FARA
Forum for Agricultural Research in Africa

Companion Document

for the

Africa Fertilizer and Soil Health Action Plan (2024-2034) & the Soil Initiative for Africa (SIA)

Soil Initiative for Africa

Africa Fertilizer and Soil Health Action Plan (2024-2034) & the Soil Initiative for Africa (SIA)

Companion Document

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Contents

List of Abbreviations

AARIEIs	-	African Agricultural Research, Innovation and Education Institutions
AARINENA	-	Association of Agricultural Research Institutions in the Near East & North Africa
AFAAS	-	African Forum for Agricultural Advisory Services
AfSIS	-	Africa Soil Information Service
AFSH	-	Africa Fertilizer and Soil Health
AFSH-AP	-	Africa Fertilizer and Soil Health Action Plan
AR4D	-	Agricultural Research for Development
ASARECA	-	Association for Strengthening Agricultural Research in Eastern & Central Africa
ATVET	-	Agricultural Training and Vocational Education
AU	-	Africa Union
AUC	-	Africa Union Commission
AUDA	-	African Union Development Agency
CAADP	-	Comprehensive Africa Agriculture Development Program(me)
CBFs	-	Community-Based Facilitators
CCARDESA	-	Centre for Coordination of Agricultural Research and Development for Southern Africa
CGIAR	-	Consortium of International Agricultural Research Centers
CoP	-	Community of Practice
CORAF	-	West and Central African Council for Agricultural Research and Development
DSM	-	Digital Soil Mapping
ECA	-	East and Central Africa
EUDASM	-	European digital archive of soil maps
FAIR	-	Findable, Accessible, Interoperable, and Reusable
FAO	-	Food and Agriculture Organization
FARA	-	Forum for Agricultural Research in Africa
FNSSA	-	Food and Nutrition Security and Sustainable Agriculture
GIS	-	Geographic Information Systems
GSP	-	Global Soil Partnership
HWSD	-	Harmonized World Soil Database
ICT	-	Information and Communication Technology

IITA	-	International Institute of Tropical Agriculture
ISRIC	-	International Soil Reference and Information Center
LandIS	-	Land Information Systems
LESIS	-	Lesotho Soil Information System
MEL	-	Monitoring, Evaluation and Learning
NARS	-	National Agricultural Research Systems
NASRO	-	National Association of Agricultural Services and Research Organizations
NGOs	-	Non-Governmental Organization
NSIS	-	National Soil Information System
RANCH	-	Regional Anchor Universities for Higher Agricultural Education
RAUs	-	Regional Anchor Universities
RSIS	-	Regional Soil Information System
RUFORUM	-	Regional Universities Forum for Capacity Development
S3A	-	Science Agenda for Agriculture in Africa
SADC	-	Southern African Development Community
SIA	-	Soil Initiative for Africa
SIS	-	Soil Information System
SROs	-	Sub Regional Organisations
STISA	-	African Union Science, Technology Innovation Strategy for Africa
SUSIS	-	Sudan Soil Information System
TSO	-	Technical Support Organization
WOSAC	-	World Soil Survey Archive and Catalogue

Chapter 1

Introduction to the Companion Document

Agricultural growth is inextricable linked to economic, health and overall wellbeing outcomes, from the household to the national level. Over 60 percent of sub-Saharan Africa's population is engaged in smallholder farming and agriculture accounts for 48 of employment in the agri-food system, compared to 29% and 9% in Asia and the Americas respectively (Davis et al., 2023). Moreover, about 23 % of sub-Saharan GDP comes from agriculture. The Green Revolution has delivered higher yields and lower prices, with productivity tripling between 1961 and 2015 (FAO, 2017). In contrast with other continents, cereal yields in Africa have stagnated and food production has increased largely through an expansion of the area under agriculture. productivity growth in SSA has failed to keep pace with demand deriving from population and income growth, resulting in rising imports for food commodities. Undernourishment has been a long-standing challenge, with uneven progress across the region. Despite being reduced from 33% in 1990-92 to 23% in 2014-16, the percentage of undernourishment remains the highest among developing regions (FAO, IFAD and WFP, 2015). For SSA, the Sustainable Development Goal to end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2035 seems like a far-off fantasy than an attainable target.

Given its role in confronting the challenge of eradicating hunger and improving food security, the Comprehensive Africa Agriculture Development Programme (CAADP) has set a goal of achieving at least 6 percent annual growth rate in agriculture. Africa's agricultural productivity is constrained by widespread land and soil degradation which has lowered soil productivity and reduced the effectiveness of inputs, especially fertilizers (Sanchez at al., 1998; Jayne & Sanchez, 2021). Moreover, adapting to climate change is becoming an increasingly urgent concern. Since the mid-2000s and heightened after the 2008 food prices there has been renewed interest in agricultural investment, and there are calls for the next Green Revolution. Convinced of the need to address the root causes of agricultural crises in Africa, aggravated by inadequate funding, the lack of adequate water control and management, poor rural infrastructure and neglect of agricultural research, African Heads of State of the African Union gathered in Maputo in 2003 committed to allocating 10% of national budgetary resources to agriculture and rural development.

In 2004, UN Secretary-General Kofi Annan[1] called for an African green revolution. Annan imagined, a uniquely Africa green revolution would be powered by proven techniques in small-scale irrigation and water harvesting scaled up to provide more crop-per-drop, improved food crops, agroforestry practices, the use of and organic and mineral fertilizers, rural electrification and access to information technologies, such as cell phones, publicly funded research focused on Africa and social safety nets that protect the most vulnerable.

The African Union Ministers of Agriculture convened in Abuja in 2006 for the Africa Fertilizer Summit recognized the urgent need for a strategic investment program to increase the availability and use of fertilizer alongside other inputs to usher the Green Revolution on the African continent. The ministers declared fertilizer, from both inorganic and

1. Secretary-general calls for 'uniquely african green revolution' in 21st century, to end continent's plague of hunger https://press.Un.Org/en/2004/sgsm9405.Doc.Html

organic sources, a strategic commodity without borders and resolved to increase the level of use of fertilizer from the current average of 8 kilograms per hectare to an average of at least 50 kilograms per hectare by 2015[2].

To achieve the ambitious 50 kilogram per hectare target, African Union Member States resolved to: i) take appropriate measures to reduce the cost of fertilizer procurement at national and regional levels especially through the harmonization of policies and regulations to ensure duty- and tax-free movement across regions; ii) take concrete measures to improve farmers access to fertilizer by scaling up input dealers and community-based networks across rural areas; iii) improve farmers' access to fertilizer, by granting, with the support of Africa's Development Partners, targeted subsidies in favor of the fertilizer sector, with special attention to poor farmers; iv) accelerate investment in infrastructure, particularly transport, fiscal incentives, strengthening farmers' organizations, and other measures to improve output market incentives; iv) improve farmer access to quality seeds, irrigation facilities, extension services, market information, and soil nutrient testing and mapping to facilitate effective and efficient use of inorganic and organic fertilizers, while paying attention to the environment.

Following the Maputo Declaration and the Abuja Declaration, African countries including Burkina Faso, Nigeria, Kenya, Tanzania, Ghana, Ethiopia, Malawi, Rwanda, Senegal and Zambia adopted input subsidy programs (ISPs) intended to raise productivity. In contrast to past subsidy programs, the new subsidy regimes were designed to benefit resource-constrained stallholder farmers and with greater participation of the private sector. Consistent with the Abuja Declaration, the ISPs focused on addressing low fertilizer adoption and use through market-based measure such as cost, input credit and last-mile distribution networks. Today, large ISPs are the cornerstone of agricultural development policy in sub-Saharan Africa. The Malawi ISP program, described by Denning et al. (2009) as the most ambitious and successful assault on hunger in the history of the African continent, persuaded many governments to adopt similar large-scale public subsidies. However, evidence from critical evaluation of ISPs suggests that yield improvements are short-lived, overall production and welfare effects of subsidy programs tend to be smaller than expected and that African yields are variable and often less responsive to inorganic fertilizer compared to other regions of the world (Messina et al., 2017; Jayne et al., 2020; Burke et al., 2019). Variable yield response to fertilizer application in SSA is hardly surprising.

Marenya and Barret (2009) and Burke et al. (2017) have shown that inorganic fertilizer become less effective on soils with soil organic carbon and acidic soils hence improved access alone may be insufficient to stimulate increased fertilizer use without complementary improvements in the biophysical conditions that affect conditional factor demand. Vanlauwe et al. (2010) distinguished three classes of soils, namely: i) soils that have relatively low yield without fertilizer and respond little to applied NPKS (referred to as poor, less responsive); ii) soils that have relatively low yield without applied fertilizer but respond well to fertilizer application(referred to as responsive), and; iii) soil that

2. Abuja declaration on fertilizer for the african green revolution
https://www.Inter-reseaux.Org/wp-content/uploads/abuja_declaration_in_english_1_.Pdf

have relatively high yields without fertilizer and respond little to applied fertilizer (referred to as rich less responsive). Hence, integrated soil fertility management (ISFM) is a set of practices– based on detailed understanding of African soils and their inherent variability – aimed at maximizing agronomic efficiency of applied inorganic fertilizers (Vanlauwe et al., 2010).

Consistent with Africa's multiple goals; increased agricultural productivity, environmentally sustainable and climate resilient production, improved water productivity and security, biodiversity conservation, and sustainable natural resource management under Agenda 2063, the Comprehensive Africa Agriculture Development Programme (CAADP), the Malabo Declaration, Africa's Climate Change Strategy, African Heads of State gathered at Africa Fertilizer and Soil Health Summit in May 2024 recognized that "focusing on fertilizers alone cannot stop land degradation nor boost the productivity of Africa's soils and their agricultural yields". Moreover, the Heads of State noted that the "decline in soil health significantly reduces the response to of crops to the use of yield-enhancing inputs such as mineral fertilizers and improved crop varieties, and greatly increases the vulnerability of smallholder farmers and communities to the impacts of climate and other shocks". In a fundamental paradigm shift, the Heads of State further acknowledged that the "perspective on agricultural sustainability has evolved from a narrow crop productivity and profitability focus to a broader focus on social, environmental, and economic sustainability, climate change adaptation and mitigation, rehabilitation of degraded land, and restoration and maintenance of ecosystem services, including biodiversity".

Soil health is the continued capacity of soils to function as a vital living ecosystem that underwrites social, environmental, and economic sustainability, and the maintenance of ecosystem services – sustainable plant and animal production, water quality control, human health and climate change adaption and mitigation (Lehmann et al., 2020; NRCS, 2017; Doran and Zeiss, 2000). Soil health as an overarching principle rather than a property to measure (Lehmann et al., 2020) encompasses agroecological principles, regenerative, organic and conservation agriculture practices – such as resource efficiency, soil and animal health, biodiversity, synergy (harnessing the integration of crops, trees, livestock and water), economic diversification, co-creation of knowledge, fairness, connectivity, land and natural resource governance, and participation – that underpin a just and equitable food systems transformation.

From the Declaration to Action

Mindful of the imperative that building soil health and regenerating degraded soils is critical for sustainable food systems transformation and supporting mechanisms and incentives necessary to enable farmer investments in soil health improvement, the Heads of State commit to triple the domestic production and distribution of certified quality organic and inorganic fertilizers by 2034, make available targeted agronomic recommendations for specific crops, soils, and climatic conditions to 70% of smallholder farmers, and to reverse land degradation and restore soil health on at least 30% of degraded soil by 2034 through the following actions:

1. Strengthen research and development on the utilization of inorganic and organic fertilizers by resuscitating the African Centre for Fertilizer Development in Harare;
2. Deploy innovative incentive mechanisms – including repurposing current subsidy programs – to encourage soil health investments by smallholder farmers;
3. Promote integrated soil and water conservation, planning, and management practices across agricultural sub-sectors and landscapes/ watersheds;
4. Promote investments in irrigation as part of integrated soil and water resource management for enhancing nutrient-use efficiency and climate change resilience;
5. Promote organic agriculture practices to improve soil health alongside conventional agriculture;
6. Provide incentives for local production, utilization and recycling of organic resources;
7. Establish small and medium (SME) ventures, especially for youth and women, that are oriented to producing and distributing organic and inorganic fertilizers.
8. Develop context-specific fertilizer and soil health advisory recommendations leveraging the potential of data and following principles of 4R Nutrient Stewardship and Integrated Soil Fertility Management;
9. Develop and deploy standardized and appropriate tools for assessing soil fertility, soil health, and context-specific sustainable soil management and nutrient requirements;
10. Establish a digital information system to operationalize fertilizer, crop and climate decision support tools on soil management at national, regional and continental levels

The Heads of State further commit to fully operationalize the Africa Fertilizer Financing Mechanism (AFFM) to improve the production, procurement, and distribution of organic and inorganic fertilizers and soil health interventions through the following actions:

1. Widening the scope of the AFFM to support the implementation of this Declaration with specific attention to de-risking farmer investments in yield-enhancing technologies and soil health of current and targeted food security crops financing infrastructure and logistics to improve availability of fertilizers, access to food markets for farmers and supporting fertilizer and soil health policy reforms;
2. Create a multi-source soil health fund for research, innovation, capacity building, and start-ups on fertilizer use and soil health actions. The fund is to be part of the already existing Africa Fertilizer Financing Mechanism (AFFM), which the African Development Bank hosts.

The Heads of State endorsed the Fertilizer and Soil Health Action Plan and the Soil Initiative for Africa Framework as key guiding documents to harness multi-stakeholder partnerships and investments to drive policies, finance, research and development, markets, and capacity building for fertilizer and sustainable soil health management in Africa. The aim of the SIA Framework is to establish a system to improve soil health agricultural productivity, economic growth, water productivity, reduce natural resource degradation and enhance resilience to climate change.

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Chapter 2

Developing Soil Information Systems for Africa

Contents

Summary

Soil information system is a convenient online infrastructure for managing and sharing soil data and information. Accessible soil information is a valuable resource in guiding investment decisions in the agricultural and environmental sectors. It is also crucial for sustainable management of the soil resource. Without adequate accessible soil information, agricultural investment decisions often end up with uncertain outcomes. In Africa, where there are more than 30 million smallholder farmers who manage over 70% of the agri-food systems and implement most of the agreements on agriculture, lack of accessible soil information imply serious implications on the agriculture performance on the continent. There are presently no more than five countries in Africa with accessible national soil information systems (NSIS) online, which is an indication of the dearth of accessible soil information at the table of investment decisions in the continent. Similarly, there is no soil information system (SIS) in any of the eight economic communities in Africa. This situation led the Soil Initiative for Africa (SIA) to consider development of SIS as one of the pillar actions for improving soil health and agricultural productivity in Africa. The present document identified necessary steps to help Africa to kickstart the development of accessible and usable SIS on the continent. The document outlined requirements for establishing SIS, which include availability of quality soil data, availability of reliable internet services, adequate policy support, sustainable budgetary allocation, sustained demand for soil data and information, appropriate SIS design, available institutional and technical capacity to maintain and operate the SIS, adherence to standards, supportive innovative research and development, institutionalized SIS management , and strong stakeholder partnership. Most of these requirements were not met by the previous attempts to establish SIS in Africa, which contributed to their failure and consequent low number of online SIS on the continent. This document has discussed strategies to overcome the challenges in meeting these SIS requirements in Africa and suggested a three-phase implantation framework to guide activities towards sustainable SIS. The framework incorporates an initial phase of infrastructure development to lay the foundation for subsequent SIS development and operationalization. It envisages monitoring the progress of SIS development using the proposals set by the SIA Action Plan and the CAADP monitoring system.

Introduction

1.1 Background

Soil information system (SIS) is a convenient online or digital infrastructure for managing and sharing soil data and information. Africa and most countries in Africa do not have accessible soil information systems. Soil data in Africa is mostly produced and held by various organizations and institutions inside and outside the continent at varied specifications. Therefore, the existing soil data and planned data collection programs in the continent have diverse temporal and spatial characteristics as well as varied soil information content. Coherent soil information systems at different administrative levels are needed to bring the diverse soil information into organized platforms and deliver harmonized information to all use cases. Organized soil information is a valuable resource in guiding investment decisions in agriculture and the environment. Without adequate and organized soil information, agricultural investment decisions often end up with uncertain outcomes (Bennett *et al.*, 2021; Martin and Lawson, 2022; Wang *et al.*, 2019). This is particularly true among smallholder farmers who are the majority in most agrarian economies and whose decisions impact the overall economic growth and agricultural productivity. In Africa, which is largely agrarian, there are more than 30 million smallholder farmers who manage over 70% of the agri-food systems and implement most of the regional decisions and agreements on agriculture. The decisions they make without adequate soil information have implications on the agriculture performance in Africa. A properly designed soil information system which the smallholder farmers and other users of soil information can access and identify with is sure to make significant changes in the overall performance of the agriculture sector on the continent.

The Soil Initiative for Africa (SIA), which was formed in 2020 to champion soil improvement activities in Africa, is prioritizing soil health and fertilizer use as the primary focus for revitalizing agricultural productivity in the continent (FARA, 2022). SIA has put development of soil information systems (SIS) as one of its pillar actions towards improving soil health and sustainable use of fertilizers. It expects SIS to improve access and catalyze use of soil information in making appropriate decisions that can positively impact soil health and agricultural production. Indeed, SIS is touted worldwide as the battlefield in which the fight to improve soil health, smart agriculture, and increased smallholder productivity will be won (Bhattacharya *et al.*, 2016; Desmet and Jonghe, 1993; Hallett *et al.*, 2017; Verdoodt and Ranst, 2006). In this regard, there are a lot of activities and progress with SIS development in different parts of the world (Board on Agriculture and Natural Resources *et al.*, 2021). In Africa, however, development of SIS is a surmountable challenge owing to the many administrative levels, scanty soil data and data collection programs, and challenges with internet service provision, among others. This calls for more consultation, awareness campaigns, partnerships, and innovative approaches to develop customizable framework that can guide and rally countries towards national soil information systems (NSIS), regional soil information systems (RSIS) and continental Africa Soil Information System (AfricaSIS). The present document outlines steps towards such a framework.

1.2 Progress with SIS development in Africa

The coverage for soil information systems in Africa is low. Out of the 55 countries in the continent, there are presently less than ten countries with national SISs (NSIS) that are findable or accessible online (Figure 1.2). This represents less than 20% of NSIS coverage in the continent. At the regional level, there is no known regional soil information system in Africa. Africa has eight regional economic blocks without any single regional soil information system. Similarly, there is no clear SIS at the continental level. Even though there were attempts to develop Africa Soil Information Service (AfSIS) at the continental level, there is presently no clear online access to AfSIS soil information. In general, SIS coverage in Africa is low and do not satisfy the principle of findable, accessible, interoperable, and reusable (FAIR) information (Wilkinson *et al.*, 2016). Perhaps this low coverage and lack of FAIR SIS are partly to blame for the current state of soil health and agricultural productivity in Africa. There is a need to increase continental activities to rally the countries and regions in Africa to develop and maintain useful SIS which can improve access to soil information and its associated benefits on the continent.

The focus of this document is to provide a clear roadmap and outline necessary infrastructure needed to steer the continent into developing operational, sustainable, and interlinked soil information systems at the national, regional, and continental levels.

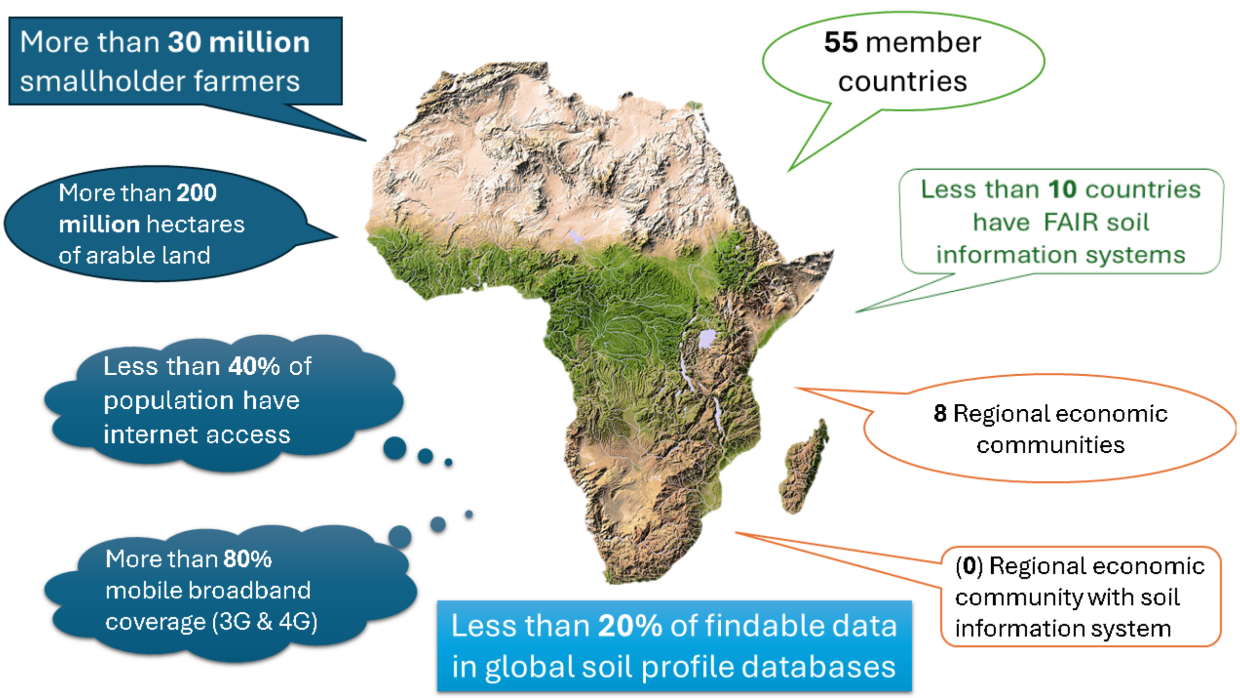

Figure 1.1: Africa facts for the case to build soil information systems

Where are we? Status of soil information systems in Africa

2.1 Status of soil data

Soil data comprise measured soil properties, observations of soil characteristics, soil maps, soil reports, and images or photographs. Soil data is generated from field surveys, laboratory analyses, cartography or digital soil mapping, documentation, or photography. The data may be presented in tables, maps, documents, or images. Soil profile data and maps are the most common among researchers and soil information developers. Soil profile data consist of measured soil properties for observed layers in a vertical cross-section through the soil depth. It is the results of field surveys combined with laboratory analysis and often presented in table form.

Status of soil data describes data available, age of available data, spatial coverage, number of soil properties covered, and extent in terms of soil depth. This section elaborates the status of soil data in Africa in terms of availability of soil profile data and soil maps. Most soil profile data and maps in Africa have been generated by governments, the private sector, research organizations, and non-governmental organizations (NGOs) for different purposes to meet their objectives. Therefore, most of the data have varied specifications and access levels.

2.1.1 Availability of soil profile data

Information about available soil profile data from African countries was obtained from diverse sources. The sources were either online databases, publications, or personal contacts and included soil survey departments in governments across Africa, ISRIC and former Africa Soil Information Service (AfSIS), Food and Agriculture Organization (FAO) including the Global Soil Partnership (GSP) and the Harmonized World Soil Database (HWSD), soil science departments of universities or agriculture research organizations, and online search.

A preliminary analysis of available soil profile data in Africa showed that ISRIC (https://www.isric.org/projects/africa-soil-profiles-database-afsp) and FAO (https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/en/) have the most complete collection of soil profile database with wide coverage in Africa. However, there are also rich national soil profile datasets which countries have not publicly shared (Nenkam et al., 2024; Omuto et al., 2024). The analysis also showed that although the countries in Africa have soil profile data, the national coverage with the profile data is seemingly low. According to findable soil profile data, less than half of the countries in Africa seem to have more than 100 sampled soil profiles in their soil database (Figure 2.1). There are also large parts of the continent, especially the Saharan Desert, where soil profile data are very scarce. This pattern of soil profile distribution also mirrors the distribution of areas in Africa with time-series periodic soil profile data collection. Routine soil profile data collection is seemingly not going on in many countries, which casts doubt on availability of monitoring data in many countries in the continent.

In terms of specific soil properties, it seems more than 70% of the countries in Africa have profile data containing basic soil chemical properties such as organic carbon (OC), total nitrogen (N), available phosphorous (P), cation exchange capacity (CEC), electrical conductivity (EC), and exchangeable cations like potassium (K), sodium (Na), Magnesium (mg), and calcium (Ca) (Figure 2.1). However, soil physical properties such as bulk density and soil structure are not included in the soil databases of many countries. Similalrly, soil properties related to water retention and infiltration characteristics are not adequately covered in most countries. A recent campaign was launched to sample Africa with more than 20,000 profiles (https://www.soils4africa-h2020.eu/, accessed on 20 April 2024). Perhaps this new effort will bring in more soil properties to available soil profile database in Africa.

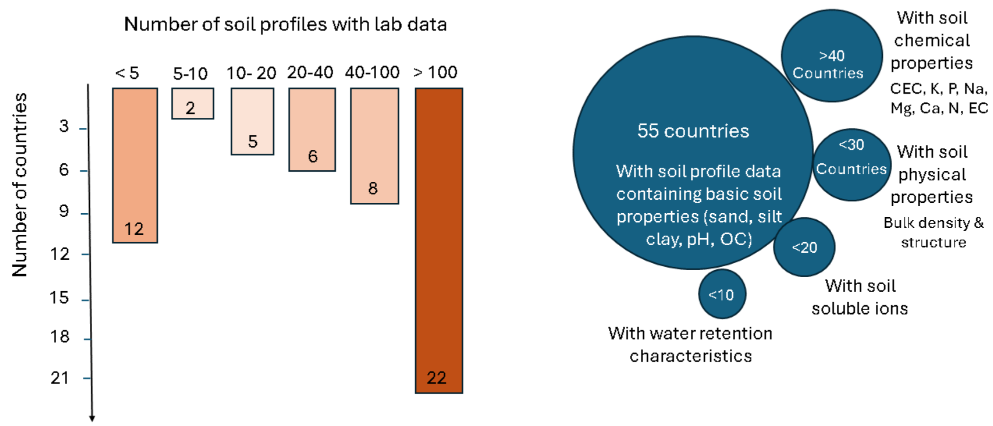

Figure 2.1: Soil profile data in Africa in April 2024

2.1.2 Soil maps and soil reports

Soil maps portray spatial distribution of soil information in two dimensions (2D) and include maps of soil types, soil properties, soil degradation, nutrient availability, rooting depth, etc. They are mostly produced either by the traditional cartography or digital soil mapping (DSM) methods. They are available as hard copies or in digital formats as scanned hardcopy maps or digitally developed maps. Traditional cartography produces vector maps in nominal scales while DSM produces raster maps with pixel resolutions.

Old vector soil maps in hard copies are available in soil departments in most countries. Some of these maps have been scanned and availed online within the countries or in publicly accessible portals such as WOSSAC (https://www.wossac.com/index.cfm accessed on 20 April 2024), FAO GeoNetwork (http://www.fao.org/geonetwork/srv/en/main.home, accessed on 20 April 2024), or EuDAS (https://esdac.jrc.ec.europa.eu/public_path/shared_folder/eudasm/africa/, accessed on 24 April 2024), Most vector maps are exploratory soil maps and cover either the whole countries or significant proportion of the countries. However, detailed maps such as 1:50k or higher only cover certain parts of agriculturally potential areas in the countries. Like soil profile data, detailed vector soil maps do not cover most parts of the continent. Continental and global scale vector maps are also available in digital formats (Dewitte et al., 2013; FAO-UNESCO, 1974).

Besides the vector soil maps, there are numerous maps of soil properties, soil nutrients, soil degradation, depths, etc. for various parts of Africa. Most of these maps have been produced using the DSM approach (https://www.isda-africa.com/isdasoil/, accessed 20 April, 2024; (Hengl et al., 2021). There have been attempts to make these maps freely accessible on websites, downloadable computer packages, or on smart phones (Miller et al., 2021).

Soil reports document soil surveys, soil testing campaigns, or soil studies in general. They carry gray details that may not be found in soil maps. Most reports of soil surveys are in soil departments of the organizations which commissioned the surveys. Some of these reports have been scanned and are available at FAO (https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/soil-legacy-reports/en/, accessed on 20 April 2024).

Existing soil data for Africa are scattered in different places. There is no single access point for these datasets nor a central location as a repository to hold and manage the data for the benefit of soil data users. A central soil data center is necessary to hold the freely accessible soil data in a central repository as well as act as the link to other soil data held by different data holders through data-sharing agreements. Such a data center will require appropriate infrastructure and data management strategy to be able to continuously and sustainably update its data portfolio. The currently available soil data is a good starting point to develop the Africa soil data center.

2.2 Soil information systems in Africa

2.2.1 National soil information systems

A search for online findable and accessible soil information systems in Africa showed that only nine countries have national soil information systems and only five of these have online accessible national soil information systems (Figure 2.2). The five countries with online SIS still have more work to improve access and general FAIR soil data and information from their portals.

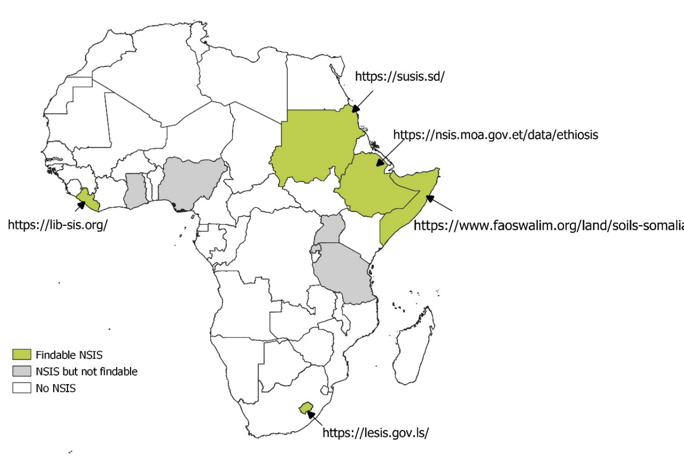

Figure 2.2: Status of NSIS in Africa in April 2024

2.2.2 Regional and continental soil information systems

There are currently no regional soil information systems in the eight economic communities in Africa. In north Africa, some countries have partnering with ICARDA, soils4med (https://mel.cgiar.org/projects/1866), and the Global Soil Partnership (GSP) to develop a regional soil information system covering north Africa region.

At the continental level, attempts were made to establish Africa Soil Information Service (AfSIS). AfSIS generated and published significant amount of soil data and information (Hengl et al., 2015, 2017, 2021). Its data is still available at https://www.isric.org/projects/africa-soil-information-service-afsis and have been used to develop new continental soil information such as https://www.isda-africa.com/, https://africasoils.info/, etc. Besides AfSIS, attempts have been made to develop new soil information systems for Africa (see for example, https://www.isric.org/projects/soils4africa, accessed on 20 April 2024). All these developments can provide the seedbed to start developing a sustainable and resourceful Africa soil information system

2.3 Availability of resources to support SIS development

The development of a soil information system is not only dependent on available soil data and reports, but also requires the necessary skills and knowledge to develop and maintain the SIS. Availability of accessible collection of resources for guiding SIS development, selection of appropriate architectures, standardization protocols, data-sharing policies, etc. can provide valuable support to institutions or organizations who want to set up SIS. Although there is no clear information on existing compendium of resources for SIS development, there are publications on various aspects of SIS development which are important references for SIS development in Africa (Burrough *et al.*, 1984; van Egmond *et al.*, 2023; Palma *et al.*, 2024). The ISRIC Resource Library (https://resources.isric.org/, accessed on 4 June 2024) and CABI's toolkit for data sharing (https://www.datasharingtoolkit.org/. Accessed on 4 June 2024) are also important resources which can benefit SIS development in Africa. There are also specific literature detailing technical and technological bottlenecks for data curation in Africa, which can benefit SIS development in Africa (see for example (Nenkam *et al.*, 2024).

What does it take?
Establishing sustainable soil information systems in Africa

3.1 The role of soil information systems in Africa

This section discusses the three main functions of soil information systems: provision of infrastructure to manage soil information, serving soil data and information, advisory and decision support , and an interactive platform for improving soil data exchange and innovations (Figure 3.1).

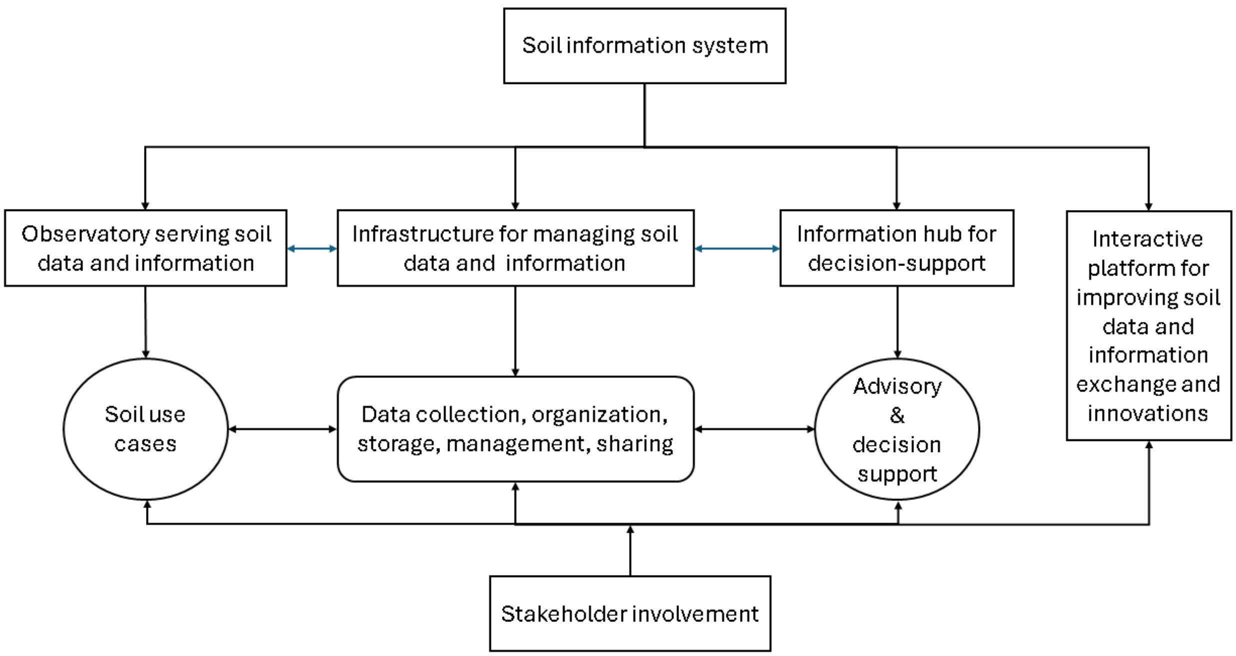

Figure 3.1: Major functions of soil information system

3.1.1 Infrastructure for archiving and managing soil data in digital formats

Soil information system innovation was originally conceived as an online platform for collecting, archiving, and managing soil data and information. This role stemmed from the need to convert soil data, photographs, and maps from hardcopies (also known as legacy data) into digital formats since digital formats are more convenient and efficient to store and share than hardcopies (Omuto, Nachtergaele and Vargas, 2013). In this regard, SIS helped to rescue, digitize, and secure hardcopy soil data and maps which were otherwise threatened with neglect, loss, or mutilation. This function of SIS is particularly important for most countries in Africa where large amounts of soil data and maps are still in hardcopies and have remained inaccessible to many users over the years. If national or regional SIS are established, they can help countries to improve storage, preservation, and management of such data in digital formats. Examples of SIS with online archives of soil data and information which Africa can consult include the Harmonized World Soil Database (HWSD) of FAO (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2012), World Soil Survey Archive and Catalogue (WOSAC) (https://www.wossac.com/index.cfm, accessed on 25 April, 2024), and European digital archive of soil maps (EU-

DASM), (https://esdac.jrc.ec.europa.eu/resource-type/national-soil-maps-eudasm, accessed on 24 April 2024), among others.

Besides digital aspects of soil data, there are also physically archived soil samples whose information can be linked with the digital information. There is an increased potential to improve access to the stored soil samples if the SIS infrastructure is also linked to the archived soil samples (or museums). Archived soil samples for Africa are lying in many stores or laboratories inside and outside Africa. They carry a lot of beneficial information for monitoring changes in the soil resource (Ayres, 2019; Karssies and Wilson, 2015; Lawrence and Creamer, 2023). Examples of a soil archive can be found in ICRAF's Spectral Soil Library (https://speclim.icraf.org/) and the soil museum at ISRIC's World Soil Museum (https://wsm.isric.org/).

3.1.2 Serving soil data and information

Most soil information systems have their core functions in serving soil data and information. The data include primary soil data (i.e., measured soil properties and field observations) or processed information in the form of maps. SIS can vary permission levels to the soil data and provide access through avenues such as downloadable links in online portals, web-based or mobile applications, email correspondence, or portable digital storage devices. They can also allow use of GIS and internet interface facilities on the websites for querying, subsetting, viewing, and exporting data to improve efficient data access such as through a Mapviewer.

Soil data service provision in Africa is not properly coordinated. Most data holders do not have proper formal agreements or networking to jointly serve their data. Therefore, most use-cases of soil data and information for the continent must rely on non-harmonized multiple sources to get the required data. There is no clear authoritative providers of soil data and information on the continent at all levels to serve the user communities satisfactorily. Suitable and interlinked soil information systems at the national, regional, and continental levels are needed to fill this gap and meet the demand of soil data and information in Africa. There are a few SIS examples in the continent presently serving soil data and information but still need more improvement and scaling up to meet the demand for tabular soil data or high-resolution soil information. Examples include Sudan Soil Information System (SUSIS) (https://susis.sd/, accessed on 24 April 2024), Lesotho Soil Information System (LESIS) (https://lesis.gov.ls/, accessed on 24 April 2024), and National Soil Information System for Ethiopia (NSIS) (http://www.nsis.moa.gov.et/, accessed on 24 April 2024).

3.1.3 Information hub for decision support

SIS with adequate soil information built on the FAIR data principles should be the information hub for all decisions requiring soil data. In Africa, several agreements or declarations have been made and translated into programs aimed at improving agricultural productivity and soil health on the continent. Implementation of these programs requires investment and policy decisions that should be supported with appropriate soil information. Well-designed and operationalized soil information systems are therefore needed to provide the required decision support.

SIS not only provides the required soil information for making decisions in the agricultural and environmental sectors but can also offer interpretation of the soil information to improve choice of appropriate decisions. As the information hub, SIS is the best location for interpreted soil information that is otherwise ambiguous to some decision-makers. In particular, smallholder farmers who are the majority stakeholders in the agriculture sector in Africa need interpreted and granulated soil information to make appropriate decisions in their farms (Adolph et al., 2021; Mulu et al., 2022; Nyoni et al., 2024).

Soil information systems can also offer advisory services through web-based dashboards or mobile apps (Golicz et al., 2020; Tobiszewski and Vakh, 2023). These application extensions can relay specific messages targeting certain user communities who need synthesized soil information. SIS in Africa can be designed with such features to target its smallholder farmers, policy makers, consultants, and land managers who need customized short messages in simple non-technical terms. Example applications using these approaches and which Africa SIS can borrow from include Land Information Systems (LandIS) for England and Wales (https://www.landis.org.uk/, accessed on 20 April 2024), virtual agronomist (https://www.isda-africa.com/virtual-agronomist/, accessed on 20 April 2024), among others.

3.1.4 Interactive platform for improving data exchange

A sustainable SIS also integrates stakeholders interactively and through partnerships to improve its functionalities. The stakeholders provide the technical support (designs, standards, research and innovations, data flows, etc.), organizational structures (management, coordination, human resources, etc.), facilitates institutional environment (regulations, laws, copyright agreements, etc.), mobilizes financial resources, and provides the requisite partnerships (collaboration, network, linkages, contacts, etc.) to improve sustainable implementation, proper function, and relevance of the SIS. SIS provides the platform where these different stakeholders engage interactively to improve data portfolio and data exchange.

3.2 Requirements for establishing soil information systems

Establishing a soil information system requires quality standardized soil data and information, reliable internet connectivity, properly designed soil information system model, quantifiable demand for soil data and information, sustainable institutional arrangements and financing, adequate data harmonization protocols and adherence to standards, and conducive policy and political environment (Figure 3.2). This section discusses these requirements and what they mean for SIS development in Africa.

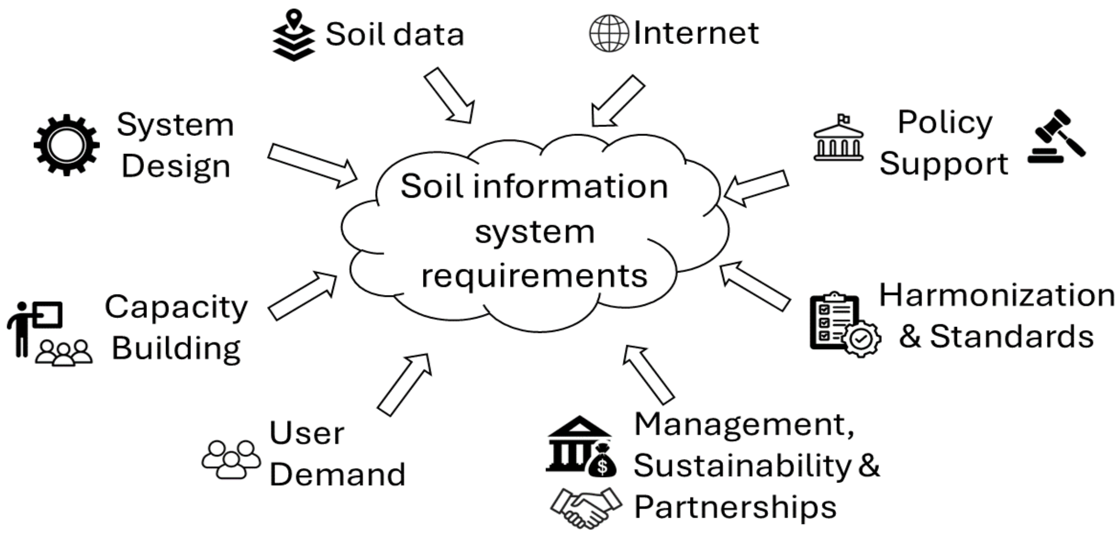

Figure 3.2: Requirements for establishing a soil information system

3.2.1 Soil data

Soil information systems are about soil data and information management. There must be quality and accessible soil data for the SIS to be relevant. Although there are many types of soil data the SIS can serve, commonly demanded soil data are tabular analytical data from the laboratories, soil maps, spectral signatures, pedotransfer rules and calibration models (Omuto, Nachtergaele and Vargas, 2013). Soil information such as degradation status, fertility/nutrient content, reports, etc. are also popularly demanded by some user communities.

Soil data is available in all countries of the world in different formats, specifications, and spatial and temporal coverage. SIS in Africa needs to organize and harmonize soil data in the continent to appropriately serve the user community. Most countries in Africa still have national level soil maps and soil profile data in non-digital formats. The SIS needs to organize workflows that can transform the data into suitable formats for efficient data onboarding, storage, and management. Furthermore, the workflows can be designed to streamline collection of new data, data contribution from partner organizations, and linkage/cooperation with other soil information systems within and outside the continent.

3.2.2 Digital infrastructure

SIS is an online facility for soil data and information management. It requires internet connectivity to be able to link with its user communities. SIS should be findable by online search engines, be able carry out data exchange, and allow online data query by users, among other operations (Balla *et al.*, 2020)the scientific community have published their results on the Internet over the last 20 years, adapting to society requirements. Due to the development of web-based spatial information soil systems, access to data on various themes and of varying quality has become substantially easier. The focus of our paper is to demonstrate a freely accessible and usable web-based soil database and soil information system (Soil Information and Soil Classifier System. Implementation of these operations requires steady internet connectivity. Therefore, organizations aiming to deploy and effectively operate the SIS need to ensure stable and reliable internet connectivity.

SIS is a web service with online or digitally accessible repositories. Therefore, it must have servers on network for hosting, managing, and serving data to linked users worldwide (Beaudette and O'Geen, 2009; O'Geen, Walkinshaw and Beaudette, 2017). Most SIS have remote or cloud servers that must be linked through internet connectivity to accommodate onboarding of incoming soil data, regular updating of data portfolio, and giving users access rights to download or interact with the data. In general, the internet is the artery of soil information systems and SIS will not be able to link with its users and data sources without it.

In addition to the Information Technology (IT) infrastructure, SIS also requires computing infrastructure to process and store soil data and information. Computing infrastructure includes computers, software, methods or models, and storage facilities. The methods or models help to streamline data collection, curation and analysis, interpretation, and data organization (including packaging, visualization, and presentation). SIS methods or models are implemented through software in a computing environment.

3.2.3 Appropriate SIS design

The design of a soil information system influences its success in delivering the core functions while maintaining soil data integrity and quality. SIS design is central to its operations and maintenance, linking with and satisfying user demands, accommodating contribution of soil data and information from diverse sources including partner organizations, protecting soil data security, complying with standards, and embracing technological advancements. Available SIS designs in the literature differ according to the roles they target to serve such as discovery hub, data repository, information hub, observatory, etc. (Fern´ndez and Rusinkiewicz, 1993; Jacquier, Wilson and Brough, 2012; Kalantzopoulos et al., 2024; Sadovski and Bie, 1978; de Sousa et al., 2021; Zhong et al., 2014).

In Africa, soil information systems are needed to open up soil data and information access to millions of users across the continent including more than 30 million smallholder farmers, to support policy and investment decisions targeting improvements in agricultural productivity and soil health, and to modernize soil data storage and security in all countries in Africa. Therefore, appropriate soil information systems designs are those that can combine many features that are not common in most existing SIS designs. Table 3.1 shows some of the additional design features SIS in Africa may consider.

Table 3.1: Additional SIS design considerations for Africa

SIS Level	Design feature consideration	Function
National level SIS (NSIS)	Online data repository	Efficient management of soil data
	Data contribution workflow	Effective data onboarding from many sources
	Firewalls and controls	Data security and access
	Customizable light deployment	Ease of adoption and operationalization
	Web-based and mobile applications	Advisory and decision support options
	Multilingual interpretations	Accommodate smallholder farmers
	Linkage with higher level SIS	Discovery at regional and higher-level SIS
Regional and continental level SIS	Information hub	Policy and investment decision support
		Support regional research and modelling
	Data/information contribution nodes	Discovery hub for SIS in member states
	Firewalls and controls	Data security
	Data/information exchange standards	Harmonize contribution from many sources

3.2.4 Policy environment and political support

Soil data or information is a national resource that should be properly managed to benefit national development. Although soil data and information are developed and managed by both private and public institutions, governments make policies that govern development, management, and beneficial use of the national soil data and information resource. In the traditional soil surveys, governments plan, fund, and carry out national soil surveys. However, most governments do not seem to take leading roles in the development and management of national soil information systems. Like soil surveys and resultant data and maps, soil information systems need the hand of governments for sustainability. Governments should step in to provide legal instruments, budgetary allocations to manage the national soil information systems, and the political goodwill to promote appropriate use of the soil information resource.

ICT revolution in Africa has awaken many governments to the potential of information management systems (Beda, 2019; David and Grobler, 2020; Williams, Mayer and Minges, 2011). Therefore, significant strides have been made in developing relevant policies to regulate and promote ICT in many countries in Africa (Makoza, 2022). Since many African countries do not have SIS in place, policies on soil information systems are generally lacking. The countries need to start putting right policies in place to attract attention and streamline SIS development. Policies around ICT in general can be the starting point for guiding SIS policy development. Africa Union Commission (AUC) institutions can be instrumental in providing countries with templates for developing relevant SIS policy for countries in Africa to adopt and customize. AUC institutions can also use their positions and roles to sensitize, mobilize and guide African governments and political class on the benefits and need for SIS at farm, political constituency, and national levels. The campaigns can use different outreach means to reach target audiences.

3.2.5 Capacity building

Soil information system technology is still evolving in many parts of the world. Over the years, SIS has evolved from simple online information storage and management to service provision using innovations such as artificial intelligence and mobile applications. Therefore, it is common to find SIS nowadays with new applications for crowdsourcing and onboarding soil data and information, artificial intelligence for decision support and advisory services, mobile applications for smallholder farmers, etc. These advancements call for capacity building to help most stakeholders catch up with the SIS trends.

Capacity building in Africa is a top priority for successful and sustainable SIS in the continent. A few considerations are needed for planning SIS capacity development in Africa. Firstly, most countries have technical and staffing challenges to be able to streamline their soil data and information development alongside SIS development. Therefore, they need national staff training to kickstart the journey of NSIS development. Secondly, there is a need for institutional capacity development in many countries in Africa to manage and operationalize NSIS. There are presently very few countries with NSIS. Thirdly, there are dwindling extension services in the continent to link smallholder farmers and advancements in the agriculture sector (Maake and Antwi, 2022; Nwobodo et al., 2019). Innovative approaches are needed to build capacity in extension service provision in most countries in Africa (Sanga et al., 2014). Fourthly, there is a need for policy capacity development to promote appropriate and favorable policies for SIS in Africa. This is because most countries in Africa do not have SIS and therefore may not have requisite experience to make policies for SIS integration into their national agenda.

3.2.6 Standardization and harmonization

Standardization requirement ensures that SIS stores and shares soil data and information in conformity to agreed specifications. Standardization is also needed in data collection and processing as a way of safeguarding soil data quality and integrity (Hoffmann et al., 2020; Nortcliff, 2002). Besides standardization, SIS also need harmonization strategies to align contributed data from different sources into a common specification. Some SIS designs allow for data contribution from different sources, which may have varied data specifications. Standardization and harmonization allow seamless data movement between different application software with minimal uncertainties due to differences in data specifications. There are many standards and guidelines in the literature for soil data collection, curation, descriptions, harmonization, and data exchange (Arrouays et al., 2014; Hoffmann et al., 2020; Nortcliff, 2002).

SIS in Africa is expected to be multilevel involving national, regional, and continental

SIS. There is a need for standardization to allow interoperability and communication between SIS at these levels. Presently, there are many countries in Africa where soil data is still in hard copies, held by different organizations, or in multiple specifications. They need standardization to harmonize digitization of the legacy data and conversion of existing soil data into a common specification. Standardization is also required by countries which are planning collection of new data.

3.2.7 Sustainability

This section discusses three sustainability factors for soil information systems: funding model, institutional arrangements, and enduring partnerships. One of the goals of soil information systems is to remain in operation over a long period of time encountering less frequent downtime/outages, showing timely and effective response to user demand queries, and providing secure, relevant, and quality soil data. The funding model illustrates how SIS gets the finances for its operations and maintenance of steady online presence to interact with its users. Figure 3.3 shows a guideline for designing appropriate sustainable SIS funding model. The guideline envisages models with co-funding at the initial stages and steady budgetary allocations for long-term operations. Funding demands at the initial stage are huge to carter for planning and establishment of necessary infrastructure, acquisition and harmonization of existing soil data and information, awareness campaigns, consultation, and networking, etc. Most SIS typically take 3 to 5 years during the initial funding phase after which they will need steady budgetary allocation to remain in operation for a long period of time.

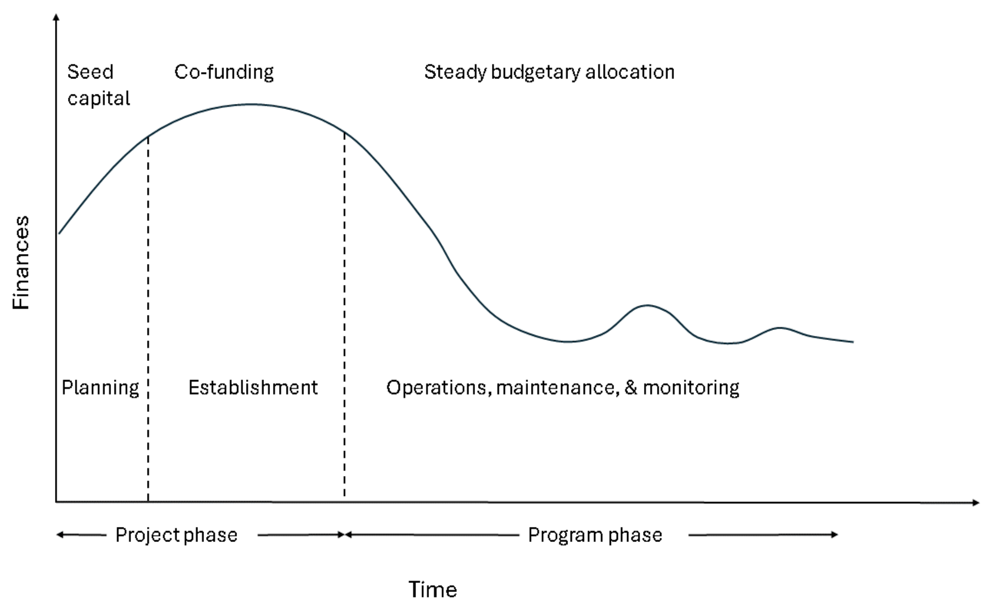

Figure 3.3: Guidelines for designing appropriate SIS funding model

Soil information systems (SIS) in Africa can consider co-funding with development partners at the initial SIS project phases and government budgetary allocations after the project phases. Since most government budgetary allocations are guided by acts of parliament, NSIS need to be legally entrenched in the national development plans to receive annual government funding. This is the most promising way for NSIS to receive both the policy and financial support.

Partnership is needed in SIS development and implementation to support shared goals such as expanding access and appropriate use of soil data, sharing or reducing the cost of soil data generation, capacity development, among others. SIS organization should identify and engage its partners from the private sector, business enterprises, soil data/information user organizations, development partners, academia, etc. Having partners on board is important because they play key roles such as supporting resource mobilization, soil data contribution, SIS policy development, feedback and decisions on data service provision, contribution on SIS management, etc. Partnership with the private sector is particularly important in Africa because most soil data are generated and held by the private sector.

Institutional arrangements for SIS sustainability encompass ownership, governance, and data exchange policies. SIS ownership is the organizational setup with responsibilities for hosting SIS and accounting for its operational tasks. Governance implies management of SIS implementation and comprise steering group, technical team, and representation of stakeholders. Ownership and governance have the overall responsibility for SIS management, central coordination, quality and assurance, and resources mobilization and accounting, and policy formulation. They are also responsible for legally binding contracts including data sharing agreements.

3.2.8 Demand for soil data and information

Soil information systems serve certain use cases of soil data and information. There must be a demand for soil data and information for SIS to be relevant. The demand and its changing characteristics influence SIS design models, operation, and maintenance. There are many demand categories for soil information such as decision-support, research and modelling, business, advisory services, education, and military, among others (Cook, Jarvis and Gonzalez, 2008; Diafas, Panagos and Montanarella, 2013; Moore and Bie, 1977).

The demand for soil data and information has been growing worldwide in the last few years (Cook, Jarvis and Gonzalez, 2008). This is due to the growing popularity of digital soil mapping approaches, increasing availability of soil data, efficient computing and software capacities, and increasing awareness of global challenges and call for systems approach for solving the challenges, among others. Africa has also seen tremendous growth in demand for soil data and information by researcher, policy makers, extension service provers, agro-business dealers, academia, farmers, systems developers, etc. (Fatunbi and Abhishek, 2020). There is a huge potential for SIS in Africa to serve these deferent use-cases of soil information.

3.3 Challenges for soil information systems in Africa

3.3.1 Inadequate infrastructure

Soil information systems require internet infrastructure to connect to its users, to link with soil data providers and collection points, and manage online repositories. Poor internet infrastructure can hamper these operations. It can cause poor service delivery with frequent outages or prolonged downtimes and the eventual loss of a proportion of SIS users. Poor internet infrastructure also creates loss of confidence and low traffic by users who link to the information site.

Although internet coverage in Africa is reportedly over 80%, internet speeds in the continent remain low compared to the global average (https://www.weforum.org/agenda/2022/09/africas-internet-speed-is-still-below-the-global-average/, accessed on 20 April 2024). Some countries do not have physical infrastructure while others experience numerous internet outages and downtime. This portends negative impacts on reliable SIS service in the continent. One way of overcoming national level internet infrastructure challenges in Africa is to build strong SIS at the regional and continental to support countries who might experience frequent outages and downtimes.

3.3.2 Sustainability

The most common sustainability factors affecting ICT projects in Africa which are also likely to affect soil information systems include inadequate funding, unclear ownership and governance, weak policy support, inadequate technical capacity or high turnover of technical staff, and weak institutional arrangements (Cevere and Gailums, 2017; Kimaro and Nhampossa, 2004). Inadequate funding largely affects projects which do not have strategies for sustainable funding in post-project activities. In soil information systems in Africa, most country SIS and the continental Africa soil information service (AfSIS) were developed as short-term projects and have been experiencing sustainability challenges after the end of the projects which created them. A possible alternative for solving these funding challenges is to design an appropriate funding model that considers co-funding at the initial SIS stages and steady annual budgetary allocations after the SIS project phase. Annual budgetary allocation especially from the government is envisaged. However, there should be adequate policy entrenchment of NSIS as an act of parliament for the NSIS to receive government budgetary allocation. In fact, having policy and legal backing for NSIS is necessary to provide both long-term funding and strong policy support for NSIS sustainability. However, there are possibilities that securing sustainable investment in soil information systems in Africa will be an uphill task since investments in the agricultural sector is inherently low (Shimeles, Verdier-Chouchane and Boly, 2018). Agricultural sector investments in Africa have been dwindling despite vigorous campaigns and signed continental agreements by governments (https://www.resakss.org/, accessed on 20 April 2024).

Ownership, governance, and institutional arrangements for SIS are the pathway for building legal and policy support for the SIS. Information systems with linkage with government departments have more leverage in attracting support from governments and their development partners. In Africa, most SIS that were conceived as private projects lost government interests after the project life cycle. They struggle to bring government support onboard and consequently miss the national infrastructure to host the SIS and recognition by governments' rank and file in the agriculture and environmental sectors. It's important to involve government technical departments throughout any NSIS project developments (Coley et al., 2024).

3.3.3 Technical capacity and technical design

There are three aspects of technical capacity challenges in agricultural information systems projects: inadequate equipment, inadequate technical skillset, and retainment of technical skills (https://hdl.handle.net/10568/42235, accessed on 20 April 2024). In soil information systems, cutting edge equipment is required for developing artificial intelligence systems, software for machine learning and digital soil mapping, secured hosting and serving of soil data and information, and standardized quality data collection and processing, among others. Many countries in Africa may have challenges with this equipment. They will need robust resource mobilization and collaboration with other organizations to get the required equipment or data for starting their NSIS development.

Availability and retainment of technical skills in the agriculture sector in Africa have been observed as important problems that need careful attention (Charzyński et al., 2022; Rozanov and Liesl, 2018). It's necessary to bear this issue in mind while planning capacity building in support of SIS development in Africa.

3.3.4 Policy support and data exchange agreements

Relevant policies are needed to anchor soil information systems within government development agenda. SIS that is aligned with government policies receive government support, regulation, and goodwill. Since most governments in Africa do not have SIS, they may not have adequate policies and legal frameworks for the SIS. Therefore, the governments need support to develop suitable and appropriate policies. There is a need for SIS policy awareness campaigns, resource mobilization and technical support to governments and political class in most African countries. Continental bodies such as Africa Union Commission (AUC) and its institutions are best suited to kickstart the campaign and policy support to AU member countries towards policy development of soil information systems in the continent.

Soil information systems also need appropriate policies for data collection and sharing. Since most SIS operations involve data exchange, there is a need for suitable policies that promote seamless data exchange. There are no clear data exchange agreements/policies in most African countries. Most countries have soil data and maps held by different organizations without clear data exchange policies. They need acceptable data exchange policies to be able to share or use different soil data sources.

3.3.5 Data availability

Soil data availability is considered in terms of physical availability of soil data, data format, proportion of data that is freely accessible, and quantity and quality of available soil data. There is scanty information on physical soil data availability in most countries in Africa, in part, because the countries do not have clearly accessible link address for their soil data portfolio. African soil data representation in the freely accessible global soil databases show that either the continent is not well sampled for soil analysis or most countries in Africa have restriction on data sharing. Recent campaigns to improve soil sample representation in the continent suggest that Africa is not adequately covered with high-resolution soil data collection (https://www.soils4africa-h2020.eu/, accessed on 23 April 2024). Although there are low resolution soil maps for Africa, there is no clear database of the extent of high-resolution soil mapping especially in agricultural areas of Africa. Besides low spatial coverage, available soil data from most countries in Africa only contain basic soil properties like texture and pH but lack detailed information on soil nutrient indicators, biodiversity, etc. Altogether, these data availability characteristics should be of concern when designing SIS in the continent.

Soil data in most countries in Africa are collected and owned by the private sector, NGOs, and research institutions. There is no clear database of how much soil data is held by these data holders in each country and their willingness to collaborate towards data sharing agreements and consolidated database.

3.4 Design considerations for soil information systems for Africa

3.4.1 Components of SIS

Soil information like other information systems should have at least six components which are data, people, internet, methods, software, and hardware. In soil information, these components can be put into three major groups: soil data, infrastructure, and user interface (Table 3.2). Infrastructure component is at the center of the SIS where it links soil data with the user community and other support systems. The infrastructure, especially IT infrastructure, is what sets SIS apart from the traditional soil data management and sharing. It facilitates efficient digital mobility of soil data and information from data sources to the user community. Prior to the advent of online infrastructure, the processing and mobility of soil data and information was less efficient with low access rate, accuracy, and transparency.

Table 3.2: Components of a soil information system

Component	Sub-component	Function
Soil data center	Data collection	Data collection, linking data sources, data networking
	Software and models	To ingest and store soil data and soil data management
Infrastructure		For data transformation, soil information development, and process automation
	IT infrastructure	Hardware and network infrastructure for data mobility
	Internal controls	To regulate access, security, and controls for data contribution and distribution
	Support system	To link data with users and for stakeholder interaction
User interface		To provide technical and institutional capacity
	Research and innovation	To improve data processing, data use, data types and data management

3.4.2 SIS design models

SIS design model is the architectural configuration for SIS components and their interaction to deliver SIS goals. The configuration integrates sub-models for the three main SIS components: models for soil data management and sharing (Batjes et al., 2017; Iivari and Koskela, 1987; Padarian and McBratney, 2020; Robinson et al., 2019), models for infrastructure such as monoliths, client-server, microservices, or service-oriented models (Antill, 1986), and models for user interaction (Hu, Ma and Chau, 1999; Palma et al., 2024; de Sousa et al., 2021). Three popularly used design models in the literature are:

1. Centralized SIS
2. Distributed/federated SIS
3. Hybrid SIS

Centralized SIS is where all soil data is hosted in the central place where SIS is built. Most countries use this model for their NSIS because it enables them to coordinate soil data from a central repository. World Soil Information System (WoSIS) is an example of this model at the global level (Batjes et al., 2017). The distributed or federated SIS is where soil data and information are crowdsourced from different sources with varied access rights. They may also be discovery hubs linking to different SISs, which act as contributing nodes to the main SIS. GloSIS is an example of this model (Palma et al., 2024; de Sousa et al., 2021). Distributed SIS is popular with sub-regional or continental or global SIS. A hybrid model is a special case of the distributed SIS where part of the providers of soil data and information elect to let the central repository handle their data. It may also be suitable for scenarios where willing contributing nodes do not have facilities to mount their own SIS.

Soil information systems in Africa are envisaged as three-level systems linking national soil information system (NSIS) at the country levels with regional soil information system (RSIS) at the regions and Africa soil information system (AfricaSIS) at the continental level. The three levels are expected to provide synergy in implementing different core functions of SIS: providing infrastructure for managing soil information, serving soil data and information, and providing advisory and decision support to different use cases. In addition, soil information systems in Africa will be expected to support activities such as development and coordination of partnerships and standards, resource mobilization and awareness campaigns, and design and implementation of features targeting soil information outreach to smallholder farmers in the continent. These roles of SIS in Africa are expected to help the continent to:

1. raise awareness on soil information as an important resource which can change the direction of soil management or investment decisions in the agriculture sector on the continent,
2. triple access to soil information to all stakeholders in the agriculture and environment sectors on the continent,
3. develop and modernize sustainable soil data acquisition and storage across the continent,
4. increase judicial use of soil information to maintain healthy soils and improve agricultural productivity in the continent.

Two aspects of design considerations are envisaged to deliver the expectations of soil information systems in Africa: governance and operational structures.

3.4.3 Governance

Past experiences with SIS in Africa show that lack of inclusive governance contributed to failure of most national and continental SIS initiatives. Clear governance structures are needed at the design stage of SIS to ensure its sustainability. Governance is in terms of ownership, institutionalization, coordination and partnership. At the continental level, it's expected that Africa Union Commission (AUC) will take ownership and overall responsibility of AfricaSIS. AfricaSIS should be domiciled in one of the AUC institutions who will host its data center and servers (Figure 3.4). The institution should also oversee:

1. Coordination, standardization, resources mobilization, and capacity building on SIS matters in the continent
2. Development of soil information products at the continental level and use of soil information in the drafting of continental agreements and declarations touching on soils
3. Harmonious implementation of SIS at the regional and national levels

4. Guiding development of relevant policies and legislations promoting sustainable SIS in Africa
5. Sensitization, awareness campaigns, and promotion of SIS in Africa and globally on behalf of Africa
6. Developing partnerships and collaboration with other SIS on behalf of Africa SIS.

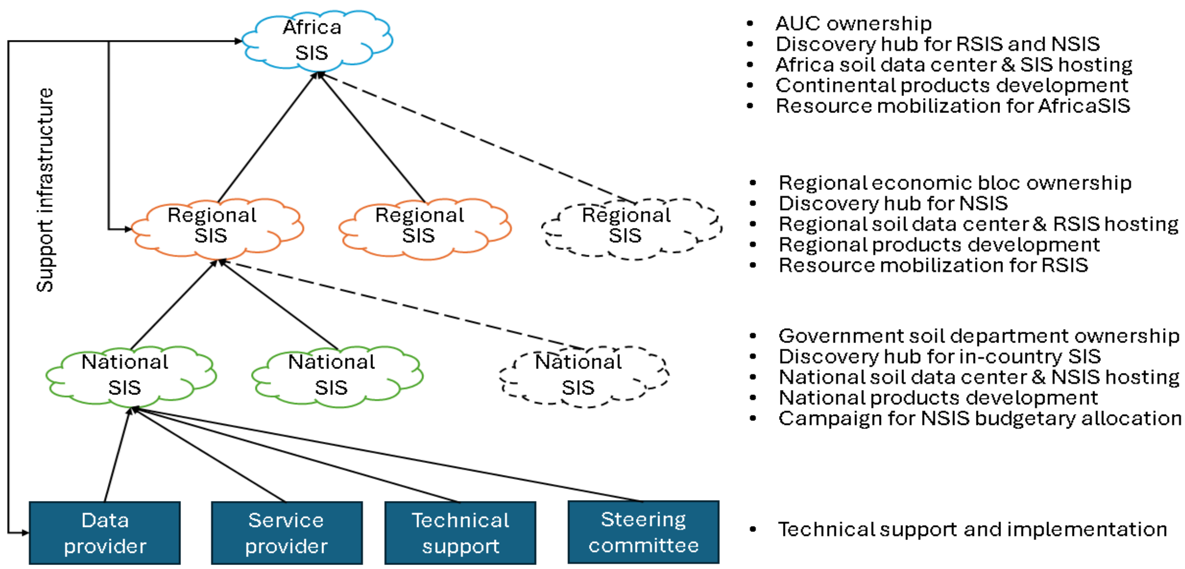

Figure 3.4: Framework for soil information systems governance in Africa

At the regional level, it is expected that the regional economic blocs will take ownership and overall responsibility for Regional Soil Information Systems (RSIS). The technical departments responsible for soil and agriculture at the regional bloc should host the SIS data center and server. In addition, the responsible departments should oversee (Figure 3.4):

1. Coordination, standardization, resources mobilization, and capacity building on SIS matters in the economic region
2. Development of soil information products at the regional level and use of soil information in the drafting of regional agreements and declarations touching on soils
3. Harmonious implementation of SIS at the regional and national levels
4. Guiding development of relevant policies and legislations promoting sustainable SIS in the region and countries of member countries/states
5. Sensitization, awareness campaigns, and promotion of SIS in the regions and among member countries
6. Developing partnerships and collaboration with other RSIS in Africa

SIS at the country level is expected to be owned by the government department responsible for soil matters in the country. The department will also take overall responsibility for National Soil Information System (NSIS). The department will represent NSIS in all government deliberations touching on soil data and information in the country, develop appropriate policies and legislation for promoting soil health, and development and use of soil information in improving agricultural productivity and environmental sustainability in the country. The department will also host the NSIS data center and server in addition to overseeing (Figure 3.4):

1. Standardized soil data collection and contribution to the NSIS
2. Development of soil information products at the national level
3. NSIS as the national soil data center serving soil data and information to all users in the country
4. Partnership with NGOs, other institutions, and the private sector in shared agreement to contribute standardized soil data and information to a central NSIS in the country
5. Guiding development of relevant policies and legislations and campaigning for national budgetary allocation for promoting sustainable SIS in the country
6. Sensitization, awareness campaigns, and promotion of SIS in the country

3.4.4 Operational structures

Operational structures include SIS architecture and implementation setup necessary to ensure successful functioning of the SIS. SIS architecture is the arrangement of crucial components which constitute the system. The components include the server, programming interfaces, database, security, management models, software, and internet network (Figure 3.5). The choice and configuration of the architecture determines how soil data and information flow and is stored.

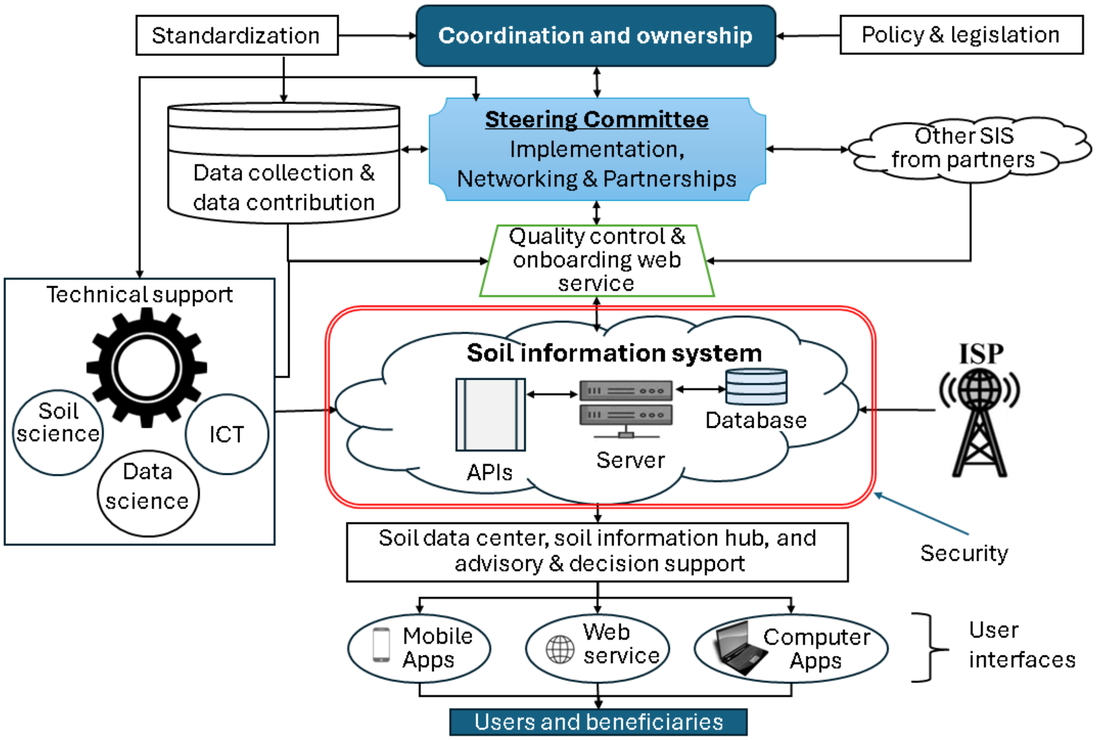

Figure 3.5: Design considerations for SIS in Africa

The following architectural considerations are proposed for the SIS development in Africa:

1. Since it is expected that there will be inter-communication and information sharing between NSIS, RSIS, and AfricaSIS, the architecture will need to incorporate designs for inter-SIS information exchange,
2. Most soil data in Africa comprise scanned maps, scanned soil reports, tabular soil data, digital maps, photographs, and digital documents. Some of these data types will have spatially georeferenced information. Therefore, the design data models are expected to consider these types of data diversity,
3. SIS in Africa is expected to serve soil data and information to various users in and outside the continent. Therefore, its design should contain structures for data and information access (user interfaces) (Figure 3.5). These user interfaces should be designed to implement appropriate standards, methods, and tools for sharing soil data and information with users and beneficiaries. Some innovative tools such as mobile applications may be preferred particularly for smallholder farmers (Figure 3.5),
4. Most soil data in Africa are held by different organizations. Therefore, the SIS design should incorporate facilities for allowing contributed data to be uploaded into the SIS, perform quality checks, and onboard the data into the SIS. The same facility can also be used for onboarding new data from field survey and labora-

tory analysis (Figure 3.5).

Implementation setup will ensure smooth and effective coordination of different parts of the SIS such as the technical support, SIS ownership, and SIS partners (such as data/ service providers, other SIS, etc.) (Figure 3.5). The following points have been considered important to be incorporated in the design of a sustainable and effective SIS in Africa (Figure 3.5):

1. Stable and easily deployable architecture for secure online management of soil information,
2. Structured engagement with service providers and partners who are willing to share their soil data,
3. Core team of technical support such as ICT, soil scientists, and data scientists,
4. Use of standards, guidelines, protocols, and quality control for new/contributed data into the SIS.

How to get there?
Implementation framework for soil information systems for Africa

4.1 Initial preparation

Initial preparation helps to set up appropriate plan for SIS implementation (Figure 4.1). The first step in the planning is to assess the status of SIS requirements and outline availability and gaps on these requirements. SIS requirements were elaborated in Section 3.2. The assessment will guide the strategy to mobilize and organize available SIS requirements and how to bridge the gap on what is missing or inadequate.

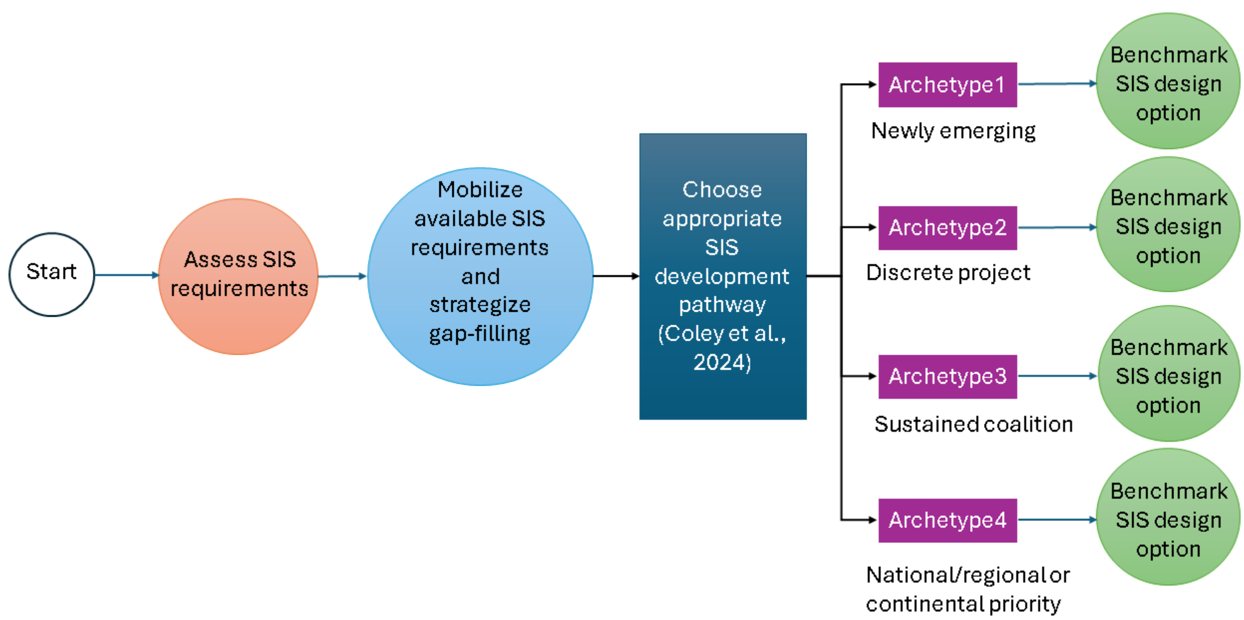

Figure 4.1: Initial preparation for SIS implementation

Assessment of SIS requirement also guides selection of the appropriate SIS development pathway. The literature shows four possible SIS development pathways (Coley et al., 2024):

1. Archetype 1: SIS without clearly targeted users and use-case and large gaps in SIS requirements
2. Archetype2: SIS with clearly targeted users and use-cases and a few gaps in SIS requirements.
3. Archetype3: SIS supported by a coalition of institutions/partners who pool up resources to overcome gaps in the SIS requirement. It's also guided by identified and existing multisectoral users and use-cases.
4. Archetype4: SIS developed as a core function of the governments or regional blocks or a continental body.

Existing SIS may be identified to benchmark the desired SIS, its development pathway and suitable design option from Section 3.4.

4.2 Implementation framework

A phased implementation framework is proposed to progressively build the soil information systems in Africa. This approach was chosen because it allows tackling of some of the challenges which occur at certain stages of the SIS development. For example, analysis of SIS challenges in section 3.3 showed that most challenges in Africa were due to misconceptions at the initial stages of SIS development. These can be prioritized in the phased implementation framework. Furthermore, the framework is suitable where potential heavy demand for resources at certain SIS development stages may require innovation to manage the demand and resource allocation. Figure 4.2 outlines the framework, which focuses on building the resource portfolios, institutionalization of SIS, and choosing appropriate models for sustainable SIS.

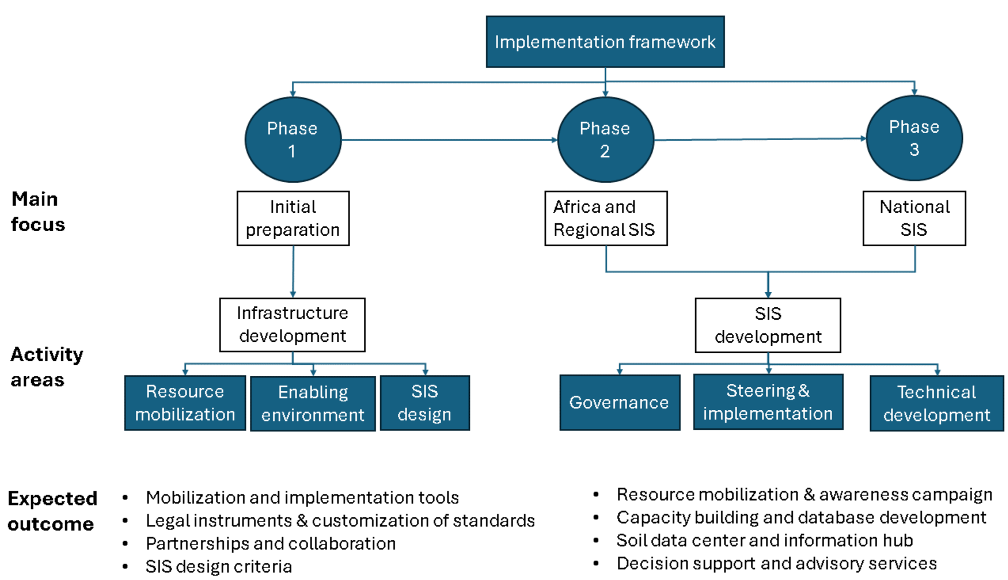

Figure 4.2: Implementation framework

The strategy in phase 1 will focus on laying the foundation for sustainable SIS. It plans for the development of appropriate infrastructures onto which subsequent activities will be built such as infrastructure for resource mobilization, development of appropriate policies, and infrastructure for designing a suitable SIS. Infrastructure for resource mobilization will target both human and financial resources and will lead to the development of tools for mobilizing financial support, capacity development, institutionalization of SIS, establishment of agreements for collaboration with partners and stakeholders, and tools for tracking and reporting SIS progress. Infrastructure for enabling environment is very important for entrenching SIS into the government development programs among Africa Union member countries. In this regard, the infrastructure development is expected to give guidelines for appropriate policies and legislation towards sustainable management of SIS in Africa. The infrastructure for enabling environment will also be expected to develop appropriate tools for data and information sharing, contract agreements with service providers, and tools for customizing standards for data collection, processing, sharing, and information interpretation across the continent. Laying the foundation for appropriate SIS design will help harmonize inter-SIS data sharing and information exchange as well as communicating common soil message to all users and beneficiaries of soil data and information in Africa. SIS design can also include a systematic workflow for data organization, handling, and onboarding into the system. A standardized and uniform workflow will be beneficial to all SIS levels in Africa.

In phase 2, a stocktaking process is envisaged to review and analyze existing soil data for Africa, drawing from various open-access data sources such as national institutes, AfSIS and WoSIS, GSP, WOSSAC, iSDA, Soils4Africa, BGS and other repositories. The stocktaking process will identify data characteristics, gaps, ownership, copyrights and license terms, and standardization needs to inform the technical requirements for establishing data centers. A comprehensive data strategy should be developed, encompassing data policy, data quality, data modelling and organization, metadata management, data security, and data analytics. Phase 2 will lead to the development of data centers at the continental, regional, and national levels. The regional and national data centers will act as nodes for serving the continental data center.

Phases 3 will focus on establishing soil information systems with priority given to the continental SIS. Continental level SIS will not only set the standards for lower-level SIS but will also support some countries who will need more time to build their SIS.

4.3 Indicator monitoring

The progress for development and implementation of SIS needs monitoring and trigger for actions to keep SIS on track. Although the framework for monitoring SIS progress will follow the procedures outlined in the AFSH Action Plan and the CAADP evaluation systems, a clear indicator set is needed to guide development of the SIS results framework. Table 4.1 proposes a potential indicator set which can be customized for monitoring SIS progress.

Table 4.1: Developing indicators for monitoring SIS progress

Main activity	Milestone	Potential monitoring indicator
Institutionaliza-tion of SIS	Establishment of NSIS governance	Permanent staff in NSIS leadership
	National SIS policy and legislation	SIS policy or act of parliament
	Annual budgetary allocation for SIS	% budgetary allocation for SIS
Development of online SIS	Online SIS website & portal	Searchable SIS website
	High resolution national soil infor-mation	% of agriculture land are mapped
	Advisory and decision support ser-vices	Available mobile/web apps for soil

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Chapter 3

Economics of Soil Degradation and Restoration in Africa

Contents

Summary

Soil degradation diminishes the ability of soil to provide essential ecosystem services such as support for plant growth and consequent agricultural productivity, water regulation, carbon sequestration, soil biota and gene pool, cleaning environmental contamination, etc. Economics of soil degradation highlights the cost of impacts of the degradation, cost of restoring degraded soil, and the foregone cost of abandoned land due to degradation. The Soil Initiative for Africa (SIA) and the 2024 Africa fertilizer and Soil Health - Action Plan (2024 AFSH-AP) proposed to incorporate economics of soil degradation in the strategies for tackling degradation challenges in Africa. This chapter demonstrates the necessary steps to incorporate economics of soil degradation in soil health strategies at the national, regional, and continental levels in Africa. It also includes a plan for national and regional soil health strategies to incorporate economics of soil degradation to guide investment in prevention and control of degradation in the continent. The implementation plan incorporates activities at the local, national, regional and continental levels. The monitoring plan is envisaged to follow the framework set by the SIA Action Plan and the CAADP monitoring system.

1.1 Background

Soil degradation diminishes the ability of soil to provide essential ecosystem services such as support for plant growth and consequent agricultural productivity, water regulation, carbon sequestration, soil biota and gene pool, cleaning environmental contamination, etc. Economics of soil degradation highlights the cost of impacts of the degradation, cost of restoring degraded soil, and the foregone cost of abandoned land due to degradation (Sartori et al., 2019; Sutton et al., 2016; Verhoeven et al., 2024). Understanding and analyzing economics of degradation is beneficial in uncovering the economic burden of unabated degradation, quantifying the cost of remediation and adaptation, and illustrating the investment needs to improve soil health. The Soil Initiative for Africa (SIA) and the 2024 Africa fertilizer and Soil Health - Action Plan (2024 AFSH-AP) proposed to incorporate economics of soil degradation in the strategies for tackling degradation challenges in Africa. This chapter demonstrates the necessary steps to incorporate economics of soil degradation in soil health strategies at the national, regional, and continental levels in Africa.

Economic assessment of degradation has been attempted in different parts of the world in the past decade. The literature shows that economics of land degradation at the global scale was estimated at more than $300 billion annually (Nkonya et al., 2016b), which is greater than the 2024 nominal GDP of more than 70% of the countries of the world and also greater than the combined 2024 nominal GDP of more than 60 least developed countries (or a third of countries of the world). This implies that degradation is significantly impacting the global economy. In Africa, reports show that soil erosion could be causing loss of productivity in croplands up to more than $60 billion annually (ELD Initiative and UNEP, 2015). This loss is more than 2024 nominal GDP of half of the countries in Africa or more than the combined 2024 nominal GDP of 16 countries (30% of African countries) with the lowest 2024 nominal GDP.

Although most works on economics of degradation focus on land degradation, soil degradation which is part of land degradation is also important. Soil degradation is concerned with decline in soil quality caused by various factors, such as erosion, contamination, salinization, and nutrient depletion among others. Land degradation is a broader concept that includes soil degradation but also encompasses the deterioration of vegetation cover, water resources, and land usability. SIA and AFSH-AP are focused on soil and soil health in agricultural landscapes with the aim of boosting agricultural productivity and food security in Africa (African Union, 2024; FARA, 2024). Therefore, economic assessment of soil degradation aligns very well with the goals of SIA and AFSH-AP.

1.2 Progress with economic assessment of soil degradation in Africa

Attempts have been made to portray the economics of land degradation in Africa at the continental level (ELD Initiative and UNEP, 2015), in the Sub-Saharan Africa (Nkonya et al., 2016a), and in some sub-regions such as in East Africa (Kirui and Mirzabaev, 2014) and North Africa (Croitoru and Sarraf, 2010) (Figure 1).

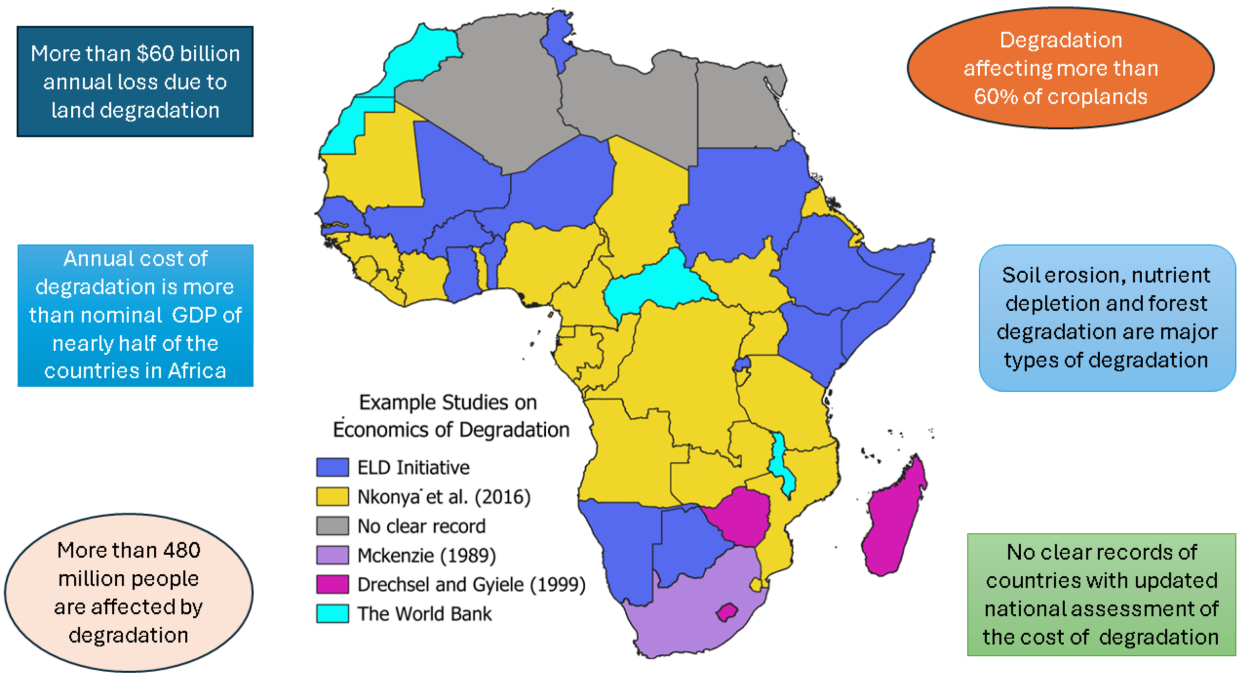

Figure 1.1: Overview of large-scale studies on economics of degradation in Africa

Most studies on economics of degradation in Africa have concentrated on land degradation than on soil degradation (Bojö, 1996; ELD Initiative and UNEP, 2015; Nkonya et al., 2016a). This is partly because land degradation which encompasses all degradation types is deemed to represent other degradation types adequately. Furthermore, the data for deriving indices of land degradation at the continental level is more readily available than data for soil degradation. The popularity of economics of land degradation over soil degradation is supported by the easy transferability of global methods and measurement to Africa case study (Bojö, 1996).

Assessing economics of soil degradation

2.1 Cost of soil degradation and benefits for its control

2.1.1 Prevalent soil degradation in Africa and economic impacts

Soil erosion, nutrient depletion, salinization, acidification, and contamination are among the most prevalent forms of soil degradation in Africa (Mesele et al., 2025; Tully et al., 2015). Soil erosion removes the nutrient-rich topsoil that is essential for plant growth. Nutrient depletion occurs when soils are over-cultivated without adequate replenishment, leading to diminished fertility and reduced crop yields. Salinization results in the accumulation of salts while acidification is due to an increase in acidic reaction. Salinization and acidification negatively affect the easy exchange of soil nutrients between the soil and plant roots and practically deny plants the moisture and nourishment they need to grow well. Additionally, contamination of soil, stemming from industrial activities, mining, and the use of chemical fertilizers and pesticides poses a significant threat to soil health and its ability to support ecosystems. Understanding these degradation types is crucial for developing strategies to mitigate their impact and enhance soil resilience across the continent.

Although there is no clearly updated information on the extent of soil degradation in Africa, it is believed that degradation is affecting more than 60% of croplands on the continent and impacting more than 480 million people in various ways. For example, soil degradation which diminishes productive potential of agricultural land, can result in low food production, nutrition and food insecurity, and overall health and economic activity of most rural populations in Africa. Diminished agricultural productivity is also reflected in the shrunken household income of the farm-families who are reliant on a agriculture as the main source of income. Unabated degradation can also render land less economically viable for agricultural production since land users would be forced to invest more to mitigate the effects of degradation.

Beyond agriculture, soil degradation impacts industries such as forestry, where diminished soil health reduces the growth rate of trees, affecting timber supply. The reduced capacity of soil to retain water and prevent erosion also leads to higher expenditures on infrastructure repair and flood mitigation measures. Degraded soil has low levels of carbon sequestration and tends to release stored soil carbon into the atmosphere (Lal, 2003). The literature shows that degradation can worsen climate change and increase the cost of mitigation efforts (Don et al., 2024; Lal, 2012).

2.1.2 Cost of action against soil degradation

Actions against soil degradation are activities which can prevent occurrence or control the rate of progression of soil degradation. They can be grouped into the following categories: Conservation, soil management, and institutional (Table 2.1). The cost of action against soil degradation entails the investment needed to implement these actions (Graves et al., 2015).

Table 2.1: Summary actions against soil degradation

Main category	Type of action	Target degradation
Soil conservation	Agronomic	Soil erosion and other physical degradation
	Structural	
	Biological	
Soil management	Nutrient management	Chemical degradation
	Pollution and contamination control	
	Carbon storage and retention	Soil carbon loss
Institutional	Education and awareness creation	All types of degradation
	Legislation and policy	
	Stakeholder involvement	
	Capacity enhancement	

The benefits of actions against soil degradation include the return on investing in degradation control/prevention activities, avoided off-site cost of degradation, etc. (Tepes et al., 2021).

2.1.3 Cost of inaction or inappropriate actions

Inappropriate actions on soil degradation include the application of poorly designed measures, use of non-suitable measures, and lack of appropriate maintenance of otherwise correct conservation techniques. Inappropriate actions can fail to prevent or control soil degradation leading to accumulation of degradation pressure and catastrophic consequences when the systems eventually break down.

Inaction limply a lack of implementation of measure for prevention or control of soil degradation. Inaction may be driven by inadequate education or awareness, lack of willingness or commitment, and lack of investment in degradation control measures.

2.1.4 Benefits of controlling soil degradation

Environmental Benefits

1. **Improved Soil Quality and Fertility**

One of the primary benefits of addressing soil degradation is the restoration of soil quality and fertility. Healthy soils are rich in nutrients and organic matter, which support plant growth, enhance crop yields, and contribute to sustainable agriculture. Adopting practices like crop rotation, no-till farming, and organic amendments rejuvenates soil health, enabling it to sustain life over the long term.

2. **Enhanced Water Retention**

Healthy soils have superior water retention capabilities, which are crucial for maintaining agricultural productivity during droughts and dry seasons. Actions such as planting cover crops and reducing soil compaction promote better infiltration and storage of water, reducing the risk of erosion and desertification.

3. Reduction in Erosion

Soil degradation often leads to erosion, where valuable topsoil is swept away by wind or water. Implementing anti-degradation measures, such as reforestation, terracing, and contour plowing, minimizing soil erosion, preserving the nutrient-rich layer essential for agriculture and plant life.

4. Carbon Sequestration and Climate Change Mitigation

Healthy soils play a vital role in sequestering carbon dioxide, acting as a natural carbon sink. Practices like regenerative agriculture and afforestation help store carbon in the soil, mitigating the effects of climate change. By reducing the need for chemical fertilizers and limiting deforestation, we also lower greenhouse gas emissions.

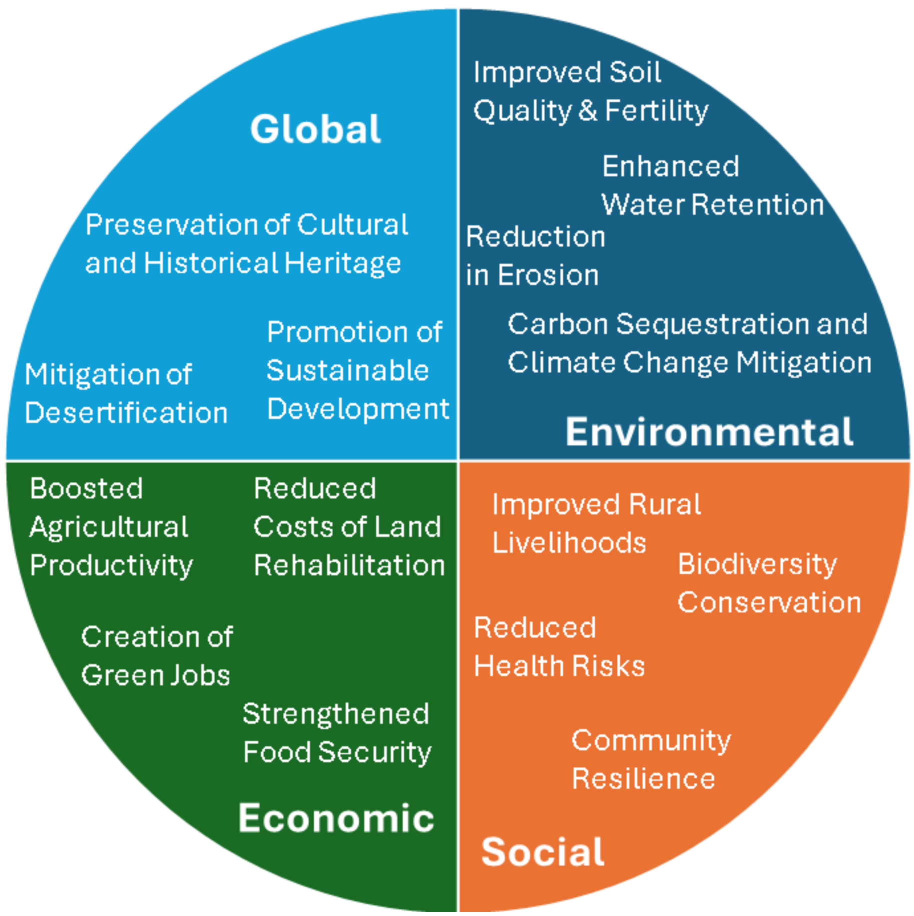

Figure 2.1: Benefits of actions against soil degradation

Economic Benefits

1. Boosted Agricultural Productivity

Combating soil degradation directly enhances agricultural productivity by improving crop yields and reducing the need for costly chemical inputs. Farmers benefit from increased profitability, while consumers enjoy more stable food prices and higher-quality produce.

2. **Reduced Costs of Land Rehabilitation**

Preventive actions against soil degradation are often more cost-effective than restoring degraded lands. By investing in sustainable practices early, governments, communities, and landowners can avoid the significant financial burden associated with land rehabilitation projects.

3. **Creation of Green Jobs**

Efforts to combat soil degradation often involve implementing eco-friendly technologies and sustainable agricultural methods. These initiatives create opportunities for green jobs, ranging from soil scientists and conservationists to workers involved in reforestation and sustainable farming.

4. **Strengthened Food Security**

Healthy soil is essential for food production, and addressing soil degradation ensures a consistent supply of nutritious food. This bolsters food security at local, regional, and global levels, reducing reliance on imports and minimizing the risk of hunger.

Social Benefits

1. **Improved Rural Livelihoods**

For communities that depend on agriculture, restoring soils can lead to improved livelihoods. Increased crop yields and sustainable practices provide financial stability, better nutrition, and enhanced resilience against climate-related challenges.

2. **Biodiversity Conservation**

Actions against soil degradation contribute to the preservation of biodiversity. Healthy soils support diverse ecosystems, including microorganisms, plants, and animals. By promoting soil health, we protect habitats and ensure the survival of countless species.

3. **Reduced Health Risks**

Soil degradation often leads to increased reliance on chemical fertilizers and pesticides, which can contaminate water sources and harm human health. Sustainable soil management reduces these risks, promoting cleaner water and safer food for communities.

4. **Community Resilience**

When soil is managed sustainably, communities become more resilient to environmental shocks such as floods, droughts, and climate change impacts. This resilience is crucial for maintaining social stability and reducing the vulnerabilities of marginalized populations.

Global Benefits

1. **Mitigation of Desertification**

Desertification is a severe form of soil degradation that threatens arid and semi-arid regions worldwide. Implementing actions to combat soil degradation can halt or reverse desertification, protecting landscapes and ensuring their continued productivity.

2. Promotion of Sustainable Development

Healthy soils are a cornerstone of sustainable development. They support agriculture, reduce poverty, and enhance environmental health. Addressing soil degradation contributes directly to several Sustainable Development Goals (SDGs), including zero hunger, clean water, and climate action.

3. Preservation of Cultural and Historical Heritage

Soils often contain archaeological treasures and cultural heritage sites. Preventing soil degradation helps preserve these irreplaceable assets for future generations, enriching our understanding of human history.

2.2 Practices and principles for quantifying cost of soil degradation

2.2.1 Principles for quantifying cost of degradation

1. Holistic Valuation

Quantifying the cost of soil degradation requires a holistic approach that accounts for both tangible and intangible losses. Tangible costs include reduced agricultural yields and increased input requirements, while intangible costs may involve decreased ecosystem services, reduced biodiversity, and long-term climatic impacts.

2. Integration of Stakeholder Perspectives

Economic analyses of soil degradation should incorporate the perspectives of various stakeholders, including farmers, governments, environmental organizations, and communities. This ensures the assessment captures local, regional, and global impacts comprehensively.

3. Use of Dynamic Models

Dynamic modeling techniques allow researchers to simulate the long-term effects of soil degradation. These models can project future costs based on current trends, enabling proactive decision-making and investment in soil conservation strategies.

4. Differentiation by Land Use

Soil degradation manifests differently across agricultural, forested, and urbanized regions. Cost assessments should differentiate by land-use type to provide a more tailored understanding of the economic impacts and the effectiveness of mitigation strategies.

2.2.2 Practices for quantifying cost of degradation

1. Estimating Agricultural Productivity Loss

One of the primary methods for quantifying the cost of soil degradation is measuring the decline in agricultural productivity. This involves comparing current yields to potential yields under optimal soil conditions and calculating the financial impact of the disparity.

2. Valuation of Ecosystem Services

Soil contributes to numerous ecosystem services, including water retention, carbon storage, and nutrient cycling. Researchers can estimate the economic value of these services and assess how degradation diminishes their effectiveness.

3. Assessing Remediation Costs

Calculating the cost of soil restoration and mitigation provides insights into the economic burden of degradation. This includes expenses associated with practices such as reforestation, organic farming, and erosion control measures.

4. Incorporating Socio-Economic Impacts

Beyond environmental costs, soil degradation affects human livelihoods, particularly in agricultural communities. Evaluating the economic impact on employment, food security, and migration trends is essential for a comprehensive assessment.

5. Utilizing Geographic Information Systems (GIS)

GIS technology enables spatial analysis of soil degradation, helping to identify affected regions and quantify economic impacts based on land-use patterns and degradation severity.

6. Application of Cost-Benefit Analysis

Cost-benefit analysis can assess the financial viability of soil conservation measures compared to the economic losses incurred due to degradation. This practice guides investment decisions in sustainable land management.

2.2.3 Challenges in quantifying cost

1. Data Limitations

A significant challenge in assessing the cost of soil degradation is the lack of comprehensive and accurate data, particularly in developing regions. Addressing these gaps requires investment in research and monitoring technologies.

2. Complex Interactions

Soil degradation is influenced by a range of factors, including climate change, land use, and human activities. These complex interactions can make it difficult to isolate and quantify specific costs.

3. Intangible Costs

Many of the impacts of soil degradation, such as biodiversity loss and reduced ecosystem services, are intangible and challenging to assign monetary values.

4. Temporal and Spatial Variability

The economic impacts of soil degradation vary over time and across regions, complicating efforts to develop standardized valuation methods.

Determining economics of degradation in Africa

3.1 Requirements for quantifying economics of degradation

3.1.1 Comprehensive Data Collection

Quantifying the economics of degradation begins with reliable and comprehensive data collection. This includes information on:

- Environmental parameters: Land degradation, water quality, air pollution, biodiversity loss.
- Economic factors: Market prices, production costs, labor metrics, trade data.
- Social indicators: Health impacts, migration trends, demographic shifts.
- Temporal and spatial dimensions: Historical trends, geographic variations, and predictions.

Data collection must be conducted using standardized methodologies to ensure consistency and comparability across regions and sectors.

3.1.2 Valuation of Ecosystem Services

Ecosystem services provide the foundation for human well-being, and their degradation can have significant economic ramifications. Valuing these services is a critical requirement, and it involves:

- Direct valuation: Assigning monetary values to tangible goods like timber or fish.
- Indirect valuation: Estimating the worth of intangible benefits, such as climate regulation or aesthetic appeal.
- Non-market valuation techniques: Contingent valuation, hedonic pricing, and replacement cost methods.

3.1.3 Identification of Drivers of Degradation

Understanding the root causes of degradation is vital to quantify its economic impacts. These drivers may include:

- Unsustainable agricultural practices.
- Deforestation and habitat destruction.
- Industrial pollution and urban expansion.
- Climate change and extreme weather events.

Identifying these drivers helps in attributing costs to specific activities and designing targeted interventions.

3.1.4 Assessment of Economic Impacts

Once the degradation is understood, its economic impacts need to be assessed. The key areas of focus include:

- Loss of productivity: Reduced agricultural yields, lower industrial outputs.
- Health costs: Increased healthcare expenditure due to pollution-related diseases.
- Infrastructure damage: Costs of repair due to flooding or erosion.
- Opportunity costs: Foregone benefits from alternative uses of degraded resources.

Economic models such as cost-benefit analysis and input-output analysis can be employed to quantify these impacts.

3.1.5 Integration of Stakeholder Perspectives

Incorporating the views of various stakeholders is indispensable for a holistic analysis. These stakeholders may include:

- Local communities affected by degradation.
- Government agencies and policymakers.
- Private sector entities and investors.
- Non-governmental organizations (NGOs) and advocacy groups.

Engaging stakeholders provides insights into socio-economic priorities and ensures that solutions are equitable and inclusive.

3.1.6 Use of Advanced Analytical Tools

Modern analytical tools and technologies are vital for accurate quantification. These include:

- Satellite imagery and remote sensing: Monitoring land-use changes and deforestation.
- Geographic Information Systems (GIS): Mapping degradation hotspots.
- Economic modeling software: Simulating scenarios and predicting outcomes.
- Artificial intelligence and machine learning: Identifying patterns and optimizing interventions.

3.1.7 Policy and Regulatory Framework

Quantifying the economics of degradation requires alignment with existing policies and regulations. These frameworks guide the analysis and ensure its relevance for decision-making. Key considerations include:

- National environmental action plans.
- International agreements like the Paris Climate Accord.
- Standards for reporting and accountability.
- Incentives and penalties for sustainable practices.

3.2 Challenges with estimating economics of degradation

Despite its importance, quantifying the economics of degradation faces several challenges:

- Data gaps: Limited availability of reliable data, especially in developing regions.
- Valuation complexities: Difficulty in assigning monetary values to intangible services.
- Uncertainty: Unpredictable environmental changes and socio-economic dynamics.
- Conflicting interests: Resistance from stakeholders with vested interests.

Addressing these challenges requires coordinated efforts, innovation, and investment in research and technologies.

3.3 Using economics of degradation to plan soil health strategies

Despite its importance, quantifying the economics of degradation faces several challenges:

- Data gaps: Limited availability of reliable data, especially in developing regions.
- Valuation complexities: Difficulty in assigning monetary values to intangible services.
- Uncertainty: Unpredictable environmental changes and socio-economic dynamics.
- Conflicting interests: Resistance from stakeholders with vested interests.

Addressing these challenges requires coordinated efforts, innovation, and investment in research and technologies.

Tracking cost of degradation in Africa

4.1 Strategies for quantifying and monitoring economics of degradation in Africa

4.1.1 Identifying Key Ecosystem Services

A primary strategy for quantifying degradation involves identifying and valuing ecosystem services affected by environmental decline. These services include:

- Provisioning services: such as water, food, and timber.
- Regulating services: such as carbon sequestration, water purification, and flood control.
- Cultural services: such as tourism and spiritual value.

Economic valuation methods, including contingent valuation and market-based pricing, can be used to assess the financial cost of lost ecosystem services.

4.1.2 Using Geospatial Technologies

Remote sensing and Geographic Information Systems (GIS) offer powerful tools for quantifying degradation. These technologies help monitor changes in land use, vegetation cover, and water resources over time. By integrating geospatial data with economic models, researchers can estimate the costs of degradation across specific regions and populations.

4.1.3 Cost-Benefit Analysis of Preventive Measures

Quantification is incomplete without assessing the economic benefits of intervention measures. Conducting cost-benefit analyses of restoration initiatives, such as afforestation projects or soil conservation programs, enables policymakers to prioritize actions based on their economic feasibility and impact.

4.1.4 Applying Environmental Accounting

By integrating environmental degradation into national accounts, governments can create more realistic measures of economic performance. Adjusted GDP metrics that account for natural resource depletion and degradation provide a clearer picture of long-term economic sustainability.

4.1.5 Leveraging Big Data and Artificial Intelligence

Big data analytics and artificial intelligence (AI) can revolutionize the quantification of degradation economics. By processing vast datasets on climate patterns, agricultural yields, and industrial impacts, AI models can predict future costs and pinpoint high-risk areas for targeted interventions.

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Chapter 4

Scaling Soil Health and Integrated Fertilizer Management

Contents

Summary

The Soil Initiative for Africa (SIA) framework (African Union, 2024) emphasises the need to achieve improved and maintained soil health, soil fertility, and productivity, along with their impacts, at scale across Africa. Achieving this requires a focus on empowering land users through improved access to science-based soil management practices combined with local knowledge, institutional support, and effective policies. Scaling is essential to combat widespread soil degradation, enhancing agricultural productivity, food security, and rural livelihoods while promoting sustainable intensification.

It is critical to understand that scaling is not only the dissemination of practices; scaling is a holistic process involving systemic change, adaptation to local contexts, and capacity development at individual, organizational, cooperation, and environmental levels. We delineate three types of scaling: scaling out to increase the number of beneficiaries, scaling up to influence policy and institutions, and scaling deep to change cultural norms and values. Scaling is also different from piloting - scaling involves extending proven innovations beyond pilot stages to broader populations with an emphasis on sustainability and adaptation. Key strategies for effective scaling include innovation platforms, systems approaches, capacity building, market and value chain development, policy advocacy, and adaptive learning through monitoring, evaluation, and learning systems. To support practical implementation of scaling it is important to identify leverage points, set common standards through a stage-gate process, and apply a value chain approach. Investment in human capital, knowledge management, and creating an enabling environment are critical for scaling success. Let's not forget, to know and track the impact of scaling, there is a need for multi-level monitoring to assess impacts and the coordination of various efforts to align with the SIA's goals, ensuring a synergistic approach to improve soil health across the continent.

Introduction

1.1 Background

The Soil Initiative for Africa (SIA) framework (African Union, 2024) emphasises the need to achieve improved and maintained soil health, soil fertility, and productivity, along with their impacts, at scale across Africa. The vision of the SIA is to create a future where Africa's soils are healthy and resilient, supported by a robust, Africa-led system to manage soil. The SIA mission focuses on empowering land users through improved access to science-based soil management practices combined with local knowledge, institutional support, and effective policies. To achieve this vision, the SIA highlights that:

1. There are many local examples of successful projects to learn from and build on to scale improved soil health and integrated fertilizer management based on local adaptation.
2. It is important to know HOW to scale at the local, national, regional, and continental levels to connect science at scale with service provision at farm level and landscape interventions.
3. Scaling of farmer and community learning, know-how, and capacity, along with systems innovation are critical to support improved soil health across Africa.
4. Scaling does not mean simply taking specific practices and rolling out standardized activities in multiple areas; in stead scaling requires a holistic, systems-wide approach to bring about human capacity growth, empowerment, and lasting change.

The SIA framework places the scaling of science-based soil health capacities, information, and practices at the center of the initiative. It aims to reach millions of land users across Africa with the best practices, research, information, and technologies for soil health and adaptive management decisions.

1.2 Why is scaling important?

Africa faces widespread soil degradation, which negatively impacts agricultural productivity, food security, and rural livelihoods. The challenge isn't a lack of knowledge about how to improve soil health *per se*, but rather ensuring that the best scientific methods, combined with local knowledge, are made accessible to all farmers in combination with community empowerment and farmer know-how. There is consensus that agricultural productivity can and must increase, while expansion of arable land, deforestation, and loss of biodiversity must be avoided. In other words, production per unit area must increase through sustainable intensification. Increasing productivity requires fertilizer and organic inputs in combination with additional measures such as good agronomic practices, improved seeds, and other amendments, as summarized in the Integrated Soil Fertility Management approach. On healthier soils, both the agronomic efficiency of fertilizer and the efficiency of water use are higher; healthy soils produce “more with less,” resulting in higher returns on investments in agro-inputs and labor. The availability of sufficient micronutrients can further increase the agronomic efficiency of fertilizers.

Agricultural technologies have the power to drive economic development and improve food and nutritional security around the globe (USAID, 2014). There has been an assumption in the past that if technologies or practices proved useful to farmers, then technology diffusion would occur naturally through peers (scale-out on its own), family and members or farmer associations. However, scaling out does not just happen by itself; it needs to be well planned and facilitated. Providing improved technologies to smallholders is essential, but their uptake is often limited by the legal, regulatory, policy, and institutional framework. This often restricts the development and distribution of agricultural technologies within countries and across borders. Therefore, there is a great need to rapidly scale up agricultural technologies to enhance the scope for increasing production, especially among smallholders, and to reduce rural poverty and hunger (Linn, 2014).

The Soil Initiative for Africa (SIA) prioritizes scaling because while many local projects have successfully improved soil health, integrated efficient fertilizer use, and increased productivity, these successes have mostly remained limited to small areas. Scaling is essential to extend these proven soil management practices across Africa to reach millions of farmers and land users. Scaling these practices and farmers’ capacities to implement them helps ensure that more land users can adopt sustainable soil management techniques, improving agricultural productivity, climate resilience, and livelihoods on a larger scale.

What is scaling?

2.1 Concepts and elements of scaling

The scaling concept has been defined in multiple ways based on different definitions and interpretations used in different disciplines (Ajayi et al., 2018). Traditional scaling approaches have often been linear, focusing on single innovations, which do not adequately address sustainable development's complexity. New thinking has emphasized the importance of approaching scaling from an integrated systems perspective (Woltering et al., 2024). The initial focus of scaling efforts was largely on the dissemination of single technologies through linear models. Over time, the focus shifted to the scaling of innovation, recognizing the complexity of involving multiple dimensions like technological, organizational, and institutional changes. Until now, scaling concepts further evolved into outcome-oriented scaling which focuses on the societal outcomes of scaling rather than just the innovation itself (Schut et al., 2020).

Scaling in the context of agricultural innovation involves expanding the impact of proven technologies or practices to achieve broader societal benefits. The process of scaling requires understanding the innovation's context, including socio-economic, cultural, and political dimensions, to tailor interventions for different locales (Schut et al., 2020; Woltering et al., 2024). It involves not just the technology or practice but also an enabling environment, which includes policy support, market access, and stakeholder engagement (Ajayi et al., 2018; Schut et al., 2020). Effective scaling strategies often involve multi-stakeholder platforms and partnerships to facilitate knowledge sharing, capacity building, and collaborative action (Ajayi et al., 2018; Schut et al., 2020; Woltering et al., 2022, 2024).

Moreover, scaling should be guided by a systems approach, considering the interdependencies of various system components like technology, institutions, and human interactions (Schut et al., 2020; Woltering et al., 2024). It's about moving from merely increasing the number of adopters to achieving sustainable systems change, which includes addressing unintended consequences and ensuring equitable access (Schut et al., 2020). The literature emphasizes that scaling is not just about replicating successes but also about adapting innovations to local contexts, fostering systemic capacity, and promoting long-term sustainability (Ajayi et al., 2018; Schut et al., 2020; Woltering et al., 2022).

2.2 Types of scaling

To achieve the goals of the SIA Framework, we need to address all three types of scaling: scaling out, scaling up, and scaling deep.

Scaling out aims to impact greater numbers by increasing the number of people or communities positively impacted by good ideas, initiatives, technologies, innovations, and capacities. This can be achieved by disseminating principles with an adaptation to new contexts through co-creation of knowledge with people and communities (Moore et al., 2015). Scaling out can thus be viewed as "horizontal scaling" which refers to the geographical spread of an innovation and principles to cover more people and communities within the same sector or area (Ajayi et al., 2018).

Scaling up is institutional in nature, aiming to impact laws and policy by changing institutions at the level of policy, rules, and laws (Moore et al., 2015). As such, scaling up involves multiple sectors and stakeholder groups from grassroots organisations to policymakers, donors, development institutions and international investors (Gündel et al., 2001). At the country level, it is imperative that efforts to scale up be led by national institutions, supported by regional or international development organizations where appropriate (Schut et al., 2020). Scaling up can also be viewed as "vertical scaling" by which innovation or interventions are scaled up the institutional ladder, influencing policy and engaging higher-level stakeholders (Ajayi et al., 2018).

Scaling deep aims to impact cultural roots by changing underlying values, beliefs, and cultural norms that are fundamental to the way systems operate. It's about understanding that culture plays a powerful role in shifting problem-domains. Change must therefore be deeply rooted in people, relationships, communities, and cultures, essentially touching the "hearts and minds" of people and communities. Scaling deep requires investment in transformative learning by intensively sharing knowledge, principles, and practices for local adaptation through learning communities, distributed learning platforms, and participatory approaches (Moore et al., 2015).

2.3 Steps before scaling (scaling vs piloting)

The agricultural research and development system is littered with technologies and innovations aimed at increasing agricultural productivity and efficiency under changing climatic conditions. However, not all technologies or innovations are equally effective in different contexts, and many more innovations are released in comparison to those that go to scale at farmer and community level. To support the efficient allocation of scarce resources, it is critical to focus on scaling proven innovations that are backed by good data. This requires a prioritization and focus of resources on successful or promising innovations that have moved beyond the piloting stage.

Scaling and piloting represent different stages in the innovation process. Piloting involves testing an innovation on a limited scale to assess feasibility, efficacy, and potential for broader adoption (Ajayi et al., 2018). It's about gathering data, refining the innovation, and demonstrating its value in controlled settings. Scaling, on the other hand, aims to extend the impact of these proven innovations to larger populations or areas, involving adaptation, expansion, and sustainability (Woltering et al., 2024). Unlike piloting, scaling concerns itself with systemic changes, stakeholder engagement, and the creation of an enabling environment (Woltering et al., 2022).

Innovation often follows a basic sequence of model or concept development, proof of concept, testing or piloting, and replication of selected best options before reaching last mile delivery to end users (people and communities). Scaling only occurs after successful last mile delivery and adoption has occurred.

What and how are we scaling?

3.1 Scaling practices vs scaling human capacities

Scaling in agricultural innovation goes beyond merely duplicating practices in new areas; it requires a nuanced approach that balances the scaling of human capacities with the scaling of practices. Scaling practices often involves disseminating successful agricultural technologies or methodologies to new regions or communities, aiming for wider adoption (Ajayi et al., 2018; Schut et al., 2020). However, this approach alone can be insufficient if it does not account for local contexts or the adaptive needs of different environments.

Effective scaling necessitates focusing on scaling human capacities (Woltering et al., 2022). This means enhancing the skills, knowledge, and abilities of individuals and organizations so they can adapt, innovate, and sustain innovations over time. As Woltering et al. (2024) highlight, capacity development at different levels (individual, organizational, cooperation, and enabling environment) is crucial. Capacity development at these different levels include the following:

- **Individual Level:** Training and education for farmers, extension agents, and other stakeholders to use, adapt, and innovate with new agricultural practices (Woltering et al., 2022). This might involve field days, workshops, online courses, or peer-to-peer learning.
- **Organizational Level:** Strengthening the internal systems, policies, and skills within organizations to support innovation and scaling. This includes improving communication, collaboration, and administrative efficiency (Woltering et al., 2022).
- **Cooperation Level:** Fostering partnerships and networks that allow for shared learning, resource mobilization, and coordinated action among diverse stakeholders, such as between research institutions, NGOs, and private sectors (Woltering et al., 2022).
- **Enabling Environment Level:** Influencing broader systemic factors like policy, market access, and cultural acceptance to create an atmosphere where innovations can thrive. This involves advocacy, policy dialogue, and establishing norms or standards that support scaling efforts (Woltering et al., 2022).

While capacity development at the organizational, cooperation, and enabling environment levels occurs, these are often not explicitly recognized or reported as such, leading to a focus primarily on individual capacity development (Woltering et al., 2022). By empowering local stakeholders through education, training, and capacity-building initiatives, we “enable others to scale” (Wigboldus & with Brouwers, 2016). This empowerment allows for:

- **Innovation and Adaptation:** Local actors can modify practices to fit their unique contexts, leading to more sustainable and effective outcomes.
- **Ownership and Sustainability:** When communities and organizations have the capacity to innovate, they take ownership of scaling processes, ensuring solutions are not only implemented but also maintained post-project (Schut et al., 2020).
- **Systemic Change:** Scaling human capacities supports the creation of an enabling environment where policies, networks, and cultural shifts support ongoing innovation (Schut et al., 2020).
- **Local Ownership:** Empowerment through capacity development fosters local ownership, enabling communities to make decisions that align with their needs and priorities, enhancing the relevance and impact of scaling initiatives (Thornton et al., 2017).

Thus, successful scaling transcends the mere replication of practices; it involves systemic capacity development that encourages local innovation, ensuring that scaling efforts are both effective and sustainable.

3.2 Scaling strategies

To achieve effective and impactful scaling of agricultural innovations, a range of strategies must be employed that address not only the dissemination of practices but also the sustainability and systemic integration of these innovations. Effective scaling strategies are multifaceted, aiming to ensure that innovations not only reach new users but also achieve sustainable impact. The following strategies have emerged as particularly effective:

- Innovation Platforms: These multi-stakeholder forums facilitate collaboration, knowledge sharing, and collective action, allowing for the integration of various perspectives and resources for scaling (Adekunle et al., 2014). They bridge gaps between research, policy, and practice.
- Use of Systems Approaches: Moving beyond linear models, systems approaches consider the complex interactions within agricultural systems, focusing on how innovations can lead to systemic change (Woltering et al., 2019). This includes analyzing leverage points for scaling and understanding unintended consequences.
- Capacity Building: As discussed, enhancing capacities at all levels ensures that stakeholders can sustain and adapt innovations. This strategy involves not just

training but also organizational development and policy advocacy (Woltering et al., 2022).

- Market and Value Chain Development: Scaling innovations often require viable business models and market access. Strategies here include developing value chains, ensuring market linkages, and focusing on value addition and agribusiness incubation to stimulate demand and support for new practices (Ajayi et al., 2018).
- Policy Engagement and Advocacy: Creating an enabling environment through policy reform is crucial. This involves advocacy for supportive policies, regulations, and incentives that can facilitate scaling at a broader level (Schut et al., 2020).
- Monitoring, Evaluation, and Learning (MEL): Continuous feedback loops through MEL systems allow for adaptive management, ensuring strategies are responsive to evolving contexts and stakeholder needs (Schut et al., 2020).
- Technology Transfer and Adaptation: Rather than one-size-fits-all approaches, strategies should involve adapting technologies to local conditions, which might require local innovation or the integration of indigenous knowledge systems (Ajayi et al., 2018).

These strategies underscore the need for a holistic approach where scaling is not just about numbers but about creating systemic, sustainable change that benefits all stakeholders involved.

Putting Scaling Knowledge into Practice for Soil Health and Integrated Fertilizer Management in Africa

(i.e., in Program/Project/Intervention Design)

4.1 Priority setting: identifying key leverage points for SIA

4.1.1 Apply the science of scaling to identify priorities within a given context

The science of scaling (Schut et al., 2020) involves understanding the systems in which innovations will operate. For SIA, this means identifying leverage points where soil health interventions can catalyze broader systemic change One effective tool for this purpose is the Scaling Scan (CIMMYT, 2023), which helps in assessing the readiness of an innovation for scaling by looking at the context, stakeholders, and systemic factors. Prioritization should focus on regions with significant soil degradation issues, where there is both a need and potential for impact. By applying the Scaling Scan, one can identify key entry points or priorities within a given context, considering socio-economic factors, local farming systems, and existing knowledge about soil management practices. The aim is to tailor interventions that not only improve soil health but also enhance resilience against climate variability and market demands (Woltering et al., 2024). The Scaling Scan's methodology aids in this by providing a structured approach to evaluate the scaling potential, highlighting areas where interventions can have the most transformative impact.

4.1.2 System of common standards for evaluation and stage-gate process

Implementing a stage-gate process involves setting clear milestones and criteria for advancing innovations from research to widespread adoption. This system ensures that only those innovations with proven efficacy, adaptability, and sustainability are scaled. Common standards should include environmental impact assessments, socio-economic benefits, and equity considerations to prevent unintended negative consequences (Ajayi et al., 2018). This structured approach, inspired by (Sartas et al., 2020)agriculture, and the environment. Research for development (R4D, supports decision-making regarding which practices or technologies to invest in for scaling.

4.1.3 Systems-oriented value chain approach

A systems-oriented value chain approach for scaling soil health practices involves understanding how each segment of the agricultural value chain—from input supply to market access—can support soil health. This includes fostering partnerships that ensure soil amendments, fertilizers, and other inputs are accessible and affordable, while also ensuring that there are markets for crops grown on improved soils (Ajayi et al., 2018). This holistic view helps in creating demand-pull mechanisms where improved soil health directly correlates with economic benefits for farmers.

4.2 Key investment needs for scaling (at macro and micro level)

4.2.1 Include incentive mechanisms for last-mile adoption of interventions

Incentive mechanisms are crucial to encourage the adoption of soil health practices at the farm level. These can include subsidies for soil health inputs, market premiums for sustainably grown products, or recognition programs for farmers who implement best practices. Incentives should be designed to align with local agricultural economics and cultural practices to ensure they are effective and sustainable (Linn, 2014).

4.2.2 Knowledge management systems

Effective knowledge management is fundamental for scaling soil health initiatives, encompassing:

- **Knowledge Value Chain Approach:** This involves capturing, storing, disseminating, and applying knowledge systematically. For SIA, this means developing databases of soil health practices, case studies, and lessons learned, ensuring this knowledge is accessible and relevant across different contexts (Woltering et al., 2024).
- **Prioritizing Farmer-Facing Approaches:** Knowledge must be disseminated in formats accessible to farmers, such as through extension services, farmer field schools, or digital platforms tailored to local languages and literacy levels (Ajayi et al., 2018).
- **Community Knowledge Hubs:** Creating physical or virtual spaces where farmers can access, share, and co-create knowledge about soil health, encouraging community-driven innovation and adaptation.
- **Interactive and Adaptive Learning Tools:** Use of interactive tools like mobile apps or interactive websites that provide real-time, localized advice on soil management practices, allowing for immediate application and feedback.
- **Documentation and Sharing of Local Innovations:** Recognizing and documenting farmer-led innovations in soil management, ensuring these practices are shared through networks and can inform broader scaling strategies.
- **Feedback Systems:** Implementing mechanisms for collecting and analyzing feedback from farmers on the usefulness and applicability of shared knowledge, enabling continuous improvement of knowledge dissemination strategies.

These practices ensure that knowledge is not only preserved but also actively used and adapted to meet the specific needs of diverse farming communities across Africa.

4.2.3 Human capital development for scaling

Human capital development is pivotal for the successful scaling of soil health practices, requiring investments in both tangible and intangible resources which includes the following:

- **Infrastructure:** Investment in physical infrastructure like training centers, labs for soil testing, and demonstration sites is essential. This supports hands-on learning and experimentation with soil health practices (Woltering et al., 2022).

- **ICT and Tech Equipment/Facilities:** Equipping farmers and extension services with tools for soil analysis, like soil augers and mobile soil test kits, can enhance the precision of soil management practices. ICT can be used for real-time advice and monitoring of soil conditions (Woltering et al., 2022).
- **Training Programs:** Development of comprehensive training modules tailored to different levels of expertise, from basic farmer education to advanced technical training for extension agents and researchers.
- **Professional Development:** Ongoing education and certification programs for agricultural professionals to keep them updated with the latest in soil science and sustainable practices.
- **Mentorship and Peer Learning Networks:** Establishing mentorship schemes and peer learning networks to foster knowledge exchange and practical experience sharing among farmers and agricultural experts.
- **Scholarships and Fellowships:** Providing financial support for education in soil science, agronomy, and related fields to ensure a steady supply of skilled professionals dedicated to soil health.
- **Cultural and Social Development:** Investments in programs that address cultural attitudes towards soil conservation, promoting a shift towards sustainable land management practices through community engagement and education.

These investments in human capital are essential to cultivate a knowledgeable and skilled workforce capable of driving and sustaining soil health initiatives across Africa.

4.2.4 Enabling environment

Creating an enabling environment for scaling soil health practices involves significant investments in various dimensions:

- **Policy Reforms:** Investment in policy advocacy to push for legislation that supports soil conservation, possibly through tax incentives for sustainable practices, subsidies for soil-enhancing inputs, or regulations that limit practices leading to soil degradation. This requires funding for research to inform policy, as well as for advocacy groups to influence policymakers (Schut et al., 2020).
- **Institutional Support:** Financial resources are needed to strengthen institutions that can support scaling, including capacity building for government agencies, research institutions, and NGOs. This involves training staff, developing institutional frameworks for collaboration, and ensuring these bodies have the tools and authority to implement soil health programs effectively.
- **Business Environment Adjustments:** Investments should support the creation of viable business models for soil health services, such as soil testing labs or biofertilizer production. This includes start-up capital for entrepreneurs, grants for research into marketable soil health products, and development of public-private partnerships to enhance market access for sustainably produced goods.

- **Multi-Stakeholder Platforms:** Funding is essential for establishing and maintaining platforms where diverse stakeholders can collaborate, share knowledge, and coordinate actions. This includes logistical support for meetings, workshops, and digital platforms for ongoing dialogue and strategy adjustment based on evidence-based learning (Schut et al., 2020).

These investments collectively aim to create a supportive ecosystem where soil health initiatives can thrive on a large scale, ensuring sustainable agricultural practices are both feasible and beneficial for all involved parties.

4.3 Factors for successful scaling

Successful scaling in soil health management requires:

- **Leadership and Vision:** Strong leadership to steer projects towards systemic change (Ajayi et al., 2018).
- Partnerships: Broad collaboration among stakeholders to ensure diverse inputs and support (Woltering et al., 2024).
- Adaptability: The capacity to adapt practices to local conditions without losing efficacy (Schut et al., 2020).
- Capacity Building: Continuous investment in human and institutional capacity at all levels (Woltering et al., 2022).
- Finance and market integration: Ensuring issues related to market integration are addressed, such as finance, value chains, and public sector governance, in addition to technologies and practices, awareness and demand, and knowledge and skills (Woltering et al., 2024).

4.4 What does success look like?

Scaling success isn't just about the number of adopters but also about systemic change and network dynamics. It further requires balancing the tension between immediate project outcomes and long-term systemic changes (Schut et al., 2020). Success in scaling soil health initiatives would manifest as:

- **Improved Soil Health Metrics:** Observable enhancements in soil organic matter, structure, and nutrient levels across scaled regions.
- **Increased Farmer Adoption:** Widespread use of sustainable soil management practices leading to higher yields or more resilient production systems.
- **Socio-Economic Impact:** Reduction in poverty and hunger, increased food security, and diversified income sources due to improved agricultural productivity.
- **Environmental Sustainability:** Reduced soil degradation, enhanced biodiversity, and lower greenhouse gas emissions from agriculture.

Monitoring Scaling Efforts and Impacts

5.1 Monitoring required at continental, regional, national, sub-national/ programmatic levels

Effective monitoring of scaling efforts for soil health and integrated fertilizer management requires a multi-tiered approach:

- **Continental Level:** Monitoring at this scale involves tracking broad indicators related to soil health across Africa, such as changes in soil carbon levels, land degradation rates, and overall agricultural productivity. Tools like remote sensing and satellite imagery can be used to assess soil health trends continent-wide (Schut et al., 2020). This level also includes harmonizing data collection methods across countries to enable comparative analysis.
- **Regional Level:** Here, the focus is on regional-specific challenges and successes, considering agro-ecological zones and cross-border issues like shared watersheds. Regional bodies could coordinate data on policy impacts, cross-regional knowledge exchange, and the effectiveness of regional initiatives or programs (Ajayi et al., 2018).
- **National Level:** Each country should monitor national soil health strategies, policy effectiveness, and the adoption rates of new practices. National statistics should include metrics on fertilizer use efficiency, soil fertility status, and the impact on crop yields. This data can inform policy adjustments and resource allocation (Woltering et al., 2022).
- **Sub-national/Programmatic Level:** At this granular level, monitoring involves detailed assessments of project outcomes in specific areas or communities. This includes tracking changes in farmers' practices, soil health parameters in demonstration plots, and the economic impacts on individual farmers or communities. Feedback loops from farmers can provide insights into the practicality and adaptability of scaled practices (Woltering et al., 2024).

Monitoring should be outcome-focused, involving stakeholders in setting indicators that matter most to them, ensuring that the process is participatory and captures both quantitative and qualitative data for a comprehensive view of impact.

Coordination of multiple efforts

Coordinating multiple efforts for scaling soil health practices across Africa involves:

- **Strategic Alignment:** Ensuring that all initiatives, whether led by governments, NGOs, research institutions, or private sectors, align with the overarching goals of the Soil Initiative for Africa (SIA). This requires a common framework or strategy that outlines shared objectives, standards, and metrics for success (Schut et al., 2020).
- **Cross-Sector Collaboration:** Facilitating platforms where different sectors can collaborate, share resources, and avoid duplication of efforts. Innovation platforms, as described by Adekunle et al. (2014), are key to this, fostering dialogue and joint action plans among diverse stakeholders.
- **Resource Pooling:** Efficient use of resources through shared funding models, joint research projects, or pooled procurement of necessary technologies and inputs. This can be supported by international donors or regional financial mechanisms aimed at sustainable agriculture.
- **Knowledge Sharing and Learning Networks:** Establishing networks or digital platforms where information about soil health practices, successes, and challenges can be shared. This would include lessons learned from different regions, facilitating adaptive management and innovation transfer (Woltering et al., 2024).
- **Policy Coordination:** Harmonization of policies at different levels (local, national, regional) to support soil health initiatives. This includes creating conducive regulatory environments for technology adoption, ensuring that soil health is a priority in agricultural policies, and coordinating between countries for transboundary issues.
- **Leadership and Advocacy:** Strong leadership to drive the agenda forward, with advocacy groups or champions who can push for the integration of soil health into broader development and climate agendas.

The coordination of these efforts should aim at creating a synergy where the whole is greater than the sum of its parts, leading to a more impactful and sustainable scaling of soil health practices across the continent.

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Chapter 5

Strengthening Agricultural Extension and Advisory Services for Sustainable Fertilizer and Soil Health Management in Africa

Contents

Summary

The problem of declining soil productivity and environmental degradation in Africa has attained a threshold that requires strategic intervention. Poor soil fertility is a key constraint to agricultural productivity, leading to agrarian poverty, food and nutritional insecurity, and other social ills. Soil degradation also has a far-reaching effect on the soil's environmental services; this is seen in water and air pollution, biodiversity reduction, and an increase in the vagaries of climate change. The Soil Initiative for Africa (SIA) and Africa Fertilizer and Soil Health Action Plan (AFSH-AP) represent the efforts of African leaders to address the core cause of this decline and manage the African soil for agricultural productivity and environmental services. While the SIA is a long-term framework to address these issues, the AFSH-AP is the 10-year implementation guide for the SIA. Achieving the four outcomes of the action plan requires dedicated Agricultural Extension and Advisory Services (AEAS). The AEAS will serve as the catalyst for achieving the outcomes by bridging the technology generation and utilization gap. It translates SIA/AFSH-AP interventions into practice by facilitating knowledge exchange, building farmer capacity, and promoting context-specific solutions. This chapter provides a more holistic breakdown of the required actions to be carried out at the different governmental and geographical levels to achieve the indicated outcomes in the AFSH-AP.

Introduction

1.1 Background and Context

Africa's agricultural productivity continues to be severely constrained by declining soil health across the continent. The degradation of soil organic matter, negative nutrient balances, erosion, acidification, loss of soil biodiversity, salinization, pollution, and overgrazing have collectively hindered agricultural productivity, food and nutrition security, rural livelihoods, and environmental sustainability. This decline significantly reduces the capacity of soil to respond to yield-increasing inputs and greatly increases the vulnerability of smallholder farmers to climate shocks.

The Soil Initiative for Africa (SIA) aims to systematically improve the health and productivity of Africa's soils by 2063. The SIA Framework establishes ambitious targets, including halting land degradation and restoring at least 30% of Africa's degraded soils to optimal health by 2032 as part of the first decade of implementation under the Africa Fertilizer and Soil Health Action Plan (AFSH-AP). Achieving these ambitious targets requires robust Extension and Advisory Services (AEAS) to translate technical knowledge into practical implementation by millions of farmers across diverse contexts.

1.2 The Critical Role of Extension in Implementing the AFSH-AP

Extension and Advisory Services act as the crucial implementation channel for the AFSH-AP, bridging research, policy, and farmer practice. EAS systems perform five essential functions that directly support AFSH-AP outcomes: translating complex soil science into practical advice, building farmer capacity, supporting integrated approaches to soil health and water management, promoting context-specific solutions, and enabling informed decision-making.

Strategic AEAS goals under the AFSH-AP include doubling the reach of soil health advisory services, ensuring 40% of extension agents are proficient in digital soil health tools by 2032, and integrating farmer feedback into 75% of national EAS programs.

Current status of Extension Systems for Soil Health in Africa

2.1 Overview of Extension Systems in Africa

Extension systems in Africa have evolved significantly since the colonial era, transitioning from top-down technology transfer models focused on cash crops to more diverse approaches serving multiple stakeholders. The current landscape is characterized by pluralistic systems featuring multiple delivery models, including public sector extension services, private sector advisory services, farmer-to-farmer extension approaches, project-based and NGO extension delivery, and digital and ICT-enabled advisory services.

2.2 Institutional Challenges and Opportunities

Extension systems across Africa face several institutional challenges that limit their effectiveness in promoting sustainable soil health management. These challenges include fragmentation of extension services, chronic underfunding, technical capacity gaps, weak research-extension-farmer linkages, and poor coordination among stakeholders. Despite these challenges, significant opportunities exist to strengthen extension for soil health, including growing policy recognition of soil health's importance, digital innovations, increasing private sector engagement, and renewed donor interest in sustainable agriculture and climate resilience.

Framework for AEAS Implementation of AFSH-AP Outcomes

3.1 Comprehensive Extension Strategy for AFSH-AP Implementation

A multifaceted extension methodology is essential to effectively implementing initiatives such as the Africa Fertilizer and Soil Health Action Plan (AFSH-AP),. This methodology blends various theoretical frameworks into a practical, action-oriented approach that addresses both the adoption of fertilizer technologies and the integration of sustainable soil health practices. Given the complexity of soil health interventions, particularly those related to fertilizer use, an integrated, holistic strategy is necessary to drive long-term success. Effective scaling of sustainable soil management practices through extension requires methodological innovations that go beyond traditional technology transfer approaches.

The extension methodology for AFSH-AP should combine the following key approaches:

1. Experiential Learning and Farmer Field Schools: Grounded in Adult Learning Theory, the foundation of the methodology should emphasize hands-on, experiential learning. Platforms such as Farmer Field Schools and demonstration plots are central to this approach. Demonstration plots established with systematic contrasts between conventional and improved practices provide visual evidence of benefits but must be combined with facilitated learning processes rather than simple observation. These interactive platforms allow farmers to observe, experiment, and directly engage with soil health and fertilizer practices fostering practical understanding and skill development.

2. Systems-Based Agroecological Approaches: Building on Systems Thinking, extension services must recognize the interconnectedness of soil health with broader agroecological systems. Integrated Soil Fertility Management (ISFM) must be promoted within the context of water management, crop rotation, and pest control. Demonstrating how practices like cover cropping enhance soil structure and water retention, thus improving the efficiency of fertilizer use, is an example of how systems thinking can be applied to soil management. This approach ensures that fertilizer technologies are viewed not as isolated interventions but as part of a comprehensive, sustainable farming system.

3. Leveraging Social Networks for Technology Diffusion: Incorporating Innovation Diffusion Theory, the extension program should utilize social networks, particularly through lead farmers and cooperatives, to accelerate the adoption of new soil health practices and fertilizer technologies. By empowering trusted community figures to share their experiences, peer influence and social capital can be leveraged to overcome initial resistance and facilitate widespread uptake. Lead farmer approaches identify and equip respected community members with knowledge and demonstration capacity, creating multiplication effects through informal interaction and organized farmer-to-farmer training. These approaches require careful selection of lead farmers, quality technical backup, and sustainable incentive mechanisms.

4. Participatory Technology Development and Adaptation: These should be complemented by Participatory Technology Development processes that engage farmers as co-researchers in adapting soil technologies to specific contexts. Farmers are directly involved in co-designing and testing fertilizer technologies and soil health practices, including participatory soil testing and local adaptation of technologies. By involving farmers in the innovation process, extension services can foster a sense of ownership and encourage long-term engagement with sustainable practices.

5. Knowledge Co-Creation and Integration: The extension methodology must embrace Knowledge Co-Creation, recognizing the value of both scientific and local knowledge. For instance, digital tools such as soil maps and research trial data can be combined with farmers' traditional soil fertility management practices to create more accurate and effective fertilizer recommendations.

6. Value chain-embedded extension: links soil management advice to market opportunities, creating economic incentives for adoption. Input supplier models train agro-dealers to provide soil management guidance alongside product information. Buyer-linked models integrate soil practices into contract farming and certification schemes, rewarding farmers for sustainable practices through market access or price premiums.

7. Gender-Transformative Strategies: To ensure that soil health initiatives benefit all members of the community, the program must adopt Gender Transformative Approaches. These approaches go beyond merely including women in training sessions and address structural barriers such as land tenure, access to credit, and decision-making power. A gender-responsive approach ensures that women, who often play a central role in agriculture, are fully engaged in the adoption of sustainable soil health practices.

The selection and combination of methodological approaches should be tailored to specific contexts, considering factors such as farming system complexity, market orientation, community organization, and extension resource availability.

3.2 Comprehensive Framework for AFSH-AP Implementation through Optimized Extension Advisory Services (AEAS)

A comprehensive framework that defines actor responsibilities and strategic actions across the continental, regional, and national levels is essential to effectively implement the AFSH-AP through optimized AEAS), This framework ensures coordination, collaboration, and the integration of diverse stakeholder expertise, fostering a unified approach to sustainable soil health management.

Actor Ecosystem and Responsibilities

Continental Level:

- **Africa Union Commission (AUC):** Provides political leadership, secures high-level commitment, and drives policy integration.
- **Forum for Agricultural Research in Africa (FARA):** Strengthens research-extension linkages and facilitates knowledge management systems.

- **SIA Secretariat:** Ensures the alignment between soil information systems (SIS) and extension approaches, facilitating the integration of accurate soil data into extension service delivery for more targeted soil management.
- **African Forum for Agricultural Advisory Services (AFAAS) and Coalition for Strengthening AEAS (C4SEAS) partners:** in partnership with the SIA Secretariat develops continental frameworks, sets standards for soil-focused extension, and promotes cross-regional learning to ensure consistent and effective soil health practices across Africa.

Regional Level:

At the regional level, Regional Economic Communities (RECs) and regional organizations adapt continental frameworks to their specific contexts:

- Regional Economic Communities (RECs): Adapt the continental AEAS framework to regional needs, harmonize extension approaches across member states, and facilitate cross-border learning. RECs also establish regional networks of extension professionals and organize knowledge exchange workshops to share best practices.
- Regional Research Organizations: Develop regionally appropriate soil management technologies and create training materials that reflect the unique agricultural systems of each region.
- Regional Extension Networks: Coordinate capacity-building programs, promote communities of practice, and provide specialized technical support for national extension systems.

National Level:

- **Ministries of Agriculture:** Lead the development of national soil extension strategies, ensuring alignment with the SIA and AFSH-AP frameworks. They are responsible for allocating resources and setting quality standards for extension services.
- **National Agricultural Research Systems (NARS)**: Conduct adaptive research on soil health, provide evidence-based advisory content, and ensure that recommendations align with the latest research findings.
- **Country Fora:** Respective country forum to provide support, guidance and active participation in mobilizing national partners for implementation
- **Extension Directorates**: Coordinate multiple service providers (public, private, NGO) and implement training programs to ensure effective service delivery at the grassroots level.
- **Farmer Organizations:** Facilitate peer learning, articulate farmer priorities, and provide feedback on service quality to ensure that extension services meet the needs of farmers and promote sustainable practices.

Other Key Actors:

- **Private Sector:** Input suppliers, financial institutions, and agribusinesses play a critical role by providing specialized advisory services, developing digital tools, and investing in demonstration sites to promote soil health and fertilizer best practices.
- **Civil Society Organizations (CSOs)**: Complement public extension services in underserved areas, test innovative approaches, and support community-based soil monitoring efforts, ensuring that even the most remote communities have access to soil health services.

3.3 Knowledge Flows and Integration with Soil Information Systems

Effective implementation of the AFSH-AP requires systematic knowledge flows that connect soil information with extension delivery and farmer adoption. These flows must operate in multiple directions:

Optimizing Soil Knowledge Transfer- Research and Extension Pathways: Research to extension flows transform scientific findings and technical soil information into practical advisory messages. This requires translation of complex soil data into decision support tools, training materials, and simplified recommendations for extension agents. This process should involve collaborative development between researchers and extension practitioners to ensure relevance and usability. Extension to farmers flows deliver soil health knowledge through appropriate channels and formats, considering literacy levels, language preferences, and access to digital tools. Messages must be timely, relevant to immediate decisions, and delivered through trusted sources.

Ensuring Effective Feedback: Farmer-to-Policy Pathways for Soil Health: Farmers to extension flows communicate local observations, innovation needs, and feedback on technology performance. These channels must be systematized through regular feedback mechanisms, participatory monitoring, and structured reporting systems. Extension to research flows ensure that research agendas respond to real implementation challenges and farmer priorities, creating feedback loops that improve the relevance of soil research. Policy flows connect field-level insights with policy formulation and adaptation, while ensuring policy directives are effectively communicated to implementers.

Harnessing Soil Information: Integrating SIS for Effective AFSH-AP Implementation: Integration with Soil Information Systems (SIS) represents a particular priority for AFSH-AP implementation. Extension services must be equipped to access, interpret, and translate soil data from national and regional SIS into actionable farm management recommendations. This integration requires three components: technical protocols that enable seamless data exchange between SIS and extension platforms; capacity development that equips extension agents to understand and utilize soil data; and farmer interfaces that make complex soil information comprehensible and actionable for different farmer segments.

The establishment of joint technical working groups between SIS developers and extension services at continental, regional, and national levels can facilitate this integration, ensuring that soil information systems effectively support advisory services in implementing the AFSH-AP.

Implementation Structures for AFSH-AP Extension

4.1 Continental Implementation Structure

At the continental level, implementation structures must provide strategic direction, coordination, and monitoring of EAS contributions to AFSH-AP objectives. The implementation architecture should include:

- **Continental EAS Coordination Platform for Soil Health**: Established under the joint leadership of AFAAS, Sasakawa Africa Association (SAA) and the SIA Secretariat, with representation from FARA, AUC-DREA, and other continental bodies.
- **Technical Working Group on Extension for Soil Health**: Develops technical guidelines, training curricula, and digital tools that can be adapted at regional and national levels.
- **Continental Soil Health Extension Observatory**: Tracks extension performance across regions, documents successful approaches, and generates evidence for policy advocacy.
- **Continental Capacity Development Program for Soil Health Extension**: Develops training modules, certification standards, and professional development pathways for extension professionals specializing in soil health management.

Continental implementation requires dedicated resources and clear institutional mandates. Integration with other continental frameworks, particularly the Comprehensive Africa Agriculture Development Programme (CAADP) and the Africa Continental Free Trade Area (AfCFTA), is essential to ensure policy coherence and resource mobilization.

4.2 Regional Implementation Structure

Regional structures provide crucial intermediation between continental frameworks and national implementation, addressing transboundary issues and facilitating harmonization across similar agroecological zones:

- Regional Soil Health Extension Network: Each Regional Economic Community (REC) should establish a Regional Soil Health Extension Network that links national extension systems within its jurisdiction. These networks will adapt continental guidelines to regional contexts, facilitate cross-border learning, and provide support to countries with limited extension capacity.

- Regional Technical Support Teams: Regional Technical Support Teams, consisting of soil scientists, extension specialists, and digital experts, should be available to provide on-demand technical assistance to national systems as they implement soil health advisory services.
- Regional Training Hubs: Regional Training Hubs should be set up in partnership with agricultural universities and research centers. These hubs will develop specialized human resources for soil health extension, offering certificate and diploma programs, short courses, and continuing education aligned with AFSH-AP priorities.
- Regional Digital Resource Centers: Regional Digital Resource Centers will be responsible for developing and maintaining region-specific digital advisory tools, mobile applications, and training materials in relevant languages, ensuring accessibility to diverse farmer groups across the region.
- Regional Coordination and Monitoring: Regional structures should establish coordination mechanisms that include regular review meetings, joint planning processes, and harmonized monitoring systems. RECs should integrate soil health extension into their agricultural investment plans and create dedicated budget lines to support regional coordination functions. Partnerships with regional private sector associations can help mobilize additional resources and promote market-linked advisory services

4.3 National Implementation Structure

National structures form the operational backbone for implementing soil health advisory services, directly interfacing with farmers and local institutions. To optimize resource use and streamline implementation, countries through Country Forums are encouraged to assess their current institutional landscape and prioritize adapting and strengthening existing ministries, agencies, and extension service frameworks to effectively undertake the outlined responsibilities. Creating entirely new organizations should be considered only when clearly necessary:

- **National Soil Health Extension Coordination Unit:** Each country should establish a National Soil Health Extension Coordination Unit within the appropriate ministry or agency responsible for agricultural extension. This unit will be tasked with developing national strategies aligned with the AFSH-AP, coordinating multiple service providers, and ensuring quality assurance for extension services.
- **National Soil Health Extension Technical Teams:** These teams, consisting of soil science specialists, agronomists, digital tool experts, farmer advisory support and education professionals, will develop contextualized advisory content and

training materials that address specific national soil health challenges.

- **Sub-national Extension Hubs:** Sub-national Extension Hubs should be established in key agroecological zones to localize soil health advisory services. These hubs will serve as training centers, maintain demonstration sites, and adapt recommendations based on local conditions. The hubs will also facilitate farmer training and serve as platforms for peer learning.
- **National Extension-Research Linkage Committee:** Every country should establish a National Extension-Research Linkage Committee for Soil Health to ensure that soil health advisory services are based on the latest research findings and that research agendas respond to implementation challenges at the field level.

National implementation will often require institutional reforms to prioritize soil health within extension systems. This includes the establishment of performance metrics that incentivize sustainable soil management outcomes. Countries should develop costed national action plans for strengthening extension services for soil health, clearly outlining resource allocation strategies and implementation timelines.

4.4 Coordination Mechanisms Across Levels

Effective implementation of the AFSH-AP through extension services requires coordinated action across continental, regional, and national levels, with clear communication channels and feedback loops:

Vertical coordination between governance levels should be formalized through a hierarchical but interactive reporting system. National coordination units should report to regional networks, which in turn report to the continental platform, with structured templates and regular reporting cycles. Annual continental soil health extension forums should bring together representatives from all levels to review progress, share innovations, and realign strategies based on implementation experience.

Horizontal coordination across sectors and stakeholders at each level is equally important. Multi-stakeholder platforms at national (Country Fora) and regional levels should bring together public extension, private advisory services, research institutions, farmer organizations, and civil society to harmonize approaches and leverage comparative advantages. Formal coordination with other AFSH-AP implementation structures, particularly Soil Information Systems (SIS) and fertilizer value chain initiatives, should be established through joint working groups and integrated planning processes.

Digital coordination tools can significantly enhance implementation efficiency. A Continental Soil Health Extension Dashboard should be developed to track key performance indicators, visualize coverage gaps, and highlight successful approaches. This system should be accessible to implementers at all levels with appropriate access protocols, enabling real-time monitoring and adaptive management.

Implementation should establish clear accountability mechanisms that flow in multiple directions: upward accountability to funding agencies and governing bodies; downward accountability to farmers and communities; and horizontal accountability among implementing partners. Practical tools for accountability include stakeholder satisfaction surveys, public performance reviews, and transparent financial reporting.

Table 4.1: Framework for Multi-Level EAAS Coordination

Governance Level	Key Actions	Practical Examples
Continental	- AFAAS to work with FARA secretariat to establish pan-African coordination platform - Harmonize soil extension strategies - Develop standardized monitoring & reporting tools	- Integrate Africa Soil Extension Forum into AEEW - FARA/AU/AFAAS Soil Health Extension Dashboard - AFAAS Digital Knowledge Platform
Regional	- Coordinate cross-border soil health initiatives - Adapt continental SIA guidance to regional agroecological zones - Facilitate regional capacity building and knowledge exchange	- ECOWAS and EAC Soil Health Extension Networks - Regional Soil Extension Working Groups - Shared soil health curricula across countries - Cross-border watershed restoration initiatives
National	- Establish national multi-stakeholder soil extension platforms - Integrate AEAS into national health strategies - Harmonize advisory content across actors - Foster public-private extension partnerships	- Nigeria's soil health card; National Farmer Helpline (FMAFS, NAERLS) - Ethiopia's Soil Health Steering Committee - Kenya's Digital Soil Advisory Platform (MoA, KALRO)
Local	- Form sub-national (district/county) AEAS coordination committees - Align seasonal extension calendars - Coordinate local demos and farmer outreach - Develop community-based monitoring systems	- Sub-national Soil Extension Committees (Uganda, Malawi - Joint Farmer Field Schools on soil practices - Community watershed management teams - Seasonal soil health extension calendars

Priority Action Areas For EAS in SIA/AFSH-AP Implementation

5.1 Capacity Development Framework

A robust capacity development framework forms the cornerstone of effective extension services for sustainable soil health management. This comprehensive approach addresses capacity gaps at three critical levels to ensure the successful implementation of the Africa Fertilizer and Soil Health Action Plan.

Individual capacity development: must equip extension personnel with technical knowledge, functional skills, and appropriate attitudes to promote sustainable soil management effectively. Technical competencies include soil science fundamentals, soil health assessment, integrated soil fertility management (ISFM), and climate-smart soil practices. Functional competencies encompass personal development, team development, organizational or methodological competencies, such as, participatory methods, digital tool application, value chain approaches, and monitoring techniques. These competencies should be developed through three complementary pathways: pre-service education through enhanced university and technical college curricula; in-service training through structured continuing education programs; and peer learning through communities of practice and mentorship networks.

Organizational capacity development focuses on strengthening the institutions that deliver and support extension services. Key interventions include developing specialized soil health units within extension organizations; establishing soil testing and advisory service protocols; improving management information systems for tracking soil health interventions; and enhancing organizational learning mechanisms. Leadership development within extension organizations should receive particular attention, focusing on change management skills, innovation capacity, and strategic planning abilities.

Systemic capacity development addresses the enabling environment for effective soil health extension. This includes strengthening policy frameworks that support integrated approaches to soil management; developing sustainable financing mechanisms for soil advisory services; enhancing research-extension-farmer linkages; and improving coordination among diverse advisory service providers. Education institutions should be engaged as strategic partners in capacity development, with agricultural universities and technical colleges revising curricula to strengthen soil health content and establishing practical collaboration with extension systems.

5.2 Digital Innovation and Technology Integration

Digital tools can significantly enhance the efficiency, reach, and effectiveness of soil health advisory services when appropriately integrated into extension systems:

Mobile Applications for Soil Health Management: These should provide location-specific fertilizer recommendations, soil management guidance, and problem diagnosis capabilities, with offline functionality for areas with limited connectivity. SMS and voice services can reach farmers with basic phones, delivering timely reminders about soil management practices and connecting farmers to soil input suppliers through structured information services.

Decision Support Tools for Extension Agents: To assist extension agents in delivering effective advisory services, decision support tools should be developed that interpret complex soil data and generate actionable recommendations. These tools must be user-friendly, integrating seamlessly with existing soil databases and capable of adapting to different contexts and languages. Decision support tools should assist extension agents in diagnosing soil health issues and recommending region-specific practices, making it easier for them to communicate technical advice to farmers.

Remote Sensing and GIS for Monitoring and Targeting: Remote sensing and Geographic Information Systems (GIS) can significantly improve soil health monitoring and intervention planning. These tools can identify soil degradation hotspots, prioritize areas for intervention, and track the progress of soil restoration efforts. By using satellite imagery, drones, and other remote sensing technologies, extension services can deploy targeted interventions, ensuring that resources are directed to the areas that need them most. Additionally, GIS can support the mapping of fertilizer application needs and soil fertility levels, helping to optimize fertilizer use and reduce waste

Foundational Infrastructure and Digital Literacy: Successful digital transformation hinges on investments in foundational elements such as digital infrastructure and digital literacy. Key investments should include improving rural connectivity, particularly in remote farming areas, and developing appropriate hardware solutions for field use, such as mobile devices, sensors, and data collection tools. Furthermore, establishing interoperable data systems is essential for linking soil information with extension platforms, allowing for seamless data sharing between farmers, extension agents, and service providers.

Equity and Inclusion in Digital Access: The implementation of digital tools must address equity concerns, ensuring that all farmers, particularly women, youth, and resource-poor farmers, can benefit from digital innovations. Strategies should be in place to ensure equal access to digital tools, and hybrid approaches that combine digital tools with traditional, face-to-face interactions should be emphasized. his approach ensures that complex soil management practices, which often require hands-on demonstrations and contextual adaptation, are delivered effectively. By integrating digital innovation into extension services, the AFSH-AP can significantly enhance the reach, accessibility, and effectiveness of soil health advisory services.

5.3 Sustainable Financing Models for Soil Health Extension Services

Securing sustainable resources for soil health extension services demands a fundamental shift from traditional public budget allocations and short-term project funding toward diversified, innovative financing approaches. Effective financing must integrate multiple funding sources, promote long-term sustainability, and align investments with broader agricultural and environmental objectives. The following comprehensive strategies outline pathways to ensure stable, scalable financing while maintaining equitable access to advisory services.

Strengthening Public Financing Mechanisms: Public funding remains the cornerstone for core extension functions that serve as public goods, including system coordination, quality assurance, and outreach to marginalized farming communities. To enhance effectiveness and predictability, governments should implement policy reforms that recognize soil health as a strategic priority. Key measures include:

- **Dedicated Budget Lines**: Establishing specific soil health allocations within agricultural ministries to ensure consistent, ring-fenced funding for extension services.
- **Decentralized Funding**: Channeling resources through local government structures to improve responsiveness to regional needs and community-based extension demands.
- **Performance-Based Allocation**: Linking funding to measurable outcomes, such as improvements in soil fertility indicators or adoption rates of sustainable practices, to incentivize impact-driven service delivery.
- **Cross-Sectoral Financing**: Leveraging synergies with climate adaptation, water management, and biodiversity conservation initiatives to unlock additional funding streams, recognizing the environmental co-benefits of soil health investments.

Public funds should prioritize public-good functions, including technical support for underserved areas where commercial models are not viable.

Private sector engagement offers complementary financing pathways. Value chain financing models embed advisory costs within private sector operations, including input supply chains and market linkages. Fee-based advisory services can be viable for commercial farmers and gradually introduced for emerging smallholders, with tiered pricing based on service intensity and farmer capacity. Corporate social responsibility initiatives can support extension in strategic sourcing areas, particularly when aligned with sustainability commitments.

Innovative mechanisms include results-based financing that links payments to verified soil health improvements; blended finance that combines public, private, and philanthropic resources; impact bonds that mobilize private investment for soil advisory services with public outcome payments; and carbon finance that monetizes the climate benefits of improved soil management through carbon credit markets.

In designing financing strategies, implementers should consider three principles: diversification of funding sources to enhance stability; appropriate cost-sharing that aligns contributions with benefits received; and financial sustainability planning that provides clear pathways from initial project funding to long-term sustainable financing.

Engaging the Private Sector: The private sector offers critical complementary financing through market-driven models that align business incentives with farmer needs. Strategic approaches include:

- **Value Chain Financing**: Embedding advisory services within agricultural value chains (e.g., input supply, procurement contracts) to create shared-value models where agribusinesses invest in extension to enhance productivity and supply chain resilience.
- **Tiered Fee-for-Service Models**: Developing scalable advisory packages, from premium services for commercial farmers to subsidized or bundled options for smallholders, with pricing aligned to farmers' capacity to pay.
- **Corporate Sustainability Investments**: Mobilizing CSR and Environmental, Social, and Governance (ESG) -linked funding from agribusinesses, particularly in sourcing regions (geographic areas where agribusinesses procure raw materials from farmers), to support extension services that align with corporate sustainability targets.

Innovative Financing Mechanisms: In addition to traditional funding sources, innovative mechanisms can be explored to attract investment and ensure the sustainability of soil health initiatives. These include:

- **Results-Based Financing (RBF)**: Link **payments to verified soil health improvements**. This model ties financing to the achievement of specific outcomes, such as soil restoration or improved fertilizer use efficiency, encouraging more efficient and impactful use of funds.
- **Blended Finance**: Combine **public, private, and philanthropic resources** to create **blended finance** models. This approach can help mitigate risk for investors while ensuring that public funds are used efficiently to leverage private sector investments.
- **Impact Bonds**: Use **impact bonds** to mobilize **private investment** for soil health advisory services, with **public outcome payments** tied to successful delivery of soil health improvements and other environmental benefits.
- **Carbon Finance**: Leverage **carbon markets** to monetize the climate benefits of improved soil management. By linking soil health practices to carbon credit mar-

kets, extension services can generate additional revenue through the sale of carbon credits, supporting sustainable farming practices.

Sustainable Financing Strategies for Soil Health Extension Services: Effective financing strategies for soil health extension must prioritize diversification, equity, and transition planning to ensure long-term viability. Diversified funding sources enhance financial resilience, while equitable cost-sharing models align stakeholder contributions with benefits received. Crucially, financial sustainability plans must establish clear pathways from initial project funding to institutionalized systems, incorporating revenue generation and phased funding mobilization. These approaches will strengthen Extension and Advisory Services (AEAS) across Africa, improving farmer access to quality advisory services while advancing the interconnected goals of the African Fertilizer and Soil Health Action Plan (AFSH-AP) and Sustainable Intensification of Agriculture (SIA) through aligned agricultural, environmental, and economic outcomes.

Table 5.1: Action Matrix for Optimizing AEAS for AFSH-AP Implementation

Level	Institutional Actions	Capacity Development Actions	Digital Integration Actions	Methodological Actions	Financing Actions
Continental	Establish Continental EAS Co-ordination Platform Develop standardized extension frameworks Create Continental Soil Health Observatory	Harmonize soil health extension curricula Set certification standards for specialists Create digital knowledge repository	Develop continental digital advisory architecture Establish data interoperability standards Create extension monitoring dashboard	Document and disseminate best practices Develop adaptable methodological toolkits Establish communities of practice	Mobilize continental funding Develop blended finance mechanisms Establish performance incentives
Regional	Establish Regional Extension Networks Form Technical Support Teams Integrate into REC agricultural plans	Create Regional Training Hubs Implement Training of Trainers Facilitate cross-country exchanges	Establish Digital Resource Centers Develop regional mobile apps Adapt to local languages	Adapt methodologies regionally Establish demonstration networks Coordinate cross-border approaches	Integrate into regional investment plans Mobilize private sector partnerships Develop results-based financing
National	Create National Coordination Units Establish Research-Extension Committees Develop national strategies	Revise extension training curricula Establish specialized soil health units Develop specialist career paths	Deploy soil health mobile apps Integrate with soil info systems Develop farmer feedback systems	Implement Farmer Field Schools Scale lead farmer approaches Establish demonstration sites	Secure dedicated budget lines Develop public-private partnerships Implement performance-based financing
Local	Form district coordination committees Establish community monitoring groups Align with landscape management	Train agents in soil assessment Develop para-extension agents Build farmer organization capacity	Establish digital access points Train digital champions Implement local interfaces	Adapt practices to local contexts Implement community learning Establish innovation platforms	Integrate into local budgets Develop cost-sharing mechanisms Link with input supply systems

Monitoring, Evaluation and Learning Framework

A robust Monitoring, Evaluation, and Learning (MEL) framework is essential for tracking the effectiveness of soil health extension services, ensuring continuous improvement, and supporting informed decision-making. By establishing clear performance indicators, aligning timelines with implementation phases, and fostering a culture of learning, this framework will guide the effective execution of the Africa Fertilizer and Soil Health Action Plan (AFSH-AP).

6.1 Performance Indicators for Extension Services

Effective implementation of soil health advisory services requires robust monitoring systems with indicators that track both process performance and outcome achievement:

Process indicators measure the operational efficiency and quality of extension delivery. These include coverage metrics (number of farmers reached, geographical coverage, inclusion of women and youth); service delivery indicators (frequency and timeliness of contact, quality of advice, farmer satisfaction); and institutional capacity measures (extension agent knowledge, organizational capabilities, coordination effectiveness). These indicators should be collected through service delivery records, periodic surveys, and organizational assessments.

Outcome indicators measure changes in farmer knowledge, practices, and results. Knowledge indicators track farmer understanding of soil health principles and management practices. Practice adoption indicators measure the application of recommended practices like integrated soil fertility management, erosion control, and appropriate fertilizer use. Result indicators capture changes in soil properties (organic matter, nutrient balance, biodiversity), agricultural productivity (yield, stability, efficiency), and economic returns (profitability, risk reduction). These require baseline assessments, periodic field monitoring, and outcome evaluations.

Impact indicators assess longer-term changes in soil health, agricultural systems, and livelihoods. These include landscape-level soil health improvements, farming system resilience, household food security and income, and environmental services like water quality and carbon sequestration. Impact assessment requires well-designed studies with appropriate comparison groups and longer timeframes.

Implementers should select a balanced indicator set that captures the full results chain while remaining practical for regular monitoring. Harmonized indicators across countries and regions can facilitate aggregation and comparison, while allowing for contextual adaptation based on local priorities and capacities.

6.2 Implementation Timeline and Action Matrix

Implementation of strengthened extension services for soil health should follow a phased approach aligned with the AFSH-AP timeframe:

The initial phase (Years 1-2) focuses on establishing foundational systems and demonstrating approaches. Key activities include strengthening partnerships, conducting baseline assessments of extension capacity; establishing coordination mechanisms at all levels; developing technical frameworks and training materials; initiating capacity building programs for extension personnel; and launching demonstration sites in high-potential areas. This phase should emphasize quick wins that build momentum while laying groundwork for systemic change.

The scaling phase (Years 3 - 5) expands successful approaches across diverse contexts. Activities include scaling training programs to reach the majority of extension personnel; expanding farmer coverage through multiple delivery channels; strengthening digital advisory platforms and tools; developing sustainable financing mechanisms; and enhancing integration with other AFSH-AP components, particularly soil information systems and input supply chains.

The institutionalization phase (Years 6-10) embeds strengthened approaches within permanent systems. Focus areas include formalizing soil health specialization within extension career structures; securing sustainable funding through government budgets and other long-term mechanisms; strengthening policy frameworks that support integrated advisory services; and establishing learning systems that enable continuous improvement based on implementation experience.

Throughout implementation, annual review and planning processes should enable adaptive management, with strategies refined based on emerging evidence, changing contexts, and evolving priorities. Major strategic reviews at the mid-term (Year 5) and end-term (Year 10) should inform broader AFSH-AP implementation and future planning cycles.

6.3 Indicator Monitoring

Progress monitoring should use harmonized frameworks across countries while allowing appropriate contextual adaptation:

A standardized monitoring framework should be developed at the continental level, with core indicators that all implementing countries report on, supplemented by country-specific indicators reflecting national priorities and contexts. Data collection responsibilities should be clearly assigned, with national systems responsible for primary data collection, regional bodies for quality assurance and aggregation, and continental structures for analysis and reporting.

Digital monitoring tools can significantly enhance data quality and timeliness. Mobile data collection applications for extension agents, integrated management information systems, and real-time dashboards should be developed and deployed with appropriate training and support. These systems should minimize reporting burden on field staff while maximizing data utility for decision-making.

Knowledge management systems should complement quantitative monitoring with qualitative learning processes. These include systematized documentation of case studies, regular learning events at all levels, and communities of practice that enable peer exchange among implementers. A dedicated soil health extension knowledge platform should be established to consolidate and disseminate evidence, tools, and learning.

Adaptive management practices should be institutionalized, with regular review meetings, data-driven planning processes, and flexibility to adjust strategies based on implementation experience. Performance incentives at individual and organizational levels should reward learning and adaptation rather than rigid adherence to initial plans.

Chapter 6

Human Capital for Soil Science and its Application in the Soil Initiative for Africa

Contents

Introduction

This Technical Note addresses the thematic area of human capital development for the Soil Initiative for Africa (SIA). The Technical Note contributes to the Action Plan output: *"Locally relevant soil health and fertilizer management technologies developed and promoted"* which in turn contributes to the Action Plan outcome: *"Institutional and Human Capacity Enhanced for Sustainable Soil Health and Fertilizer Management"*.

Human Capital refers to the knowledge, skills, and health that people invest in and accumulate throughout their lives, enabling them to realize their potential as productive participants in the economy and as active members of society. Investing in people through nutrition, health care, quality education, jobs and skills helps develop human capital, and this is key to ending extreme poverty and creating more inclusive societies". (World Bank 2024).

This Technical Note is informed, firstly, by the opinions of experts that participated in a three-day consultation workshop that led to the first draft; and, secondly, by virtual consultations with a wider range of interested experts on human capital development on soil management in the context of the SIA.

The Note addresses human capital at four levels of aggregation - farm level, local level[1], national level, and sub-regional/ continental level. At each level, of aggregation, the Note explores the current human capital situation in three domains - research, education and advisory services. In the process, it identifies the existing problems and the underlying causes. It then develops a vision of what the characteristics of a good system should be thereby revealing the gaps between the current situation and the desired situation. The Note finally constructs the types and scale of investments and reforms needed to bridge the gaps. Emphasis is put on the public sector in all the aspects.

1 For the purposes of this Note, the local level is regarded as being made up of farms, villages, landscapes and watersheds that are administered by a local government.

Farmer Level Human Capital

2.1 Current situation

The condition of farmers' soils is a potential (and alarmingly frequent) constraint to farm productivity, sustainability and profitability across the Continent. While farmers have traditional knowledge and their own experience to draw upon in managing their soils, in many or most cases, such knowledge is valuable – most African farmers do not, on their own, have full command of extant soil science knowledge, information, and techniques that could be valuable if brought to bear to complement the insights of their own experience in the management of the soils on their lands. To take full advantage of existing soil science knowledge and information, a farmer would need to: (1) identify the needs for soil knowledge and technologies (in their social and economic context) on their own fields; (2) identify available sources of the needed knowledge; and (3) have the capacity to access (effective demand) and ultimately use the needed knowledge, information and techniques effectively and appropriately on their own farms. For many farmers, this would require technical assistance (often in the form agricultural extension or advisory services). Farmer competencies in these regards are not homogeneous. Farmers can be put in three categories, namely: (i) traditional farmers (predominantly women) practicing subsistence on small farms, (ii) emerging commercially oriented farmers with larger multi-enterprise farms, and (iii) commercial farmers with large farms that specialize in a few commodities. All the categories play a role in identifying needs and articulating demand, assessing and monitoring the performance of applying the available information, knowledge and technologies to their contexts, providing feedback to advisory service providers, and diffusing the information and technologies to their peers. However, they differ in the following respects

- The subsistence farmers play the roles when they are organized in groups in which peer knowledge exchange takes place with or without facilitation by advisory services providers;
- The emerging commercially oriented farmers also perform the functions when linked to public and private advisory service providers - including community-based facilitators (CBFs) - and when organized in groups. They have some level of soil science general education to the extent that it is covered in the primary and secondary school curriculum. They have a better ability than subsistence farmers to proactively engage in the soil science knowledge networks and ecosystem. They have varied capacities forl obtaining information and services from public and private sources especially via mobile phones;
- The soil and soil sciences human capital at the commercial farmer level may include graduates (owning farms or employed as managers) from tertiary agricultural education institutions. Most have a generalist understanding of soil science and its application in the context of agronomy - good agronomic practices, plant health management, variety choice, climate/ weather management, etc. This cadre of human capital has a higher knowledge seeking propensity and can ob-

tain the information and services they need from the same sources as the emerging farmers but with a higher intensity. In addition, they can contribute more proactively to sharing their soil science knowledge if there are means and incentives for doing so.

2.2 Characteristics of the desired human capital at the farmer level

The specific desirable characteristic of farmers in the context of soil science and its application are listed in Table 1.

Table 1: Desirable characteristics of farmers for contributing to advancement and application of soil science

Advisory services	Education	Research
Crosscutting farmer human capital Farmer of any category able to: • identify the needs for soil knowledge and technologies; • exchange and share information, knowledge and experiences with other farmers; • provide feedback to advisory services, education and research; • identify and engage with advisors (neighbors, extension agents, farm advisors, researchers, etc.) who might assist on questions beyond the farmers capacity to answer; • identify and access information on soils via mobile and online platforms; • socially network with and/or belong to a group that includes concerns on soils in its agenda; • socially network with a community-based facilitator (CBF) and/or extension agents		
A farmer or FG: • empowered to demand advisory services on soils; • able to access appropriate technologies, innovations and knowledge on soil health • able to use agricultural inputs and adopt practices as recommended; • able to monitor effects of adopting advice on soil health;	A farmer or FG: • has attained at least the recommended primary school education and training on soil science; • able to use self-directed learning material, tools and platforms to improve their knowledge (e.g. courses delivered via mobile phones) • able to provide feedback through appropriate channels and platforms	A farmer or FG able to: • take part in participatory agricultural research; • access and participate in demonstrations and farmer training on soils • can recognize changes in soil health and to attempt to develop/adapt solutions based on their own knowledge (indigenous research) • able to provide feedback

2.3 Investments needed for strengthening human capital at the farmer level

The types of services that farmers may demand and/or be proactively supplied with strategically from other levels for strengthening their human capital attributes mainly relate to institutional and organizational mechanisms that embed them (farmers) into soil science information and knowledge systems. They include the following:

2.3.1 Awareness creation and dialogue:

The precondition for voluntary behavioral changes needed for building farmers' human capital in soil science and its application, is awareness. So, the first action that needs to be taken is to launch campaigns to inform farmers about the deteriorating soil health situation at farm level, the causes, and the available options to halt and reverse the trends. These campaigns must be tailored for farmers of different categories in the media they use to engage and communicate;

2.3.2 Building the capacity of farmers to access and utilize information and communication technology (ICT) platforms:

Already there are examples of ICT tools and platforms for making information available to different categories of farmers. They range from those that make information available - intuitively or proactively - to subsistence farmers using simple mobile phones, to specialized online platforms with the type of information that commercial farmers may need. The availability of soil science content in appropriate media and formats is the determinant of the value of these channels;

2.3.3 Empowering farmers to participate in information and services marketplaces:

The African Forum for Agricultural Advisory Services (AFAAS) is advancing the concept of marketplaces for information and services as a mechanism for accelerating scaling up of knowledge and technologies. It would work by creating a demand for - in this case - soil science knowledge and services through grants for farmers to access information and services from suppliers of such information and services. The physical and virtual marketplace mechanisms would broker the interactions between the farmers and the suppliers. The supply side would, if so needed, be incentivized through challenge funds e.g. for producing content on a specific topic in specific media for a specific demographic.

2.3.4 Reinforcing the soil science in primary and secondary school curricula.

Currently, primary school curricula in many African countries, includes aspects of soil science as a topic in the general science subject. Many primary school leavers end up engaged in farming. By inference, their foundation soil science knowledge is derived from primary school education. The continuous flow of human capital for agriculture from primary schools contributes to the sustenance of soil science human capital at the farmer level. In many African countries, universal primary education is beginning to be entrenched at the local level. This will contribute to the long-term accretion and sustenance of soil science human capital in the communities. Reinforcing the soils science aspects in the general education curricula should entail contextualization of the way it is taught to the realities in the communities. This will inevitably necessitate a more practical approach to the subject.

2.3.5 Farmer-to-farmer networking:

Farmers operate in social networks of various configurations determined by cultural, socio-economic and - significantly - trust factors. The importance of these networks is currently under-emphasized and not given the due attention it deserves in developing human capital at the farm and community level, yet it is one of the main catalysts for scaling out knowledge and technologies through diffusion. It is therefore important that the networks that are effective in communities are identified, nurtured and used as the entry points for soils science knowledge;

2.3.6 Indigenous knowledge entry points:

Farmers have their own indigenous knowledge on soils. It should be taken into consideration as a baseline before interventions that aim to change farmers approach to management of soils. Unfortunately, it is not systematically documented and can only be derived from anthropological studies on soil management practices[2] and the associated underlying stories.

2.3.7 Participatory research:

The farmers' human capital for research on soils is low yet it is important for tailoring technologies to geographic and socio-economic realities at the farm and landscape/ watershed level, and to develop feedback loops from the targeted users of the technologies. It is therefore important to engage farmers in participatory agricultural research as a way of building their human capital. The research on soils and soil health may be undertaken in other contexts such as agronomy, regenerative agriculture and farming systems research.

2 An example of an anthropological study: "Bringing soils to life in the human and social sciences" https://www.sciencedirect.com/science/article/pii/S266700622200048X

Local Level Human Capital

3.1 Current situation

3.1.1 General soil science human capital at the local level

The soil science human capital at this level is comprised of people with qualifications ranging from certificates from c institutions, diplomas from agricultural colleges, as well as graduate and post-graduate degrees from universities. At the local level there is serious systemic weakness in the soils and soil science information and knowledge system. The negative consequence of this weakness on soils human capital is sluggish flow of (often inadequate) information through the "last mile" to the farmers. Most specifically there is low human capital for transforming knowledge products from research into content that can be used in engaging with farmers and other stakeholders at this level. This is compounded by low capacity or propensity to use digital tools and platforms to gain additional knowledge and to network and to engage with the farmers.

The value of the human capital at the local level is amplified by the availability (or unavailability) of operational funding to plan and sustain soil management interventions. Commonly, the operational funding is low and the flow is erratic.

3.1.1 Human capital for advisory services at the local level

According to findings of Rozanov and Wiese (2018)[3], as summarized in Figure 2 below, very few soil scientists work at the local level - 2% in local governments (most presumably as subject matter specialists) and 6% in businesses. The majority of the 8% are self-employed soil scientists, most likely also work at this level.

Human capital for advisory services can be augmented by formally embracing Community-Based Facilitators (CBFs) into the human capital structure at the local level. This is already happening, for example, in the Sasakawa Global 2000 programs. In this case, the CBFs are given contracts within the structure of its programs. The contracts include re-tooling and capacity development. Since Sasakawa 2000 works directly with governments, this category of service providers is being institutionalized in the public sector.

Vanlauwe (2024)[4] has identified the following qualitative gaps in human capital for soil science advisory service:

- Knowledge: Diagnosis of constraints (crops, soils, agronomy, etc); access to adapted and up-to-date practices; understanding of enablers for adoption of improved practice; digitalization of knowledge interface
- Empowerment: Access to new tools (smartphone, sensors, etc); effective linkages with the national R&D community; operationalization of feedback systems

3 Andrei Rozanov and Liesl Wiese (2018): Report on soil scientists and where to find them in Africa: Assessment of Human Capital. Eurasian Center for Food Security. https://envalert.org/wp-content/uploads/2019/02/Africa-report-on-soil-science-human-capital.pdf

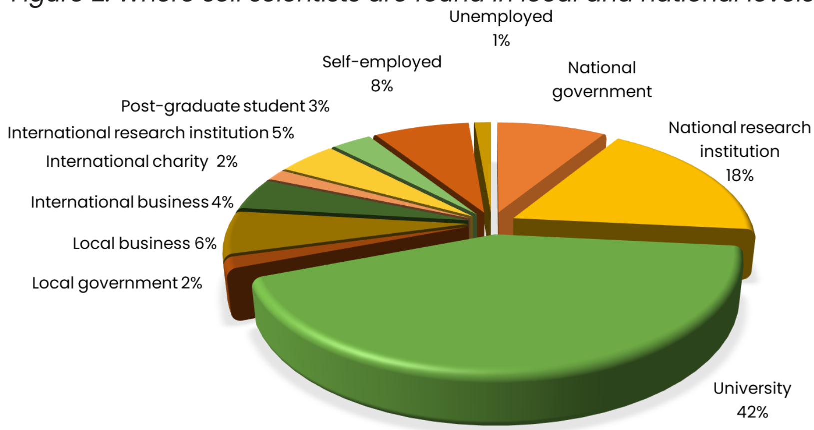
4 Bernard Vanlauwe (2024): Delivering soil science to the farm – challenges and needs for capacity strengthening. Presentation made at the Expert Workshops to Develop Guidance Material on the Human Capital Development Thematic Elements of the Soil Initiative for Africa. b.vanlauwe@cgiar.org

from farmers to research; facilitation of bundling of required services

- Incentives: Certification schemes for extension agents (e.g., ASA certified agronomists); continuous capacity strengthening schemes; payment for advisory services

One common observation is that there is no effective demand exerted by farmers on local level advisory services for knowledge and services in general and for soil health management in particular.

Figure 2: Where soil scientists are found in local and national levels



3.1.2 Human capital for soil science education at the local level

The majority of subsistence farmers have no formal education, with the highest level attained being primary school levels. These farmers mostly attain their soils and soil science knowledge from the advisory services and other farmers. Currently, primary school curriculum in many African countries, includes aspects of soil science as a topic in the general science subject. Many primary school leavers end up engaged in farming. By inference, their foundation soil science knowledge is derived from primary school education. This means that the continuous flow of human capital for agriculture from primary schools contributes to the sustenance of soil science human capital in the communities. In many African countries, universal primary education is beginning to be entrenched at the local level. This will contribute to the long-term accretion and sustenance of soil science human capital in the communities.

Outside primary schools, human capital development at the local level is undertaken through farm schools that include educational dimensions in the methodologies they use (as opposed to simply training) also contribute to education of farmers.

3.1.3 Human capital for research at the local level

Most national agricultural research systems (NARS) are structured such that they have institutional and organizational presence at the local levels. Thus, where it exists, soil science human capital at the local level is linked to soil science capacity at the national level. The utility of this human capital in the research system includes supporting field research, technology demonstration, research needs identification and prioritization, monitoring and evaluation, research-advisory service liaison (through advisory services subject matter specialists, scaling out technologies, and fostering local level networking and partnerships. There is expert consensus that, at present, the soil science human capital at local level is grossly inadequate.

3.2 Characteristics of the desired human capital at the local level

Table 2: Desirable characteristics of human capital for SHWM at the local level

<table>
<tr><th>Advisory services</th><th>Education</th><th>Research</th></tr>
<tr><td colspan="3">Crosscutting
Enablers of soils innovation by farmers and their integration in soil science knowledge systems empowered for:
• Undertaking liaison between education-research-advisory service on soils;
• Fostering local level networking and partnerships on soils;
• Interfacing with virtual and physical digitalized soil health systems and services;
• Using new tools for linking with national-level soil health knowledge, information and technology systems;
• Operationalizing feedback systems from farmers to national level human capital;
• Understanding farmer and farm typologies
• Monitoring and evaluation of innovation processes on soil health;</td></tr>
<tr><td>Advisory service providers empowered to:
• respond to demands/ needs for advisory services;
• diagnose soils constraints;
• access information on up-to-date practices;
• understand enablers for adoption of improved soil health practices;
• integrate soil health services advisory in service bundles;
• understanding farm typologies;
• generate soil health farmer advisory content from knowledge products from education and research;
• scale out soil health knowledge, technologies and innovations
• access opportunities for continuous capacity strengthening;
• sustain their career growth and livelihoods.</td><td>• Teachers in primary schools empowered to effectively deliver soil science in the curriculum;
• Education planners and implementers empowered to generate and disseminate resources for teaching soil science (as part of the science curriculum) in in primary schools
• Resources (land, tools, knowledge etc) available for basic practical skills development in schools…</td><td>Agricultural innovation enablers empowered to:
• support field research;
• implement technology demonstrations;
• undertake research needs identification and prioritization;
• implement scaling out of technologies;
• validate indigenous knowledge and sharing
• receive and respond to questions and requests from agricultural extension and from farmers</td></tr>
</table>

3.3 Investments needed for strengthening human capital at the local level

3.3.1 Establishing local level coordination nodes for soil health activities

Coherent engagement with farmers on soil science and its application necessitates creation/strengthening of soil health advisory services, education and research. The mechanism would enable articulation of a coherent common agenda and local-level programme for technical capacity development, resource mobilization, last mile engagement with farmers, managing feedback systems from farmers to the local level, networking and partnerships, vertical and horizontal cross-sectoral linkages, information sharing, and knowledge management. Operationally the node would require a coordinator - who may be the public sector soil science subject-matter specialist - and a small technical committee bringing expertise from advisory services, education and research. The node should ideally be embedded within existing institutional and organisational structures spearheading agricultural development at the local level.

3.3.2 Recruiting soil scientists and para-soil scientists

The recruitment of soil scientists at the local level - with guidance from the national level should be stimulated by ring-fencing an appropriate number of posts as opposed to assuming that all agricultural science graduates can serve the purpose. It is not likely that the need for human capital at local level will be met through recruitment alone. Therefore, the human capital at local level should be bolstered by recruiting and community-based facilitators (CBFs) and training them on soil health management. *Sasakawa* 2000 is piloting this approach. It is difficult to estimate the demand for soil scientists and "para soil scientists" CBFs needed at the local level. The estimate based on the experience of *Sasakawa* 2000, is a ratio of one scientist to 20 CBFs to 500 farmers. These ratios can be greatly modified by the extent of application of digital technologies.

It shall be critically important to ensue that soil scientists operating at the local level have pathways for career growth and the necessary access to opportunities or continuous professional development.

3.3.3 Creating a local-level soil health community of practice/social network

To enhance the intellectual focus on local level issues on soil health a community of practice (CoP)/ social network should be created to link all stakeholders in the communities with an interest in soil management. It should be managed by the designated soil health coordinator at the local level or other level based on the subsidiarity principle. Its main function should be to enable sharing of information and experiences and to be the information and knowledge nexus with external sources of information and knowledge. Ideally it should be managed virtually by embedding as an open or closed group within the national/regional/continental virtual social networking and knowledge management platform.

3.3.4 Establishing and managing a grant for human capital development at the local level

The priorities for human capital development at the local level will be diverse and will vary spatially and temporally within and between countries. The general mechanisms that should be put in place is a grant awarding system dedicated to local level soil health human capital development. The priorities at a point in time shall be identified by the local soil health CoP/social network. Managing the grant shall be one of the responsibilities vested in the coordination node. Some funders may prefer to deposit the grants in marketplace mechanism at national or sub-regional levels. Within the marketplace grants could be ringfenced for establishing human capital development e.g. for women, youth, communities, thematic training courses, participatory research, content generation, digitalization of soil heath and extension and education.

3.3.5 Establishing and managing infrastructure for soil testing

The efficacy of SHWM human capital at the local level is greatly enhanced by having access to functioning soil testing facilities. So it is necessary to establish and sustain such facilities at the local level, and networking them at national level. This would have immediate use for the advisory services at local level as well as contributing to continuous updating of a national soils database.

National Level Human Capital

4.1 Current situation

4.1.1 General status of soil science human capital at national level

It is generally accepted that soils science human capital at national level is inadequate and, the capital that exists, is not optimally distributed within the knowledge and skill structure needed to support the soils innovation system. There is a consensus among soil science experts in Africa that the human capital structure is an inverted "pyramid" with more soil scientists at the source of the skills and knowledge than at the level at which soil science is applied. This consensus is validated by the findings of Rozanov and Wiese (2018) which indicated that the majority of the soil scientists are in universities, national research institutes and national governments while, the numbers at local / watershed levels (including local businesses) are very low (Figure 2). This "missing middle" is a significant contributor to the low human capital at the farm-level since it is the determinant of scaling out of soil science knowledge and skills.

The distribution of the scientists across the soil science disciplines was 33% soil chemistry and fertility, 20% soil classification and mapping, 12% soil physics, drainage, irrigation, and salinity management, 6% soil biology and health, 5% soil conservation and erosion control, and 19% are generalists.

The Rozanov and Wiese (2018) study cited above indicates that only 17% of the soil scientists are women and that their involved in soil science programs is also constrained by prejudice of employers and industry customers. It was also found that the young generation is not attracted to the field. Already the number of students in soil departments in many universities has drastically reduced. The apparent disincentive for soil science careers is that there are no ring-fenced jobs for soil scientists. In circumstances where recruitment at national and local levels is broadly targeted to holders of bachelor degrees, graduates who majored in soil science are not competitive in the job market. This is due to a general perception that the training of soil scientists is too academic. To become competitive, soil scientists require a post-graduate qualification.

For the African continent as a whole, soil science expertise is not equally distributed among countries. There are some distinct centers of excellence, which include Algeria, Egypt, and Tunisia in North Africa; Ethiopia and Kenya in East Africa; Burkina Faso, Côte d'Ivoire, Ghana, and Nigeria, the Democratic Republic, South Africa, Zambia, and Zimbabwe. Some of these centers have a strong influence on the neighboring countries particularly through offering education and facilitating regional collaboration. These efforts, however, require substantial support and improvement. Not surprisingly, the biggest African economies (Egypt, Nigeria, and South Africa) have the most numerous human resources in the field of soil science.

4.1.2 Human capital for soil science advisory services at national level

The human capital for soils and soils science advisory services at the national level is embedded within government ministries of agriculture, non-government organizations, and - to a very limited extent - in the private sector. Within these entities, there appears to be no standard way for configuring human capital for a functional advisory services system on soil issues. The professed desired policy is that of a pluralistic system in which both the public and private sectors play a part. This is playing out variously in the way advisory services human capital is evolving in different countries. On one extreme, are countries like Uganda that have experimented with developing human capital for a publicly-funded privately-delivered advisory services system, and on the other extreme are countries like Ethiopia that have made bold investments in developing a robust publicly-funded and publicly-delivered advisory services. It is worth noting that the latter has delivered tangible results manifested by Ethiopia having the highest rate of agricultural growth in Africa.

4.1.3 Human capital for soil science education at national level

Soil science human capital for soil science education exists within soil science degree programmes in agricultural universities. The universities that offer such programmes are presented in Figure 3. However, mainly in North Africa (e.g., Tunisia and Algeria), soil science degree studies are offered as part of geology programs within science faculties. Multiple universities on the continent offer both undergraduate and post-graduate programs with soil science as a major or one of the two major subjects—for example, a BSc in soil science and agronomy. Currently, the teaching facilities and equipment are inadequate as are the technical staff and funds to operate them.

Figure 3: Universities Offering Degree Programs in Soil Science in Africa

Soils and soil science training and education for human capital cadres below university degree level ("para-soil scientists") takes place in agriculture colleges, agricultural technical vocational education and training (ATVET) institutes, secondary schools, and primary schools. As highlighted previously, the current status of the soil science human capital at the local and farm level is inadequate. This partly reflects the quantitative and qualitative weaknesses of the human capital for soil science education at the national level.

4.1.4 Human capital for research at national level

In relative terms, the soil science human capital in research is only surpassed by that in education (Figure 2), however in absolute terms, this does not necessarily translate into numbers that are adequate for the soil research tasks at national level. The situation is worsening as the current cadre of soil scientists are ageing and retiring yet they are not being sufficiently replaced by young scientists. The factors that are precipitating this trend are reduced funding for soils research, low prospects for career progression or recognition and a lack of demand for their services. Consequently, national agricultural research institutes have vacant positions and declining staff. However, the growing awareness of the impact that soil quality has on fertilizer effectiveness is gradually providing an incentive for private sector (fertilizer companies) to invest in supporting agricultural research in ways that may enhance soil science human capital.

In general soil scientists at local level research centers attached to national agricultural research institutes are increasingly required to participate in technology demonstrations and technology dissemination, however they have tended to lag behind other agricultural scientists in adopting new participatory methods, thus the need for retooling.

Human capital for research at national level is greatly boosted through the partnerships that the NARS have with agricultural research institutions (ARIs) outside Africa and, most significantly, through partnerships with the Consortium of International Agricultural Research Canters (CGIAR) - the main one in this regard being the International Institute of Tropical Agriculture (IITA). However, the human capital in these centers is not oriented towards soil science as a stand-alone topic but primarily as an input into farming systems. Furthermore, the CGIAR focuses its resources predominantly on research rather than on development. Boosting national level soil science human capital through partnerships with the CGIAR is further constrained by the fact that the CGIAR centers are also currently struggling to get funding for soil science research. As such, they are finding it difficult to attract soils scientists from the national agricultural research institutes to partner with counterparts from the CGIAR. Additionally, the CGIAR are increasingly responding to their insular internal reforms by focusing use of their resources for their own research activities. Therefore, the prospects for the CGIAR continuing to be a major partner in soils and soil science human capital development in Africa are not as promising.

4.2 Desired characteristics of human capital at the national level

Table 3: Desirable characteristics of human capital for SHWM at the national level

<table>
<tr><th>Advisory services</th><th>Education</th><th>Research</th></tr>
<tr><td colspan="3">Crosscutting
Ministry-level technical leaders, planners and policy makers of advisory services, education and research empowered for:
• understanding the political economy better to inform on policies, strategies and approaches to moving SIA forward;
• develop and align with national soil management plans and accountability frameworks with the recommendations of the SIA;
• mobilizing resources for crosscutting soil health programs;
• developing capacities for the establishment/operation of physical and virtual soils information and knowledge management systems;
• creating awareness on soil crisis and the need for urgent action;
• analyzing trends in agricultural development and their implications for soil science;
• undertake digital data processing for;
• undertaking national manpower planning for advisory services, education and research on soils;
• establishing/ linking with local and sub-regional/ continental soils communication and knowledge management systems;
• creating systemic linkages between advisory services, education and research on soil-related issues;
• creating cross-sectoral linkages with soils-related ministries, departments and agencies;
• forming partnership with the private sector on soil-related issues;
• creating linkages with civil society on soil-related issues;
• creating platforms for sustaining engagement with farmers on soil-related issues;
• engaging with national soil science/ soil health societies/ associations;
• organizing national soil advisory services, education and research review and agenda setting conferences.
• contributing to open access / public repositories of knowledge on soils;
• establishing and contributing to a national soils and soils science communication and knowledge management system;
• monitoring and evaluating soil health innovation;</td></tr>
</table>

Advisory services	Education	Research
Ministry-level technical leaders of advisory services empowered to: • integrate advisory services in national agricultural policy, strategy and programming processes; • lobby, advocate, formulate and champion policies for advisory services at all levels; • assess and prioritize needs for soils advisory services; • develop a national advisory services strategies and programs on soils health and cascade them to local and farm levels; • mobilize resources for soils advisory services; • establish baselines for soils advisory services capacities; • identify needed skills and capacities needed for soil health advisory services • contribute to development of new approaches and methods for soils advisory services; • promote new advisory services methods and approaches in the context of soil health; • develop online and mobile advisory services content on soil health for farmer and local levels; • set standards and regulations for soil health advisory services; • Develop and operationalize a monitoring and learning system for advisory services on soils;	National and university agricultural education leaders empowered for: • integrating soils science in agricultural education policy, strategy and programming processes; • Developing and establish soil education development framework for implementation at all segment of the society. • developing and linking soil science curriculum for all levels of education (developing the agricultural soils education value chain ..embracing general education and ATVETs); • lobbying, advocating, formulating and championing soils science education at all levels; • mobilize resources for education on soil science; • establish baselines for soils education capacities; • assess and prioritise needs for soils education at all levels; • developing online and mobile training courses on soil health for advisory service providers and farmers; • Develop and operationalize a soil science education monitoring and learning system.	National agricultural research leaders and researchers empowered to: • integrate soils research in national agricultural research policies, strategies and programs; • lobby, advocate, formulate and champion policies for agricultural research; • mobilize resources for soils research; • assess needs and priorities for soils research; • implement soils science research for national contexts; • undertake soil surveys and mapping; • establish baselines for soils research capacities; • Update national or subnational soil maps at high resolution; • Use geographic information systems (GIS), digital soil mapping (DSM), geostatistics, remote sensing and the interpretation of satellite and airborne images to create updated and detailed national soils maps; • assess soil health and fertilizer requirements with location precision; • undertake cross-disciplinary research; • establish stronger links between university education on soil science and researchers at the NARIs who are working on soil-related issues.

4.3 Investments needed for strengthening human capital at the national level

4.3.1 Domesticating the human capital development actions of the continental frameworks and action plans on soil health

The interaction between politics and, specifically in this case, with the economic factors that determine human capital in soils health management and soils science is one of the primary systemic determinants of the soil science human capital in research, education and advisory services at national level. Currently, the global community is keen to contribute to the tackling of the soil health crisis in Africa and has good-will for investing in improving African soils. In the past this has not been sufficiently matched by enthusiasm from African leaders - especially in terms of making policy interventions and providing financial commitments to support soil health ameliorating interventions. In part this is due to the weak voices reaching the leaders from the Africa's research, education and advisory services community. Hence political economy considerations have been overpowering scientific evidence in decision making on soil health. Policy makers and planners are not sufficiently aware of the seriousness of the decline in soil health and its costs. There is therefore a need to develop clarity on scale and scope of the crisis and realistic objectives and cost-effective high impact priority interventions. The Declaration of the [2024 Africa Fertilizer and Soil Health Heads of State Summit]() has endeavoured to change this through the endorsement by African Heads of State and the Afric Union of the Fertilizer and Soil Health Action Plan and the Soil Initiative for Africa (SIA) Framework as key guiding documents to harness multi-stakeholder partnerships and investments to drive policies, finance, research and development, markets, and capacity building for fertilizer and sustainable soil health management in Africa. Countries will now be expected to domesticate the Action Plan and SIA in their own planning processes, policies, and concrete actions. This should include explicit investments on developing soils science human capital. Some of the actions to be considered in this regard are outlined below:

4.3.2 Training of soil scientists

The need for soil scientists in different countries varies greatly. The Rozanov and Wiese (2018) study cited previously indicated that there was zero need by the Democratic Republic of Congo, seven for Malawi, nine for Botswana, 35 for Equatorial Guinea, 60 annually for Morocco, 400 - 500 for Sudan, 731 in the next five years for Uganda, 1000 for Nigeria. Regarding the qualitative needs the primary area where soil scientists were found to be insufficient was soil survey and mapping, which is a primary task for soil scientists, especially pedologists. Several countries indicated that they have outdated national or sub-national soil maps at coarse resolution based on old data generated from the 1960s to the 1980s. Higher-resolution soil maps are developed mostly for small areas, as part of specific projects or developments. Also indicated, as areas of human capital insufficiency are specific training in geographic information systems (GIS), digital soil mapping (DSM), geostatistics, remote sensing and the interpretation of satellite and airborne images, digital data processing, assessing soil health and fertilizer requirements, linking with advisory services and farmers, training and education, and design research.

4.3.3 Developing soil science training and research capacities

In the last fifty years, investment in soil science and associated human capital and research infrastructure has largely been driven by international development agencies rather than the national governments. This has jeopardized the long-term sustainability of these efforts. The international aid for the African soil research landscape started to change in the mid-1980s, when the focus shifted from supporting national institutions to establishing continental and regional networks. Such networks have tended to have a short life span as they were underpinned by time-bound projects. The roll-back of international support for national institutions was not matched by increased spending by national governments. Subsequently, many institutions created by post-colonial development investment have experienced substantial budgetary reductions first and most of all on research infrastructure, followed by reduced human resources spending. If the human capital development for the SIA is to be realised, it will be necessary to make substantial investments in the organisational, institutional and infrastructural capacities of the soil science units in universities, research institutions and colleges of agriculture.

4.3.4 Review of soil science curricula at universities and colleges

There is a general consensus among stakeholders that the soil science curriculum at universities is stagnant while the discipline is changing quickly. Hence the generation of soil science human capital may not have the depth of skills required by graduates to enter into emerging ancillary niches and to have more practical experience during the training. Overall, the capacity of the universities to effectively contribute to soil science human capital is declining from already weak levels. This is evidenced by the low numbers of students in soil science departments which is directly correlated with the low demand for graduates with qualifications below the MSc level. The necessity to attain a post-graduate qualification is a disincentive for applying for the soil science courses in the first place. This sets into motion a negative feedback that leads to declining numbers of qualified and experienced soil science technicians, lecturers and professors at universities. Investments will therefore have to be made in reviewing and updating the soil science curricula of soils science courses at universities and agricultural colleges.

4.3.5 National networking of soils scientists

In the past, national soil science associations/societies provided mechanisms for soil scientists in research, advisory services and education to network, collaborate, partner, and coordinate. However, almost all of the national soil science societies have disappeared. In the previously cited survey by Rozanov and Wiese (2018), only six countries were found to have soil science societies but they were largely not fully functional. Networking, linkage and partnership with the soil science human capital in the private sector is generally recognized as being important and possible but that it is currently not taking place to a significant extent in research, education and advisory services. Investments will be needed to form/ reactivate the national soil science networks and associations.

4.3.6 Developing information systems for human capital development

The information systems for the SIA are described in detail in a standalone Technical Note. The Note shall inform the establishment of a soils digital information platform and database. The investments in the platforms and database at the national level should ensure that the needs for human capital development are embraced for the national, local and farmer level. It should have functionalities that support generation of information and knowledge products, transformation and packaging of these products into communication products in diverse media for diverse audiences, enable those who use the communication products to engage with the audiences using appropriate tools, platforms and methods to promote learning at the different levels including the farmer level.

In the context of this Technical Note, the above information, communication and knowledge management (ICKM) processes take place horizontally between research, education and research and vertically between the different levels of aggregation. The current situation in the soils and soil science ICKM is that these linkages are weak and the configuration of the ICKM human capacity mirrors the inverted pyramid of the soil and soils science human capital structure outlined previously - essentially greater soils and soil science ICKM human capacity at the high levels of the research, education and advisory services systems. Furthermore, flow of information within and between the different levels tends to be of a linear and hierarchical "one-to-many" modality[5]. In such a system the rate and extent of flow of information is determined by the weakest link along the chain - which in this case is the "missing middle". This configuration of the human capital in the soils and soil science ICKM (and generally in the ICKM for agricultural development) is inefficient in terms of scaling out information and knowledge in two main regards. First, it fails to recognise that everyone in the system is a generator and consumer of information and knowledge. Second, it does not have strong feedback loops needed for creating a dynamic and responsive information and knowledge system. A many-to-many configuration of the ICKM human capital would be more ideal. Modern information and communication technologies, artificial intelligence and machine learning greatly enhance the value of human capital. Currently, the leveraging of these new tools to facilitate the information flow in the soil science domain is low although there is enhanced awareness of their potential value.

Sub-Regional and Continental Levels

5.1 Current situation of human capital at the sub-regional and continental levels

5.1.1 General research-education-advisory services human capital status

At regional and continental levels, there are networks in which the human capital for advisory services, education and research is embedded. The main ones at the continental level are the Forum for Agricultural Research in Africa (FARA), the Regional Universities Forum for Capacity Development (RUFORUM) and the African Forum for Agricultural Advisory Services (AFAAS). Only agricultural research has sub-regional networks.

5 An example of a one-to-many flow of information is when information from a researcher/advisory services specialist is transmitted to many subject matter specialist (SMS), and one SMS transmits the information to many advisory services provoder, and one advisory services provider transmits the information to many farmers.

These are: Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA), the West and Central African Council for Agricultural Research and Development (CORAF/ WECARD, and the Association of Agricultural Research Institutions in the Near East & North Africa (AARINENA). These sub-regional institutions are all linked closely to FARA. AFAAS also has sub-regional networks that have formed in both Southern Africa and in West Africa - although they are currently still very weak. RUFORUM is in the process of establishing 'hubs" at the sub-regional level.

The generic functions of the continental/ sub-regional networks include coordination of national level agendas, providing mechanisms for networking, information and knowledge management including hosting information and data repositories, resource mobilization, lobbying and advocacy, and thematic thought leadership and foresight. The performance of these functions requires human capital that blends high-level academic qualifications, a broad view of science in agricultural development, and a strong track record of managing multi-disciplinary and multi-sectoral agricultural development institutions. Specialized expertise is needed on a permanent or ad hoc basis to ensure that the focus on particular disciplines - like soil science - is maintained when performing the above functions. The specialized expertise may be provided by specialists or technical thematic working groups comprised of experts from the national level.

5.1.2 Human capital for advisory services at sub-regional and continental levels

The AFAAS is the continental umbrella organization that aims at strengthening national Agricultural Extension and Advisory Services (AEAS). Its mission is to promote lesson learning and add value to initiatives in AEAS through policy advocacy and lobbying, sharing of knowledge and information through increased professional interaction among AEAS providers. AFAAS has already established Country Fora (CF) in 24 countries[6] with a total of 5382 members (including 4853 individuals - of whom 3743 are frontline extension agents - 460 Civil Society Organisations; 32 academic institutions; 15 media organisations and 22 private companies).

The AFAAS has a mandate from the AU to implement the agricultural extension and advisory services (AEAS) aspects of the Comprehensive Africa Agriculture Development Program (CAADP). It works in close collaboration with other continental and sub-regional bodies contributing to CAADP - most notably those in the areas of agricultural research, organizing farmers and fostering private sector involvement.

Currently, AFAAS does not have a thematic working group on soils and soil science, and it is not coordinating any projects that require it to have sub-regional or continental experts on soils and soil science. Consequently, its central human capital for performing regional and continental functions related to soil science and its application is virtually non-existent.

6 Benin, Burkina Faso, Cameroun, Egypt, Ethiopia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Nigeria, Rwanda, Sierra Leone, South Africa, South Sudan, Sudan, Tanzania, Uganda, Zambia, Zimbabwe

5.1.3 Human capital for education at sub-regional and continental levels

The RUFORUM is the main network for agricultural education at continental level. It is a consortium of 170 African universities operating within 40 countries spanning the African continent. It derives its political legitimacy largely from its acknowledged role in development and implementation of continent-wide policy frameworks especially of the CAADP, the African Union Science, Technology Innovation Strategy for Africa (STISA 2024); the African Union Policy Framework on Revitalizing Higher Education in Africa; and the Sub-regional Multi–Country Agricultural Productivity Programs.

Currently RUFORUM does not have the human capital - in the form of regional experts or technical thematic working groups - to specifically spearhead soil science education from a regional perspective. It is also not supporting any regional projects on soil science education.

5.1.4 Human capital for research at sub-regional and continental level

The human capital for soil science research at the sub-regional and continental level is embedded in that for executing functions related to general mandates outlined below:

- **FARA** has a mandate from the African Union Commission (AUC) to facilitate the mainstreaming of the Science Agenda for Agriculture in Africa (S3A) into national policy and planning processes. It is the convener of the AUC Technical Network on Research and Extension. It supports the European Union - Africa research and innovation partnership on Food and Nutrition Security and Sustainable Agriculture (FNSSA);
- **ASARECA** is mandated by its 15 Member States to strengthen, catalyze, facilitate and coordinate their agricultural research for development (AR4D) to improve delivery of national and regional research-driven inclusive and sustainable agricultural transformation and development outcomes and impact in East and Central Africa (ECA) region;
- **CCARDESA** was established by the Southern African Development Community (SADC) Member States to coordinate agricultural research and development in the SADC region;
- **CORAF** is the technical arm of the ECOWAS Commission with the mandate for the implementation of agriculture research aspects of CAADP in West Africa;
- **AARINENA** was established in 1985 to strengthen cooperation among national, regional and international research institutions and centers in the Middle East and North Africa through the dissemination and exchange of information, experiences and research results.

Apparently, there are currently no ring-fenced human capital (technical thematic working groups or experts) for soil science research at the continental (FARA) or sub-regional (ASARECA, CORAF, CORAF, AARINENA) levels.

5.2 Desired characteristics of human capital at the sub-regional and continental level

Table 4: Desirable characteristics of human capital for SHWM at the local level

<table>
<tr><th>Advisory services</th><th>Education</th><th>Research</th></tr>
<tr><td colspan="3">Crosscutting
Sub-regional and continental education, research and advisory services leaders, managers and institutions capable of facilitating:
• Foresight and thought leadership on soils and soil science;
• Creation of systemic linkages between education, research and advisory services across countries;
• Facilitating and coordinating resource mobilization for retooling and capacity development on soils and soil science at national, local and farm levels;
• Leadership in planning and implementation of the recommendations of the Soil Initiative for Africa;
• Creation of physical and virtual platforms and marketplaces for enabling exchange of soil science information and services;
• Creation of regional soil science associations/ societies;
• Identification and nurturing of champions and thought leaders on soils and soil science in Africa.
• Creation and management of intra-operable soils and soil science information and knowledge platforms for education, research and advisory services;
• Creation of open access / public repositories of knowledge for the benefit of teaming population;</td></tr>
<tr><td>Sub-regional and continental advisory services leaders, managers who have capacity to:
• Create and support networking of soils advisory service providers;
• Coordinate sub-regional and continental initiatives on soils advisory services;
• Provide foresight and thought leadership on soils and soil advisory services;
• Support technical advancement of advisory services in the soils area;
• Create and manage intra-operable platforms for data, information and knowledge on advisory services human capital on soils;
• Create common soil advisory services capacity development of knowledge products and training courses;
• Mobilize resources for of strengthening the quality of, and the scale-up of, soil-related agricultural advisory services</td><td>Sub-regional and continental agricultural education leaders, managers who have capacity to:
• Spearhead regional approaches/ centers of excellence for soil science education;
• Create networks and partnership among tertiary education institutions for training in soil science;
• Coordinate sub-regional and continental initiatives on soil science education;
• Develop common resources for teaching soil science education;
• Establish expert mobility program for cross-learning and exchange materials;
• Develop online courses and other virtual programs at different levels on soil management;
• Establish regional soils training and research chairs in tertiary institutions.</td><td>Sub-regional and continental agricultural research leaders, managers who have capacity to:
• Coordinate and network soil research scientists;
• Coordinate sub-regional and continental initiatives on soils research;
• Provide foresight and thought leadership on soils research;
• Collect and manage outputs of research;
• Develop knowledge and communication products on soils science;
• Spearhead regional approaches for soils research;</td></tr>
</table>

5.3 Investments needed for strengthening human capital at the sub-regional and continental levels

Strengthening human capital for soils science is needed at all levels - farmer, local and national. The needs at one level are aggregated and those that require collective action form the basis for drawing down support from the next level. Hence, continental and sub-regional investments should be rooted into aggregation and synthesis of the needs at the national level.

5.3.1 Strengthening sub-regional and continental networks and associations of soil scientists

Sub-regional and continental human capital can be strengthened through the existing regional and continental networks. Efforts are currently underway to bring these networks together into a consortium - the African Agricultural Research, Innovation and Education Institutions (AARIEIs) consortium - through which horizontal linkages of research, education and advisory services can be enabled. Both RUFORUM and AFAAS are engaged in the process of formation of sub-regional networks and the emergence of the AARIEIs consortium may provide an opportunity for creating common sub-regional research, education and advisory services sub-regional networks. Investments should be made to create a soil science network hosted by the SIA Secretariat. The network could be built on the foundations of the soil science societies. The Soil Science Society of East Africa was formed in 1974 with the aim of promoting the study, research, teaching and application of Soil Science and related subjects in East Africa for improved Soil Productivity. At the continental there is the Africa Soil Science Society which was founded in 1986. Both are sporadically active.

5.3.2 Establishing a continental communication and knowledge management platform and marketplaces for facilitating soil science human capital development

Marketplace mechanisms are proposed at farm, local and national levels. These marketplaces should be integrated into a single platform that acts as a one-stop center for soil science information and services at the continental level. The marketplace should be intraoperable with SIA soils information system under FARA and the social networking platforms established at the different levels of operation. It should have functionalities for governance of the knowledge management processes, generation of knowledge and communication products, and communication and engagement with diverse audiences. Given the likely preponderance of tools and platforms developed independently by actors at different levels - and by external actors - in such a way that it can be intra-operable with such tools and platforms through application programming interfaces (APIs), artificial intelligence and machine learning. The platform should also have functionalities for stimulating demand and supply of soil science information and services.

5.3.3 Supporting human capital development in agricultural advisory services

As pointed out previously, AFAAS has the Union Commission mandate for coordinating and facilitating human capital development for agricultural advisory services in Africa but it does not have the human, institutional and organizational capacities for implementing this mandate in soil science and its application. It will therefore be necessary to invest in developing these capacities. This could be in the form of creating a dedicated unit at the AFAAS Secretariat manned by a senior officer with a ring-fenced budget for supporting SIA initiatives. The first functions that this unit should perform is creating a database and social network of advisory service providers currently active in providing soil health-related services at the different levels. Armed with this database and network, AFAAS should, in the short term, proactively spearhead a process for developing a curriculum and approach for mass capacity development of advisory service providers at national, local and farmer level. The focus areas would be surfaced through the farm/local/national process outlined above. To be effective and immediately impactful capacity development could be initiated through seminars intended to develop trainers at national level who would engage with local level advisors who in turn would engage with farming households. In the medium to long-terms, human capital development should be through grants managed by centrally through AFAAS or channeled directly to RUFORUM and ATVETS. The grants should cater for direct commissioning and competitive mechanisms at regional, national and local levels as well as through the marketplace outlined above. In addition to these, investments will be needed to enable RUFORUM and AFAAS to work together developing/ expanding in-service training for existing agricultural advisors at all levels.

5.3.4 Establishing a continental/ sub-regional program for strengthening faculties of soil Science

The RUFORUM already has mechanisms for managing initiatives for strengthening agricultural education in its member universities and ATVET institutions. However, as noted previously, it does not have dedicated capacities focusing on soil science and its application. Therefore, investments should be made to establish - at the RUFORUM Secretariat - a unit focusing on supporting the SIA. Associated with this, a grant/ grants should be established for enabling RUFORUM to develop a programme for strengthening faculties of soil science. In addition - and to enhance efficiency and synergies between universities - investments should be made to establish centers of excellence in soil science and its application. The investments should embrace creating tenured faculty positions at these centers, development of laboratory infrastructures, equipping the laboratories, developing/ strengthening M.Sc. and Ph.D. programs. The RUFO-

RUM Vision 2030 Strategy and the associated Medium-Term Operational Plans provide for such initiatives to be undertaken under its "Regional Anchor Universities for Higher Agricultural Education (RANCH)" Flagship programme. The Programme aims to establish Regional Anchor Universities (RAUs) as hubs of excellence converging on a number of academic and socio-economic goals for greater engagement across universities in the same country and across countries in "key gaps areas" and other technical fields in agriculture. RUFORUM also has the appropriate instruments for managing grants and scholarships for supporting universities and students respectively, and for enabling academic mobility between universities.

5.3.5 Establishing a continental/ sub-regional program for strengthening human capital for soil science research

Strengthening human capital for soil science research and application is inextricably linked to the strengthening of faculties of soils science. For the Centers of Excellence to generate human capital on soils science and its application, investments will be required for providing scholarships for M.Sc. and Ph.D. students. Again, RUFORUM already has mechanisms for managing such scholarships. Other mechanisms are needed to stem the migration of soil scientists from soil science research departments and programs and to attract young scientists to join soil science research programs and projects. The following investments should be considered:

- Grants for upgrading research facilities at regional national and local levels;
- Establishing soils science research fellowships in the NARS;
- Establishing competitive research grants and challenge funds that may be managed through the marketplace;
- Creating continental and/ or sub-regional soils science research programs;
- Creating soils science research chairs within the NARS
- Awards for recognition of soils scientists who have undertaken sustained and or exemplary research;

The investments should be managed by FARA and channeled to national systems through processes managed by the SROs. To enable FARA and the SROs to perform these functions, they should be funded to strengthen their capacities for networking soil science researchers and for managing regional soils science research programs.

5.1.6 Developing partnerships and resource mobilization

The mandates of AFAAS, FARA and RUFORUM require them to develop partnerships in their spheres an of operation, and to mobilize resources for all levels of operation. Investments shall be needed to support resource mobilization efforts for human capital development. The resources shall be used for counterpart funding needed to leverage partnerships e.g. with universities outside Africa, and for convening regional "writeshops" for developing human capital development proposals in response to opportunities that may arise from time to time.

Start-Up Action Plan for Operationalization

The desired characteristics of human capital at the different levels (Tables 1 - 4) provide a basis for developing an action plan for human capital development at the different levels. Each level is a module for action as illustrated in Figure 4. Failure within a level may arise when there is internal disconnect between what needs to be done and what is actually done. There is an implicit hierarchy in the relationships from farm level to continental level. However, this is not to be taken rigidly. There are situations, for example, when the national level can interact directly with the continental level - bypassing the regional level. This is determined by the need for efficiency by reducing unnecessary bureaucracy and applying the subsidiarity principle.

The following generic interactions (de facto theory of change) occur within a module: Human capital policies, priorities and strategy drive formulation and implementation of programs the outcomes of which are subjected to monitoring, evaluation and learning (MEL) that is also informed by the MEL results from adjacent levels. The results of the MEL are subsequently used to adjust the policies, priorities and programs.

The cascading interactions between the modules at the different levels of operation are also shown in Figure 4. The programs at a higher level provide inputs to the lower levels. Generically these inputs include guidance, tools, resources, expertise, networking and partnerships. The data, outcomes and lessons from the monitoring, evaluation and learning (MEL) from the lower levels are synthesised and aggregated by the MEL processes at the higher levels to inform the review and planning processes at that and higher levels.

The ambition of the AFSH-AP is to implement systems approach to human capital development whereby human capital development for SHWM is coordinated as a value chain from the farmer level to the continental level. The the operationalisation challenge is how to deal with the diversity and context specificity and dynamic spatial and temporal nature of the needs - especially at the farm and local levels. Facilitating this requires non-prescriptive assessment and planning tools - such as checklists - that can guide the generation of plans that can be easily amalgamated. Table 5 gives tentative lists of issues that should be assessed within and between the modules in Figure 4. The issues are clustered under policy, strategy, institutional, organisational, programs, networking, partnership, knowledge management, agricultural extension and advisory services, University education, Agricultural Technical and Vocational Education and Training (ATVET) Colleges, general education, agricultural research, MEL, and resource mobilisation.

Figure 4: INTER AND INTRA ISSUES FOR SOIL HEALTH AND WATER MANAGEMENT HUMAN CAPITAL DEVELOPMENT AT THE DIFFERENT LEVELS OF OPERATION

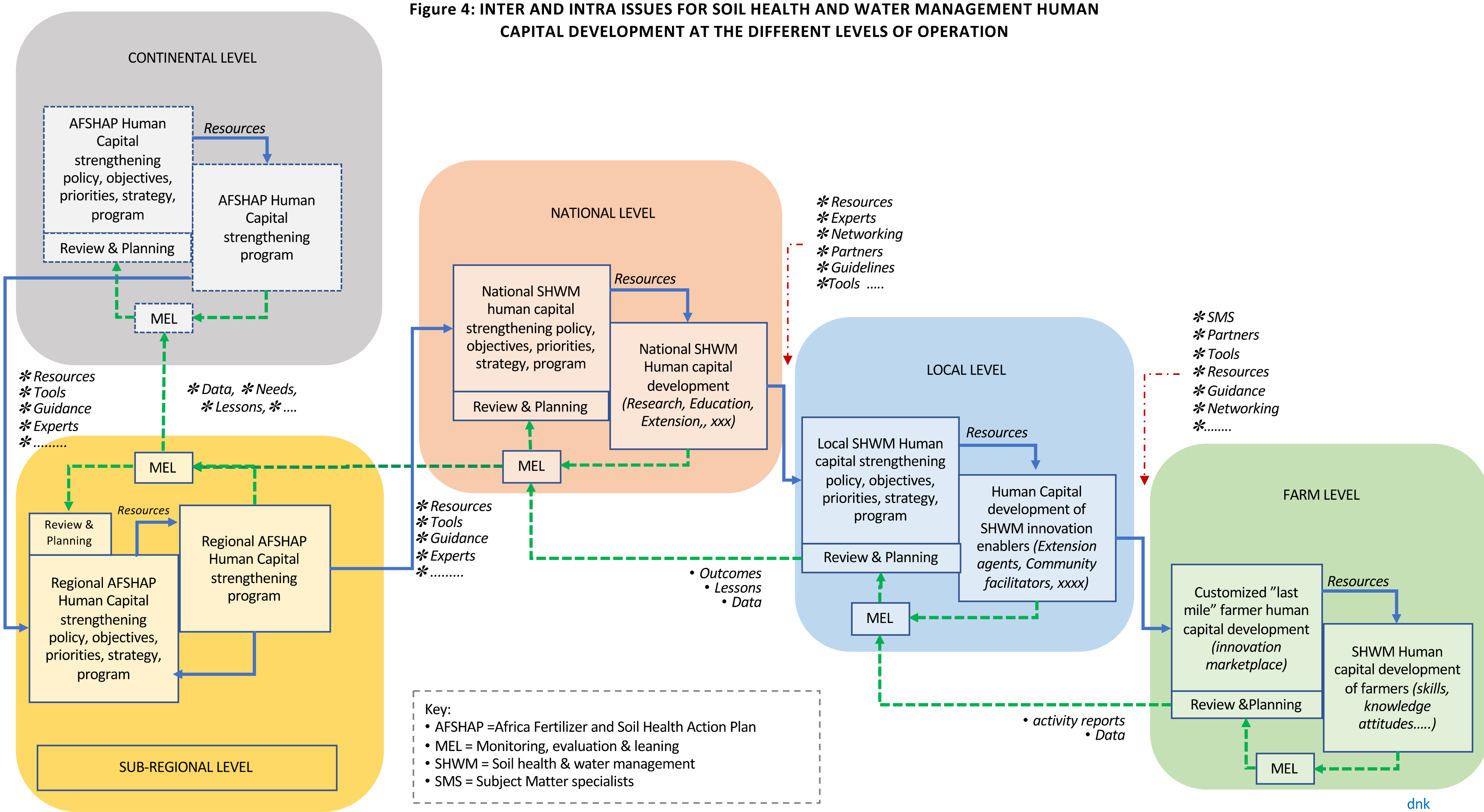


Table 5: Checklists to facilitate SHWM human capital planning at the different levels of operation

PLANNING QUESTION				
Continental	**Sub-Regional**	**National**	**Local National**	**Farm**
POLICY				
• Are there resources, experts, funding and guidelines for supporting the domestication of the SIA human capital declarations as policies at sub-regional and/or national levels? • What policy gaps exist?	• Is there a sub-regional policy on agricultural development? • Is it aligned with the SIA declaration? • Does the policy include aspects of SHWM human capital development? • Is there guidance for supporting the domestication of the SIA in national policies? If so… • Is the guidance explicit on human capital development? • Are there resources including experts and funding for supporting and mentoring national governments on SHWM human capital development? • What gaps need to be addressed at the policy level in relation to SHMM human capital development policies?	• Is there a good understanding of the political economy as it relates to SHWM? • Is SHWM human capital development addressed in the National Agri. Development Plan? • How well is the policy aligned with SIA and AF-SHAP? • What policy gaps need to be addressed? • What actions need to be taken to address the gaps? • Are there guidelines for implementing the policy by the lower level? If so… • Are the guidelines explicit o SHWM? • What needs to be done?		

PLANNING QUESTION				
Continental	**Sub-Regional**	**National**	**Local National**	**Farm**
STRATEGY				
• Are there resources, experts, funding and guidelines for supporting the domestication of the AFSHAP at sub-regional and/or national levels?	• Has the AFSHAP been translated into a sub-regional SHWM strategy that explicitly addresses SHWM human capital? • Are there guidelines and resources for cascading the sub-regional strategy into national agric. development strategies? • What strategy gaps exist at the sub-regional level?	• Does the Agric. Sector Development Strategy address SHWM human capital development? If so.... • Is the element of SHWM human capital development in the strategy aligned with the policy? • Are there guidelines for implementing the Strategy at the local level? • What actions need to be taken to address the gaps?		
INSTITUTIONAL				
	• Is SHWM provided for in the institutional structure of the Sub-regional institution? If so.... • Is the level at which it is institutionalized high enough for it to influence sub-regional SHWM policies strategies and programs? • Are there guidelines for linking SHWM institutional arrangements at sub-regional level to the national level? If so.... • Is SHWM human capital provided for in the Guideline? • What needs to be done?	• Is SHWM provided for in the institutional structure of the Ministry of agric.? If so.... • Is the level at which it is institutionalized high enough to influence national SHWM human capital policies, strategies and programs? • Are there guidelines for linking institutional arrangements at national level to the local level? If so.... • Is SHWM human capital provided for in the Guideline? • What needs to be done?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
ORGANISATIONAL				
	• Is there a department/ unit/ individual assigned to SHWM human capital development? • Are financial, infrastructural, operational resources provided for SHWM human capital development within the institution? • Is there funding ring-fenced for supporting national-level SHWM human capital development? • What organisational gaps need to be addressed?	• Is there a department/ unit/ individual assigned to SHWM human capital development? • Is there a sufficient budget for SHWM human capital development? • Are operational resources for SHWM human capital development within the Ministry? • Is/are there functional soil testing laboratories? • Is there a budget ring-fenced for supporting local level SHWM human capital development (subject matter specialists)? • What organisational gaps need to be addressed? • What needs to be done?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
PROGRAM				
		• Is there a program for SHWM capital development within the Ministry of Agric.? • Do the current programs Is the current SHWM human capital development sufficiently addressed in the Agric. Sector development programmes? • Are the programmes sufficiently aligned with the strategy and policy? • What gaps exist and how should they be addressed? • Are there guidelines for translating the national SHWM human capital development to local level programs?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
NETWORKING & PARTNERSHIPS				
		• Does the Ministry of Agric. host a national network/ association of soil science? If so.... • Is SHWM human capital development explicitly addressed as a thematic group or community of practice (CoP)? • If a national network/ association exists, does it embrace membership from individuals and/or public entities and/or non-profit entities and or private companies? • Does the Ministry of Agric. belong to any sub-regional/ continental/ global network/ association of Soil Science? • Is SHWM systematically projected in the interactions of the Ministry in the network/ association? • Are there any ongoing partnership projects on soil science? ....if so... • Is SHWM human capital development embraced by the projects? • What needs to be done?		

PLANNING QUESTION				
Continental	**Sub-Regional**	**National**	**Local National**	**Farm**
KNOWLEDGE MANAGEMENT				
		• Does the Ministry of Agric. have a well-structured knowledge management ecosystem? • Is the Ministry generating any knowledge and communication products focusing on SHWM human capital? • Does the Ministry have repositories of knowledge and communication products? If so… • Do the repositories have distinct "shelves" for SHWM human capital? • Does the Ministry have a system for engaging with stakeholders on SHWM human capital issues? • Does the Ministry have digital tools and platforms for communication and knowledge management? If so… • Do the platforms support formation of thematic groups or CoPs? If so… • Is there an online thematic group or CoP on SHWM human capital?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
AGRICULTURAL ADVISORY AND EXTENSION SERVICES (AEAS)				
		• Is SHWM included in the established human resources positions in the Ministry? If so ..... • Are the positions filled or are the functions embraced in the job descriptions of appropriate staff? • Is the status quo sufficient to cater for the human capital needs for AEAS at the national level? • Are there ring-fenced organisational resources for catering for the operational needs of AEAS human capital? • Are there national networks (fora, associations, CoPs, etc) for AEAS providers? If so... • Are they active in the area of SHWM? • Is the national AEAS system networked/ in partnership with any regional/sub-regional/continental/ global associations or fora? If so... • Are these active in the area of SHWM? • Are there any regional SHWM-AEAS programs or projects in which the national AEAS system participates? • What needs to be done?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
AGRICULTURAL EDUCATION AT UNIVERSITIES				
		• Is the staff in university faculties of agriculture quantitatively sufficient for the needs of SHWM education and training? • Is the staff in university faculties of agriculture qualitatively sufficient for the needs of SHWM education and training? • Do individual universities have the organisational resources for training of SHWM scientists? • Do the curricula of agricultural faculties sufficiently cover SHWM? • Do the universities offer BSc degrees in soil science? If so • Is SHWM covered sufficiently? • Do the universities offer post-graduate degrees in soil science? If so... • Is SHWM covered adequately for purposes of research and advisory services? • Are there scholarships available for soils science? • Are there universities that can provide national centres of excellence in SHWM human capital development? • Are the universities • What needs to be done to enhance the capacities of university faculties of agriculture for SHWM human capital development?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
AGRICULTURAL TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING (ATVET)				
		• Is the staff in ATVETs quantitatively sufficient for the needs for SHWM technical education and training? • Is the staff in ATVETs qualitatively sufficient for the needs of SHWM education and training? • Do individual ATVETs have the organisational resources for technical training and education on SHWM? • Do the curricula ATVETs sufficiently cover SHWM? • Are the ATVET SHWM capacities linked to those of universities? • What needs to be done to enhance the capacities of ATVETs for SHWM human capital development?		
GENERAL EDUCATION				
		• Does the national general education curriculum cover SHWM? • Does the guidance on agricultural education from the Ministry of Education explicitly address SHWM science?		

PLANNING QUESTION				
Continental	**Sub-Regional**	**National**	**Local National**	**Farm**
RESEARCH				
		• Does the national agricultural research system (NARS) have a soil science institute or program? If so... • Is the human capital for soil science quantitatively adequate for research on SHWM? • Is the human capital for soil science qualitatively adequate for research on SHWM? • Is the infrastructure for SHWM research adequate? • Is the funding for SHWM research adequate? • Are there networks/ associations of research scientists that embrace to which SHWM? If so.. • Are they active? • Are there national/ regional/ continental/ global research partnership and projects? If so.... • Do they embrace human capital development for SHWM?		

PLANNING QUESTION				
Continental	Sub-Regional	National	Local National	Farm
RESOURCE MOBILISATION				
		• Is SHWM human capital development explicitly included in the resource mobilisation for national agricultural development programs and projects? • Are there any linkages with continental/ region-al resource mobilisation initiatives for SHWM human capital development that • What needs to be done?		
MONITORING, EVALUATION AND LEARNING (MEL)				
		• Do the national M&E frameworks have explicit indicators for SHWM hu-man capital? If so... • Are the mechanisms (digital and non-digital tools and methods) for linking with M&E frame-works at lower levels or is M&E done directly as a national activity? • What needs to be done?		

Chapter 7

Soil Health and Climate Change in Africa

Contents

Summary

Soil health and climate change have a reciprocal relationship. While soil health significantly influences climate change, climate change also impacts soil health. Healthy soils act as carbon sinks, which remove greenhouse gases from the atmosphere while degraded soils exacerbate climate change by emitting greenhouse gases to the atmosphere. Climate change on its part impacts soil health by altering temperature, precipitation patterns, and extreme weather events which affect soil structure, organic matter, soil water reserves, and nutrient cycling. Climate change poses significant challenges to soil health in Africa, including increased organic matter decomposition, irregular rainfall and its impact on erosion and loss of organic matter, and extreme weather events which exacerbate soil vulnerability.

The impacts of climate change on soil health vary across Africa with arid regions being prone to desertification and tropical regions experiencing increased soil leaching and nutrient loss. Therefore, region-specific soil management practices are needed to mitigate the effects of climate change. The Africa Fertilizer and Soil Health Action Plan (AFSH-AP) proposed a plan to enhance soil fertility and resilience through appropriate sustainable soil management, innovative technologies, and conducive institutional support for soil health and climate change mitigation at different levels (such as national, regional, and continental levels) in Africa.

The present document outlines the strategies which can guide the implementation of soil health for mitigation of climate change at different levels in Africa. Besides the strategies, the document also discusses the factors influencing soil health and requirements for implementing climate-smart soil health practices which need to be taken into consideration when strategizing implementation of soil health practices for mitigating climate change. These factors and requirements include policies and regulations, technical capacity, education and awareness levels, access to information and advisory/extension services, proper planning and prioritization, sustainable resources for implementation, monitoring and evaluation, among others. These factors are critical and need sustained action in Africa where there are challenges such as socio-economic barriers, adverse climate change impacts, low level of soil education, high rate of soil degradation, inadequate technological and IT infrastructure, and inadequate prioritization and planning of soil health management.

The document illustrates how these factors and challenges can be integrated in planning implementation and monitoring of soil health practices at the landscape level, national, regional and continental levels. It also shows which aspects of the factors and requirements of soil health can be adequately taken at each implementation level with synergies and catalysis between the different levels. The document also shows the implementation framework for soil health practices which includes three phases: situation analysis and gap-filling strategies, development of implementation tools, and actual implementation and monitoring.

This framework aims to ensure effective and sustainable soil health management. It also shows how monitoring the implementation of soil health practices can consider tracking key indicators such as soil carbon stocks, adoption of climate-smart technologies, and policy impacts. These indicators help assess progress and ensure alignment with climate change mitigation goals and should be integrated with the CAADP evaluation and monitoring program.

Introduction

1.1 Background

The relationship between soil health and climate change is intricate and reciprocal. Soil health significantly influences climate change, while climate change, in turn, impacts soil health. Healthy soils can sequester carbon, acting as a carbon sink and mitigating greenhouse gas emissions (Veni et al., 2020). Conversely, degraded soils release carbon into the atmosphere, exacerbating climate change. Moreover, climate change affects soil health through changes in temperature, precipitation patterns, and extreme weather events. These changes can alter soil structure, organic matter content, and nutrient cycling, ultimately affecting soil fertility and productivity (Brevik, 2013). The interplay between soil health and climate change underscores the importance of sustainable soil management practices to enhance resilience to climate impacts and support global food security.

Climate change poses significant challenges to soil health in Africa, where variations in temperature and precipitation patterns are particularly pronounced (Atoloye, 2024). These environmental alterations can lead to soil degradation, affecting its ability to sustain plant growth and maintain ecosystems. Rising temperatures can increase the rate of soil organic matter decomposition, reducing soil fertility and disrupting nutrient cycles. Additionally, irregular rainfall patterns can cause both droughts and floods, leading to soil erosion, loss of organic matter, and deterioration of soil structure. Extreme weather events, such as intense storms and prolonged dry spells, further exacerbate the vulnerability of African soils (Furtak and Wolińska, 2023). These conditions can strip the soil of its vegetative cover, making it more susceptible to wind and water erosion. As a result, the land's productivity diminishes, threatening food security and the livelihoods of millions of people who depend on agriculture. The impacts of climate change on soil health are not uniform across Africa; they vary depending on the region's specific climatic conditions and soil types (Nigussie, 2024). For instance, arid and semi-arid regions are more prone to desertification, while tropical regions may experience increased soil leaching and nutrient loss due to heavier rainfall. Therefore, it is crucial to implement region-specific soil management practices to mitigate these adverse effects and promote soil resilience. Implementing sustainable soil management practices, such as conservation agriculture, agroforestry, and organic amendments, can help mitigate the impacts of climate change on soil health. These practices enhance soil structure, improve water retention, and increase organic matter content, making soils more resilient to climatic stresses. Moreover, adopting climate-smart agricultural techniques can contribute to carbon sequestration, reducing greenhouse gas emissions and helping to combat climate change (Bhatnagar et al., 2024; Zheng et al., 2024). By addressing the interconnected challenges of soil health and climate change, Africa can work towards achieving greater agricultural sus- tainability, food security, and environmental resilience. The present document elaborates on the strategies for optimizing soil health practices to mitigate effects of climate change while improving agricultural productivity and environmental quality on the continent

1.2 SIA and AFSH-AP provisions for soil health and climate change

The Africa Fertilizer and Soil Health Action Plan (AFSH-AP) has been formulated to address the pressing challenges of soil degradation and climate change on the continent. This comprehensive plan emphasizes the importance of enhancing soil fertility and resilience through integrated soil management practices. One of the key provisions of the AFSH-AP is the promotion of balanced fertilization, which involves the judicious application of macro and micronutrients to improve soil health and crop productivity. By ensuring that soils receive the right nutrients in the right amounts, the plan aims to prevent nutrient imbalances and deficiencies that can compromise soil structure and fertility. Another critical component of the AFSH-AP is the adoption of conservation agriculture techniques. These techniques, which include minimal soil disturbance, permanent soil cover, and crop rotations, are designed to protect the soil from erosion, enhance water retention, and increase organic matter content. The plan also advocates for the incorporation of organic amendments, such as compost and green manure, to replenish soil organic matter and improve soil biodiversity (FARA, 2024). These practices not only enhance soil health but also contribute to carbon sequestration, thereby mitigating the impacts of climate change. The AFSH-AP also recognizes the diverse climatic conditions and soil types across Africa, and therefore, it promotes region-specific soil management practices (FARA, 2024). For instance, in arid and semi-arid regions, the plan encourages the use of drought-resistant crop varieties and water-efficient irrigation systems. This chapter of the companion document outlines strategies which countries, regions and the continent will need to employ to promote soil health practices aimed at mitigating climate change on the continent.

Capacity building and knowledge dissemination are also integral to the AFSH-AP. The plan calls for the establishment of training programs and extension services to educate farmers on sustainable soil management practices. It also emphasizes the need for research and development to innovate and refine soil health technologies. By fostering collaboration among governments, research institutions, and the private sector, the AFSH-AP aims to create a conducive environment for the widespread adoption of these practices. Ultimately, the AFSH-AP seeks to create a sustainable agricultural landscape in Africa, where healthy soils form the foundation for food security, environmental resilience, and economic prosperity. Through the implementation of its provisions, the plan aspires to transform the continent's agricultural systems and ensure a resilient future in the face of climate change.

The present state of soil health in Africa demonstrates both progress and challenges in the continent's readiness to mitigate the impacts of climate change. Extensive research and initiatives such as the Africa Fertilizer and Soil Health Action Plan (AFSH-AP) have been implemented to enhance soil resilience and fertility. However, the region still faces significant hurdles due to diverse climatic conditions, soil types, and socio-economic factors. Recent studies indicate that integrated soil management practices, including balanced fertilization, conservation agriculture, and organic amendments, are being adopted across various regions (Nezomba et al., 2018; Raheem et al., 2025). These practices have shown promising results in improving soil structure, water retention, and organic matter content. Furthermore, region-specific approaches, such as using drought-resistant crops in arid zones and employing efficient irrigation systems, have contributed to better soil health outcomes (Akinnagbe and Irohibe, 2015; Lankford et al., 2023).

Despite these advancements, Africa's soil remains vulnerable to the adverse effects of climate change, such as temperature fluctuations, irregular rainfall patterns, and extreme weather events. These challenges necessitate continuous efforts in capacity building, knowledge dissemination, and research to innovate sustainable soil management techniques. Through the collaborative efforts of governments, research institutions, and the private sector, Africa is making strides towards achieving a sustainable agricultural landscape. However, the journey towards full readiness to mitigate climate change impacts on soil health is ongoing, requiring persistent dedication and strategic implementation of best practices.

Status of Soil Health Practices for Mitigating Impacts of Climate Change in Africa

2.1 Soil health practices

Soil health practices are human actions aimed at improving or promoting soil health. They are essential for maintaining and improving the quality of soil, which in turn supports sustainable agriculture and helps mitigate the impacts of climate change. Figure 2.1 summarizes some of the key soil health practices for mitigating climate change, controlling soil degradation, improving soil quality, and providing support services.

Examples of soil health practices are (Al-Kaisi and Lowery, 2017):

- Conservation Agriculture: This involves minimal soil disturbance, maintaining a permanent soil cover, and practicing crop rotations. These techniques help protect the soil from erosion, enhance water retention, and increase organic matter content.
- Organic Amendments: The incorporation of compost, green manure, and other organic materials helps replenish soil organic matter, improve soil biodiversity, and enhance soil structure.
- Agroforestry: Integrating trees and shrubs into agricultural landscapes helps improve soil fertility, reduce erosion, and increase carbon sequestration.

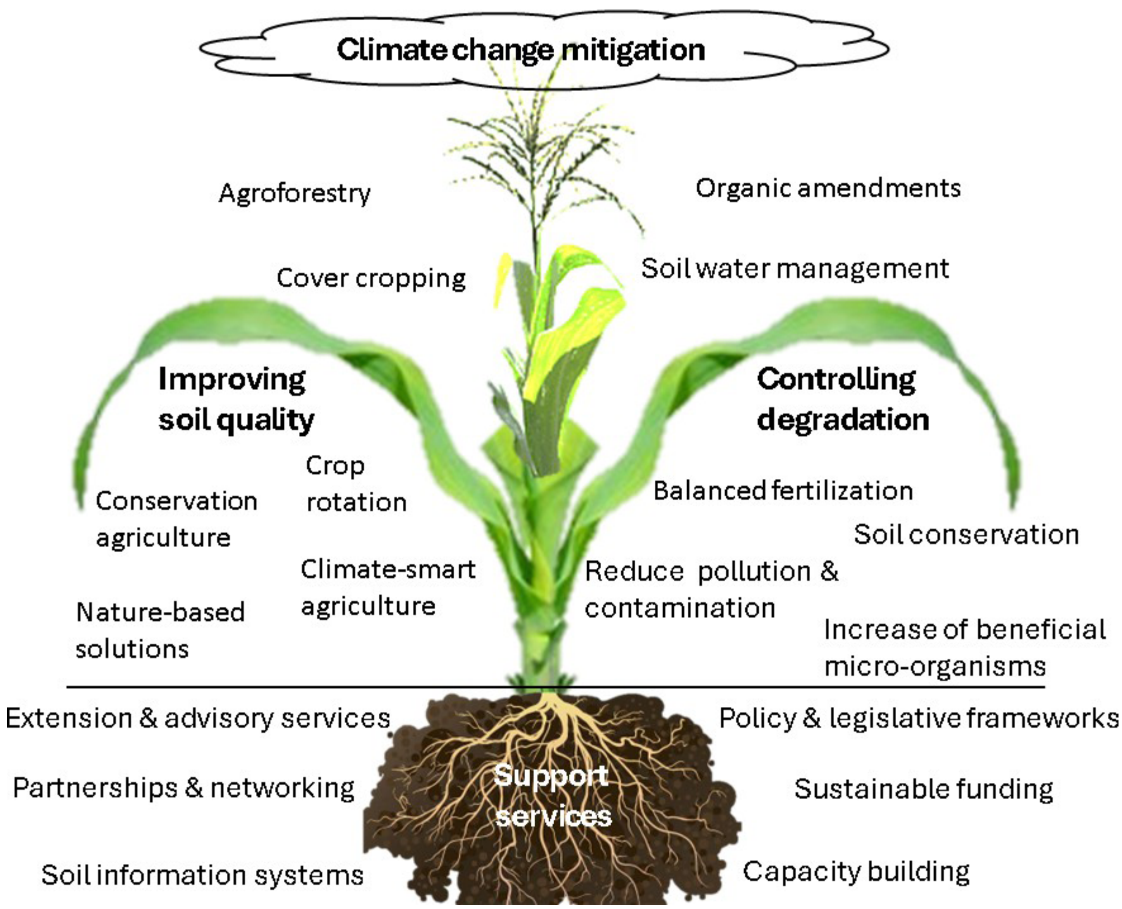


Figure 2.1: Examples of soil health practices

- Balanced Fertilization: Applying the right amounts of macro and micronutrients ensures that soils receive the necessary nutrients to maintain fertility and support crop productivity.
- Climate-Smart Agriculture: Techniques such as using drought-resistant crop varieties, efficient irrigation systems, and practices that enhance carbon sequestration contribute to both soil health and climate change mitigation.
- Cover Cropping: Growing cover crops during off-seasons helps prevent soil erosion, improve soil structure, and enhance nutrient cycling.
- Soil conservation: Protecting soil from different forms of degradation by employing structural, agronomic, vegetative, and any combination of these practices

2.1.1 Status of soil health practices in Africa

Soil health practices vary across Africa due to many factors including ecological, socio-political, economic, regional climates, soil types, and agricultural traditions. In the arid regions of Northern Africa, practices such as crop rotation and the use of organic compost are vital to maintaining soil fertility (Araya et al., 2024). Similarly, in the Sahelian zone, the focus has been more on the development of water-harvesting systems than conservation agriculture because crop residues are highly prized for animal fodder. In contrast, the tropical cli- mates of Central Africa often utilize cover cropping and agroforestry to prevent soil erosion and maintain nutrient levels. The diverse landscapes and farming systems found across the continent necessitate a localized approach to soil health management, ensuring that each region can sustainably support its agricultural needs.

In terms of conservation agriculture (CA), Africa does not seem to have widely embraced the practice. CA in Africa is reportedly accounting for less than 1% of the global CA coverage. The global area under conservation agriculture (CA) is more than 200 million hectares, which is about 12% of the world's cropland area (Kassam et al., 2022). Most conservation agriculture practices in Africa are found in East and Southern Africa regions. In West and Central Africa, CA is can also be found in Ghana and Cameroon (Nana et al., 2014). Climate-Smart Agriculture (CSA), like CA, is also not widely adopted in Africa. However, CSA has been steadily increasing in adoption over recent years. Through the combined action by researchers, international development partners, and the Food and Agriculture Organization (FAO), several African countries have recognized the vital importance of sustainable agricultural practices in combating the adverse effects of climate change. According to recent studies, approximately 30% of farming households in sub-Saharan Africa have adopted some form of climate-smart agriculture (CSA) practices (Ariom et al., 2022; Ogisi and Begho, 2023). These practices include water conservation techniques, the use of drought-resistant crop varieties, and integrated pest management, among others.

Table 2.1: Challenges with soil health practices for mitigating climate change in Africa

Main group	Sub category	Affected Stakeholders
Socio-economic barriers	Poverty and resource limitations	Smallholder farmers
	Knowledge and awareness	Smallholder farmers and policy makers
Environmental and climatic challenges	Variability in climate conditions	All stakeholders
	High rates of land degradation	Smallholder farmers
Policy and institutional constraints	Weak policy frameworks	National governments and regional coordination units
	Institutional support	National, regional, and continental leadership
Technological and infrastructure limitations	Access to technology	Smallholder farmers, extension officers
	Infrastructure development	All stakeholders
Poor planning and prioritization	Poor planning	Smallholder farmers, national governments
	Lack of prioritization	Smallholder farmers, national governments

Soil conservation is the only soil health practice with a long history and widespread application in Africa (Reij, 1991). Today, soil conservation efforts in Africa are a mix of traditional practices and modern scientific approaches. Various governments, non-governmental organizations (NGOs), and international agencies are actively involved in promoting sustainable soil conservation practices. The World Overview of Conservation Approaches and Technologies (WOCAT, https://wocat.net/en/about-wocat) has established a global database of soil conservation practices which show areas in Africa with different types of conservation typologies. However, the status of most conservation efforts as well as their impacts in improving soil health is not fully documented for many places in Africa.

In general, most soil health practices in Africa have poor documentation to support clear judgment of their impacts on soil health at the national, regional and continental levels. Efforts are needed to support ongoing soil health practices including appropriate documentation to benefit further actions and promotion on the continent.

2.1.2 Challenges with Soil Health Practices for Mitigating Climate Change in Africa

Despite the numerous benefits of soil health practices and promising adoption in Africa, numerous challenges still impede widespread adoption and effectiveness of soil health practices in mitigating climate change across the continent. Table 2.1 gives a summary of the main challenges affecting soil health practices for mitigating climate change in Africa.

1. Socio-economic barriers

Poverty and Resource Limitations: Many African farmers operate on small-scale subsistence farms with limited resources. Financial constraints hinder their ability to invest in soil health practices such as organic amendments, cover cropping, and advanced irrigation systems. The lack of access to credit and financial services further exacerbates this issue, making it difficult for farmers to adopt sustainable practices (Mogaka et al., 2021).

Knowledge and Awareness: There is a significant knowledge gap among farmers regarding the benefits and implementation of soil health practices. Extension services, which play a crucial role in disseminating agricultural knowledge, are often underfunded and understaffed. Consequently, many farmers remain unaware of the techniques that could improve soil health and mitigate climate change (Eze et al., 2021).

2. Environmental and climatic challenges

Variability in Climate Conditions: Africa's diverse climatic zones present a challenge in implementing uniform soil health practices. Techniques that work in one region may not be suitable in another due to varying rainfall patterns, temperatures, and soil types (Atoloye, 2024). This variability necessitates tailored solutions that require extensive research and adaptation.

High Rates of Land Degradation: Land degradation, driven by deforestation, overgrazing, and unsustainable agricultural practices, is a significant issue in Africa. Degraded soils have reduced fertility and water-holding capacity, making it challenging to restore soil health (Muchena et al., 2005; Tully et al., 2015). Efforts to rehabilitate degraded lands require substantial investment and long-term commitment, which are often lacking.

3. Policy and institutional constraints

Weak Policy Frameworks: Many African countries lack robust policies that promote and support soil health practices. Existing agricultural policies may not prioritize soil conservation, and there is often a disconnect between policy formulation and implementation (Ginzky and Ruppel, 2022). This gap hinders the scaling up of effective soil health interventions.

Institutional Support: Effective implementation of soil health practices requires strong institutional support, including research institutions, government agencies, and non-governmental organizations. However, institutional capacity is often limited in African countries, with insufficient funding and coordination among stakeholders. This lack of support undermines efforts to promote and sustain soil health initiatives.

4. Technological and infrastructure limitations

Access to Technology: The adoption of soil health practices is closely linked to the availability and accessibility of appropriate technologies. In many parts of Africa, farmers lack access to modern agricultural tools, equipment, and inputs that are essential for implementing sustainable practices. Bridging the technology gap is crucial for enhancing soil health and mitigating climate change.

Infrastructure Development: Poor infrastructure, including inadequate trans- portation networks and storage facilities, poses a significant barrier to the adoption of soil health practices. Efficient supply chains are necessary for delivering inputs, accessing markets, and disseminating knowledge. Investing in infrastructure development is essential to support sustainable agricultural practices.

Table 2.2: Examples of impacts of climate change on soil health

Impact.area	Influence	Reference
Soil management	Changes in soil conservation to adjust to cli- mate change	[@ling_exploring_2024]
	Climate change causes change in use of soil amendments	[@rubin_climate_2023]
	Changes in cropping calendar and land preparation	[@waha_adaptation_2013]
Soil functions	Changes in soil properties	[@prasad_climate_2020]
	Changes in soil functional capacities	
Land use	Changes in land use types and diversification	[@winkler_global_2021]
	Intensification of land uses	

2.2 Impacts of climate change on soil health

2.2.1 Impacts of climate change on soil health

Climate change in the form of variability, rising temperatures and precipitation, and change of onset time for seasons have affected soil management programs, altered soil properties, and influenced land use types in ways that have introduced significant impacts on soil health (Table 2.2).

1. **Altered soil management programs**

Climate change is touted as a main driver to changes in soil management pro- grams worldwide. For example, changes in precipitation characteristics have been shown to in- fluence the rate and amount of soil loss when all other factors remain constant (Adeyeri et al., 2024). Consequently, the soil conservation measures must be changed to deal with the new threat volume. In areas where climate change has caused a decrease in soil moisture, the soil conservation types seem to also change to focus more on soil moisture management. Simi- larly, increase in temperature due to climate change can occasion change in soil organic matter mineralization which forces the need for increase in use of or- ganic amendments to sustain soil fertility (Rubin et al., 2023). Climate change in the form of changes in duration and arrival of seasons also influences the type and intensity of cropping interculture and investment decisions by majority of land users. The shift in arrival of seasons and change in duration of the seasons in cropland areas influence changes in cropping calendar and spiral effects on soil management programs that are needed to conform to the available window for land preparation.

2. Altered soil properties

Rising temperatures, increased precipitation, and extreme events put pressure on the soil which may result in changes in soil properties such as organic matter content, fertility, salt accumulation, etc. The literature shows that climate change has caused some soils to become net sources of atmospheric carbon which indicate lowering of soil organic carbon (Brevik, 2013). Similarly, there are also reports indicating increase in salinization due to climate change in some parts of the world (Hassani et al., 2021), signifying changes in soil electrical conductivity, pH, and cation exchange characteristics.

3. Influenced land use changes

There is a close association between land use/cover change and climate change (Bununu et al., 2023). However, from the perspective of response to climate change, the literature show that land use types have been changed to accommodate the reality brought about by climate change. For example, in the face of dwindling livestock pastures, some communities abandon free-range livestock management to feedlots, controlled grazing, zero-grazing, etc. Similarly, increased swamping due to climate change potentially increases opportunities for paddy rice production and vice versa for drying of swamps which trigger reclamation of the wetland for crop production (Khairullah et al., 2021). Climate change can also trigger mitigation responses that focus on intensification of land use types (Campbell et al., 2014).

2.2.2 Extent of impacts of climate change on soil health in Africa

Impacts of climate change on soil health in Africa have not been adequately studied at the continental level. However, information gleaned from global studies shows that soil health is likely to deteriorate in the near future in more than half of the continent (Figure 2.2) [Borrelli et al. (2020); hassani_global_2021].

Areas projected with the most deteriorating soil health are found in West Africa, Sahel, East Africa, Southern Africa, and northern Mediterranean coastal areas (Figure 2.2). They are also expected to show declining soil fertility due to climate change (St.Clair and Lynch, 2010). Coincidentally, these areas are the breadbasket areas of Africa, implying significant impacts on food security as well on the continent in the near future.

Figure 2.2 shows that more than half of Africa is likely to experience deteriorating soil health in the near future. The literature also depicts 65% of the continent as undergoing soil different forms of soil degradation. This implies that a vast majority of the continent will continue to experience poor soil health unless proper action is taken. AFSH-AP and SIA framework is likely the antidote for this soil health problem.

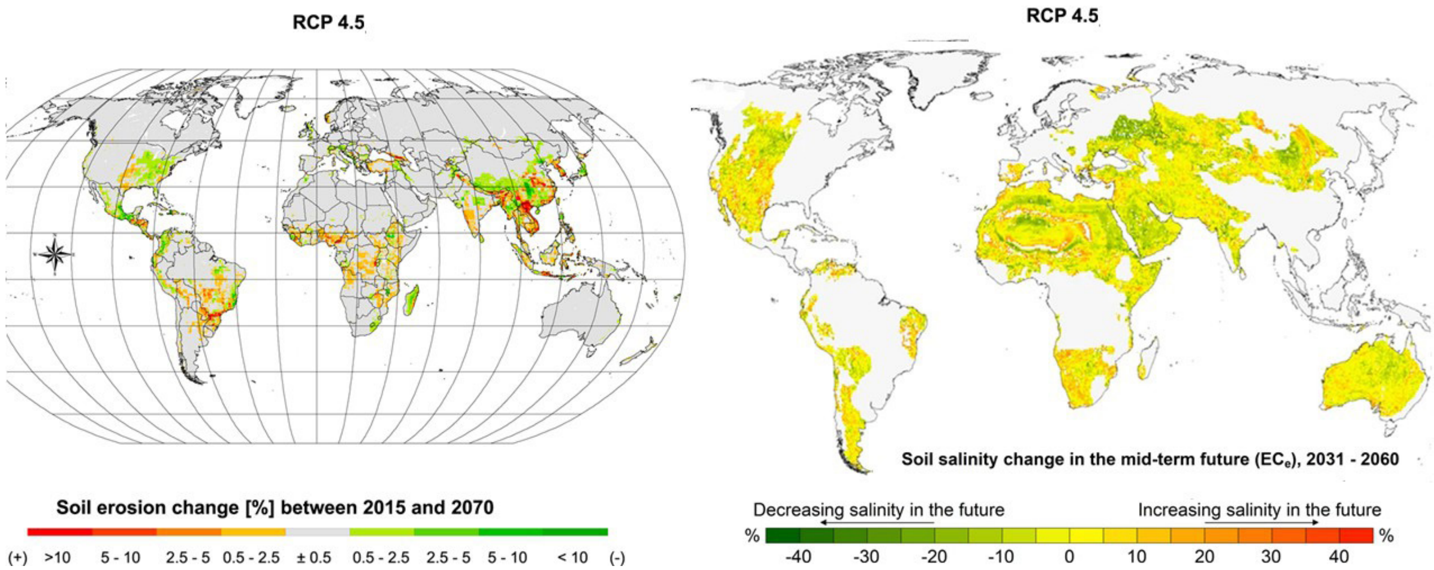


Figure 2.2: Impacts of climate change on erosion (Borelli et al., 2020) and salinization (Hassani et al., 2021)

Requirements for Soil Health Practices to Mitigate Climate Change

3.1 Factors influencing soil health practices to mitigate climate change

Factors influencing soil health practices for mitigating climate change are conditions which support or control proper selection of soil health practices. They mirror the responses to challenges identified in challenges with soil health practices for mitigating climate change in Africa and include types of land use, government policies and incentives, farmer education and awareness, availability of resources, technological advancements, etc. (Figure 3.1).

3.1.1 Agricultural practices and rate of adoption of sustainable techniques

Adopting sustainable agricultural practices such as crop rotation, cover cropping, and reduced tillage can improve soil health. They enhance organic matter, increase water retention, and reduce erosion, thereby contributing to carbon sequestration. A high rate of adoption of these practices can motivate many actors and contribute to widespread use of the practices and the spiral effect in contributing to improved soil health and mitigation of climate change. A low rate of adoption has the reverse effect (Mogaka et al., 2022). The rate of adoption of soil health practices to mitigate climate change is varied in Africa.

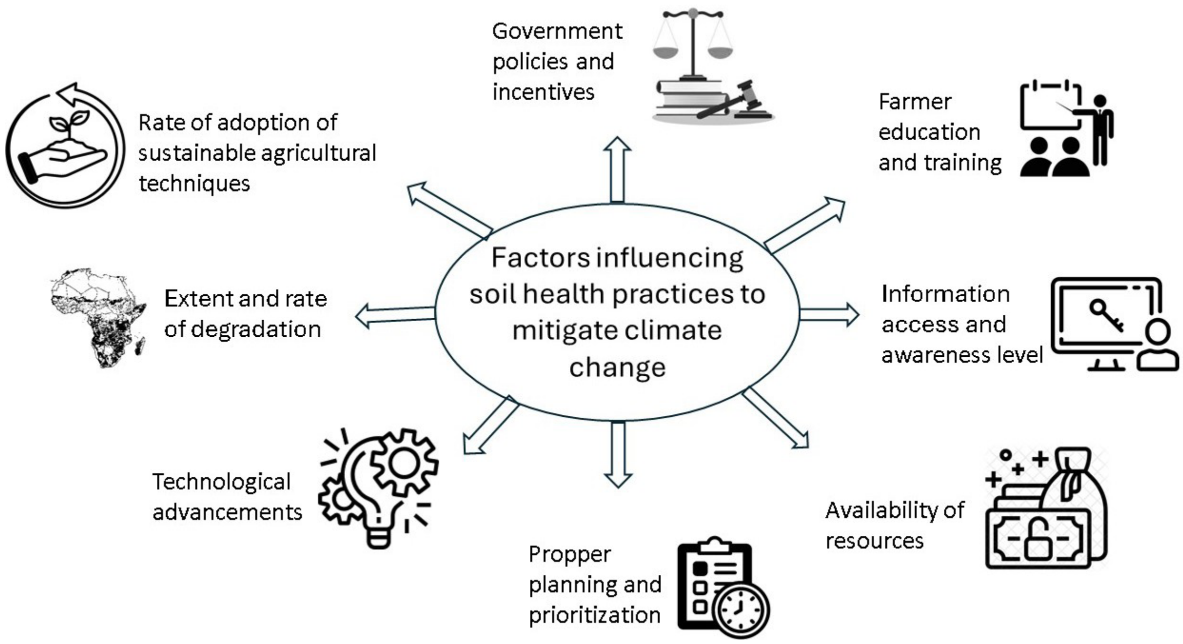


Figure 3.1: Factors influencing soil health practices for mitigating climate change

The literature reports average low rate of adoption as much as less than 20% (Araya et al., 2024; Ogisi and Begho, 2023).

3.1.2 Technological advancements

The use of precision agriculture technologies, such as remote sensing, soil sensors, and data analytics, allows for more efficient use of resources and better management of soil health. These technologies help farmers make informed decisions that can lead to improved soil fertility and reduced greenhouse gas emissions. Technological advancements in soil health practices can also significantly influence climate change mitigation by enhancing soil carbon sequestration, optimizing water usage, and improving overall agricultural efficiency, thereby reducing greenhouse gas emissions and promoting sustainable farming practices. Examples of technological advancements in soil health practices in- clude precision agriculture, biochar application, conservation agriculture, smart irrigation, internet of things, etc. (Parra-López et al., 2024).

3.1.3 Policy and incentives

Government policies and incentives play a crucial role in promoting soil health practices. Programs that offer financial support, technical assistance, and education can encourage farmers to adopt practices that benefit both soil health and the environment. Government policies promoting healthy soil practices can also significantly influence climate change mitigation by encouraging carbon sequestration in soils, which acts as a natural sink for atmospheric carbon dioxide, thereby reducing greenhouse gas emissions and helping to combat climate change; this can be achieved through initiatives like incentivizing no-till farming, cover cropping, and responsible fertilizer use (Kabir et al., 2024).

3.1.4 Level of education and awareness among stakeholders

Raising awareness about the importance of soil health and its impact on climate change is essential. Educational initiatives targeting farmers, agricultural professionals, and the general public can foster a better understanding of sustainable soil management practices and their benefits (Brevik, 2013). Education and training help stakeholders to choose and promote the right technology for responding to climate change.

The level of education and awareness on soil health matters and climate change remain comparatively low in Africa. A large portion of African farmers, particularly in rural areas, lack comprehensive knowledge about soil health indicators, the impacts of poor soil management, and effective practices to improve soil fertility (Eze et al., 2021; FARA, 2024). The low level of education and awareness among the core stakeholders in Africa may pose a significant effect of soil health practices for mitigating climate change in Africa.

3.1.5 Research and innovation

Ongoing research and innovation are vital to developing new and improved soil health practices. Collaboration between scientists, farmers, and industry stakeholders can lead to the discovery of innovative techniques and solutions that enhance soil health and mitigate climate change. Some of the ways in which research and innovations can improve soil health and climate resilience include:

- Developing new soil management techniques
- Increasing the understanding of soil microbial communities
- Developing new technologies for monitoring soil health and shaping deci- sions
- Genetic modifications to improve climate resilience
- Identifying optimal practices which target soil health and climate change mitigation

Table 3.1: Requirements for planning soil health practices for mitigating climate change in Africa

Key.considerations	Planning.requirements
Resource availability	Financial investment
	Availability of workforce and prime movers
	Land ownership and management
Policies and regulatory framework	Relevant policies and legislations
	Law enforcement
	Incentives, business environment, and service providers
	Availability and access to technical institutions
Research, innovation and technological advancement	Research support and living labs
	Partnerships and collaborative network
	Data strategies and monitoring technologies
	Applicable innovations
Proper planning and prioritization	National soil health strategies
	Socio-economic and political leadership
	Technical guidance
	Standardization and scaling strategies
Awareness and education	Adequate understanding of soil health principles
	Extension and advisory services
	Capacity-building and exchange programs
	Information systems (soil, climate, agricultural, marketing)
	Communication and promotional programs
Magnitude of soil degradation	Soil health dashboard
	Identification of hotspots and champions
	Soil fertilization and conservation program
	Community mobilization and engagement

3.2 Requirements for strategizing appropriate soil health practices to mitigate climate change in Africa

Strategizing soil health practices to mitigate climate change in Africa requires careful consideration that put into perspective the factors influencing soil health practices and associated challenges and limitations in the continent. Figure 3.1 shows the factors influencing selection and adoption of soil health practices while Challenges with soil health practices for mitigating climate change in Africa presents the challenges and limitations facing soil health practices in Africa. The relationship between these two key points (influential factors and challenges) can help identify the requirements for strategizing soil health practices for mitigating climate change in Africa. The relationship identifies 6 key points for consideration for soil health practices in Africa: resource availability, policies and regulatory frameworks, research and innovations, proper planning and prioritizations, awareness and education, and extent of degradation. The requirements for planning soil health practices in Africa using these key considerations are shown in Table 3.1.

Implementation of Soil Health Practices for Mitigating Climate Change In Africa

4.1 Implementation framework Implementation plan

4.1.1 Implementation plan

The implementation plan focuses on developing the roadmap for a smooth and efficient roll-out of the soil health practices for mitigating climate change at different levels in Africa. The plan entails three main steps (Figure 4.1):

- Step 1: selecting the appropriate implementation level
- Step 2: initial preparation for implementation
- Step 3: designing implementation frameworks

The choice of implementation level in step 1 guides the activities to be priori- tized at that level. For example, while the landscape level remains the lowest level for implementation of soil health practices for mitigating climate change, higher levels like national, regional and continental levels can deal with soil health factors that need policy, regulatory, standardization, and coordination actions. The choice of implementation level is followed by initial preparation in step 2, which includes the establishment of a coordination unit and the identification of stakeholders to support the implementation process. The coordination unit and stakeholders will design and carry out stocktaking and assessment of climate change and status of soil health, identification of factors of soil health to tackle at the selected implementation level, and determination of soil health implementation requirements in Challenges with soil health practices for mitigating climate change in Africa. The last step entails the development of an implementation framework which includes implementation strategy, mobilization of human, financial and institutional resources needed to implement the plan, and monitoring and evaluation aspects.

The implementation plan also portrays the relationship and synergy between different implementation levels (landscape, national, regional and continental) to maximize success and impacts of soil health practices for mitigating climate change in Africa. The relationship is manifest in the way different levels identify the soil health factors to prioritize, the stakeholders between and within the levels, and coordination and communication between the levels.

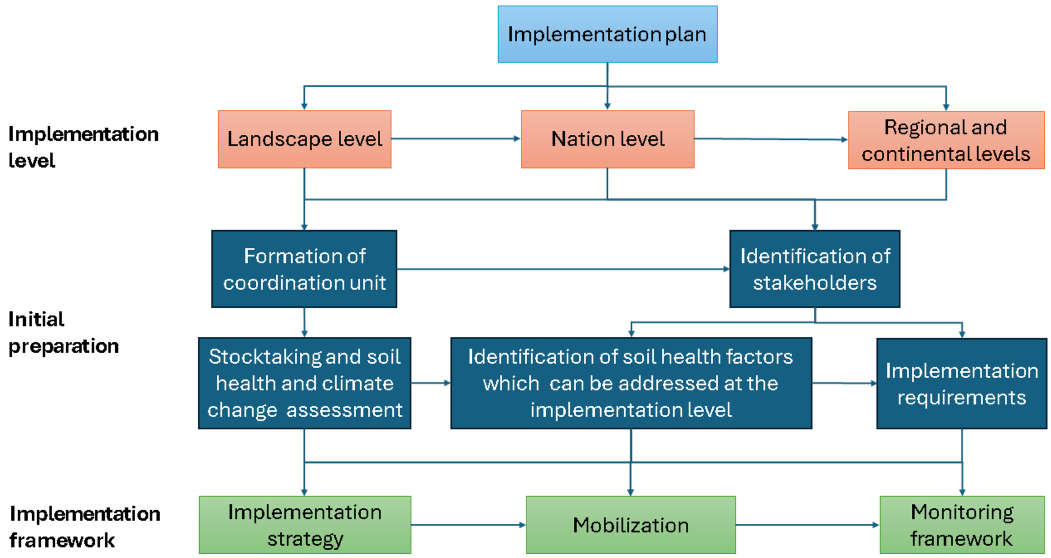


Figure 4.1: Implementation plan for soil health to mitigate climate change in Africa

4.1.2 Implementation framework

The implementation framework provides the structure for carrying out soil health management to mitigate climate change at any of the planned implementation levels. The framework is envisaged in three phases to provide room for accomplishing the implementation in sizeable and manageable chunks.

Phase 1: Situation analysis and strategies for gap-filling

Phase 1 of the framework is concerned with analysis of the situation, identifying gaps and strategies for gap filling. It focuses on soil health and climate change assessment to determine bright and hotspot areas in the landscape for prioritization (Figure 4.2). It also includes resource-needs assessment and assessment of human and institutional capital. These assessments are necessary to develop a suitable sustainability plan.

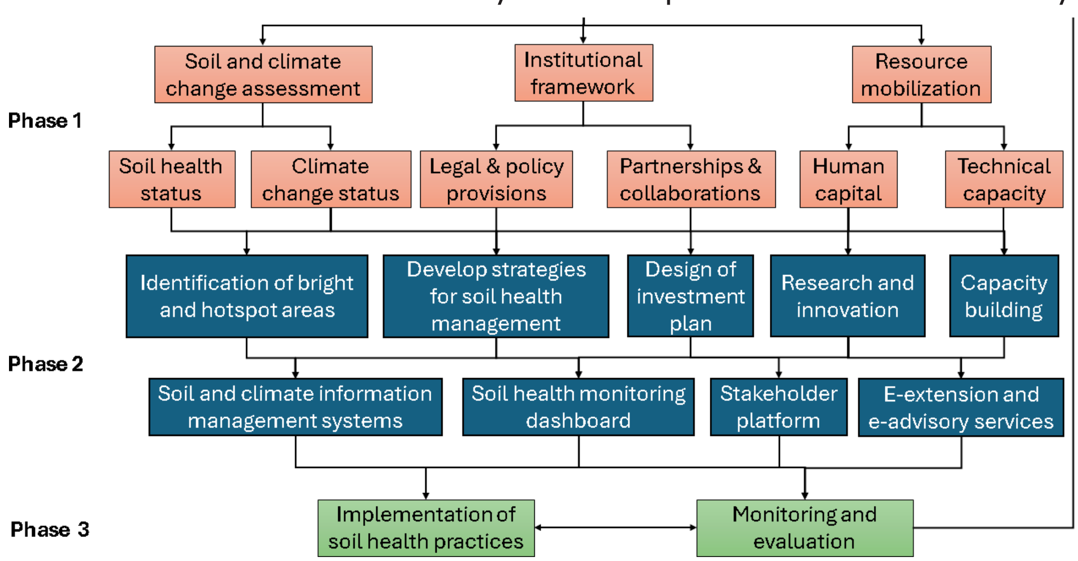


Figure 4.2: Implementation framework for soil health management to mitigate climate change

Phase 2: Development of implementation tools

Phase 2 of the implementation framework integrates the outputs of phase one to develop implementation tools such as soil and climate information management systems, soil health monitoring dashboard, stakeholder platform, and decision support (e-advisory and e-extension tools). The implementation tools are also useful in tracking policy impacts on soil health and trigger for improvements.

Phase 3: Implementation and monitoring

Actual implementation of designed strategies and soil health occurs in phase 3. Soil health practices for mitigating climate change are implemented at the landscape level while other strategies (such as national strategies for promoting soil health, regional or continental agreements on soil health, etc.) are recommended for other, higher levels of implementation.

Table 4.1: Considerations for planning monitoring of implementation of soil health in Africa

Level	Objective	Target
Landscape level	Increasing resilience to climate change	Increase rate of adoption of climate-smart agriculture (CSA)
	Reducing GHG emissions	Technological advancements Information access and awareness level
	Reducing soil degradation	Extent and rate of degradation Proper planning and prioritization
National level	Providing institutional support	Policy, legal, and coordination support Financial support and partnerships Standardization and regulation of soil health practices
	Providing technical support	Capacity building, promotion, awareness Information access and advisory services
Regional and continental levels	Promoting climate-smart decisions in agriculture	Policy support and awareness raising programs
	Prioritizing soil health	Strategies for incorporating soil health in development agenda
	Mitigating climate change	

4.2 Monitoring framework

4.2.1. Monitoring plan

Monitoring implementation of soil health practices for mitigating climate change should consider the target objectives at different implementation levels. The plan is to integrate the monitoring framework with the CAADP monitoring and evaluation system.

The plan also seeks to identify key indicators which are easily determined and carry the necessary information to track implantation progress. Table 4.1 summarizes key considerations that should be prioritized when planning monitoring of implementation of soil health strategies to mitigate climate change.

4.2.2 Indicator monitoring

Indicators for monitoring implementation of soil health for mitigating climate depends on the level of implementation. Using the implementation plan factors in Table 4.1, the following indicators have been proposed for monitoring and reporting the progress of implementation of soil health strategies for mitigating climate change in Africa (Figure 4.3):

- Spatial distribution of soil carbon stocks and degradation
- Number of CSA technologies being implemented
- Number of policies and legislation for promoting CSA
- Budgetary allocation for CSA at the national level

Where applicable, these indicators can be integrated into CAADP monitoring and evaluation program.

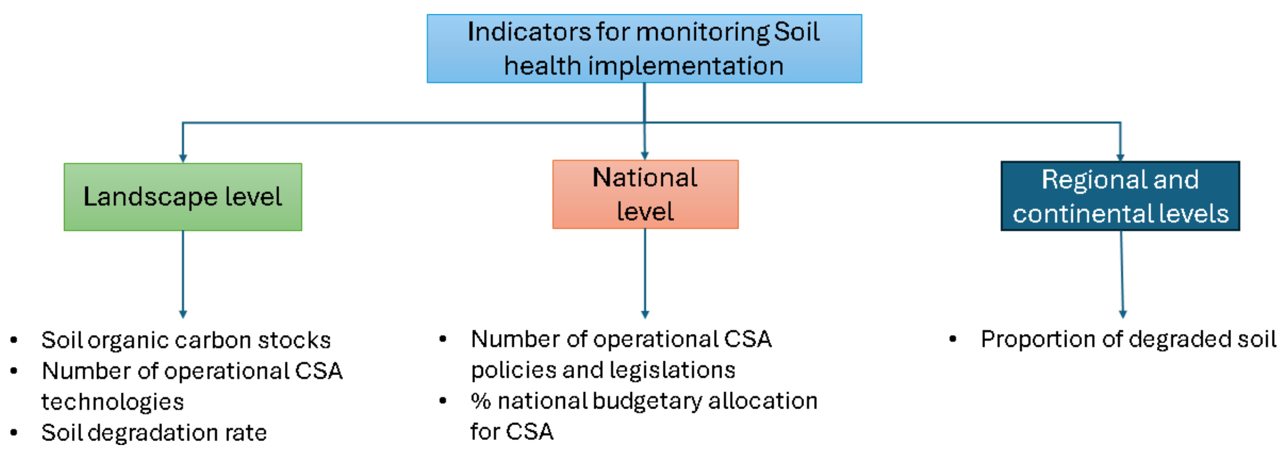


Figure 4.3: Implementation Framework

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Chapter 8

Optimizing Soil Health and Water Management in Africa

Contents

Summary

Soil health and soil water are major issues of concern that influence agriculture productivity in Africa. They directly impact all plant growth and hence food security, environmental quality, and overall human and livestock health. Soil water and soil health are interrelated. Healthy soil supports better water absorption and water retention and release characteristics. Similarly, soil health management increases organic matter and aggregate formation and stability, which influences soil water relations. One essential way of safeguarding soil health is through soil and water conservation. Soil and water conservation is a traditional practice in agriculture for controlling soil erosion, preserving or increasing soil water, enabling nutrient cycling, soil structure maintenance, and microbial activity. There are many options for soil and water conservation practices in the literature which can fit different scenarios in Africa. A careful selection of the appropriate and sustainable practices is needed which will also promote soil health on the continent. Since the "appropriateness" of different options is so location and resource-specific, the direct involvement of smallholder farmers (SHF) in the selection process is essential. The Africa Fertilizer and Soil Health Action Plan (AFSH-AP) and the Soil Initiative for Africa (SIA) framework have highlighted the need for actions to optimize soil health and water management in Africa to improve agricultural productivity and environmental quality. The objective of this chapter of the companion document is to outline strategies for implementing appropriate soil health and water management in Africa. It is important to note that inadequate implementation of soil conservation will cause soil degradation and exacerbate poor soil health. Therefore, the document not only outlines strategies to implement soil health and water management at farm and landscape levels but also how to scale successful interventions throughout Africa to tame the growing soil degradation on the continent. Presently, it is believed that more than 65% of African is degraded. The degradation state is further compounded by a lack of detailed informa- tion on the coverage and impacts of soil conservation on the continent. This document outlines the steps needed to improve innovative and successful soil conservation efforts at farm and landscape levels (deep scaling), expanding the geographic coverage of successful conservation interventions (scaling out or horizontal scaling) as well as to involve many stakeholders to improve the enabling environment for the implementation of soil conservation (scaling up or vertical scaling) in Africa. It also includes a four-phased plan to develop national and regional soil health strategies and development of soil health dashboard to track impacts of the strategies on soil health. The implementation plan incorporates activities at the local, national, regional and continental levels. The monitoring plan is envisaged to align with the framework set by the SIA Action Plan and the CAADP monitoring system.

Introduction

1.1 Background

Soil and water conservation aims to control or prevent soil loss (erosion), loss of soil nutrients, and general deterioration of soil and water quality, which are the major global threats to soil health, agricultural productivity, and environmental quality. Planning for soil and water conservation is traditionally part of agricultural and environmental planning to protect and maintain the crucial media for plant growth, biodiversity sustenance, climate regulation, and environmental exchange (Hudson; Morgan). It is therefore not surprising to find soil and water conservation aspects included in the 2024 Africa Fertilizer and Soil Health Action Plan (AFSH-AP) and the Soil Initiative for Africa (SIA)a framework (AU-FARA). Soil and water conservation also targets soil water, which is one of the major limiting factors for agriculture production, particularly in the drylands. Soil water management is especially important for Africa's agriculture performance where close to half of the continent is dryland that supports over 75% of Africa's agriculture (cer). Further, the collection and conservation of rainwater in the soil is also essential for maintaining and increasing water resources in general, which are in turn critical for both productive uses (like livestock production) and domestic uses (drinking, bathing and washing of household goods like clothing, etc.) Water resources are already in short supply in Africa and are predicted to decline further - thus this aspect of soil and water conservation has massive implications for human life and livelihoods well beyond plant growth. Lastly, it needs to be noted that soil and water conservation at the level of individual plots is essential, but not sufficient, to restore soil health and water resources across the continent. Soil and water conservation at the landscape level is also essential for fully capturing rainwater as it falls, and for the protection of the productivity of grazing areas, forest lands, wetland areas and other critical ecosystems. Thus, the SIA framework clearly calls for action on soil and water conservation at both the farm-level and the landscape level.

There are many options for soil and water management in the literature which can fit different scenarios in Africa (Diop et al.; Namirembe et al.; Hudson). A careful selection of appropriate and sustainable practices is needed, which will also promote soil health on the continent. Soil health and soil and water management are interrelated, and in fact in many instances it is necessary to manage soil to manage water. Soil and water management influences numerous physical, chemical and biological processes that shape soil health (Williams et al.). This inter-relationship can be used to guide the selection of appropriate soil and water management alternatives that optimize soil health to improve agricultural productivity and environmental quality. This document elaborates on the strategies for optimizing soil health and water management across agricultural sub-sectors and landscapes in Africa with a view to improving agricultural productivity and environmental quality on the continent. However, it should also be recognized that the selection of locally viable soil and water management strategies and technologies is highly location specific (influenced by culture, availability of farmer's resources, topography, rainfall averages, etc.). It is therefore essential to involve local farmers in the final selection of technologies for soil and water conservation.

Technologies which have been developed for managing soil water and improving soil health primarily target reduced soil disturbance, increased organic carbon and fertility, reduced soil loss, increased availability of soil moisture, and reduced weed, pest and disease infestation (Altobelli et al.; Blanco and Lal; Hudson). Globally, the trend of adopting of most technologies for soil and water management is shaped by the increasing impacts of climate change, population pressure on available land, competing demand for resources, socio-economic and legal challenges, and access to information and advancing technologies. In Africa, weak policy support and inadequate prioritization of soil and water management (at both farm and landscape levels) in most countries have compounded the challenges with the adoption of the technologies, thus contributing to negative consequences on overall soil health and declining water resources on the continent (Degfe et al.; Diop et al.; Rotich et al.). The Soil Initiative for Africa (SIA) prioritized soil and water management to alleviate soil health, agricultural productivity, declining water resources and environmental quality in Africa (AU-FARA). It is anticipated that its implementation will catalyze existing campaigns to promote improved soil and water management, soil health and agricultural productivity in Africa.

1.2 Progress with sustainable soil and water management in Africa

Sustainable soil management (SSM) is a set of practices and technologies that preserves or improves the long-term services provided by soil without significantly impairing the present or future soil functions (FAO; Smith and Powlson).

SSM aims to limit misuse, neglect, and degradation of the soil resource while improving overall long-term soil health and productivity. The practices and technologies under SSM vary by ecoregions, landscapes, land use types, etc. This variation complicates the development of a complete spatial distribution of SSM practices and technologies at the global, continental or national levels, which would have been useful in tracking areas under SSM, impacts of SSM on multilevel soil degradation, etc. The World Overview of Conservation Approaches and Technologies (WOCAT), which is a global network on Sustainable Land Management (SLM), has attempted a global database of SSM practices and technologies (https://explorer.wocat.net/). Although the WOCAT database is not complete, it can serve as an indicator of existing SSM practices and the starting point for assessing the global progress with SSM (Haregeweyn et al.).

In Africa, many SSM practices and technologies exist in different places although the majority of them have not been adequately published (Brempong et al.; Critchley and Graham; Diop et al.; FAO; Namirembe et al.; Reij). There is no clear and complete documentation in the literature on the progress with implementation of SSM at the country, regional or continental levels. The WOCAT database of SSM, which shows data at the national level in more than half of the countries in Africa, does not represent a complete compendium of existing practices and technologies. In contrast, land degradation (23), soil erosion (Borrelli et al.), and even salinization (Omuto et al.) are well documented at all levels in Africa. The CAADP pillars and SIA framework have identified the need for building an information platform in the form of a database which will be used in sensitizing, promoting, tracking, and optimizing soil and water management and soil health across agriculture sub-sectors and landscapes in Africa (NEPAD; AU-FARA). This chapter highlights the necessary steps to implement SIA and AFSH-AP strategies for promoting SSM and soil health in Africa.

Status of Soil Health and Water Management in Africa

2.1 Major threats to soil health in Africa

Threats to soil health are processes or direct drivers that cause soil quality deterioration over time. They can be generally categorized as soil degradation, the negative impacts of climate change, and misuse/abuse of the soil resource (Table 2.1). The first seminal work on the global extent of threats to soil health was undertaken in the late 1980s (Oldeman). New global estimates have since been published in terms of rates of soil erosion, salinization, pollution, nutrient depletion, etc., which show an increasing trend of the extent and intensities of some of the threats to soil health (23; Hassani et al.; Tan et al.; Wuepper et al.). There are also reports of regional prioritization of the main threats, which depict soil degradation as the most dominant global threat to soil health (Montanarella et al.).

In Africa, soil degradation remains the major threat to soil health (Figure 2.1) (Jones et al.; Montanarella et al.). The extent and intensity of soil degradation on the continent has been variously estimated in literature.

Table 2.1: Major threats to soil health

Major Group	Threat	Reference
Soil Degradation	Physical degradation (e.g., erosion, compaction, sealing, structural deterioration, etc.)	[@saljnikov_types_2022]
	Chemical degradation (e.g., salinization, Soil degradation acidification, sodification, nutrient imbalance, organic carbon loss, nutrient depletion, etc.)	[@oldeman_global_1992]
	Biological degradation (loss of soil biodiversity)	[@stewart_biological_1990]

Climate Change	Drought (e.g., desiccation, soil moisture decline), flooding (waterlogging)	[@girija_veni_soil_2020]
Misuse or Abuse of Soil Resource	Soil nutrient mining/depletion	[@tan_global_2005]
	Soil pollution and contamination (e.g., waste disposal, waste-water, deposition of heavy metals, oil spills, microplastics, etc.)	[@fao_state_2021]
	Loss of soil vegetative cover, soil mixing (e.g., mining, urban-ization, excavations and constructions, microplastics, etc.)	[@ihenetu_impacts_2024]

`Table 2.2: Soil and water conservation practices

Main Group	Features	Practices
Agronomic	Use of cropping and tillage methods to increase soil moisture and nutrients, dis-sipate raindrop impact and increase the resilience of cropland	Cropping methods (e.g., strip, contour, mixed, relay cropping, etc.), crop selec-tion, mulching, crop rotation, soil fertil-ization, tillage, etc
Vegetative	Use of vegetation to improve soil cover, dis-sipate erosive power of wind or water (e.g., raindrop impact, to limit abrasive power of wind and runoff speed), as nitrogen-fixing fodder, etc.	Grass strips, hedgerows, windbreaks, agro-forestation, woodlots, etc.
Structural	Engineering methods to modify land slope, direct runoff, reduce runoff speed, trap run-off/rainwater, etc.	Terraces, ditches, pits, ridges, drains, rainwater harvesting, bunding, etc.
Management	Management of land use, salinity, pests and diseases, management of soil mois-ture, etc.	Wetland restoration, area closure, rota-tional grazing, soil amendment, irriga-tion, pest and disease control, etc.

(Oldeman) estimated it at 65% of agricultural land, 31% of permanent pasture, and 19% of forested land in Africa. Recent estimates have been more specific to the types of degradation and have estimates that vary depending on the methods used. For example, (Wuepper et al.) estimated that 80% of Africa is affected by slight erosion and more than 12% is affected by moderate and high soil erosion rates. The Soil Atlas of Africa reported more than 26% of Africa as vulnerable to desertification (Jones et al.) while (Omuto et al.) reported 10% of land area and 0.2% of croplands in Africa as affected by salinization. More work is needed to give an accurate estimation of the extent and intensity of the major soil health threats in Africa.

2.2 Responses to soil threats in Africa

2.2.1 Soil and water conservation

Soil and water management practices respond to soil threats by implementing strategies for controlling soil degradation and mitigating climate change effects. The practices are grouped as agronomic, vegetative, structural, and management measures (Table 2.2). The literature includes many soil and water conservation practices for different agro-ecological zones (Blanco and Lal; 22). Some of the practices have been documented in the WOCAT database (https://explorer.wocat.net/, accessed on 20 June 2024).

The adoption of soil and water conservation practices varies from place to place due to many factors, including agro-ecological zones, climate, soil types, topography, target threats to soil health, socio-economic factors, and land tenure, etc. (Asafu-Adjaye; Belayneh; Rotich et al.; Savari et al.; Wordofa et al.). (Diop et al.), (Negassi et al.), (Namirembe et al.), and (Reij) have documented some of the practices in different parts of Africa. Proper documentation and spatial distribution, including at the local and national levels, are needed for promoting and scaling successful practices in different parts of Africa. Example distribution as shown in Figure 2.2 needs to be developed, periodically updated, and its information system enriched and shared with extension officers and farmers at all levels in the continent.

Factors influencing effectiveness of soil and water conservation in promoting soil health are:

- Proper design and appropriate use of the practices
- Use of catchment or landscape approach in implementing appropriate practices
- Adequate and regular maintenance of selected practices
- Combined application of different practices
- Adequate research and periodic improvements of the best practices in given scenarios
- Suitable scaling and promotion of successful practices
- Proper capacity building and awareness campaigns
- Adequate information systems to support management, promotion, and scaling of the practices

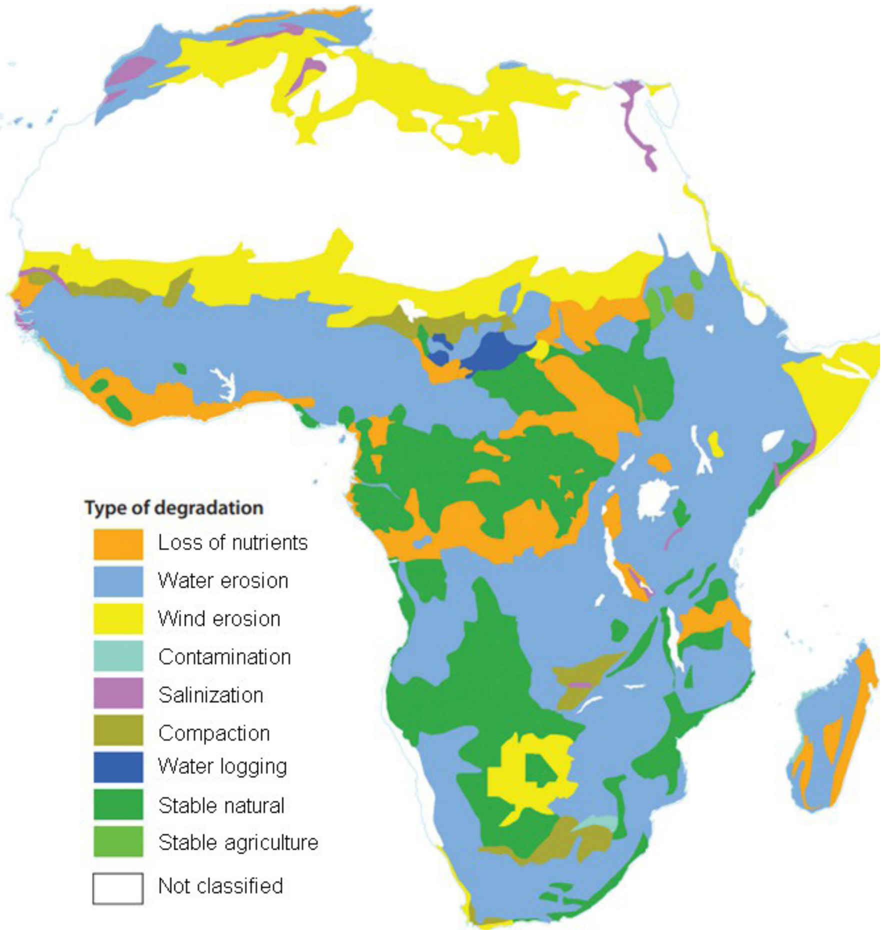

Figure 2.1: Example of approximate distribution of some types of soil degradation in Africa (adapted from Jones et al. 2013)

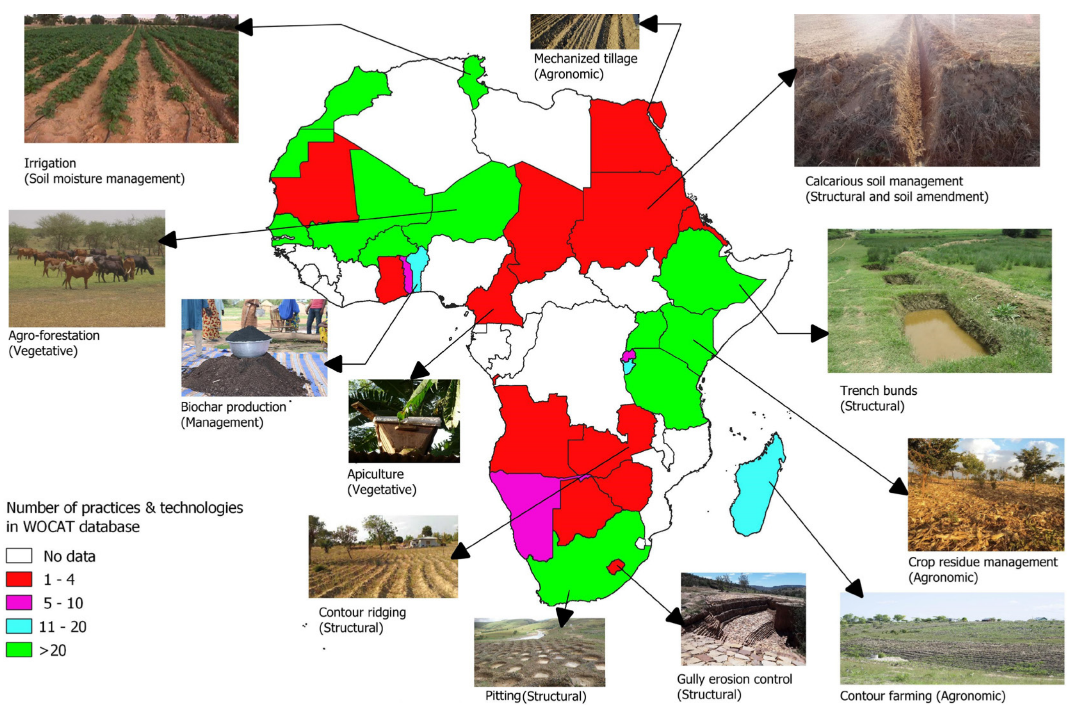

Figure 2.2: Examples of soil and water management practices in Africa (adapted from WOCAT database)

2.2.2 Policy and legislative interventions

Policy and legislative support in soil protection is an area of globally recognized crucial response for halting or controlling the advancement of threats to soil health. Policies and legislation provide the instruments needed to raise necessary resources (including budgetary allocations) to fund activities/measures against soil threats, the basis for legal restrictions to human actions promoting the advancement of threats to soil health, and the framework for coordinating actions for soil protection, among others (Montanarella). Since the European Soil Charter of 1972 and the first World Soil Charter in 1981, and its revision in 2015, there has been a growing global debate about the need for a formal binding framework for soil protection (Ruppel). Many countries have, therefore, developed various environmental and soil protection laws and guidelines. The Food and Agriculture Organization of the United Nations (FAO) developed a global online database (FAOLEX) detailing national laws, regulations and policies on food, agriculture and natural resources management in different countries (https://www.fao.org/faolex/en/, accessed on 20 June 2024). FAO also developed another database for soil-related national laws, regulations, and policies in all countries (https://www.fao.org/soils-portal/soilex/soil-keywords/waterlogging/en/, accessed on 20 June 2024). Although these databases are not complete, they give an indication of available soil protection policies and legislation in individual countries. An analysis of the database of African documents gives the impression that there are insufficient policies and legislation in the continent to support actions against soil chemical degradation and misuse or abuse of the soil resource (Figure 2.3a).

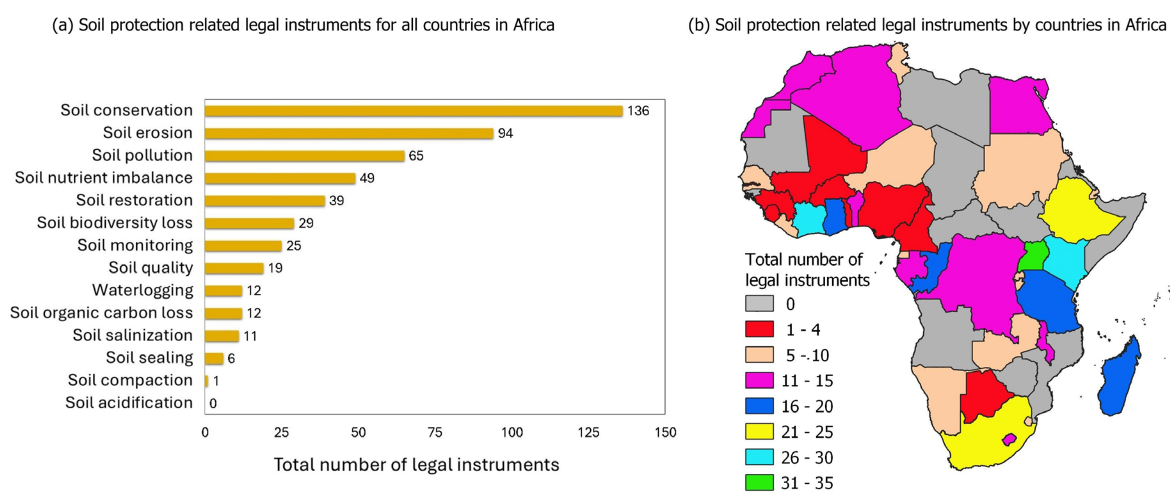

Figure 2.3: Summary of legal instruments for soil protection in Africa in FAO SoiLEX database

The FAO SoilLEX database portrays most countries in Africa as lacking adequate soil protection policies and legislation. For example, it shows that although the total number of soil conservation legal instruments may be significant, they are mostly found in less than half of the countries on the continent. Furthermore, it shows that more than

20% of countries in Africa do not seem to have clear soil protection policies and legislation (Figure 2.3b). Therefore, more work is needed to update the database, sensitize and rally African countries to improve formulation and enactment of relevant national policies and legislation for soil protection, and to raise awareness and mobilize the countries to enforce the national soil protection policies and legislation.

2.2.3 Research on soil and water management

Research is crucial in generating information and advancing knowledge on different soil and water management measures and their impacts on the threats to soil health. In this regard, research is mainly responsible for:

1. Generating and sharing information and data regarding soil water management and soil health
2. Developing soil health trends with/without appropriate soil and water conservation measures
3. Comparing successes and causes for failure of existing soil and water conservation measures
4. Evaluating impacts of different conservation measures and their scaling requirements
5. Developing new methods, technologies, and equipment for soil and water conservation
6. Guiding decisions and identifying critical areas for targeting soil conservation measures

The trend in research on soil and soil water at the global scale is shown in the literature as having had an exponential growth between 1934 and 2022, which indicated an increasing research interest in soil water management over the years (Dumanski; Jia et al.; Zhang et al.). However, the trend does not portray a prominent presence of African research on soil water and soil conservation. Africa has many agriculture research centers (for African Agricultural Research), at least four sub-regional agricultural research organizations (https://faraafrica.org/partnerships/, accessed on 3 July 2024), and many soil scientists, soil science societies and international soil research centers (Rozanov and Wiese; Ryan et al.). Yet, the research activities regarding soil and water conservation from Africa do not significantly reflect in these global research trends. This shows that more work is still needed to improve research on soil and water conservation in Africa, which is commensurate with global trends. Nonetheless, research in Africa on soil water management has demonstrated different approaches to and types of conservation practices, adoption of soil management technologies, impacts of management measures, challenges with ongoing conservation measures, etc. (Critchley and Graham; Diop et al.; Reij; Wolka et al.).

2.2.4 Extension and advisory services on soil and water management

Extension and advisory services provide the link between research or technology/policy development with the end users (such as farmers or owners of land). They are important in:

- Information and technology transfer
- Feedback for improvements
- Awareness campaigns
- Product promotion
- Adoption of technology
- Catalyzing scaling strategies
- Capacity-building

Extension service is the engine for driving the implementation of soil and water conservation measures. During the 20th century, agricultural extension was dominated by government researchers and extension workers (Greenwood; Rivera and Qamar; swa). In Africa, the implementation design for extension services changed at the end of most donor-supported extension programs, which also saw the entry of the private sector and non-governmental organizations (NGOs) (Nwafor et al.; Saliu et al.). The trend of extension and advisory ser- vices has since changed in the continent and new methods through digital platforms are being considered in various agricultural sub-sectors (FAO). Although the use of digital extension and advisory services has not prominently taken root in the soil and water conservation sub-sector, there are many promising opportunities which can be further developed. This is the current rallying call by most leading organizations involved in extension and advisory services in Africa (e.g., https://www.afaas-africa.org/). These organizations are embracing digital technology and slowly advocating for e-extension and e-advisory approaches to improve soil health in Africa.

2.2.5 Awareness campaigns and mobilization to improve soil and water conservation

Awareness campaigns and community mobilization are popular techniques for capturing public attention, improving community knowledge, empowering communities, influencing decisions, and rallying the public and local communities to work together towards improving soil and water conservation (Mango et al.). While awareness campaigns target at raising public consciousness and change of behavior towards promoting soil and water conservation practices, mobilization is concerned with increasing public participation and involvement in conservation efforts. Many countries have used awareness campaigns and community mobilization to expand the coverage and overall effectiveness of soil and water conservation efforts. Figure 2.4 shows some of the strategies often adopted by countries in Africa to raise awareness and mobilize communities to promote soil and water conservation measures (Khan; Mango et al.; woo).

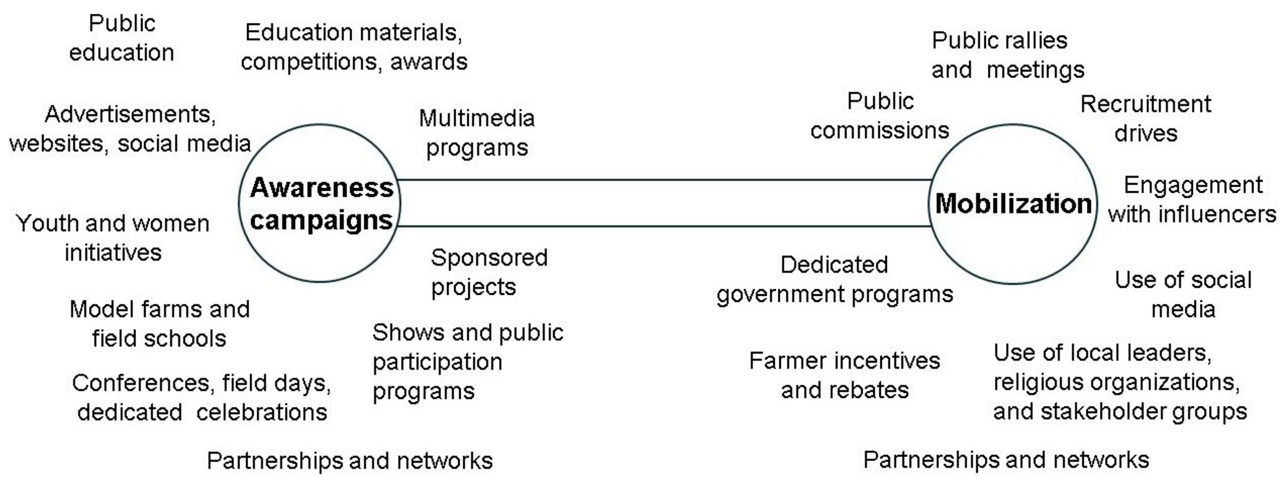

Figure 2.4: Awareness and mobilization strategies for soil and water conservation

Impacts of awareness campaigns and community mobilization towards soil and water conservation have been reported as being able to (Dangiso and Wolka; Masha et al.; Willy and Holm-Müller):

1. Improve public perception and attention to practices that promote soil health
2. Facilitate scaling strategies for soil and water conservation measures,
3. Catalyze landscape-level activities which limit threats to soil health,
4. Improve the adoption rate of soil and water conservation measures
5. Encourage innovations and investments in soil and water conservation

What it takes to Optimize Soil Health and Water Management in Africa

3.1 Requirements for optimizing sustainable soil and water management

Optimizing soil health and soil water management entails minimizing threats to soil health while increasing or maintaining the availability of good quality soil water. Therefore, soil health and soil water management options to consider in the optimization are those that focus on attaining maximum desired conditions for soil health and soil water while limiting the advancement and/or impacts of threats to soil health (Figure 3.1).

3.1.1 Control threats to soil health

Reduced or minimal threats to soil health are the most important requirement for optimizing soil health and water management. Soil threats negatively impact soil health and the availability of quality soil water. Therefore, it is essential to focus on reducing the threats to achieving optimal soil health. Threats to soil health are controlled by reducing soil degradation (such as through proper soil and water conservation measures, (Mahajan et al.)), limiting soil misuse/abuse (e.g., through awareness creation and community mobilization against misuse and abuse of the soil resource, (Drechsel et al.)), and building adaptation measures against effects of climate change (such as through conservation agriculture practices, (Lal)).

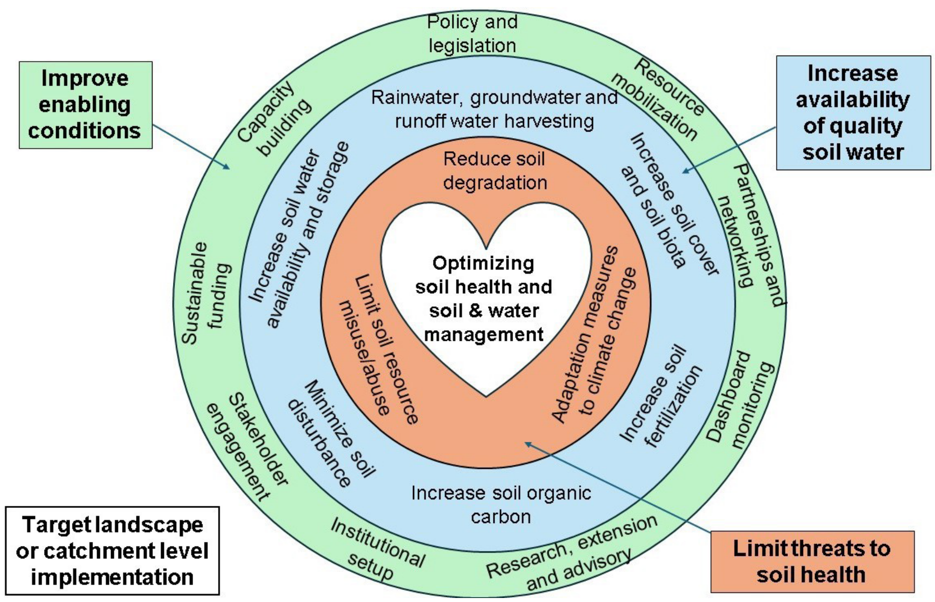

Figure 3.1: Important considerations for optimizing soil health and water management

Soil degradation is the major reason soil health is declining worldwide. In Africa, soil degradation is approximated to affect more than 65% of the continent and this is increasing the negative impacts of climate change. Soil degradation, together with nutrient depletion, is also touted as the primary enemies of Africa's sustainable agricultural productivity (Dimkpa et al.; AU-FARA; Lal and Stewart). Therefore, limiting soil degradation and soil threats in gen- eral should be a priority requirement for improving soil health in Africa. In Figure 3.1, controlled soil threats are prioritized by putting them in the innermost circle close to the heart of soil health and water management.

3.1.2 Increasing availability of quality soil water

Increasing the availability of quality soil water ensures adequate exchange of nutrients between soil and plant roots, facilitates the supply of water needed by soil biota, regulates the exchange of water between soil and the environment, and provides a cooling effect in the soil, among other functions. Water is also important in soil health because, being a universal solvent, it can dissolve and influence the characteristics of pollutants and contaminants in the soil. In the drylands where water is an important limiting factor for plant growth, soil water plays a crucial role in shaping overall soil health. Therefore, increasing the availability of quality soil water is very important in optimizing soil health and water management. In Figure 3.1, it is included in the second tier of important considerations for promoting soil health and water management.

Strategies for increasing quality soil water include (Ali et al.; Shaxson and Barber):

- Increasing soil water infiltration and storage through techniques such as irrigation, drainage, sub-surface water storage (e.g., deep tillage), careful use of soil amendments, etc.
- Increasing soil organic carbon through organic manuring, residue incorporation, etc.
- Minimizing soil disturbance such as in conservation agriculture
- Increasing soil cover through agroforestry, cover cropping, mulching, etc.
- Increasing soil fertilization through integrated soil fertility management
- Harvesting water from rainwater, runoff, and groundwater resources

3.1.3 Targeting landscape or watershed level implementation of soil and water conservation measures

Landscape or watershed level soil conservation is important because it integrates conservation plans with other societal plans which address issues affecting communities, such as climate change, water resources management, etc. Targeting landscape level implementation of soil and water conservation measures is also important because most threats to soil health depend on processes that occur at landscape or watershed scales. Furthermore, focusing on watershed or landscape scale can bring different stakeholders and many landowners/farmers together and improve group discussions and knowledge sharing, which is more inclusive and successful than disjointed attempts at many local or plot levels. There are also studies which show that soil and water conservation measures at the landscape scale are more effective in controlling soil degradation than at the local or plot scale (Wickama et al.). Therefore, targeting the implementation of soil conservation measures at the landscape level should be a prerequisite for effective optimization of soil health and water management.

Effective implementation of landscape level planning for soil and water management requires the following factors to be considered:

- Identification of degradation hotspots and extent of degradation
- Factors influencing degradation and their distribution on the landscape
- Options for soil and water conservation measures for different target area
- An enabling institutional arrangement
- Available stakeholders and partner

3.1.4 Improving enabling conditions

Enabling conditions are the social, policy, legal, institutional, technical, and financial contexts which can influence the implementation of soil and water management. Improving enabling conditions aims to promote the influential factors to favor the establishment and sustainability of soil and water conservation measures. It includes:

- Improving and implementing relevant policies and legislation
- Supporting relevant government departments to oversee technical guidance, supervision, and enforcement of regulations and standards
- Developing relevant information systems and monitoring dashboard for sharing progress on the status of soil health
- Promoting the framework for stakeholder engagement, collaborations, and for forging partnership and networking
- Assessing and encouraging mechanisms and collaborations for resources mobilization, budgetary allocations, and farmer investments in establishment and maintenance of soil and water conservation measures
- Promoting cutting-edge research and development of efficient technology and monitoring systems for soil water management
- Supporting capacity-building through farmer field schools in model farms or living labs, extension, and advisory services

3.2 Implementation challenges for sustainable soil and water management in Africa

3.2.1 Poorly planned conservation measures

Poorly planned conservation measures are difficult to implement and maintain during their lifespan. They are often not properly matched with the soil degradation they are supposed to control, improperly placed in the landscape, have poor technical designs, and may not be suitable for the ecological conditions where they have been implemented. Poorly designed conservation measures may lead to degradation due to the impacts of their negative influence. Some of the features of poorly planned conservation measures are:

- Inadequate number and spacing of the conservation measures in the target area
- Inadequate consideration of the influential factors during the planning and implementation of the conservation measures
- Focusing on plot-scale instead of landscape scale for processes that occur at the landscape scale
- Inappropriate conservation measures for the target soil threat to be addressed
- Incomplete implementation or technical design of the conservation measures concerned
- Top-down approach without the involvement of the local communities during planning and implementation of the conservation measures

3.2. 2Stakeholder behavior and changing land uses

Stakeholders in soil conservation are landowners, local users of natural resources, and government representatives. Others are agro-input dealers, scientists, NGOs, and organizations of agri-food industries and consumers. The active involvement of stakeholders in planning, implementation and maintenance of soil conservation measures has a bearing on the success of the soil conservation efforts (Wang and Aenis). This implies implementation challenges when stakeholders withdraw their participation or change their interest mid- stream of the soil conservation projects. Stakeholders can change their interest or withdraw their support because of leadership or coordination changes, poor coordination and incentives, changes in regulations and priorities, changes in funding mechanisms, wrangles and infighting, competing interests, changes in land use, and impacts of natural disasters, etc.(Mekuria et al.). Other forms of stakeholder behavior that can bring implementation challenges include resistance to change, sneaking in old habits into new technologies, and insubordination (Aghabeygi et al.).

Implementation challenges may also be experienced when land use changes in the target area, which can alter the factors driving soil degradation, the stakeholders' priority focus, the availability of funds and technical staff to implement or carry out maintenance, etc. Apart from land use changes, changes in land sizes can also influence the effectiveness of some soil and water conservation measures.

3.2.3 Inadequate maintenance and monitoring

Some soil conservation measures require regular maintenance to function effectively throughout their lifespan. Poorly maintained conservation measures can lead to soil degradation, promote the growth of pests and diseases, encourage unwanted plants and consequent competition for nutrients and water with crops, etc. Poor maintenance of conservation measures may arise due to a lack of technical knowledge, inadequate resources for maintenance, inadequate or incomplete design, changes in ownership, socio-economic factors (e.g., conflicts, political influence, changing demography of active workforce, etc.), abandonment, aging conservation measures that are cumbersome and expensive to maintain, etc.

Lack of proper monitoring can also affect maintenance and timely management of soil conservation measures. Monitoring provides requisite information that can be used to maintain, improve, or change the design of soil conservation measures.

3.2.4 Inadequate financial sustainability

Most sustainable soil and water conservation measures promoting soil health require sustained financial support to cater for the cost of installation, maintenance, improvements and adjustments, extension services, and labor requirements. Lack of or insufficient funding can starve the operationalization of soil conservation efforts. In Africa, most funding of soil conservation projects comes from governments, development partners (donors, NGOs, well-wishers, loans or grants from financial institutions, etc.), local communities, and landowners/farmers. The motivation to invest in soil and water conservation measures often comes from global/continental initiatives, governments, environmentalists, scientific research, incentives from the business community, public demand, es- pecially where degradation is viewed as threatening public lives or livelihoods, and from farmers'/landowners' own initiatives (such as to reduce loss of land to erosion, increase yields, produce quality agri-products, etc.). Inadequate or lack of proper motivation can trigger insufficient investment in soil and water conservation projects and consequently hinder conservation efforts (Aghabeygi et al.).

Inadequate funding or investment in soil and water conservation projects may be due to:

- Low level of prioritization of soil conservation and soil health
- Lack of awareness and knowledge of the importance of soil health and soil conservation
- Low confidence in the ability for proper management of financial resources
- Poor publicity and communication with funding organizations
- Shrinkage of economic performance from sources of funding

3.2.5 Inadequate institutional support

Inadequate institutional support encompasses insufficient or lack of adequate social, policy, legal, and technical support in the implementation of soil and water conservation projects. Inadequate support may fail to enjoin stakeholders, fail to cover implementation activities legally, lack regulatory mandate to guide and standardize soil and water conservation measures, or lack motivation to promote conservation activities.

Inadequate policy and legal support may be in the form of:

- Inconsistent or lack of proper policies and laws for soil protection
- Lack of adequate policies, laws and detailed regulations for protecting the destruction of natural resources, dealing with encroachments, and for committing landowners or users to install soil conservation measures on their property
- Inadequate enforcement of existing policies, laws and detailed regulations regarding soil conservation measures
- Lack of properly constituted community organizations to champion soil and water conservation efforts
- Social organizations without a clear vision for soil conservation
- Improperly motivated social groups who are not pulling together to drive soil and water conservation activities in the target areas
- Inadequate technical government departments to support conservation may be in

the form of:

- Understaffed technical government departments
- Underfunded technical government departments and inadequate facilita- tion of core activities in soil conservation projects
- Lack of coordination and leadership among relevant institutions
- Unclear mandate of institutions involved in various aspects of soil and water con-servation
- Lack of expertise in technical areas of soil and water conservation
- Weak enforcement of regulations and standards

3.3 Strategies for scaling soil health and water management

Scaling soil health and water management can take different dimensions. For example, there is a scaling dimension involving the replication of successful conservation interventions to similar ecological settings in different geographic extents/boundaries (Ajayi et al.). A second scaling dimension involves an increase in the intensity of activities in a geographic boundary due to innovations or improvements of the existing interventions. In addition, the third scaling dimension involves the incorporation of more stakeholders hierarchically from the local level to communities, national governments, up to the continental or global levels (Ajayi et al.).

Various strategies can be employed to scale soil health and water management depending on the target scaling dimensions (Figure 3.2).

3.3.1 Strategy for increasing scope in a geographic location (deep scaling)

Implementation of soil and water conservation measures may sometimes attract innovations and improvements that give more success and scope. For example, the use of superabsorbent polymers to increase water retention in combination with traditional runoff water harvesting and cover crops is an interesting innovation that may be more effective in soil water management in drylands (Yang et al.). Similarly, combining the push-pull system of mixed cropping with fodder crops (such as Brachiaria, Desmodium, etc.) can expand the scope of soil conservation to include pest and disease control and the provision of animal feeds. Such innovations can scale the scope of soil and water conservation at the plot/farm level, which may be beneficial for soil health improvement.

The strategy for scaling the scope and intensity of soil and water conservation is to develop guidelines to test, validate, and promote innovations using research for development, living labs, show-casing model farms, extension services, agribusiness incubators, etc. (Figure 3.2). Innovative mobile apps, publications (such as farmer-centered periodicals, journals, newsletters, etc.), dedicated promotional websites, shows, conferences, and webinars are examples of programs that can be used to promote the scaling of innovations.

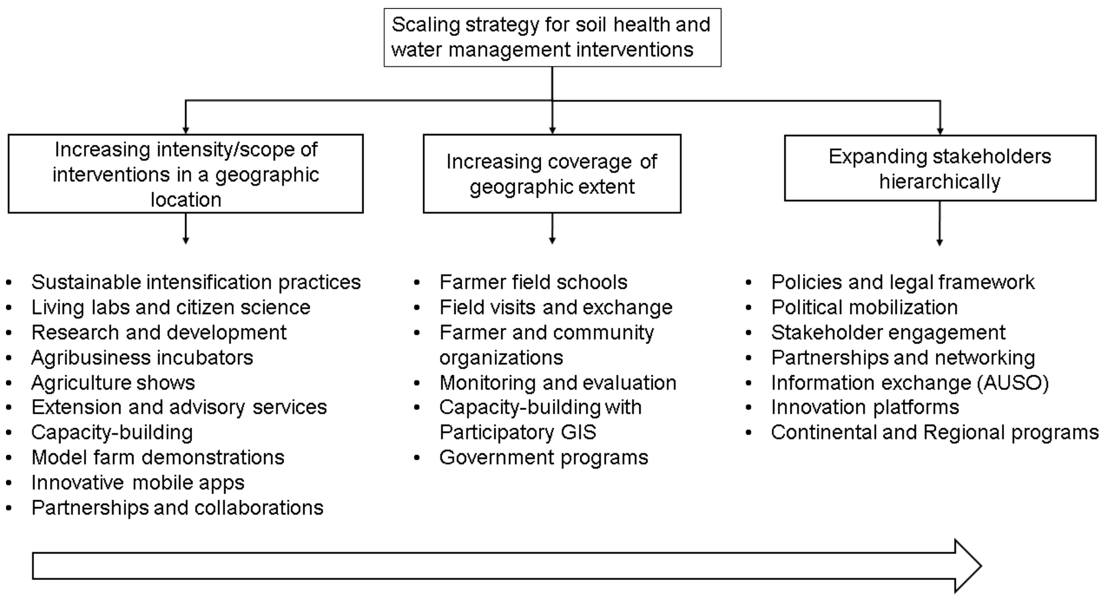

Figure 3.2: Strategy for scaling soil health and water management interventions in Africa

3.3.2 Strategy for covering wider geographic extents (horizontal scaling)

Expanding the areas under successful soil and water conservation measures is the antidote for widespread soil degradation in Africa, estimated to affect more than 65% of the continent. Scaling into wider geographic extents will ensure that many African areas will eventually be covered with successful soil and water conservation measures. Currently, the total coverage of soil and water conservation measures is not clearly known in Africa, particularly in the croplands, grazing lands (grasslands), and forested areas.

The strategy for scaling geographic coverage will target expanding successful soil and water conservation measures for croplands, grazing land (grasslands), and forested areas with similar ecological conditions. The strategy will involve developing scaling toolkits for farmer field schools, field visits and exchange programs, customizable capacity-building curricula that include community participatory GIS, monitoring and evaluation, etc. (Figure 3.2). The strategy should be discussed with relevant national government departments for incorporation into their plans and agenda.

3.3.3 Strategy for hierarchically incorporating more stakeholders (vertical scaling)

Stakeholders are the engine for driving the implementation of soil health and water management interventions. Their involvement can also be scaled accordingly to further catalyze the implementation of conservation interventions. The scaling may entail incorporating higher-level stakeholders such as the national government (for aligning soil conservation and soil health into national development plans and budgetary allocations), regional bodies (such as regional economic blocks (RECs) to foster transboundary conservation efforts), and continental initiatives and programs. Hierarchical scaling also ensures vertical communication and coordination that is necessary for harmonized conservation efforts and equitable enabling environments in different parts of Africa.

Strategies for vertical scaling include increasing the participation of various stakeholders such as local NGOs, government departments, development partners, regional economic blocks (RECs), and continental organizations such as AU, AUC, FARA, etc. (Figure 3.2).

Implementation Framework

4.1 Implementation plan

4.1.1 Scoping and development of implementation support tools

Scoping and development of implementation support tools are envisaged to establish baseline information about the current situation or baseline information. Baseline information is useful in guiding preparation for implementation of soil and water conservation interventions. Baseline information will also support monitoring impacts of soil health interventions.

Scoping will entail review and documentation of existing institutional arrangements, identification of soil health champions, development of baseline soil degradation status, identification of conservation typologies and their success strategies, etc. at the country and local levels. Development of implementation support tools (such as moble Apps, guidelines, templates, etc.) will also be undertaken simultaneously with the scoping exercise. However, the tools should be developed at the continental levels and guidelines or prototypes shared with the countries for further customization. The tools will include standards, design guidelines, mobile apps, soul health monitoring dashboard (and AUSO), etc.

4.1.2 Supporting national soil health strategies

National soil health strategies will be necessary to charter the path for attaining soil health in each country. The national strategies must be aligned with the continental strategies for soil health. Therefore, the draft continental strategy will be first developed and used to guide national strategies in AU member countries. A national coordination team, a coalition of implementers, and national stakeholders are expected to be part of the team for guiding the development of national soil health strategies.

Progress in implementing the national strategies and their impacts on soil health will be monitored using agreed upon and harmonized monitoring indicators. The monitoring outcome will be reflected in the AUSO soil health monitoring dashboard.

4.1.3 Incorporating scaling strategies (deep, horizontal and vertical scaling)

The implementation plan will need to incorporate the scaling strategies in Section 3.3. Scaling will be the omnibus for popularizing soul conservation efforts in Africa. Deep scaling (for increasing intensity and scope of conservation efforts), horizontal scaling (expanding the geographic coverage) and vertical scaling (for enhancing stakeholder involvement and enabling environment) are expected to address soil degradation at all levels in Africa.

Scaling toolkits are envisaged to help implement scaling strategies at various levels. The toolkits are expected to be first developed at the continental level, then shared, and thereafter appropriately customized at the regional, national, and local levels.

4.2 Implementation framework

4.2.1 Conceptual framework

Phased implementation is anticipated where the initial preparation will be undertaken in Phase 1 to establish the necessary background information as the foundation for sizing the implementation requirements and for future monitoring. Phase 1 will entail commissioning of scoping studies described in Section Scoping and development of implementation support tools. Data emanating from the Phase 1 scoping study is expected to contribute to the Africa Soil Data Center (ASDAC) (Figure 4.1).

Phase 2 of the Implementation Framework will develop implementation tools to guide and harmonize the implementation of soil health and conservation efforts throughout the continent. The tools will include survey tools for data collection, software and mobile apps (for e-extension, for tracking degradation status, for designing conservation measures, etc.), contribution to the development of AUSO and Africa soil health and soil water monitoring dashboard, guidelines and standards for management and reporting soil conservation, etc. The tools will be co-developed at the continental level to facilitate uniform and the harmonized application at scale. The tools will form the toolkit for the implementation of soil health and water management in Africa.

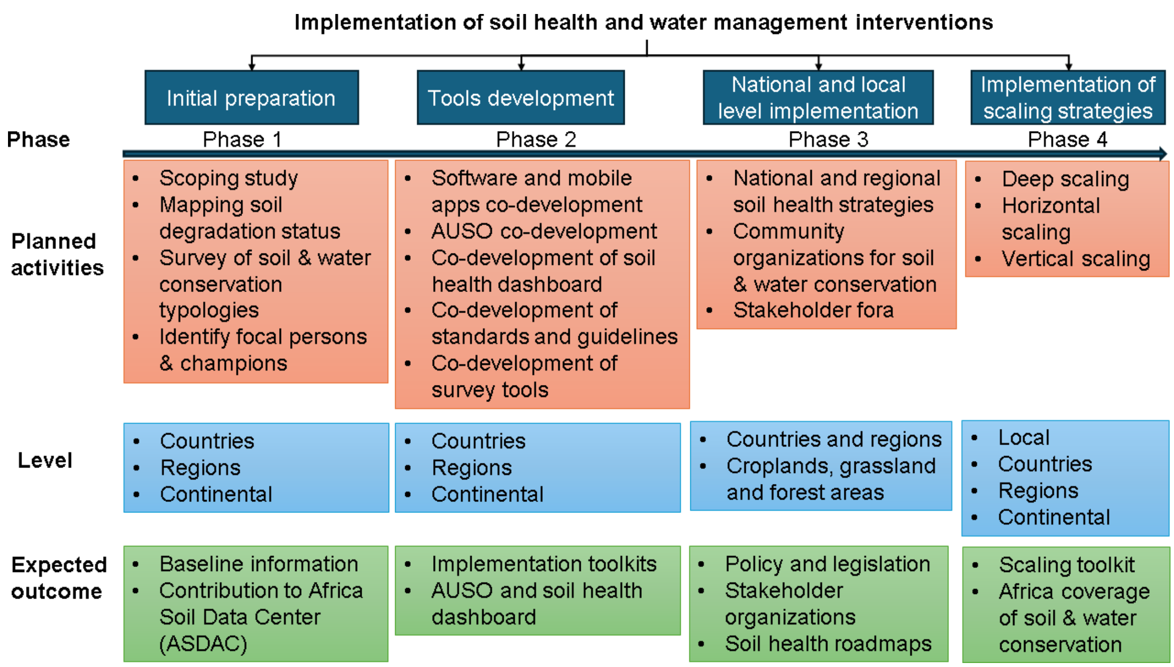

Figure 4.1: Implementation Framework

Phase 3 will target the implementation of national strategies for soil health and soil water to reverse soil degradation, and support increased sustainable soil management in Africa. These strategies will address institutional and political challenges, capacity building, incentives for sustainable practices, promotion of scaling of successful soil conservation measures, solutions for marginalized groups, land tenure issues, and the delivery of effective advisory services. The strategies will also include roadmaps to highlight trends in soil health in response to policy instruments. The roadmaps will include how soil health and soil water indicators will respond to the policy and regulatory frameworks, investments, subsidies, land use, and land management recommendations. Phase 3 is expected to deliver improved policies and legislation supporting soil health and water management at the country and regional levels, a register of stakeholders for soil conservation at the country level, and a clear roadmap for mainstreaming soil health and water management in all countries and regions in Africa.

Phase 4 will implement the scaling strategies in Section Strategies for scaling soil health and water management. It is expected that Phase 4 will produce a scaling toolkit and coverage of the extent of soil conservation and water management in Africa.

4.2.2 Indicator monitoring

The progress of the implementation of soil health and water management will need periodic monitoring, which will trigger actions to ensure that the implementation remains on track. Although the monitoring will follow the procedures outlined in the AFSH Action Plan and the CAADP evaluation systems, a clear indicator set will be necessary to guide the soil conservation results framework. Table 4.1 proposes a potential indicator set which can be customized for monitoring the progress of implementation of soil conservation and soil health and water management activities.

Table 4.1: Developing indicators for monitoring implementation of soil health and water management

Main Activity	Milestone	Monitoring Indicator	Target Level
Strategies for improving soil health and water management	National soil health and water management policy and legislation	Soil health policy and act of parliament	Countries and regions
	Annual budgetary allocation for soil health and water management activities	% budgetary allocation for soil health and water management activities	
	Adoption of soil and water conservation in croplands, grasslands, and forest areas	% area covered with different types of soil and water conservation measures	
	Reduced threats to soil health in Africa	% area coverage for soil degradation	

Soil health and water management implementation toolkit	AUSO and soil health dashboard	Searchable AUSO website	Africa
	Toolkit for implementation of soil and water conservation in Africa	Customizable toolkit for soil health and water management	
	Database of soil and water conservation typologies	Online database of soil and water conservation measures and stakeholders involved	Countries
	Database of stakeholders in soil health and water management	Online database of soil and water conservation measures and stakeholders involved	

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Chapter 9

Fertilizer Production, Marketing and Use In Africa

Contents

Introduction

Fertilizers are any organic of inorganic materials added to soils and/or other plant growing mediums to supply nutrients which are essentail and beneficial for plant growth and development, and/or contribute to desired attributes of a plant or its harvested products. These materails can be either naturally exisiting or sythetic in nature. The use of fertilizers can be traced back to ancient civilizations, with Egyptians, Romans, Babylonians, and early Germans recorded as using minerals and manure to boost agricultural productivity. These early farmers recognized the value of organic materials in enriching their soils and commonly used wood ash and fish as ancient forms of fertilizer as early as 1620. However, fertilizers became more prominent in main stream agriculture since early 20th century when synthetic fertilizer production technologies were developed starting from the invention of the Haber-Bosch process of manufaturing Nitrogen fertilizers from atmospheric Nitrogen by german chemists Fritz Haber and Carl Bosch. Fertilisers are indeed essential to feeding the growing global population and is estimated to now accout for feeding at about 50% of the global population. Over the last century, fertilizer use have been on the increase globally and have helped many countries of the world to produce food at levels that reach and surpass their food need. According to IFA, the current global average fertilizer use is 136kg/ha of nutrients. Unfortunately, Africa's use of fertilizer has been amongst the world's lowest levels, currently estimated at 17kg/ha of nutrients, a key factor responsible for the continents low agricultural production. The consequences of this situation includes persistent food and nutrition insecurity, high food import bill (estimated at $64.5 billion annually), and widespread poverty amongst it population of which 0ver 80% derives their livelihood from agriculture.

In recognition of the importance of fertilizer for agricultural production to meet Africa's food security needs and to reverse the degradation of the continent's soils, African leaders have been making efforts to ensure inproved access of farmers to appropriate fertilizers and affordable cost. As a commitment in this direction, the African Union and the heads of government of the countries held the first Africa Fertilizer summit in Abuja in 2006 during which the commitment was made to drive towards increasing fertilizer use from the then less that 8kg/ha to 50kg/ha of nutrients by 2015. As of 2024, available data shows that although the continent have made some progress, it was still far short of the objective, due to several factors. Over the same period, the challenge have become exhesabated by increasing climate chage issues and its associated soil degradation, such that it is now estimated that over 40% of Africa's soils are degraded. To take stock of the progress, assess the current challenges and set new direction for the fertilizer and soil health agenda of the continent, the African Union and the heads of governments converged at the Nairobi summit in May 2024 from which a new set of ojectives were set. Key amonge those objectives included tripling the production of organic and mineral fertilizers, doubling the supply of appropriate fertilizers to smallholder farmers and ensuring that at least 70% of smallholder farmers on the continent have access to crop and location specific fertilizer recommendations and extension services. This chapter of the companion document outlines the framework for achieving these objectives.

Where are we?
Status of fertilizer production, marketing and use in Africa

2.1 Status of fertilizer production in Africa

Fertilizers are any organic of inorganic materials added to soils and/or other plant growing mediums to supply nutrients which are essentail and beneficial for plant growth and development, and/or contribute to desired attributes of a plant or its harvested products. These materails can be either naturally exisiting or sythetic in nature. The use of fertilizers can be traced back to ancient civilizations, with Egyptians, Romans, Babylonians, and early Germans recorded as using minerals and manure to boost agricultural productivity. These early farmers recognized the value of organic materials in enriching their soils and commonly used wood ash and fish as ancient forms of fertilizer as early as 1620. However, fertilizers became more prominent in main stream agriculture since early 20th century when synthetic fertilizer production technologies were developed starting from the invention of the Haber-Bosch process of manufaturing Nitrogen fertilizers from atmospheric Nitrogen by german chemists Fritz Haber and Carl Bosch. Fertilisers are indeed essential to feeding the growing global population and is estimated to now accout for feeding at about 50% of the global population.

2.1.1 Availability of natural resources for fertilizer production

Africa is endowed with vast geological resources essential for fertilizer production, yet these remain significantly underutilized. The continent holds some of the world's largest deposits of phosphate rock, potash, and natural gas—key inputs for manufacturing fertilizers such as phosphate-based compounds, potassium chloride, and urea. Despite this wealth, limited investment, infrastructure gaps, and geopolitical challenges hinder full exploitation.

Phosphate Rock: Africa dominates global phosphate rock reserves, holding approximately 60% (50 billion metric tons) of the world's total deposits (USGS, 2023). These reserves are primarily concentrated in North Africa, with Morocco controlling 75% of Africa's reserves, Tunisia 12%, and Algeria 8%.

Potash, a vital source of potassium for fertilizers, is found in significant quantities in: Ethiopia's Danakil Depression (2.5 billion metric tons) and Congo's Mengo Basin (1.2 billion metric tons) (EITI, 2023). Despite these reserves, Africa contributes minimally to global potash production, ranking 5th worldwide due to underdeveloped extraction infrastructure.

Natural gas is crucial for urea production, a nitrogen-based fertilizer. Africa's major reserves include Nigeria (206 trillion cubic feet—TCF) and Algeria (159 TCF) (OPEC, 2023).

However, only 25% of domestic demand is met due to export-oriented policies and insufficient local processing capacity.

Table 1 Strategic Mineral reserves for fertilizer production

Resource	Reserves (MT)	Primary African Holders	Global Ranking
Phosphate Rock	50,000	Morocco, Tunisia, Algeria	1st
Potash	2,500	Ethiopia, Congo	5th
Limestone	120,000	Egypt, South Africa	3rd

Despite abundant reserves, several challenges impede optimal exploitation:

- **Underinvestment in Exploration:** Only **40%** of Africa's potential reserves have been mapped (World Bank, 2022).
- **Geopolitical Barriers:** Political instability, regulatory hurdles, and lack of infrastructure deter investment.
- **Export-Oriented Extraction:** Most raw materials are exported unprocessed, depriving local fertilizer industries of affordable inputs.

2.1.2 Existing fertilizer production facilities in Africa

2.1.2.1 Mineral fertilizer manufacturing the Africa

Africa currently hosts **32 large-scale mineral fertilizer plants** producing nitrogen-based and phosphate-based fertilizers, though significant production inefficiencies persist. The sector is dominated by a few key countries with access to essential raw materials, while others remain dependent on imports.

Nitrogen-Based Fertilizer Production

Nitrogen fertilizers, primarily **urea**, are manufactured using natural gas as a feedstock. Africa's production is concentrated in:

- **Nigeria** – With an installed capacity of **6.5 million metric tons (MT) per year**, Nigeria is the continent's largest urea producer. However, output fluctuates due to unreliable gas supply and infrastructure constraints.
- **Egypt** – The second-largest producer, with an annual capacity of **2.5 million MT**, benefits from stable natural gas availability and established export markets.

Phosphate-Based Fertilizer Production

Phosphate rock processing into fertilizers such as **DAP (Diammonium Phosphate)** and **TSP (Triple Superphosphate)** is concentrated in North Africa:

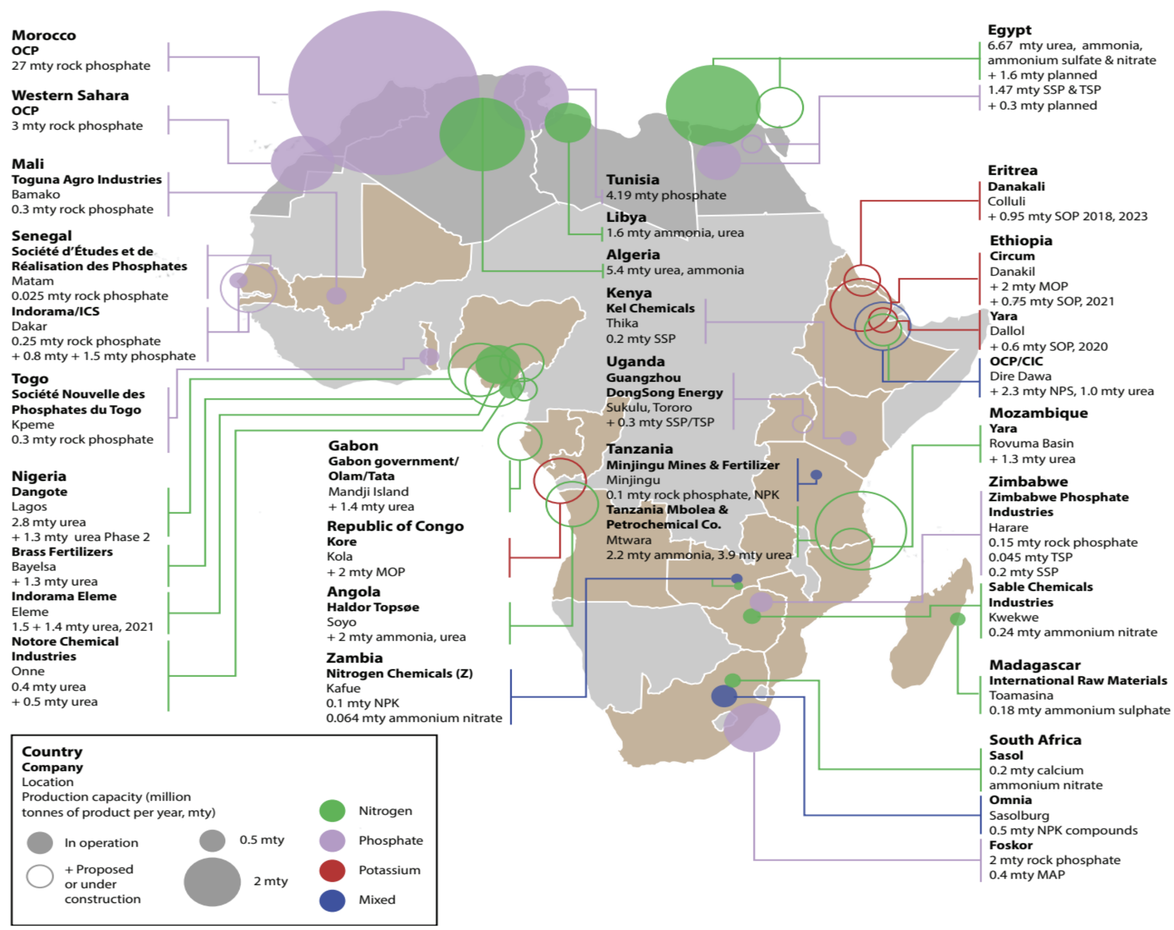
- **Morocco** – Dominates with an annual production capacity of **15 million MT**, leveraging its vast phosphate reserves.
- **Tunisia** – Produces **1 million MT/year**, primarily for export due to limited domestic

demand.

Despite existing infrastructure, the sector operates at only **65% average capacity utilization** due to:

- **Energy supply instability**, particularly gas shortages in Nigeria and electricity disruptions.
- **Maintenance deficiencies**, leading to frequent plant shutdowns.
- **Logistical bottlenecks**, including poor transport networks for raw material distribution.

Figure 1: Map of Fertilizer Manufacturing Facilities in Africa



Sources: Chilande, G. IFDC (2018), Harrison (2017, 2018), CRU (2017), AFO (2018), Heffer and Prud'homme (2018), news reports and company websites

Table 2: Fertilizer Manufacturing Capacity by sub-regions of Africa (2023)

Sub-Region	Nitrogen (MT)	Phosphate (MT)	Blending Units
North Africa	8.2M	16.5M	45
West Africa	4.1M	0.3M	38
East Africa	0.5M	-	22

2.1.2.2 Mineral fertilizer blending in Africa

With a total installed capacity of XXX MT per annum, Africa's 124 fertilizer blending facilities play a crucial role in producing customized nutrient formulations, yet face significant operational challenges.

The sector suffers from chronic underutilization, with 60% of plants operating below 50% capacity due to heavy reliance on imported raw materials. West Africa, despite hosting the highest concentration of blending units (38 facilities), experiences particularly severe supply chain disruptions.

Quality control remains a persistent issue, with 45% of West African facilities reporting deviations exceeding 10% in final products. This stems from multiple factors:

- Variable quality of imported raw materials
- Inadequate testing infrastructure (only 30% of plants have full-spectrum testing capabilities)
- Lack of harmonized quality standards across regions
- Technical capacity gaps in formulation and mixing

The market faces additional challenges including product degradation from poor packaging/storage (affecting 20-30% of products), counterfeit fertilizers, and limited farmer knowledge about proper application methods.

Opportunities for improvement include:

1. Developing regional raw material sources through AfCFTA
2. Implementing continent-wide quality standards
3. Adopting modern blending technologies
4. Strengthening farmer education programs

2.1.2.3 Organic fertilizer production in Africa

Africa's organic fertilizer sector remains predominantly informal, characterized by small-scale production units with limited commercialization. Despite growing interest in sustainable agricultural practices, organic fertilizers constitute less than 5% of total fertilizer use across the continent (FAO, 2023). This marginal contribution reflects both structural challenges in production and persistent barriers to market penetration.

The **compost production segment** represents the most widespread form of organic fertilizer manufacturing, with over 5,000 small-scale units operating across various countries. These decentralized operations typically utilize locally available agricultural waste, livestock manure, and other organic residues. However, their collective output remains modest at less than 1 million metric tons annually, constrained by several factors including limited processing technology, inconsistent quality standards, and seasonal variability of raw materials.

More formalized production occurs in the **biosolids sector**, where several countries have established systematic processing of organic waste into commercial fertilizers. Kenya has emerged as a regional leader with an annual production capacity of approximately 10,000 metric tons of processed organic fertilizers derived from municipal and agricultural waste streams. Similar initiatives in other countries demonstrate varying degrees of success, with production capacities ranging from several hundred to a few thousand metric tons annually.

The **commercialization** of organic fertilizers faces multiple obstacles. Most significantly, the nutrient density of organic products remains substantially lower than mineral alternatives, requiring larger application volumes to achieve comparable agronomic effects. This characteristic, combined with higher transportation costs per nutrient unit, makes organic fertilizers less economically attractive for many farmers. Additionally, the sector suffers from inconsistent quality control measures, with significant variation in nutrient content between production batches and across different manufacturers.

2.1.2.4 Organomineral fertilizers

Organomineral fertilizers represent an innovative hybrid approach that combines organic matter with mineral nutrients, potentially offering the benefits of both fertilizer types. This emerging sector shows particular promise in addressing soil health concerns while maintaining adequate nutrient supply for crops. Several African countries have begun pilot production programs, with annual outputs currently ranging from a few thousand to several tens of thousands of metric tons.

The development of this sector faces two primary constraints: **economic competitiveness and regulatory frameworks**. Price differential presents a substantial barrier to widespread farmer adoption, particularly among smallholder operations with limited capital. Regulatory challenges further complicate market development as many national agricultural input frameworks lack clear classification and quality standards for organomineral products, creating uncertainty for both producers and consumers. This ambiguity extends to certification processes, where existing systems designed for either organic or mineral fertilizers often prove inadequate for hybrid products.

Technical barriers also influence adoption rates. The optimal application methods for organomineral fertilizers often differ from conventional products, requiring extension services to educate farmers about proper usage. Additionally, storage and handling requirements may vary from traditional fertilizers, necessitating adjustments in distribution logistics.

Despite these challenges, the organomineral sector continues to attract interest from agricultural researchers and policymakers. Its potential to improve soil organic matter content while providing readily available nutrients aligns with both productivity and sustainability goals. Several research institutions across the continent are actively working to optimize production processes and reduce costs, while some governments have begun considering policy adjustments to better accommodate these innovative products.

2.1.2.5 Fertilizer imports into Africa

Africa's agricultural sector remains heavily dependent on imported fertilizers, with the continent sourcing approximately 80% of its needs from global markets. This import dependency creates significant economic vulnerabilities and limits the potential for agricultural self-sufficiency. Annual fertilizer import costs now exceed $10 billion (World Bank, 2023), representing a substantial drain on foreign exchange reserves for many African nations.

The import portfolio shows marked regional variations in both quantity and composition. Non-phosphate fertilizers, particularly urea and potash, dominate import volumes, accounting for 90% of total fertilizer imports. This reflects the continent's relative self-sufficiency in phosphate fertilizers due to abundant domestic reserves, while nitrogen and potassium-based products must be sourced externally.

The 2022 global fertilizer crisis exposed Africa's import vulnerability, with prices spiking by 300% in landlocked countries (WFP, 2023). Transportation bottlenecks and currency fluctuations exacerbated the situation, particularly for nations without direct port access. These disruptions had immediate impacts on agricultural productivity, with many smallholder farmers unable to afford essential inputs.

Table 3: Africa's Fertilizer Imports By Sub-Region (2010-2024 in Million Metric Tons)

Region	2010	2015	2020	2024 (est.)	Primary Import Types	Key Suppliers
West Africa	1.2	1.8	2.4	3.1	Urea (65%), NPK blends (25%)	Russia, Morocco, China
East Africa	0.8	1.1	1.5	2.0	Urea (60%), DAP (20%)	Saudi Arabia, Egypt, UAE
North Africa	0.9	1.0	1.2	1.4	Potash (50%), Specialty fertilizers	Canada, Belarus, Jordan
Southern Africa	1.5	1.7	2.0	2.3	Urea (40%), Potash (30%)	China, Russia, Middle East
Central Africa	0.3	0.4	0.6	0.8	Complete blends (70%)	Europe, Morocco

Key observations from the import data:

1. **West Africa** has shown the fastest growth in imports (+158% since 2010), reflecting agricultural intensification

2. **Southern Africa** maintains the highest absolute import volumes due to large-scale commercial farming
3. **Central Africa** remains the smallest importer due to limited arable land and infrastructure constraints
4. **All regions** show steady increases in import volumes, with projected 2024 levels 40-60% above 2010 baselines

The import dependency creates multiple systemic risks:

- **Currency fluctuations** can dramatically affect affordability
- **Global supply shocks** (e.g., Ukraine war, COVID disruptions) have disproportionate impacts
- **Logistical challenges** increase costs, particularly for landlocked nations
- **Quality control issues** arise from inconsistent import standards

Efforts to reduce import dependency through local production have achieved limited success. While some regional initiatives have emerged, particularly in nitrogen fertilizer production, most countries remain price-takers in global markets. The situation underscores the urgent need for coordinated continental strategies to develop domestic fertilizer production capacity while improving import efficiency through regional trade agreements and infrastructure development.

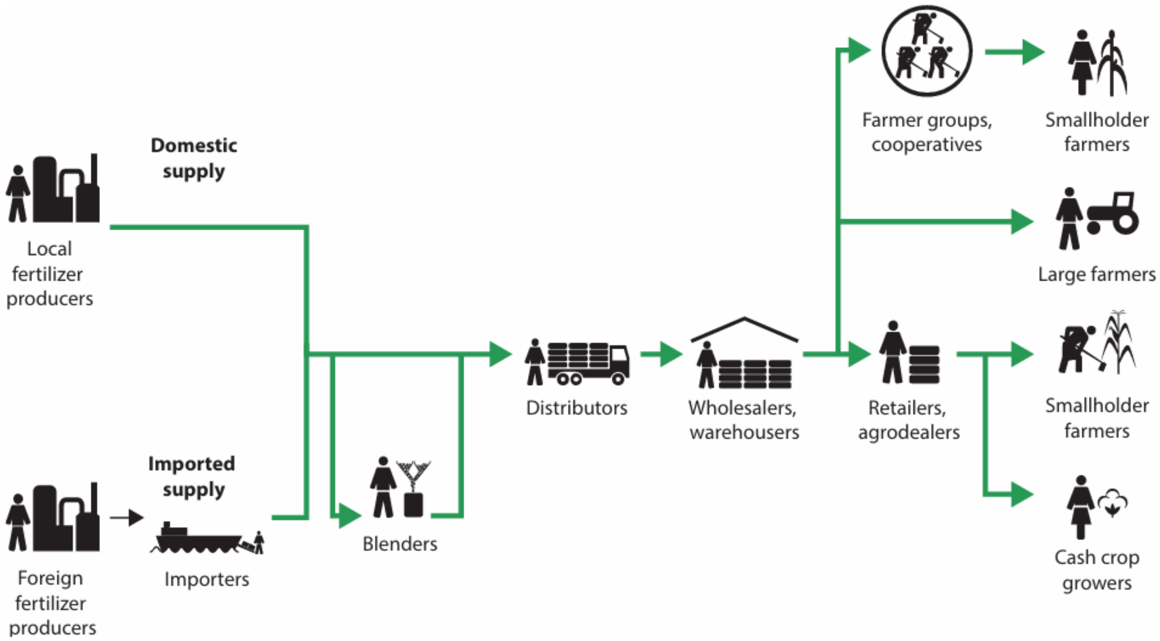
2.2 Distribution structures in Africa

Fertilizer distribution systems includes a number of organizations who play different roles in the process of moving fertilizers from the local production or import points to reach farmers who use them on the field. These distribution systems vary from country to country and from time to time but can generally be classified into three (AGRA, 2019) as follows:

- Private systems that seek to serve individual farmers,
- Government bulk-procurement systems that deliver fertilizers to known farmers or farmer groups,
- Private bulk-procurement through "anchor" crop buyers and plantations (IFDC and AFAP 2018)

Private sector distribution: In this system, as the names implies, the flow of fertilizer from the production to the the farmers is handled entirely by private sector operators including major distributors, retailers, whoelesalers, warehouses and other service providers each of which seek to make some profit in return for the services they offer. Figure xxxx illustrates this distribution model.

Figure 2: Illustration of Private Sector Distribution Network

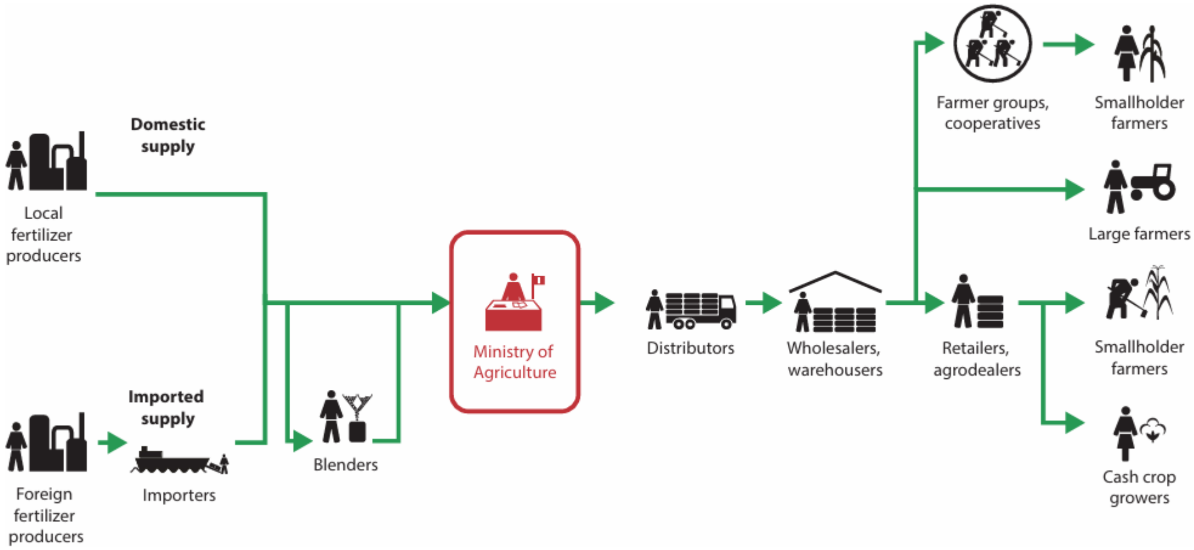


In this system, fertilizers are first sold by producers and importers to distributros who often buy in large quatities. These distributors in-turn sell in smaller quantities to whoelesalers and/or retailers who sell in farm less unit quanties to end users. These end users can buy either as individual smallholder farmers, a group of farmers (in formal or informal cooperatives) or as large farmers. The number of actors involved in moving the product from the beginning of the chain to the consumer at the last mile tends to increase with the distance between the production/import point and the farming community, especailly when the farmers are localted in rural communities, thus leading to usually higher prices of the fertilizers at the end user point.

Business relationships between the actors often develop slowly and get stronger with time. In locations where these channels have operated without significant intefarence for a long time, the actors tend to have build strong relationships and trust over time. These trusts then allow for some form of credit arrangement between the actors that reduces the working capital requirement of many actors (especailly wholesallers and retailers). A common example is the case in which wholesaler gives trade credit to retailers by providing them fertilizers and allowing the retailer to pay for a consignment after the retailer has sold it and received the cash from the farmers.

Government distribution: This method is common in many countries where the government is involved as a direct actor in the fertilizer supply channel, mostly through direct procurement of the fertilizer and subsequently controlling the process of its delivery to end users. This model is often established with the objective of enabling farmers to access fertilizers at affordable costs (either as an economic empowerment initiative or as a political incentive), hense it is believed that the direct government involvement of government cuts out many of the private actors and their profit interests, leading to lower prices for farmers. Figure xxxxx shows the arrangement of actors and the flow of fertilizers in this method.

Figure 3: Illustration of Government Distribution Systems (AGRA, 2018)



In this system, the government (mostly represented my the ministry of agriculture, or other special agencies of government) plays the role of the main buyer from the producers or supplier (through imports). The government then manages the distribution of the fertilizers to farmers either thorugh their own established structures or through selected retailers/agrodealers often applying some subsidies to the product and determining the price at which the product is sold to the end user. The most common practice is for these systems to supply generic fertilizer products to a large number of farmers, however, there have been instances when the sysytems were used to deliver target fertilizers for particupar farmers (based on region, crop, economic situation, or involvement in certain initiatives). In more recent times, efforts are bieng made by some governments to improve the efficiecy of such distribution systems by better targeting farmers, e.g. through subsidy vouchers programs.

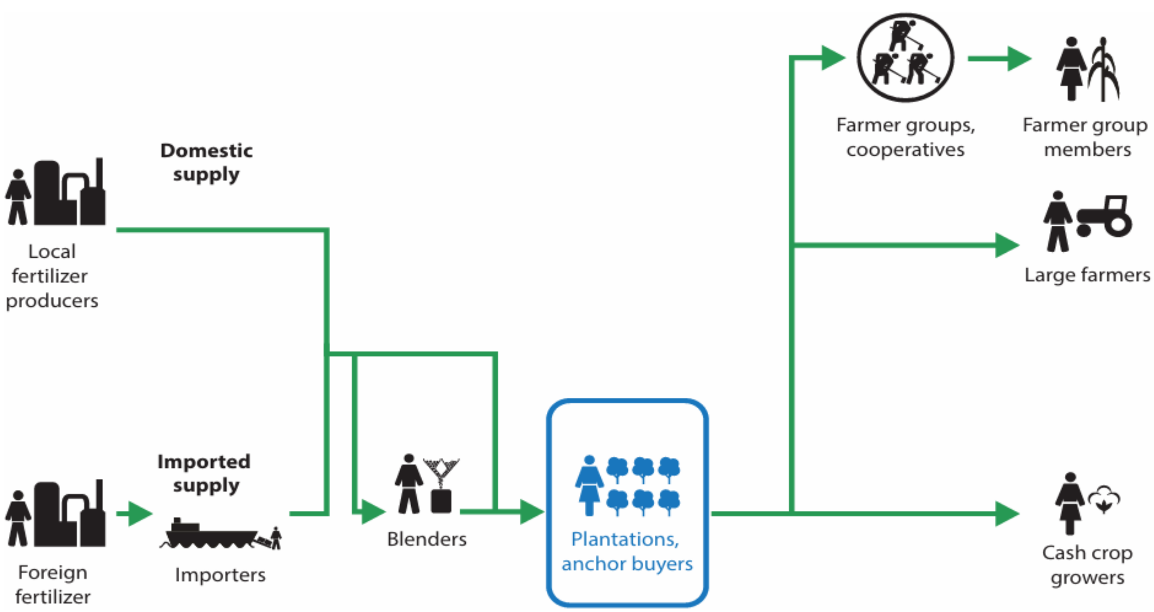
In countries where this system in practiced, it forms a major element of the government's agricultural interventions and the subsidy element being a significant spend item of government budgets. For instance, Jayne and Rashid (2013) reported that ten African governments spent roughly $1 billion annually on input-subsidy programs, amounting to 28.6% of their public expenditures on agriculture. Similarly, in Nigeria, "between 1990 and 1996, the fertilizer subsidy cost as a percentage of the national budget ranged from 16.8% in 1991 to a high of 42.7% in 1992" (Nagy and Edun 2002).

The effectiveness and efficiency of of the government distribution system for subsidized fertilizers have been a major concern stemming from a number of unintended challenges often identifed with the system. The includes: i) corruption -officials sell subsidized fertilizers at market prices to create personal profits for themselves, ii) leakages - farmers divert the fertilizers to crops other than those for which the fertilizer is intended, or sell them to someone else often to get quick cash, and/or iii) Smuggling –movement of cheap subsidized fertilizers across the border to where they can fetch a higher price thereby depriving the target programs of the products, is a problem in some locations.

Private bulk procurement: This is the system commonly used by plantation crop produccers or crop processing companies (generally refered to as Anchors) that also work with a network of farmers. Under this system, the bulk buyer from the producers, improter or blender is the 'Anchor' plantation firm which procures fertilizers for use on their farms and for distribution to farmers included in their network of producersor outgrowers. The rational of the anchor in engaging in this system includes ensuring that fertilizers are available for their production at the apporprite time, strengthening their relationship with their selected farmers (outgrowers) by supplying them fertilizers (and other inputs), ensuring the quality of the fertilizers used by their outgrowers (thereby enabling good farm outputs) and ringfensing their operations from the impact of any fertilizer supply challenges that may prevail in the open market.

This system often engages organised farmer groups and provides them the opportunity to get cheaper fertilizer prices either by shortening the supply chain (thereby removing the margins for the retailer layers) and/or by negotiating bulk discounts (since they are buying an aggregated volume as a group), hence improving the chance of prifitable production. The organized farmer groups engaged in such systems also generally have greater access to and adoption of improved production practices leading to production of higher-quality products which attracts higher output prices. This cycle of a self-funding production system makes farmers involved in this systems more attractive to bank finance or trade credit facilities.

Figure 4: Illustration of Private Bulk Procurement Distribution System (AGRA, 2018)



The private bulk procurement systems are often well controlled with very minimal interfarence with private distribution channels. Rather, the tend to complement them by reaching select set of farmers with improved access and services. These channels often handle smaller and more predictable fertilizer volumes, are often not big enough to create distortion for the private distribution channel.

These systems often offer some for of production credit to farmers, especially when they are in organized groups. These credits come either directly from the anchors or by linking them to finacial institution since their relationship with the anchor is ofter backed with a contract under which their farm output can be treated as collateral for the credit they intend to receive. The anchors ofter serve as quarantors for financial institutions credit to these farmers.

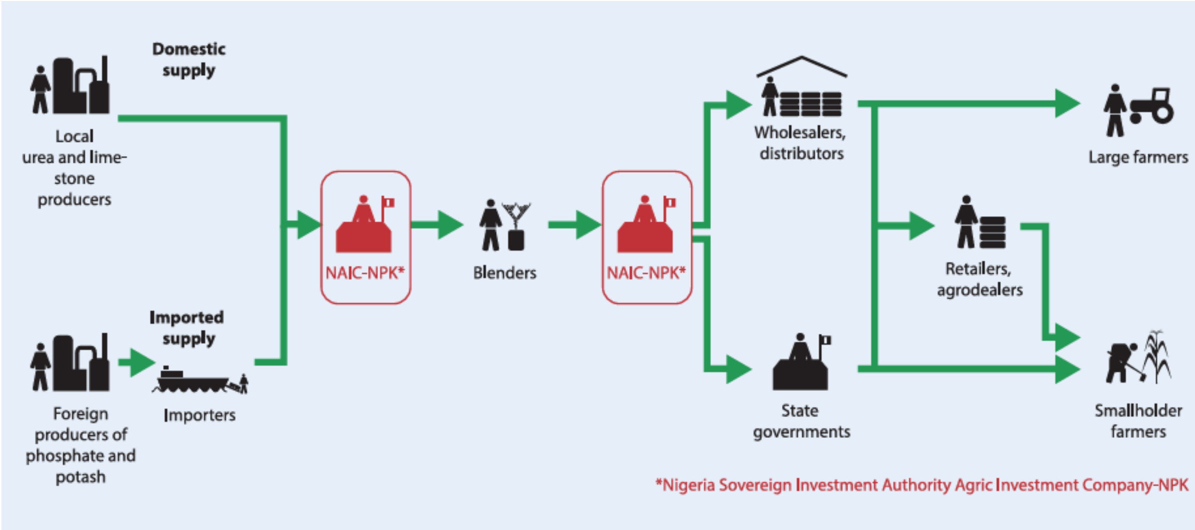
In countries where the crops produced by these anchors nad their networks are considered strategic by the government, the government often gets involved in supporting the supply of inputs either by directly managing the fertilizer tender sysytem, by providing some subsidies to farmers involved in the program and/or by increasing the number of farmers involved in the anchor managed program. Examples of this inlcude cotton in Mali and Burkina Faso. In cases when governments get involved, the systems tends to lose its efficiency and become more currupt than without government.

Hybrid Systems: Although the above three systems are most common, there are a few cases where a hybrid between two of the three systems have be deployed with the specific objectives. A prominent example is the Presidential fertilizer initiative (PFI) introduced in Nigeria in November 2016. This system is a hybrid version between the private distribution and the government distribution system in which government intervened in particular points of the distribution run by private sector with the aim of achieving the following objectives:

1. Get better prices of fertilizer imports through aggregation of needs of private actor through a single vehicle
2. Improve the capacity utilization of local fertilizer blending facilities in the country by banning the imortt of finished(complex) fertilizer products
3. Improving access of farmers to crop and region specific fertilizers
4. Reduce the budgetary expense of government on fertilizer programs, especially subsidies

The PFI was establshed by the government by creating a special purpose vehicle (NAIC-NPK) who took responsibility for procurement of all fertilizer blending raw materials (locally produced Urea, improted DAP, Imported MOP and locally produced limestone fillers). The procured raw materials were supplied to blenders who upon blending the recommended composition sold the products to NAIC-NPK identified customers (state governments, retailers and/or intervention programs). Figure xxx illustrates the flow of the PFI at its inception and early stages in 2016-2020.

Figure 5: Illustration of the Nigeria Presidential Fertilizer Initiative System (AGRA, 2018)



Following a number of annual reviews by its stakeholders, the program have seem a number of modifications over the years and has become less government controlled and more driven the the Fertilizer Producers and Suppliers Association of Nigeria (FEPSAN) with greater private sector participation. Some of these modifications include:

1. NAIC-NPK dropped the function of selling the products produced by blenders allowing them to determine their customers, identify what quantities of raw materials they needed, what prices they sell and how to serve their customers.
2. NAIC-NPK stoped funding the operations but requiring each blender to provide financial instrument for the volume of raw materials it requires.
3. NAIC-NPK focused mainly on procurement from suppliers and distribution to blenders.

Since its inception in 2016, the PFI have rrsulted in some positive outcomes including i) Increased investment in fertilizer blending in the country thereby improving possibility of supplying crop and soil specific fertilizer blends to farmers (from less than 10 blending plants in 2017 to over 80 blending plants in 2023), ii) significant discounts on imported raw materials for blending as a result of aggregated procurement, and iii) increased fertilizer use by farmers. Despite the above benefits, the challenges inlcudes i)restriction of direct imports by market actors constrain supply, ii) suppliers of raw materials are limited to a few firms, thus looking like some sort of cartel which limits competition, and iii) overdependence on government involvement which can impeed fertilizer supply during the pesk demand period.

2.3 Fertilizer use levels across Africa

Despite the critical role of fertilizers in boosting agricultural productivity, nutrient application rates in Africa remain alarmingly low compared to global averages. According to the Food and Agriculture Organization (FAO, 2023), the continent's average fertilizer use stands at just 18 kilograms per hectare (kg/ha), a stark contrast to the global average of 135 kg/ha. This deficit severely limits crop yields and perpetuates food insecurity across the region.

The distribution of fertilizer use is highly uneven, reflecting broader agricultural inequalities. South Africa, with its more developed commercial farming sector, applies an average of 60 kg/ha, whereas Central Africa lags far behind at a mere 3 kg/ha (FAO, 2023). This disparity highlights the uneven access to agricultural inputs, with smallholder farmers—who dominate Central and West African agriculture—facing financial and logistical barriers to fertilizer adoption.

Fertilizer allocation is heavily skewed toward certain crops. Cereals (maize, wheat, and rice) receive about 70% of total fertilizer inputs, driven by government subsidy programs and market demand. In contrast, legumes—which are crucial for soil nitrogen fixation and dietary protein—receive less than 10% of fertilizer applications (Jayne & Sanchez, 2021). This imbalance undermines the potential for diversified, sustainable farming systems.

Low Nutrient Efficiency: compounding the problem of low fertilizer use is the widespread degradation of African soils. An estimated 65% of croplands suffer from nutrient depletion, erosion, or organic matter loss (Vanlauwe et al., 2023). Soil acidification further restricts productivity, affecting 30% of Africa's arable land (IPNI, 2022). Acidic soils (pH <5.5) reduce phosphorus availability by up to 40%. As a result, Nutrient Use Efficiency (NUE)—the proportion of applied fertilizers actually absorbed by crops—is drastically reduced. For example, NUE for maize in Africa is just 25%, half the global average of 50%.

A Dual Challenge of Access and Efficiency : Africa's low fertilizer use, combined with poor soil health, creates a vicious cycle of low productivity and persistent poverty among smallholder farmers. Addressing this requires not only increasing fertilizer accessibility (through subsidies, infrastructure, and credit systems) but also improving soil management (via integrated approaches like organic amendments, balanced fertilization (4Rs), precision fertilizer blends, and pH correction).

Why are we where we are?
Factors influencing fertilizer production, distribution and use in Africa

The current state of fertilizer production, distribution and use in Africa as described in the previous section have been influenced by a number of factors, ranging from policies and their attractiveness for investors, state of infrastructure, subsidies and how they are implemented, acess to investment and trading funds, state of the markets for farm outputs, knowledge of and adoption of good agricultural practicies across the value chains, quality assurance issues and access to soil information amongst other things. This section explains how each of these factors have influenced the state of fertilizer industry on the continient over the past three decades.

3.1 The prevailing government policies in Africa

The importance of fertilizers in boosting agricultural production on the African continent have been strongly emphasized by a number of continent-wide policy instruments over the past two decades. These instruments includes the following:

1. The Comprehensive Africa Agriculture Development Programme (CAADP), under which African governments committed to doubling agricultural productivity by focusing on the provision of improved inputs.
2. African Fertilizer Summit in Abuja, Nigeria, (2006) and the declaration of fertilizer as a strategic commodity and the resolve that African Union member states should promote the use of fertilizer via targeted subsidies and the call for member states to increase their fertilizer consumption to 50 kilograms per hectare by 2015 from 8 kilograms per hectare in 2006 (AUC 2006).
3. The Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods, which affirmed the need to improve access to quality and affordable modern inputs through the provision of "smart" protection—subsidies that are carefully targeted and managed—to smallholder agriculture (AUC 2014).

While the above policies have been serving as guiding frameworks for fertilizer promotion on the continent, the progress made in their implementation at country levels have been mixed. For instance, the declarations inspired some countries to update or reformulate their fertilizer polices and regulations (for example, Burkina Faso, Ghana, Kenya, Mali, Mozambique, Rwanda, Tanzania, Uganda, and Zambia), but there are still many countries in Africa that do not have a coherent fertilizer policy and, instead, rely on decrees and ad hoc guidelines or statements (resakss.org). As a result of these policy situation and other factors, very limited progress have been made towards achieving the goals of the Abuja declaration. For instance, athough substantial improvements in fertilizer use have been made since the Abuja Declaration, current levels are still very far behind targets, and vary considerably across countries (AUC 2006; Sheahan and Barrett 2017; FAO 2020). Similarly, except in the areas of fertilizer production and trade promotion, reducing the distance traveled to purchase fertilizer, and provision of subsidies for smallholder farmers, progress toward meeting the other Abuja resolutions has been inadequate (AGRA 2019).

Inspired by CAADP, the Abuja and Malabo Declarations, regional economic communities within Africa have developed a number of initiatives focused primarily on the implementation of two specific resolutions contained in the Abuja Declaration: (1) the harmonization of fertilizer polices and regulations and (2) the promotion of national/regional fertilizer production and intraregional trade. Some notable initiatives include the following (AGRA 2019).

1. **ECOWAS:** In 2012, the Economic Community of West African States (ECOWAS) adopted protocols for the harmonization of fertilizer polices and regulations. In 2019, ECOWAS, through the USAID feed the future project support, developed a draft guideline for fertilizer subsidy programs for adoption by its member states.
2. **EAC:** in 2014, the East African Community (EAC) made adopted a harmonized regulatory framework and procedures for fertilizer markets, reviewed existing policies, standards, legislation, and regulations and developed guidelines on how harmonization of fertilizer policies and regulatory frameworks should be undertaken in the region.
3. **COMESA:** In 2014, the Common Market for Eastern and Southern Africa (COMESA) and its agency, the Alliance for Commodity Trade in Eastern and Southern Africa, launched a Joint Program on Fertilizer Policy and Regulatory Harmonization in partnership with the African Fertilizer and Agribusiness Partnership (AFAP) with the objective of harmonizing fertilizer policies and financing mechanisms.
4. **SADC:** in 2010, the Southern African Development Community (SADC) assessed fertilizer production opportunities in the region with support from the International Fertilizer Development Center (IFDC) and recommended regional harmonization of fertilizer standards.

Although all of the above initiatives point to the significant efforts being made at improving fertilizer access and its contribution to food securirty on the continent, there is major shortfall with regard to the implementation of these regional initiatives, and based on the Abuja Declaration scorecard, while their performance is rated as unsatisfactory (AGRA 2019). With the renewed commitment emerging from African fertilizer and soil health summit of Nairobi in May 2024, regional economic communities can and are expected to play a crucial role in advancing new objectives through inducing political commitment among their member states. A good example was already set by ECOWAS who had ralied its member states to develop a raodmap for fertilizer and soil health in its region based on the guidelines of the African Union for the fertilizer and soil health strategy.

3.2 Private sectors friendliness of government policies

In many countries across Africa, government policy environments have had mixed effects on private sector participation. Ranging from inconsistencies in policies that prevents predictability of business climate, hence limit ability of private sector to invest, to outright domination of the supply chain activities (production/importation, distribution and delivery) by public institutions which crowds out private sector actors, unfriendly policy environments are common in many countries. In addition, a long list of other problems that can further impeed private sector participation includes the following (AGRA, 2019):

- Bureaucracy in registering new fertilizer products, and in registering businesses to import, manufacture and distribute fertilizers
- Requirements of export and import licenses for trade with neighboring countries
- Access to finance (and particularly foreign exchange)
- Subsidies that displace commercial sales of fertilizer
- High costs of fertilizer clearance at ports, charges and demurrages
- Poor regulation and quality control that enables the sale of fake and adulterated fertilizers
- Lack of harmonization and domestication of fertilizer quality standards within regional economic communities.
- Fertilizer is sometimes is used as a political tool to gain votes.

3.3 Infrastructure and power

Infrastructure deficits and poor digital integration are critical systemic gaps: only 25% of rural roads are paved (AfDB, 2023), delaying deliveries and raising costs during rainy seasons. Fewer than 5% of supply chains use digital traceability tools (AU, 2023), hindering transparency and efficiency in pricing, quality control, advisory service delivery, and subsidy targeting.

3.4 Government subsidies

As many African countries grapple with the challenge of increasing agricultural productivity to boost incomes and meet growing food demand amidst resource constraints and climate variability, fertilizer subsidies have emerged as a key policy instrument aimed at enhancing smallholder farmers' access to essential inputs (AGRA, 2024). However, the implementation of fertilizer subsidy programs have resulted in a mixture of positives and unintended negatives all of which have implication for fertilizer production, distribution and effective utilization in Africa. For instance, from an assessment that covered subsidy programs in 11 AGRA focal countries, AGRA, 2024 identified reduced fertilizer system efficiency as a major unintended negative impact of subsidy programs. Specifically, the reduced system efficiency manifested as- crowding-out of demand for commercial fertilizer, especially from SME agrodealers as evidenced in 77% and 88% decline in volumes handles by distributors and agrodealers, respectively in Kenya. Also, 33% of fertilizer intended for Fertilizer Subsidy Programs were diverted, leaked, and resold commercially in Malawi (AGRA, 2024).

3.5 Agribusiness financing climate

Although the agricultural sector employs over two-thirds of the African labour force and serves as their main source of income as a significant contributor to GDP, less than 5% of net bank funding in most nations is goes to agriculture (www.safinetwork.org) leaving the sector hugely underfinanced. For instance, the demand for loans by Agricultural Small and Medium Enterprises (Agri-SMEs) in sub-sahara Africa-including fertilizer traders and blenders- is estimated at USD 90 billion of which 83% of are unmet annually. It is estimated that to increase fertilizer consumption by africa from the current 11.7 million tons (www.safinetwork.org) to the Nairobi declaration of doubling local consumption (AUC, 2025) will require over $15 billion in product financing annually. The major factors limiting access to financing include lenders risk perception, high-interest rates, and collateral challenges.

The financing challenge of fertilizer suppliers is further compounded by a common trend of long delays in payment for fertilizer supplies for government programs. For instance, anectodal evidences indicate that delays in payment for fertilizers supplied for governmet subsidy programs in some countries could be as long as 2 years which is often in significant disalignment with the duration of financing available to actors in the agricultural sector.

3.6 Agricultural markets

Agricultural markets in most African countries are mostly underdeveloped with farmers. This is promarily driven by inadequate transportation facilities and other infrastructure limitations. An annual loss of about 2% of the African economic growth has been attributed to inadequate infrastructure. On the other hand, well developed infrastructure could result in up to 40% productivity increases of African firms in general (Ondiege et al., 2013). For agricultural produce particularly, post-harvest loss could reach up to 40% of the crop (Gashu, et al., 2019) resulting from a number of factors including mechanical damage, contamination by spoilage microorganisms, and invasion by birds, rodents, insects and other pests. Changes in weather conditions and poor pre- and post-harvest practices such as inappropriate handling, storage and processing techniques are the most important factors responsible for post-harvest food loss (Abass et al., 2014, World Bank et al. 2011). With these levels of losses often translating to finantial losses for farmers, investment in farm inputs becomes less attractive to farmers.

3.7 Technical Knowledge across the fertilizer value chain

The low use of fertilizer in Africa is also due to Africa's failure to establish a strong and powerful fertilizer value chain to meet the needs of the agriculture sector (AfDB, . A fast-growing population requires large-scale fertilizer production to ensure better productivity).

3.8 Quality assurance

Fertilizer quality issues are aomngst the many challenges limiting the effective use of fertilizers in many countries of Africa, especailly with products imported into the continent. According to IFDC (2019), Some of the quality issues identified include levels of nutrient content inconsistent with the fertilizer grades, short weight in packaging and presence of contaminants beyond tolerable levels in the fertilizer products. These challenges have resulted mainly from the absence of appropriate regulatory control mechanisms, a problem that is now being addressed by many of the national and regional authorities. For instance, the ECOWAS developed and approved its Regulation C/REG.13/12/12, which related to fertilizer quality control in 2012 and four implementing regulations in 2016 to support Regulation C/REG.13/12/12.(IFDC, 2019).

What does it take?
Improving fertilizer production, marketing and efficient use in Africa

4.1 The role of fertilizers in achieving food security and sustainable soil health in Africa

Achieving Africa's food and nutritional security and soil health goals can only be achieved by moving away from an unsustainable food system in which Africa spends $64.5 billion annually on importing food that could be produced by African farmers (AfDB, 2022). To achieve this goal requires that farmers have access to vital agricultural inputs including fertilizer, seeds, irrigation and crop protection products. Several data have shown that the low fertilizer use in Africa is one of the main drivers of food insecurity as well as soil degradation. For instance, according to IFA, 37% of households in sub-Saharan Africa were food insecure in 2016 where fertilizer use is the lowest in the world. Today, average fertilizer consumption in sub-Saharan Africa remains extremely low, estimated at 17kg of nutrients per hectare of cropland compared to a world average of 135kg/ha. Little wonder the 2024 UN report on the state of food security and nutrition in the world reports that Africa now has the highest rate of fodd insecurity with 20.4% of its population (about 298.4 million people) being nudernurished. At the same time, as estimated 40% of Africa's soils are degraded, thus threathening the livelihood of the over 80% of its population who depend on it for their pivelihood (www.thoughtco.com).

To both increase productivity as well as restore degraded soils, the use of fertilizers within the context of Integrated soil fertility management and regenerative agriculture approaches is critical. According to the In this context, the use of organic and bio-based fertilizers, with the additional benefits of improving the health of the soil, in combination with mineral fertilizers is being promoted, especially with increased concern for environmental sustainabilty.

4.2 Enabling policy environment

Governments at all levels - continental, regional, and national – must adopt policies that create an enabling environment for private sector participation in the fertilizer and soil health agenda as outlined in the AFSH-AP, the Soil Initiative for Africa as well as the Kampala Declaration.

These policies should:

- Ensure that the private sector and businesses have unhindered access to opprtunities for product supply to the market
- Limit the creation of government-led procurement and distribution channels that undermine the private sectors efforts. The creation of government-led procurement and distribution systems, when necessary, must be structured in a way that does not distort private channels but rahter complement its supply and improve market efficiency
- Provide predictable incentives and fair policies to build private sector confidence

4.3 Market friengly subsidy programs

Given the evidences of significant unintended negitive effects of most fertilizer subsidy programs, there is a need to ensure that the use of subsidy programs is deployed only in times of critical needs and they are properly taylored. Some suggested guiding pronciples inlcude:

- Subsidy programs, if necessary, should incentivize improved soil health and balanced crop nutrition combined
- The private sector, including large corporates and SMEs, must be actively consulted in the development of subsidy programs
- Subsidy program designs must clearly define roles and responsibilities, payment mechanisms, to ensure successful implementation
- Payment security mechanisms must be integral to any type of subsidy frameworks to ensure that suppliers are paid promptly.

4.4 Aligning international support to sustainable market development

International aid have in many cases resulted in limited impact and fertilizer market distortion. It is therefore important to assess international development support not only from its contribution to addressing the immediate shock, but also for its ability to facilitate continuos market development. In this regard, it is strongly recommended that no international aid that will inhibit Africa's journey towards acomlishing any of the goals of the Nairobi declaration be accepted.

4.5 Building Strategic Agricultural Commodity Compacts

Output Market-led input sector development approaches have proven to deliver more sustainable use of fertilizers and adoption of soil health enhancing practices over the years. For instance, smallholder production systems connected to output markets through some sort of aggregation mechanisms are amongst those using the highest levels of fertilizers, adopting the highest soils testing and remediation practices, as well as having greatest access to finance. Therefore, similar mechanisms that promote agricultural commodity compacts should be widely promoted. Some specific elements of such approaches are as follows:

- Implement systematic soil and agricultural data collection, storage, and management for targeted nutrient and soil health recommendations
- Develop science-based, crop-specific nutrition plans tailored to key agricultural regions and commodities
- Strengthen farmer outreach through more strategic capacity-building initiatives and promote safe and effective fertilizer use among smallholders via 4R nutrient stewardship training
- Invest in localized in-market storage facilities to improve access to inputs and agricultural services for farming communities
- Design policies and financial programs to support private sector-led distribution and 'last mile' retail networks in key agricultural regions

4.6 Focus on balanced fertilization and complementary use of mineral and organic fertilizers

Whilst Africa seeks to rapidly increase its level of fertilizer use, it must do so over the next decade in a way that addresses its two paradoxical challenges: producing more and preserving the soil. The most sustainable way to do this is to adopt the principle of complimentary use of fertilizers from multiple sources: mineral, organic and biological. In addition, the adoption of regenerative agricultural principles which will advance the restoration of already degraded soils must be integrated into the soil management approaches. The quantification of fertilizer needs of the soil must go beyond just providing to replace what the crop will extract, to providing delibrately over the next decade fertilization schedules that will gradually grow the organic matter content and residual nutrient of the soils.

4.7 Information on explorable resources for fertilizer production

Although vast deposits of fertilizer raw materials are reported in many parts of Africa, their exploration has been limited to a few places, making Africa remain a net importer of fertilizers. One of the reasons for the limited exploration is the sketchy nature of available information on the resources. To fast track investments in these untapped resources, governments at national level need to urgently provide more detailed information about the fertilizer resources in their countries. Such information should be detailed enuogh to enable potential investors determine if it is worth pursuing and reduce the level of investment in data collection required by investors to reach a decision point. This should include quantity, quality and ease of access parameters alongside incentives for investors.

4.8 Upscaling extension and farmer education

Ensuring that over 70% of Africa's smallholder farmers receive access to appropriate recommendation on fertilizer use for their specfic crops and soils requires that Africa's extension service delivery be significantly upscaled and upskilled. With the significant penetration of private farmer advisory services, mobile devices and social media platforms, the opportunities to rapidly grow extension penetration is ripe. A complementation between public and private farmer advisory service providers, and, between in-person and electronic advisory services, should be pursued. However, to ensure that farmers receive accurate and up-to-date advisory services on fertilizer use and soil health, a mechanism for standardization of content and delivery methods in required at all levels.

4.8 Deployment of appropriate financing instruments

Africa's dependence on aid finance for agricultural development have proven to be unsustainable. Coupled with the recent closure of USAID and overall reductions in aid, there are key implications for AFSH-AP and SIA. This opens up a genuine opportunity to lay a better foundation for a more market- and business-oriented agriculture on the continent, potentially fostering more genuine and lasting growth among farmers and national economies through more provate sector led funding for agricultural development including fertilizer and soil health issues. Some key areas to consider include the following:

- Focus more on a private sector led value chain development and related financing mechanisms
- Further capitalize AFFM to be able to support the fertilizer sector

- Development finance institutions on the continent, including AfDB and AFREXIM be mandated to create specfic pools of funds for financing investments in fertilizer production and commercialization
- Countries to consider providing soverign guarantees to unlock investment in the fertilizer resources available in their countries
- Agree on key bottlenecks in the supply chain and markets and align financial support and financial products accordingly

4.9 Improving infrastructure and power

Access to power and public infrastructure are tow major disincentives to investment in fertilizer production and distribution in rural Africa where most of the needs for fertilizers and the resources for its production exists. Key required investments include development of transport nextworks that will connect production sites to the wider parts of the continent for easy evacuation. For instance, urea manufacturers in Nigeria are reported to export more than 70% of their production to the rest of the world mainly because of undeveloped transport infrastructure to deliver products to other parts of the continent. Expansion in ports infrastructure and Pan-African road and rail networks are critical requirements for achieving increased fertilizer production and distribution to reach farmers at affordable prices on the continent.

4.10 Improved engagement of organized private sector

An improved cooperation between the fertilizer industry and policy makers is a critical requirement in achieving the goals of AFSH-AP and SIA. In this regard, the fertilizer and soil health private sector actors have mobilized and are in the process of establishing a unified Pan African association, which will bring together all actors. The establishment of a unified platform is essential for fostering private sector representation, as well as dialogue and collaboration with the public sector on the implementation of the agenda. This should replace fragmented interest groups with a consolidated industry association for streamlined communication with AUC, AUDA-NEPAD, WB, AfDB, and other partners and interest groups in shaping the development of the sector. Effort should be made to quickly establish and bolster the Africa Continental Fertilizer Industry Association (ACFIA) to serve as the main ‘continental voice’ for private sector actors and represent fertilizer industry stakeholders effectively.

Table 4: Implementation Framework for Fertilizer Production, Distribution and Use

Elements/ Objectives in the AFSH-AP	Relevant activities/ actions to be taken	Where would this activity be performed (geographical location, and at what level)	Who should be leading this action and why? (institutions, group of institutions etc.)	Important contributors to this activity?		What inputs are required to implement the action?	Who will be financing this activity?	Ideal timeframe in alignment with the 10year AFSH-AP	What are the indices to track progress?
				Who are they?	What they can contribute				
Action 3.1.1. Develop digitally-enabled context-specific efficient fertilizer and soil health advisory recommendations	- Geospatial systems characterization to define the agro ecological and socio-economic fertilizer use contexts. - Establish national and regional data infrastructure & management systems. - Develop standardized models and decision support systems for generating locally relevant fertilizer recommendations based site-specific soil, crop, season, target yield and economic information. First, we must define Digitally enabled, i.e. must it be digitally derived or expert derived and must it be digitally accessible or hybrid. These platforms must be linked to private sector companies who have access to extension services (JA)	National and regional	National Agricultural Research Services (NARS)/ PVT Sector where capacity and resources are available	Farmer associations; Extension workers; private sector	Research findings, experience with various products and practices,	AFSIS soil information data	Governments	3-5 years	No of countries with digital soil maps; number of crops agro ecologies with digital fertilizer and soil health recommendations

Action 3.1.2. Develop and deploy standardized and appropriate tools for assessing soil fertility, soil health, and context-specific sustainable soil management and nutrient requirements.	Systematic review of existing tools, platforms, digital solutions to select most robust solutions, or suite of solutions, that support the objectives of harmonised and standardised SOPs for achieving the outcomes of reporting on soil fertility, soil health (defined appropriately) and management practices (JA).	National and regional	National Agric Research Services/ private sector (including insurance companies)	PVT Sector; NARS	Existing tools, research findings, human resource	All existing tools,	Development partners and national governments	3-5 years	no of tools developed, no of countries using tools to assess soil fertility and health status
Action 3.1.3. Bundle fertilizer and soil health recommendations with Climate Information Services to reduce and address the risks associated with climate variability.	Identify region specific suitable fertilizer and soil health practices (based on soil maps; soil info system). National Baseline study to establish current state of adoption of the bundled practices; We need to write in insurance to help reduce the risk of adoption by farmers we must look at bundled finance solutions to incentivise bundled solutions (JA). we can also bundle the solutions with extension. (JA)	National and regional	Meteorological departments; National Agric Research Services; Mobile phone and internet service providers; insurance companies; Policy Think Tanks (PVT sector)	Farmer associations; Extension workers; private sector		Technical assistance to systematically review polices/ programmes and conduct baseline studies;	Government / Cooperating partners	1-2 years	Number of farmers adopting the recommended practice bundles; area under recommended practice bundle

Action 3.2.1. Promote integrated soil fertility management practices to enhance crop response.	* Organic fertilizer promotion as a compliment to mineral fertilizer regimes, Promotion of soil testing services * Mechanisation * Incentive the use of organic inputs, liming and water management and conservation technologies *Data systems dashboards on soil health and ag-input access	National and regional	*Government, Fertilizer companies, Private sector companies, Research institutes and NGO's	Fertilizer companies-Government, NGOs., Research organisations	Technical assistance, Research around soil and soil health parameters, Soil health and ag-input dashboards	Organic fertilizer facilities, Soil health and fertilizer dashboards, Innovative mechanisation suitable for small holder farmers	Governments, private sector/partnerships	1-2 years	Organic fertilizer quantities effectively used by farmers, organic production facilities set up, soil health data dashboards created, No. of farmers brought under some level of mechanisation
Action 3.2.2. Promote context-specific solutions for the use of the right sources of nutrients at the right rates, time, and place.	Right formulation development. Timely procurement, field extension. Testing facilities, globally harmonised standards	National and regional	*Government, Fertilizer companies, Private sector companies, Research institutes and NGO's	Research institutions, fertilizer companies-Government, NGOs.	Private sector deployment of innovative formulations, Research centres on the quality assurance, Knowledge transfer, Procurement frameworks	Farm level knowledge transfer dossiers, training, Investments around blending facilities for formulation development	Governments, private sector/partnerships	1-2 years	Number of farmers adopting the 4R principles, blending facilities set up, soil specific fertilizer formulations developed
Action 3.2.3. Promote access and affordability of liming for ameliorating acidic soils to enhance crop productivity and fertilizer use efficiency.	Include lime as part of input subsidy package, Increase local production of lime, promote policies to include organic matter in the soils as a long term measure to balance soil acidity, Product substitution with less acidifying values	National and regional	*Government, Fertilizer companies, Private sector companies, Research institutes and NGO's	Research institutions, fertilizer companies-Government, NGOs.	Production of lime, enabling policy environment around liming solutions,	Lime distribution network developed, lime used in blending operations	Governments, private sector/partnerships	2-5 years	Lime deposits beneficiated, no of policies supporting the liming agenda, Ha under acidic soils rehabilitated

Action 3.2.4. Promote context specific CSA innovations to ensure the cost-effectiveness of investments in fertilizer use, while mitigating the effect of climate change and variability	Promote irrigation and irrigation systems, Precision ag methods like use of drones for spot sprays, use of bio-stimulants and climate adapted varieties, promotion of indigenous varieties	National and regional	*Government, Fertilizer companies, Private sector companies, Research institutes and NGO's	Research institutions, fertilizer companies-Government, NGOs.	Policy and Budgetary allocation to irrigation infrastructure, Private sector innovations in promoting drone technology, NARIs promote indigenous varieties	Irrigation schemes and infrastructure setup, Research on climate adapted varieties strengthened	Governments, private sector/partnerships	2-5 years	Land put under irrigation, no of climate resilient/ adapted varieties released commercially
Action 3.3.1. Establish and operationalize continental, regional, and national soil health monitoring and soil information systems.	-central data centre, innovative data collection tools and libraries, harmonization and standardization, agile national and regional level fertilizer and soil health Dashboards	Each country and region	Ministries/soil departments, NGO's	Country-level scientists and experts	Technical expertise, technical backstopping	Soil lab, SOPs, Investments in data infrastructure and ecosystems	Governments, private sector/partnerships	2-3 years	Evidence of budgetary allocation, online infrastructure, soil lab establishment, SOPs, agile fertilizer and soil health dashboards expanded to all 55 AUC member states

Action 3.3.2. Establish and operation-alize a soil health, fer-tilizer, crop, and climate dashboard for decision support on sustainable soil man-agement.	Develop the dash-board	Country and regional levels	Ministries/soil departments, NGOs	Coun-try-level scientists and experts	Technical expertise and back-stopping	soil database	Governments, private sec-tor/partner-ships	3-5 years	Soil and cli-mate data-base, Digital soil maps
Action 3.3.3. Establish and operational-ize analytical and decision support	Digital soil maps development, mobile apps development for extension and advisory services	Country and regional levels	Ministries/soil departments, software development consultants, NGOs	Country and region-al-level sci-entists and experts	Technical expertise	Soil and cli-mate data-base, software, digital infra-structure	Governments, private sec-tor/partner-ships	3-5 years	Software for decision support and extension services, dashboard created

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Chapter 10

Monitoring, Evaluation, Accountability and Learning (MEAL) Framework for the Africa Fertilizer and Soil Health Action Plan (AFSH-AP)

Purpose and Guiding Principles

The M&E Framework is designed to ensure accountability, evidence-based decision-making, and adaptive management during the ten-year implementation of the AFSH-AP (2024–2034). It operationalizes the *Nairobi Declaration*'s call for a systematic monitoring system aligned with CAADP processes and integrated within the broader *Soil Initiative for Africa (SIA)* framework.

It aims to:

- Track progress toward the AFSH-AP outcomes and targets, including the commitments to triple fertilizer use efficiency and restore 30% of degraded soils by 2034.
- Harmonize soil health and fertilizer performance indicators across the continental, regional, and national levels.
- Enable learning and continuous improvement through feedback loops and knowledge exchange.
- Promote transparency, inclusiveness, and mutual accountability among AUC, AUDA-NEPAD, RECs, SROs, and Member States.

Institutional Anchoring and Governance

The MEAL system is anchored within the AUC Department of Agriculture, Rural Development, Blue Economy and Sustainable Environment (ARBE) and implemented through the AUDA-NEPAD, with FARA serving as the Technical Support Organization (TSO) for data management and reporting.

At each level:

- **Continental level:** AUC-ARBE and AUDA-NEPAD co-chair the Steering Committee and oversee integration into the CAADP Biennial Review (BR).
- **Regional level:** RECs and SROs coordinate data consolidation and quality control through Regional Fertilizer and Soil Health Hubs.
- **National level:** Ministries of Agriculture, National Soil Health Programs, and Fertilizer Councils lead implementation and data collection.
- **Coalitions and Partners:** Thematic coalitions (C4SISA, C4SEAS, C4FB, C4PA, CIFSH) ensure technical backstopping, learning documentation, and indicator alignment across their domains.

Theory of Change and Results Chain Alignment

The M&E Framework mirrors the SIA Theory of Change: if integrated soil and water management, targeted fertilizer use, capacity development, and enabling policies are implemented coherently, then soil health will improve, leading to higher productivity, resilience, and food security.

The results hierarchy therefore follows:

Impact: Healthier soils and resilient agri-food systems contributing to inclusive growth and poverty reduction.

Outcomes:

- Improved policies, investment, and financing for sustainable soil management.
- Improved access and affordability of fertilizers.
- Enhanced efficiency and resilience in fertilizer and soil management systems.
- Strengthened institutional and human capacities for soil health management.

Outputs: Correspond to the 14 priority outputs in the AFSH-AP (e.g., digital soil information systems, policy harmonization, capacity-building programs, regional research networks).

Overview of the Key Performance Indicators

Indicators for the Africa Fertilizer and Soil Health Action Plan (AFSH-AP) will be systematically tracked through a multi-tiered monitoring framework that aligns with the Comprehensive Africa Agriculture Development Programme (CAADP) Biennial Review (BR) indicators and global Sustainable Development Goal (SDG) reporting systems. This alignment ensures coherence with continental and international monitoring commitments, promotes comparability across countries and regions, and enables evidence-based policy decisions at all levels.

The AFSH-AP monitoring framework integrates data collection from multiple sources—including national statistical systems, regional observatories, and the African Union Soil Observatory (AUSO)—to provide a comprehensive picture of progress toward the Action Plan's objectives. The indicators are designed to capture changes at three primary levels: **impact**, **outcome**, and **output**, thereby allowing for the measurement of both direct programme results and the broader systemic effects of policy and investment interventions.

At the **impact level**, the framework will track the proportion of degraded land restored to sustainable use and the increase in average cereal yields as key indicators of improved soil health, agricultural productivity, and food security. By 2034, the goal is to restore 30 percent of degraded soils across the continent and to double cereal yields from an average of 1.7 tonnes per hectare to 3.5 tonnes per hectare. Verification will be carried out through a combination of national reporting systems, remote sensing technologies, and data from the African Soil Information Service (AfSIS) and AUSO databases, complemented by global datasets such as FAOSTAT and the CAADP BR dashboard.

At the **outcome level**, progress will be measured through a set of indicators that reflect the institutional, policy, and technical effects of AFSH-AP implementation. These include the number of countries that have harmonized their fertilizer and soil health policies with the continental framework—targeted at 40 countries by 2034—and the establishment of an operational Soil Health Fund within the Africa Fertilizer Financing Mechanism (AFFM), expected to be fully functional by 2026. In addition, domestic fertilizer production is projected to triple from 15 to 45 million tonnes, while the average fertilizer use rate is expected to rise from 18 to 54 kilograms per hectare, as reported through the AFAP, AFIDA, and national agricultural surveys.

Environmental and institutional outcomes will also be tracked through indicators measuring land-use efficiency, digital innovation, and technical capacity. By 2034, 30 percent of Africa's arable land should be managed under sustainable soil management practices, and at least 40 countries should have operational national digital soil information systems integrated with the AUSO. Furthermore, the programme aims to strengthen laboratory capacity, with 100 accredited soil and fertilizer laboratories established across Africa's five regions, ensuring improved analytical quality and fertilizer assurance. Finally, a critical indicator of farmer-level impact is the percentage of farmers receiving soil-specific fertilizer advice, targeted to reach 70 percent of smallholder producers through the combined efforts of national agricultural extension services, AFAAS, and the Coalition for Strengthening Extension and Advisory Services in Africa (C4SEAS).

These indicators, summarized in the AFSH-AP Results Framework and detailed further in **Annex 1**, will form the backbone of the monitoring and evaluation (M&E) system. Together, they will enable the African Union Commission (AUC), the African Union Development Agency (AUDA-NEPAD), Regional Economic Communities (RECs), and national governments to monitor collective progress, strengthen accountability, and ensure that the continent stays on course toward achieving sustainable soil health and agricultural transformation by 2034.

Annex 2—*AFSH-AP Activity Framework (2024–2034)* operationalizes **delivery across eight components**: ***(1)***- *continental-to-national policy and investment alignment* (validated guidelines, CAADP/AfCFTA coherence, 45 country alignment reports); ***(2)***- *financing (AFFM Soil Health Fund manual, pledges, performance*; 15 PPPs); ***(3)***- *production and trade (feasibility and environmental dossiers, harmonized standards, AfCFTA toolkit)*; ***(4)***- *ISFM and soil information with 10 validated protocols, extension modules, AUSO and five regional SIS dashboards, 200 analysts trained)*; ***(5)***- *research and networks (30 R&D projects, five alliances, annual Science Week)*; ***(6)-*** *capacity and last-mile advisory (curricula, 500 trainings, AEAS toolkit/app, ≥1M farmers reached)*; ***(7)-*** *advocacy and knowledge portal*; *and* ***(8)-*** *MEAL (framework, dashboard, five BR syntheses, mid-term and final evaluations)*.

Data Architecture and Information Flows

The monitoring system will leverage the **CAADP Biennial Review (BR) digital dashboard**, enhanced by the **African Union Soil Observatory (AUSO)** hosted by FARA.

Key functions include:

- Data will flow upward from community and sub-national actors through national M&E systems to regional hubs, which validate and submit to AUC/AUDA-NEPAD.
- The Coalition for Soil Information Systems in Africa (C4SISA) will standardize digital soil databases, metadata protocols, and dashboards for comparability.
- Remote sensing, mobile-based farmer surveys, and soil laboratory data will complement conventional reporting.
- Annual analytical reports and biennial performance reviews will inform adaptive management decisions at the Steering Committee level.

Evaluation and Learning

6.1 Evaluation Design

- **Mid-Term Evaluation (2029):** assess policy uptake, institutional performance, and early impact on soil fertility indicators.
- **Final Evaluation (2034):** assess contribution to Agenda 2063 targets, cost-effectiveness, and sustainability of interventions.

Both evaluations will apply mixed methods—quantitative indicator tracking, case studies, cost-benefit analyses, and geospatial trend assessments.

6.2 Learning and Knowledge Management

Learning is embedded through:

- A **digital MEAL Dashboard** linking SIA and CAADP knowledge platforms.
- Annual **Soil Health and Fertilizer Learning Weeks** convened by AUDA-NEPAD and FARA.
- Documentation of good practices and innovations by RECs and Coalitions for cross-country peer learning.
- Integration of feedback from farmers' organizations and extension networks to adapt implementation approaches.

Reporting and Accountability

- **Quarterly reporting:** by implementing partners and coalitions to national coordination units.
- **Annual consolidated report:** by RECs and AUDA-NEPAD, feeding into CAADP BR.
- **Biennial continental synthesis:** presented to the AU Specialized Technical Committee on Agriculture, Rural Development, Water, and Environment (STC-ARDWE).
- **Public dissemination:** through open dashboards, policy briefs, and the AUDA-NEPAD Soil Health Bulletin.

Accountability will be ensured via:

- Joint performance reviews among AUC, AUDA-NEPAD, FARA, and RECs.
- Multi-stakeholder scorecards evaluating national and regional progress.
- Peer review and learning forums to share corrective actions.

Integration with Country MEAL Systems

At the national level, domestication requires that:

- Each **Country Action Plan** includes a tailored MEAL plan consistent with continental indicators and reporting templates.

- National agricultural statistics services collaborate with soil laboratories, AEAS, and private sector platforms for data collection.
- Countries are supported by RECs and the TSO to build capacity for data management, analytics, and geospatial monitoring.
- Resource allocation to MEAL (≥ 5% of total program budgets) is recommended to sustain data systems and evaluation functions.

Key Tools and Instruments

- **AFSH-AP Results Framework Template** (for outcome and output tracking).
- **Digital Data Collection Toolkit** integrated with KoboToolbox and CAADP BR dashboard.
- **Performance Scorecards and Heat Maps** to visualise progress across Member States.
- **Learning Repository** linking to the African Soil Data Center (ASDAC) and Afrisoils Knowledge Hub.

Risk Management and Adaptive Response

The MEAL system will monitor contextual risks (e.g., climate shocks, political instability, data gaps) and include mitigation measures:

- Establishing early warning indicators (rainfall variability, fertilizer price index).
- Adaptive planning reviews by the Steering Committee when indicators deviate from targets.
- Flexibility to adjust interventions through annual learning cycles.

Conclusion

The MEAL Framework provides the operational backbone for tracking Africa's commitment under the *Nairobi Declaration* and the *AFSH-AP*. By embedding digital systems, harmonized indicators, and multi-level learning mechanisms, it ensures that the implementation of the Fertilizer and Soil Health agenda contributes measurably to the goals of **Agenda 2063**, **CAADP 2026-2035**, and the **Sustainable Development Goals**.

ANNEXES

Annex 1, AFSH-AP Results-Based Logical Framework (RBLF)

Results	Results Description	Indicators	Targets	Means of Verification	Critical Assumptions / Risks
Impact	Healthier, more resilient African soils contributing to food security, inclusive growth and climate-resilient agri-food systems in line with Agenda 2063 and SDGs 2, 13, 15.	**Imp1-** % of degraded land restored and maintained under sustainable management **Imp2-** Average cereal yield (t/ha) **Imp3-** Fertilizer use rate (kg nutrients/ha) **Imp4-** Decrease in the Prevalence of food insecurity **Imp5-** Decrease in Agriculture's carbon footprint per ha	≥ 30 % of degraded land restored Cereal yield > 3.5 t/ha Fertilizer ≥ 54 kg/ha Food insecurity ↓ by 50 % GHG intensity ↓ 20 %	CAADP Biennial Review; AUSO dashboard; remote-sensing data; national statistics; FAOSTAT	Sustained peace and political stability; adequate financing; no major climate catastrophe; continued AU leadership and Member-State commitment.
Outcome 1	Enabling policies, investments, and financing frameworks strengthened for sustainable fertilizer and soil-health management.	**Outc1.1-** # of countries with aligned national fertilizer & soil-health policies **Outc1.2-** # of operational soil-health investment plans integrated into NAIPs **Outc1.3-** Volume of public-private investment mobilized (USD bn) with Operational Soil Health Fund within AFFM **Outc1.4-** % of countries applying incentive mechanisms for soil restoration	≥ 45 countries ≥ 45 NAIPs ≥ 10 bn USD mobilized Fund operational by 2026 ≥ 60 % countries apply incentives	AUDA-NEPAD / AFFM reports; policy audits; investment tracking dashboards; national budget statements	Governments sustain policy reform momentum; private sector interest maintained; macroeconomic stability.
Outcome 2	Improved access, affordability, and intra-African trade of organic and mineral fertilizers.	**Outc2.1-** Domestic fertilizer production (Mt) **Outc2.2**- Average retail price index vs 2024 baseline **Outc2.3**- Intra-African fertilizer trade volume **Outc2.4**- # of countries with functioning agrodealer networks **Outc2.5-** % of farmers using certified fertilizer	Production tripled (15 → 45 Mt) Price index ↓ 20 % Trade doubled ≥ 40 countries with networks ≥ 70 % farmers use certified inputs	AFAP & AFIDA market data; customs records; national survey data; AfCFTA monitoring	Supply-chain disruptions minimized; stable energy markets; effective AfCFTA implementation.

Outcome 3	Greater efficiency, resil-ience, and sustainable use of fertilizers and soil-health interven-tions across agricultural sub-sectors.	**Outc3.1-** Nutrient use efficiency (%) **Outc3.2-** % of agricultural land under ISFM or SSM practices **Outc3.3**- # of countries with digital soil information systems **Outc3.4-** # of validated soil maps **Outc3.5**- % of farmers receiv-ing soil-specific advice	NUE ≥ 60 % 30 % land under SSM ≥ 40 countries with SIS 50 updated maps ≥ 70 % farmers advised	AUSO and C4SISA dashboards; national extension M&E reports; satellite data	ICT and lab infra-structure maintained; data sharing policies harmonized; extension systems resourced.
Outcome 4	Institutional and human capacity of national and regional actors en-hanced for sustainable soil and fertilizer man-agement.	**Outc4.1-** # of functional soil/ fertilizer labs **Outc4.2**- # of trained extension agents **Outc4.3**-% of farmers reached by AEAS **Outc4.4**- # of regional knowl-edge networks **Outc4.5**- Gender/youth partic-ipation rate in capacity pro-grams	≥ 100 labs accredited ≥ 10 000 agents trained 70 % coverage 5 networks ≥ 40 % women / youth	Training reports; RECs capacity inventories; university curricula re-views; AFAAS records	Staff retention and ca-reer incentives main-tained; gender barriers reduced; stable ICT systems.
Output 1	Continental and national policy and investment frameworks developed and harmonized.	**Outp1.1-** # of policy guidelines and investment frameworks produced **Outp1.2-** # of policy dialogues conducted **Outp1.3-** # of countries with legal instruments revised	≥ 10 guidelines ≥ 15 dialogues ≥ 30 countries adopt laws	Deliverables from AUC/AUDA-NEPAD; meeting records; poli-cy briefs	Timely technical inputs; ministerial endorse-ment.
Output 2	National and regional financing mechanisms and partnerships opera-tionalized (AFFM window, PPP models, Soil Health Fund).	**Outp2.1-** # of Soil Health Funds/PPP agreements signed **Outp2.2-** Value of investments mobilized **Outp2.3-** # of stakeholder in-vestment roundtables	≥ 15 funds or PPPs ≥ 10 bn USD mobilized ≥ 10 roundtables	AFFM & AfDB reports; MoUs; conference proceedings	Investor confidence sustained; risk-sharing instruments functional.

Output 3	Fertilizer production, distribution and trade facilities strengthened through local manufacturing and AfCFTA mechanisms.	**Outp3.1-** # of new or upgraded blending plants **Outp3.2-** # of countries adopting AfCFTA trade protocols **Outp3.3-** Transport cost index	≥ 25 plants ≥ 40 countries cost ↓ 15 %	AFAP/AFIDA data; AfCFTA reports; logistics studies	Energy and transport infrastructure financed; tariff harmonization progress.
Output 4	Integrated Soil Fertility Management (ISFM) packages and digital soil information systems developed and piloted.	**Outp4.1-** # of validated ISFM protocols **Outp4.2-** # of SIS platforms operational **Outp4.3-** # of trained data analysts	≥ 10 protocols ≥ 5 regional SIS ≥ 200 analysts	AUSO reports; training records; platform analytics	Data standards adopted; cross-institutional collaboration ensured.
Output 5	Research, innovation, and knowledge networks established for soil and fertilizer management.	**Outp5.1-** # of joint research projects **Outp5.2-** # of peer-reviewed publications **Outp5.3-** # of continental learning events	≥ 30 projects ≥ 60 publications ≥ 10 events	FARA and SRO reports; bibliometrics; conference records	Researchers and funders remain engaged; open-access policies supported.
Output 6	Capacity-building and extension programmes for farmers and technicians implemented.	**Outp6.1-** # of training sessions **Outp6.2-** # of beneficiaries **Outp6.3-** % female participants	≥ 500 sessions ≥ 1 000 000 beneficiaries ≥ 40 % female	Training evaluations; AFAAS and RECs records; post-training surveys	Institutional support for continuing education; funding for extension.
Output 7	Communication, advocacy and knowledge-management systems established.	**Outp7.1-** # of policy briefs and media products **Outp7.2-** # of stakeholder platform meetings **Outp7.3-** # of visits to AUSO/AFSH web portal	≥ 100 briefs ≥ 20 platform events ≥ 50 000 web visits	Communication analytics; media reports; AUDA-NEPAD portal stats	Continuous visibility funding; internet access reliable.
Output 8	Monitoring, Evaluation, Accountability and Learning (MEAL) system for AFSH-AP operational.	**Outp8.1-** Continental MEAL framework adopted **Outp8.2-** # of countries reporting through dashboard **Outp8.3-** # of biennial reviews completed	1 framework ≥ 45 countries 5 biennial reviews (2026-2034)	MEAL dashboard records; CAADP BR reports; evaluation studies	Timely data submission; capacity for M&E maintained.

Annex 2, AFSH-AP Activity Framework (2024-2034)

Activitiy Component	Subcomponent	Activity	Subactivities	Deliverables
Component 1 Continental and national policy and investment frameworks developed and harmonized.	1.1 Policy development and harmonization	1.1.1 Develop continental policy guidelines and investment frameworks for fertilizer and soil health.	1.1.1.1 Draft and validate continental guidelines through regional and national consultations.	D1.1 – Validated Continental Policy & Investment Framework for Fertilizer and Soil Health.
			1.1.1.2 Align with CAADP and AfCFTA frameworks.	D1.2 – Consultation report from 5 regional workshops.
	1.2 Policy domestication	1.2.1 Support Member States to revise or develop national fertilizer and soil-health strategies.	1.2.1.1 Provide technical assistance to integrate AFSH-AP priorities into NAIPs.	D1.3 – 45 country policy alignment reports.
			1.2.1.2 Facilitate peer-review and endorsement through RECs.	D1.4 – REC peer-review briefs.
Component 2 National and regional financing mechanisms and partnerships operationalized (AFFM window, PPP models, Soil Health Fund).	2.1 Financing frameworks	2.1.1 Operationalize a Soil Health Fund under the AFFM.	2.1.1.1 Design governance and funding modalities.	D2.1 – Soil Health Fund operational manual.
			2.1.1.2 Hold investment roundtables to mobilize capital.	D2.2 – Roundtable proceedings and investment pledges.
			2.1.1.3 Launch fund and track performance.	D2.3 – AFFM-fund performance report.
	2.2 PPP and private sector engagement	2.2.1 Establish Public-Private Partnerships for fertilizer and soil-health projects.	2.2.1.1 Identify high-potential private actors through AfCFTA corridors.	D2.4 – PPP agreements database.
			2.2.1.2 Develop 15 PPP agreements for local blending, logistics, and R&D.	D2.5 – Annual PPP performance review.
Component 3 Fertilizer production, distribution, and trade facilities strengthened through local manufacturing and AfCFTA mechanisms.	3.1 Local manufacturing support	3.1.1 Facilitate establishment or upgrading of local blending and production plants.	3.1.1.1 Conduct investment feasibility and site assessments.	D3.1 – Feasibility & environmental assessment reports.
			3.1.1.2 Provide technical design standards and environmental guidelines.	D3.2 – 25 plant-upgrade technical dossiers.
	3.2 Trade facilitation	3.2.1 Harmonize fertilizer standards and reduce intra-Africa trade barriers.	3.2.1.1 Align certification and quality-control systems under AfCFTA.	D3.3 – Harmonized fertilizer standards compendium.
			3.2.1.2 Establish cross-border transport agreements.	D3.4 – AfCFTA trade facilitation toolkit.

Activitiy Component	Subcomponent	Activity	Subactivities	Deliverables
Component 4 **Integrated Soil Fertility Management (ISFM) packages and digital soil information systems developed and piloted.**	4.1 ISFM technology development	4.1.1 Develop and validate ISFM packages adapted to major agro-ecological zones.	4.1.1.1 Conduct participatory field trials and cost-benefit analysis.	D4.1 – 10 validated ISFM protocols.
			4.1.1.2 Produce technical guides and extension materials.	D4.2 – Extension guidebook and training modules.
	4.2 Soil Information Systems (SIS)	4.2.1 Operationalize continental and regional soil information systems (SIS).	4.2.1.1 Integrate existing national databases into the African Union Soil Observatory (AUSO).	D4.3 – Functional AUSO platform and five regional SIS dashboards.
			4.2.1.2 Train analysts in geospatial soil data management.	D4.4 – Training reports for 200 analysts.
Component 5 **Research, innovation, and knowledge networks established for soil and fertilizer management.**	5.1 Collaborative research	5.1.1 Launch multi-country R&D programs on soil fertility, biofertilizers, and nutrient recycling.	5.1.1.1 Design and fund 30 joint research projects.	D5.1 – Portfolio of 30 R&D projects.
			5.1.1.2 Facilitate technology exchange workshops.	D5.2 – Technology-exchange workshop proceedings.
	5.2 Knowledge networking	5.2.1 Establish regional and continental research and innovation networks.	5.2.1.1 Form 5 regional knowledge alliances (through SROs and FARA).	D5.3 – Network MoUs and membership lists.
			5.2.1.2 Host annual African Fertilizer & Soil Health Science Week.	D5.4 – Annual Science Week reports and policy communiqués.
Component 6 **Capacity-building and extension programmes for farmers and technicians implemented.**	6.1 Farmer and technician training	6.1.1 Design and deliver training curricula for AEAS, youth, and women.	6.1.1.1 Develop modular courses on ISFM and fertilizer efficiency.	D6.1 – Training curricula and facilitator guides.
			6.1.1.2 Conduct 500 training sessions and field schools.	D6.2 – Field-school reports and trainee database.
	6.2 Advisory services and last-mile delivery	6.2.1 Strengthen extension networks and digital advisory platforms.	6.2.1.1 Integrate fertilizer advisory tools into existing AEAS systems.	D6.3 – Operational extension toolkit and AEAS app.
			6.2.1.2 Deploy mobile and radio advisory campaigns.	D6.4 – Communication reach report (≥ 1 M farmers).

Activitiy Component	Subcomponent	Activity	Subactivities	Deliverables
Component 7 Communication, advocacy and knowledge-management systems established.	7.1 Advocacy & outreach	7.1.1 Conduct policy dialogues, campaigns, and media outreach.	7.1.1.1 Organize 20 continental and regional stakeholder forums.	D7.1 – 20 forum proceedings and communiqués.
			7.1.1.2 Produce communication materials, policy briefs, and media stories.	D7.2 – 100 policy briefs and 50 media features.
	7.2 Knowledge management	7.2.1 Develop the AFSH-AP Knowledge Portal and Repository.	7.2.1.1 Design architecture linking AUSO, AFFM, and CAADP dashboards.	D7.3 – Operational knowledge portal integrated with CAADP BR dashboard.
			7.2.1.2 Upload all studies, progress reports, and learning materials.	D7.4 – Quarterly analytics and usage reports.
Component 8 Monitoring, Evaluation, Accountability and Learning (MEAL) system for AFSH-AP operational.	8.1 MEAL system setup	8.1.1 Design and validate continental MEAL framework and indicators.	8.1.1.1 Draft MEAL manual aligned with CAADP BR.	D8.1 – Validated MEAL Framework and Indicator Compendium.
			8.1.1.2 Conduct validation workshop with RECs and Member States.	D8.2 – Workshop proceedings and endorsement report.
	8.2 Data and reporting	8.2.1 Establish digital dashboard and reporting mechanisms.	8.2.1.1 Configure online reporting system through AUSO/CAADP portal.	D8.3 – Digital MEAL dashboard operational.
			8.2.1.2 Train 45 country focal points in data entry and analysis.	D8.4 – Country focal-point training reports.
			8.2.1.3 Produce 5 Biennial Review reports.	D8.5 – Five Biennial Review synthesis reports.
	8.3 Learning & evaluation	8.3.1 Implement mid-term and final evaluations; capture lessons.	8.3.1.1 Conduct mid-term evaluation (2029).	D8.6 – Mid-term evaluation report.
			8.3.1.2 Conduct final evaluation (2034).	D8.7 – Final evaluation and Lessons-Learned Compendium.
			8.3.1.3 Prepare learning compendium and policy recommendations.	

Chapter 11

Financing Mechanism for the Africa Fertilizer and Soil Health Action Plan

1. Executive Summary

The Africa Fertilizer and Soil Health Action Plan (AFSH-AP) provides a continental framework for enhancing soil fertility, improving fertilizer use efficiency, and promoting sustainable land management across Africa. To ensure its effective implementation, AUDA-NEPAD, in partnership with AfDB, FAO, IFAD, and FARA, proposes the establishment of a comprehensive financing mechanism. This mechanism combines traditional pooled funding with innovative blended finance instruments to mobilize resources from governments, development partners, and private investors. The mechanism will drive investment into soil health, fertilizer value chains, and climate-smart agriculture initiatives that contribute to food security, livelihoods, and environmental resilience.

2. Introduction and Rationale

Africa faces an acute challenge to soil fertility, with nearly 65% of arable land affected by degradation, low nutrient availability, and declining organic matter. Fertilizer consumption remains below 25 kg/ha far short of global averages, undermining crop productivity and food system resilience. Recognizing this, African Heads of State adopted the AFSH-AP to drive coordinated action on soil health and responsible fertilizer use. However, implementation requires sustainable financing that bridges the gap between policy ambition and field-level investments. The proposed Financing Mechanism aims to operationalize this vision through predictable, inclusive, and accountable resource mobilization.

3. Vision and Objectives of the Financing Mechanism

The Financing Mechanism envisions a well-coordinated, transparent, and sustainable funding architecture that supports the implementation of the AFSH-AP at continental, regional, and national levels. Its objectives are to:

- Mobilize and coordinate domestic, regional, and international financing.
- De-risk private sector investments in fertilizer and soil health value chains.
- Support evidence-based decision making through research, data systems, and innovation scaling.
- Ensure country ownership, accountability, and performance-based financing.

4. Institutional and Governance Framework

The Financing Mechanism will be led by AUDA-NEPAD, serving as the convener and policy coordination hub. AfDB will manage financial operations and leverage its Africa Fertilizer Financing Mechanism (AFFM). FARA will provide technical backstopping in research, innovation scaling, and knowledge brokering, while FAO and IFAD will contribute technical guidance and investment support. National implementation windows will be coordinated through Ministries of Agriculture, supported by Regional Economic Communities (RECs). Governance principles will emphasize transparency, inclusivity, and results-based allocation.

5. Financing Windows and Instruments

The mechanism will operate through four interlinked financing windows:

- Public Sector Window, mobilizing domestic budgets and grants.
- Private Sector Window, crowding in agribusiness, fertilizer companies, and SMEs.
- Development Partner Window, leveraging bilateral, multilateral, and philanthropic resources.
- Innovative Finance Window – deploying blended finance instruments such as soil health bonds, carbon credits, and climate adaptation funds.

These windows will ensure flexibility and inclusivity, enabling countries and partners to invest in various areas, including fertilizer production, distribution, soil testing, data systems, capacity building, and farmer support programs.

6. Resource Mobilization Strategy

AUDA-NEPAD, in collaboration with the development partners, and FARA, will lead a structured resource mobilization campaign to attract contributions from African governments, development partners, and private investors. The strategy will include establishing a continental trust fund, promoting co-financing with development banks, and facilitating country-level investment plans that align with the AFSH-AP. Innovative finance mechanisms, such as green and soil health bonds, result-based financing, and impact investment, will be prioritized to diversify funding sources.

7. Operationalization and Fund Flow

Funds will be channeled through the AUDA-NEPAD Secretariat to AfDB's managed account, from which country and project-specific disbursements will occur. Implementation at the national level will follow approved National Agricultural Investment Plans (NAIPs) that are aligned with the AFSH-AP. FARA will facilitate monitoring through its data and knowledge platforms, ensuring integration with the African Union Soil Observatory (AUSO) and other regional data systems.

8. Partnerships and Co-financing Platforms

Strategic partnerships will underpin the success of the Financing Mechanism. AUDA-NEPAD will collaborate with AfDB, IFAD, FAO, FARA, and regional institutions such as AGRA and IFDC to harmonize efforts and ensure complementarity. Private sector engagement will be promoted through Public-Private Partnerships (PPPs) in fertilizer manufacturing, distribution, and soil health service delivery. Co-financing agreements will align external investments with national priorities.

9. Monitoring, Reporting, and Learning

The Financing Mechanism will adopt a performance-based monitoring and evaluation framework. FARA, leveraging its knowledge and innovation systems, will coordinate data collection and synthesis to track financial flows, outputs, and impacts. Regular progress reports will be submitted to AUDA-NEPAD and the AU Assembly through the Specialized Technical Committee on Agriculture, Rural Development, Water, and Environment.

10. Sustainability and Exit Strategy

The mechanism's sustainability will hinge on strong domestic resource mobilization, private sector participation, and institutional capacity development. Over time, national financing windows are expected to transition into self-sustaining facilities supported by domestic finance, market-based instruments, and long-term credit facilities.

11. Risk Management and Safeguards

Key risks include insufficient funding commitments, governance lapses, and market volatility. Mitigation measures include diversified funding portfolios, strong fiduciary oversight, and transparency mechanisms. Environmental and social safeguards will align with AU and AfDB policies to ensure sustainability and equity in implementation.

Annex 1: Tables and Illustrative Financing Architecture

Table 1: Financing Windows and Instruments

Financing Window	Description	Example Instruments
Public Sector Window	Mobilizes domestic budgets, subsidies, and grants from national governments.	Budgetary allocations, subsidies, grants.
Private Sector Window	Encourages agribusiness, SMEs, and fertilizer companies to co-invest.	PPP investments, guarantees, blended credit lines.
Development Partner Window	Channels multilateral and bilateral donor funds.	Concessional loans, grants, technical assistance.
Innovative Finance Window	Deploys market-based mechanisms for soil health investment.	Soil Health Bonds, Carbon Credits, Climate Funds.

Table 2: Roles and Responsibilities of Key Partners

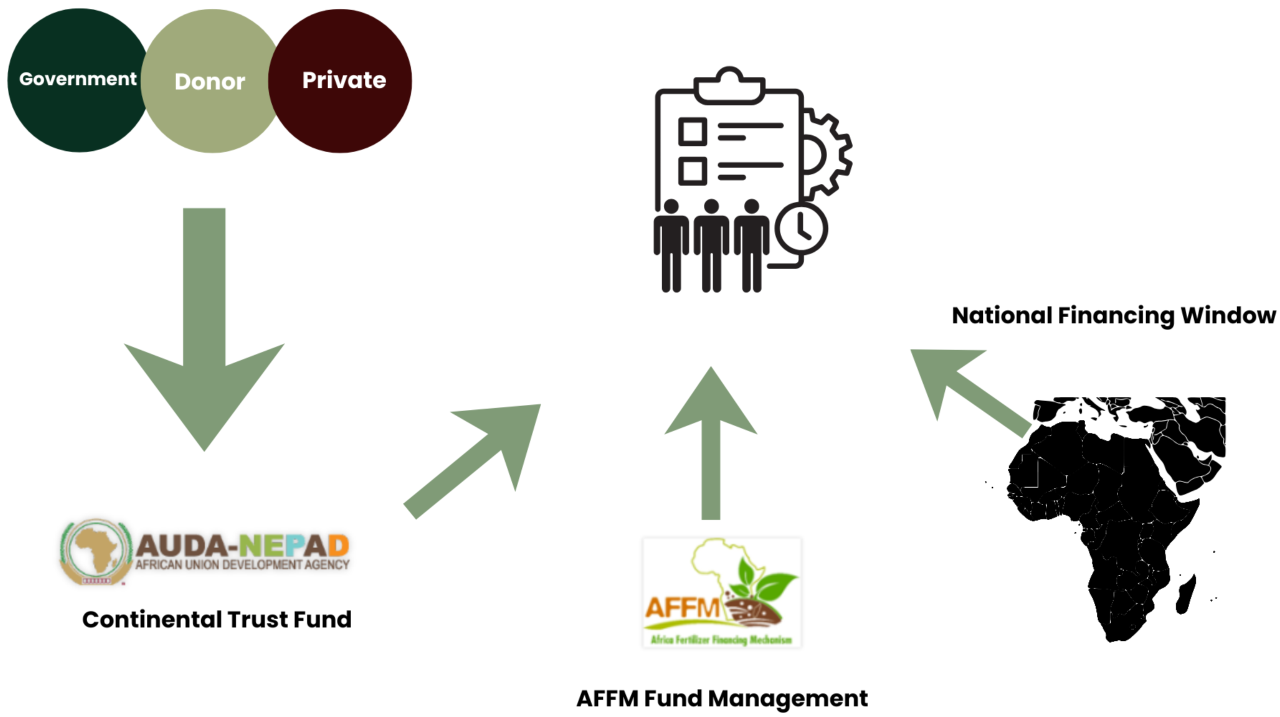
Partner	Role and Responsibility
AUDA-NEPAD	Overall coordination, policy oversight, and fund governance.
AfDB/AFFM	Financial management, fiduciary oversight, and fund disbursement.
FARA	Knowledge brokering, research coordination, data systems, and innovation scaling.
IFAD	Investment support and project-level co-financing.
FAO	Technical guidance on soil fertility, fertilizer use, and monitoring frameworks.
RECs & Member States	Implementation, country coordination, and national financing windows.

Table 3: Indicative Resource Mobilization Targets (USD Millions)

Timeframe	Public & Donor Funds	Private Sector Leverage	Total Projected Resources
Short-term (2025–2027)	800	400	1,200
Medium-term (2028–2032)	1,500	1,000	2,500
Long-term (2033–2040)	2,000	1,500	3,500

Annex 2: Stylized Financing Flow Diagram

The diagram below illustrates the hierarchical and color-coded flow of funds and co-ordination across the Africa Fertilizer and Soil Health Action Plan (AFSH-AP) financing mechanism:



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The development of the toolkit for country domestication of the Soil Initiative for Africa (SIA) and the Africa fertilizer and Soil health Action Plan (AFSH-AP) draw inputs from broad range of actors, experts and organizations that are involved in soil management issues in Africa.

A small team of experts work together to develop the key topics and draw input from several experts virtually. This was followed by convening a two to three-day workshop of key experts on each topic to discuss and develop the draft chapter. A knowledgeable expert on the subject matter was engaged to facilitate the discussion and develop the draft chapter, in some instances, other experts that participated in the workshop took the responsibility of drafting the chapter. Each draft chapter went through a peer review process to ensure scientific rigor and relevance to country domestication of AFSH-AP.

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