

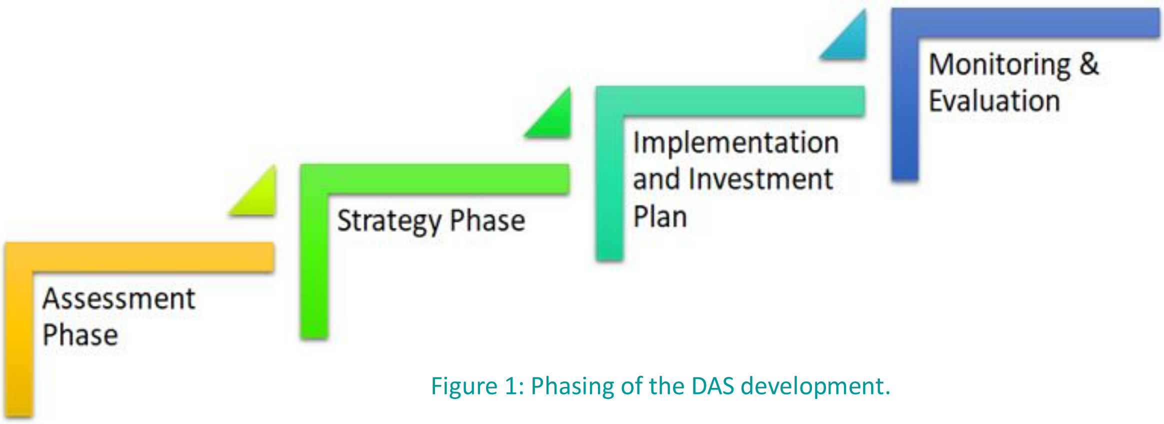


Figure 1: Phasing of the DAS development.

1. Introduction and Context

1.1. Context and Background

Agriculture is a major driver of the African economy. The role of agriculture has been well defined by the African Development Bank and the World Bank as being of leading importance to the livelihoods of countries. The Status of African Agriculture report shows that agriculture is a major contributor to the Gross Domestic Product (GDP) of most of the Sub-Saharan Africa (SSA) countries[1].

In the last decade, threats to the sustainability of agriculture have increased from natural and anthropogenic causes. Climate change as the main threat has led to reduced production and productivity, an increase in pests and diseases, and the early onset of drought and floods, posing a threat to livelihoods. While humans have exacerbated this situation, it should also be noted that the drift of young people out of agriculture into other fields of work has slowed down the development of agriculture. Increased rural to urban youth migration adds to the reduction in available labour. Africa is a young[2] continent with the greatest share of the young population globally. An exodus of these populations from agriculture is not only a threat to the sustainability of agriculture but ultimately the economic status of AU member states.

A bright spot that is emerging despite the challenges above, is digital agriculture. The Digitalisation of Africa Report[3] states that "prior to 2010, conversations about digitally-enabled agriculture had already begun – primarily among donors and multilateral agencies - but there were very few D4Ag solutions in Africa or globally."

D4Ag or **digital agriculture** refers to the integration of digital technology into agriculture and related industries. D4Ag is getting more attention because of the various evidence urging the necessity of ensuring that the sector is sustainably managed[4] by providing promising solutions to sustainability. Modern and innovative technologies appear to address emerging agricultural problems such as changing climates, pests and disease attacks, degrading soils, and depleting water resources to provide a growing young African population with perspective and tools at hand to solve the various problems.

While agricultural development in the first decade of the millennium has been mostly donor-driven, it has since become evident that the sector needs more in terms of harmonisation, enablers, and accelerators. Mostly with a focus on ensuring sustainability in this dynamic sector.

In the 2017 **AU-EU Summit** in Abidjan, the African Union (AU) and the European Union (EU) committed to seize the opportunities for technological development and the digital economy. Subsequently, the Policy and Regulation Initiative for Digital Africa **(PRIDA)** was set up. PRIDA is a joint initiative of the African Union (AU), the European Union (EU) and the International Telecommunication Union (ITU), that enables the African continent to reap the benefits of digitalisation by addressing various dimensions of broadband demand and supply in Africa and building the capacities of AU Member States in the Internet Governance space. It is supported by the EU-funded Pan African Programme.

In February 2020, the AU departments were requested to develop sectoral implementation strategies under the AU digital transformation strategy (DTS). Digital agriculture is one of the key sectors that was identified and the need for

[1] https://agra.org/wp-content/uploads/2018/10/AASR-2018.pdf

[2] https://au.int/en/youth-development/

[3] Tsan, Michael; Totapally, Swetha; Hailu, Michael; Addom, Benjamin K. 2019. The Digitalisation of African Agriculture Report 2018–2019. Wageningen, The Netherlands: CTA/Dalberg Advisers

[4] https://www.fao.org/in-action/e-agriculture-strategy-guide/documents/detail/en/c/1121618/

a Digital Agriculture Strategy (DAS) was articulated. The Vision of the DAS, in line with the Malabo declaration of June 2014, recalled at the 2022 AU assembly, is "Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods". The DAS also contributes to the goals of Agenda 2063, such as modern agriculture for increased productivity and production (goal 5), and a high standard of living, quality of life, and well-being for all citizens (goal 1). It shares the target of establishing regional value chains with one of its flagship projects, the African Continental Free Trade Area (AfCFTA), signed by 55 AU member states.

The mission goal of the DAS is to provide guiding principles for the fifty-five member states of the AU to attain digital agricultural transformation and build their own autonomous national digital agriculture strategies as per their own national development plans.

1.2. Agriculture Sector Context

In **2020 the Executive Council** decided that AU departments develop, under the **Policy and Regulation Initiative for Digital Africa (PRIDA)**, continental sector strategies and plans and Agriculture was identified as a priority sector. PRIDA has specific goals, including connectivity, political legislation, Internet governance, and the inclusion of ICT in other sectors.

The **Digital Agriculture Strategy (DAS)** follows the mission of PRIDA "to foster universally accessible and affordable broadband across the continent to unlock future benefits of internet-based services."

The DAS for Africa will build on existing initiatives and frameworks such as the **Programme for Infrastructure Development in Africa (PIDA)**, and the **African Continental Free Trade Area (AfCFTA)**, the **African Union Financial Institutions (AUFIs)**, to support the development of a **Digital Single Market (DSM)** for Africa, as part of the integration priorities of the African Union. The **Smart Africa** Initiative has set the creation of a Digital Single Market in Africa as its strategic vision.

The **Agenda 2063**[5] of the AU "for the Africa that we want" contains aspirations which include goals that recognize the importance of ICT and well-educated citizens for inclusive growth and sustainable development. The key transformational[6] outcomes of agenda 2063 align with the vision of the DAS:

- **Improved living standards** will be accomplished with increased production and productivity and job opportunities that digital agriculture provides.
- **Empowering women, youth and children** via access to resources through digital agriculture tools for example, mobile money, markets information, weather data and job opportunities along the value chain.
- **Transformed, inclusive and sustainable economies via ICT penetration and contribution.** The DAS highlights examples and avenues on how this can be made possible via collaborations between the agriculture and ICT sectors
- **Integrated Africa** via intra-African trade and free movement. The RECs have a unique opportunity with the digitalisation of Agriculture via central systems for markets, forecasting and pest and disease management as examples.

In addition, the DAS recognises the **2014 Malabo Declaration**, recalled at the 2022 AU Summit, which addresses the transformation of the agricultural sector. While the digitisation of agriculture is not mentioned as a direct field of action, the objectives of ensuring a sustainable and robust agricultural system, leveraging regional cooperation through the **Comprehensive African Agricultural Development Programme (CAADP)**, improving financing in agriculture, ending hunger, promoting intra-African trade, and reducing poverty are consistent with the benefits of digitalising agriculture.

[5] https://au.int/en/agenda2063/overview

[6] https://au.int/agenda2063/outcomes

1.3. The Digital Agriculture Ecosystem

A digital ecosystem is a distributed, adaptive, open socio-technical system with the properties of self-organisation, scalability, and sustainability. The term is inspired by natural ecosystems that function with a certain grade of resilience to internal and external shocks. Figure 2 shows a digital agriculture ecosystem that not only comprises technology but also describes the use cases, how technology can contribute to address agricultural problems, details all stakeholders and their roles and responsibilities, outlines business processes, the interfaces and needs for interoperation. Enablers such as **human capital**, **investment ecosystem** are equally important as **network performance**, **coverage**, and **affordability**. The ecosystem thus reaches into the sphere of politics and regulation. While in life science, the ecosystem describes how biotic and abiotic components are linked together, the digital agriculture ecosystem describes how agriculture, digital tools, stakeholders, and processes are linked and how they interact.

Current D4Ag solutions are part of this ecosystem and will over time be replaced by better, more precise, more effective, and less expensive solutions. The technology layer will also evolve, and new technologies will appear that can be helpful to increase production, improve efficiency, and finally make the lives of millions of African farmers more resilient. These technologies allow for the improvement of other processes along the value chain, such as aggregation, quality control, transformation, processing, storage, transport, and marketing. The solutions landscape will change and evolve, and so will technologies, policies, and regulations. What will remain is the demand for quality food and changing diets, for work and respective abilities. To continuously meet these demands, modern agriculture needs to accommodate future changes in climate patterns, soil degradation, population pressure, land and water scarcity, migration, and displaced persons.[7]

The digital agriculture ecosystem, thus, is much more than digital technology. Digitalisation alone will not improve yields or provide sufficient water, digital technologies must interact with traditional practices and communication, improve mechanisation, and enable knowledge and information sharing. Logically, the digitalisation of agriculture concerns all stakeholders of the agricultural ecosystem, including those who do not have digital skills or access to digital devices. They interact indirectly through data in a database of a cooperative, an aggregator, a central (nucleus) farm or extension service. Digitalisation thus, permeates all levels of stakeholders so that they all are part of that digital agriculture ecosystem.

more information on stakeholders

more information on agricultural use cases

more information on technologies

[7] https://www.fao.org/publications/fofa/en/

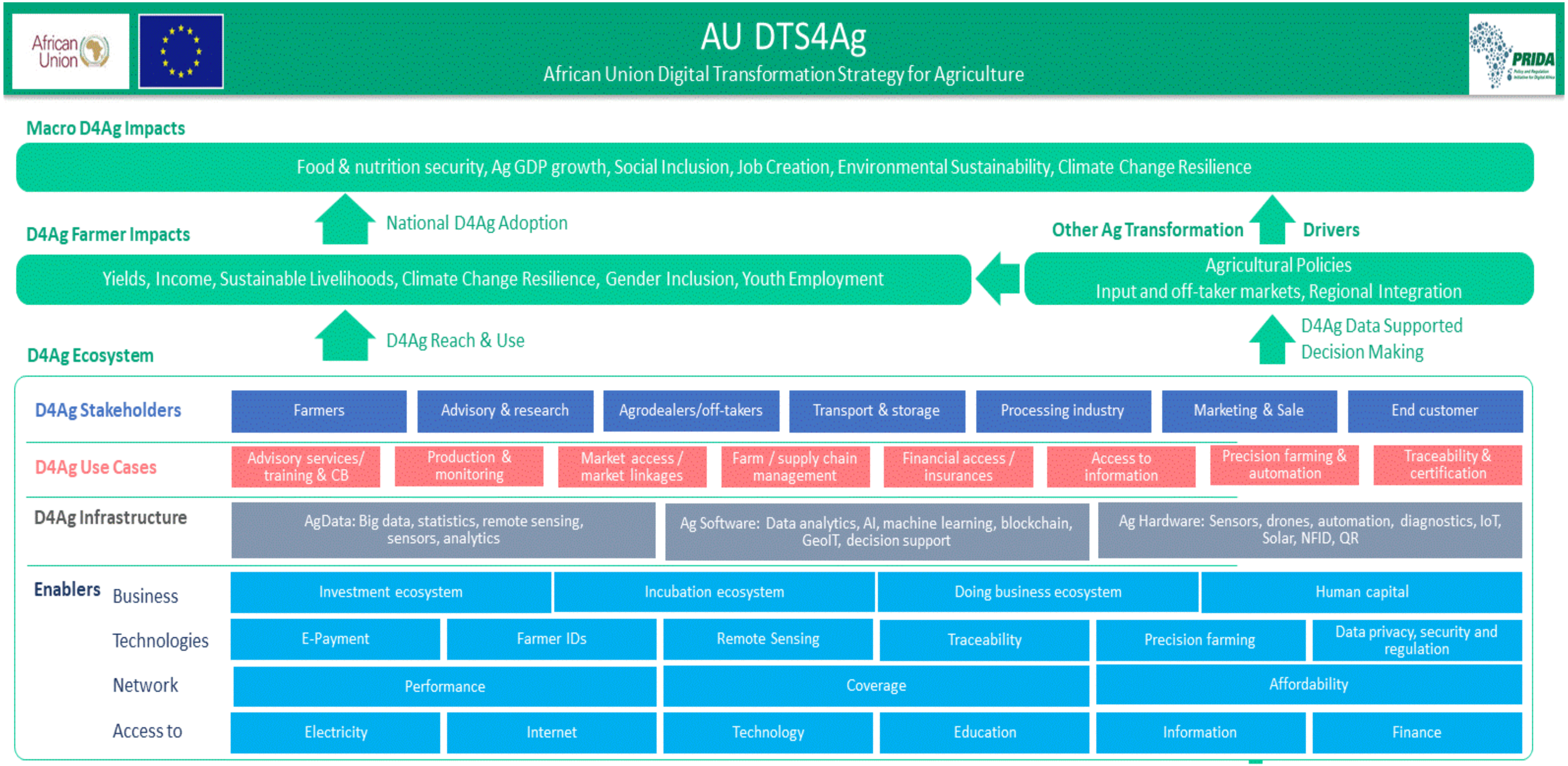


Figure 2: The D4Ag Ecosystem. Diagram based on the D4Ag ecosystem graph of the 2019 Dalberg Report, figure 3, page 36, modified by the authors.

1.4. Digital Agriculture Governance

Digital agricultural governance, as the name suggests, is spearheaded by two different facets, i.e., agricultural governance and digital governance under the Ministries of Agriculture and ICT/Infrastructure, respectively. The governance framework(s) for digital agriculture directly influences its potential for growth and development and indirectly controls the subsector. National governance frameworks play especially important roles in steering the sectors; via the creation of confidence for investments by providing suitable rules and regulations, the sustainability of the sector via environmental laws, pathways, and sustainable quality input supplies for selected value chains. Moreover, a good doing-business environment and free trade arrangements enable various stakeholders to interact and conjointly develop the agricultural business ecosystem. Infrastructure and ICT ministries indirectly provide parts of the enabling environments for the digitalisation processes. While e-government, e-trade, e-health, or e-education primarily start in urban areas, the digitalisation of agriculture needs investments and development in rural areas where agriculture primarily takes place.

A lack of good governance can be a significant impediment to development. Weak or non-existent rules and enforcement, an unregulated financial sector, and a lack of investments and critical infrastructure can contribute to conflict and corruption.

Recognising that sector governance for digital agriculture goes beyond governments, to include other levels of governance like the private sector and the civil society, implies that the interaction of agriculture and ICT regarding governance needs a more succinct approach.

Whilst the larger share of digitalisation in agriculture is driven by the private sector, the public sector controls most of the enablers and thus decides on obstacles or accelerators. The private sector organises around the regulations, which are set by the public sector. To specify appropriate governance elements for digital agriculture, the public sector needs to build an understanding of the various parameters that influence digital agriculture.

Government regulations and policies for digitalisation are usually defined, specified, and ratified by the ICT and Infrastructure Ministries, other sectors such as health, education or agriculture require appropriate regulations, but the ICT Ministries are not necessarily aware of this or do not necessarily take them into account.

A strong and permanent collaboration between the Ministries of agriculture (including livestock and fisheries) and ICT/ Infrastructure is needed, to define a suitable governance framework for digital agriculture. It is necessary for knowledge generation, capacity and skills building regarding both digitalisation as well as the predominant agricultural problems to be solved in a country. It is not possible to have a governance framework for digital agriculture independent from the general digital or ICT governance framework. The agricultural ministries should take the lead in this process, as only they can guarantee the seamless integration of digitalisation into existing agricultural policies and goals. Thus, most other sectors must be included in the discussion. Muluneh[8] suggests looking at digital agricultural governance from several aspects, including:

- **Regulation quality** which includes policies that allow for innovation, private sector investments and technology development.
- **Equal data** access, sharing and security. This includes how smallholder producer data is collected and handled. How this data is shared, including the platforms used and the accessibility of these platforms. Regulation around big data.
- **Accountability and Voice** of the various stakeholders involved in the digital agriculture sector. This includes producers, investors, agro-dealers, off-takers,

[8] Muluneh T.W. 2021

processing industry, field staff etc.

- **Political stability:** the stability of regions creates confidence for stakeholders and allows for the development of the sector and ensures that human ability is available for the development of the sector.
- **Institutional Support** and existing programs and mechanisms that allow for the ease of some of these functions including D4Ag initiatives, financial instruments for digital agriculture, training and knowledge resources on digital agriculture and existing data laws and
- **Common International Goals** facilitate the process of good governance. Climate change, cross-border pest and disease pandemics, increased production and productivity are borderless issues that require collaboration at different governance levels.

The governance of digital agriculture would have similar goals to general governance frameworks for the agricultural sector, including livestock and fisheries. In as much as there is a need for cooperation and collaboration with the ICT sector. There may also be a need to collaborate with other sectors, for example, digital education, which may have an influence in the implementation of some of the D4Ag programs.

The interlinkage of digital governance and agricultural governance can be stimulated via finding areas of convergence as a starting point. The digital agriculture framework in the below describes potential areas of convergence and suggests areas of focus. Agriculture, especially in the continent, is demand-driven. The approach to governance from the supply-driven perspective has been successful and resulted in reforms. For effective governance within the agricultural value chains, there must be considerations at ministries, extension services and agencies.

Justice, equity, and **ethics** are at the core of better governance, and must be adhered to for sectoral transformation. The effectiveness of digital agricultural governance for food security and improved livelihoods can only be quantified with the existence of good governance practices and cross sectoral collaborations of the agriculture, livestock, and fisheries ministries together with the ICT/Infrastructure ministries.

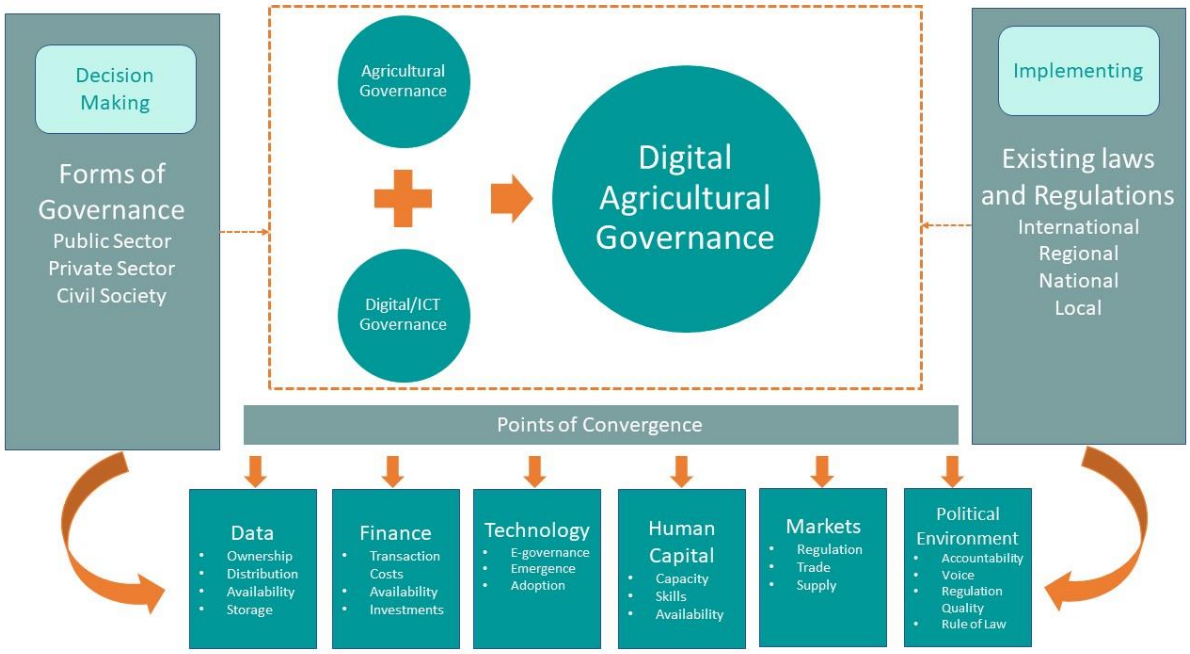


Figure 3: Digital Agriculture Governance as convergence of agriculture and ICT.

1.5. Core Drivers for Digital Transformation in Agriculture

The main driver for the digitalisation of agriculture is the need to establish a resilient and robust agri-food system. The demand for digital tools has led to the industry, mostly being spearheaded by the private sector to develop innovations and markets. International and national companies have developed digital solutions for farms, farmers, agro-dealers, off-takers, the processing industry, as well as the storage-, cooling- and transport industry. Software companies and data intermediaries respond to the demand for communication tools, traceability software, training, and e-commerce platforms, for example.

There is a large set of enablers that are important for a fair, inclusive, and harmonised digital transformation process. Existing gaps in the landscape of enablers can hinder the process and lead to asymmetric developments leaving already marginalised communities behind. According to the Digitalisation of African Agriculture Report[9], the lack of D4Ag infrastructure – farmer registries, digital agronomy data, soil mapping, pest and disease surveillance, and weather data infrastructure – in most contexts reduces the effectiveness of D4Ag solutions and the evolution of the sector. National policies and regulations play an important role as enablers for digitalisation processes in all sectors, however, there are specific enablers of particular importance for the digitalisation of African agriculture. These are:

ACCESSIBILITY LAYER

1. **Access to electricity** is a basic precondition for any digital technology. Even though solar-powered stand-alone solutions are no longer rare today, access - physical and financial - must be guaranteed for all users for digitalisation to take place. In many remote areas of Africa and even in urban areas, power outages are common, making digital solutions inadequate.
2. **Access to Internet** is another prerequisite for digital agriculture. Most modern software exchanges data with servers on the Web. There are applications which function offline, a necessary functionality for African farmers, but from time to time they need a server connection to take advantage of the advice, news, forecasts, price information etc. Enhanced data coverage in rural areas and affordable data prices are important for the digitalisation of agriculture.
3. **Access to digital devices** is another important factor. Although mobile phone and smartphone prices have dropped significantly over the last few years, this technology is still not affordable for many smallholder farmers. They often don't take their devices to the field, as one household may have access to one device or devices are shared within the household. In addition, the existence of a smartphone in a household does not necessarily mean access to an Internet connection. Often, the data costs are too high, or data coverage is unreliable, patchy or non-existent in the area, further limiting their access to available technologies. Furthermore, certain technologies or applications do have minimum requirements not just for the smallholder but also for the extension agent and governments to interact with. Software might require the latest version of Android OS, but higher versions tend to be associated with newer and more expensive devices, creating an additional access barrier.
4. **Digital skills** are necessary to operate the devices and to use D4Ag tools. Software targeting smallholders needs to consider their lower literacy and digital skill levels as well as the locally prevalent conditions. Farmers worldwide usually are among the

[9] https://www.cta.int/en/digitalisation-agriculture-africa

last to adopt new digital technologies. USSD menus and apps must provide usability adapted to the skills of the targeted users. On the service provider side, digital skills are needed at all levels, from developers to customer support. A local network of competent ICT service providers with agricultural knowledge is also necessary. This would include ensuring that extension agents are conversant with existing and developing technologies but are also skilled enough to transfer this knowledge to farmers. There are various e-marketing platforms in existence that would easily connect agri-food producers with better markets. Some of them are more advanced and need specific skills but some adapt to common use options like social media which are already widely used.

5. The availability of devices, internet and skills still does not guarantee equal **access to information**. Open data initiatives are evolving, but national databases should also be accessible. Sharing information enables the value of data to be unlocked, it is the combination of data from different sources that leads to added value. Agriculture needs informed decision-making, and the national databases have valuable data for this purpose on meteorology, soils, water resources, production statistics etc. These datasets should be shared with all agricultural stakeholders.

6. **Access to finance** is a critical issue for African smallholders. They typically lack financial resources to purchase better quality inputs, for example. Financial institutions are not interested in providing small-scale credit because risks are difficult to assess, and procedures are resource-consuming. ICT can help by creating a critical mass of clients, it can help build trust through farmer profiles. Sophisticated solutions work with e-vouchers and e-wallets where e-payments are reserved for the purchase of quality inputs from certified agro-dealers.

7. **Access to equal data, privacy, security and regulation** build the environment in which digitalisation can develop. A solid data regulatory framework is important to guarantee responsible data handling by all stakeholders. This would include how digital agriculture data is collected, stored, and shared.

NETWORK LAYER

8. **Reliable, performant, and affordable networks** with sufficient coverage (mobile phone, mobile broadband, but also electricity) are proven to be accelerators for digitalisation processes. Rural areas are typically disadvantaged in this regard as their development is expensive and potential revenues low. Availability of mobile networks allows for mobile telephone penetration, providing an opportunity for farmers to access mobile banking platforms, markets etc.

D4Ag INNOVATION LAYER

9. **Mobile payments** or **e-payments** are known to drive digital innovations in agriculture as they can be integrated with all sorts of digital solutions. Mobile money transfers build trust, reduce risks, and tend to be inexpensive and safe compared to other options available to smallholders. Mobile money is easy to use and allows for real time banking with or without a smartphone and doesn't require specialised skills. Africa is a frontrunner in mobile payments, and in countries with e-payment services, digital skills are rising.

10. **Farmer IDs** or more general, digital personal IDs help in identifying a person. This can facilitate any digital service which interacts with farmers and customers. It is part of the national policy to promote processes toward digital IDs. In their absence, cooperatives and large companies introduce their own IDs, however, these may at times be incompatible with other systems.

11. **Traceability** is key for certification and accessing new markets. It helps in finding and mitigating quality problems, introducing transparency and trust. Having digital traceability solutions connects even smallholder farmers in the most remote areas to regional and international markets.

12. **Remote sensing** provides large-scale information about the status of the environment and natural resources, about plant health and biomass at regular intervals. Free data is available and can be used for monitoring and forecasting, pest and disease detection and for optimising field operations such as irrigation.

BUSINESS LAYER

13. In most AU member states, the **Investment Ecosystem** is underdeveloped. A global network of financial service providers therefore rarely reaches out to African companies when innovation and start-ups need seed funding, and businesses need capital for growth.

14. A strong **Digital Innovation System** favours the development and growth of innovative companies. African countries with well-developed D4Ag acceleration programs, incubation centres, hackathons, boot camps and provisions for innovations are naturally frontrunners in digitalisation.

15. The (Ease-of-) **Doing-Business-Environment** describes a country's regulations for starting a business, registering property, accessing credit, paying taxes, enforcing contracts etc. A well-developed doing-business-environment logically attracts more people to start businesses.

16. **Human capital**, trained and skilled in digital agriculture, is paramount for the work related to the digitalisation processes. Knowledge and skills gaps hinder the development process but specifically digital transformation, as this would require highly specialized human capital. This is further determined by the different literacy levels.

Digital agriculture transformation requires collective and collaborative efforts from the various actors in the sector. The mentioned necessities for transformation, require good governance but also an investment to make work easier for the transformation of the sector. The ecosystem of digital agriculture consists of different, interconnected levels that need to be addressed systematically in order to initiate and promote the transformation process.

2. Situation Analysis

Digital agriculture is a relatively new topic. It covers a wide range of technologies, that are constantly evolving, making it difficult to keep track of progress in the sector. Furthermore, there exist digital solutions for various agricultural systems, value chains, languages, for production, aggregation, processing, financing, insurance, access to markets, transportation etc. creating an extensive and complex field. Although there are many projects with components that promote digitalisation in African agriculture, there exists a lack of understanding of the technologies and their potential for digital transformation. The Food and Agricultural Organisation (FAO) cites lack of skills at the government level as one of the main obstacles to faster digitalisation. At the state level, the competencies for digitalisation are usually found in the ministries of infrastructure. The problems to be solved are, however, of agricultural nature and the responsibility for this lies with other relevant ministries. Consequently, close cooperation and collaboration is needed between multiple ministries. FAO has joined with ITU to commission the preparation of corresponding documents that illustrate the topic of agricultural digitalisation from the ICT/digital perspective.

In principle, there are two very different ways to approach the topic:

From the agricultural perspective the problems of agriculture are known to the state ministries, and most of them are traditionally addressed through better advisory services, improved inputs, mechanisation etc. The potential to use digital solutions to solving some of these problems needs to be identified, and where possible, proper initiatives started so that solutions can be developed. The state directly develops and offers digital solutions for some use cases (e.g., e-advisory, national ID, data sharing platforms, weather forecasts). For most use cases, the technical solutions are to be developed by the private sector and so the state can only intervene indirectly by creating the appropriate enabling environment. Policies and regulations and educational initiatives are the main drivers.

From an ICT perspective, development means more broadband coverage, higher broadband speeds, lower broadband access prices, and higher smartphone penetration rates. In general, well-known technologies like the Short Message Service (SMS), IVR, USSD, mobile apps etc. are suitable for the digitalisation of diverse sectors. There exist many digital technologies and most of them can be useful in the agricultural context. More complex and newer technologies like remote sensing, ML and big data can provide very specific solutions to agricultural problems. AI and blockchain technology might be useful for some specific agricultural use cases but their use is still small.

Digitalisation is not the silver bullet, it is not the panacea, thus the digitalisation process of agriculture should start by understanding the agricultural problems and not by identifying innovative technologies. With the necessary insight, ICT professionals can then work with agriculture profesisonals to find appropriate technologies and identify or develop suitable solutions. To raise awareness and build capacity in the agricultural sector on the topic of digitalisation and to sensitise the ICT side to agricultural problems, both sides need to work more closely together. FAO and ITU, both UN organisations, have joined their efforts for the digitalisation of agriculture and published a series of documents presenting digital solutions for agriculture both by agricultural use case and by technology as aforementioned. The DAS largely refrains from presenting successful and/or particularly innovative solutions and instead refers to suitable existing documents.

Figure 4: A data manager enters information into a financial tracking system, contents of the warehouse are monitored, audited, and used for collateral so that local farmer groups can secure bank financing.
Photo credit: Xaume Olleros/RTI International

2.1. Readiness for Digital Agriculture Transformation

The **DAS Situation Analysis Report**, issued in November 2021, presents national data relevant for digital agriculture for all 55 AU member states. The status of each country is presented on two pages with data from various sources in a standardised and comparable manner. This data originates from various official sources such as **FAO**, **World Bank**, **ITU**, **GSMA** – data sources which cover all AU member states and thus deliver comparative information in terms of data quality and timeliness.

Based on this data, a national **Digital Agriculture Readiness Index (DAgRI)** was calculated for African nations by combining a set of selected indicators with data specifically relevant for digital agriculture. The Situation Analysis Report highlights the data sources, the formula applied, and country pages summarise data in a detailed manner. The formula includes indices for digital infrastructure, access to technologies, digital skills, business environments with a special emphasis on rural areas and populations. The formula also includes parameters relevant for agriculture such as existence and type of drone regulations, e-payment services, and national agricultural data portals. Figure 3-1 summarises the DAgRI for all AU member states in a map.

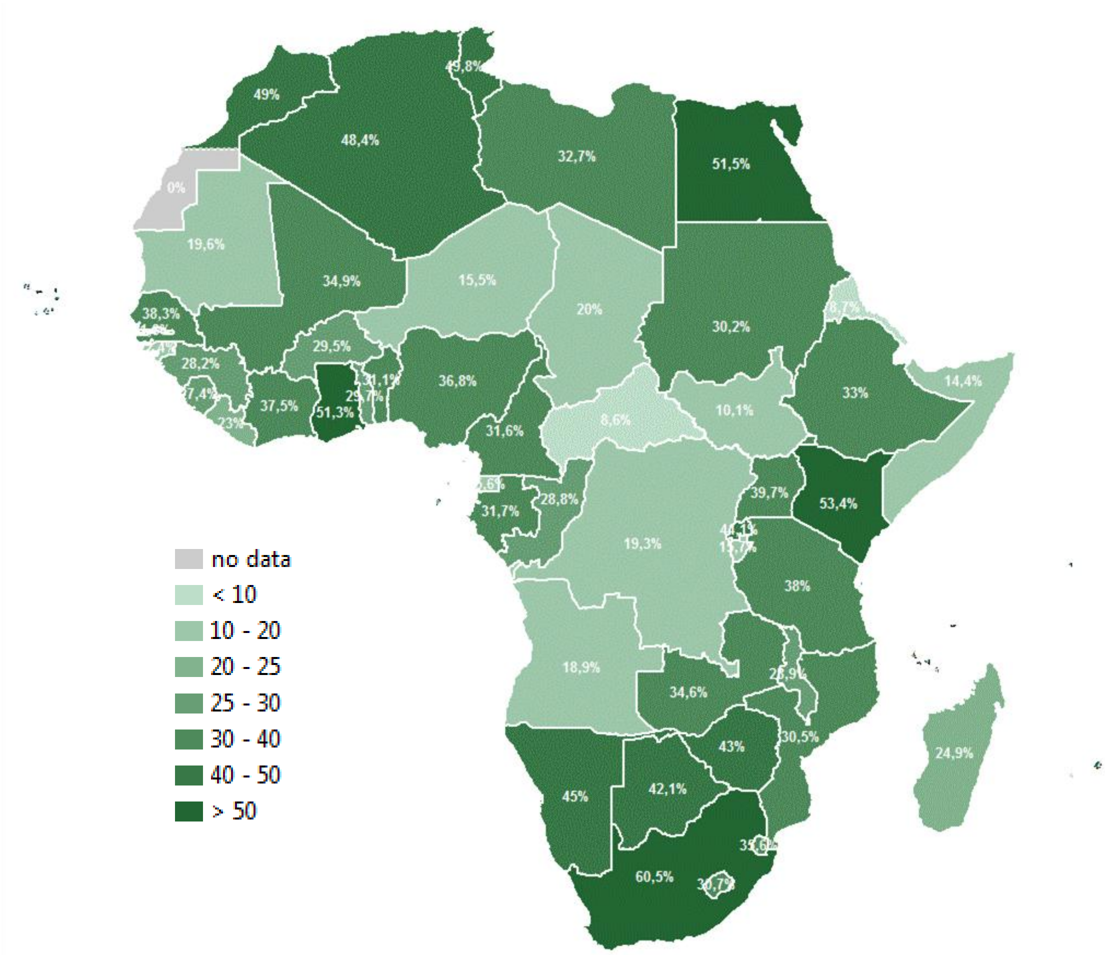


Figure 5: PRIDA DAS 2022 elaboration: Digital Agriculture Readiness Index for Africa 2022.

Based on this assessment it is possible to cluster countries by their readiness for digital agriculture. Five clusters were formed by equal intervals (<15, 15-30, 30-45 etc.) with a 15% range each. Top performers, Mauritius with a DAgRI of 61.4 and South Africa with 60.5 were merged into the lower cluster, resulting into 4 concise and manageable clusters. The importance of a country's agricultural sector for the national economy, however, is not captured by the DAgRI. The assumption is that agriculture needs transformation, irrespective if it is the economic backbone or not.

Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Higher than 45		Between 45 and 30		Between 30 and 15		Lower than 15	
61,4	Mauritius	44,4	Cape Verde	29,7	Togo	14,4	Somalia
60,5	South Africa	44,2	Seychelles	29,5	Burkina Faso	12,4	Guinea-Bissau
53,4	Kenya	44,1	Rwanda	28,9	Malawi	10,1	South Sudan
51,5	Egypt	43,0	Zimbabwe	28,8	Congo, Rep	8,7	Eritrea
51,3	Ghana	42,1	Botswana	28,2	Guinea	8,6	Central African Rep
49,8	Tunisia	39,7	Uganda	27,4	Sierra Leone	*0,0*	*Western Sahara*
49,0	Morocco	38,3	Senegal	24,9	Madagascar		
48,4	Algeria	38,0	Tanzania	23,0	Liberia		
45,0	Namibia	37,5	Ivory Coast	22,2	Sao Tome and P.		
		36,8	Nigeria	22,0	Comoros		
		35,6	Swaziland	21,8	Gambia		
		34,9	Mali	20,0	Chad		
		34,6	Zambia	19,6	Mauritania		
		33,0	Ethiopia	19,3	Congo, Dem. Rep.		
		32,7	Libya	18,9	Angola		
		31,7	Gabon	17,6	Djibouti		
		31,6	Cameroon	15,7	Burundi		
		31,1	Benin	15,6	Equatorial Guinea		
		30,7	Lesotho	15,5	Niger		
		30,5	Mozambique				
		30,2	Sudan				

The **DAgRI** represents the general readiness of a national agriculture sector for digitalisation. However, the digitalisation of agriculture involves many areas, which different stakeholders have classified in a variety of ways. Over time, the term "**use case**" has become accepted, but there is no official classification scheme for this.

While the DAgRI makes a general statement about a country's ability to digitalise agriculture, this value can be different when it comes to a specific use case. For example, automation of major irrigation schemes does not require ICT skills on the part of smallholders, while digital extension services require some ICT literacy as well as access to technology on the part of the recipient. The above clusters provide a good overview, but more detailed and suitable cluster formulas can be developed for the different use cases.

In Appendix C, several parameters are presented, which influence the potential for digitalisation and help in prioritizing areas of intervention for regional and national digital agriculture/e-agriculture strategies.

2.2. Digital Agriculture Transformation Issues

Transformation refers to change i.e., the alteration of a system from its current state to a more sustainable system. In combination with digitalisation, the term 'transformation' is associated with progression, modernization, and innovation. This implies a development towards an improvement of the agri-food complex system. Transformation is the progress from a known status towards an envisioned status, defined by a set of strategic goals. To enable transformation of a sector, an assessment is required, goals must be identified, appropriate actions derived and prioritised, and an enabling environment built. In the case of digital agricultural transformation, the assessment is complex, it must cover many aspects: the natural environment given by parameters such as climate, water resources, soils, availability of land, topography, and many others. Agricultural systems differ in the value chains, in their structures, large plantations versus smallholder farming, cooperatives and contract farming schemes. The agro-food system is based on trade, thus access to inputs, to markets, availability of functioning road and railway networks, of harbours and airports play a role as well as trade agreements and custom regulation. Digital skills at all levels play a major role, and thus the demography of a society mainly influences its capability for digital transformation. For digital transformation, the existence, status and development perspectives for digital infrastructure is critical. No digital transformation without a strengthening of the various elements which build the digital environment.

A transformation strategy then must develop a vision, define appropriate goals and, based on the current situation, identify appropriate measures and actions. The overall goals are based on the Sustainable Development Goals and concern food security and nutrition, environmental sustainability, end of poverty and hunger, inclusivity, climate resilience and others. The defined targets in agriculture can be manifold and can cover sustainable productivity, rural linkages, linking local, regional and global markets, professionalizing extension systems, access to knowledge, densifying transport networks, etc. (Bachewe et. al, 2018; Tsakok 2011; X Diao 2016)

The last 10 years have seen an extraordinary evolution of digital solutions for agriculture. Digital agriculture has already contributed solutions to many problems and improved the efficiency of multiple value chains. The Digitalisation of African Agriculture CTA-Dalberg Report shows the evolution timeline from the advent of e-agriculture towards the digitalisation of agriculture. Digitalisation refers to enabling or improving processes by using digital technologies and digitized data. In the context of the agri-food sector and its various processes and value chain this forms the field digital agriculture.

As in any system there are various challenges that must be considered, as they can limit the transformation of the systems. These are highlighted as:

1. **Data:** data is not only needed for the assessment of the current situation. There is an overarching need for better data collection and analysis to improve efficiency along the value chains, thus, enabling digital agriculture. Data is collected through surveys, by sensors, human data-entry, through digitalisation of existing analogue data, etc. Data is at the core of digitalisation, but data handling bears certain risks.
   Data availability and quality:
   In order to assess the actual situation, data must be complete, accurate and accessible. Data sources and property must be known, data formats must follow certain standards, data has to be made accessible to those in need. Data quality is often a function of the resources spent for data collection, data validation and data analysis. Statistical data needs proper sample size, sufficient validation and meta data which describes the processing chain of the data. **Data sustainability**: Data collection must be financially sustainable to enable monitoring of the transformation process. Outdated data must be archived and replaced by

more current data. "To improve (..), the six core principles of data quality, equity, co-creation, accountability, financial sustainability, and scalability should guide investment and service provision." – GCA digital blueprint. (Ferdinand, T. et. al, 2021)

Data Sharing: Available data should be shared with others to maximize value. Care must be taken to ensure that the data has been validated, excludes personal or identifiable information, and includes the necessary meta-data.

Data scalability: data can be collected at plot level, or aggregated at farm, cooperative, or lead farm level. National planning needs the data by crop type, region, and crop cycle. On a continental level, a broader, coarser view is necessary. Data must be interoperable, and interchangeable to attain scalability.

Meta data builds trust in data. Meta data tells the story of the data from data collection to data analysis. It provides information about data properties, precision, and accuracy as well as the standards followed.

Data equity refers to the availability of data without bias or exclusion. The ITU promotes open data as key (ref…CGIAR big data, ITU) to enable all regions, countries and sectors that may not have the ability to access data or the resources to arrange data, so that no one is left behind.

There is need to address the **Digital Data Divide—**between those who contribute the data and those who control, aggregate, and share the data, resulting in an inequality of bargaining power. Farmers will only provide data voluntarily if they also benefit and see utility.

2. **Knowledge Sharing and Experience Capitalisation:** Digital agriculture being a relatively new defined concept means that a lot of innovation is occurring. There are a lot of ongoing innovations, mostly spearheaded by the private sector and entrepreneurs, often with adoption from other sectors. These new innovations or technologies often work in silos, without benefitting or learning from each other, and duplicating resources. Due to a lack of collaboration and cooperation, there is limited knowledge sharing and documentation across innovations, resulting in slow progress, missed synergies, and a risk of stagnation. Documentation and communication of innovations through various channels and use cases can help foster the transformation process. On a lower level, the agricultural workforce must be informed about available technologies and developments which can help them making their businesses more sustainable.

3. **Synergies of Key Players:** Digital Agriculture pertains to two sectors: Agriculture and ICT. They are represented by ministries and departments for agriculture and infrastructure (or ICT). Digitalisation processes are only possible, if appropriate digital infrastructure is in place, is physically and financially accessible and sufficiently maintained. This is the domain of the infrastructure sector. Stakeholders from agriculture are aware of the sector problems, may have a vision for the development of the sector, and would need to know about potential innovations and the potential for digitalisation. In addition, there are various stakeholders engaged in digitalising the African agriculture from both government and the private sector. All players have their own manifold priorities in their approach to digital transformation. Digital agriculture also has many links to other sectors such as water, health, trade, education, and energy in national plans. National agriculture plans look at all aspects of agriculture including livestock, fisheries, crops, soils, climate change adaptation and mitigation etc. But often, digitalisation is a missing element of the plans, thus there is no overall plan which can link the activities. The ICT departments drive the development of infrastructure, internet access, data management etc. but not always in line with the demands of other sectors. The potential of digital agriculture, however, relies on the existence of sufficiently performant ICT infrastructure and access to technologies to be able to develop. For digital agricultural transformation to occur, the two sectors and their respective departments need to work together to ensure synergies in development plans.

Further to this, the digitalisation of agriculture is mainly driven by the private sector, including young agricultural entrepreneurs, they self-organise and greatly influence development. Government policies and plans that solely focus on specific one aspect of agriculture end up being limitations to the overall development of this sector. Sectorial development plans should understand the private sector as an accelerator of the various digitalisation processes and develop appropriate enablers.

4. **Access to technology for all stakeholders** is key for Digital transformation. Access to technology by end users and developers is dependent on several factors, including finance. The Digitalisation of African Agriculture CTA-Dalberg report shows the important role of youth in leading innovations. As they create these innovations, youth face the challenge of financing their start-ups, getting their businesses registered and paying taxes for their digital agriculture enterprises. Smallholder farmers often cannot afford the small fees necessary to access e-extension services or market information via USSD, SMS or voice mail. Furthermore, access to technology is also limited by availability of infrastructure and internet access. While there are open data and free software, the lack of network coverage, mobile broadband etc. limits access and usage. Finally, limitations in knowledge and skills on the usage of these technologies further reduces their value. Certain use cases require a level of digital literacy not only for the end user but also for the development and maintenance of the systems and for use by extension agents and lead farmers for example. Drone and data regulations can also have a limiting effect on certain technologies. Digital transformation requires that all stakeholders can perform in the ecosystem. The ease of use of these technologies also plays a critical role for the adaptability, continuity and sustainability of the technologies which subsequently create change and thus transformation.

5. **Digital Skills at all levels** are needed, from developers to the end users, otherwise digital systems fail. Various studies have shown that the failure of digital agriculture technologies in most cases is due to lack of understanding and/or skills. There is often an asymmetry between the digital skills of the end user and the skills needed to leverage the technology. GSMA has shown the ease with which USSD powers mobile phones and makes services more accessible to the smallholder farmers compared to advanced apps that require the smallholder farmer to use more complex devices and knowledge. This may also account for extensionists or village-based agents who are supposed to bridge the last mile to the farmer. Intense capacity building is necessary for the end users to adequately use the technologies which sometimes cover a wide array of activities within the value chain. The youth can play a key role: In every farmer family there is a young generation and they typically are faster in adopting new innovative digital technologies. Community farming can also remediate the problem of older people's lack of appropriate digital skills.
   Digital innovation hubs and incubators have been developed in major cities within African countries. These hubs are mainly filled with ICT professionals, and they provide interesting innovations in digital technologies. However, there needs to be a link with agricultural professionals to enable and ensure co-creation of appropriate innovative digital solutions that addresses pertinent challenges in the agriculture sector. Digital agriculture can be a topic in post-secondary education to attract young people to the agricultural sector.   .
   Instead of closing the gaps of the triple divide, there is a veritable risk that the introduction of digital technologies in agriculture will rather widen the gap. At any point in the digitalisation processes, attention must be paid to how the marginalized parts of the farming society can be integrated and supported. Policies can encourage the development of skills relevant for the digital transformation of agriculture.

6. **Energy consumption** of digitalisation and the related infrastructure is a major

concern. Digitalisation processes need energy access; thus, they logically increase energy consumption. While smartphone-based solutions typically do not consume much energy and the required power is often provided by standalone solar solutions, high-end technologies such as blockchain and ML require server farms and generate a lot of internet traffic, which results in high energy consumption. Thus, costs and benefits must be balanced and energy can be obtained from renewable sources wherever possible.

3. Guiding Principles

- **Gender Inclusion**
  The gender gap is part of the triple divide women are facing in rural areas of Africa. The DAS aims at gender-mainstreaming in the use of information and communication technologies for agriculture and rural development. more

- **Youth in Digital Agriculture**
  Digital agriculture contributes to job creation and transforms traditional agriculture into innovative businesses and attractive job. Digital agriculture thus helps to make the agri-food sector attractive four the younger generations. more

- **Climate Smartness**
  The African agri-food sector faces major challenges due to climate change. Digital agriculture can help improving resilience through innovative solutions such as early warning systems, IPDM, digital learning, index-based insurances, use of solar energy, and others. more

- **Rural Digital Literacy**
  Low digital literacy levels among smallholder producers are a major barrier for the digital transformation of agriculture. The DAS aims to improve digital literacy in rural areas where smallholder agriculture primarily takes place. more

- **Rural Financial Inclusion**
  The DAS identifies financial inclusion as a key driver for development. The DAS promotes financial inclusion of smallholder producers in rural areas through digital tools. more

- **Digital Agriculture Innovation**
  Innovative technologies for agriculture help improving yields, reducing losses, accessing markets, saving lives, building resilience, enabling learning, connecting people. The DAS aims to promote innovation for agriculture on all levels. more

- **Enabling environments**
  The development of a vibrant agro-industrial subsector in agriculture depends on technology and innovation and is mainly driven by the private sector. The DAS aims to provide the enabling environments for innovation in digital agriculture. more

4. The Strategy Framework

4.1. Vision and Mission

Vision of the DAS

An inclusive, resilient, and transformed agricultural sector with access and connectivity to digital agriculture tools. An enabling environment conjointly developed by agriculture and ICT departments fosters collaborations of the public, private and civil society sectors in agriculture for the African continent. Digital transformation of Agriculture contributes to improved rural livelihoods, food security and nutrition, reduction of poverty and hunger, increased resilience to climate change, youth employment and social inclusion.

VISION

Mission of the DAS

Empower and support AU member states to create national digital agriculture strategies. Support, steer and coordinate the digital transformation efforts of agriculture in AU member countries. Defragment, consolidate and synergize the digital agriculture sector in Africa. Co-create knowledge on Digital Agriculture, share expertise and solutions among the continent. Introduce and assure standards through policy and regulation to create an inclusive enabling environment for Digital Agriculture for all stakeholders.

MISSION

The vision for Digital Agriculture is in accordance with the vision of agricultural transformation. Agricultural transformation aims at disruption of agri-food systems to ensure sustainability. The vision of agricultural transformation ensures that there are social, economic, and environmental changes to the agri-food sector that are resilient. The principal goals for agricultural transformation are in line with the UN Sustainable Development Goals (SDGs) and more specifically [10]SDG 2 which "recognizes the interlinkages among supporting sustainable agriculture, empowering small farmers, promoting gender equality, ending rural poverty, ensuring healthy lifestyles, tackling climate change, and other issues addressed within the set of 17 Sustainable Development Goals in the Post-2015 Development Agenda."

The digital agriculture transformation vision, therefore, employs digital tools to achieve the goals of agricultural transformation.

1. **Food security and nutrition** are traditionally the primary goals of any form of agriculture. Secondary drivers for food security and nutrition are improved product quality, improved yields, reduction of food losses and wastage, improved market access, access to finance, and traceability. For farmers, incentives for digital agriculture are improved access to quality inputs, markets and regulated market prices, and to finance with the overall goal of higher yields and incomes. Digital agriculture and smart technology contribute via tools for e-advisory and e-learning, technologies for cooperative and farm-management, enhanced technologies

[10] https://sustainabledevelopment.un.org/topics/foodagricultre

for storage, processing, and transport, reduction in food wastage, and barcode, QR-code and RFID-chip enabled traceability solutions. Finally, it is in the interest of every farmer to become more professional, to achieve higher incomes and sustainable livelihoods. To assure food security, local, regional, national, and international markets have to be linked. This may also require the certification of product quality, and thus traceability.

2. **Protecting the environment** needs surveillance, data collection, analysis, and informed decision making. Monitoring on a large scale is supported by satellite-based remote sensing solutions, drone-based crop assessments, and ground-based sensor-networks. Various kinds of transmission technologies connect different sensors with cloud-based servers and analysis is done almost in real-time. Hi-end precision agriculture ensures that optimal amounts of water, fertiliser and pesticides are applied.

3. The agricultural sector globally is increasingly focusing on **building resilience** and **sustainability**. Most countries in the global south are more vulnerable to climate changes that may occur. Digital solutions can contribute to climate resilience through hyper-localized weather forecasts, real-time flood warnings, and long-term information on droughts and floods. In addition, Index-based insurance helps to compensate for and cushion losses and to obtain seed again after crop losses. Integrated pest- and disease management enables farmers to prepare early for such problems and to undertake countermeasures before massive losses occur. Solar-powered water pumps and other equipment contribute to the lower consumption of fossil resources. Automatic irrigation and fertilisation controlled by sensors and micro-controllers help save water and other resources, just to mention a few.

4. **Job creation** and **youth employment** are important aspects for African societies. The African Agri-food market bears great potential. Unlocking this potential can improve food security, nutrition and create jobs. But the digitalisation of agriculture requires specific skills, which may attract the younger generations to want to engage as it allows for the flexibility of work while providing room for innovation. In addition, digital agriculture contributes to job creation by providing opportunities to convert traditional agriculture into attractive jobs for the youth and the development of a vibrant agro-industrial subsector in agriculture as well as in ICT.

   The AU Malabo declaration of accelerated agricultural growth and transformation for shared prosperity and improved livelihoods (2014) established various visions that are to be met by 2025. The Digital Agriculture Vision is in line with most of the declarations, including the use of more partnerships with civil society, farmers, and agribusiness to support implementation at country levels and play a coordinative role. The commitment to ending hunger via improved practice and technologies, increasing youth employment via job creation, strengthening multi-sectoral efforts for mutual learning and development, and a commitment to enhancing livelihoods and increasing climate change resilience are all in line. Digital agriculture has the capacity to enhance these declarations via the creation, use, implementation and development of D4Ag initiatives along the agri-food value chain. African agriculture needs to be more robust and resilient with increased innovation to tackle the various issues it faces, such as climate change, reduced production, rural-urban migration, increased pest and disease attacks and so forth. Digital Agriculture has ease of reach which allows for strengthening of extension services and allows for innovation that is attractive to the youth and private investors, which are beneficial to African agriculture.

4.2. Objectives and Focus

The main **objective of the DAS** is to identify and understand potential, successes, obstacles, and bottlenecks of digital agriculture, to enable the AU and RECs to guide Member states to develop national digital agriculture strategies based on country agricultural priorities, provide necessary tools and frameworks to adequately monitor these national plans and facilitate the digital agricultural transformation for the African continent. The DAS targets a consolidated continental agricultural sector by fostering collaboration of the public, private and civil society sectors across the continent. In addition, the DAS strives to create **synergy** for the myriad of work that has been done in digital agriculture, reduce fragmentation and foster consolidation for the continent and bring the infrastructure/ICT and agricultural ministries to cooperation.

The areas of focus of the DAS include:

1. Build an accessible shared **knowledge platform** for AUC, RECs, and member states. Highlight digital technologies and use cases for replication by countries with similar parameters.
2. Promote hi-end smart technologies such as **AI**, **blockchain** technology, **IoT**, **ML** and **Big Data** and present potential for their use in the African agricultural context. The DAS enables the member states to assess their needs and levels based on the indices provided. This allows for the member states to make autonomous decisions on which hi-end technologies are based suited to their status.
3. Conduct a **situational analysis** study of the AU member states to show their readiness for the digitalisation of their agri-food systems. The aim is not to rank the various member states but to provide the countries with reliable and comparable data from official data sources as a basis for a self-assessment. The status quo must be known as it is the starting point of the transformation process. With defined future goals, gaps can be identified, and appropriate actions defined and prioritised to achieve these goals and to estimate the related costs.
4. Collate various work undertaken by different stakeholders and identify ways to leverage this work for the digital agricultural transformation of the continent. This includes, as far as possible, **understanding**, **prioritising, translating,** and **consolidating** the work done by the various players. One challenge of the digitalisation process is that numerous actors work on similar themes but don't share their experiences, especially lessons learned. The DAS aims to bring together and gather data from all the stakeholders to provide the AUC with the right tools.
5. Aid in defining the explicit **role** that the **AUC**, **RECs**, and **member states** can play in ensuring the **digital agricultural transformation process**. The DAS aims to show how the different RECs can learn from each other based on similarities in countries such as climate and agricultural priorities. There are cross border challenges such as pests and diseases and natural hazards, where regional coordination is needed. The DAS also allows for co-learning.
6. **Data** issues such as interoperability, quality, and sharing are critical as are data security and privacy. The DAS focuses on proper standards and policies for data management for the continent. Data is the basis of digitalisation, and it is important that data management follows clear standards.
7. Ensure that **cross-cutting issues** are respected and included in the digital agriculture strategies. Gender inclusiveness, youth employment, and **climate resilience** have high priority and the provisions necessary for these are made aware to policymakers.
8. The DAS will be complemented by an **implementation plan** which provides a complete road map of actions to follow to implement the proposed DAS and obtain the established objectives in line with the

defined mission and vision statements. Each task will be clearly structured with specific information on leadership, time-frame, resources and linkages with other tasks. The Plan will also have guidelines for communication and coordination of the involved stakeholders during the implementation phase

9. For each proposed action in the Implementation Plan, a preliminary budget will be produced. The illustrative **budget plan** will provide stakeholders involved with the information necessary to calculate the resources needed for each aspect of the DAS development. The budget for each item will be based on similar experiences as well as the costs and value of resources reported by the stakeholders involved.

10. The DAS will include an **M&E system** that enables tracking performance of the strategy and define causal relationships between implementation on one hand and the outputs and outcomes on the other, including a value judgement along a specific set of criteria.

4.3. Theory of change

The results of the situation analysis at the AU, RECs, and member country levels suggest six areas of intervention of digital agriculture to be addressed by the DAS and Implementation Plan for Africa. These include raising awareness, capacity building and access to knowledge on digital agriculture, access to and affordable digital infrastructure, and the development of National digital agriculture or e-agriculture strategies. The difficulties and challenges in digital transformation listed under chapter 2.2 are considered. The specificities of member countries' agricultural systems and their respective agricultural development plans cannot be addressed at a continental level and have to be considered in national digital agricultural transformation strategies. The DAS provides in chapter A3 recommendations for the development of national strategies and chapter A3.1.4 specifies D4Ag action packages for the AU member countries to select from and prioritise, depending on their national visions and goals for the digital transformation of their agriculture.

It is envisioned that:

1. **Awareness for digital agriculture is raised on continental, regional and national levels**, and along the various value chains, thus for farmers, aggregators, processors, and traders. Digital agriculture should also be promoted through hackathons, Tech Hubs, research centres and integrated into university curriculums.
2. **Fragmentation of the sector is reduced**. Successful solutions are reused in other countries, in other languages, for other value chains and target groups. Corresponding tools are operational and a continental exchange on the topic of digital agriculture takes place horizontally (between regions and countries) and vertically (between different stakeholders in the same country).
3. **Access to knowledge on Digital Agriculture is strengthened** on continental, regional and national levels. Knowledge on success stories as well as failures should be shared on continental level.
4. All African countries develop and implement **National Digital Agriculture Strategies (NDAS)** that serve as a basis for investment in accelerating digital transformation of, and ICT integration in the national agricultural development visions. All African countries have a NDAS in place by 2030.
5. **Digital infrastructure** including **services** such as e-payment are available to all,

with a special focus on rural areas where most farming activities take place.

6. **Enabling environments** are set in place. For digital agriculture this includes respective policies and regulations, but also access to technology, electricity, Internet, Information, and finance. This also includes favourable business environments including investment ecosystem, incubation systems and human capital.

Error! Reference source not found. Figure 6 s hows a **Theory of Change (ToC)** for Digital Agriculture that describes the assumptions, inputs, outputs, and outcomes. In line with Agenda 2063 and the 2014 Malabo Declaration, recalled at the 2022 assembly, the continental and regional digital agriculture program aims primarily to support AU member states in their efforts to reduce hunger and poverty, to accelerate agricultural growth and transformation for shared prosperity and improved livelihoods through increased efficiency of agricultural production and greater resilience of smallholder agriculture to climate shock.

The ToC assumes that the AU in partnership with RECs and development partners will support coordinated continental and regional efforts to develop and implement National Digital Agriculture or e-Agriculture Strategies. A coordinated effort towards the availability of affordable, safe, secure digital devices, connectivity, content, and platforms, free data, and analytics, improved digital literacy and skills for all agricultural stakeholders will contribute towards accelerated digital transformation of African agriculture. Adequate financial resources must be made available from public, private and development partners, synergies must be developed with other sectoral development plans.

Political will, coordination, and partnerships, especially between governments, development partners and the private sector will ensure success of the transformation process.

AU and RECs will have a coordinating role and will monitor the transformation process.

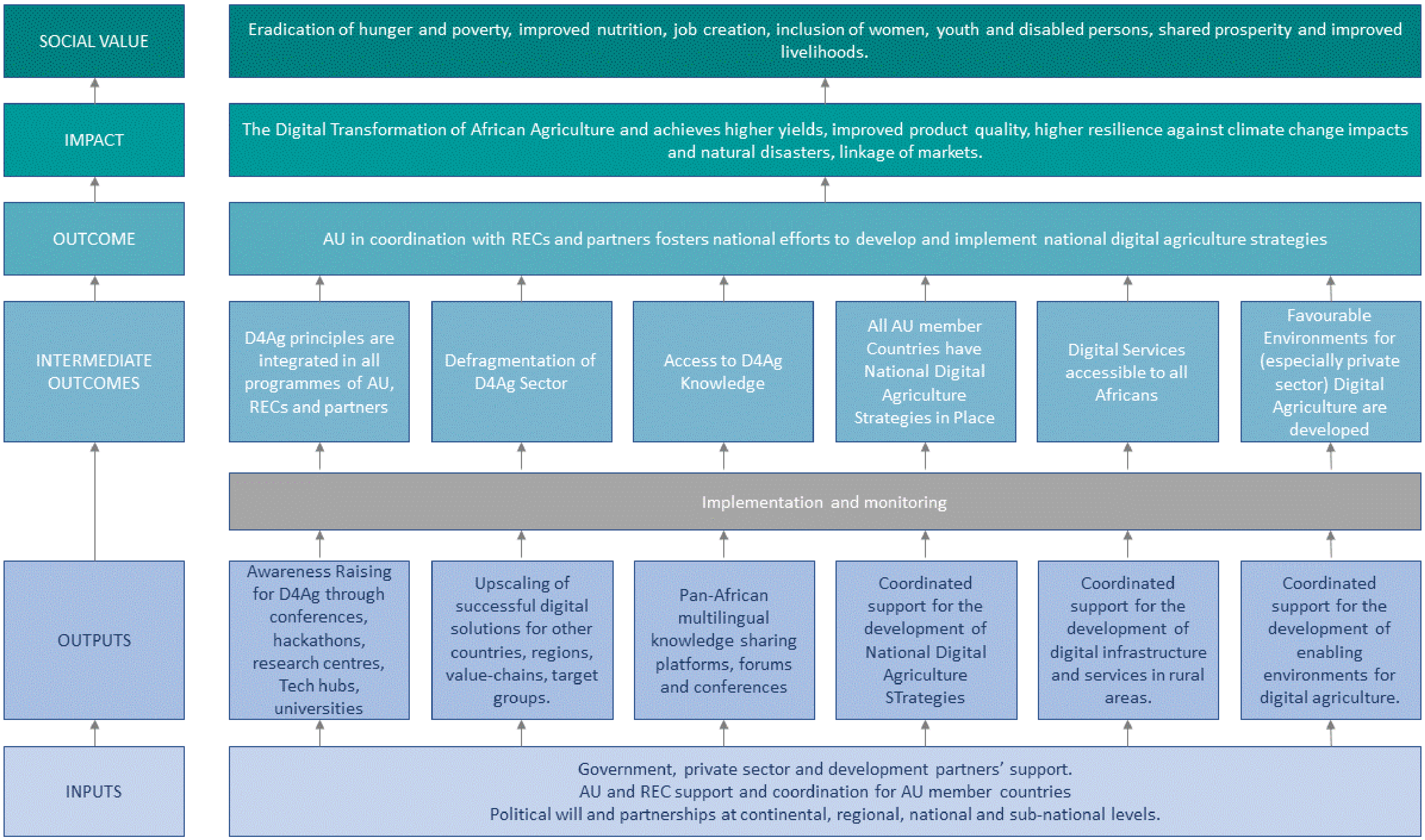


Figure 6: The Theory of Change of the DAS.

4.4. The Strategic Objectives

The implementation of the DAS is based on seven strategic objectives, built on the assumptions presented by the Theory of Change in chapter 4.3. These strategic objectives each cover an important thematic area for the DAS and include well-defined tasks and activities with expected outcomes and indicative targets. There are specific activities for continental, regional and national levels or a combination of these levels. In all cases, different stakeholders and partners are necessary to support implementation and play different roles as summarized in section A5.

Strategic Objective A

Strengthen and Develop Digital Agriculture Infrastructure.

Availability of performant and reliable ICT infrastructure is equally important as is affordability of devices and data. Likewise, a healthy doing business environment can foster digital transformation. The digital transformation of agriculture needs these enablers to be present in rural areas, which typically lack such development. Decision-makers aspiring for the digital transformation of agriculture must promote the development of the various factors that influence the framework conditions specifically in rural areas, along with other, non-digital factors such as access to energy and transport.

Goal A.1: Provide connectivity and infra-structure necessary to support digital agri-culture with a focus on rural communities.

- **Activity A1.1:** Promote investment into basic and inclusive infrastructure (electricity, mobile networks, fibre, satellite, data centres…) to improve readiness for digital agriculture.
  → *Improved coverage and connectivity in rural areas enables development and delivery of digital agriculture services.*

- **Activity A1.2:** A1.2: Explore new and affordable locally driven connectivity options to enable digital agriculture in rural and remote areas/communities.
  → *Reduced costs - improved affordability.*

Activity A1.3: Empower smallholder farmers with access to basic inclusive digital technologies and innovations to improve their productivity and access to markets.

→ *Food security, sustainable livelihoods.*

Activity A1.4: Promote **last-mile connectivity** in all countries.

→ *Increased demand and use of digital agriculture.*

Strategic Objective B

National D4Ag Adoption.

All African governments require a digital agriculture strategy, an e-Agriculture strategy or at least to include digital agriculture as a pillar in their national agricultural development plans. These will provide a framework for future investment in digital technologies that support the sector. These national strategies will differ across regions and MS as they need to align with the national agricultural development plans, which in-turn align with national priorities. FAO provides some guiding principles to support MS in the development of national digital agriculture/e-agriculture strategies,[11] and the DAS promotes, supports and will coordinate this process.

Goal B.1: Promote the elaboration of national and regional digital agriculture strategies.

Activity B1.1: Promote the elaboration of national digital agriculture or e-Agriculture strategies and support member states to align with national development plans.

→ *Available national digital agriculture strategies that serve as a basis for investment in the digitalisation of the agricultural.*

[11] https://www.fao.org/in-action/e-agriculture-strategy-guide/en/

Activity B1.2: Ensure that cross-cutting issues are applied at all times.
→ *All national strategies have included aspects of gender inclusion, youth employment, climate smartness etc.*

Goal B.2 Promote National Digital initiatives.

Activity B2.1: Support member states to develop and strengthen farmer registries.
→ *Farmer registries provide accurate data on farmers and their land enabling better control of subsidies, voucher systems, traceability, and assessment of creditworthiness.*

Activity B2.2: Promote solar irrigation and irrigation automation, including the regulation of grid feed-in tariffs (studies, trainings, manufacturing).
→ *Reduced costs, reduced use of fossil energy for irrigation, reduced emissions.*

Activity B2.3: Introduce and foster traceability and certification (agriculture and livestock).
→ *Improved product quality, access to international markets, disease control.*

Activity B2.4: Promote index-based insurances and other hybrid insurance models (studies, trainings, implementation).
→ *Improved resilience of farming systems.*

Strategic Objective C

Provide enabling environments.

Enabling environments are key drivers for digital development. Availability of performant and reliable ICT infrastructure is equally important as is affordability of devices and data. Likewise, digital literacy and skills development at school and a healthy doing business environment foster digital transformation. The digital transformation of agriculture needs these enablers to be present in rural areas, which typically lack such development. Decision-makers aspiring to the digital transformation of agriculture must promote the development of the various factors that influence the framework conditions specifically in rural areas, along with other, non-digital factors such as access to energy and transport.

Goal C1: Promote an Enabling Infrastructure for Digital Agriculture.

Activity C1.1: Enhance **data interoperability, quality, and sharing.**
→ *Open data platforms offer free access to agriculturally relevant data.*

Goal C2: Improve regulations for privacy and cyber security.

Activity C2.1: Develop continental minimal **standards for data privacy and cyber-security**.
→ *Continental minimal standards are used where national standards are not available.*

Activity C2.2: Engage in legislative, policy, and regulatory work to support requirements for digital agriculture at all levels (e.g., cybersecurity, drone and remote sensing regulations, digital IDs, data governance, data sharing, etc.)
→ *Provide the enabling requirements for the private sector to engage in digital transformation.*

Goal C.3: Digital Agriculture Governance and Collaboration.

Activity C3.1: Support member states to ratify international treaties and frameworks and to integrate these into their national digital agriculture standards (e.g., the Malabo Convention on Cyber Security).
→ *International frameworks are adopted.*

Activity C3.2: Strengthen collaboration between agriculture, ICT and other sectors necessary to deliver digital agriculture at all levels (e.g., task forces, multi-partite round tables).
→ *Foster digital agriculture through awareness rising and collaboration between agriculture and ICT ministries.*

Goal C4: Promote an enabling business environment for Digital Agriculture.

Activity C4.1: Promote the creation of **TechHubs**.
→ *Growth and maturation of Africa's D4Ag incubation and investment ecosystems.*

Goal C5: Improve data quality and access.

Activity C5.1: Conduct a study **on free data and data sources** for digital agriculture. Establish a **data hub** for agriculture.

Integrate a guide **to free data sources**. Possible integration with Knowledge Hub.

→ *Data used as accelerator for digital agriculture.*

Strategic Objective D

Build an agricultural workforce with digital literacy, skills, and expertise.

Technology uptake in the agriculture sector varies with the smallholders that form the backbone of the system, being the least likely to use digital technology. While there are many contributing factors for this, lack of digital skills is a major one. MS need to invest in programs to build the digital skills and literacy across the D4Ag ecosystem, from smallholder farmers to agro-dealers, from government ministers to AUC directors. While the investment required will be huge, all sectors will benefit from this, from agriculture to trade, from education to health.

Goal D1: Build capacities for Ag data collection, validation, and analysis.

Activity D1.1: Implement data initiatives for data collection and analytics, build national data centres and make accurate, up-to-date data on agriculture accessible. Collaboration will be ensured with the 50x2030 Initiative[12].

→ *All MS have agricultural data centres in place.*

Goal D.2: Promote hi-end smart technologies such as Artificial Intelligence, blockchain technology, IoT, Machine Learning and Big Data.

Activity D2.1: Scientific collaboration on innovative digital agriculture technologies:

- Build tech hubs around smart agri-tech.
- Promote international collaboration between universities.
- Promote collaboration with international organisations with D4Ag programs
- Short collaborative courses and seminars (including MOOCs) on hi-end technologies.
- International exchange programs to support African universities.

→ *More smart technologies integrated into African digital agriculture solutions.*

Goal D.3: Promote collaboration between agriculture and infrastructure departments.

Activity D3.1: Establish a digital agriculture task force that has representatives both from the REC's agriculture and ICT/Infrastructure departments with regular (bi-annual) e-meetings.

→ *Improved inter-sectoral collaboration.*

Goal D.4: Promote digital advisory and extension services.

Activity D4.1: Continental analysis study on e-advisory/e-extension.

→ *Improved understanding of potential, challenges and risks of the digitalization of extension and advisory systems.*

Activity D4.2: Provide centralized servers and software for the establishment of e-advisory platforms for use by MS, NGOs, and others.

→ *National extension services are using the platform for free. More farmers reached by e-advisories. Improved farming practices, higher yields, higher incomes, improved resilience.*

Strategic Objective E

Awareness, knowledge, and networking on digital agriculture.

Raising awareness for Digital Agriculture at all levels of the D4Ag ecosystem helps accelerate the digital transformation of African agriculture. This starts at school, continues at university, can be promoted through radio and television, can be the theme of Hackathons and international conferences. To mitigate the problem of fragmentation of the D4Ag sector, strong networking between MS and between RECs is necessary. Similarity of problems in agriculture and potential solutions in

[12] The 50x2030 Initiative is a multi-agency partnership for data-smart agriculture that seeks to transform data systems in 50 countries by 2030. https://www.50x2030.org/

digitalisation can be observed and shared across the continent

Goal E1: Raising Awareness for Digital Agriculture.

Activity E1.1: Creation of a **continental knowledge hub on D4Ag**, all documents auto translated into the official AU languages so that all countries and RECs can base decisions on the same knowledge base.

→ *A digital agriculture knowledge platform is available on continental level.*

Activity E1.2: Annual **continental conferences** on digital agriculture.

→ *Increased awareness for potential, benefits, risks and lessons learned regarding digital agriculture.*

Goal E2: Knowledge Exchange.

Activity E2.1: Establishment of a continental digital agriculture forum with sub-groups for use-case related topics (e-advisory, market access, precision agriculture, machinery pooling etc.) and cross sectorial topics (e.g. climate-smart agriculture (see chapter A4.4)., gender inclusion, youth employment). AI and ML enable automatic translation between the official AU languages, enabling exchange across all borders.

→ *Improved exchange on continental level on digital agriculture.*

Activity E2.2: Registration of all national and regional **strategies** and **policies** for agriculture, digital agriculture and ICT on the digital agriculture knowledge hub.

→ *Improved monitoring of D4Ag activities.*

Goal E3: Align and collate the various stakeholder programs, projects, and initiatives.

Activity E3.1: Establish a multi-partite round table for digital agriculture with regular virtual meetings.

→ *Improved monitoring of D4Ag activities.*

Activity E3.2: Build a repository of all national and regional digital agriculture initiatives, programmes, projects on the digital agriculture knowledge hub).

→ *Synergies in promoting and developing digital Agriculture.*

→ *Learning from success stories as well as from failures.*

Strategic Objective F

Promote D4Ag reach and use.

The DAS recommends promoting public-private-partnerships, to create innovation and tech hubs, accelerators, and worker spaces. It proposes promoting international cooperation and collaboration between research centres and universities together with national ministries, to teach digital skills at school (see Digital Education Strategy) and to stimulate university students' interest in the world of digital agriculture.

Good enabling environments foster the digital transformation processes and the private sector is the main implementer of digital agriculture. Access to knowledge, access to finance, a network of Tech Hubs, accelerators and incubators are key to success.

Goal F1: Promote regional digital agriculture platforms on climate change.

Activity F1.1: Create regional working groups on climate-smart digital agriculture with bi-annual meetings. Continental annual exchange on climate smart agriculture (see chapter A4.4)..

→ *Awareness for climate-smart agriculture, improved technology exchange.*

Activity F1.2: Develop regional data portals on climate change.

→ *Improved coordination in risk mitigation and higher resilience of farming systems.*

Goal F2: Promote regional digital agriculture platforms on pest and disease early warning and management.

Activity F2.1: Create regional working groups on pest and disease early warning.

→ *Awareness for transboundary IPDM, improved technology exchange.*

Activity F2.2: Develop regional data platforms for IPDM.

→ *Improved coordination in IPDM and higher resilience of farming systems.*

Goal F3: Promote youth digital agriculture entrepreneurship and women's participation.

Activity F3.1: Create youth specific content and integrate with the knowledge hub. Add a youth digital agriculture specific section in the knowledge hub.

→ *Higher attractiveness of agriculture for young people.*

Activity F3.2: Promote digital agriculture at school and at university (-> DTS EDU). Organise Hackathons, bootcamps.

→ *Foster start-up creation. Accelerate digital transformation of agriculture.*

Goal F4: Promote AgTech Entrepreneurship and Innovation.

Activity F4.1: Public and Private Partnership for Digital Agriculture Technology.

→ *Strengthen private sector driven digital transformation of African agriculture.*

Strategic Objective G

Mobilise resources and financing for the sustainable implementation of digital agriculture programs.

Smallholders are the predominant force in agriculture in the continent, but most still face financing challenges and are in rural and remote areas that tend to be marginalised when it comes to digital infrastructure and services. MS will therefore need to mobilise resources to be able to sustainably implement their DAS. MS need to identify sources, mobilise, and pool resources, innovate new investment models and prioritise investments to fund the different components necessary for successful implementation of DAS that range from improving infrastructure, building digital skills, developing the right applications and services and building the right institutions. MS will also need to coordinate the financing and implementation of the DAS with other critical sectors like health and education.

Goal G1: Resource mobilisation.

Activity G1.1: Collaborate with MS, development partners, multilateral entities to mobilise resources to invest in digital agriculture.

→ *Secure funding for implementation of the DAS.*

Activity G1.2: Encourage participation by development partners and the private sector in co-ordinated funding for digital agriculture.

→ *Secure funding for implementation of the DAS.*

Goal G2: Financing and investment.

Activity G2.1: Integrate digital agriculture into existing and future AU programs.

→ *Inclusion of digital agriculture in all new AU/REC programs related to agriculture.*

Activity G2.2: Explore models to increase private sector financing for digital agriculture through public and private partnerships.

→ *Secure funding for implementation of the DAS.*

Activity G2.3: Promote the SDG Investment Framework at all levels (continental, regional and national) through various channels.

→ *Exploit transformation synergies between sectors.*

Activity G2.4: Invest in organisations that will help grow digital agriculture at all levels (national, regional, and continental).

→ *Synergize digital agriculture transformation.*

4.5. Interaction Framework for the DAS

It is no secret that the main engine of digitalisation is the private sector, and this is also valid for the agricultural sector. Understanding the D4Ag Ecosystem (chapter 1.2) is essential for the specification and prioritization of the DAS strategic pillars, objectives, activities, and tasks. The AU RECS and AU member states generally have very limited options for D4Ag activities that directly target producers and production. Most possible actions are aimed at improving the framework parameters for both producers and the private sector. The DAS must consider two very different channels to foster digital transformation of African agriculture:

- **Direct activities** for knowledge, capacity building, and networking at AUC, RECs, and member-state level, including the support for the development of national strategies and regulations.
- **Indirect activities**, aimed at developing and improving framework conditions conducive to the D4Ag transformation. These include the development of appropriate policies and regulations, improvements of the doing-business environments, development of regional and national strategies for performant IT infrastructure and services, and for digital skills at all levels. These enablers target either the private sector (agribusinesses and ICT) or the producers themselves.

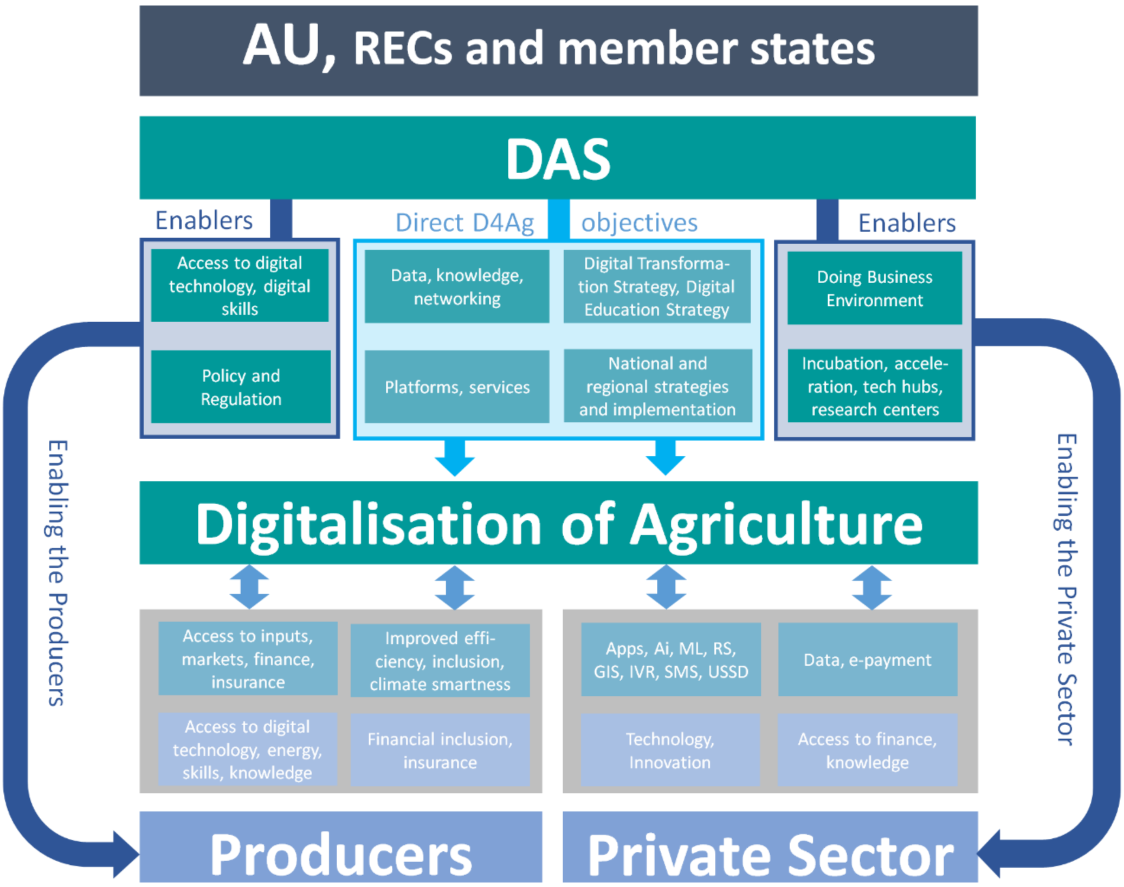


Figure 7: The DAS Interaction Framework.

5. Digital Agriculture Implementation Plan 2024-2030

5.1. Roles and Responsibilities

5.1.1. Stakeholder Pyramid

The implementation of the DAS requires the involvement of various stakeholders who either contribute in various ways from crafting sector policies and regulations, funding, development, implementation, or the practice of digital agriculture. At the helm is the AUC, whose mandate is to serve as a central coordination point for knowledge sharing, implementation activities, and technical assistance through her departments, together with its implementation body, the African Union Development Agency AUDA-NEPAD. At the bottom of the stakeholder pyramid are the producers involved in smallholder activities such as cultivating crops, rearing livestock, and fish.

Other stakeholders with a role within the value chain include civil society, the private sector and entrepreneurs in D4Ag. The private sector adds dynamism of the sector through constant development of various D4Ag programs and innovations that power the digital transformation of the sector. One downside to the independence and room for innovation, is the resulting fragmentation and duplication. The DAS in its mission creates an opportunity for consolidation by creating a focal centre for knowledge exchange and collation of these D4Ag programs, innovations, and initiatives, while allowing for the freedom and innovation that make the digital agriculture sector successful. The AUC at the top of the pyramid will take on this coordinative role.

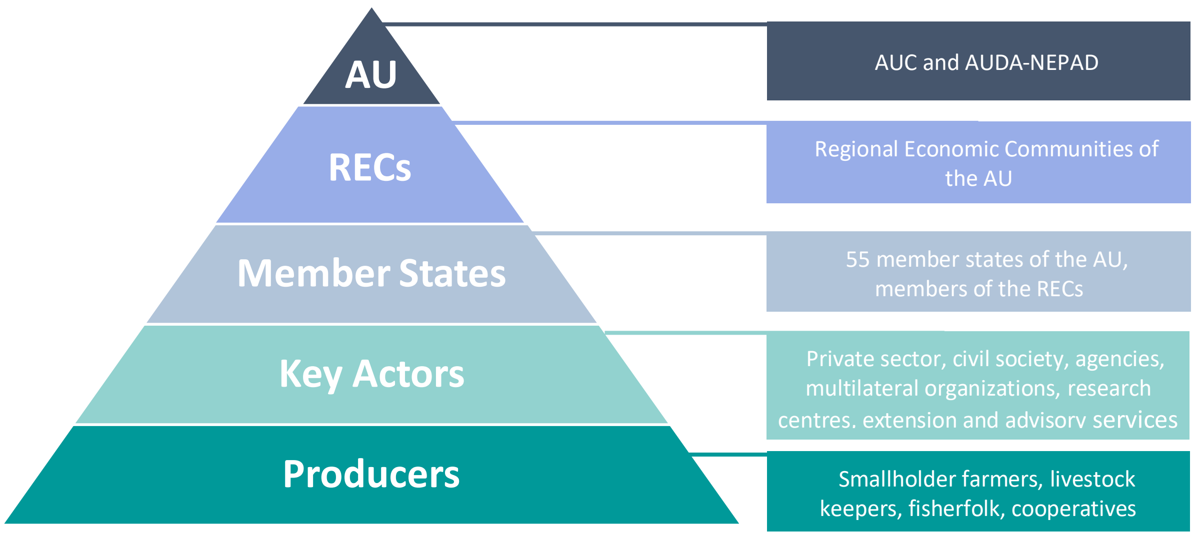


Figure 8: Hierarchical D4Ag stakeholder pyramid for the continental strategy.

5.1.2. AU Roles

The AU consists of 55 member states and is mandated to coordinate and intensify cooperation and efforts to achieve a better life for the people of Africa. This includes securing livelihoods through food security and creation of sufficient jobs. Thus, food must be available in sufficient quantity and quality, jobs must be created, both to reduce poverty in line with the SDGs.

The Digital Agriculture Strategy is led by the AU with the following tasks:

- Coordinate and steer the process including building awareness and capacity at REC level.
- Promote collaboration between the Agricultural and Infrastructure/ICT/Innovation sectors.
- Introduce, encourage and monitor the use of standards.
- Build and host accessible knowledge and learning platforms and encourage co-learning between the different regions to create synergies.
- Promote gender inclusion and youth employment.
- Monitor the implementation process, maintain the integrity of the DAS, and ensure that the RECs and MS benefit from the strategy.
- Create a suitable investment ecosystem and engage with potential donors and funders

The African Union Development Agency AUDA-NEPAD can assist for implementation.

more

5.1.3. REC Roles

RECs of the AU support coordination of member states in their geographic regions and “facilitate regional economic integration between members of the individual regions and through the wider African Economic Community (AEC), which was established under the Abuja Treaty (1991)”.for the implementation of the DAS, the regional environmental centres must adopt specific tasks::

- Coordinate and assist the DAS development process at country level.
- Provide capacity building for member states. This may encompass digitalization if climate resilience, pest and disease management, extension systems, integration of new technologies, management of ICT systems, etc.
- Promote collaboration of agricultural and Infrastructure/ICT/Innovation sectors.
- Promote and monitor the use of standards in MS to streamline the agriculture sector to minimise data fragmentation and the duplication of efforts.
- Establish regional digital initiatives, particularly addressing cross-border challenges (e.g., forecasting, IPDM, early warning systems, data access).
- Promote gender inclusion, climate-smart agriculture, and youth employment.

more

5.1.4. Member State Roles

AU member states are sovereign bodies with internal governing structures. The AU in its mandate works in close collaboration with these MS to ensure that they are developing towards a prosperous Africa. Both the AU and RECs contribute to the socio-economic development of states and seek to ensure that member states' policies are harmonised (see chapters 0 and 5.1.3).

MS have developed national agricultural development plans, led by their ministries of agriculture, livestock, and fisheries. MS must ensure that digital agriculture strategies are compatible with existing development plans and build on existing digital initiatives.

The DAS mandates the MS to:

- Integrate and align existing D4Ag programs/initiatives in national agricultural development plans to minimise fragmentation of efforts.
- Establish and maintain standards.
- Build national data pools that provide accurate, complete, and timely agricultural data to support good decision-making across different levels of the different value chains.
- Provide the requisite infrastructure necessary to support digital agriculture with specific focus on rural areas (e.g., improved coverage of mobile networks to bridge last mile to the farmer).
- Provide an enabling environment to support digital agriculture in terms of: policy and regulatory environment, digital literacy and skills of agricultural workforce.
- Incentivise and support youth entrepreneurship and interest in agriculture.
- Identify, select and implement appropriate use cases that apply digital technologies to solve challenges across the agriculture sector in collaboration with appropriate stakeholders:
  - Digital advisory/e-Advisory services that compliment and improve national extension services.
  - Market access/linkages/ aggregation to provide periodic and current price information, access to markets and facilitate linkages between farmers and other service providers.
  - Financial inclusion and index-based insurance products to improve farmer access to finance and minimise farmer losses and uncertainties caused by climate change.
  - Weather forecasting and alert systems including those with cross-border utlity e.g., pest and disease management systems.
  - Traceability systems with clearly defined roles, data ownership and buy in from different stakeholders across agricultural value chains.
  - Smart and precision farming technologies that leverage ICT to improve efficiency and minimise consumption of valuable resources and other purposes e.g., water consumption for irrigation, fertilisers, etc.
  - Improve capacity to collect and share agricultural data (e.g., farmer registries/ databases/rosters), and develop national capacities to use agricultural data to support decision-making and other processes across the sector.

more

5.1.5. Other Stakeholders

Implementation of the DAS goes beyond the AU, RECs, and MS to include various other stakeholders that play a critical role in different aspects of agriculture that will need to be coordinated in order to ensure successful implementation. These stakeholders include:

- **Multilateral organisations**, development agencies, NGOs and research centres provide critical funding, advocacy, research and implement initiatives that shape developments across the agriculture sector. MS need to align their activities with these stakeholders to leverage their funding, research, technical expertise, partnerships and collaborations to implement their national DASs. more
- The **private sector** is a core driver for the digitalisation of agriculture, when it comes to investments, technology, products, and distribution systems. The private sector can improve D4Ag information solutions, improve access to finance and to markets, provide capacity building and support, provide business development and appropriate insurance products. more
- **Small-scale producers** (farmers, livestock keepers or fisherfolk) are the backbone of African food production. They tend to live in rural areas and to be marginalised in terms of access to infrastructure and services. They are key for implementation of the DAS and a primary beneficiary of successful digitalisation of the sector. more
- The **youth** make up the bulk of the African population and provide most farm labour. Disillusioned and turning away from agriculture, digital agriculture is seen as one avenue to stem the youth exodus. As fast digital technology adopters, the youth can play an active role in the implementing the DAS through agri-entrepreneurship, tertiary education as well as advocacy and resilience building. more

5.1.6. Investment Plan

The strategic objectives, actions, primary outcomes, target KPIs, schedule, cost and partners for financing the different aspects of the implementation of the DAS are summarised in Appendix A5. The DAS and Implementation Plan proposes the need for **US$11,8 million** to launch and implement continental programmes, **US$1.8 million per REC** for regional programmes and up to **US$2.4 million per country** (on average US$2.1) to facilitate digital agriculture coordination in member states (this excludes costs for the implementation of the national strategies). The AU will work with all partners to mobilise financing, technical assistance, data and knowledge for the various actions and tasks. It will coordinate its member states' efforts towards developing well-articulated digital national strategies. The DAS will promote and harmonize knowledge management and sharing on digital agriculture, which will serve as a basis and catalyst for engagement and development. Furthermore, the AU will coordinate and monitor all activities to achieve the targets of the DAS investment plan. In total, an amount of up to **US$142 million is** required for the implementation period 2024-2030. This excludes any costs for infrastructure development, any private sector investment, and the implementation of the national strategies.

5.1.7. Time Plan

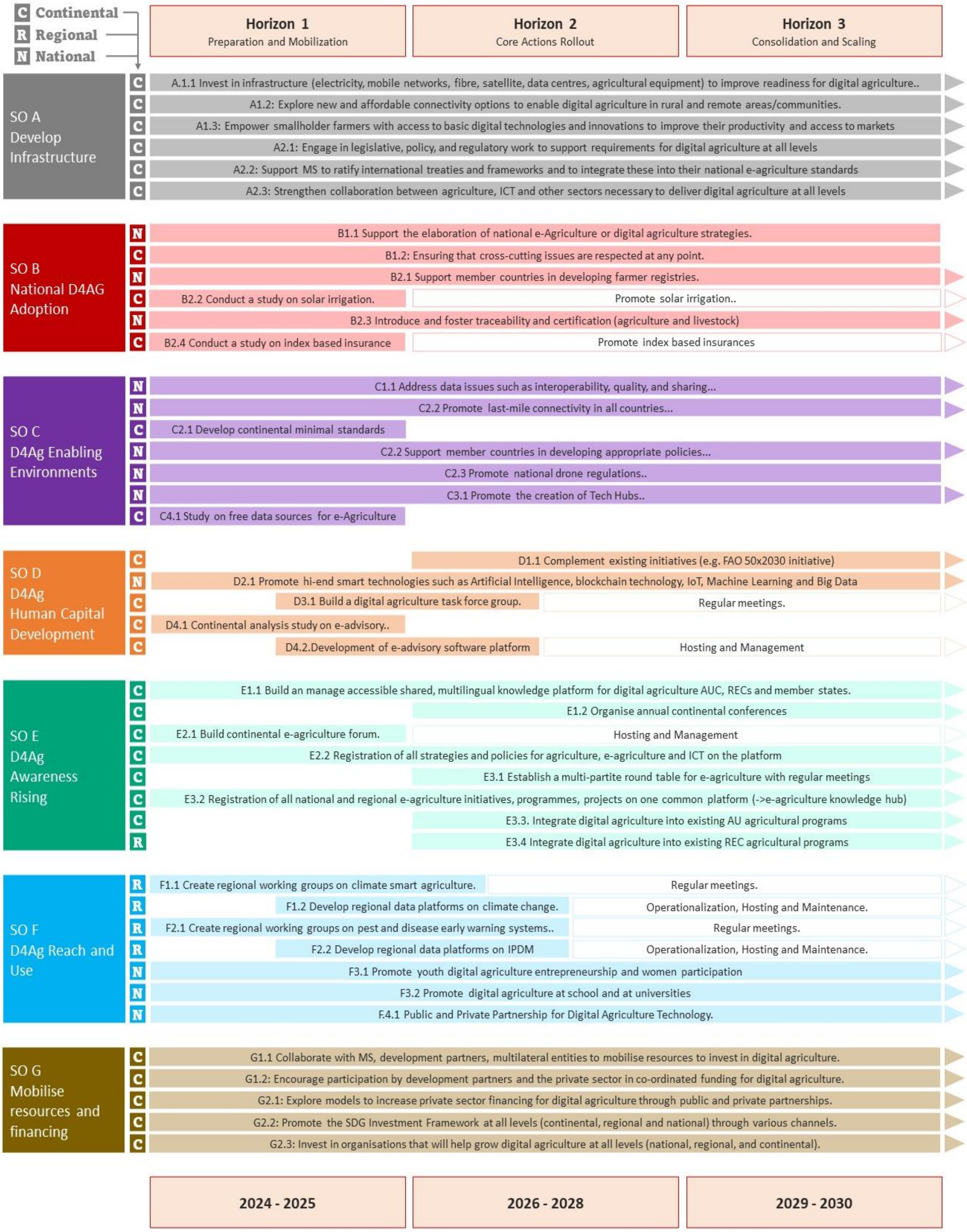


Figure 9: The time plan for the DAS implementation.

6. Conclusion

Agriculture is recognized as a major contributor to the GDP of most Sub-Saharan Africa (SSA) countries. Despite this, the **sector is beset by increased threats to its sustainability** from natural and anthropogenic causes—climate change, pests and diseases, and the early onset of drought and floods—posing a threat to livelihoods.

African agricultural systems are very diverse and member countries have different strategies for the development of their agricultural sectors given their context and objectives. The AU Digital Agriculture Strategy (DAS) and Implementation Plan provides guiding principles to facilitate digital agriculture transformation across member countries in a flexible manner that recognizes the need to develop and implement unique national digital agriculture strategies that respond to national plans and context. The main driver for the digitalisation of agriculture is the need to establish a resilient and robust agri-food system.

The DAS proposes several activities organized into six pillars that need to be carried out at different levels (continental, regional or national) over three horizons spanning the next seven years. At AUC level, the DAS recommends leveraging multi-lingual digital agriculture knowledge platforms and digital agriculture forums. At REC level, capacity building is essential to enable RECs to support their member countries in developing national digital strategies/e-agriculture strategies. At the AU member state level, the DAS provides recommendations for the elaboration of national digital agriculture/e-agriculture strategies. The implementation of the DAS requires collaboration and partnership across a wide range of stakeholders, who either directly contribute to policies and laws that govern local and international enablers, or they are directly involved via funding, development, implementation, or the practice of digital agriculture.

The AU will work with all stakeholders and partners to mobilise financing, technical assistance, data and knowledge for the different actions and tasks. The DAS projects the requirement for US$10.7 million to enable the AU, and its partners to launch and implement continental programmes, US$1.2 million per REC for regional initiatives, and up to US$2.65 million per member country in digital agriculture coordination. This results in a total of US$165 million over the next seven years, excluding any costs for infrastructure development and private sector investment.

Successful digital transformation of agriculture in the continent has the potential to improve the efficiency and effectiveness of African agricultural systems, making them more resilient and climate-smart (see chapter A4.4)., attracting youth to agriculture, creating jobs in modern agriculture, and the ability to make agriculture more inclusive.

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Annex

Background Material

A1 Understanding Potentials and Challenges

A1.1 The Digital Agriculture Landscape

The digitalization of agriculture is taking place in all its subsectors. To put this in context: Livestock production has digitalisation needs that differ from agriculture or fishery. Irrigated agriculture requires specific automation and modelling solutions, contract farming has specific communication-, training- and traceability needs. Beekeepers need different digital tools compared to poultry farmers; a sugar mill requires different digital instruments from a cotton ginnery. Crop health monitoring can be done from space or on the ground, while information can be disseminated via radio, video streaming, SMS, voice mail or through apps.

The diversity of possible solutions is vast, and the number of existing solutions is constantly rising. All these solutions are contributing to the essential transformation of agriculture that is taking place around the world, faster in some countries compared to others. In addition, the goals of these transformation processes are also manifold: increasing efficiency, improving quality, raising crop yields, protecting the environment, safeguarding against natural hazards, resilience for climate change to name a few.

Digital agriculture needs very specific solutions depending on national visions for agricultural development, business development strategies of private companies, value chains, climate conditions, soils, labour, topography, exposure to droughts, floods and climate change.

Many documents have been published presenting successful D4Ag solutions. They cluster solutions around use cases, present them by value chain, by target group or by technology. While it is interesting to understand what digital solutions exist on the market, of particular interest to continental, regional, and national strategy development are those in which states, and RECs can invest directly. For most D4Ag use cases, the state can only create the framework conditions, enabling the private sector, agribusinesses as well as ICT service providers, to leverage these enablers and develop the market accordingly.

The development of a D4Ag strategy must consider the national or regional goals of any existing agriculture sector strategy and the current situation. An extensive gap analysis in combination with a deep understanding of the potential for the introduction of digital tools will facilitate the selection and prioritisation of the right measures, which should work collectively towards achieving the D4Ag goals. In this context, the D4Ag use cases are presented in this section.

There is no standard or common method for clustering use cases for digital agriculture in existence. Different organisations came up with different approaches, the boundaries between use cases are often ambiguous and most digital solutions can encompass multiple use cases. The classification here is less important, the goal is to ensure that all use cases are presented. A brief introduction is given for each use case, taking care not to promote individual products and reference to literature is made where appropriate.

Farm management software supports farmers in managing their farms. In principle, the software replaces the traditional farm book that farmers use to keep records of purchases, yields and sales, and all relevant information about their farming practices. Sometimes referred to as Agri-data management systems, farm management software can be tailored to the specific farm, value chain(s), plots, region, climate, language etc. The market for farm management software is huge and all big international players in agro-chemistry and agro-biology do provide this type of software. Likewise, global Big Tech companies are entering this market as potential looks promising. Farm management software typically offers planning support for crop or breeding cycles, yield projection, financial tools for farm budgeting and planning. Supply chain management may also be an integral part and monitoring tools for economic projections. Farm management software often targets larger farms, smallholder farmers usually have difficulty to access this type of software due to a lack of access to technology, financial resources and low digital literacy and skills. A few existing smaller solutions target livestock farmers in Africa, and they are successful because livestock is a high-value product, losses are difficult to compensate for and thus farmers are willing to pay. Thus, advice through farm management or e-advisory software can justify the financial effort. In contrast to e-advisory software, farm management software tends to be self-service software which can be bought, downloaded, and installed. Operating such software requires specific digital skills from the farmer, thus successful use is not guaranteed. The **CTA-Dalberg Digitalisation of African Agriculture Report** states, that while there are many sophisticated farm management software solutions for large-acreage farms in the developed world, the segment of D4Ag services for smallholders is understandably nascent (Dalberg 2019 p50). Farm management systems are typically operated on computers, tablets, and smartphones, which may have Internet access. Smartphones are particularly suitable as their in-built GPS functionality and mobility facilitate the collection of valuable spatial information.

Cooperative management and contract farming software by its nature involves many farmers. Some schemes have thousands of contracted smallholder farmers, making it impossible to communicate with each individually. But each farmer has a specific profile in terms of name, address, location, parcel etc. with a need to treat them individually. They might receive different amounts and types of inputs according to the crop they grow and the size of their parcels. The larger schemes contract 500,000 farmers or more. This type of software typically offers mobile farmer registration, mobile delivery registration, bulk SMS, IVR or USSD communication, coupled with digital scales, GPS, barcode-based traceability, and e-payment functionality. Tracking of training activities is another important feature as is tracking of input deliveries, financial loans, and the management of the collection of the farmers' produce. The introduction and use of such software can allow cooperatives and contract farming schemes to improve traceability, assuring quality standards for certification and access to new national and international markets.

The software typically operates offline, with occasional online-synchronisation across devices. Smartphones with their mobility, GPS functionality and ease-of-use are the most suitable device for extension personnel, lead farmers and agents, who may have basic phones.

Unfortunately, there is a great variation in how cooperatives and contract farming schemes are managed. They differ in size, value chains, type of contracting, area coverage, and services offered. Some lead farms collect the produce at the farm gate, while others receive deliveries at the factory inlet. This makes it difficult to develop a one-size-fits-all solution and often, new solutions must be developed, and existing solutions modified. The lead farms naturally do not have the necessary ICT skills and competent ICT service providers can often be found only in the larger urban cities – while smallholder farming takes place in the most remote rural areas. Thus, successful cooperative and contract farming software needs to be highly customizable, but simple and robust for the user. It must support the local language but may not rely solely on the latest end device technology.

Supply chain management solutions are business-to-business services that help agribusinesses, cooperatives, nucleus farms, input agro-dealers and other smallholder farmer value chain intermediaries to manage their smallholder relationships in ways that lower costs through greater efficiency, improve value chain quality through better traceability and accountability and ultimately increase smallholder farmer yields and incomes by making it easier for more commercial players to formally engage with large numbers of smallholder farmers (CTA-Dalberg 2019).

Supply chain management can include all sorts of logistics such as input delivery, product collection, transport, storage, cooling services, quality assurance, traceability, and financial loan management. On the off-taker side of the value chain they range from smallholder cooperatives over large contract farming schemes to globally operating buyers and processors. On the agri-input side there are local agro-dealers, mid-sized and large national and regional input providers and the globally operating big players.

Supply chain management solutions often introduce traceability (see next chapter) and quality control for certification and thus connect smallholder farmers to new markets. Even though the smallholders do not directly interfere with such software, they benefit from it through a higher efficiency of the value chain, improved product quality and access to distant markets.

Even though the systems are led by private sector initiatives, large supply-chain management solutions can have hundreds of thousands of farmers connected to the system.

Given the high number of stakeholders with different needs and varying access to technology, such systems can comprise various technologies. Cloud technology, web services, mobile apps, GPS, GIS, and business intelligence are all important components. The systems typically are value chain specific and most successful solutions exist for tea, cocoa, coffee, high-value horticultural crops and cotton.

Traceability Solutions help tracking products '**from-farm-to-fork**', making the different steps of the value chain visible and thus compliant with global standards. Requirements for traceability are constantly increasing as customers demand for transparency and quality improvements worldwide. Standards and certification requirements increasingly insist on traceability. Traceability helps companies in identifying and mitigating quality issues, and helps them to better understand their value chain, and can enable crop productivity monitoring. Most enhanced systems are coupled with GIS data to track the end product back to the origination plot.

Animal traceability is important for exporting livestock to foreign (overseas) markets and for the identification of heat zones during disease outbreaks. Typically working with ear tags, each individual animal receives a unique identifier and digital records must be kept per animal.

Wood traceability systems help in protecting biodiversity and are needed for international certification standards.

Traceability can also play a role in the input market and can guarantee smallholder farmers a certain quality of the purchased products.

Traceability needs very specific solutions depending on the value chain, and the way product collection, quality control, cleaning, packaging, and transportation are organised. Off-the-shelf software is rarely available or needs extensive modification or customization. The number of specialised traceability solutions providers in Africa is still low but improving. There are still very few examples using blockchain technology to improve traceability.

Ideally, traceability systems work with machine-readable identifier tags such as scannable QR or bar codes on tickets, stickers, packages, or ear tags. Modern systems use RFID chips and readers to automate data capture, improving data quality and accelerating all business processes enormously.

Traceability is mostly driven by the private sector, with a few government-led initiatives targeting livestock and wood traceability.

e-advisory and information services are one of the first applications of ICT in agriculture. ICTs are particularly suitable for delivering information to many farmers in an efficient and inexpensive way. The goal is to help farmers improve their practices, enhance efficiency and quality, and finally make their businesses more sustainable and more resilient against shocks. Message contents can consist of information on best farming practices, weather and market information, pest alerts, management skills and other information relevant for their business (CTA-Dalberg 2019, p.42). The information can be general but can also be precisely tailored to the farm/ farm's location, value chain and/or practices. The respective information channels can be adapted to the circumstances and the required technology must be accessible to the end recipient. Solutions that allow the recipient to select the technology are particularly successful. This encourages farmer interest in using better technology and thus fosters participation in digital development. Voicemail technology delivers pre-recorded messages to any number of mobile phone users. IVR technology allows users to request for selected information by pre-recorded voice messages via simple mobile phones without the need for literacy. USSD technology works similarly, but information is sent via text messages, providing potential for auto-generated messages. Farmer profiling allows the delivery of localised and customised messages to farmers depending on the location of their plots, the level of mechanisation, and what crops they plant. African farmers often still have difficulties in accessing technology, thus lead farmers, village-based agents, farmer friends etc. act as multipliers to bridge the last mile to the farmer. Sophisticated systems process requests sent by farmers and AI-based algorithms send back proper advice. This usually requires a large knowledge-base and a high number of users to be viable. At the highend, this maybe complimented by AI-based chatbots. Frequently, electronic advice is just an additional service offered by traditional call centres, as farmers usually prefer to speak to humans. These call centres, however, can use electronic databases and sophisticated search functions to deliver the required high level of services. There exists a few successful large-scale government-run e-advisory systems in Africa (Ethiopia, Kenya, Rwanda, and Zambia). At the other end of the spectrum, social-media based groups work with peer-to-peer advice using free software (Facebook, WhatsApp, etc.) on a voluntary basis.

Virtual aggregation allows larger volumes to be offered to the market with greater bargaining power, ultimately allowing higher prices to be achieved. This finally results in access to guaranteed markets for crops, a key for successful smallholder farming. Intermediaries can then promote the integration of the products in the national and international market.

Aggregators must have huge storage facilities and bear risks such as variation in product quality, demand and selling price as well as perishing of goods. Ideally, the aggregator identified a buyer and sold the produce before he has it in stock. This helps reduce storage costs but makes it difficult to guarantee consistent quality.

Virtual aggregation is done by village-based agents, company staff or independent entrepreneurs who register farmers and their crop on a platform for sale. They are responsible for quality checks and accurate estimation of best harvest dates. On the platform, off-takers can buy aggregated produce from many farmers (and many agents). Ideally, the agents dispose of the necessary transport facilities to collect the produce at the farms so that farmers and off-takers do not meet in person.

The setup of a community-based agent network is a prerequisite, and the agents need smartphones and Internet access for communication with the aggregation platform. An integrated extension/advisory service has proven to be helpful by helping to ensure quality, quantity, and punctuality of deliveries. Extension officers then play the role of the system's local aggregation agents. Where cooperative-based aggregation already exists, this digital solution can help make it more efficient without the need to invest in storage and cooling facilities.

One of the major problems is that the aggregation system cannot guarantee to find a buyer and thus the farmers also must look for alternatives. It frequently happens that the produce was already sold to a third party, or the product no longer meets the quality criteria when a buyer is found on the platform.

Market access platforms provide farmers with access to input- and output markets through e-commerce platforms. These platforms help farmers solve the problem of dependence on intermediaries. In urban and industrialised environments these platforms are typically web-based, with users accessing them via browsers on computers and tablets. Solutions for smallholder farmers, however, need low-technology entry points and robust solutions to reach a higher number of users. If e-payments are included, those platforms can perform better, and valuable price information can be derived.

The line between market access and market linkages is not always clear. The **CTA-Dalberg Digitalisation of African Agriculture Report** considers market access as a subset of market linkages and distinguishes between agri-input e-commerce, input e-marketplaces and off-take e-marketplaces (CTA-Dalberg 2019, p.51). **FAO** introduces market access as one of three main areas of digital agriculture next to ICTs for production systems and ICTs for financial inclusion (FAO 2015 p.17) and thus market linkages here are part of market access. **GSMA** summarises this aspect under the name of **agri e-commerce**. There are also combinations of these subgroups and besides goods, also services can be offered or farming equipment can be booked. Geographical distance between seller and potential buyer can be an obstacle, as transport logistics frequently are absent or underdeveloped. By integrating transport, storage, packaging and cooling services, the market access platform transforms to a market linkage platform. A critical mass of sellers and buyers is important and trust-building processes must be incorporated.

Rarely are **Market Access Platforms** developed and operated by government structures, but partnerships with government agencies and NGOs are observed. Potentials can be seen especially for the input marketplace where quality of inputs are relevant for building trust into such systems.

Market Linkage Services link producers with customers in both directions. But linking farmers to off-take markets and input providers is only one aspect of the business. To make market linkages operational, inclusive and sustainable **transport**, **storage**, **cooling**, **processing**, **packaging**, **payment** and **insurance services** all have to be integrated along the value chain. Without linking these logistic services to the farmers' business, the farmers remain dependant on local demands and resources while on-going urbanisation and international trade transforms market patterns. Intermediaries benefit from this gap; they typically provide the transport services and farmers have no option but to take the prices the intermediaries pay. Market linkage platforms can help introduce the necessary transparency and competition. They can solve the problem of inefficient, fragmented agricultural markets, help reduce price asymmetries and link different services.

Market linkage systems bring together producers, consumers, and service providers. These systems typically require little effort for interaction, they also base them on simple technology. However, accessing the systems usually requires a smartphone, tablet or computer, technology which usually is not accessible for the smallholder. Frequently, cooperatives are aggregating and selling the products or village-based agents and independent entrepreneurs can fill this gap and offer these services to the farmers. Mechanisation services and machinery pooling can be part of market linkage systems, but this document lists these services as a separate use case. Market linkage is also frequently bundled with other use cases such as advisory systems, e-payment and e-voucher systems. Credit plays a significant role, as smallholder farmers generally do not have the financial resources to expand their operations or overcome shortages caused by natural disasters or human activity. Some market-linkage systems thus link farmers only to certified and trusted input providers and off-takers. Farmers can purchase quality inputs with e-vouchers on credit and the grants are subsequently charged when the farmer delivers the harvest to the off-taker.

Price Information Systems are one of the most difficult use cases to operationalize. While they technically do not need high expertise for development and setup, it is very difficult to continuously gather reliable price information due to the presence of informal markets and their nature. According to FAO, these data are often national or regional in scope, and so may not be entirely relevant for the farmer in the field, depending on his/her proximity to markets (FAO 2013, p vii). Moreover, even with accurate and prompt market price information, farmers are often not capable of taking advantage of potential price advantages that exist between markets because they are physically unable to transport their products to markets with higher prices.

However, there are successful examples for specific value chains, especially those, where bulk prices are paid. Prices then are pushed to interested customers in defined regular intervals e.g., via SMS. Sugar cane, corn, soybeans, cassava etc. are products traded on food exchanges, so international and national price fluctuations have an impact on local prices as well. E-commerce systems can automatically collect, analyse and provide price information, but in Africa, these systems frequently only connect buyer and seller, the price then is traditionally negotiated offline. Payment procedures need to be integrated into e-commerce systems to collect statistical price information. Functioning market price information systems run with agents who regularly collect price information on markets – a resource intensive process. They typically are operated by government agencies, regional organisations or NGOs.

Price information can be highly relevant for perishable products such as fish. Informed fishermen and farmers can achieve higher incomes, but this also results in an increased dispersion in revenues between informed and uninformed farmers. The results of a study by Jakob Svensson and David Yanagizawa Drott in 2010 indicates that access to price information reduced market failures due to asymmetric information between farmers and traders and led to increased market activity and incomes for informed farmers (J. Swenson 2010).

Precision farming or **Smart Farming** is a vast area of high technology applications targeting higher efficiency of actual agricultural practices. Numerous literature and databases indicate that there is a huge gap in terms of productivity for most crops between sub-Saharan Africa and other developing regions (Boyera, S. 2018 p.9). Typically, sensor networks continuously collect environmental information, transmission networks deliver this data to databases on servers where algorithms automatically analyse these data and derive decisions and instructions which then get implemented by machines or human beings.

Precision irrigation systems measure soil humidity in various depths and deliver the right amount of water at the right time to the roots of the plants. They can be coupled with precipitation forecasts to irrigate only when needed. In **Precision Spraying**, satellite based or airborne Normalised Differential Vegetation Index (NDVI) sensors, coupled with GPS identify plants under stress. Based on these maps, instructions for fertilisation are computed and sent to the tractor. While working on the plot, the tractor's control unit automatically opens and closes the fertilisation nozzles to deliver the right amount of fertiliser only to those plants in need. Precision farming targets the automation of best practices by automating data collection and analysis, resulting in environmental protection and the sustainable management of resources. ML algorithms play a key role to enhance the quality. **Precision livestock farming technologies** help livestock farmers find animals that require special care. Sensors on collars record sleep patterns, eating habits and movement patterns, send these to evaluation algorithms, and the results are then transmitted to the farmer via proper digital channels.

While advanced technical skills are needed to develop such systems, the final message to the farmer can be as simple as a 50-character SMS or a voicemail. By analysing the seven-days rainfall history, predefined SMS messages can be sent to farmers where the rainfall value is below or above certain threshold levels (Hanna Camp 2018 p.8). Knowing the farmers' plot locations is key to success. Thus, either farmer profiles must be created, or farmers need to use GPS-enabled smartphones to access the services. There are successful examples of satellite-based predictions for best grazing grounds using smartphones or even simple phones as end devices.

Weather and climate information services forecasting and correct meteorological data is very essential for all agricultural stakeholders, especially in times where traditional weather knowledge no longer is reliable. Crop growth is controlled by weather variables and therefore agricultural production is a direct function of weather conditions. Global satellite systems supply weather forecasts for free and meteorological stations on earth adjust and refine these forecasts for specific location and use cases.

Access to open data and particularly weather-related data was identified as a key factor in transforming agriculture and nutrition by the G8 in 2013 (Msengezi 2018, p.2). Today, it is relatively easy to access these weather forecasts with an Internet connection from a smartphone or a computer and many providers offer localised information at the district or town-level. By using the geolocation information recorded by Smartphone GPS, weather information can be highly localised. But translating weather information into agriculturally relevant warnings and recommendations is more complicated because weather has different impacts on agriculture depending on the crop grown and the stage of crop development.

Most weather forecast services are bundled with other services e.g., e- advisory solutions. If farmers are already part of an ICT-based messaging solution, it is technically straightforward to integrate weather forecasts. The impact on the farmer side, however, cannot be underestimated and the delivery of such information can help improve the farmers' trust in the system. The information can be supplied even to users of simple phones as weather information usually comprises only a few elements (temperature, precipitation, humidity, wind etc.) once per day.

Long term weather forecasts and real-time weather warnings are important for farmers to become climate resilient. Early knowledge of droughts and floods helps mitigate risks of loss of life, infrastructure, and crops. This data is also very important for companies offering weather indexed crop and livestock insurance. For this reason, insurance companies are building their own weather station networks to make climate forecasts more accurate. Other private sector companies offer precise weather information for any location worldwide and they provide interfaces so that these services can be integrated into existing digital systems.

Early warning systems play a crucial role in preventing loss of life, infrastructure, and crops. Agriculture traditionally poses many risks: long-term weather extremes such as floods and droughts, and exceptional short-term weather events such as thunderstorms, hail, frost, and heavy rains threaten both crops and livestock. Localised weather forecasts are available, they need to be automatically analysed, appropriate warning messages created and disseminated via automated systems.

Warning systems on pest and disease infestation play an equally important role, but to gather the underlying data in real time by automatic monitoring systems is more difficult. Automatic insect traps are promising but still at infant state. Often, these systems rely on crowd-sourced data: observations and alerts sent by the users. Pastoralists can only be warned if the system knows their position, thus, smartphone-based solutions are preferable.

Early warning systems inform farmers early enough so that they can act before the actual event: They can postpone sowing, bring in the harvest, ensure early irrigation and move the animals to secure locations.

For farmers to be warned in time, they must be technically reachable, in the simplest case by radio, in the advanced case automatically in digital form by SMS, voicemail or in-app messages. Early warning systems are usually value-added services in e-advisory systems. Farmer profiles need to exist to localise and customise the messages according to the farmer's plot location and the crops grown. The warnings then can be supplemented by appropriate advice on mitigation.

Early warning systems are an example of how (often freely available) information obtained using advanced sensor technology via satellites and sensor networks can be analysed, summarised, and customised to send helpful and understandable information packages to those in need, often smallholder farmers without digital skills.

An increasing number of drone operators provide crop health assessments on demand. While these services deliver very precise information, they are very cost-intensive and in Africa often prohibited by national drone regulations.

Agricultural insurance products play an increasingly important role in farming. Farmers are highly vulnerable to external shocks, as they are exposed to environmental hazards like pests, diseases, and weather events, unpredictable price fluctuations at international commodity markets, and the increasing unpredictability of all of these factors in the wake of climate change. While in many countries agricultural insurance is still in its infancy (the CTA- Dalberg report reports that only 3-6% of African farmers are using these services), they are an important component for farmers' climate resilience and can help lower the impacts of extreme weather events. Weather index-based insurance uses a weather index such as rainfall to decide pay-outs to covered farmers, thus allowing the system to better manage weather and climate risk (CTA-Dalberg 2019 p7). They rely on hyperlocal weather monitoring, on the one hand, and detailed inventories of farmer assets, plot sizes, and crop cycles, on the other, to help the system assess risk and calculate premiums. This is an improvement compared to earlier efforts that used photo-based crop loss validation to model insurance pay outs (Ceballos et al., 2019).

It is of utmost interest to insurance companies to mitigate risks before losses occur, which is why these services are often bundled with agricultural extension services.

While most insurance products are provided by private companies, there are examples of government-led initiatives. In Nyanza District, Southern Province of Rwanda, the Ministry of Agriculture and Animal Resources (MINAGRI) launched the National Agriculture Insurance Scheme (NAIS) in 2019. The business model includes a 40% subsidy by the government, justified by the fact that government benefits from the incomes of a healthy agricultural sector. Its livestock insurance product is based on a very innovative technology where animals can be tracked through RFID chips to create animal traceability and to minimise fraud.

The high cost of onboarding individual farmers has led insurance companies to work with multipliers such as cooperatives or contract farming schemes. Extension agents, lead farmers, or community workers help build trust in insurance products, so that the farmers buy in. Instead of working with individual farmers, the insurance companies then interact with the groups.

Mobile payments, e-vouchers/e-wallets, e-finance. Access to finance and financial services is a common problem for African smallholders. **Mobile payment** systems are well developed in Africa, they allow all sorts of stakeholders along the value chain to make cashless payments without the need for bank accounts. These systems are fast, have low transaction costs and eliminate risks of cash being stolen. According to GSMA, there were 548 million accounts registered in Sub-Sahara Africa in 2020 with a transaction volume of 490 billion USD. More than 50% of Africa's adult population (15+) has a mobile money account, the highest proportion worldwide. While there is only a slight variation in use of mobile money between urban and rural areas (World Bank Global Findex database 2017), it can be difficult to withdraw cash from a mobile account in rural areas as the density of the network of agents can be low. There is still a problem of network coverage in the rural areas where the smallholders live, and high fees when transferring money between operators' networks or bank accounts, leading to low uptake by farmers. Mobile money services are usually provided by the MNOs, and they offer programming interfaces to integrate these services into digital systems.

E-voucher and **e-Wallet systems** tie subsidy transfers for farmers to purchase quality-approved agricultural inputs. In addition to farmers, these systems can include agrodealers, buyers, banks, and insurance companies. According to CTA-Dalberg (2019), e-wallets can be the first step to higher-value financial products like input credit, agricultural insurance, or commitment savings.

E-finance is a wide field including digital savings, credits, and crowd farming. Digital payment solutions allow the monitoring of financial flows and business activities which can help financial institutions to analyse farmers' creditworthiness. **Crowd farming** involves raising funds from several individuals to invest in smallholder farmer projects or other small-scale agricultural enterprises. These solutions typically are bundled with extension services which not only provide farming advice but also identify the most promising farmers' projects. This is particularly interesting for smallholder farmers who would otherwise not have access to sufficient financing of their projects.

e-learning complements traditional extension methods based on trainers, on-site training, and trial plots. Modern technology can be a useful complement and help to reach a wider audience. Videos are trustworthy, avoid any possible hierarchy, can be viewed, downloaded, and shared at any time. Videos watched together on large screens in the evening can be a social event and can stimulate professional discussion. Agricultural training videos can be found on common video channels for free. However, their quality, both in terms of content and design, is not guaranteed. Neither is their independence from trade and industry organisations.

Video portals, dedicated to providing high quality training to agriculturalists in developing countries are an important complement to traditional training and advice activities. The videos can be of interest for research and development (R&D) staff, service providers, extension agents, communication professionals and representatives of farmer organisations.

Such portals offer online video streaming, but some additionally offer videos for download: Owners of a smartphone or tablet can then download interesting videos and show them to others with no additional data cost. In this way they act as multipliers and the training material reaches farmers who would otherwise not have access to it. Video portals can be community-driven, in this case quality control must be provided. Some governmental extension services provide the farmers with Video channels, a not inexpensive but very effective method to reach large audiences.

E-learning software allows the compilation of digital learning contents. This content can comprise text, diagrams, photos, audios, and videos. These courses target larger farms, extension services and agents as a certain degree of digital literacy is required and access to technology such as computers or tablets. There are, however, examples where even illiterates are targeted through e-books or other specialised devices.

Machinery pooling, mechanisation services. In Africa, most farmers still process their fields manually. This is labour-intensive and not very productive; the low level of mechanisation of small farms is one of the main factors limiting the growth of productivity in African agriculture. Mechanisation would allow higher yields on larger areas with less labour. With a tractor, a field that might take 40 days to prepare for planting by hand can be prepped in eight hours and even in countries with low labour costs, it can be cheaper to rent a tractor than to hire farm workers.

Machinery pooling services help connect farmers with machine owners/operators, allowing temporary access to tractors and other machinery for farmers when needed. In addition, ICT can help in monitoring equipment, building confidence, and making machinery rental more transparent for both parties. ICT can streamline reservation and payment processes.

In all cases, small landowners get access to affordable farm machine services and can increase their productivity and tractor owners are more likely to be able to finance their equipment. The sharing business makes acquisition of machinery more attractive, helping to intrinsically modernise African agriculture.

Mechanisation services link farmers with mechanisation service providers. These systems typically allow farmers to use most simple technology such as simple phones to book services via a USSD- or IVR-driven menu. The model is also applicable to other mechanisation services that require capital intensive yet mobile agricultural machinery such as high-cost field diagnostic equipment and land-levelling equipment. Likewise, farmers can be linked to irrigation, storage, and cooling technology.

A1.2 The Technology Landscape

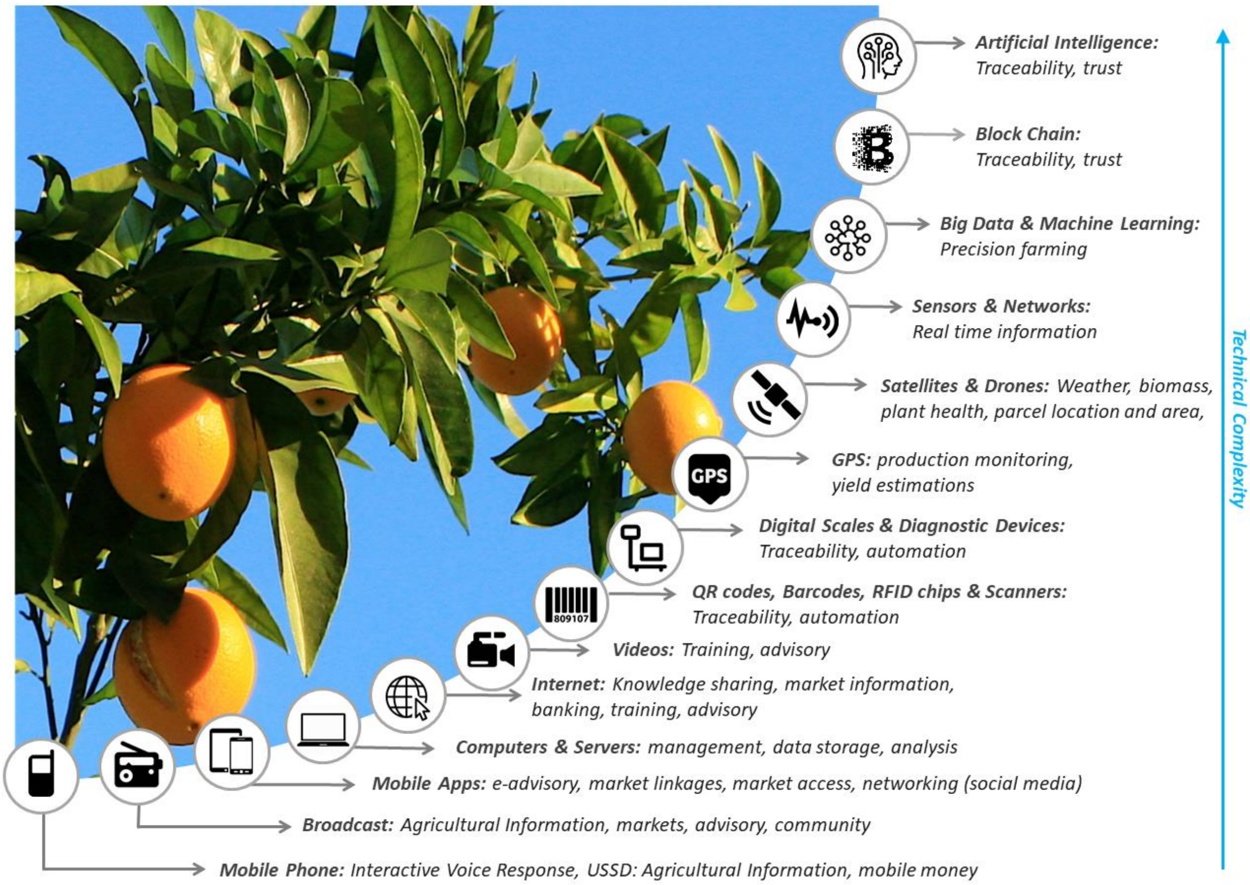
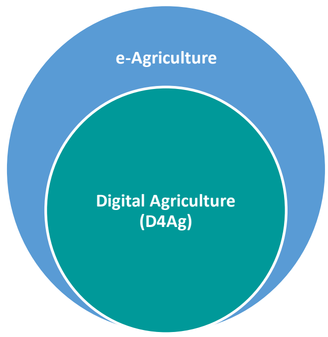


Figure 10: Information and Communication Technologies, their complexity and applicability for digital agriculture. Source: own elaboration.

Digital Agriculture, Information and communication technology for agriculture (**ICT4Ag**), Digitalisation for Agriculture (**D4Ag**) or **e-agriculture**, are terms often used synonyms for the integration of modern electronic and digital technologies with a focus on developing agriculture and related fields through improved information and communication processes. Strictly speaking, e-Agriculture includes all digital technologies included in ICT4Ag or Digital Agriculture and, in addition, other electronic areas such as radio or analogue data acquisition of e.g., temperature and humidity.



The number of available technologies is large, with new ones emerging constantly. This chapter discusses the main technologies but does not claim to be complete in either depth or breadth. It focuses on the technologies that are important in the context of agriculture, forestry and fisheries with a special focus on innovation and potential contributions to promote climate-smart development.

Hardware Devices

Among the available types of **Mobile End Devices**, the classical **Mobile Phone** is the simplest and cheapest. It is used for making phone calls, sending and receiving SMS and voice messages. Some devices already have an integrated camera, a calendar etc. but those are difficult to handle as the keyboard is limited. A **Feature Phone** extends these functionalities by adding a better screen, a full web browser and optionally a General Positioning System (GPS). The **Smartphone** is the high-end mobile device. With specific operating systems (e.g., Android) and LTE/4G/5G Internet speeds, they are closer to a computer than to a feature phone. Modern smartphones feature a large touch screen, Wi-Fi connectivity, High Definition (HD) cameras, Bluetooth and GPS. Of particular interest for work in the agricultural context are niche sensor technologies such as temperature, humidity, barometer, light, and Near Field Communication (NFC) sensors that are only installed on certain smartphones. Smartphones allow users to edit documents, use social media, handle email and create spreadsheets. They are used as navigation devices, as music and video players. One of the greatest features is that they can run third-party programs and thus be configurable to any personal need. The smartphone became the standard option in Europe while in Africa, their use is still limited as prices are comparably high both for the device[13] and for the data. A **Personal Digital Assistant** (**PDA**) is a pocket computer, very similar to a smartphone, but usually operated with a small keyboard and a pen. A PDA does not necessarily need to offer mobile phone features. A **Tablet** is a small computer, larger than a smartphone, usually with a very responsive touch screen but without the mobile phone features. They all have WIFI, often also mobile data, but rarely have a GPS. Like smartphones, they run mobile operating systems and thus allow the user to run third-party software.

The traditional **Computers**, both desktop and notebook (also known as laptop), still play the main role for all office workflows: Word processing, communication, spreadsheets, designer software, database applications. Specific software for modelling, mapping, image-, audio- and video-processing usually is developed for computers. Computers are very flexible and can easily be extended by sensors, additional monitors, input devices, scanners, and printers. In the African context, notebooks have the great advantage of running on battery in case of a power outage. For particularly dirt-intensive environments, there are robust solutions with casings, keyboards, touch screens that are insensitive to dirt and water.

Servers are powerful computers dedicated to simultaneously serve multiple requests. They provide content for websites and mobile apps, and they offer data and applications to multiple users connected via any type of network. They can offer professional data backup systems, provide Internet security, and email functionality. They are at the basis of any **Cloud Computing**, ML and AI. Because these multi-processor devices need cooled compartments, expert maintenance, and performant Internet connections, they are often operated in large numbers at server farms and provided to numerous clients for rent.

A **Sensor** is a hardware device with the purpose to detect events or changes in its environment. It communicates information to other electronics for processing. That way, various environmental parameters can be electronically and automatically measured such as humidity, pressure, temperature, wind speed, light etc. In the agricultural context, sensors are used for meteorological observation, to check water levels, flow, and quality, to quantify biomass and that way detect water stress or infestations. Sensors can even measure soil parameters, chemical residuals or simply the weight of the produce. The dairy sector uses sensors to measure temperature, weight, and the fat content of

[13] According to IDC, 40% of the smartphones sold in Africa in Q2 2020 were sold for below 80USD. https://www.idc.com/getdoc.jsp?containerId=prMETA46793820

milk. In livestock, sensors detect animal health and herd movement. Sensors are key to automation and therefore a valuable part for the digitalisation of agricultural processes. A camera can be considered as an optical sensor and digital image processing can make information visible that is invisible to the human eye. Most sensors operate from a fixed position, but the GPS sensor does the opposite: it measures the three-dimensional position on earth or in space. Four systems are available: The US American **Navstar-GPS** is the oldest system, the Russian **Glonass** and the Chinese **Beidou** are recent developments complemented by the European **Galileo** with the highest accuracy, up to 10 cm precision everywhere on Earth. Modern GPS chips can operate with a mix of these signals. Altitude values usually are less exact, but the operation of base stations with Differential GPS or the correction by Continually Operating Reference Stations (CORS) allow precisions of millimetres in case of need.

Remote Sensing (**RS**) is the science of earth observation from the sky where sophisticated sensor technology, mounted on **Satellites, Aeroplanes** or **Drones** records various physical parameters. Multi-band images not only deliver colour images of the visible light but also invisible bands such as infrared and ultraviolet. This allows, for instance, the mapping and supports assessment of crop type, crop density and crop condition, land use and trends (e.g., degradation), water use, rainfall, yield forecasts, and others. The combination of different bands allows the determination of the spatial distribution of physical parameters such as temperatures, humidity, or the different vegetation indices. For instance, the Normalised Differential Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). This helps in identifying biomass, water stress, pest infestations and thus the health of the crop. Laser-based sensor technologies such as **Light Detection and Ranging** (**LIDAR**) can help monitor the crop height and the **Leaf Area Index** (**LAI**) of plantations and forests. **Synthetic Aperture Radar** (**SAR**) sensors measure crop moisture and soil moisture content, crop indices (Radar Vegetation Index RVI) and they are able to penetrate the clouds: A radar does not depend on reflected sunlight, but instead sends out its own energy pulse and measures the return signal ('backscatter') after interaction with the surface. Remote Sensing technologies can be used to estimate agricultural areas, crop yields and crop health. Satellite data usually is very expensive, especially if the images are taken on demand, but on the other hand, more satellite data is becoming available for free (e.g., MODIS, Sentinel 1 and 2, Landsat 7-8, SPOT 5-7). Ground truth data usually is necessary for calibration to derive quantitative results.

On a larger scale, monitoring technologies help evaluate different impacts on the environment. Water use and resulting resource depletion can be monitored remotely as well as erosion or loss of biodiversity. While satellites follow their orbit and therefore pass a specific area in a defined interval, aeroplanes and drones can be operated on demand. The latter usually flies very low which is less sensitive to weather events and results in higher image resolution. Based on this data, **RS Technologies** provide crop classification maps, land use maps, digital elevation models and much more. Such technology can help detect the nearest open water pond, the most easily accessible grazing grounds and even monitor livestock welfare through sensors mounted on collars worn by the animals. However, these technologies are expensive, sensitive and need a high level of expertise for operation and data processing. They all use coordinate systems to make these data visible on topographic maps or to overlay, merge and intersect these data on/with other data sources.

Geoinformation systems (GIS) are special database systems that can handle spatial data in two and three-dimensional space. They have become indispensable in agriculture for monitoring, forecasting and decision support. GIS software is usually run-on computers, with large screens and colour printers attached, but light systems are also available for tablets and smartphones, mainly for mobile data collection. They are used for the preparation of maps but can also support all sorts of geospatial analyses such as the calculation of population densities, tracking of animals, management and monitoring of the environment, routing of multi-modal transport and so on. They are incredibly useful for understanding spatial relationships and making them comprehensible via maps.

Information Storage and Information Exchange

Databases are at the core of any ICT system. They help structuring, organising, storing, and analysing huge amounts of information produced by ICT. MS Excel and its open source derivates are not databases, but a pre-stage of them. A **Database Management System** (**DMS**) consists of a **Backend**, which is the technical data access layer, and which hosts all data and a Frontend offering the user tools to interact with the data. Relational database systems are well structured with interlinked tables while NoSQL (non-Structured Query Language) databases can be as simple as a data repository. In modern systems, the data is centrally hosted on one or more server(s) (which may run in the cloud) and accessed from user interfaces from different devices via a network, from a website or a mobile app. Such modern architecture which separates the database from the user interfaces is called a **Three-Tier** architecture. An **Information System** adds the people (users), the roles and the tasks to the technical database and thus adds value to the collected information. If the information system supports business or organisational decision-making activities, it is called a **Decision Support System (DSS)**.

With the emergence of **Phones** and **Smart-phones**, access to technology changed. Most farmers worldwide nowadays have at least simple phones and smartphone penetration is increasing rapidly. Smallholders worldwide use SMS services to get market prices, weather alerts or to share machinery and irrigation equipment, they use e-advisory services to get information about possible pests and diseases. ICT can help streamline the dissemination of information, especially if the number of recipients is large.

Communication

Bulk SMS messaging helps in disseminating SMS messages to large numbers of mobile phones. All recipients may receive the same message, but bulk SMS messaging also allows sending custom-tailored messages for individual, localised content such as local weather forecasts and alerts for a given farm area or sales figures for a given farm. Bulk SMS messages can be sent by either using a website of a SMS service provider on the Internet or by installing desktop software, which communicates with an SMS gateway. Both solutions can send to as many phone numbers as required. Some desktop software can schedule sending at specific times and/or to a specific group of recipients based on the criteria available in the farmer registry (e.g., by gender, value chain, region etc.).

Bulk SMS messaging makes it possible to automate and localise weather forecasts, to timely remind farmers of the application of fertiliser, or to send individually configured SMS listing the amount of milk delivered by the recipient farmer during the current week. In case of low literacy among the recipients, **Voice Mailing** also known as **Outbound Voice Messaging (OBD)** can replace the bulk SMS messaging. In that case, pre-recorded audio messages are sent to a large number of recipients. It is similar to bulk SMS messaging except that it does not allow to automatically configure custom-tailored messages to individual farmers. The administration of a voice-mail system, however, is more complex as the messages must be pre-recorded before they can be sent. The development of speech output systems has not yet progressed far enough for African idioms to be rendered in sufficient quality.

The **Unstructured Supplementary Service Data** (USSD) technology offers a way for bi-directional communication. USSD technology is well known by users of prepaid mobile phones as it allows them to query the available balance. This technology can be used to provide on demand information to the farmer by offering menus for selection. The farmer can dial a number and is then led through a menu, e.g., "… for the weather forecast, press 3". The technology is more complex and expensive than SMS services as it requires a USSD server which must be maintained – usually by the mobile phone provider.

Similar to USSD, the **Interactive Voice Response (IVR)** technology allows callers to navigate to content using their voice. It is even more complex than USSD as there normally are several idioms spoken in the same region. This technology specifically targets illiterate people, but also the blind.

Videos and **Audios** are still a good means for training and learning. It is a fact that literacy rates usually are lowest among smallholder farmers in remote areas. Therefore, community radio and local television still play an important role for dissemination of information. Videos, audios , and the radio can help to make information dissemination inclusive. Strictly speaking, the community radio transmitted by radio stations, and television are not digital technologies, but other digital technologies can make these videos and audios available for on-demand streaming.

Several web portals and apps offer videos and audios for various agricultural topics in several languages. To digest this information, the end user needs a mobile device with a large screen and a good Internet connection. But once downloaded, the videos can be shown to interested farmers in offline mode.

ICT offers a wide range of **Transmission Technologies**. Different generations of mobile networks offer different bandwidths and data transfer performance – the newest usually lack widespread coverage in most African countries. General Packet Radio Service (GPRS), 3G, Long Term Evolution (LTE), 4G, and the new 5G, are standards for data transmission. But even the old GPRS allows the transmission of sensor data to servers. In case of emergency situations, mobile networks frequently break down and it is the old-fashioned radio transmitter which then still works or the modern, but expensive, satellite data services. Wireless networks (WLAN or WIFI), Local Area Networks (LAN), Wide Area Networks (WAN) and derivatives such as LoRaWAN (Long Range Wide Area Network) all offer their own technical advantages, and the right technology can be found for each specific case.

Mobile Apps, Web Apps and Web Services

A **Mobile App**, often simply called **App**, is a program prepared for mobile devices such as Android, iOS or Windows phones or tablets. A **Native app** runs only on the specific operating system, meaning that an Android App cannot run on an Apple iPhone. A native app can run without the Internet, it is an independent program which can run offline, while a **Web App** runs in a web browser and therefore needs permanent Internet connection. Behind most apps is a web server which communicates at least from time to time with the program on the mobile device.

All apps are made for a specific purpose. In the agricultural context there are for instance Farmer Management Systems, Diagnostics & Advice apps (e-Advice), Weather & Early Warning apps, Market access apps / market platforms, training and learning apps, apps for traceability and many more. The well-known social media apps (Facebook, WhatsApp, and others) are frequently the only apps Smartphone users use.

ID Technologies

Traceability, which is very important in the agricultural sector for certification and export, is introduced or digitised using **Barcodes**, **QR codes**, **RFID** (Radio frequency Identification) chips and the matching scanners, which help to uniquely identify farmers, animals or agricultural products. **Farmer Registries** and **Livestock Databases** make use of these codes, and scanners, digital scales, tickets, and stickers to streamline processes and help complete traceability. The digitalization of these processes enables traceability for large numbers of farmers and their products and gives new insights into agricultural practices which can be valuable for their optimization. **E-payment** by using smartphones, feature phones and optionally **NFC** (Near Field Communication) chips can be made available to many users who previously had no access to bank accounts and respective technologies.

Smart/High Technologies

Blockchains are continuously growing lists of blocks of information, each of which has the information of the previous block in an encrypted format. Thus, they can hold information from different sources and cannot easily be counterfeited. They are seen as possible means to introduce or strengthen transparency and trust. **Artificial Intelligence (AI)** applies to intelligence shown by machines (computers) and thus often is used for any device and algorithm which mimics human learning behaviour. Classical examples are speech recognition or autonomously operating cars. The term **Machine Learning (ML)** is used for computer algorithms that improve automatically through experience. **Blockchain**, **AI** and **ML** are terms which risk being misused because they are misunderstood as placeholders for modernity and innovation. These technologies are not a panacea for all kinds of problems, but properly applied, they can help alleviate or even solve many problems. But all three need performant computer processors, performant Internet, storage devices and power supply. Thus, they are not always, or rather rarely applicable in the context of African agriculture. However, they all have their justification: **Blockchain** technology can introduce transparency and trust all along the value chain. **AI** and **ML** can help to derive sophisticated management data from the huge data sets sensor networks provide. Using **ML**, apps can accurately show related plant and weed species and even related pests and diseases. **ML** and **AI** enable hyper-localised weather forecasts and thus can significantly enhance early warning systems.

The installation and operation of such systems are expensive and need many resources. **Cloud Computing** allows the outsourcing of these problems to competent service providers. That way, an agricultural business can run databases and apps without any computer knowledge and without an IT department. Cloud computing offers a flexible way to allocate resources and it is irrelevant where the infrastructure is installed. Through the **Platform-as-a-Service- Technology (PaaS)**, farm agents might use apps which directly communicate the collected data to a cloud-based database where they get processed, analysed, and made available for decision makers via a web portal. The farm management then accesses this data via their computers or smartphone browsers. No data is stored in-house, no database installed, and no experts are necessary to supply the knowledge for maintenance of the system. The software developers can easily make updates and provide more functionalities without the need for re-installation on the several devices of the company.

Models and Simulation Games

Weather, plant and soil processes have been topics for **Simulation** and **Modelling** since computers have existed. Water balance models, crop models, models for animal nutrients requirements, livestock herd dynamics and the environmental impact of agriculture are more recent. Models play an important role for understanding complex relationships and for the mitigation of various risks through early warning and DSSs.

Serious Games and **Simulation Games** try to gamify these complex relationships (**Gamification**) to make them understandable for the multitude of stakeholders and to force behavioural change towards better management, better protection of the environment and fairer distribution of the limited resources. Serious games/applied games are board games or computer games designed for education or behavioural change and not for pure entertainment.

A2 Stakeholders and their role

The implementation of a digital agriculture strategy requires the involvement of various actors. These stakeholders either contribute by crafting the policies and laws that govern local and international digital agriculture programs, are involved via funding, development, implementation, or the practice of digital agriculture. At the helm of the continental DAS is the African Union Commission (AUC) whose mandate is to serve as a central point for coordination of knowledge sharing, implementation activities, and technical assistance through the Department of Agriculture, Rural Development, Blue Economy and Sustainable Environment (DARBE) together with the Department of Infrastructure and Energy (DIE). At the bottom of the stakeholder pyramid are the producers involved in smallholder activities such as cultivating crops, rearing livestock, and raising fish. The performance of the smallholder farming system[14] is an important success indicator of African agriculture including food self-sufficiency, production and productivity and adoption of new technologies. A transformed agricultural system is shown by the resilience and increased self-sufficiency of the system. There are other stakeholders who play roles in the sector within the value chain. The civil society, the private sector and entrepreneurs in D4Ag are constantly innovating and introducing programs along the value chain. The role of these private sector stakeholders has been shown to add to the dynamism of the sector. This has led to the constant development of various D4Ag programs and innovations that are powering the digital transformation of the sector. The downside to this is that the independence and room for innovation, has led to fragmentation and duplication. The DAS in its mission is creating an opportunity for consolidation by creating a focal centre for knowledge exchange and collation of these D4Ag programs, innovations and initiatives, while allowing for the freedom and innovation that make the digital agriculture sector successful. The AUC at the top of the pyramid will take on this coordinative role.

The development of this strategy has involved exchanges with different stakeholders aimed at achieving synergies where appropriate, to share promising technologies and approaches, and to learn from each other's experiences and best practices. This enables co-learning, co-development and helps to avoid duplication, a frequently observed problem in digital agriculture. Figure 11 shows the results of the stakeholder mapping activities of the inception phase. Stakeholders met are printed in bold letters, with more information on their roles further detailed in the annexes. In general, all stakeholders met confirmed that African agriculture is so diverse that a single strategy for all countries is not realistic. There is need to consider the different level and status of each member state. The strategy has to take into account different value chains, farming systems, soil conditions, water availability, languages and cultures, etc. Often even within one member state. Different markets need different digital solutions and thus also different digital agriculture strategies. The DAS can foster the process towards national strategies, coordinate, identify synergies, facilitate, and finally define a monitoring framework for the process. Logically, the multitude of stakeholders from different regions and countries, different organizations, different value chains and different fields of action also have very different roles.

[14] Giller, K.E., Delaune, T., Silva, J.V. et al. Small farms and development in sub-Saharan Africa: Farming for food, for income or for lack of better options?. Food Sec. 13, 1431–1454 (2021). https://doi.org/10.1007/s12571-021-01209-0

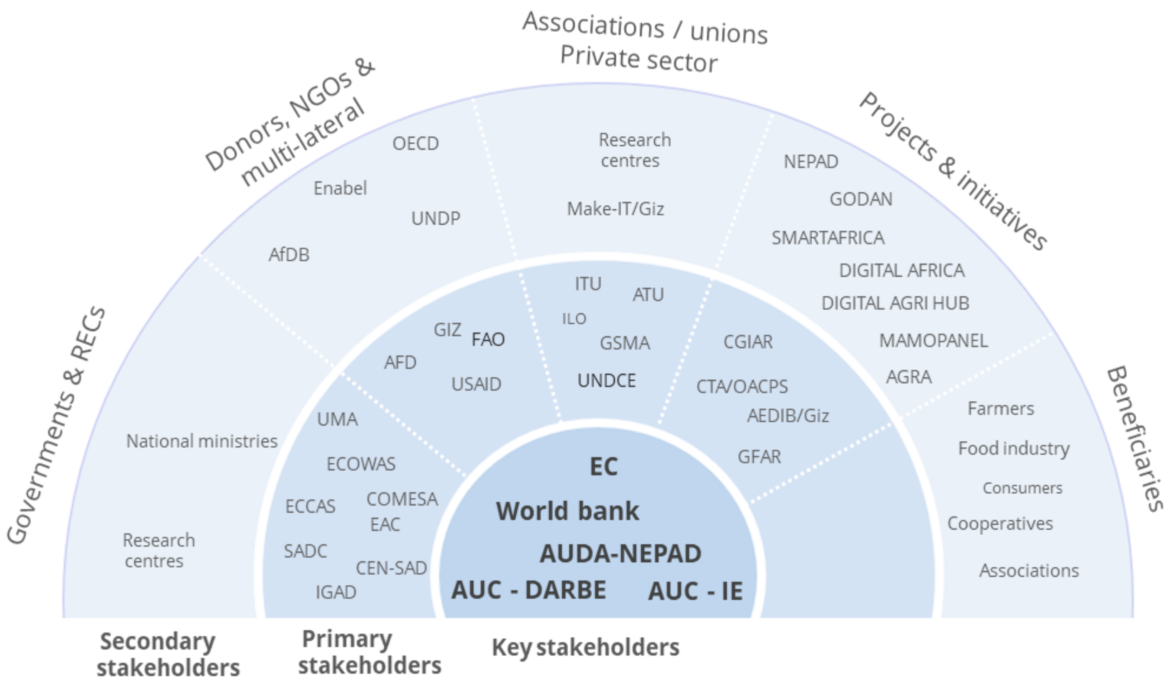


Figure 11: Stakeholders for digital transformation of African agriculture.

A2.1 AU Role

The AU consists of 55 member states and is mandated to coordinate and intensify cooperation and efforts to achieve a better life for the people of Africa. This includes securing livelihoods through food security and creation of sufficient jobs, both to reduce poverty in line with the SDGs.

The AU does this by working with the RECs and member states. Through policy development and monitoring, the AU seeks to achieve its objectives: secure good international relations for the African continent, promote science and technology, and encourage the participation of marginalised persons. The AU comprises several decision-making entities including the AU Commission[15] which will directly spearhead the digital agriculture strategy development through its Department for Agriculture, Rural Development, Blue Economy, and Sustainable Environment (DARBE)[16] and the Department of Infrastructure and Energy (DIE). “In the 2017 AU-EU Summit in Abidjan, the African Union (AU) and the European Union (EU) committed to seize the opportunities of technological development and the digital economy. Subsequently the Policy and Regulation Initiative for Digital Africa (PRIDA) has been set up [...]. The specific aims of PRIDA are (1) Connectivity: Continental spectrum, (2) Policy Legislation: Harmonization, (3) Internet Governance: to strengthen Africa’s voice in the global internet governance debate and (4) Mainstreaming ICT in other sectors.”[17]

The Digital Agriculture Strategy is spearheaded by the AU having multiple roles:

- Ensuring that the **DAS’s integrity** is maintained and that the RECs and the member states can benefit from the document. The AU will promote, validate, and escalate the strategy.
- **Coordination** and **steering** the process including awareness raising at REC level. In its coordinating role, the AU is at the top of the pyramid and responsible for DAS information and knowledge dissemination. National agriculture strategies are very country specific, they respond to national needs, expressed in national agriculture development plans. An AU guiding strategy document allows for standardisation and allows monitoring. With a continental perspective, synergies can be identified and potentials for replication and upscaling exploited.
- **Capacity building** at REC level. The AU needs the capacity of providing the technical support that the RECs may need to advise the member states. This will include training on emerging technologies like artificial intelligence and block chain, as well as policy development, use case prioritization and specification, and best practices. The AU will assist in building the capacities at REC level to understand the challenges and opportunities of national digital agriculture strategies.
- Promoting the **collaboration** between the Agricultural and Infrastructure/ICT sectors. Digital agriculture involves collaboration between the agriculture and ICT ministries at different levels. At the bottom, in the hierarchy of needs is the availability of electricity and affordable, stable, and high-speed internet access. Rural areas tend to be neglected in terms of these infrastructures, yet this is predominantly where agriculture takes place. Whilst the ICT ministry is used to working with other sectors for these needs, the the agriculture ministry needs to articulate industry needs, including appropriate standards for data access and management, and policy regulations.
- Encouraging **co-learning** between the different regions and creating synergies. RECs are in different regions of the continent. These regions are not necessarily homogeneous in terms of climate, topography, soils etc. Often the countries

15 https://au.int/en/organs/commission.

16 https://au.int/en/arbe.

17 https://au.int/en/pressreleases/20191209/policy-and-regulation-initiative-digital-africa-prida-digital-platform

belonging to one REC have very different agricultural systems, but countries belonging to other RECs may have similar systems. The AU can promote cross-border shared learning between such countries.

- **Promoting gender inclusion**. The AU has a mandate to promote inclusive services. A digital agriculture strategy must include marginalised persons as beneficiaries and integrate them in the decision making and implementation processes. As such the AU DAS should try to leverage resilience for the most vulnerable persons.
- **Promoting youth employment.** Digital agriculture offers a great opportunity to modernise and professionalise agriculture and to generate well-paid jobs, especially for young people.
- **Direct D4Ag activities:**
  - Building and hosting of an **accessible knowledge hub, including introduction of standards.** A common digital agriculture knowledge platform can help RECs and member states to build capacities. Automated translation into official AU languages will enable access and use and bridge gaps. This knowledge hub can help assure the introduction of standards.
  - Building and hosting of an **digital agricultural Forum** fosters continental learning and exchange.
  - Development of a common **e-Advisory platform software** for individual use by AU member states builds synergies.
- **Monitoring of the implementation process.** A monitoring and implementation plan for the Digital Agriculture Strategy will be put in place. Through this, the AU will ensure that the national strategies and implementation plans are aligned to maximise resources and inclusively foster the transformation process.
- **Engage with potential donors and funders.** Being the continental organisation, the AU has an important international position and voice. This allows for collaboration with donors and funding agencies. AU can liaise with continental NGOs such as AGRA, IFAD, ASARECA and FARA as well as international development banks, donors and implementers.
- **Create a suitable investment ecosystem** The AU and member states need to ensure that the environment within which funding is being provided is suitable for donors and financiers. This includes security and policies that allow for investments and minimise transaction costs.

For the implementation of the various activities, the African Union Development Agency AUDA-NEPAD can be responsible.

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A2.1.1 Project: The AUC D4Ag knowledge hub

There exist a multitude of important documents on the topic of digital agriculture, all important donors, implementers, NGOs published guides, reports, and newsletters on the topic, targeting specific use cases, geographic regions, target groups or technologies. Likewise, hundreds of videos are available on D4Ag use cases, country programs and projects, international and national conferences. This rich information base is difficult to exploit, as the documents are provided by various sources, some already outdated, they exist in different formats, and sometimes the documents are simply too large to download in areas with low bandwidths.

As all digital agriculture relevant literature is of younger date, the documents are available in digital format and no document scanning is necessary. Native PDF documents are smaller in size than scanned documents and they offer the possibility of free text search.

Most literature on digitalisation is only available in English. However, in many regions of Africa, other languages are still more important, which is also reflected in the high number of official languages of the AUC.

Article 11 of the Protocol on Amendments to the Constitutive Act of the African Union states "that the official languages of the Union and all its institutions shall be Arabic, English, French, Portuguese, Spanish, Kiswahili…"[18]. Automatic translation software and web services allow a relatively high-quality translation of entire documents. This allows to make available the knowledge base also in languages other than English.

Key to success is a professional keyword system, developed by digital agriculture professionals. The keyword system also needs to be provided in the official AUC languages.

Contents of the knowledge base can be:

- Stored documents, translated into official AUC languages in pdf-format.
- Weblinks to important stakeholders, project and initiative-websites, data sources, web portals. Keyword-tagged in official AUC languages.
- Web Links to videos (tutorials, conferences, learning material), keyword-tagged on official AUC languages.
- A repository of official national and regional strategies for
  - agriculture
  - e-agriculture/digital agriculture
  - digitalisation and telecommunication
  - e-education
  - e-trade
- A repository of resource persons, and consultants for digital agriculture.

A2.1.2 Project: Digital Agriculture Forum

The AUC is mandated to steer the continental agricultural transformation process. This can include advice, planning, coordination, capacity building, knowledge exchange, technical assistance, monitoring and evaluation. To perform this role, the AUC needs to build and strengthen its own capacities regarding digitalisation and digital agriculture. This concerns the two departments DARBE and IED; an intensive collaboration and exchange is to be envisaged.

Once such capacities are developed to a certain degree, a **digital agriculture forum** (multilingual with automatic translation) can be set up and continuously hosted by the AUC. Experts from various institutions, from AUC, RECs, national ministries, NGOs, donors, multilateral organisations, consulting firms and freelancers can participate in the forum, co-create knowledge and enrich the quality of advice.

Specific knowledge van be exchanged and accessed e.g. for the specification of data regulations or drone regulation.

Thus, the digital agriculture forum has to be structured in sub-groups around specific topics such as:

- Data privacy,
- Cyber-security (see Agenda 2063 flagship project 13),
- Drone regulations,
- E-Payment regulation,
- Digital agriculture strategy/e-agriculture strategy development.

Digital agriculture use cases such as

- E-commerce,
- E-Advice,
- Traceability
- E-Payment
- Index-based insurances.

Cross-themes such as

- Financial inclusion,
- Gender Inclusion,
- E-Identity,
- Climate resilience
- Technology trends (AI, ML, Blockchain, IoT).

While IT platforms for the creation and hosting of forums are readily available, such forums need permanent staff for administration of systems and contents.

[18] https://au.int/en/about/languages.

A2.2 REC Roles

The regional economic communities (RECs) of the AU are regional economic groupings of countries of the continent. The purpose of the RECs is to “facilitate regional economic integration between members of the individual regions and through the wider African Economic Community (AEC), which was established under the Abuja Treaty (1991)”[19]. The RECs can be seen as antennas of the AU but also as independent operating regional bodies. They directly aid in the coordination of member states for the AU in the different regions where they exist. The RECs are individually developed and have different structures. RECs do overlap – some African countries belong to three RECs at the same time.

- **CEN-SAD**: Community of Sahel-Saharan States,
- **COMESA**: Common Market for Eastern and Southern Africa,
- **EAC**: East African Community,
- **ECCAS**: Economic Community of Central African States,
- **ECOWAS**: Economic Community of West African States,
- **IGAD**: Intergovernmental Authority on Development, and
- **SADC**: Southern African Development Authority.
- **UMA**: Arab Maghreb Union,

These regional economic blocs can assist the member states of the AU to implement their digital agriculture strategies. The RECs have appropriate governing structures that can bring together countries for coordinated processes and regular interregional exchanges where member states can exchange experiences and learn from each other. The different RECs meet at AU level for regular meetings. Here is the place where knowledge can be created and exchanged, knowledge which might be important for countries with the same agricultural problems on the continent but not within the same REC. The RECs have specific roles:

- **Coordinating and assisting the strategy development process at country level:** The RECs have first-hand contact with the member states. The AU would act as the regional hub that has a guiding principle for the strategy. The RECs through the AU can assist member states in establishing national digital agriculture strategies based on the individual country's needs.
- **Capacity building at country level:** Through CAADP and AUC-NEPAD, the RECs can collaborate in identifying the technical expertise that is needed. This may include climate resilience, pest and disease management, extension systems, integration of new technologies, management of ICT systems, etc.
- **Promoting collaboration of agricultural and Infrastructure/ICT sectors:** digital agriculture brings together two different components: agriculture and ICT. The respective ministries (and sometimes agriculture may be split between agriculture, livestock, fisheries, and environment) have different mandates. Communication and collaboration are required to build a common understanding. This applies to AUC level, REC level and national level. The RECs can highlight this need and bring the ministries together to discuss roles and responsibilities for D4Ag processes. For example, Internet connectivity, a typical role for the ICT/infrastructure ministry, needs to be promoted in rural areas to function for digital agriculture
- **Monitoring standards:** The development of the digital agriculture subsector has been highly influenced by the private sector and Agri entrepreneurs. As a result, there has been some duplication of innovations and solutions. A lot of data has been generated by digital agriculture, but this data is still fragmented in different formats and different locations. Governments and international

[19] https://au.int/en/organs/recs.

governing bodies are keen on collaborating to set accepted standards on data storage, sharing, production, and security. The RECs can ensure that their member countries are able to have guiding standards that would streamline the sector and to ensure that the standards are respected.

- **Regional digital initiatives (e.g., forecasting, IPDM, data access):** There are various needs that are of cross-border nature. These agricultural needs go beyond one country and have regional causes and effects. Pest outbreaks as for instance, the common locust invasions in East Africa and the continental fall armyworm or climate-change impacts such as cyclones, floods, and droughts. The RECs can set up regional platforms for Integrated Pest and Disease Management (IPDM), early warning systems and weather forecasting, Long- and mid-term climate forecasting can be important also for index-based insurances, regional platforms for pastoralists, and for price information.
- **Promoting gender inclusion, climate-smart agriculture, youth employment:** Understanding the different actors in digital agriculture greatly aids in ensuring that the implementation of digital strategies is successful. Youth and women face unique challenges. Climate change resilience is paramount for the productivity of small-holder farmers. The digital agriculture strategies must take these cross-sectorial problems into account, identify mitigation actions, and facilitate mitigation actions. RECs can help these sectors gain the proper attention by the member countries.

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A2.3 AU Member State Roles

All AU member states are **sovereign bodies** with **internal governing structures**. The AU in its mandate works in close collaboration with these member states to ensure that they are developing towards a prosperous Africa. This means that the AU contributes to the socio-economic development of states and seeks to ensure that **member states' policies are harmonised**. The AU strategically positions member states at the international level and enables them to address challenges on an equal footing, but also promotes their engagement in emerging areas. The main role of AU member states is to address their immediate needs as a country and find synergies with the AU to move them forward. In the case of agriculture, this may include not only sector-specific needs, but also cross-cutting issues and sectors that impact the agricultural sector. The major step for the digital agriculture transformation at national level is the development of **national digital agriculture strategies**. Only a few countries already achieved this step and even fewer have these strategies ratified. Government organisations should always consider the private sector as a main driver for digital agriculture and include private sector stakeholders as key actors in any activity.

AU member states can work with AU ministries through RECs to learn from other countries. While member states often belong to different RECs, they can collaborate with a REC that aligns with their National Agriculture Plans. They can also take the opportunity to collaborate with countries in different RECs and benchmark in areas where they may have shortcomings. These include policies and laws regulating drones and data security, cross-border challenges such as climate change, but also lessons learned from best practices. Different countries have different development indices in relation to D4Ag. Some countries may have better financial performance, while others have better skill levels. AU member countries have a responsibility to observe their neighbours and find areas of shared learning and collaboration that would be useful for D4Ag practices. Furthermore, digital agriculture is a growing and dynamic sector. New technologies often emerge and the ways of collecting, managing, and working with data are constantly evolving. AU member states can incorporate D4Ag considerations more into their national agriculture plans. This, and the inclusion of D4Ag in their food system plans beyond their local needs, improves the sector, and in turn, the livelihoods of the population. D4Ag offers member states an opportunity for economic progress through healthy people, job creation and the development of innovation.

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A2.3.1 Integrating and aligning existing D4Ag programs/initiatives

AU member states have their national agricultural development plans, which are led by their ministries of agriculture, livestock, and fisheries. Some of these development plans have already integrated D4Ag components and projects. Additionally, a variety of projects, initiatives and private sector developments already exist in member countries related to the digitalization of the agricultural sector.

One of the biggest challenges for a national digitalization strategy is to overcome the fragmentation of the D4Ag sector. In developing a national strategy, states should take care to integrate and align existing D4Ag initiatives and programs to the greatest extent possible, to establish and maintain standards, and to create national data pools. This should include projects, programs, and initiatives on local, national as well as international level. Thus, national ministries must cooperate with decentralised structures at provincial or county level as well as with RECs and multi-national organisations. Without an integration of existing initiatives and programs, without an introduction of standards for future D4Ag projects, the potential for success of a strategy is very low.

At the continental level, member states may take the opportunity to learn from existing programs such as CAADP. Learning from the successes and failures of similar programs would facilitate the integration of existing programs.

A2.3.2 Access to data for decision making

The availability of accurate, complete, and timely data is a prerequisite for good decision making. In agriculture, data comprises a variety of parameters which must be observed. The natural environment is described by information about soils, climate, water availability and quality, topography; production is influenced by availability of quality inputs, labour cost, degree of mechanisation; finally, the demand for agricultural products is defined by the consumer's habits for type of produce, quality, price, time, and volume. Global price fluctuations can heavily impact on local production. And local crises can influence global market prices.

The resilience of farming communities depends on the availability and accessibility of this data. National governments can collect this data from various sources, validate and analyse it and make it available to agribusinesses, cooperatives and individuals through appropriate channels. The accessibility of quality data can also help national extension services to deliver complete services.

The African Commission on Agricultural Statistics (AFCAS)[20], a statutory body of FAO, fosters data collection and analysis for agriculture and provides assistance for data management to AU member countries. Their 50x2013 initiative[21] aims to build partnerships to close existing data gaps in agricultural statistics, to improve national capacities to produce, analyse, interpret, and apply data to policies and decisions in the agricultural sector, and to provide infrastructure to build evidence-informed policies for rural development and food security. The initiative supports countries showing a high level of political commit-

[20] https://www.fao.org/food-agriculture-statistics/resources/events/afcas/en/#:~:text=The%20African%20Commission%20on%20Agricultural%20Statistics%20%28AFCAS%29%20is,and%20established%20by%20the%20Director-General%20in%20October%2C%201962.

[21] https://www.fao.org/3/cb7187en/cb7187en.pdf

ment, ensuring effective governance, undertaking efficient planning and providing adequate human resources. The initiative currently collaborates with Ethiopia, Malawi, Nigeria, Senegal, Tanzania, and Uganda.

A2.3.3 Direct D4Ag programs/initiatives

There are a variety of use cases for the application of digital technologies for agriculture, a detailed listing and description is given in chapter A1.1. However, only a few are suitable for direct implementation by national ministries. Most of the digital transformation in agriculture is driven by the private sector and governments can only indirectly steer and influence through the provision of suitable enablers (see chapter A2.3.4).

Use cases for direct implementation through governments typically comprise:

- **Farmer registries/databases/rosters** : Farming involves many stakeholders. The biggest group are the smallholder farmers, each single one with a specific profile in terms of name, location, parcels, crop types, etc. A comprehensive database of the farmers would empower governments for better decision making, better advice-delivery, more transparent subsidies. In most cases, advanced information like phone numbers, bank account details, water consumption, etc. is not available. Neither are maps of the farmers' lands available, which would help to identify best agricultural practices and to fight pest incidents. In some cases, the bigger part of this information is available, but only on paper. Updating this information is difficult and making use of it by computer applications impossible. In most listings, the farmers are identified by their names only which can lead to mistakes. The digitalisation of this information can help significantly in streamlining various processes such as government subsidies programs, early warning systems, and making advisory systems more efficient. AU member countries can commit on tax reduction in order to attract farmers to registration.
- **E-Advisory:** National extension services typically struggle to reach out to the high number of smallholder farmers active in the country. ICT enabled extension systems (e-extension/e-advisory) are commonly seen as a useful and powerful instrument to complement traditional extension services. These systems not only provide extentionists with databases, analytical tools and tools for communication, navigation, mapping, and management, but also allow the dissemination of information, warnings, and advice to a high number of recipients. E-advisory systems must consider the diversity of value chains, farmers' skills, farmers' access to technology and the regional and local conditions of climate, soils, and water availability. E-advisory systems typically connect to farmer registries/rosters/ databases.
- **Forecasting and alert systems:** Investments in early warning systems, alert systems, long-term, integrated pest- and disease management systems are long-term investments, which finally pay back by improved resilience of farming systems and farmers' livelihoods. Those systems might entail significant costs for monitoring networks, data transmission, servers, personnel, remote sensing data, they require skilled staff and training of users, but they can help prevent the loss of life, livestock, and crops.
- **Data centres:** It is the sovereign task of states to collect and analyse statistical data of agricultural productivity. FAO and other organisations support the setup of respective systems and the required capacity building. However, these valuable resources are mostly inaccessible to farmers and agribusinesses. There exist national initiatives providing this information to interested users through bulletins, dashboards and newsletters. Data which helps agribusinesses, cooperatives, and individual farmers to better understand risks and opportunities, can help improve business and resilience. Market information can be part of it, valuable information not only for farmers,

but also for trade and commerce.

- **Traceability systems:** While traceability systems are typically developed and maintained by agribusinesses in supply chain management and along the value chains, national governments and development agencies must expand investments in developing the foundation upon which effective traceability systems can be implemented. Governments are responsible for the setup and operation of **animal traceability** systems. A major obstacle for their development is in getting all relevant stakeholders to the table. Frequently, data ownership is unclear, as are the roles and responsibilities of stakeholders. International organisations, such as AU Interafrican Bureau for Animal Resources, World Organisation for Animal Health (OIE) and FAO, are increasing their activities in this field by providing funding for traceability-related projects. Platforms for animal registration will become more available in Africa within the next ten years, though group/herd identification might frequently be sufficient as a first step. The registration of individual animals might not yet be possible in many African countries since the necessary technology step is a great challenge

There are other potentials for direct government activities such as standards for the communication of laboratory reports for water, soil quality or animal health.

AU member states should be aware of these technologies and initiatives and the possible cross-cutting value chain activities. Their potentials should be assessed and programs eventually integrated when developing the national digital agriculture strategies.

A2.3.4 D4Ag enablers

The successful implementation of D4Ag initiatives is dependent on various other industries. These enablers, described in detail in chapter 1.5, directly or indirectly influence digital transformation. Mobile telephony, for instance, is a prerequisite to bridge the last mile to the farmer for production advice, market information and weather data. There is a need for respective digital skills to be able to efficiently make use of the D4Ag innovation. There is an increasing demand for data scientists and software developers who understand both agriculture and ICT. Therefore, post-secondary education curricula need to be geared towards this.

The private sector, and particularly young agri-entrepreneurs greatly drive the D4Ag sector, an enabling[22] business environment provides the space for these businesses and innovations to thrive. These include access to finance and credit, ease of doing business, affordability of services and the availability of tech hubs, worker spaces, incubators and accelerators.

Availability and affordability of the necessary services in rural areas is crucial for the digital transformation of agriculture. Access to electricity, performant and reliable mobile networks, affordable and high-speed broadband services, are key to success.

Other D4Ag enablers are centred around the adoption of technologies, factors including social and cultural attitudes towards certain technologies that break the norm in practice.

Market fragmentation with no standardisation affects the actual implementation of these technologies. AU member states therefore should consider D4Ag enablers as a controlling mechanism to direct the digital transformation of the national agriculture sector towards the national goals.

[22] https://thedocs.worldbank.org/en/doc/354261452529895321-0050022016/original/WDR16BPEnablingdigialentrepreneursDWELSUM.pdf

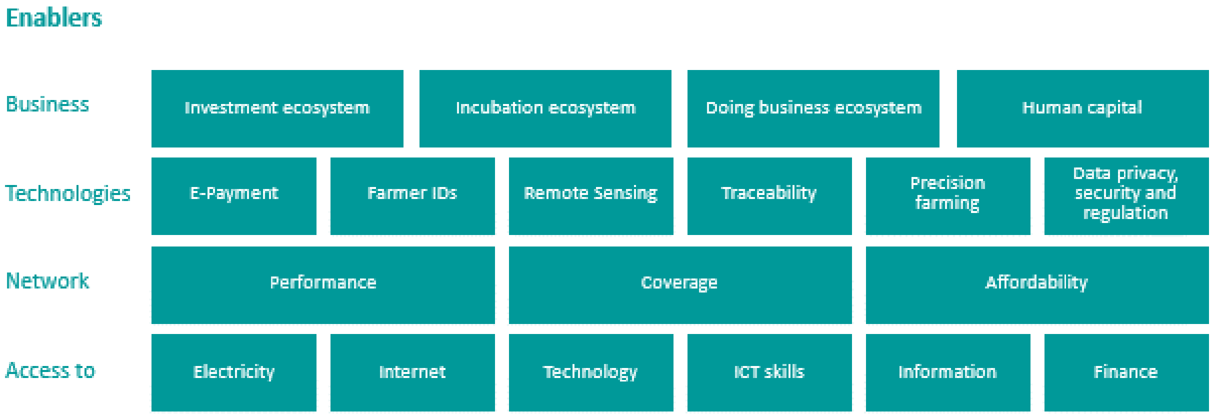

Figure 12: DG4 Enablers.

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A2.4 Other stakeholders

The implementation of D4Ag solutions cannot only fall on the AU, RECs, and Member states. Collaborations with key stakeholders would ensure that there is a collective effort in the implementation. Further to this, implementation would require building infrastructures, building capacities via technical support and training, local, regional, and international cooperation including monitoring and evaluation. The digital agriculture sector comprises of various other stakeholders who innovate and are enablers to the development of the sector. These stakeholders participate at different levels of governance as civil society and private sector. They work independently in their formulation of initiatives and programs whilst abiding to local and international laws and policies. This has allowed for the digital agriculture sector to expand and grow exponentially. The stakeholder engagement of the DAS strategy has shown that there is similar work ongoing in the continent including strategies focused on digital agriculture. It is therefore of importance that this strategy highlights these roles and provides an opportunity for consolidation and coordination by the AUC-DARBE and DIE. The various stakeholder has major entry points in their contribution to the DAS as shown in figure 6-3 below.

Figure 13: Stakeholder Entry Points to the DAS.

A2.4.1 Multilateral organisations, development agencies, NGOs and research centres

The African continent has the privilege of having sector specific continental bodies that can facilitate and collaborate with the AU i.e., AGRA, FARA, IFAD, ASARECA , AFAAS etc. The AU can play a coordinating, harmonising, and monitoring role in this case and can align the activities of the various stakeholders to leverage synergies.

These key actors in the digital agriculture landscape comprise development agencies, donors, multilateral organisations, and NGOs. These stakeholders often have their own digital strategies and can have a major impact on digital transformation in the countries where they work. Their programs and projects typically align with the national vision for agricultural development and thus their activities can be considered as valuable building stones towards the digital transformation of the national agricultural systems.

FAO and ITU can be considered as the primary players in this group, World Bank, African Development Bank, IFAD, AGRA and Commonwealth as additional important multilateral partners, GIZ, USAID and ENABEL as most important development agencies for the digital transformation of the African Agriculture. COLEAD are the largest NGOs engaged in digital transformation of African agriculture.

What are the specific roles these stakeholders can play?

A distribution of responsibilities that benefits the subsector and the various stakeholders is a suitable solution centred approach for the development of the subsector.

1. **Aligning activities.** The African Union's CAADP programme[23] is Africa's policy framework for agricultural transformation with country implementation programs that serve as guidance for activities. The specific objectives of the CAADP program provide guidance on what would be necessary for the processes. The private sector and civil society should align with the CAADP objectives in their regional and country D4g programs. CAADP has committed to enhancing resilience in livelihoods and production systems to climate variability and other shocks, halving poverty by 2025 through inclusive agricultural growth, to enhancing investment finance in agriculture, ending hunger by 2025, boosting intra-African trade, and of course promoting mutual accountability in all the programs. The various stakeholders have to ensure that their D4Ag programs, solutions, interventions, and strategies are in alignment.
2. **Investing in Digital Agriculture** Financial investments are needed for the development of the digital agriculture sector. In general, and for the implementation of the DAS in particular. This includes investing in ICT infrastructure enablers, e.g. last mile projects for the availability of electricity in rural areas, internet connectivity and telecommunication channels. There exist several programs that focus on financing digital agriculture. For instance, the African Development Bank provides various products[24] that focus on key areas of digital agriculture. Other programs and projects consider digital agriculture as one of many components. A specific focus on digital agriculture is necessary as this ensures the holistic view on the necessary financial resources, including the enabling environment. The handbook[25] for digital agriculture financial services by the international finance corporation shares valuable insight, for example.
3. **Provide technical support to the member states.** Member states may have plans of developing national D4Ag strategies or of integrating D4Ag activities into other policy documents. For these activities, the AU DAS offers guidance to the member states.

[23] https://www.fao.org/policy-support/mechanisms/mechanisms-details/en/c/417079/

[24] https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/agriculture-fast-track-aft-fund

[25] https://www.ifc.org/wps/wcm/connect/region__ext_content/ifc_external_corporate_site/sub-saharan+africa/resources/dfs-agriculture

Nonetheless, there is technical assistance necessary for these processes as well as for the implementation of these strategies. Financial resources and technical assistance can be provided by the stakeholders to facilitate these processes towards digital transformation of national agricultural systems.

4. **Strengthen public service provision via partnerships and collaborations.** The respective stakeholders can support AU member countries' ministries in modernising their e-extension services, in building national farmer registries, introducing farmer-IDs, market information systems, traceability and certification systems. The creation and support of agricultural training centres, tech- and innovation hubs can also be supported to leverage agricultural transformation on national levels.
5. **Increase research.** Digital agriculture is a sector with a high potential for innovation. There are various aspects of digital agriculture that become emergent, these stem from improving production[26,27], natural resource management[28] to the social[29] implications of these applications. The stakeholders can foster research and development of the D4Ag sector. PPPs can help link start-ups with access to knowledge about most innovative technologies with research centres where the required knowhow about the application-level domain is available.
7. **Direct Strategy Involvement.** The development of digital agriculture strategies may be supported at different levels and by different stakeholders. The DAS introduces the necessary standards and guides these processes towards a harmonised and aligned approach. All stakeholders engaged in digital agriculture strategy development should consult the DAS and the respective working groups and knowledge hubs (see implementation plan).

These are immediate overarching entry points and roles in which the various stakeholders can interact with the AU-DAS.

Other direct contributions may be:

- Escalating the strategy via sharing within their networks and/or applying the tools suggested in this document
- Support the implementation of the strategy (see implementation plan).
- Consult directly with local and national levels of governance on the use of the strategy.

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A2.4.2 Private Sector

The private sector is a core driver for the digitalisation of agriculture, when it comes to investments, technology, products, and distribution systems. The digital agriculture landscape of the African continent shows major privates sector involvement in digital agriculture from mobile network operators, banks, insurance companies, from the agro-industry as well as from IT companies. Nonetheless, there needs to be better partnerships and financial instruments that favour the sector. The private sector via Public-Private-Partnerships should find the most suitable framework that works for the current D4Ag ecosystem. When exploring the most sustainable PPP framework, existing policies, skill levels, agribusiness, and participatory principles should be considered. Public Private Partnerships allow governments to create the right working environment for the private sector. Kenya's e-surveillance [30] is an example of what collaboration could look like. Private sector

[26] https://www.frontiersin.org/articles/10.3389/fsufs.2020.00066/full

[27] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8780442/#:~:text=Digital%20farming%20aims%20to%20use,and%20requires%20sophisticated%20management%20systems.

[28] https://cas.cgiar.org/evaluation/publications/evaluation-cgiar-platform-big-data-agriculture-online-survey

[29] https://www.sciencedirect.com/science/article/pii/S1573521419301769

[30] https://avcdkenya.net/2021/08/02/syndromic-e-surveillance-averting-livestock-disease-outbreaks-improving-livelihoods/

engagement in innovation for sustainability and longevity should focus on co-creation. Various participatory approaches should be used in the design phase of innovations. Kenya's e-surveillance [31] is an example of how collaborations could look like. Private Sector engagement around innovation for purposes of sustainability and longevity should be centred around co-creation. Different participatory approaches should be used in the design phase of the innovations. This allows for the upholding of agency at individual and institutional levels. Co-creation of innovation also allows for assessment of community perceptions of technology. The private sector should therefore work closely with the communities in which they operate, i.e. the end users, in the development of these innovations and also coordinate with government agencies accordingly. Access to finance is a huge determinant to the development of digital agriculture. A good entry point for the private sector must also include financial incentives. Financing research and development allows for upscaling of existing solutions and for the creation of new knowledge.

The development of sustainable business models can guarantee the success of D4Ag solutions and the ICT companies. But it is a major hindrance that small producers usually cannot invest into digital skills, devices and solutions. While for digital agricultural use cases such as e-commerce, market access, aggregation, automation, of access to finance and insurances it is relatively easy, it is much more difficult for e-advice and e-learning.

The private sector has several pivotal areas in their contribution to the digitalisation of agriculture that are worth considering in the development of national digital agriculture strategies.

1. **Digital agriculture information solutions** via **mobile apps**[32] IVR, SMS and USSD. These apps provide solutions ranging from production advise, weather advise, markets, transportation, irrigation and so forth. There are countless examples on the continent. The Digital AgriHub[33] at Wageningen University and Research is working to create a database of all these solutions.
2. **Market access:** the private sector plays a role in providing access to markets via mobile apps that provide direct information on prices and demand or that link buyers to sellers both locally, regionally, and globally. Market access is also provided via contract farming, via contract farming and distribution technologies for example block chain.
3. **Digital training and support** by input suppliers, aggregating and processing companies. Private agrodealers are distributed all over the continent and agrochemical companies such as Bayer crop science or Syngenta for example create own solutions for training and advice.
4. **Access to finance** via different financial models. Mobile money and e-finance solutions are widespread in Africa and are seen as major drivers of financial inclusion. Access to finance is critical for farmers to obtain timely and appropriate credit to purchase inputs, even if the crop has not yet been sold or paid for.
5. **Access to insurances.** Various insurance models can help improve the resilience of African small producers. Index-based insurances can help prepare against the impacts of climate change and the shocks of natural hazards. The development of insurances needs comprehensive data on climate patterns, agricultural practices, farm data, impossible without powerful ICT networks.
6. **Business development** through a range of nonfinancial services to small holder farmers along the value chain. Provision of information services, mechanical, veterinary, transportation, cleaning, packaging services, that allows for agribusinesses to run efficiently. The private sector can provide appropriate technologies to link such services to the various value chains.

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[31] https://avcdkenya.net/2021/08/02/syndromic-e-surveillance-averting-livestock-disease-outbreaks-improving-livelihoods/

[32] https://www.fao.org/e-agriculture/category/e-agriculture-taxonomy/icts-agriculture-e-agricultural-related-technology/computers/mobil-0

[33] https://digitalagrihub.org/

A2.4.3 Small-scale producers

The smallholder farmer, livestock keeper or fisherfolk is the backbone of the African food production. These producers are at the influence of weather patterns, input supply, markets, price variations and laws and regulation. There are about 33 million[34] smallholder farms in the African continent that produce about70% of the food supply for the population. A smallholder[35] farming system is defined as the production of food, rearing of livestock and fishery production in less than 1 ha of arable land. Typically, the value chains include the small producer and activities from land preparation, input purchase, production and harvesting all remain in the hands of the smallholder farmer. Agricultural transformation has to consider this fact and digitalisation preferably has to include the small producer.

While the different actors of the sectors of transportation, processing, storage, manufacturing, distribution and wholesale/ retail typically have access to digital skills, digital devices, energy, finance and data, the small producer lives in rural areas where access to these services is low. However, the digitalisation of agriculture has proven to have a role to improve the efficiency of these value chains through technologies but also human capital and investments from governments, NGOs and private sectors.

Therefore, the smallholder farmer is one of the main beneficiaries of the digital transformation of agriculture. On the other hand, smallholders can also be one of the main drivers. Without onboarding the smallholders, the transformation process will lack an important element. Smallholder farmers play a crucial role, they need appropriate information about markets, prices, demands, weather, soils, good agricultural practices, seed certification etc. but they also provide data and give direct feedback on the various D4Ag practices as they are the most direct interface to agriculture and environment. For some of the suggestions provided in the DAS implementation plan, the small producer is key for implementation, they have to network and collaborate with other sector stakeholders in the digital agriculture sector. This includes the extension agents, civil society organisations, development partners that have programs in the area. In addition, smallholder farmers play an important role in reporting problems related to yield increases, seed certification, soil and water management, and pest and disease infestations in order to find digital solutions to these problems. Opportunities for smallholder farmers in the development of digital agriculture strategies includes:

- Access to good governance including input subsidies, stable market prices, peace and stability and security. Protection from broker exploitation. Access to improved irrigation that optimize water consumption, storage and cooling facilities that reduce post-harvest losses.
- Access to high value inputs and technologies that allow for higher yields but also sustainable production.
- Forecasting and information on weather and climate changes, pest and disease attacks.
- Access to e-extension services that provide localized, customized advice. These apps typically collect data about the agricultural practices for banks and insurance companies to develop and promote their products.
- Food security via proper farm management

[34] https://www.ifad.org/thefieldreport/

[35] Giller, K.E., Delaune, T., Silva, J.V. et al. Small farms and development in sub-Saharan Africa: Farming for food, for income or for lack of better options?. Food Sec. 13, 1431–1454 (2021). https://doi.org/10.1007/s12571-021-01209-0

A3 Supporting AU member states to develop national strategies

Agricultural transformation is a permanent process. In the last decade, ICT was seen as a main driver for transformation. All major donors, research centres, implementers as well as national ministries started initiatives for the introduction of ICT for agriculture. The variety of agricultural systems, value chains, geographies and cultures resulted in an extremely high number of implementations in Africa without standards, often incompatible and isolated. A strategic approach is needed to find and exploit synergies, to specify and develop standards, to define goals and to monitor the implementation processes.

Many countries worldwide started the development of specific digital agriculture strategies or a-agriculture strategies. In Africa, only a few national strategies are available and their structure and content differs very much depending on the author and the supporting structure. E-Agriculture/digital agriculture strategies exist for Benin, Ivory Coast, Kenya, Nigeria, Rwanda, and Sudan. Strategies are under development for Niger and Madagascar.

Benin

Stratégie Nationale pour l'é-Agriculture au Bénin 2020-2024

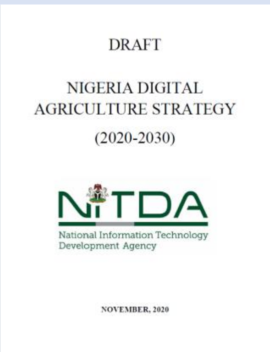
Link[36]

Supported by FAO/ITU

The strategy starts with an introduction to the potentials of TIC4Ag. It gives an overview of Benin agriculture and its potentials and risks. It then gives detailed insights into the situation of the national ICT sector and existing digital agriculture solutions in the country.

It then looks into the enabling environment for e-agriculture and existing policies and strategies (also from other sectors).

From here it derives vision and targets for the development of e-agriculture in Benin and complements it with an action plan and a M&E system.



Nigeria

Nigeria Digital Agriculture Strategy (2020-2030)

Link[37]

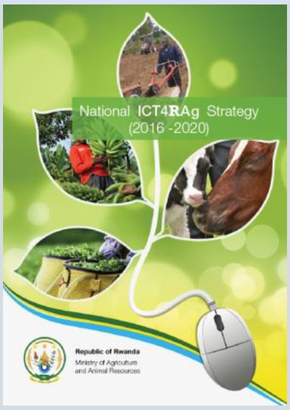
The strategy introduces Nigerian agriculture and related problems, introduces the reader to the topic of digital agriculture, gives an overview of existing digital agriculture solutions and initiatives and then structures the strategy along vision, goal, strategic objectives, value proposition and guiding principles.

It identifies three strategic objectives and eight complementary initiatives (similar to what was presented in chapter 5.5).

An implementation framework is presented targeting the enablers, and core drivers such as digital platforms, business models and DAAS.

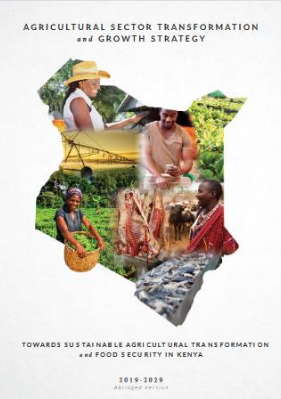
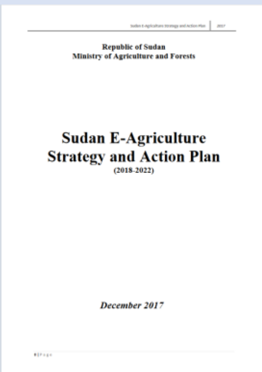
[36] https://assets.fsnforum.fao.org/public/discussions/contributions/Strat%C3%A9gie%20nationale%20e-Agriculture%20Benin%2025-08-2019.pdf.

[37] https://nitda.gov.ng/wp-content/uploads/2020/11/Digital-Agriculture-Strategy-NDAS-In-Review_Clean.pdf.

		The strategy is completed by a high-level implementation governance structure and plan and by an M & E system.
	**Ivory coast** Changement Climatique et Agriculture Intelligente face au climat (AIC) Link[38] Supported by FAO/ITU	Strictly speaking, the document is not an e-agriculture strategy. It illuminates the field of e-agriculture in the perspective of climate resilience. As this, it is a comprehensive toolbox for climate-resilient e-agriculture and it prioritises activities specifically for the Ivorian context. Logically there are many application fields for digital agriculture without linkage to climate change and r´they are not part of the strategy. The document introduces the reader to climate-change related agricultural problems in Ivory Coast, lists all relevant stakeholders, identifies the most appropriate digital solutions to these problems, discusses risks and potentials and ends with general recommendations. No action plan or budget plan is included.
	**Rwanda** National ICT4Rag Strategy 2016-2020 Link[39] A conjoint development of various national ministries.	The document starts with the vision, the mission and the objectives of the Rwandan strategy. A situation analysis defines the starting point, core objectives, projects and subprojects are identified and presented: ▪ Development of a common user interface and a repository for farmer and farm information. ▪ Increase the number of skilled and knowledgeable farmers using ICT. ▪ Spur job creation among youth in the agricultural sector. ▪ Increase access to agricultural information, knowledge and market. ▪ Support access to and the uptake of agricultural finance. This action plan is complemented by a budget plan, an implementation plan and an M&E system.

[38] https://www.fao.org/3/ca3437fr/CA3437FR.pdf.

[39] https://imbaraga.org/IMG/pdf/ict4rag_strategic_plan_2016-2020_final__final__3_.pdf.

	**Kenya** Agricultural Sector Transformation and Growth Strategy (ASTGS) 2019-2029. Link[40] Supported by AGRA/FAO/GIZ/JICA/ UNEP/USAID	The strategy defines nine flagship D4Ag projects including clear indicators, an implementation plan and an M&E framework: **Anchor 1 – Increase small-scale farmer, pastoralist and fisherfolk incomes** ▪ FLAGSHIP 1: Target 1 million farmers in ~40 zones (initially) served by 1,000 farmer-facing SMEs ▪ FLAGSHIP 2: Shift nationwide subsidies focus to register 1.4 million high needs farming households and empower them to access a range of inputs from multiple providers through e-vouchers **Anchor 2 – Increase agricultural output and value addition** ▪ FLAGSHIP 3: Establish 6 large-scale agro-processing hubs through a one-stop shop for agro-processors ▪ FLAGSHIP 4: Unlock 50 new large-scale private farms (bigger than 2,500 acres) and sustainable water supply for more than 150,000 acres of irrigation from existing infrastructure **Anchor 3 – Boost household food resilience** ▪ FLAGSHIP 5: Restructure governance & operations of the Strategic Food Reserve (SFR) to better serve 4 million vulnerable Kenyans ▪ FLAGSHIP 6: Boost the food resilience of 1.3 million farming and pastoralist households in arid and semi-arid lands (ASALs) through community-driven intervention design **Enablers** ▪ FLAGSHIP 7: Launch three skill programmes for 200 government leaders, flagship implementers and 3,000 youth-led and digitally-enabled extension agents ▪ FLAGSHIP 8: Strengthen research and innovation as launch priority digital and da ta use cases to drive better decision-making and performance management ▪ FLAGSHIP 9: Monitor two key food system risks - those addressing sustainability and climate, and a second category for crisis management for pests, diseases and global price shocks
	**Sudan** Sudan E-Agriculture Strategy and Action Plan (2018-2022). Link Supported by FAO/ITU	The document identifies Sudan's agricultural sector problems and specifies 48 ICT solutions around 9 programme areas and categorizes them by impact, dependency, and feasibility. A prioritization is given, and a time plan for their development and rollout. Its total cost for 2018-2022 was estimated to be 110 Million USD.

[40] https://wrsc.go.ke/resources/publications/42-agricultural-sector-transformation-and-growth-strategy-2019-2020.

In general, it is advisable to develop national digital agriculture or e-agriculture strategies jointly with the national ministries of agriculture and infrastructure/ICT. In addition, areas of responsibility for agriculture in many African countries are spread across several ministries: agricultural sub sectors such as livestock, fisheries and environment, are all relevant for digital agriculture and there is also overlap with other sectoral ministries such as health and education. The number of stakeholders can therefore be high, with the risk of uncertainty as to where such a strategy WILL ultimately lead. It is the nature of a national digital or e-agriculture strategy that it has a very specific focus. It has to support activities in line with the national agricultural development plan, it has to consider,, among others, the realities of network coverage, Internet broadband performance, people's access to technologies. The strategies therefore have different contents, nevertheless the development of these strategies can follow a common approach. The Continental Digital Agriculture Strategy aims to develop a knowledge base which will serve as guidance to the development of national digital agriculture or e-agriculture strategies.

The following approach is recommended for the development of national digital or e-agriculture strategies:

Before the process is launched, a clear and understandable name for the strategy has to be found and the timeframe defined. The 'e', 'ICT' or 'D' should be part of the name, likewise the sector's identifier 'Agriculture'. Strictly speaking, 'Digital' does not include radio and analogous sensor technology, but finally the content counts. 'D4Ag', 'e-Agriculture' and 'ICT4Ag' are common names.

Digitalisation strategies generally shouldn't cover long periods of time, as technology is rapidly evolving. Typically, digitalisation strategies for agriculture cover 4 to 8 years.

The AC can build appropriate capacities and provide technical assistance to member states for the development of national digital or e-agriculture strategies.

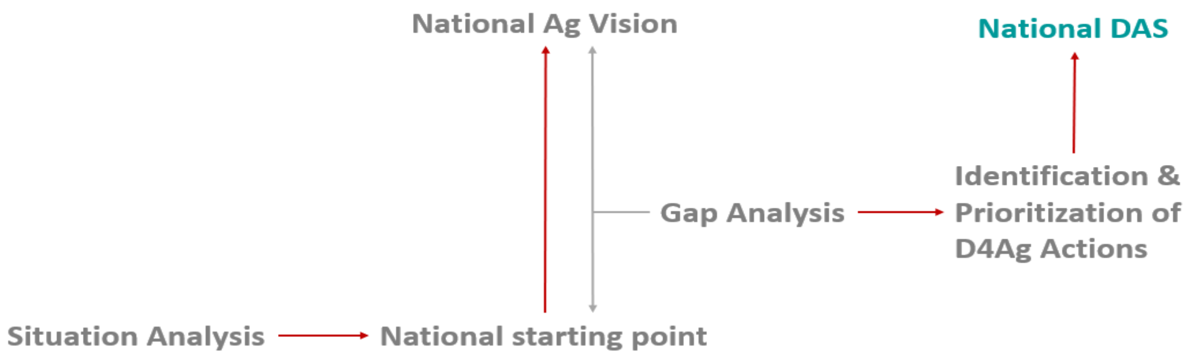


Figure 14: Aligning a National Digital Agriculture Strategy to the National Agricultural goals.

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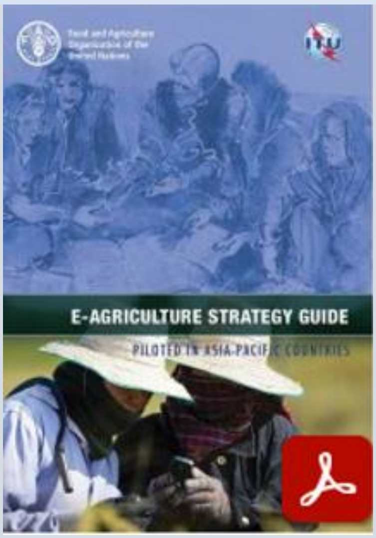
In the past, FAO, together with ITU have been the major supporters for the development of national digital and e-agriculture strategies. The Kenyan strategy has been supported by AGRA. These organisations also provide the most important documents and guidelines for the development of national strategies. The following main D4Ag frameworks and strategy guides for digitalization of agriculture have been identified:



FAO/ITU e-Agriculture Strategy Guide

2016

Link[41]

This document is the main resource available for the development of national digital and e-agriculture strategies. It has been used by many countries around the world, including some of the above-mentioned in Africa. FAO and ITU are currently updating the document.

SmartAfrica Blueprints

(AgriTech, ICT Skills Capacity Development, e-Payment, artificial intelligence)

Link[42]

The blueprint is meant to assist African countries to accelerate agricultural productivity using Information and Communications Technology (ICT). Led by the Zimbabwe Government, the blueprint was developed by Smart Africa.

A methodology which was derived from African Union's Comprehensive Africa Agriculture Development Programme (CAADP), was followed for this project.

ITU SDG Digital Investment Framework

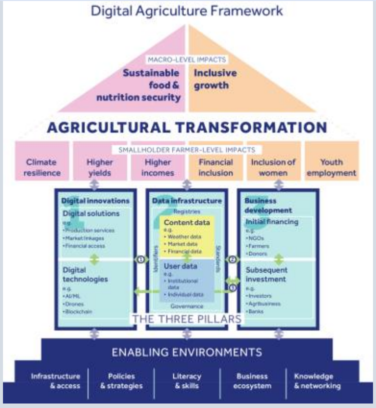
Link[43]

The framework aims to enable government and their partners to take a whole of government approach to invest in shared digital infrastructure to strengthen the sustainable development goals programming across sectors

41 https://assets.fsnforum.fao.org/public/discussions/contributions/Strat%C3%A9gie%20nationale%20e-Agriculture%20Benin%2025-08-2019.pdf.

42 http://www.fao.org/in-action/e-agriculture-strategy-guide/en.

43 https://www.itu.int/dms_pub/itu-d/opb/str/D-STR-DIGITAL.02-2019-PDF-E.pdf



The commonwealth

The Commonwealth is currently developing two reports on the state of digital agriculture and digital fisheries in the Commonwealth using the framework as an example. These reports build on a Digital Agriculture framework which was developed recently.

1. Institutional Anchoring

Identify key stakeholders. Ministries, NGOs, development agencies, funding agencies, farmer associations, research centres, tech hubs, private sector representatives, etc.)

2. Stakeholder Engagement

Identify and classify secondary stakeholders, including projects. Engage through workshops. It can be of benefit, to later group these stakeholders around certain priority axes.

3. Situation Analysis

Assess ICT technical parameters, skills, access to technology, assess the national agricultural development vision for potentials for digitalisation, assess major bottlenecks for agriculture development AND for digitalisation, assess existing D4Ag solutions, existing policies, and regulations.

4. Identification and prioritisation of D4Ag actions.

Identify main strategic axes , build working groups and identify, discuss, specify, and prioritise actions.

5. Establish a National D4Ag Action Plan

Feed the action plan with concrete activities and indicators (results from working groups) and align it with existing national and regional sectoral and horizontal plans.

6. Establish a National D4Ag Implementation Plan

Specify a national implementation plan for the timeframe of the strategy. All actions and sub-tasks included.

7. Establish a National D4Ag M&E System

Define indicators and milestones for all actions for the timeframe of the strategy.

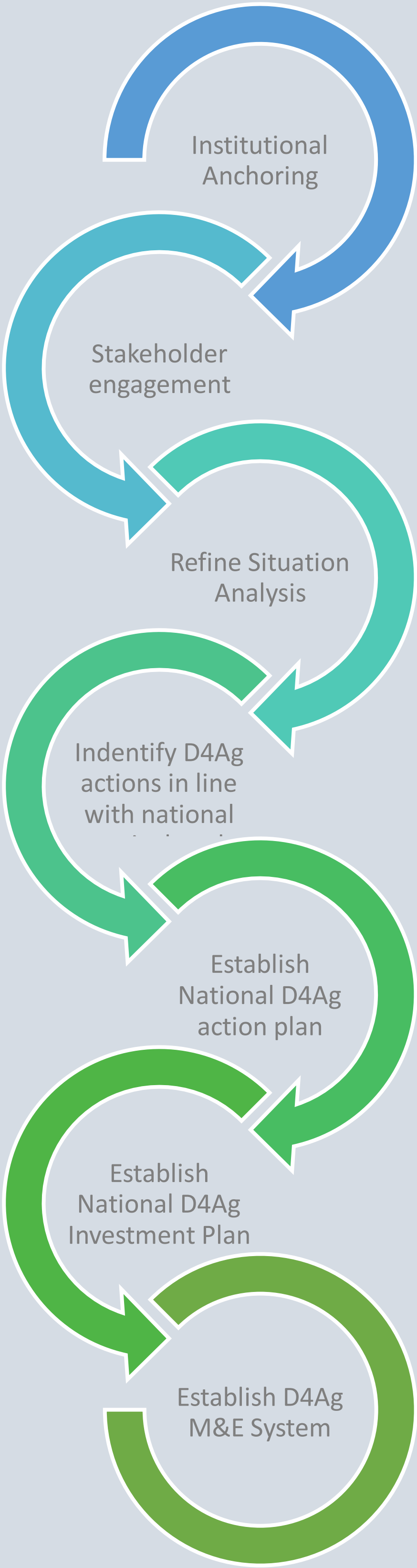


Figure 15: Steps for the development of national DAS.

A3.1.1 Minimum requirements for a National Strategy

- Vision and mission of the strategy
- Stakeholder map
- Presentation of national agriculture, its visions, and existing problems
- Quantitative and qualitative situation analysis of ICT4Ag enablers, policies, regulations and existing digital agriculture initiatives and solutions.
- Definition of goals
- Development of a strategic approach, alienation with existing national and regional sectoral and horizontal plans.
- Identification of priority areas for intervention
- Identification of appropriate digital agriculture and supplementary actions and integration with other sectorial development plans.
- Implementation plan
- Budget plan
- M&E system

A3.1.2 Optional elements for a National Strategy

- Synergies with other sectoral digital strategies (see ITU SDG investment framework).
- Consideration of cross-sectorial topics such as gender inclusion, financial inclusion, climate resilience, digital literacy, e-identity, youth employment and others.

A3.1.3 Hurdles and risks

- A large number of stakeholders can lead to a protracted and difficult process.
- Disputes about ownership of the strategy.
- The integration of (successful) existing initiatives can be difficult.
- Without integration of successful existing initiatives, the strategy is likely to fail.
- Digitalisation bears the risk of digital divides.
- The lack of positive spill-overs to rural communities might discourage rural stakeholders.
- Potential changes in employment structures might discourage stakeholders.
- Budget plans need to consider realistic figures.
- Missing link of the strategy with other sectoral plans, defined actions can be unrealistic without infrastructure development. .
- Difficult and lengthy adoption process.
- Missing funds for implementation.

A3.1.4 Action packages – for selection and prioritisation

The elaboration of regional and national strategies for digital agriculture/e-agriculture requires the identification of priority areas where a REC or a state ministry can engage. But not all D4Ag use cases are equally suitable for state engagement. E-commerce solutions or supply chain management systems, for example, are usually beyond the responsibility of the state. National e-advisory systems and data sharing platforms, in contrast, are. In addition, there is a whole range of D4Ag use cases that when successfully implemented by governments can provide good enabling environments. The use cases identified therefore are those that are of immediate actionable need in addition to possibility of state interventions.

In Appendix C, several parameters are presented, which influence the potential for digitalisation and help prioritizing areas of intervention for regional and national digital and e-agriculture strategies. They are used here to cluster AU member countries for specific D4Ag use cases. Most of these indices were developed by expert groups, are well known, get updated regularly and can be accessed publicly.

The subsequent subsections present those use cases, which can be part of national digital and e-agriculture action plans, or which ask for governmental regulation. All action packages are presented following a common structure:

Page one presents typical technological solutions for the use case (further information on the use cases can be found in chapter 3.1). Potentials are described and typical bottlenecks and risks discussed. A box presents successful use cases from Africa. The presentation of these examples is a random selection and does not follow any particular strategy. In most cases, successful and widely known solutions are highlighted here.

Page two presents possible actions and necessary activities per country cluster, for RECs and the AU. Depending on the use case and the underlying technologies and technological infrastructure requirements, the demographic and geographical situation, countries fall in different clusters. The map on top left of the page shows the countries coloured according to the cluster they belong to. For clarity, the countries are again listed in the cluster rows (some of the countries are too small to be identifiable on the maps).

NB: The criteria clusters represented in the next chapter does not rank countries but rather supplies a guideline based on available country ready indices. Different countries at any point would fall into different clusters and it is important for the countries to prioritise the use case for their country. The cluster should be taken as a starting point.

A3.1.4.1 Use Case: Digital Advisory / e-Advisory

Use case and technologies

According to the Digital AgriHub, which "tracks the development of the digital agriculture (D4Ag) sector in low- and middle-income countries", e-Advisory is the dominant use case of African digital initiatives, page 19 of the **PRIDA Situation Analysis Report** comes to the same conclusion. Depending on the setup of the e-advisory system, digital advisories are either received directly by the farmers, or by an intermediary such as a lead farmer, village-based agent, farmer cooperative or by an extensionist who then transfers to the farmer. Different technologies are available depending on the literacy of the target group, their digital skills, access to technology and networks, the network performance and data costs. Push systems work in one direction only, while pull systems allow farmers to ask for specific advice. The recent decade has seen a lot of extension move from supply to more demand driven models[44]. In most cases, e-advisory systems are an add-on for existing call-centres and on-site advisory systems.

Potentials

Advisory services are established almost in all African countries. However, most extension systems have difficulty reaching out to the high number of farmers. ICT can help to make services accessible to a larger number of recipients. e-Advisory has been shown to be an effective tool[45] to reach more farmers especially in the recent covid-19[46] pandemic[47].

ICT can also help to build a structured knowledge base, to provide contents accessible for extensionists. Innovative systems can deliver hyper-localised and customised advice. AI-driven ChatBots which automatically can deliver suitable answers to specific questions are under development.

Frequently, e-advisory systems are bundled with other services such as aggregation, input delivery, access to finance and even insurance.

Successful examples from Africa

Esoko's Digital Farmer from Ghana is an example of successful implementation of the ideas of digital advisory. The service offers farmers information about financial opportunities, connections to other farmers, market prices for inputs and outputs, weather and climate information services, and good agricultural practices. The service has already helped more than a million farmers in Ghana and other countries.

Econet's EcoFarmer from Zimbabwe provides advisory services to farmers through SMS and website. Farmers can get advisory information, weather-related information, market information, marketing services, financial services and information on their markets using their phone.

CocoaLink is a mobile application for farmers across West Africa, that provides agronomic tips, practical tools ,and critical information, originally based on a successful SMS and voice messages service with the same name. Information shared includes good agronomic practices from production to harvesting, approved input information, and weather forecasts. **CocoaLink** is mainly used by the cocoa farmers in Ghana and Côte d'Ivoire.

AgriBiz from Nigeria is a reference site that aggregates relevant information about the value chain in agribusiness in Nigeria and across Africa It offers

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44 https://www.shareweb.ch/site/Agriculture-and-Food-Security/focus-areas-overview/ras

45 https://www.un.org/esa/dsd/csd/csd_pdfs/csd-17/followup/presentations/kramer-leblanc-2.pdf

46 https://globalagriculturalproductivity.org/covid-19s-impact-on-agriculture-systems-in-africa/

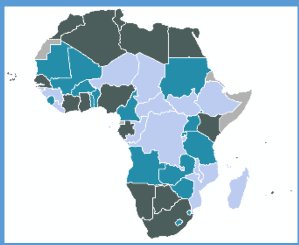
47 https://www.tandfonline.com/doi/full/10.1080/23311932.2021.1918428

Bottlenecks	The percentage of the African population engaged in farming activities is comparatively high to other continents Because of these large numbers the national extension systems fail to reach all farmers. Less than 10% of existing e-advisory systems are government-led (GSMA 2020, p. 39). The systems are complemented by project-driven systems through NGOs or development agencies, and by private initiatives (contract farming). Further to this, the extension systems often are value-chain related so gaps exist in the overall system. When introducing national e-advisory systems, it is essential to take existing systems and processes into account and to build on available knowledge. The aim must be to use existing knowledge in the best possible way and make it available to all service providers. However, it must be said that e-Advisory may not be able to provide all the knowledge necessary for agriculture, on-site demonstration and human interaction still are an important element to successful service.	information about health and safety regulations, most important people and contacts in the industry, factors of success and other useful tips. **SmartCow** is a useful app for Kenyan livestock farmers. It keeps track of herds, sends reminders, suggests information about loans, insurance, quality inputs and feeds, as well as information about access to vets and other cattle experts. For Ethiopian farmers, for whom using a simple phone is more convenient than a smartphone, there is an IVR and SMS service, **Ethiopia 80-28 hotline**, that provides farmers with requested information on the dial or sends out warnings in case of emergency.
Risks	Not all farmers have the necessary literacy level, access to technology, and networks to benefit from e-advisory systems. The introduction of ICT tools can lead to further marginalisation of the already marginalised groups. The **“Leave no-one behind”** paradigm must be at the centre of the services. Many examples exist on the use of social media[48] network groups for the delivery of extension messages. But these groups tend to grow to a size where message traffic grows to an unmanageable size.	

[48] https://www.g-fras.org/en/good-practice-notes/social-media-new-generation-tools-for-agricultural-extension.html

Use Case: Digital Advisory / e-Advisory

Clustering on the basis of Mobile Connectivity Index, Data Price Index and % of pop. using mobile broadband.

	**Technology** Various technologies can be used, from community radio, SMS, USSID, IVR to smartphones and even AI-driven chatbots.	**Infrastructure** e-Advisory is possible only in regions where network coverage or Internet is available.	**Skills** Depending on the skill level of the target group an appropriate technology has to be selected. It is recommended to distribute the advisories through multiple technological channels.
Cluster 1: Algeria, Botswana, Cabo Verde, Egypt, Gabon, Ghana, Ivory Coast, Kenya, Libya, Mauritius, Morocco, Namibia, Nigeria, Senegal, Seychelles, South Africa, Tunisia	A reliable and performant network coverage allows the use of smartphones as end devices enhancing advisory services through the transmission of photos and videos. Furthermore, the GPS functionality allows hyper-localised advisories.	Promote the development of networks in remote areas.	The skill Levels are relatively high, this allows the use of modern app-technologies. The GPS functionalities of smartphones offer potentials for hyper-localised advisories.
Cluster 2: Angola, Benin, Burkina Faso, Eswatini, Mali, Mauritania, Rwanda, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe	In areas with sufficient network coverage and performance but with low digital skills, advisory messages can be delivered through pre-recorded voice-messages.	Promote the development of networks in remote areas.	Farmer-profiling allows customization and localization of advisories.
Cluster 3: Burundi, Central African Republic, Chad, Dem. Rep. Congo, Equatorial Guinea, Eritrea, Guinea, Liberia, Madagascar, Niger, Rep. Congo, Somalia, South Sudan	In areas with very low network performance, advisory delivery has to be based on SMSs (eventually by USSD). Areas without network coverage can be developed through satellite link or by using the TV white spaces, the unused TV channels in any given market to deliver broadband access, services, and applications.	Promote the development of networks in remote areas.	The community radio can still play an important role. The information dissemination can be complemented by additional technologies such as SMS, USSD, and IVR. The advantages of these technologies become visible let farmers buy-in.
RECs	Knowledge bases do not necessarily have to be limited to national boundaries. A regional exchange can be beneficial. However, **local languages** have to be considered and advisories have to be adapted to the local climate, soil, and socio-cultural norms.	Promote the development of networks in remote areas.	
AU	On continent-level, a multilingual knowledge-base has to be developed. The most relevant documents can be automatically translated into the official AU languages.	Promote the development of networks in remote areas.	The documents target researchers, decision makers, extensionists. They usually do not directly target the farmers.

A3.1.4.2 Use Case: Market access / Market linkages / Aggregation

Use case and techno-logies

Price Information systems deliver product-specific daily, weekly or monthly prices for given markets or regions to interested users over the radio, by SMS, by newsletter (email) or to an app. Appropriate technology and robust examples exist, but it is difficult, time and resource-consuming to keep a price database up to date. A dense network of on-site agents is necessary, and the maintenance adds to the cost.

Market linkage systems for mechanisation, extension and veterinary services are robust and simple. However, aggregation systems need a local agent network responsible for quality control. These agents usually can operate smartphones and thus serve as an Interface in case the digital skills of farmers and their access to technology is low.

Additionally, virtual aggregation is a relatively new field. Local agents have to estimate product quality, yields and the optimal harvest date. Typically, this service is bundled with an advisory service which guarantees a good product quality. Produce is virtually aggregated on platforms and can be sold before the products are harvested.

Poten-tials

Access to markets is key for successful agriculture. The knowledge about the demands of customers and prices which can be achieved in other parts of the country and abroad help farmers make appropriate decisions. Market linkages not only link suppliers with customers but also link with service providers such as transporters, veterinary services, cooling and packaging services, processing industry etc.

Bottle-necks

The lack of access to technology of the target group often hinders the use of modern innovative technology (Web and App). It is almost impossible to establish market linkage systems without app- and Web-technology. It is very difficult to build a successful system with low-level technology such as SMS. None the less price information systems can be built with USSD technology. Maintaining price-information services is a tedious job and needs adequate resources. These systems are usually only successful, if they are implemented on government level and if they are integrated into existing agent networks.

Successful examples from the field

UsomiRubi is a platform that offers small-holder farmers across East Africa access to markets and services and helps them receive better price offers. **Usomi** agents verify the quantity and quality of commodities the farmer is offering for sale and upload the information on the **UsomiRubi** platform where the produce is matched with the buyer. When a buyer is found, and the prices are determined by a transparent bidding process, the farmer gets a message to transport the commodity to an aggregation point. Rubi tries to 'virtually' aggregate produce from many farmers in each geographic area to get better prices by offering higher volumes.

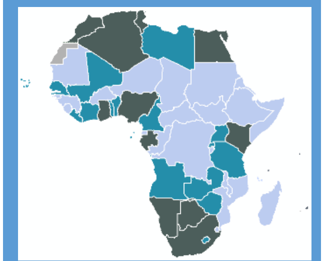
Twiga is another aggregation service from Kenya that offers farmers access to a fair market and competitive prices. **Twiga** collects requests from the offtakers and matches these requests to farmers' capabilities and offers. For farmers that means constant demand, fair prices, and payment within 24 hours. For vendors - fresh produce from a variety of sources, and free timely delivery.

FoodPrint is a digital platform that connects smallholder farmers in Africa with buyers and experts in agriculture. Farmers register with **FoodPrint** and grow their crops. When the harvest is ready to be sold, a farmer can upload all the information into the system. The harvest is then stored in special cold rooms and provided with a QR code that will ensure traceability on its way to the end customer.

Risks	All market information systems share the risk that product quality is mostly unknown. Farmers often do not have the equipment to measure quantities and volumes accurately. If aggregation is done virtually, that is, the produce still on the field the optimal harvest date, volumes and product quality have to be estimated. Side selling might reduce these volumes before a buyer is found and /or exchange rate fluctuations would also influence prices in international trade.	Farmer aggregation is also important when it comes to optimising use of hardware and access to the hardware. Both **TroTro Tractor** and **Hello Tractor** are aggregation platforms that allow farmers to cooperate and share agricultural equipment and learn from the specialists in the field how to best use farming machinery.

Use Case: Market access / Market linkages / Aggregation

Clustering on the basis of the Mobile Connectivity Index, the Data Price Index and % of population using mobile broadband, Financial Inclusion Index FIIAG, status of transport network, urbanisation.

	**Technology** Web- and app-based technologies are most suitable. However, the lack of networks and access to technology forces the use of simpler technologies.	**Infrastructure** Market access and market linkages need transport infrastructure as well as storage and transformation facilities.	**Skills** Product quality is a major issue for all ICT-based systems linking supply with demand. Therefore, skills are required, thus the systems often are operated by intermediates.
Cluster 1: Algeria, Botswana, Egypt, Gabon, Ghana, Kenya, Mauritius, Morocco, Namibia, Nigeria, Seychelles, South Africa, Tunisia	Web- and app-based technologies allow sophisticated systems to be built. Smartphone GPS technology allows to include routing functionality and localised prices.	For market access and market linkage systems to function on a large scale, all service providers along the value chain should be integrated, from input suppliers, agro-dealers, mechanisation services, veterinarians, and farmers to transporters, extensionists and customers.	If farmers don't have the skills or the necessary access to the technology, intermediaries can fill this gap.
Cluster 2: Angola, Benin, Cameroon, Ivory Coast, Lesotho, Liberia, Libya, Mali, Rwanda, Senegal, Tanzania, Togo, Uganda, Zambia, Zimbabwe	The use of SMS, USSD and IVR reaches a larger number of possible users. Hybrid systems can offer the same information through two technical channels (e.g. SMS and Smartphone).	Including transporters as users of the e-commerce and aggregation systems makes the systems complete and efficient.	
Cluster 3: Burkina Faso, Central African Rep., Chad, Dem. Rep. Congo, Equatorial Eswatini, Guinea, Eritrea, Ethiopia, Guinea,	USSD-based systems deliver price information to users with simple phones on demand via SMS. IVR technology can help in reaching farmers who are unable to be reached with	SMS technology is the most robust digital channel. If a user is temporarily out of network reach, he/she will receive the SMS	If the literacy of the target group is low, price information can be delivered through pre-recorded voicemails.

Guinea-Bissau, Madagascar, Malawi, Mauritania, Mozambique, Niger, Rep. Congo, Somalia, South Sudan, Sudan,	written text.	later.	
RECs and AU	Many commodities are transported over borders and finally sold at harbours or towns far away. For farmers and aggregators, the knowledge of the prices is crucial for appropriate negotiation and decision making. The Internet allows the integration of national price information systems into regional initiatives.		Regional exchange on price-information and aggregation systems.

A3.1.4.3 Use Case: Financial Inclusion and insurances

Use case and techno-logies		
	Access to finance[49] is one of the major issues for farmers in Africa. For example, lack of finance for harvest work often forces them to sell their produce early for low prices. Late payments for selling yields often make them miss a full planting season. Finally, the loss of harvests due to natural events and crises leads to the destruction of the economic basis. **Mobile payment systems** streamline payment processes, money is available immediately after transfer. The systems use simple USSD technology and are therefore accessible with a simple phone, if a network is available. These systems typically are provided by the MNOs. **e-Voucher systems** try to bridge the gap by providing alternative finance for specific purchases. Typically, the vouchers are only valid for purchase of specific inputs at qualified agro-dealers. Vouchers are often part of a subsidy system. Technically, they can be as simple as an SMS containing a specific code. While an e-voucher usually entitles the holder to purchase a certain quantity of a specific product, **e-wallets**[50] offer more flexibility and function more like a currency that is only accepted by qualified agro-dealers. Buyers usually pay out part of the yield before harvest in the form of this currency so that smallholders can pay labour for the harvest or prepare for the new planting season. **Index-based insurances** are the answer to the uncertainties caused by climate change. They offer	**Successful examples from the field** **ZuriCap** is a Kenyan invoice financing programme. With **ZuriCap** a supplier can receive payments for their outstanding invoices they have with their buyers. **ZuriCap** also provides short-term credit facilities to farmers. The company leverages technology to operate a paperless process making financing process faster, cheaper, and more reliable. The suppliers are farmers growing maize, wheat, milk, and soya. **Harvesting** is another Kenyan digital solution to improve farmers' access to financial services. In case of **Harvesting** – access to agricultural insurances. The Agri Intelligence Engine used by Harvesting utilises remote sensing data alongside a range of traditional and alternative data points to assess a farmer's creditworthiness. The three main services offered by **Harvesting** are credit risk assessment, farmland monitoring, and land record monitoring. Nigerian company **eFarms** provides a different way for farmers to get access to finance. It provides a linkage mechanism between smallholder farmers and investors. It allows farmers without their

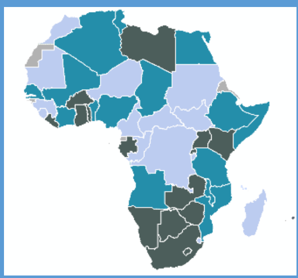
[49] https://agra.org/wp-content/uploads/2020/10/AGRA-Mid-term-evaluation-of-FISFAP-Evaluation-Report.pdf

[50] https://www.rabobank.com/en/raboworld/articles/a-digital-wallet-is-transforming-kenyan-farmers-finances.html

	a way to help farmers withstand extreme weather events by making pay-outs based on triggers rather than actual losses.	own capital to start or expand their farming business. **AgriPME** is an e-wallet from Togo. It allows farmers to receive payments and pay for their inputs without using cash or having to meet the offtaker in person. **Orange Money** from Botswana is a mobile phone-based payment system that allows customers to carry out simple banking operations and transaction such as cashing in and out, transferring money, and paying bills. To aid accessibility of the service it does not require a bank account. **AgroPay** from Zambia is another example of a mobile payment system for farmers. Built and managed by Mobile Payment Solutions. In order to use a mobile payment system **MobiGrow** farmers do not need to have access to the internet or have a smartphone. All the operations can be done over the phone. Farmers can access it by dialling *225# from their mobile phones.
Potentials	Financial inclusion leverages the professionalism of farmers and thus contributes to food security and resilience. Insurance companies can complete these services and interest banks in lending to small farmers as well. Mobile payment services can be integrated into mobile applications for most of the agricultural use cases. In contrast to most other D4Ag use cases, it is relatively easy to develop suitable business models for financial inclusion. But this does not necessarily mean that all farmers can have access to these services.	
Bottle-necks	The delivery of banking services in remote areas without sufficient network coverage and capacities needs workarounds. While transfers within accounts of the same payment system are often cheap or free, transfers to accounts of other systems, or to bank accounts and cash withdrawals are often more costly. Insurance products frequently are difficult to understand, and adoption rates are low.	
Risks	Further to this, the delivery of payment and banking services in remote areas with low population densities is expensive and mostly inefficient. There is a risk to further marginalise these already marginalised areas due to missing incentives for service providers. Insurance products and financial models should aim to fill these associated transaction costs.	

Use Case: Financial Inclusion and insurances

Clustering on the basis of the financial inclusion index, number of available payment services, and the climate resilience index.

	**Technology** Mobile payment and mobile banking systems need no high technology for the end user.	**Infrastructure** Mobile payment systems need a mobile network, and a network of agents or branches to function.	**Skills** Mobile banking needs some digital literacy. But the proliferation of mobile banking in Africa over the last decade has shown that mobile banking in fact has led to an increase in mobile literacy as well as banking literacy.
Cluster 1: Botswana, Burkina Faso, Ghana, Kenya, Liberia, Libya, Mauritius, Namibia, Rwanda, Seychelles, Togo, Uganda, Zambia, Zimbabwe	With a relatively well-developed banking and insurance sector, there is a potential for the introduction of e-wallet systems. Index-based insurances can complete these systems and lead to a high resilience of farming systems, especially in relation to climate change.	The use of smartphone technology for financial inclusion offers new potentials for including and promoting loans and insurances.	It has been observed that financial inclusion through ICT helps developing ICT skills as well as financial skills. Simulation games can help understanding insurance projects and can lead to the necessary behavioural change.
Cluster 2: Algeria, Angola, Benin, Cabo Verde, Egypt, Ethiopia, Ivory Coast, Madagascar, Malawi, Mali, Mozambique, Nigeria, Senegal, Somalia, Tunisia,	National regulation should control transaction costs of mobile money services, especially the service prices for money withdrawals and inter-service transactions.	Mobile payment networks need an agent network which reaches out to the rural remote areas. These services work best, if they allow payments in shops.	The mobile banking systems usually are the systems where people gain their ICT skills.
Cluster 3: Burundi, Cameroon, Central African Rep., Dem. Rep. Congo, Eswatini, Guinea, Guinea-Bissau, Madagascar, Mauretania, Niger, Morocco, Rep. Congo, South Sudan, Sudan	National regulation should foster the development of mobile money services.	Mobile networks should be developed also in remote rural areas.	The introduction of mobile payment services will foster digital skills as well as financial management skills of the agriculturalists.
RECs	Promotion of index-based insurances. They usually rely on a dense monitoring network (meteorological, pest and disease monitoring) – regional observation networks here can help make the services competitive and affordable.	Setup of regional observation networks for climate change, meteorology, pest and disease monitoring.	RECs can promote index-based insurances because this type of insurance often is not understood by farmers, extensionists or banks.

AU			Include index-based insurances into the continental D4Ag knowledge hub.

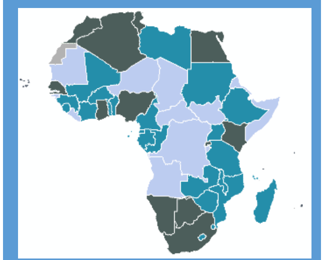
A3.1.4.4 Use Case: Smart Farming

Use case and techno-logies	Remote Sensing (RS) offers sensor technology enabling the mapping of crop type, crop density, crop health, crop water demand and other parameters. LIDAR sensors derive precise digital terrain models for the design of irrigation systems and to estimate crop height. Based on all this data, tractors and other machinery can be automatically controlled to optimise yields, reduce inputs and protect the environment. Optimal harvest time can be modelled as well as transport to the processing plant. Drones allow to derive this data in higher precision at any condition (flying below the clouds) and any given day and time. Ground based sensors measure soil health, plant health, the environment and help to optimise fertilisation and irrigation. Transport, storage and processing likewise is monitored and controlled through sensors and data loggers.	**Successful examples from the field.** UjuziKilimo offers timely weather updates and predictive insights on the weather expectations through SMS for registered Kenyan customers. UjuziKilimo must have visited and analysed the farm first in order to develop customised information for the farmers. VillageLink Satellite Services (VLSS) from Myanmar is a platform that aggregates satellite data related to agriculture and transforms them into key information. Agri-businesses and organisations can use this information to improve their operations and decision making. A native Android app receives localised weather forecast, crop classification maps, yield estimations, allows crop performance and crop growth stage tracking, and flood monitoring. This app also connects the farmers to agricultural professionals and services. PlantVillage, a user-moderated Q&A forum for agriculture, developed the Nuru-App. Using satellite data from the FAO WAPOR initiative, this app allows Kenya's farmers to monitor their crop with eyes from the sky. HelloErf (Ethiopia) is an example of how heavy machinery such as tractors and combine harvesters can be managed better with the use of IoT. This service connects farmers and machinery owners and allows the latter to plan how they rent their GPS-equipped machinery, organise the most efficient use of time and minimise fuel loss and theft. HelloErf equips the machinery with IoT devices that transmit all the necessary data directly to the app that is accessible for equipment owners as well as farmers. This allows farmers to have access to machinery; and tractor owners to manage their equipment in the most efficient way.
Potentials	There is an incredible number of smart farming examples, but not all of them would be adaptable in the African context. If the right expertise is available, energy and data networks performant, reliable and affordable, these technologies may make sense. Contextualization of the smart farming information products can even be translated into simple understandable directives and sent to farmers in SMS format (e.g. fertilisation recommendations based on remotely sensed plant stress maps).	
Bottle-necks	The backbone of African agriculture is still the African smallholder farmer who needs simple and robust solutions for his daily work. He/she is working in remote areas under unpredictable weather patterns and often difficult farming conditions, frequently without access to finance, energy, machinery, mobile networks. Additionally, his literacy level and level of digital skills might hinder him from using modern technologies.	

Risks	The introduction of ICT in agriculture needs functioning business models to develop sustainable solutions. Smart farming solutions typically are expensive as they need technology and data transfer; thus, smart farming solutions work best in countries with high labour prices. On the other hand, smart tech in agriculture can help make farming more efficient and thus can result in higher wage rates. Smart farming is seen as a huge future market; countries should foster and companies should invest in smart farming to avoid falling behind and to keep up with future development trends. Smart farming is seen as a huge future market; thus, countries may have to invest, in order not to match up with future development trends.	**Zenvus Yield** (Nigeria) provides farmers with insights on the vegetative health of their crops. The Yield is a special hyper-spectral imaging camera that works with **Zenvus Web App** to provide farmers actionable information for their farming businesses. By analysing the images, stressed crops, droughts, outbreaks of pests and diseases etc can be seen and managed. The **YieldFly** uses drones but more affordable for farmers is **YieldSky**, a camera which is mounted on a stick to walk around on the farm. Also, with Yield and **Smartfarm** (App for farm management from **Zenvus**) working together, farmers can evaluate the effectiveness of irrigation and fertiliser application by correlating soil data with overall vegetative crop health.

Use Case: Smart Farming

Clustering on the basis of the network performance, data prices, innovation space, drone regulation.



	Technology	Infrastructure	Skills
	Smart agriculture is based on high technologies such as remote sensing, Big Data, machine learning and artificial intelligence. When the mechanisation of agriculture is already underway, tractors and equipment can be programmed to automatically help increase yields while minimising the use of expensive inputs, and thus protect the environment.	Smart farming typically involves the collection of a considerable amount of data. This data needs to be transferred from the sensors to the analytics server, performant data transmission networks and cloud servers have to be available.	The development, introduction, operationalization and maintenance of smart farming systems demands high skills. AgTech innovation hubs can help develop these skills.
Cluster 1: Algeria, Botswana, Cabo Verde, Ghana, Kenya, Mauritius, Morocco, Namibia, Nigeria, Rwanda, Seychelles, South Africa, Tunisia	Performant networks, low data prices and an innovative D4Ag business ecosystem allow the implementation of smart farming technologies. Many satellite data are available for free, crop water demand, plant health, biomass can be modelled and information services can provide this information either to machines or to farmers. The use of drones for agriculture should be considered and any mechanisation of agriculture should keep smart farming in mind.	Smart farming usually works with sensors, data analytics, machine learning, IoT etc, technologies which require continuous power supply and performant data transmission lines. The existence of national data centres, server hosting, worker spaces, tech hubs is a prerequisite.	High skills are required for the development, installation, maintenance and operation of smart farming systems. Tech hubs, worker spaces and cooperation with research centres are key to development. Regional and international exchange is necessary and helpful.

Cluster 2: Benin, Burkina Faso, Cameroun, Equatorial Guinea, Eswatini, Gabon, Guinea, Ivory Coast, Malawi, Madagascar, Mali, Mozambique, Rep. Congo, Senegal, Sierra Leone, South Sudan, Sudan, Togo, Zambia, Zimbabwe	Introduce already existing successful smart farming technologies in areas where conditions are favourable.	Smart farming initiatives can be started in areas with relatively stable and performant Internet and energy supply.	Promote smart farming at universities and research centres. Promote ICT for agriculture already at schools.
Cluster 3: Angola, Chad, Dem. Rep. Congo. Eritrea, Liberia, Libya, Mauretania, Niger, Sierra Leone	Small independent smart farming technologies can be promoted: Smart traps, smart solar cooling containers. If satellite remote sensing data is used, the messages for the farmers must be translated into understandable and usable information packages.	Smart farming technologies need reliable, performant and affordable networks, local server hosting services, and local ICT service providers.	Basic skills in ICT can be part of school education. The potentials of innovative agriculture must be made visible.
RECs	Implement regional early warning systems. Help member countries develop national drone regulation.		Promote regional and thematic smart farming initiatives. Promote academic exchange programs.

A3.1.4.5 Use Case: Climate-smart digital agriculture (Forecasting)

Use case and technologies

Weather forecasts are a simple, yet important D4Ag use case for farmers. With accurate knowledge of the weather in the near future, farmers can make better decisions for sowing, fertilising and harvesting. Accurate forecasts of cyclones, hail storms or thunderstorms help reduce losses of yield and livestock. Typically, weather forecasts and alerts are bundled with classical e-advisory systems as an additional service.

Long-term forecasting helps farmers to prepare for droughts or floods. These forecasts are also relevant for insurance analytics of index-based insurances. This type of insurance is an appropriate answer to the uncertainties caused by climate change. They offer a way to help farmers withstand extreme weather events by making pay-outs based on triggers rather than actual losses.

Pest- and disease warnings are of equal importance and regional collaboration is needed.

The rich information has to be translated into short messages understandable for the farmer. Radio, SMS, USSID, IVR and smartphones are all suitable channels – the later offers highest potentials through the geo-location coordinates provided by the onboard GPS chip.

Successful examples from Africa

UjuziKilimo offers timely weather updates and predictive insights on the weather expectations through SMS for registered Kenyan customers. UjuziKilimo must have visited and analysed the farm first in order to develop customised information for the farmers.

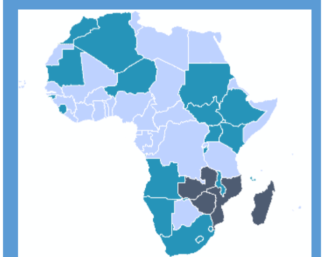
VillageLink Satellite Services (VLSS) from Myanmar is a platform that aggregates satellite data related to agriculture and transforms them into key information. Agri-businesses and organisations can use this information to improve their operations and decision making. A native Android app receives localised weather forecast, crop classification maps, yield estimations, allows crop performance and crop growth stage tracking, and flood monitoring. This app also connects the farmers to agricultural professionals and services.

PlantVillage, a user-moderated Q&A forum for agriculture, developed the Nuru-App. Using satellite data from the FAO WAPOR initiative, this app allows Kenya's farmers to monitor their crop with eyes from sky. HelloErf (Ethiopia) is an example of how

Poten-tials	Climate events are of regional nature, they have cross-border effect, thus, early warning systems for climate as well as pest- and disease control should be understood and built as regional systems. The costs of such systems are quickly returned as these systems not only help to increase the resilience of the farm systems but also contribute to minimising crop losses. More and more satellite data today are freely available and can be integrated in regional or national early warning and weather forecasting systems. The use of GPS through smartphone-technology allows hyper-localised weather forecasts. Farmer profiling (location, crops) enables customised warning and alert messages even for SMS and IVR recipients.	heavy machinery such as tractors and combine harvesters can be managed better with the use of IoT. This service connects farmers and machinery owners and allows the latter to plan how they rent their GPS-equipped machinery, organise the most efficient use of time and minimise fuel loss and theft. **HelloErf** equips the machinery with IoT devices that transmit all the necessary data directly to the app that is accessible for equipment owners as well as farmers. This allows farmers to have access to machinery; and tractor owners to manage their equipment in the most efficient way. **Zenvus Yield** (Nigeria) provides farmers with insights on the vegetative health of their crops. The Yield is a special hyper-spectral imaging camera that works with **Zenvus Web App** to provide farmers actionable information for their farming businesses. By analysing the images, stressed crops, droughts, outbreaks of pests and diseases etc can be seen and managed. The **YieldFly** uses drones but more affordable for farmers is **YieldSky**, a camera which is mounted on a stick to walk around on the farm. Also, with Yield and **Smartfarm** (App for farm management from **Zenvus**) working together, farmers can evaluate the effectiveness of irrigation and fertiliser application by correlating soil data with overall vegetative crop health.
Bottle-necks	Weather information is available free of charge today, but often not accessible to farmers in most remote areas. Pastoralists often stay in inaccessible areas where there is neither electricity nor mobile networks. If only SMS technology can be used, messages have to be reduced to 160 characters. If different languages are spoken, messages have to be prepared accordingly.	
Risks	Ground stations for measuring precipitation or water levels are often the target of vandalism, solar panels often subject to theft. It is therefore extremely important to protect the stations accordingly, for which it can make more sense to involve local manufacturers than to buy expensive international products.	

Use Case: Climate-smart digital agriculture (Forecasting)

Clustering on the basis of the climate risk index (CRI)

	**Technology**	**Infrastructure**	**Skills**
	High-tech satellite-based remote sensing, ground-based sensor networks, transmission technology, data analytics, Geomatics, GPS help identifying and forecasting. Smartphone technology, simple phones and radio as end devices to receive alerts and warnings.	Access to data, data sharing, transmission lines and mobile network coverage.	While high skills are necessary to develop, maintain and manage these systems, the end user should not need any skills to understand the messages. Messages should be delivered in local idioms.
Cluster 1: Madagascar, (Malawi), Mozambique, Zambia,	A regional system for weather forecasting and flood modelling, combined with localised warning	The setup and operationalization of early warning systems not only need networks and end	The necessary capacities exist at the level of the international (and

Zimbabwe	messages for the basins of Zambezi, Limpopo, Pungwe, Save, Buzi.	devices to reach out to the people, it also incorporates the setup and operationalization of notification and emergency command chains. Regional systems need real-time access to data from national hydrological networks. Stations and transmission lines need to function in times of extreme weather events.	national) basin authorities. The Limpopo basin authority has a relatively good flood warning system. These systems can be connected to the farming sector.
Cluster 2: Algeria, Angola, Burundi, Ethiopia, Guinea-Bissau, Kenya, Malawi, Mauretania, Morocco, Namibia, Niger, Sierra-Leone, South Sudan, Sudan, Uganda,	Regional systems for drought early warning systems should be set up by RECs. Member countries have to support the process. If warnings are to be sent to end users, regional systems have to consider the variety of local idioms.	As the systems provide long-term information, immediate access is not required. Thus, network performance plays a minor role.	Information on drought probability and water scarcity are of specific relevance for index-based insurances.
All countries	Weather forecasting can be done on a national or regional scale. Respective data is available on the Internet for free and can be incorporated into existing or new e-advisory systems through APIs.	Local weather stations can refine weather forecasts. WMO registered stations are already included for the generation of weather forecasts. Many technologies exist for data transmission.	Weather forecasts must be sent through multiple technology channels such as radio, push SMS, USSD and smartphone apps, messages must be clear and in local idioms.
RECs	Regional flood and drought early warning systems should be supported and set up by RECs. Recipients of alerts can be national authorities which then would activate appropriate national measures.		National ministries usually take care of emergency communication and activities. Thus, the regional systems process the information, but national authorities are responsible for emergency plans.

A3.1.4.6 Use Case: ICT for climate-smart irrigation

Use case and techno-logies

Africa bears a high potential for irrigation agriculture. But in some many regions, the renewable resources already are overexploited due to inefficient irrigation practices. In other regions, population growth and rising standards of living are leading to higher water consumption, both domestic and agricultural. Digital applications for improving efficiency and for monitoring agricultural water use play an increasing role in this debate on irrigation. On the one hand, ICT can support technical processes for minimising irrigation water volumes and reducing the use of fertilisers as well as for energy savings in irrigation technology. On the other hand, apps can often facilitate management processes and the monitoring of irrigation and operating systems.

Irrigation can be improved in many ways through monitoring. Today, satellite-based meteorological forecasts allow relatively precise predictions about precipitations even in regions without rain gauging stations installed. For accurate local water resources management, however, a network of level sensors is indispensable. Irrigated agriculture also influences other environmental areas, such as soil fertility (salination, water logging) and erosion and residuals in the final products. Monitoring therefore plays a far greater role than just in connection with water resources and their use. Next to water resources monitoring, soil parameters, vegetation and erosion have to be monitored too.

Potentials

ICTs help automating irrigation, reduce water consumption, reduce labour costs and enhance yields through solar pumps, sensors, controllers and transmission technologies. Machine learning and artificial intelligence help optimising irrigation efficiency and apps allow monitoring and remote control. Spatial technologies help assessing water resources, planning irrigation schemes, monitoring water consumption and environment. Satellites, drones, sensors, remote sensing and GIS help to create a global picture for decision makers at a higher level. Through serious games, e-learning and access to ICT-based training material, knowledge can be shared and behavioural change triggered. Understanding the complex environment of irrigation helps protecting resources, increasing smallholders' incomes and enhancing environmental sustainability.

Bottle-necks

The high initial costs of automatic and solar irrigation systems discourage farmers from opting for them. But electricity services are not always available, affordable and reliable enough. Especially for small scale irrigation high-tech solutions are rarely suitable. High investment and operating costs cannot be financed by individual farmers.

Knowing about scarce water resources does not

Successful examples from Africa

To make informed decisions about irrigation, farmers need to have a good grasp on the conditions of the soil. **Chameleon**, a system of smart soil sensors, is already used by farmers in Mozambique, Tanzania, Zimbabwe. The sensors provide farmers with an easily understood readout. The **Chameleon** soil water system has been designed to be inexpensively manufactured, simple to install, and easy to understand. An additional suite of tools allows measuring salt and nitrate levels.

Watermark by **Zenvus Smartfarm** offers similar services. Electronic sensors which when inserted in a farm soil collect data like humidity, temperature, pH, moisture, nutrients etc and wirelessly transmit the data to a cloud server where computational models help to calculate the current crop situation. The hardware is powered by solar energy with a battery backup. To communicate with the hardware, farmers use the free **Zenvus** Web App which works on desktop and mobile. Connectivity is provided via WIFI, GSM and Satellite but manual data collection with microSD card is provided as well. It has in-built GPS and compass to help validate and authenticate the locations.

Rainmaker2 from **Sun Culture** is an example of smart hardware for irrigation. This smart solar powered irrigation system is already used by many Kenian farmers. The system provides water to households and livestock, and is also equipped with a smart notification option.

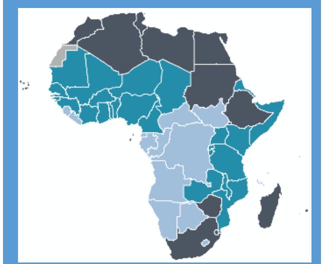
Ferme Digitale from Niger is a smart irrigation solution that offers farmers such functionalities as smart bio-fertilization and automatic watering. **Ferme Digitale** provides the irrigation hardware including solar panels, mobile weather scanners in remote areas and telecommunication hardware and software needed for remote-control.

Phyt'Eau is a platform linking agriculture and the IOT (Internet of Things) for the management of real-

Risks	automatically mean that farmers are more careful with it. Behavioural change is required which needs assistance and time. Switching to solar pumping eliminates the costs for fuel. This often makes farmers over-irrigate which not only affects the local water resources but also decreases yields. Automation of irrigation here can be a remedy. In India, energy not used can be fed into the public grid on a remunerated basis and provides therefore an incentive for the farmers to pump less water.	time irrigation. **Phyt'Eau** is a solution that allows the prediction of doses of irrigation based on sensor information. The **Phyt'Eau** platform connects intelligent sensors to a high-performance analytical system for monitoring the water status of crops and for real-time irrigation management.

Use Case: ICT for climate-smart irrigation

Clustering on the basis of the Irrigated Agriculture Index and the FAO Water Stress Index

	**Technology** Solar pumping and irrigation automation need ICT: hardware, software and data transmission. Mobile devices can be used to control and monitor irrigation.	**Infrastructure** Solar pumping makes connection to the electricity grid obsolete. Sophisticated automatic irrigation systems can function independent from any service.	**Skills** Automated irrigation systems still need skills to install, maintain and operate them. They usually are not suitable for small-scale irrigation.
Cluster 1: Algeria, Cabo Verde, Egypt, Ethiopia, Libya, Madagascar, Mauritius, Morocco, Réunion, South Africa, Sao Tomé, Sudan, Tunisia, Zimbabwe	Large scale professional irrigation allows the introduction of high-tech automatic solutions. SCADA-systems connected to soil moisture sensors and weather forecasts allow optimising irrigation, fertilisation and yields.	Irrigation systems can be operated independent from the electricity grid or mobile network coverage. There exist various technologies for data transmission from sensors to control units independent from the mobile network.	Installation, maintenance, and operation of large-scale automatic solutions need extensive local knowledge. Countries in this cluster typically have a vital sector of professional service providers. The sector can be leveraged through subsidies, education initiatives, the sector also bears a high export potential for technology.
Cluster 2: Burkina Faso, Benin, Burundi, Cameroon, Chad, Eritrea, Ghana, Ivory Coast, Kenya, Mali, Malawi, Mauretania, Mozambique, Niger, Nigeria, Senegal, Somalia, Tanzania, Togo, Uganda, Zambia	Small-scale irrigation needs affordable solutions for plots of typically 0.5-2ha. In East Africa, there exist leasing-models for solar pumps for as less as 5USD per day. Farmers can join forces and share the equipment in farmer groups.	Solar-operated irrigation systems can operate elsewhere in Africa, they do not need any connectivity.	The small-scale irrigation solutions operate without sensors for soil moisture, thus the necessary skill level for farmers is low. There exist also simple and easy-to-read independent soil moisture sensors.

Cluster 3: Angola, Botswana, Central Africa Rep., Comoros, Dem. Rep. Congo, Equatorial Guinea, Gabon, Liberia, Namibia, Rep. Congo, Sierra Leone, South Sudan,	Irrigation systems are only sporadically in use. Water stress is low; thus, no automation of irrigation is needed.		No specific skills needed.
RECs			

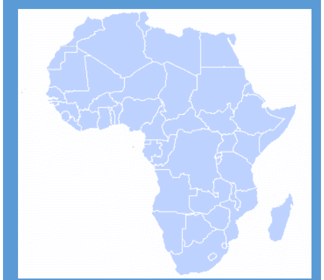
A3.1.4.7 Use Case: Data sharing and data access

Use case and techno-logies	Many international organisations regularly collect statistical data on agriculture and digitalisation. FAO, the World Bank, GSMA, ITU and others are publishing yearbooks, bulletins, offering dynamic dashboards with mapping functionality for free. Meteorological data is provided by WMO and national data centres, biomass, water demand, and other agricultural rele-vant data can be accessed, by those with good Internet connectivity. National ministries, departments and research centres often have more detailed, more accurate and more recent data available on their servers and in their data repositories. Sharing of this information with those who require it for decision making, will improve the efficiency of agriculture, thus the incomes of farmers and their resilience for shocks through extreme weather events or another crisis. ICT offers many ways to make information accessible and usable for all sorts of stakeholders. From radio transmission via SMS, USSD, IVR to sophisticated smartphone apps and web sites.	**ONAGRI Tunisia** is a National Data Portal that offers data on all aspect of agriculture over multiple years, provinces, and regions of the country. **FAO WAPOR** is a database created by FAO for public access and crucial for research and data driven solutions. It contains variables associated with water and land productivity assessments, such as evapotranspiration, precipitation, NDVI and biomass productivity. Apart from WAPOR that focuses on land productivity, FAO has numerous other dataset and statistical data pages that are focused on different aspects of agriculture, including FAO AQUASTAT database. **REAL-GUD** is the East African Groundwater Database which consists of the information accumulated through IoT devices, namely solar powered water pumps and irrigation systems. The database is open and serves to improve understanding of irrigation needs and tasks. The **Africa Soil Information Service (AfSIS)** is developing continent-wide digital soil maps for sub-Saharan Africa using new types of soil analysis and statistical methods and conducting agronomic field trials in selected sentinel sites. These efforts include the compilation and rescue of legacy soil profile data, new data collection and analysis, and system development for large-scale soil mapping using remote sensing imagery and crowdsourced ground
Potenti als	Access to statistical data as well as to operational real-time data allows the development of a variety of applications. There are many tools already available delivering data from all around the world, mostly based on satellite remote sensing. The availability of open data already gave a push to the development of sophisticated solutions for agriculture and water management. More investments into data regulation and policies will further accelerate the digital transformation.	
Bottle-necks	Often, available national data is not shared except on a commercial basis. Due to a lack of money, national departments must seek alternative sources of income. Selling data might create income in the short run. But a faster development, a more efficient agriculture and a higher resilience of farmers will, on the long run, have a larger effect on the national economies.	

Risks	Accessing information requires skills, access to technology (radio, mobile phones, smartphones, computers, data). There is a risk that the introduction of innovative information technologies marginalises the already disadvantaged part of the society. The quality of data is not easy to assess. If data is presented in a colourful way, it is rarely questioned. Thus, there is a risk that decisions are made on the basis of erroneous or outdated data. Therefore, it is essential to provide comprehensive metadata, which describes the author of the data, the collection, validation and processing steps, the date of collection/processing, the data collector, the data owner and other descriptive items along with the data itself..	observations. **Prep-eez** is an organisation that seeks to improve farmers' possibilities to access information and data. This goal is achieved by working together with Mobile Network Operators and other relevant stakeholders. The team has over the years successfully developed technological solutions that are being utilised by other African countries to boost business processes and transactional solutions.

Use Case: Data sharing and data access

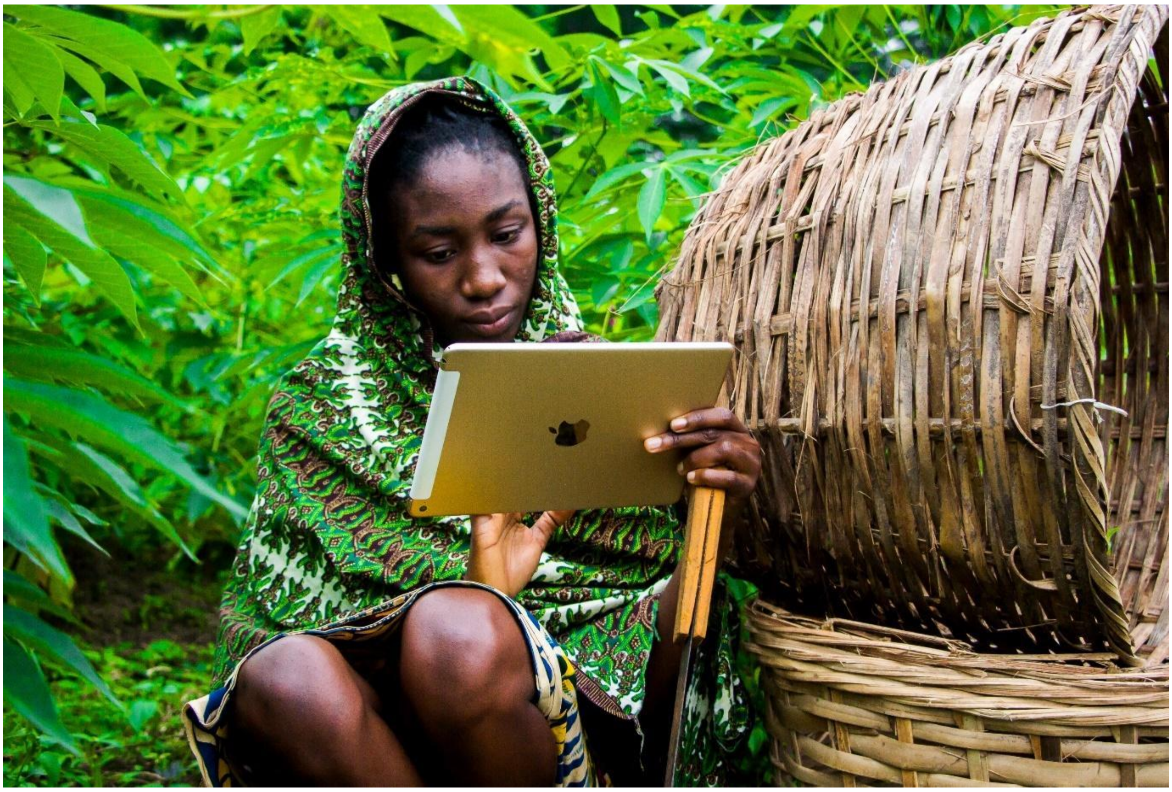
Clustering is not useful here. Instead, activities are presented in three gradations of complexity.

	**Technology** Various technologies exist to make data available to interested users. The most common channel is the Internet but information can also be shared digitally by SMS, USSD or even on static CDs, DVDs or memory sticks.	**Infrastructure** Today, data is shared by using the Internet. Rarely, CDs and DVDs are produced. Thus, Internet has to be performant and affordable so that interested agriculturalists can access the required data.	**Skills** Data can be processed so that contents are made visible without interpretation. Raw data from satellites, drones and other sensors first need validation, analysis and interpretation, appropriate software and skills.
Level 3: high complexity	The national databases can provide application programming interfaces (APIs) which allow developers to integrate the data from these databases dynamically into other applications.	Integrated systems have a high connectivity. Data from various sources gets requested and received, a performant and reliable Internet connection and is thus a prerequisite.	The integration of Web services and Web Map Services (WMS) asks for high programming skills as well as higher end user capabilities to handle these applications.
Level 2: medium complexity	Web sites coupled to the databases can give interested users dynamic access to the data. These web portals can be empowered by GIS and export functionalities.	The larger share of African Internet users uses smartphones to open Web sites. Web sites should follow responsive Web design, a technology which offers Web contents depending on the used device.	Navigating on Web pages needs certain skills. Secondary education should initiate children to a sensitive use of the Internet.
Level 1: low complexity	National databases should be made accesssible for the public. In a first step, this can be done in the	Reports and bulletins should be made available for download in form of native PDFs. Internet	

	form of reports and bulletins, digitally for download.	connection quality often is insufficient for their download.	
RECs	Regional knowledge hubs allow a direct exchange on D4Ag topics. Information about lessons learned should be shared as well as success stories.		RECs should build D4Ag skills at the national level of member states. This considers the agricultural ministries as well as the infrastructure/ICT ministries.
AUC	The AUC can provide a data portal for agricultural information. Also, a knowledge base for D4Ag should be made available in all official AUC languages.		AUC should build D4Ag skills in DARBE and IED, through working groups, forums and an accessible knowledge hub.

A4 Cross-cutting initiatives

A4.1 Gender inclusion



There is much written about women's role in all phases of agricultural production and across agriculture value chains in Africa. It is well-documented that women's immense contributions, especially in small-scale farming, is disproportionate to the benefits they reap. While women comprise the majority of agriculture labour, they have less access to credit, inputs, tools, extension services, and the kind of technology intended to catalyse productivity. Reviewing current projections, the One Campaign state

> *Agricultural productivity for female farmers in a sample of sub-Saharan African countries is an astonishing **23%-66%** lower than that of male farmers… Globally, providing female farmers with the same access to productive resources as male farmers (i.e., closing the gender gap in agriculture) could increase agricultural yields by 20–30%, raise economic output by 2.5–4%, and reduce the number of people who go hungry by 12–17% (100–150 million people).”*[51]

Technology for agricultural productivity is transforming the sector quickly, with new private sectors entering the market monthly. The need to boost food production globally is spurring huge investment in such things as precision farming, the use of drones, big data, internet of things, and supply chains. The more revolutionary the technology, however, the greater the gap for women farmers to access and use these digital tools for all the reasons already discussed. The AU Digital Agriculture Strategy (DAS) can illuminate the need to

[51] Walker, E. 2015. “Male farmers are up to 3 times more productive than female farmers.” https://www.one.org/international/blog/male-farmers-are-up-to-3-times-more-productive-than-female-farmers/.

address this gender gap for the economic benefit of the entire sector. In doing so, it is key to look at gender gaps through a holistic lens that includes women and girls, but also men and boys as their support in gender equality is key to any successful intervention that champions gender parity.

As stated in the inception report, the "development of a Digital Agriculture strategy is a complex task, as the continent is very diverse in terms of climate, geography, culture, technology level, human development index." Adding a gender lens to digital agriculture is an additional degree of complexity, but necessary to fulfil the transformative potential of what we will refer to as "D4Ag," based on common development vernacular. The inception report states that "females play an important role in African agriculture and the introduction of modern innovative ICT-based solutions in agriculture must be gender-responsive." The accompanying presentation given to the African Union in Fall 2021 also demonstrates the challenge of being gender-responsive as there is little research data about the specific gender D4Ag divide, other than the many anecdotal regional studies that show women do not use the many applications designed to improve farming.[52] Only 25% of mobile-owning female farmers in Kenya's Rift Valley use their mobiles for agricultural information, despite the dozens of applications that have been deployed up and down this regional breadbasket.[53] Second-hand phones, misinformation from social media, and other gendered factors inhibit rural women's use.[54]

The D4Ag sector is often defined by the outputs and economics. Gender equality is not an obvious component of this sector unless people are specifically aware of the inequities in resource allocation and opportunities. It is only when carefully studying gaps in productivity that gender enters the conversation. Cornell University's "Study on Digital Agriculture Technologies" shows that out of 7000 digital agriculture reports surveyed, only 26 mention gender. Of those, most studies discussed the positive outcome of women using ICT to access extension education; there were no studies that looked at women and digital market linkages.[55]
The AU's Agenda 2063 specifically lists women's agricultural involvement as part of Aspiration 1, Goal 5: Modern Agriculture for increased productivity and production with an aim of increasing the number of women commercial farmers. However, agriculture is not listed in the gender equity and empowerment indicator, nor are there any ICT and agriculture indicators. This is not to say that governments and organisations do not understand the critical role women play in the agriculture sector.

Goal 5: Modern Agriculture for increased productivity and production

Priority area	Agenda 2063 Target	Indicator	Corresponding SDG Indicator
Priority Area 1. Agricultural productivity and production	1. Double agricultural total factor productivity	Total factor productivity	
	2. At least 10% of small-scale farmers graduate into small-scale commercial farming and those graduating at least 30% should be women.	(a) % of small-scale farmers graduating into small-scale commercial farming by Sex	
	3. End Hunger in Africa	a) Prevalence of moderate or severe food insecurity in the population based on the Food Insecurity Experience Scale (FIES)	2.1.2

[52] Sterling, R. Agrilinks. 2021. "Why Women Aren't Using Your Ag App." https://agrilinks.org/post/why-women-arent-using-your-ag-app.

[53] Krell, N. et al. 2021. "Smallholder farmers' use of mobile phone services in central Kenya, Climate and Development. Climate and Development. https://www.tandfonline.com/doi/full/10.1080/17565529.2020.1748847.

[54] Wyche, S. and Olson, J. 2018. "Kenyan women's rural realities, mobile Internet access, and "Africa Rising." Information Technologies & International Development. https://itidjournal.org/index.php/itid/article/view/1595.html

[55] Porcello, J. et al. 2021. "A Systematic Scoping Review: How are farmers using digital services in low- and middle-income

Leading development organisations such as FAO advocate for national digital and e-agriculture strategies to take gender into account.[56,57] FAO states that it is "critical that any digital strategy should be gender sensitive and participatory" and that "closing the technology gap requires that the necessary technologies exist to meet the priority needs of female farmers, that women are aware of their usefulness, and that they have the means to acquire them."[58] Kenya's national policy includes specific references to women and technology in its policy commitments:

"In order to address the above issues, the agricultural sector actors will:

- *Facilitate both female and male farmers to scale up value addition for increased profitability.*
- *Invest in improved,* ***gender responsive and accessible technology*** *to enhance the ability of both male and female farmers to add value to agricultural products and earn more from them.*
- *Advocate with regulatory bodies for an enabling environment for agro-businesses.*
- *Build the capacity of agro-entrepreneurs to equip them with skills along all the value chains e.g., business planning, securing finance, processing, quality control, compliance with regulatory requirements, marketing and financial management."*[59]

From a technology provider perspective, investing in rural women farmers is "a major market opportunity for the mobile industry that also offers substantial social benefits" to an underserved but unique customer segment.[60] According to GSMA, female farmers required a thoughtful, tailored approach as they are more "invisible," have different price sensitivities, invest more back into their families (thus strengthening development overall), and have less access to technology.[61] This toolkit recommends a variety of design questions that mobile network providers can use to better reach and serve female clientele.

However, according to a report by Strategic Impact Advisors, most technology providers and D4Ag developers drastically underestimate women's roles in potentially using their services - estimating women's involvement in agriculture value chains at 20 percent, instead of the more accurate 50 percent, and thus not prioritising women's specific barriers to ICT.[62] This represents a significant opportunity loss as digital agriculture offers unique prospects to women who face significant social norms such as not being able to leave their homes or attend schooling or trainings: "Digital tools like advisory services and market linkage can allow them to access products…these tools have the potential to increase women's ability to organise and work collectively – one of the most significant drivers of women's empowerment."[63]

This report suggests three key ways for technology providers to engage women, noting these recommendations require significant engagement from all stakeholders who advocate for women's empowerment, agricultural productivity, and overall poverty reduction:

1. Reduce barriers to women's use of mobile technology, such as improving their confidence to use mobile devices;
2. Design tools for women in the areas of agriculture where they tend to be more active, such as seedling raising and sowing, processing, or feeding for livestock or fish; and
3. Engage women in the design and

countries?" https://ecommons.cornell.edu/handle/1813/103771.

[56] FAO. 2016. E-agriculture Strategy Guide. http://www.fao.org/in-action/e-agriculture-strategy-guide/en.

[57] Sophie Treinen, S. and van der Elstraeten, A. FAO. 2018. "Gender and ICTs - Mainstreaming gender in the use of information and communication technologies (ICTs) for agriculture and rural development." http://www.fao.org/documents/card/en/c/I8670EN/.

[58] FAO. 2011. "The State of Food and Agriculture. Women in agriculture: Closing the gender gap**."** http://www.fao.org/docrep/013/i2050e/i2050e.pdf.

[59] Republic of Kenya. 2013. "AGRICULTURAL SECTOR GENDER POLICY." https://publicadministration.un.org/unpsa/Portals/0/UNPSA_Submitted_Docs/2018/2B59EE82-1EB8-43D3-922B-1D54625BA13D/GENDER%20POLICY_AGRIC_KENYA_3.pdf?ver=2018-02-12-151630-320.

[60] GSMA. 2014. "Women in Agriculture-a Toolkit for Mobile Services Practitioners." https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2014/06/Women_in_Agriculture-a_Toolkit_for_Mobile_Services_Practitioners.pdf.

[61] FAO. 2011.

[62] SIA. 2020. "USAID/Bangladesh Digital Agriculture Assessment Follow-on: An updated review of the AgTech landscape for Feed the Future." https://pdf.usaid.gov/pdf_docs/PA00WRBB.pdf.

[63] *Ibid*.

promotion of D4Ag wherever possible.[64]

The PRIDA gender-responsive review coincided with a focus group held with 30 D4Ag and gender advocates from Africa and South Asia who provided feedback about the challenges of gender mainstreaming in D4Ag, and who agreed to share their insights in the service of PRIDA.[65] One expert stated that there are so many things to think about when designing D4Ag that a gender perspective gets lost or ignored: "There is no gender consideration in D4Ag programming. The number one priority "should be involving the real women farmers from grasp." This was echoed unanimously. Another practitioner shared:

"To target gender in ICT we should design projects with specific focus on gender. Most of them (agtech projects) I have seen that gender/ women's engagement or empowerment is just an add-on. The value chains that were targeted are male dominated. So, in reality, it is extremely difficult to address the bottlenecks and achieve the objective of women's engagement and empowerment. ICT itself is a challenging arena due to the lack of connectivity, social norms and practices etc. So, if women's empowerment through ICT is to be addressed, the project needs to identify value chains that are female-friendly and already engagement is there. Once an example and/or business case can be set with those value chains, then there will be possibilities for scaling up as well."[66]

Other concrete recommendations included the need to develop content and context that resonates with women, the use of intermediaries with smart phones to reach out to female farmers, and the need to create D4Ag opportunity and onramps where women will generate income quickly to show its value, and the requirement of D4Ag providers need to sensitise husbands so that they enable their wives. Four types of success stories stood out that can be replicated to larger development aims: add education and health content to D4Ag services that women use, create leadership roles for women to engender trust with men about women's ICT use, build incentives into women's' D4Ag use that can be redeem locally for goods, and publicly recognize men who support women's D4Ag and larger ICT use.[67] A synthesis of reports that discuss gender equality in D4Ag iterate the need to mainstream women's participation in D4Ag deployments, pay attention to the sociocultural norms and roles that reduce women's presence, and to budget for the investment that is required to reach and train women.

These findings were supported and added to by a series of interviews with female agriculture entrepreneurs conducted for this report. Respondents were solicited with help from CGAIR's gender team, and shared the following about how governments could better assist women in the value chain:

- The government should subsidise inputs to empower and encourage women and youth in agriculture (Nigeria).
- Invest more funds and efforts to scale up successful projects/innovations; it's been difficult to get governments to move beyond and build strong broad-based partnerships unless there's political motivation (Ghana).
- Government should take more action on coordination; there are too many cooks doing siloed activities; the government is well placed to ensure better coordination, collaboration, and more effective use of resources (Kenya).
- Financing for women farmers/agritech start-ups (microfinance and collaborative finance/insurance, supportive schemes for land property or other assets ownership/ shared ownership) (Ethiopia).

In an agricultural country like Uganda - we need to improve the language of technology and agriculture at a policy through to media level. It remains exclusionary in favour of men while women appear as props. The aforementioned statement then impacts on women ag-tech- preneurs who have to navigate a landscape that to some extent doesn't recognise them or their audience. This is further reinforced by costs associated with data and/or digital access that weigh heavier

[64] *Ibid.*

[65] USAID internal focus groups held for Feed the Future report on AgTech – June 2021.

[66] *Ibid.*

[67] *Ibid.*

on women than they do men. (Uganda)

The five women interviewed did not want their names used. However, in her 2016 Quartz Africa article, m-Farm founder and Kenyan Jamila Abass wrote about closing her initially well-funded start-up, citing these necessary steps that the government needs to take to catalyse digital agriculture enterprises: (1.) Secure the natural resource base. (2.) Alternative financing options are a must for smallholder farmers who are largely cash-strapped and unbanked. (3.) Institutions must ensure timely payment of farmers to allow farmers to progressively access bigger and better markets. (4.) Prioritise crucial infrastructure.[68] These are areas where the AU team could provide guidance and support; financing, infrastructure, and gender inclusivity also apply to any female-led education and health businesses.

Any conversation of gender and D4Ag would be remiss if it did not discuss the application of digital financial services (DFS), such as mobile savings, credit access, and crop/weather insurance programs. Women are active users of mobile money, and the latest Global Findex Database shows a sharp uptick of DFS adoption by women from 2011-2017, although access to DFS is also gendered -- women are still 33 per cent less likely than men to own a mobile money account.[69] Likewise, DFS efforts in the Agriculture sector are growing, providing an "an active and diverse, yet nascent, landscape" that can "improve aspects of a smallholder farmer's quality of life and that of other rural agricultural actors by expanding access to financial services, improving resilience, and raising income.[70] While there are many private-sector and NGO-based DFS programs that support women farmers and women's-led agriculture savings groups[71] [72], there do not seem to be examples of direct government programming to women in the agriculture value chain, according to CGAPs gender community of practice. Thus, there is a large opportunity for African governments to promote state-led gender equitable DFS programs to strengthen the D4Ag sector.

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[68] Abass, J. 2016. "I built a mobile app to help Africa's farmers but our countries' infrastructure must work too." https://qz.com/africa/603214/i-built-a-mobile-app-to-help-africas-farmers-but-our-countries-infrastructure-must-work-too/.

[69] GSMA. 2021. "State of the Industry: Report on Mobile Money 2021." https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/03/GSMA_State-of-the-Industry-Report-on-Mobile-Money-2021_Full-report.pdf.

[70] IFC. "Digital Financial Services for Agriculture." https://www.ifc.org/wps/wcm/connect/3d053636-c589-47ac-865d-731068f0736e/Digital+Financial+Services+for+Agriculture_IFC%2BMCF_2018.pdf?MOD=AJPERES&CVID=moq-VoG.

[71] World Bank. 2021. Women in Agriculture Using Digital Financial Services: Lessons Learned from Technical Assistance Support to DigiFarm, Fenix, and myAgro." https://openknowledge.worldbank.org/handle/10986/35471 .

[72] World Bank. 2017. "Mobile Technologies And Digitized Data To Promote Access To Finance For Women In Agriculture." https://documents1.worldbank.org/curated/en/855471513670397514/pdf/Mobile-technologies-and-digitized-data-to-promote-access-to-finance-for-women-in-agriculture.pdf.

A4.2 Youth in D4Ag

About **70%** of the population of the African continent **is under 30 years of age**. This number is expected to increase. Youth are the future of the African continent; they should be seen as a resource and it is important that future strategies take this into account. Young people are usually **very fond of mobile technologies**, and they look to the urban world to build a future for themselves. Youth are turning away from agriculture, and greater efforts need to be made to attract young people to agriculture. In this regard, **digital agriculture offers an excellent opportunity** to engage youth more. The role of youth in digitizing African agriculture is well documented. Youth play an important role in providing innovations for African agriculture. Digital agriculture has been argued to be a major contributor to attracting and retaining youth in agriculture. In addition, rural youth[73] are a major labour force for agriculture and are responsible for production and value addition and diversification. **Young agri-entrepreneurs** are another important component of youth participation in agriculture. The youth are fast in adopting digital technologies and are therefore more inclined to adopt technology-mediated agricultural innovations to upgrade farming practices and operations. However, there are limitation to their participation, rural youth[74] unfortunately do not have capital, nor do they have access to credit due to lack of land or assets that would guarantee the financing. Further to this they lack skills for creating and managing their businesses. Most financial institutions do not consider the youth as reliable business partners and therefore do not provide the financing that the youth would need to develop and bring to scale their innovations. The private sector can create financial models that would allow for these innovations to thrive.

Given the important role the youth play for the digital transformation, they need to take an active role in communicating their needs and collaborating with the various other stake-holders. They can play an active role in the implementation of the DAS:

1. **Agri-entrepreneurship** through value addition along the value chain, con-solidation of produce for markets, use of drone technologies, provision of services, e.g. mechanisation, packag-ing, commerce etc.
2. **Tertiary education** that includes the use of digital tools in agriculture and contributes through research and development. Through theses and dis-sertations, new innovative approaches can be promoted, and the application of these technologies and their socio-economic impact can be better explored.
3. **Advocacy** and **resilience** building through participating in climate change dialogues and ensuring that the needs of the youth are met as the future of the continent.

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[73] https://www.ifad.org/ruraldevelopmentreport/
[74] https://www.ifad.org/documents/38714170/41187395/08_White_2019+RDR+BACKGROUND+PAPER.pdf/8c891caa-12f1-783e-3b88-7e2b903c66de?t=1632400832835

A4.3 Digital agriculture career

The future of labour is determined by the implications of the 4th industrial revolution. The COVID-19 crisis has significantly exacerbated the labour landscape everywhere in the world and put more pressure on the African markets and economies. E-careers imply the readaptation of workers to new economic demands including readjustment of skills such as digital literacy and digital knowledge; support through policy, regulatory and private initiatives the youth, entrepreneurs and SMEs active in technology-intensive sectors or in economic sectors that require a shift towards digital technologies as there is untapped potential for higher, sustainable productivity; development of local digital innovations, and enable low-skilled workers to reorient towards worker-enhancing technologies. In short, **e-careers** are jobs involving digital technologies that require adequate human capital[75]. Most rural income in African countries emerges from farming activities. Food systems are expected to generate more than 70% of all jobs by 2025 in selected countries such as Ethiopia, Malawi, Mozambique, Tanzania, Uganda and Zambia. Agriculture by itself is the largest employer across the continent and it represents a sector with a multitude of opportunities for rural young people. Digital agriculture careers imply specific skills and knowledge that have the potential to be channelled towards the young labour force to get involved in productive, more ecological and sustainable agriculture. African youth are often deterred from working in this sector, but the shift towards innovation and new disruptive digital technologies aims to attract and integrate youth in the agricultural sector. In other words, the main driver of **digital agriculture careers** is the African youth which must be supported in the long-term with investments in education at all levels and a robust business environment that can support incomes and agricultural value chains. Essentially, digital agriculture careers are understood as the research and exploitation of innovations in farming technologies applied by smallholder farmers to the supply chains and national and international commodity markets. Such shift in labour force on the African continent would release the pressure on the rural communities, increase employment opportunities, decrease poverty rates and

[75] https://openknowledge.worldbank.org/bitstream/handle/10986/32124/9781464814440.pdf?sequence=11&isAllowed=y

migration to urban areas[76]. Digital griculture can pave the way towards more, better and **qualified jobs** in the food and agriculture sector and represent a way to encourage the youth to access professions in the sector also trough development of **skills and vocational education**[77]. In this sense, digital agriculture career can bridge the **gap between urban and rural communities** and facilitate the youth a viable roadmap for business success in the agriculture sector. One facilitating route is represented by partnerships between international institutions and national governments, NGOs and the private sector leading to the creation of **multi-stakeholder alliances for digital skills and jobs**. All these stakeholders are key to boosting the needed expertise on market needs and digital skills. This comprehensive alliance would create educational curricula and would implement appropriate knowledge transfer strategies, training and exchange programmes. **Digital innovation hubs and research centres** should provide the required mentorship and knowledge to encourage youth to pursue digital agriculture careers. These initiatives can be accompanied by regional qualification frameworks and incentivize a proper system of mechanisms where **ICT centres of excellence** would be enabled to provide accredited training programmes following market needs. In this manner, the rural youth can find greater attractiveness and opportunities in agriculture, farming and related sectors (processing, logistics, sales, agronomists, etc.).[78] Strategic linkages (training, internships, etc.) between research institutes, digital innovation hubs and young agripreneurs and rural youth can unlock the untapped potential for digital agriculture careers in African countries and favour digital enabling solutions developed in urban centres to be practically implemented in agriculture areas.

Governments, donors and investors are recommended to invest or **increase investments in training**, digital literacy programmes, promote knowledge sharing and initiatives that can allow a digital agriculture in Africa sector to develop, thrive and prosper in a sustainable and inclusive way and represent a solid source of economic and social prosperity[79]. The expected impact of these types of initiatives with focus on digitalised agriculture is envisioned to lead to greater youth interest in agriculture as digitalisation increases sector **attractiveness for the young; job creation and attraction** as well as improving the conditions and quality of existing jobs in agriculture; new employment layers in farming and adjacent sectors that can oversee and foster greater digital uptake in agriculture practices (e.g. farm agents, processing jobs) and finally it can contribute to an already growing market based on new high-tech employment opportunities (e.g., D4Ag software development, data collection and analytics, hardware development, trade and maintenance).[80]

[76] https://reliefweb.int/sites/reliefweb.int/files/resources/africa-agriculture-status-report-2015.pdf

[77] https://www.worldbank.org/en/topic/food-system-jobs

[78] https://www.cta.int/en/digitalisation-agriculture-africa

[79] https://www.cta.int/en/digitalisation-agriculture-africa

[80] https://www.cta.int/en/digitalisation-agriculture-africa

A4.4 Climate-smartness

Climate-smartness needs to be integrated in agricultural policies as it aims to be an integrative approach targeting issues such as food security and climate change. Climate-smart agriculture (CSA) has three pillars: **productivity, adaptation, and mitigation**. The goal also considered as the "triple win" is to implement an integrated approach for cropland, livestock, forests and fisheries to increase and improve nutrition security, raise agricultural incomes; enhance resilience in managing climate risks and reduce emissions from food production[81]. At the same time, FAO advances five action points: *expanding the evidence base for CSA, supporting enabling policy frameworks, strengthening national and local institutions, enhancing funding and financing options, and implementing CSA practices at field level*[82].

Climate-smartness is acknowledged as a mid to long-term intervention. The World Bank has developed some indices that can help CSA gain traction with a view to implementing climate-smart practices, key technologies that fit national and local contexts, monitorization of results and policy assessments. These indicators include **CSA Policy Index**, CSA Technology Index and CSA Results Index[83]. CSA Technology indicators are used to foresee ex-ante applications on all three pillars in order to use the most appropriate technologies during concrete project and instrument implementation. The tech indicator is used to assess the cost and long-term benefits, deciding on the optimum technologies to be used in a certain context. These actions can lead to **reduction of climate risk uncertainties** and render the best results if they are applied in context specific environments, without aiming for a generalisation of results. Therefore, CSA indicators and interventions must be monitored in accordance with the needs of each agricultural area (soil, water, natural resources); farmers' equipment, existing agricultural infrastructure, and the financial advantages of implementing specific technologies and practices[84].

As a panacea to climate-smartness, **CSA methodologies** follow three phases: targeting and prioritisation, implementation and monitoring and evaluation (M&E). Strategic decisions for prioritisation of applications across all three CSA pillars have four stages. First, CSA Prioritisation Framework (CSA-PF) supports policy and decision makers in how to best target investments for CSA interventions. Second, the CCAFS compendium of CSA practices with numerous technologies and applications geographically distributed and depicted according to potential benefits can serve to evaluate the available options for each case in point. Third, the impact of these options must be evaluated in the context of different dimensions (social, environmental, economic). Fourth, **all relevant stakeholders** should engage in a portfolio analysis to identify which options render most benefits in order to prioritise CSA investments. **Key assessment tools** can include *Climate-Smart Agriculture Prioritisation Toolkit*[85], *Mitigation Optimisation Tool*[86], *Ex-Ante Carbon-balance Tool (EX-ACT)*[87] and *Participatory identification of climate-smart agriculture priorities*[88]. Climate-smartness outcomes imply transformation at different levels from farmers' involvement to governmental policies, access to finance and involvement of CSA providers.

CSA implementation includes tools such as

[81] https://www.worldbank.org/en/topic/climate-smart-agriculture

[82] https://www.fao.org/3/cb5359en/cb5359en.pdf

[83] https://openknowledge.worldbank.org/bitstream/handle/10986/24947/Climate0smart0agriculture0indicators.pdf?sequence=1

[84] https://openknowledge.worldbank.org/bitstream/handle/10986/24947/Climate0smart0agriculture0indicators.pdf?sequence=1

[85] https://cgspace.cgiar.org/rest/bitstreams/38402/retrieve

[86] https://ccafs.cgiar.org/mitigation-options-tool-agriculture-0#.VxYb4_mLRaR

[87] http://www.fao.org/3/a-i3325e.pdf

[88] https://cgspace.cgiar.org/rest/bitstreams/78307/retrieve

technical guides and manuals translated into local languages and adapted to local farming conditions; use of checklists to identify the current infrastructure and additional local needs for early warning systems implementation as it was shown in the case of Horn of Africa[89]; **technical guides** for weather index-based insurance programmes scaling up from successful pilot projects[90]. So far, CSA country profiles to assess methodological baselines have been developed for Benin, Côte d'Ivoire, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Rwanda, Senegal, Tanzania, The Gambia, Uganda, Zambia and Zimbabwe[91]. Climate-smart agriculture investment plans have been developed for Côte d'Ivoire, Mali and Zambia, with additional ones being in progress (Burkina Faso, Cameroon, Congo-Brazzaville, Ghana, Lesotho, Namibia and Zimbabwe)[92].

Practices of CSA are strongly dependent on local/national contexts, agricultural focal points. **CSA technologies** thus require inclusiveness to achieve uptake with the involvement of farmers, private actors, governments and development project leaders. Different initiatives have been implemented in various African countries (e.g., Kenya, Tanzania, Ghana, Ethiopia) [93]. Existing technologies (e.g., WaPOR) that tackle climate-change risks become more **difficult to scale-up** if they are not integrated in agricultural policies and instruments, financially supported as CSA practices, and locally used by farmers[94]. For this reason, CSA has "multiple entry points" that include not only farm level digital technologies to tackle climate change issues, but also the development of climate change models that include interventions in the food system, landscape, value chain, and/or policy level[95]. Esoko is a good practice example of digital CSA tool implemented in Ghana which collects and transmits weather information to farmers[96].

CSA requires holistic applications. The United Nations (UN) **Climate Technology Centre and**

[89] https://www.fao.org/3/ca0227en/CA0227EN.pdf

[90] https://csa.guide/csa/what-is-climate-smart-agriculture

[91] https://ccafs.cgiar.org/resources/publications/csa-country-profiles

[92] https://www.worldbank.org/en/topic/agriculture/publication/climate-smart-agriculture-investment-plans-bringing-climate-smart-agriculture-to-life

[93] https://www.worldbank.org/en/topic/climate-smart-agriculture

[94] https://www.fao.org/3/cb5359en/cb5359en.pdf

[95] https://cgspace.cgiar.org/rest/bitstreams/60479/retrieve

[96] https://ccafs.cgiar.org/resources/publications/ transforming-food-systems-africa-under-climate-change-pressure-role

Network (CTCN) advanced the concept of digital innovation as a "match-maker for climate technology transfer". Digitalisation in CSA means lower prices, simplified usage, better decision-making, sustainability and profitability of agricultural business models. At the same time, the success of CSA digital tools depends on financial resources, regulatory environments and digital literacy which are pressing needs in rural areas of African countries. Lessons learned from Digitalisation Technical Assistances (D-TAs) covered early warning systems, environmental information and resource management systems optimisation. In Ivory Coast, **CSA digital tools** have been implemented in terms of climate data integration systems and community-based monitoring platforms. In Ghana, crop resilience to drought through early warning Satellite data (crop, climate, soil moisture condition). CTCN has proposed a way forward based on a general analysis of critical challenges and needs. Hence, digitalisation is needed for climate risk prediction (early warning systems); decision-making for climate policies (environmental information systems); and optimisation of climate resources (resource management systems). Main barriers to this endeavour have been identified as lack of climate/digital datasets; limited digital capacity and lack of new digital markets in this field.

The way forward involves the conduct of simultaneous strategies for **climate technology transfer innovation** such as: i) collaboration with climate stakeholders, global database partners and digital companies; ii) co-creation of new D-TA projects with local SMEs; iii) online provision of marketplace and public dissemination for successful D-TA results[97]. A scalable example is provided by Norway which has developed an open-source technology platform for prognosis, monitoring and decision support for integrated pest management (IPM) in agricultural crops. The platform has been developed in collaboration with the Norwegian Agricultural Extension Service and has been financed by the Norwegian Ministry of Food and Agriculture. The solution designs pest risk models and relevant early warning systems and is sufficiently adaptable to be scaled at international level. The **operationalisation of the platform** in a country implies the involvement of an advisory organisation/ extension service within a university or similar organisation in order to set up the software. Currently, VIPS is adapted for use in Mali, Niger and Malawi. VIPS as a standalone tool seeks to become complementary to other integrated pest management elements such as diagnosis, identification, monitoring and advice and become part of an international platform for digital plant health services[98]. Africa RISING has been implementing automated irrigation systems in Tanzania, Ethiopia, Malawi, Ghana and Mali using automated drip kits for harvests. The results showed yield increased, returns on investments were higher, labour effort was lower, soil was better protected and water saved[99]. Regarding solutions such as solar pumping, the main inhibitor is the limited financing. Smallholder farmers need to afford these types of tools. Governments can include the subsidising of these types of appliances in their national agriculture plans. Private companies can pursue either crowdfunding or attract different types of public-private investments to enable the installation of solar pumps on agricultural lands. Farmers can be supported with schemes such as **"pay-as-you-go"**, in order to relieve them from the financial burden[100]. Other relevant examples are ripping instead of tilling technologies implemented as a pilot project in East Africa to improve soil health and fertility. This has been co-initiated by Hello Tractor, PAFID (Participatory Approaches for Integrated Development) and CGIAR. In this respect, Hello Tractor has developed a digital platform to encourage the use of this technique in agriculture, in the hope it is able to attract more smallholder farmers in Eastern Africa to pursue this type of practice for their soils[101]. As crop productivity is heavily

[97] Lee, Woo-Jin and Mwebaza, Rose, Digitalisation to Achieve Technology Innovation in Climate Technology Transfer, MDPI, December 2021, Available at https://www.mdpi.com/2071-1050/14/1/63/htm

[98] https://nibio.no/en/subjects/plant-health/vips--a-digital-pest-prediction-platform

[99] https://africa-rising.net/automated-irrigation-as-a-game-changer-for-farming-in-sub-saharan-africa-is-it-enough/

[100] https://www.lightingglobal.org/wp-content/uploads/2019/09/PULSE-Report.pdf

[101] https://www.euractiv.com/section/agriculture-food/news/boosting-climate-smart-agriculture-through-

dependent on rainfall on the African continent, "hyper-local" digital solutions have been developed to support smallholder farmer planning of their crops. In West Africa, the agCelerant platform implements a combined approach of both **physical and digital agriculture solution** where prototype rain gauges offer weather based critical information to all stakeholders involved in the agricultural value chain from farmers to financial service providers, potential investors and governments, thus leveraging climate risks. This practice has been implemented in Kenya, Tanzania and soon to be deployed in Ghana, Ethiopia, Mali, Burkina Faso and Senegal[102].

In general, any type of CSA digital tool for IPM or early warning, in order to be sustainable, should be based on interoperability systems. To collect data faster, farmers can deliver real-time information on their crops through mobile phones to either extension agents or plant scientists. Crop data collection is essential for plant doctors in order to validate, share and use data to develop projections for future crop productions and inform farmers. Kenya has started to use e-clinics where plant doctors use tablets to fill in factsheets with collected data and using Plantwise (a dedicated app for data collection) enabling them to benefit from peer-to-peer support in finding solutions to pest and disease problems. A next step would entail an integration of such systems with **weather-based data sets and satellite imagery.** This implies the support of both governments and technology providers to create integrated pest management digital solutions[103].

CSA practices and actions can give best results if applied depending **on regional requirements, needs and challenges**. As the examples above-mentioned reveal, scaling up CSA technologies such as early warning digital systems or integrated pest management systems depend on the cumulated involvement of the private sector, policy makers and farmers at both national and regional level. FAO encourages that National Adaptation Plans (NAPs), Intended National Determined Contributions (INDCs), National Appropriate Mitigation Actions (NAMAs) and Agriculture Investment Plans need to be evidence based and adapted to specific contexts and needs of the agriculture landscapes across African countries. **Monitoring and Evaluation** (M&E) is essential in assessing the impact of CSA, their standardisation and regulation at country level and cooperation at regional level in order to share key data and develop integrated models for climate-smart agriculture. Digital platforms for transfer of knowledge should be accompanied by interoperable technological repositories and should target farmers as well as CSA providers[104].

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access-to-ripping-technology/

102 https://www.euractiv.com/section/all/opinion/matching-farmers-to-innovation-in-africa-makes-communities-resilient-to-climate-change/

103 https://www.p4arm.org/app/uploads/2015/02/uganda_crop-pests-and-disease-management_full-report_vWeb.pdf

104 https://www.fao.org/fileadmin/user_upload/gacsa/docs/POLICY_BRIEF_-_CSA.pdf

A4.5 Rural digital literacy

Capacity building needs to be applied at all D4Ag value chain levels to increase rural digital literacy. The scale-up and success of digital technologies in agriculture is directly dependent on the capacity of farmers, extensionists, agro-dealers, logistics, processing industry, marketing and consumers to effectively use digital tools and apps[105].

Increased rural digital literacy levels is all the more strategic, since **niche and localised solutions** have started to emerge in various agricultural sub-sectors in African countries, but their scale-up encounters barriers due to low digital literacy levels among smallholder farmers. This aspect prevents a majority of farmers to be more connected with a larger portion of the **value chain**, rendering digital technologies to favour wealthier farmers[106]. By the same token, digitally literate intermediary actors can make a change comparative to traditional extension agents, agro-dealers, agro-vets as they would play a more direct and transformative role in the relationship between private entities, in this case technology companies, and smallholder farmers. These **intermediary agents** should receive training directly from technology companies, hubs, incubators, accelerators and other formal and informal models of education. It is also an opportunity to attract the youth back to not only rural areas, and to also to create new job segments in the agriculture sector where young people in African countries can be attracted to Therefore, digitally literate intermediary agents will be able to directly support smallholder farmers with using not only digitally advanced, but also targeted technologies to tackle the main challenges in crop production and will be well-equipped with the necessary know-how to ensure the sustainability of those solutions in the

[105] https://digifyafrica.com/industries-in-africa-digital-literacy-essential/

[106] https://www.cta.int/en/digitalisation-agriculture-africa

agriculture context[107]. In this respect, digital literacy requires a coordinated approach from governments, donors and private actors so that the D4Ag penetration and digital literacy levels in rural areas can take place faster and be able to bypass the barriers and market disruptions posed by traditional intermediaries[108]. In maximising the impact of D4Ag, the scope and length of this complementary initiative should be directed at "human intermediation". Private actors developing **innovative solutions** can allocate resources in support of the **digital education** of smallholder farmers. Moreover, this is an approach that can be integrated into their business growth strategies. Donors can coordinate actions within their projects towards digital literacy training. Governmental flagship programmes for digital education of farmers can positively impact the spin on D4Ag in African countries[109]. **Rural digital literacy** is also key in addressing the demographic and geographic digital divide. Therefore, the simple existence of technological tools in rural areas is insufficient in addressing digital literacy issues. All societal groups should receive training to acquire, improve and keep up with new digital skill developments[110]. Gender digital divide is an additional challenge. Half of the agricultural workforce includes women in Eastern and Southern Africa. They receive limited compensation due to cumulated factors such as climate change, uncontrollable weather conditions, low soil quality and overall gender inequality. In many countries, women start from a disadvantageous position, unable to own land due to specific regulatory frameworks. At the same time, financial services such as banks or insurance stakeholders limit the access to their services for women. These elements hinder women from conducting long-term sustainable agriculture. Current digital technology advancements favour closing the gender digital gap. The incorporation of advanced technologies in the farming processes supports an increased crop productivity and quality irrespective of gender and actively helps the integration of women into the agricultural value chain. Rwanda has launched the initiative **"buy from women"** boosting an adoption of digital agriculture technologies in order to help women farmers connect with the agricultural supply and value chain. Kenyan women have been supported to adopt and use smartphone applications that predict the weather and thus supporting them in cultivating premium quality crops. The Uganda Network is actively working with women to use digital technologies in order to create profiles with their crop data[111]. Moreover, private entities such as Vodacom, a well-known MNO across the continent, has launched the project *Female Farmers Programme* destined for increasing the digital agriculture literacy for rural women smallholder farmers while simultaneously promoting them and their production output[112].

Since the **digital divide is unequal**, the goal should focus on universal access to digital knowledge. To this end, there are propositions which imply a coordination of capacity building in digital literacy based on rural segmentation, adaptation to individual and regional market needs and correlation between the educational level; farmer specialisation and existing digital technology solutions[113]. Furthermore, good practices show there is a pressing need of a coagulated response at the level of both government and private actors to close the gender digital divide gap in the agriculture sector as it will both empower women in this field as well as rebalance the uneven infrastructure, policy and strategic frameworks concerning digital literacy levels across the African continent.

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[107] https://ictupdate.cta.int/en/article/the-potential-of-digital-agriculture-in-africa-sid0bb634e64-d72a-4d29-a4e9-acde09785b7b

[108] https://agra.org/wp-content/uploads/2020/09/ Knowledge-series-Ghana.pdf

[109] https://www.cta.int/en/digitalisation-agriculture-africa

[110] https://osjournal.org/ojs/index.php/OSJ/article/viewFile/2984/382

[111] https://www.nepad.org/blog/gendering-agriculture-empowering-african-women-farmers-using-modern-technologies

[112] https://venturesafrica.com/hundreds-of-sa-female-farmers-empowered-in-vodacom-digital-skills-initiative/

[113] https://www.sciencedirect.com/science/article/pii/S2589721721000362

A4.6 Rural financial inclusion

Since a large proportion of people live in rural areas, financial inclusion in African countries is both a challenge and an opportunity. Main challenges to be overcome are represented by **lack of network infrastructure** and bank branches in rural areas and affordability of financial services. Many local initiatives based on ICT tools and solutions such as **mobile platforms** have been tested for identification of local market prices, property and land registration, purchase agricultural insurance and provide access to private equity. Nonetheless, these initiatives have room for scaling up and increase the **financial inclusion of small-scale farmers** in the agribusiness sector[114]. Rural financial inclusion through digital technologies means better control for farmers over their own income, increased savings rates; more efficient, transparent and traceable payments contributing to a more resilient and cost-effective value and supply chains[115]. Rural financial inclusion can take many forms and sometimes even cumulatively in order to cater to different needs of smallholder farmers. Recently, a relevant initiative has been implemented by FAO using an agri-voucher platform developed in Somalia and transferring it onto a digital platform in Mozambique where women farmers can access it to buy seeds and fertilisers[116]. An e-voucher system is preferred to a conventional one as it can monitor and evaluate smallholder farmers' needs for agriculture inputs in real-time and with much greater transparency. Several pilot projects have been rolled out in countries such as Lesotho[117], Burkina Faso[118] or Zambia[119]. Each project had both challenges and positive effects. Therefore, the replicability of these solutions depends on several factors such as simple and user-friendly e-voucher systems, consolidated trust between farmers and agro-dealers, awareness and provision of higher quality agriculture inputs and the need to avoid unintentional market distortions generated by governments, NGOs or UN Agencies. In Mozambique, the success and scalability of this initiative has been the result of creating e-voucher systems tailored according to farmer segmentation (subsistence/emerging), close cooperation between the developers of the system and central/local governments to identify beneficiaries and register them on the platform. Essentially, these types of digital solutions are the result of a concerted effort between public entities, service providers, NGOs and inclusion of smallholder farmers with potential of rendering traceable, secure and reliable financial services for the most vulnerable populations[120]. E-wallets also represent a viable digital solution that has the ability to cut through bureaucracy and intermediaries in the agriculture value chain. In one of Ghana's poorest rural regions with very low access to private financial services and banks, an initiative between a local NGO (ASI) and AGRA's programme Financial Inclusion for Smallholder Farmers in Africa introduced the concept of digital wallets to Ghanian smallholder farmers. MNOs such as Vodafone and Bharti Airtel supported agribusinesses (input suppliers, product buyers, etc.) to integrate in their process digital payment solutions. Farmerline provided assistance with tracking and processing e-payments from smallholders. On the other end, farmers received basic financial and digital literacy training to understand how to operate with mobile money transactions[121]. In Kenya, Agri-Wallet[122] has been developed as a free app for

[114] https://www.rfilc.org/wp-content/uploads/2020/08/Financial_Inclusion_in_Africa.pdf

[115] https://documents1.worldbank.org/curated/en/915271601013162558/pdf/Digitization-of-Agribusiness-Payments-in-Africa-Building-a-Ramp-for-Farmers-Financial-Inclusion-and-Participation-in-a-Digital-Economy.pdf

[116] https://www.fao.org/news/story/pt/item/1375626/icode/

[117] https://www.fao.org/africa/news/detail-news/en/c/1460280/

[118] https://agra.org/wp-content/uploads/2021/01/Revised-Electronic-Voucher-System-Brings-Transparency-to-Agricultural-Subsidy-Programme-1.pdf

[119] https://www.balancingact-africa.com/news/telecoms_en/26064/zambia-to-implement-e-voucher-system

[120] https://www.fao.org/3/I9140EN/i9140en.pdf

[121] https://agra.org/news/how-digital-payments-simplify-cash-flow-for-african-rural-economies/

[122] https://agri-wallet.com/

mobile payments destined to smallholder farmers. It is connected with the M-Pesa platform and it acts as a business account for farmers giving them access to loans from private lenders, a platform to sell produce to buyers, a direct connection with agriculture input suppliers (C2B) and access to state subsidies (C2G). Agri-Wallet is envisioned to work internationally through the integration of blockchain in its platform in the near future[123]. Underinvestment is one of the main challenges in African agriculture. **Crowdfarming** platforms are an ecosystem by themselves on the continent. Still in an infant stage, crowdfarming platforms developed by agri-tech start-ups have emerged in several countries - Agripool in Ghana, Farmcrowdy in Nigeria, AgriCrowdfunding in South Africa[124], iFarm360 in Kenya[125] to name a few. Scaling up crowdfarming depends deeply on land ownership and the incentives for farmers to invest in their soil for high quality produce, insurance of crops and farmer training for state-of-the-art agriculture techniques. The future outlook shows that crowdfarming has the potential of offering localised solutions and transforming African agriculture into sustainable socio-economic development where agritech companies provide a trustworthy link between private investors and African governmental strategies to enhance the role of agriculture in their countries[126].

Digital finance services in rural areas need to follow a different approach from the urban ones. First, they need to be adapted to the irregularity of agriculture revenues of smallholder farmers; a customer service that has enough presence on the ground to help and educate farmers in making use of digital financial services; protection against transaction fraud, mobile connectivity and public-private partnership to enhance rural connectivity infrastructure; coordination between tech providers of digital finance solutions, service providers, central and local governments and smallholder farmers; adapt financial inclusion to rural realities (expansion of mobile money solutions); provide targeted services including private and/or governmental support for crop insurance; access to knowledge and information on farming methods and market prices that can increase agricultural incomes[127]. **Digital finance** can also be a game changer in terms of partnerships between MNOs and microfinance providers to develop what is known as "digital credit" such as has been developed by HaloYako in Tanzania. Mobile service providers already have established and growing customer bases, therefore such partnerships with traditional microfinance institutions. Microfinance providers can also form partnerships with technical service providers or fintechs directly[128].

The success of financial inclusion in rural Africa should follow two simultaneous approaches: a supportive **regulatory environment and a business model** that relates directly to the challenges of African farmers. For instance, mobile money become a feasible and scalable option in the framework of a public-private partnership where national central banks partner with mobile network operators and financial institutions to regulate the fluctuations of mobile payments[129]. There is considerable untapped potential in Sub-Saharan Africa for **mobile money and digital payments**. This alternative has gained traction due to its cost-effectiveness, secure channels and benefits to the agricultural value chain. Some rural areas are financially integrated through agent networks who apply direct payments to farmers for agricultural crops (B2P)[130]. Private sector actions should also aim for an agreement at supply/value chain levels for the adoption of digital payments. In this respect, an entire sector can embark on the transition towards greater financial inclusion in

[123] https://www.cta.int/en/digitalisation/article/agri-wallet-a-wallet-for-smallholder-farmers-sid00f60f624-f62a-4b58-bd27-bd2c838b724f

[124] https://agricrowdfunding.co.za/

[125] https://www.ifarm360.com/crowdfund

[126] https://african.business/2020/08/agribusiness-manufacturing/agritech-platforms-revolutionise-farming-investment/

[127] https://www.ifad.org/documents/38714170/40185433/dfs_teaser.pdf/3f055c11-380e-443c-bc1b-be7a8dbeb2aa

[128] https://www.afi-global.org/sites/default/files/publications/2018-08/AFI_AfPI_Special%20Report_AW_digital.pdf

[129] https://media.africaportal.org/documents/saia_sop_210_oji_20150224.pdf

[130] https://www.gsma.com/mobilefordevelopment/resources/agri-dfs-emerging-business-models-to-support-the-financial-inclusion-of-smallholder-farmers/

rural areas. **Partnerships** between agriculture stakeholders and digital payment service providers (PSPs) can also favour smaller transaction fees through bulk payments if all the value and supply chain actors are onboard[131].

However, the main challenge constitutes the current limitations of mobile money – instant digital payments cannot be used immediately for other purchases at local level. Governmental subsidy schemes are also distrusted by smallholder farmers because the funds do not arrive immediately. In the short-term, digitalisation in agriculture can accelerate financial inclusion in rural areas through government to person (G2P) payment schemes[132]. In this respect, governments should implement targeted actions for the rural DFS ecosystems and ease the process of **converting e-money to cash** reducing the financial burden for farmers[133]. Regulatory frameworks dedicated to digital payments and control over the taxation of digital services should be reviewed by governments in order to incentivize rural financial inclusion. A governmental top-down approach in terms of **digitalisation of public services and resources** of agriculture ministries will enable the acceleration of digitalised payments. Development partners together with African countries' governments, PSPs and local financial institutions need to implement targeted actions to consolidate and build the necessary ICT **infrastructure** in rural areas, create single **digital platforms** to expand acceptance of e-money, increase traceability of transactions for small farmers, achieve interoperability between supply and demand, achieve financial stability and increase the availability of CICO (cash in-cash out) points. In this respect, taxation in areas with no CICO points or agents should be subsidised as much as possible; attraction of DFS rural agents, thus increasing the network in the underserved areas; and limiting additional transaction fees can lead to greater financial inclusion.

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[131] https://documents1.worldbank.org/curated/en/915271601013162558/pdf/Digitization-of-Agribusiness-Payments-in-Africa-Building-a-Ramp-for-Farmers-Financial-Inclusion-and-Participation-in-a-Digital-Economy.pdf

[132] https://www.cta.int/en/digitalisation-agriculture-africa

[133] https://documents1.worldbank.org/curated/en/915271601013162558/pdf/Digitization-of-Agribusiness-Payments-in-Africa-Building-a-Ramp-for-Farmers-Financial-Inclusion-and-Participation-in-a-Digital-Economy.pdf

A4.7 Digital Agriculture Innovation

The **Goal 9** of the Sustainable Development Goals, "**Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**", implies that without technology and innovation, development will not happen. Improving agriculture research, technology dissemination and adoption is one of the four priority areas of the continental framework **Comprehensive African Agricultural Development Programme (CAADP)**.

Innovative technologies play a key role and the **digital agriculture innovation space** in African countries is continuously developing. Most agri-tech hubs are located in Kenya (58), South Africa (46), Nigeria (34) and Ghana (15). These countries have the largest penetration of technology incubation and acceleration hub ecosystems in Sub-Saharan Africa. Kenya ranks first not only due to its **techhub density**, but also due to the fact that over 70 percent of its population uses mobile money [134]. Other relevant countries with technological hubs are Senegal and Ivory Coast in West Africa; Morocco, Tunisia and Egypt in Northern Africa and Zimbabwe and Uganda in Eastern Africa[135]. Nonetheless, the scalability of agri-tech innovation spaces depends greatly on several factors: regulatory environment, access to finance, human capital, infrastructure and cultural integration[136].

While local governments have a rather limited involvement in the incubation ecosystem, international development organisations have extended their presence at regional level in developing innovation spaces focused on the agricultural sector. The scope of these innovation spaces such as hubs, incubators or accelerators focused on ICT4Ag is to coordinate with the identification of local initiatives and disseminate funding opportunities to attract local entrepreneurs. These global practices with local impact include the organisation of innovation bootcamps within the WFP Innovation Accelerator where local entrepreneurs have the opportunity to pitch their idea and become eligible for funding, mentorship and access to a global network of leaders in the digital agriculture sector[137]. Two success stories are brought by the **iREACH technology park** as the first West African Agriculture Technology Park, with a second one soon opening in Ghana[138]. WFP has also launched the **IGNITE Innovation Hub** for Eastern Africa region as an extension of WFPs Innovation Accelerator. The goal is to create strong liaisons with key digital agriculture stakeholders from NGOs to start-ups and private sector companies to test, pilot and scale-up innovations in agri-tech, food systems, food value chains, nutrition, social protection, energy and smallholder farmer support[139].

The most essential aspect to be drawn from these developments is that innovation spaces on the African continent can better function in **ecosystem frameworks** where bundling solutions from research to proof of concept and pilot solutions can be adapted to the farmers' needs and challenges[140]. Many start-up initiatives and businesses are still acting within a fragmented innovation ecosystem. For this reason, **regional centres of excellence, national research institutions, private sector initiatives** can better scale up and become sustainable within functional models dedicated to supporting smallholder farmers and their access to knowledge as well as engagement with innovative technologies developed by key stakeholders[141]. Innovation

[134] https://olc.worldbank.org/system/files/59440_ASA%20Exec%20Summ_bleeds-crops.pdf

[135] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/03/Africa

[136] https://olc.worldbank.org/system/files/59440_ASA%20Exec%20Summ_bleeds-crops.pdf

[137] https://innovation.wfp.org/eastern-africa

[138] https://www.agridigitale.net/art-first_west_african_agriculture_technology_park_opens_doors_to_public.html

[139] https://innovation.wfp.org/eastern-africa

[140] https://openknowledge.worldbank.org/bitstream/handle/10986/33961/9781464815225.pdf?sequence=2&isAllowed=y

[141] https://reliefweb.int/sites/reliefweb.int/files/resources/WFP%20FOOD%20SYSTEMS%20REPORT_FINAL_FOR%20PRINT_26.01.22.pdf

spaces have a fair chance of becoming scalable once governments, entrepreneurs, investors, and smallholder farmers form an ecosystem that seeks, tests and launches digital solutions for typical challenges that prevent harvest losses, educate farmers towards using digital technologies, encourage governments to launch funding schemes and persuade key local actors from fintech, academia and the start-up field to create partnerships for digital innovation in African agriculture[142]. Therefore, disruptive agricultural technologies in Africa should provide solutions to agricultural productivity, market links, data intelligence, financial inclusion and alternative sources of energy[143]. In this sense, **technological parks** can be viewed as an enlarged and inclusive partnership framework acting as a supportive mechanism for both private investors, innovators, public actors and smallholder farmers. Investments in innovative technologies within technological parks can provide continuity to **capacity building and development projects**. Agriculture innovative solutions can be disseminated in an integrated manner targeting directly smallholder farmers who would holistically benefit from them on multiple dimensions: improved digital literacy rates, productivity, food and nutrition security. In the same logic, public and private financing in agri-tech would register decreased risks on return on investments as they represent robust models for pooling growth capital. In this manner, the fragmented current status-quo and dissociation of agricultural development from technology would lead instead to a more **consolidated collaboration** between programme partners, donors, investors, public/private funders, R&D&I and technological partners in African countries[144]. Innovative uptake can also be provided in technological parks where agri-tech companies and mobile operators would benefit from a more supportive roadmap towards market entry and usage by smallholder farmers. Notably, mobile operators play a key role within digital agriculture innovation spaces since most disruptive agriculture technologies can be piloted by them in real environments.

Moreover, the nexus with both **government policies** and **MNOs** is crucial in order to maximise the benefits of adopting disruptive technologies in agriculture. In this sense, the digital agriculture innovation space can be strengthened if it becomes the centre of digital transformation strategies[145]. The role of mobile operators still needs to be increased and better integrated in existing and future innovation ecosystems, since only 13% of all tech hubs across the African continent have an established partnership with a mobile company, revealing a significant untapped potential. In other words, digital solutions tested in innovation spaces can be further marketed through MNOs associated with them, acting as a multiplier effect and reaching faster and more efficient smallholder farmers[146].

Another strategic path can be further consolidated through concrete implementation plans and actions such as the **African Agribusiness Incubation Programme (AAIP)** advanced by the African Union Commission. This initiative could lead to the creation of **hubs, incubators and accelerators networks** focused on digital agriculture. The success of such approaches depends on the formation of synergies between agripreneurs, country-level strategic plans, specific projects dedicated to access funding for innovative developments and global innovators that can provide relevant mentorship and training.

Other models of cooperation imply bilateral and even multilateral partnerships such as the recent initiative between Tunisian start-ups and Senegalese agri-food stakeholders for developing jointly agri-tech solutions[147].

University collaborations also represent valuable approaches in the context of innovation spaces if students and researchers are encouraged to create internal incubators to

[142] https://olc.worldbank.org/system/files/59440_ASA%20Exec%20Summ_bleeds-crops.pdf

[143] https://openknowledge.worldbank.org/bitstream/handle/10986/33961/9781464815225.pdf?sequence=2&isAllowed=y

[144] https://reliefweb.int/sites/reliefweb.int/files/resources/WFP%20FOOD%20SYSTEMS%20REPORT_FINAL_FOR%20PRINT_26.01.22.pdf

[145] https://www.gsma.com/mobilefordevelopment/blog/the-opportunity-for-smart-farming-in-the-middle-east-and-north-africa/

[146] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/03/Africa

[147] https://www.agri-tech.tn/un-nouveau-projet-en-agri-tech-pour-les-professionnels-de-lagriculture-au-senegal/

develop and test relevant digital technology applications. These types of actions can lead to the establishment of regional programmes for scholarships, mentorship grants, incubation hubs or centres of excellence. One example is the Memorandum of Understanding between the Inter-University Council of East Africa (IUCEA) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) in East Africa. They follow the roadmaps of the Continental Education Strategy for Africa, or CESA, 2016-25, and the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) [148]. In January 2022, a call for proposals was launched with the support of governments of Ghana, Malawi, and Mozambique under the Eastern and Southern Africa Higher Education **Centres of Excellence** Project (ACE II). The scope is to strengthen the collaborations at university level and pursue research in key regional agriculture gap areas[149]. Scientific exchanges between Africa and Europe are also gaining traction. INRAE and CIRAD have drafted a joint partnership with 20 African universities and agricultural research bodies that aim to develop comprehensive research, training and innovation programmes focused on agriculture. The scope will be to create international laboratories and research infrastructure open to African, French and EU partners[150]. Another good practice has evolved in the context of the ERASMUS+ GEOMAG project in Tunisia with students and professionals actively participating in educational academic engineering sessions thus sharing know-how on the ways for optimising the agricultural sector through the use of Geomatics[151]. Hence, university collaborations have different dimensions either as intra-regional cooperation (South-South) or international cooperation (North-South) and can be focused on the application of specific digital technologies in agriculture or can have general purposes aimed at attracting funding to boost digital innovation in the scientific field focused on the agri-food sector.

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[148] https://www.universityworldnews.com/post.php?story=20220123223921277

[149] https://www.iucea.org/pre-call-for-applications-for-additional-financing-under-the-african-higher-education-centres-of-excellence-ace-ii-af/

[150] https://www.cirad.fr/en/press-area/press-releases/2021/africa-france-agricultural-research-programme

[151] http://geomag.uvt.tn/moodle/

A5 Strategic Objectives, Goals, Activities and Outcomes

Roles: **C** Actions at the Continental level (AU) | **R** Actions at the Regional level (RECs) | **N** Actions at the National level (member states)

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
Strategic Objective A Strengthen and Develop Digital Agriculture Infrastructure.	**Goal A.1 Provide connectivity and infrastructure necessary to support digital agriculture with a focus on rural communities**	C R N	**Activity A.1.1** Promote investment into basic and inclusive infrastructure (electricity, mobile networks, fibre, satellite, data centres…) to improve readiness for digital agriculture.	→ Improved coverage and connectivity in rural areas enables development and delivery of digital agriculture services.	Connectivity of smallholder farmers in rural areas doubled.	2024 - 2030	Infrastructure costs not estimated.	
		R N	**Activity A1.2:** Explore new and affordable connectivity options to enable digital agriculture in rural and remote areas/communities.	→ Reduced costs - improved affordability.	25% of African farmers have access to the Internet.	2024 - 2030	Infrastructure costs not estimated.	
		R N	**Activity A1.3:** Empower smallholder farmers with access to basic and inclusive digital technologies and innovations to improve their productivity and access to markets	→ Food security, sustainable livelihoods.	Income levels of African smallholder farmers with access to basic digital technologies rose by 100%.	2024 - 2030	Infrastructure costs not estimated.	

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
		N	**Activity A.1.4** Promote last-mile connectivity in all countries.	→ Increased demand and use of digital agriculture.	Cost lowered below $25 per Mbps/month in all countries by 2027 (similar to African e-rate initiative).	2024 - 2030	Infrastructure costs not estimated.	UN Agencies, International Development Agencies, Development Banks, Private Sector, Member States
Strategic Objective B **National D4AG Adoption**	**B.1 Promote the elaboration of national digital agriculture/ e-agriculture strategies.**	C R N	**Activity B1.1:** Promote the elaboration of national digital agriculture or e-Agriculture strategies and support member states to align with national development plans and to integrate existing digital agriculture initiatives and projects. Facilitate the sharing of experience in designing and implementing national digital agriculture across the continent.	→ Available national digital agriculture/e-agriculture strategies that serve as a basis for investment in the digitalisation of the agricultural sector.	Each member state has a digital agriculture/e-agricukture strategy ratified by 2030.	2024 - 2030	**12.500.000** 250.000 per national strategy for 50 countries. This does not include the implementation of the national strategies.	AU, Multilateral Organisations, Development Banks, International Development Agencies, Research Centres
		C	**Activity B1.2:** Ensure that cross-cutting issues are respected at any time.	→ All national strategies have included aspects of gender inclusion, youth employment, climate smartness (see chapter A4.4).	National strategies have the aspects included.	2024 - 2030	**550.000** 10.000 per national strategy	AUC

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
	B.2 Promote National Digital initiatives	C R N	**B.2.1** Support member stated to develop and strengthen farmer registries.	→ Farmer registries enable better control of subsidies, voucher systems, traceability, and assessment of creditworthiness.		2024 - 2030	**12.500.000** 250.000 per national registry for 50 countries	Member States, UN Agencies
		C	• **B.2.2** Promote solar irrigation and irrigation automation (studies, training, manufacturing, grid feed-in tariffs).	→ Reduced use of fossil energy for irrigation, reduced emissions.	The study is developed and shared in 2025.	2024 - 2025 (2030)	**100.000**	AU, Multilateral Organisations, Development Banks, International Development Agencies, Research Centres
		N	**B.2.3** Promote the introduction and strengthening of traceability and certification (agriculture and livestock)	→ Improved product quality, access to international markets, disease control.	20 countries introduced traceability for at least one value chain.	2024 - 2030	**13.750.000** 250.000 per country and per value chain	Member states
		C	**B.2.4** Promote index-based insurances and other hybrid insurance models (studies, awareness raising).	→ Improved resilience of farming systems.	Availability of the study by 2025. 90% of African farmers have access to index-based insurances by 2030	2024 - 2025 (2030)	**1.000.000** (implementation not included) **private sector engagement**	Private sector, AUC, Multilateral Organisations, Development Banks, International Development Agencies, Research Centres

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
Strategic Objective C Provide Enabling Environments for Digital Agriculture	**C.1 Promote Enabling Infrastructure for Digital Agriculture**	N	**C.1.1** Enhance data interoperability, quality, and sharing. Develop national agriculture data platforms.	→Open data platforms offer free access to agriculturally relevant data.	All member states have data platforms in place, offering free access to relevant statistical agricultural data.	2024 - 2030	**55.000.000** 1.000.000 per national data platform	UN Agencies, Multilateral Organisations, Development Banks, International Development Agencies
	C.2 Improve regulations for cyber security and privacy	C	**C.2.1** Develop continental minimal standards for cyber-security, data privacy.	→ Continental minimal standards are used where national standards are not available.	Continental minimal standards are developed	2024 - 2025	**200.000**	UN Agencies
		N	**C.2.2** Engage in legislative, policy, and regulatory work to support requirements for digital agriculture at all levels.	→ MS have appropriate policies implemented.	25 countries have a national data privacy regulation in place 25 countries have a cyber-security taskforce operational	2024 - 2030	Part of national strategies and implementation plans	UN Agencies
	Goal C.3: Digital Agriculture Governance and Collaboration.	C R N	**Activity C3.1:** Support member states to ratify international treaties and frameworks and to integrate these into their national digital agriculture standards e.g., the Malabo Convention on Cyber Security.	→ International frameworks are adopted.	All member states adopted international frameworks relevant to digital agriculture.	2024 - 2030	**1.000.000** for support measures. Integration into national policies is part of national implementation plans.	UN Agencies, Multilateral Organisations, Development Banks, International Development Agencies

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
		C R N	**Activity C3.2:** Strengthen collaboration between agriculture, ICT and other sectors necessary to deliver digital agriculture at all levels (e.g., task forces, multi-partite round tables).	→ Foster digital agriculture through awareness rising and collaboration between agriculture and ICT ministries.	80% of the national agriculture strategies were developed by a joint effort of national ministries of agriculture and ICT.	2024 - 2030	**1.300.000** 500.000 on continental level and 100.000 per REC.	UN Agencies, Development Banks, International Development Agencies
	C.4 Promote an enabling business environment for Digital Agriculture	N	**C.4.1** Promote the creation of Tech Hubs	→ Growth and maturation of Africa's D4Ag incubation and investment ecosystems	Each country has at least one tech hub in place per 5 Mio inhabitants	2024 - 2030	**Unknown** -> sector-independent	UN Agencies
	C.5 Improve data quality and access	C	**C.5.1** Conduct a study on free data and data sources for digital agriculture	→ Accelerator for digital agriculture	Free Data for Agriculture guidebook available.	2024 - 2025	**200.000**	UN Agencies, Research Centres
Strategic Objective D **D4Ag Human Capital Development**	**D.1 Build capacities for Ag data collection, validation and analysis.**	C R N	**D.1.1** Implement data initiatives for data collection and analytics, build national data centres and make accurate, up-to-date data on agriculture accessible. Collaboration will be ensured with the 50x2030 Initiative	→ Improved availability, accuracy, completeness, timeliness and accessibility of agricultural data.	80% of MS have skilled staff employed in national agriculture data centers.	2026 - 2030	**10.000.000** (400.000 per country for 25 countries)	UN Agencies, Statutory Bodies of UN Agencies, RECs, member states

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
	D.2. Promote hi-end smart technologies such as Artificial Intelligence, blockchain technology, IoT, Machine Learning and Big Data.	N	**D.2.1 Scientific collaboration** on innovative digital agriculture technologies. ● Promote international collaboration between universities. ● Promote collaboration with international organisations with D4Ag programs ● Short collaborative courses and seminars (including MOOCs) on hi-end technologies. ● International exchange programs to support African universities	→ Smart technologies integrated into African digital agriculture solutions.	Each MS has at least one new international or regional collaboration on digital agriculture with a university	2024 - 2030	**11.000.000 (200.000 per country)**	Private sector, International Development Agencies, UN Agencies, Global Business and Industry Groups, Research Centres, tertiary institutions and incubation programs, mobile network operators
	D.3. Promote collaboration between Agriculture and Infrastructure departments	C	**D.3.1** Establish a **digital agriculture task force** that has representatives from the REC's agriculture department and ICT/Infrastructure department. Regular (bi-annual) e-meetings	→ Functioning task force with regular meetings	Cross-border REC task force group created by 2026 that has representatives from the agriculture/ICT and infrastructure group.	2025 - 2026 (2030)	**100.000** (25.000 per year)	AUC, RECs, UN agencies
	D.4 Increased farmer and rural advisory services D4ag proficiency	C	**D.4.1** Continental analysis study on e-advisory.	→ Comprehensive understanding of availability, type, quality, and outreach of digital advisory systems in Africa.	Comprehensive document on the status and perspectives of e-advisory in Africa is available and accessible.	2024 - 2025	**100.000**	AU Continental Initiatives, Research Centres

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
		C	**Goal D.4.2** Provide centralized servers and standard software for the establishment of e-advisory platforms.	→ National extension services are using the software and the servers for their platform. → Improved number of farmers reached by e-advisories. → Improved farming practices, higher yields, higher resilience.	• Platform available 2026 • 25% of AU member states adopted the AU advisory platform by 2030.	2024 - 2026 (2030)	**1.400.000** Development: 1.000.000 Annual costs: 100.000	AUDA-NEPAD, UN Agencies
Strategic Objective E Awareness, knowledge, and networking on digital agriculture.	**Goal E.1: Raising Awareness for Digital Agriculture.**	C	**Activity E1.1:** Establish and manage **accessible shared, multilingual knowledge platform for digital agriculture** for AUC, RECs and member states. All documents auto translated into the official AU languages so that all countries and RECs can base decisions on the same knowledge base.	→ A digital agriculture knowledge platform is available on continental level.	100 documents are available in 4 languages by 2027 1.000+ downloads by 500+ users from 25+ countries by 2027	2024 - 2025 (2030)	**800.000** Development: 300.000 Annual costs: 100.000	AUDA-NEPAD, International Development Agencies, UN Agencies, Research Centres
		C	**Activity E1.2:** Organize annual **continental conferences** on digital agriculture.	→ Increased awareness for potentials, benefits, risks and lessons learned regarding digital agriculture.	1st conference organised 2026 5 conferences organised till 2030	2026 - 2030	**500.000** (100.000 each)	AU Continental Initiatives, UN Agencies, Research Centres

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
	Goal E2: Knowledge Exchange	C	**Activity E2.1:** Establishment of a **continental digital agriculture forum** with sub-groups for use-case related topics (e-advisory, market access, precision agriculture, machinery pooling etc.) and cross sectorial topics (e.g. climate-smart agriculture, gender inclusion, youth employment). AI and ML enable automatic translation between the official AU languages, enabling exchange across all borders.	→ Improved exchange on continental level on digital agriculture	1,000 users from +10 countries registered and 200 topics created by 2026	2024 - 2025 (2030)	**800.000** Development: 300.000 Annual costs: 100.000	AUDA-NEPAD, UN Agencies, Research Centres
		C	**Activity E2.2: Registration** of all national and regional **strategies** and **policies** for agriculture, digital agriculture/e-agriculture and ICT on the platform.	→ Improved monitoring of D4Ag activities.	In 2030, all strategy and policy documents are registered and accessible.	2024 - 2030	**100.000**	RECs, Member States
	Goal E3: Align and collate the various stakeholder programs, projects, and initiatives.	C	**Activity E3.1:** Establish a **multi-partite round table** for digital agriculture with regular virtual meetings.	→ Improved monitoring of D4Ag activities.	5 meetings held on international level.	2026 - 2030	**250.000** (50.000 each)	AUC, UN Agencies, Research Centres, Multilateral Organisations, Global Business and Industry Groups
		C	**Activity E3.2:** Build a **repository** of all **national** and **regional e-agriculture initiatives**, **programmes**, **projects** on the digital agriculture knowledge hub.	→ Synergies in promoting and developing digital agriculture. → Learning from success stories as well as from failures.	By 2030, 80% of national initiatives, programmes and projects are registered on the platform.	2024 - 2030	**1.475.000** *Development of platform functionalities: 100.000* *Initial Survey (2026): 275.000* *Annual survey: 275.000 (5.000 per country)*	Member States, RECs

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
		C	**Activity E3.3: Integrate** digital agriculture into existing and future **AU agricultural programs**.	→ Inclusion of digital agriculture in all new AU programs related to agriculture.	X number of partnerships and commitments established	2024 - 2030	**500.000** + **private sector engagement**	UN Agencies, Development Banks, Research Centres, International Development Agencies
		R	**Activity E3.4: Integrate digital agriculture** into existing and future **REC agricultural programs.**	→ Inclusion of digital agriculture in all new REC programs related to agriculture.	X number of partnerships and commitments established	2024 - 2030	**800.000** *(100.000 per REC)* **private sector engagement**	UN Agencies, Development Banks, Research Centres, International Development Agencies
Strategic Objective F: D4Ag Reach and Use	**Goal F.1 Promote regional digital agriculture platforms on climate change**	R	**Goal F1.1** Create **regional working groups** on **climate smart digital agriculture** with bi-annual meetings. Continental annual exchange on climate smart agriculture.	→ Awareness for climate-smart agri-culture, improved technology exchange.	Workgroup created and functional.	2024 – 2025 (2030)	**2.400.000** 50.000 per REC per year	UN Agencies, Development Banks, Research Centres
		R	**Goal F.1.2** Develop **regional data platforms on climate change** on one platform.	→ Improved coordination in IPDM and higher resilience of farming systems.	Data platform functional and accessible end 2025.	2025 - 2026 (2030)	**2.040.000** Development: 1.000.000 Annual costs for hosting and maintenance: 100.000 Annual cost per REC: 20.000	UN Agencies, Development Banks, Research Centres

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
	Goal F.2 Promote regional digital agriculture platforms on pest and disease early warning and management	R	**F.2.1** Create **regional working groups** on **pest and disease early warning** systems.	→ Awareness for transboundary IPDM, improved technology exchange .	Workgroup created	2025 - 2026 (2030)	**2.400.000** 50.000 per REC per year	UN Agencies, Development Banks, Research Centres
		R	**F.2.2** Develop **regional data platforms for Integrated Pest and Disease Management**.	→ Improved coordination in IPDM and higher resilience of farming systems.	Data platform functional and accessible	2027 - 2028 (2030)	**2.000.000** Development: 1.000.000 Annual costs for hosting and maintenance: 100.000 Annual cost per REC: 50.000	UN Agencies, Development Banks, Research Centres
	Goal F.3 Promote youth digital agriculture entrepreneurship and women participation	N	**F.3.1** Promote **youth digital agriculture entrepreneurship** and **women participation**. Add a youth digital agriculture specific section in the knowledge hub.	→ Improved youth and women participation.	Contents created and integrated into the Hub	2024 - 2030	**100.000**	UN agencies, multilateral organisations
		C N	**F.3.2 Promote digital agriculture** at **school** and at **tertiary institutions** (-> DTS EDU). Organise Hackathons, bootcamps	→ Foster start-up creation. Accelerate digital transformation of agriculture.		2024 - 2030	**Not known, private sector engagement**	AU Continental Initiatives, private sector, universities
	Goal F.4 Promote AgTech Entrepreneur - ship and Innovation	N	**F.4.1 Public and Private Partnership** for Digital Agriculture Technology.	→ Higher number of ICT companies with Ag knowledge. → Higher number of successful Agtech start-ups.		2024 - 2030	**Not known, private sector engagement**	Private Sector

Strategic Objectives	Goals	Role	Activities	Outcomes	Target and KPI	Time-line	Estimated Resource Requirements (US$)	Potential Partners
Strategic Objective G: **Mobilise resources and financing for the sustainable implementation of digital agriculture programs.**	**Goal G1: Resource mobilisation**	C	**Activity G1.1:** Collaborate with MS, development partners, multilateral entities to **mobilise resources to invest in digital agriculture**.	→ Secure funding for implementation of the DAS.		2024 - 2030	**Not estimated**	
		C	**Activity G1.2: Encourage participation** by development partners and the private sector in co-ordinated funding for digital agriculture.	→ Secure funding for implementation of the DAS.		2024 - 2030	**Not estimated**	
	G2. Adequate financing and D4ag programs	C	**Activity G2.1: Explore models** to **increase private sector financing** for digital agriculture through public and private partnerships.	→ Secure funding for implementation of the DAS.		2024 - 2030	**Not estimated**	
		C	**Activity G2.2: Promote the SDG Investment Framework** at all levels (continental, regional and national) through various channels.	→ Exploit transformation synergies between sectors.	Cross-sectoral synergies developed.	2024 - 2030	**Not estimated**	
		C	**Activity G2.3: Invest in organisations** that will help grow digital agriculture at all levels (national, regional, and continental).	→ Synergize digital agriculture transformation.		2024 - 2030	Unknown	

A6 Indices relevant for the selection of priority areas for national digital transformation strategies.

Climate Risk

The Climate Risk Index (CRI)[152] is a value which is based on the losses of life and infrastructure a country faced in a particular year. The GermanWatch Global CRI is an analysis based on of very reliable datasets on the impacts of extreme weather events. This data is collected, cleaned, validated, analysed and provided by the world largest re-insurance company Munich-Re. As these extreme events are of erratic and punctual nature, there is an aggregated index derived from these annual values which averages over the past two decades and gives a better understanding for the climate risks a country is exposed to. It can be criticised that this index is based on historical data while climate change is introducing changes, but there is no reliable index for the future.

The map proves that digital systems for forecasting extreme climate weather events and mitigating the related list can be of regional nature. The countries in red colour were exposed to the highest risks in the last twenty years, predominantly caused by cyclones from the Southern hemisphere of the Indian ocean. Most of the countries in orange colour need long term forecasting systems for droughts; there can be synergies found between countries of Southern, Northern and North-Eastern regions.

The International Federation of Red Cross and Red Crescent Societies (IFRC) is publishing similar data[153] but they include diseases and do not look at it from a country perspective. The respective International Disaster Database EM-DAT is accessible here: https://www.emdat.be/database.

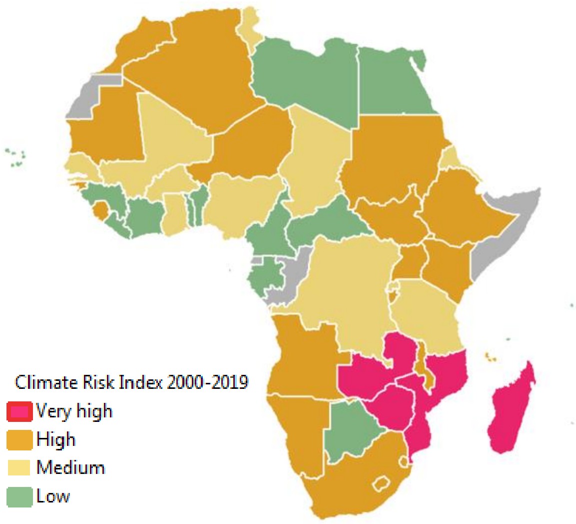

Figure 16: PRIDA DAS 2022 elaboration: Climate risk based on CRI data of the last two decades 2000-2019

Water Stress

The FAO Water Stress Indicator is based on an assessment of the renewable water resources of the countries. The value is proportional to the water stress a country is facing. Water stress is defined as the ratio between total freshwater withdrawal by all major sectors and total renewable freshwater resources, after taking into account environmental water requirements. Countries under water stress have an increased need for water saving solutions in agriculture. Digital agricultural solutions such as precision irrigation and remote sensing-based monitoring of plants under stress can help in optimising water consumption and therefore protecting

[152] https://www.germanwatch.org/en/cri

[153] https://reliefweb.int/report/world/world-disasters-report-2020-come-heat-or-high-water-tackling-humanitarian-impacts.

resources. There exist various indicators for water stress, some include industrial production, some exclude agriculture. The FAO water stress index is specifically developed for the agricultural sector. The spatial representation of the dataset clearly shows that, especially the states in northern African countries. Synergies can be found by e.g., using common satellite platforms for data acquisition, establishing multi-country think tanks and Tech hubs for digital irrigation,

research, production, and trans-boundary marketing of equipment such as digital soil moisture sensors according to software.

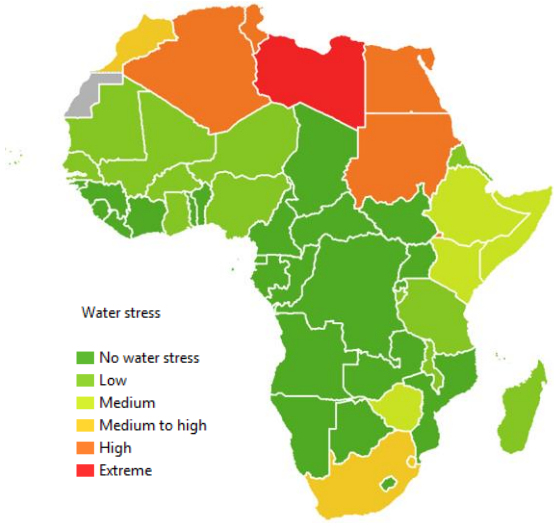

Figure 17: PRIDA DAS 2022 elaboration: water stress based on FAO data 2000-2017. Countries in red and dark orange colour are over extracting their renewable freshwater resource

Percentage of Irrigated Agriculture

Water stress alone does not justify the investment in better irrigation technology. These technologies are of use only if irrigation agriculture produces an important share. FAO publishes an indicator for the percentage of crop area of a country which is equipped for irrigation. Plotting these figures on a continental map shows that the countries under water stress are also the countries which rely most on irrigated agriculture. Exceptions might be Ethiopia and South Africa. In the Ethiopia-Sudan context it is unclear whether international river basin agreements on water resources are taken into account.

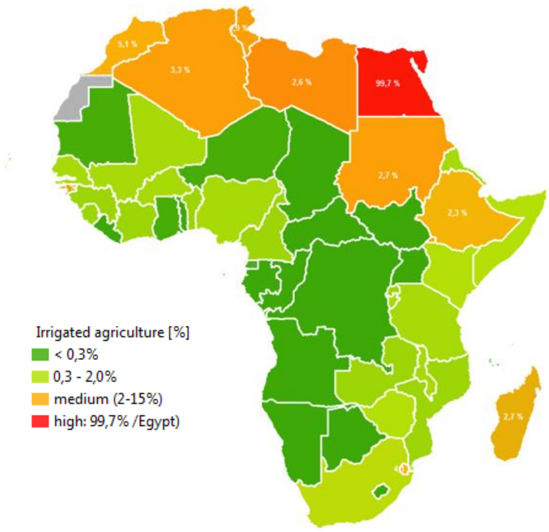

Figure 18: PRIDA DAS 2022 elaboration: Percentage of irrigated agriculture based on FAO Statistical Yearbook 2020 data.

The global connectivity

A country's mobile connectivity plays an important role for agriculture for all sorts of digital solutions targeting end users such as farmers, fishermen and livestock keepers. A certain level of connectivity is needed, otherwise apps and SMS-, USSD- IVR- and Voice Mail-based systems cannot function.

Thus, this indicator is essential for use cases such as e-advisory, farm management solutions and early warning systems.

GSMA calculates this indicator based on 39 sub-indicators for infrastructure, affordability, consumer readiness and content.

All data is accessible on the GSMA web tool[154] or in annual reports.

Other sources of information in this respect are coming from ITU (pricing of ICT services[155], ICT Regulatory Outlook[156]), World Economic Forum (the Network Readiness Index[157] measuring the potential ability of countries to be able to exploit the opportunities offered by ICT using 4 pillars: technology, people, governance and impact), the Alliance for Affordable Internet (A4AI) (Cost of Internet access).

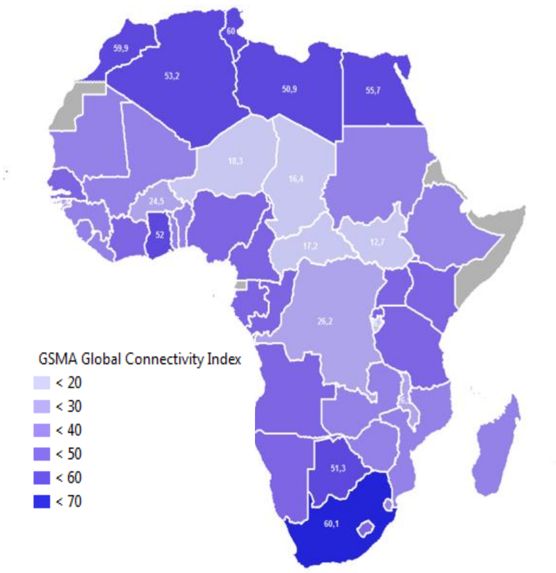

Figure 19: PRIDA DAS 2022 elaboration: Mobile connectivity based on the 2021 GSMA Mobile Connectivity Index.

Rural access to electricity

The access rate of rural population to the electrical grid plays a role for any use case where farmers, fishermen and livestock keepers need to operate end devices, typically with either simple phones or smartphones. Lack of access is a major hindrance for digitalisation of agriculture, as the smallholders usually live in the most remote, rural areas.

Access to Electricity is available from various sources:

- The International Energy Agency's (IEA) World Energy Outlook-2020[158] provides a proportion of the population with access to electricity and those without, disaggregated at national as well as for urban and rural populations.
- The World Bank provides data for energy access[159] aggregated from a joint database with other partners in the Sustainable Energy for All program (International Energy Agency, and the Energy Sector Management Assistance Program), disaggregated for urban and rural population.
- The Sustainable Energy for All[160] (SEforALL) initiative monitors the SDG progress and thus includes the monitoring of the populations' access to electricity. Latest data[161] is from 2020.

As most of the described data is available for free, there are several data intermediaries offering combined access to this data through maps, tables and reports. Datareportal[5], an online collection of thousands of resources, offers Web access to a comprehensive set of data by country, region and continent.

[154] https://www.mobileconnectivityindex.com/

[155] https://www.itu.int/en/ITU-D/Statistics/Pages/ICTprices/default.aspx.

[156] ICT Regulatory Tracker: https://app.gen5.digital/tracker/

[157] https://networkreadinessindex.org/nri-2020-countries/.

[158] https://www.iea.org/reports/world-energy-outlook- 2020.

[159] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

[160] https://www.seforall.org.

[161] https://www.seforall.org/data-stories/ seforall-analysis-of-sdg7-progress-2020

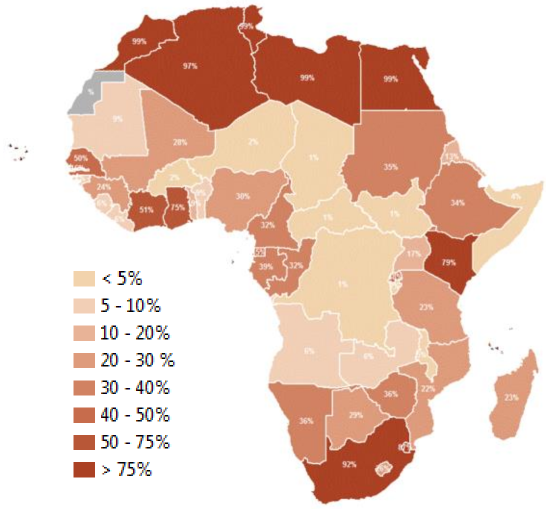

Figure 20: PRIDA DAS 2022 elaboration: rural access to electricity based on IEA 2018 data .

Global Innovation

Innovative technologies are a driver for digital transformation of agriculture. The World Intellectual Property Organisation (WIPO) developed the **Global Innovation Index** which covers selected African countries. It "ranks the innovation ecosystem performance of economies around the globe each year while highlighting innovation strengths and weaknesses and particular gaps in innovation metrics."[162]

It therefore is an indicator for the enabling environment for innovative technologies.

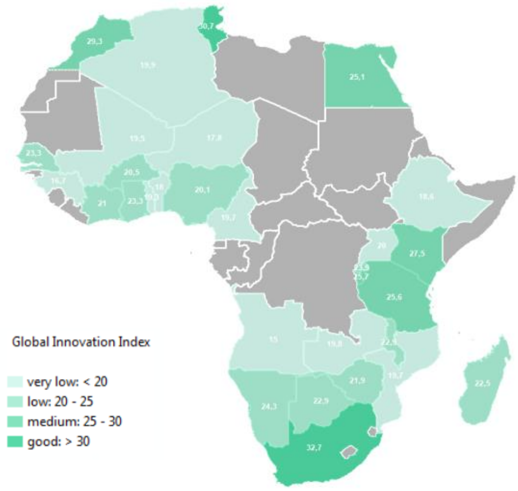

Figure 21: PRIDA DAS 2022 elaboration: Global Innovation Index based on WIPO 2018 data.[163]

Urbanisation

Urbanisation plays a role as with high urbanisation rates markets get centralised. Transport distances may rise, but if transport networks are good, this can also be a potential. Higher urbanisation rates have the negative effect of youth migrating to these centres. On the other hand, these urbanised areas usually produce the highest number of skilled young workers, of entrepreneurs, software developers, most of them have roots in farming families. But by correlating the map with the DAgRI, high urbanisation rates seem to be rather an obstacle for the digitalisation of agriculture. Kenya, Nigeria, Ghana and Egypt, all with outstanding DAgRI values, all have medium urbanisation rates.

FAO is providing this data annually through the FAOSTAT database: https://www.fao.org/faostat/en/#data/OA.

[162] https://www.wipo.int/global_innovation_index/en/.

[163] Tracking SDG7: The Energy Progress Report, 2020: https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2021.

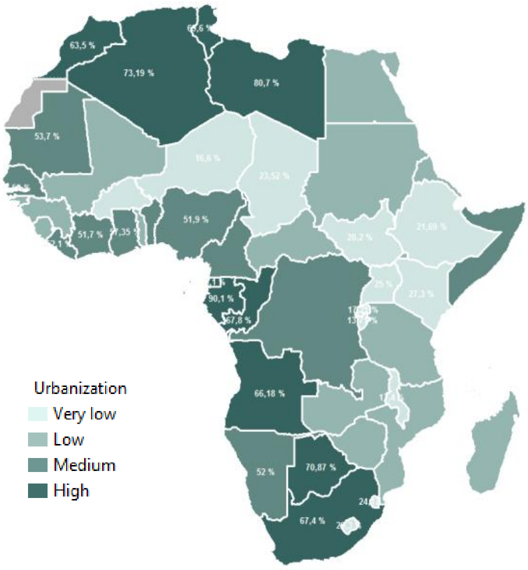

Figure 22: PRIDA DAS 2022 elaboration: Urbanisation rates of African countries, based on 2018 FAO data[164].

Rural Financial Inclusion

The Financial Inclusion for Agriculture Index (FIagI) was developed in the frame of the situation assessment phase of the DAS. The index is calculated on the basis of data collected by the World Bank, provided by the FINDEX database. Formula and parameters are described in the DAS assessment report. Country values for financial inclusion are not necessarily useful to assess potentials for digital agriculture as figures are usually very asymmetrically distributed between urban and rural areas. Financial inclusion in rural areas is a major driver for the digitalisation of agriculture and particularly important for e-marketplace solutions, cooperative management and contract farming software and any software, where services are payable.

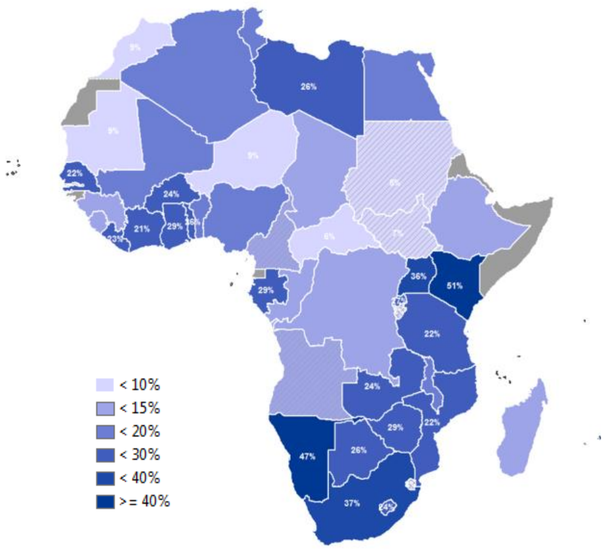

Figure 23: PRIDA DAS 2022 elaboration: Rural financial inclusion indicator based on indicators from the 2018 World Bank FINDEX database[165].

Mobile Broadband Data Prices

The use of mobile data depends highly on the price which has to be paid by the consumer. The map of mobile data prices for Africa shows, that land-locked countries are disfavoured while Ghana, Kenya, Namibia, Egypt, and South Africa, data prices are moderate or low. Consequently, they have the highest numbers of D4Ag solutions use. This indicator mainly plays a role for data-intensive applications, those which are powered by maps or offer video-streaming. Simple SMS- or USSD-based advisory services are not affected.

164 https://www.fao.org/faostat/en/#country.

165 https://www.fao.org/faostat/en/#country.

ITU's database on pricing of ICT services compares retail prices of ICT services allowing comparison of affordability across countries. The price basket comprises five types of services: (1) mobile-data-and-voice-low usage, (2) mobile-data-and-voice-high usage, (3) Mobile-voice, (4) Mobile-data, and (5) Fixed-broadband.

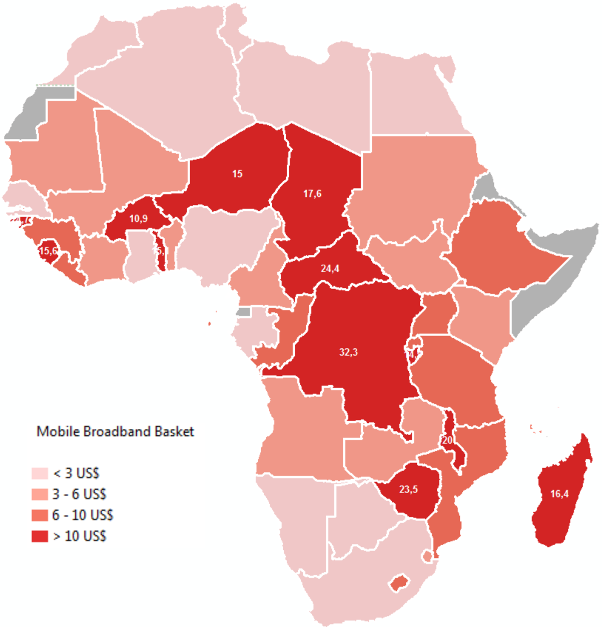

Figure 24: PRIDA DAS 2022 elaboration: Data Only Mobile Broadband Data Basket as a percentage of countries' monthly GNI per capita, based on 2021 ITU data[166].

166 https://www.itu.int/en/ITU-D/Statistics/Pages/ ICTprices/default.aspx .

A7 Literature

Addom,B and Enghild, A. (2018, December). *Attracting private sector investment to digitalise African farming'. Technical Centre for Agricultural and Rural Cooperation.* Retrieved November 4, 2021, from https://www.cta.int/en/digitalisation/article/attracting-private-sector-investment-to-digitalise-african-farming-sid053a6cbed-475f-46fe-bc5d-a5feb137495c

ACET. (2017). *African Transformation Report- Agriculture Powering Africa's Economic Transformation* The African Center for Economic Transformation. Retrieved November 4, 2021, from https://acetforafrica.org/acet/wp-content/uploads/publications/2017/10/ATR17-full-report.pdf

Boyera, S., (2018). In ICT Update Issue 86/CTA. https://ictupdate.cta.int/en/issues/86-precision-agriculture-for-smallholder-farmers

Camp, H., (2018). In ICT Update Issue 86/CTA. https://ictupdate.cta.int/en/issues/86-precision-agriculture-for-smallholder-farmers

Ceballos, Francisco, & Kramer, B. (2019). From index to indemnity insurance using digital technology: Demand for picture-based crop insurance (0 ed.). International Food Policy Research Institute. https://doi.org/10.2499/p15738coll2.133524

Derlagen, C., Magrini, E. (2020, December 28). *Four policy game-changers for post-pandemic African agriculture in 2021.* LSE. Retrieved November 4, 2021, from https://blogs.lse.ac.uk/africaatlse/2020/12/28/four-policy-game-changers-fao-post-pandemic-african-agriculture-2021/

Ehui, S. (2018, July 16). *How can digital technology help transform Africa's food system?* World Bank Blogs. Retrieved November 4, 2021, from https://blogs.worldbank.org/node/28640

Ehui, S. (2018, February 7). *Why technology will disrupt and transform Africa's agriculture sector—in a good way.* Retrieved November 4, 2021, from https://blogs.worldbank.org/voices/why-technology-will-disrupt-and-transform-africa-agriculture-sector-good-way

Ekekwe, N. (2017, May 18). *How Digital Technology Is Changing Farming in Africa?* Harvard Business Review. Retrieved November 4, 2021, from https://hbr.org/2017/05/how-digital-technology-is-changing-farming-in-africa?autocomplete=true

FAO. (2013) Calvin Miller, V.N. Saroja and Chris Linder. *ICT uses for inclusive agricultural value chains*. Rome. Retrieved February 2022, from www.fao.org/docrep/017/aq078e/aq078e.pdf

FAO. (2018). *The future of food and agriculture – Alternative pathways to 2050*. Rome. 224 pp. Licence: CC BY-NC-SA 3.0 IGO. Retrieved November 4, 2021, from https://www.fao.org/3/I8429EN/i8429en.pdf

FAO. (2020). *The State of Food and Agriculture 2020. Overcoming water challenges in agriculture*. Rome. Retrieved November 4, 2021, from https://doi.org/10.4060/cb1447en

Fritz, S., et al. *A comparison of global agricultural monitoring systems and current gaps*. Agricultural Systems, Volume 168, 2019, Pages 258-272, ISSN 0308-521X, Retrieved November 4, 2021 from https://doi.org/10.1016/j.agsy.2018.05.010.

Graham, K. (2017, October 3). *Africa's agriculture needs a big dose of digital transformation.* Digital Journal. Retrieved November 4, 2021, from https://www.digitaljournal.com/tech-science/africa-s-agriculture-needs-a-big-dose-of-digital-transformation/article/504124

Gray, B., Babcock, L., Tobias, L., McCord, M., et al. (2018, November). *DIGITAL FARMER PROFILES: Reimagining Smallholder Agriculture.* USAID. Retrieved November 4, 2021, from https://www.usaid.gov/sites/default/files/documents/15396/Data_Driven_Agriculture_Farmer_Profile.pdf

GSMA. (2021). *The Mobile Economy Sub-Saharan Africa - gsma.com*. GSMA. Retrieved November 2, 2021, from https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/09/GSMA_ME_SSA_2021_English_Web_Singles.pdf.

GSMA. (2018). *Opportunities in agricultural value chain digitisation. Learnings from Ghana.* Retrieved November 4, 2021, from https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/01/Opportunities-in-agricultural-value-chain-digitisation-Learnings-from-Ghana.pdf

Jouanjean, M., Casalini, F., Wisemani, L. and Gray, E.(2021, March 3) *Issues around data governance in the digital transformation of agriculture.* European Commission. Retrieved November 4, 2021 from https://knowledge4policy.ec.europa.eu/publication/issues-around-data-governance-digital-transformation-agriculture_en

Krishnan, A., Banga, K., and Mendez-Parra, M. (2020, March) *Disruptive technologies in agricultural value chains. Insights from East Africa.* Retrieved November 4, 2021, from https://cdn.odi.org/media/documents/disruptive_agritech_-_5_mar_2020_-_final_draft.pdf

Malabo Montpellier Panel. (2019) *Byte by Byte: Policy Innovation for Transforming Africa's Food System with Digital Technologies.* Retrieved November 4, 2021, from https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/133277/filename/133488.pdf

Malabo Montpellier Panel (2020). *Trading Up: Policy innovations to expand food and agricultural trade in Africa.* Dakar, Senegal: AKADEMIYA2063. Retrieved November 4, 2021, from https://www.mamopanel.org/media/uploads/files/MaMo-summary-english-Trade-der.pdf

Msengezi, C. and Nesoba, D, (2018). In ICT Update Issue 87/CTA. https://ictupdate.cta.int/en/issues/87-weather-data-for-agriculture

OECD. (2019). *Digital Opportunities for Better Agricultural Policies*, OECD Publishing, Paris. Retrieved November 4, 2021, from https://doi.org/10.1787/571a0812-en.

OECD. (2019) *Digital Transformation of the Agriculture and Food System.* Retrieved November 4, 2021, from https://issuu.com/oecd.publishing/docs/the_digital_transformation_of_the_a

OECD (2021), *Agricultural Policy Monitoring and Evaluation 2021: Addressing the Challenges Facing Food Systems*, OECD Publishing, Paris, https://doi.org/10.1787/2d810e01-en.

Phatty-Jobe, A. (2020, September). *Digital Agriculture Maps 2020 State of the Sector in Low and Middle-Income Countries.* GSMA. Retrieved November 4, 2021, from https://www.idhsustainabletrade.com/uploaded/2020/10/GSMA-Agritech-Digital-Agriculture-Maps.pdf

Svensson, J., Yanagizawa Drott, D (2010). *Tuning in the Market Signal: The Impact of Market Price Information on Agricultural Outcomes*. Retrieved February 22, 2022, from https://citeseerx.ist.psu.edu

Treinen, S and Van der Elstraeten, A. (2018). *Gender and ICTs: Mainstreaming gender in the use of information and communication technologies (ICTs) for agriculture and rural development.* FAO. Retrieved November 4, 2021, from https://www.fao.org/3/i8670en/I8670EN.pdf

Tsan, M., Totapally, S., Hailu, M. and Addom, B. (2021). *The Digitalisation of African Agriculture Report, 2018-2019.* CTA. Retrieved November 4, 2021, from https://www.cta.int/en/digitalisation-agriculture-africa

USAID. *Digitizing the Agriculture Value Chain.* Retrieved November 4, 2021, from https://www.usaid.gov/sites/default/files/documents/15396/Why_Where_and_How_Digital_Tools_Impact_the_Value_Chain.pdf

World Bank. (2018). *The Role of Digital Identification in Agriculture: Emerging Applications*, Washington, DC: World Bank License: Creative Commons Attribution 3.0 IGO (CC BY 3.0 IGO). Retrieved November 4, 2021, from https://openknowledge.worldbank.org/bitstream/handle/10986/31216/The-Role-of-Digital-Identification-in-Agriculture-Emerging-Applications.pdf?sequence=5&isAllowed=y

World Bank. (2011). *ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions. Washington, DC. © World Bank.* Retrieved November 4, 2021, from https://openknowledge.worldbank.org/handle/10986/12613 License: CC BY 3.0 IGO

World Bank. (2015). *Big Data Solutions: Innovative Approaches to Overcoming Agricultural Challenges in Developing Nations by Harnessing the Power of Analytics. World Bank, Washington, DC. © World Bank.* Retrieved November 4, 2021, from *https://openknowledge.worldbank.org/handle/10986/26436 License: CC BY 3.0 IGO*

World Bank. (2019, April 23). *Future of Food: Harnessing Digital Technologies to Improve Food System Outcomes.* Retrieved November 4, 2021, from https://www.worldbank.org/en/topic/agriculture/publication/future-of-food-harnessing-digital-technologies-to-improve-food-system-outcomes

Wyrzykowski, R. (2020, November 24). *Mobile connectivity in Sub-Saharan Africa: 4G and 3G connections overtake 2G for the first time*. Mobile for Development. Retrieved November 2, 2021, from https://www.gsma.com/mobilefordevelopment/blog/mobile-connectivity-in-sub-saharan-africa-4g-and-3g-connections-overtake-2g-for-the-first-time/.