Coalition of the Willing

Powering Data-Driven Solutions for Ethiopian Agriculture

Alliance

Bioversity International

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Ethiopian Institute of Agricultural Research

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The **Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT)** delivers research-based solutions that address the global crises of malnutrition, climate change, biodiversity loss and environmental degradation.

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In partnership with

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Georgina Smith / CIAT

Global Food Security Challenges

How to feed the fast-growing world population sustainably is the greatest quest today's agriculture is facing. The Coalition of the Willing is a local response to the threat of global food shortage aimed at offering Ethiopian agriculture data-driven decision-making tools that enhance productivity.

The world population is projected to hit the 10 billion mark by 2050. The surge in population increase means more food is needed to feed Earth's population. A distinctive feature of today's demographics is the unprecedented increase in the middle-income population as a result of global economic growth. The increasing rate of urbanization is also changing consumption patterns. These scenarios create demand for more diversified and protein-rich food that cannot be supplied by the current agro-food value chain. According to different research reports, agricultural productivity needs to increase by 70% to cope with the exponentially growing food demand. The trajectory of agricultural demand and supply is more complex due to factors such as climate change and land degradation that cause e severe strains on traditional agriculture. The growing application of chemical fertilizers has improved overall global food production but with a telling negative effect, especially in the developed world. The loss of productivity because of pests and poor postharvest handling plays its share in undermining agricultural productivity. With 40% of Earth's surface already used for agriculture, the notion of "more land for agriculture" no longer surfaces as a viable solution.

The impact of factors such as population growth, climate change, and environmental degradation is felt more severely in developing countries that are accommodating one-third of the global population increase. At the same time, developing countries with few exceptions are not equipped with resources and resilient systems to cope with the challenge at hand and ahead. Thus, they are more vulnerable and at increased risk of food insecurity.

GLOBAL FOOD INSECURITY IN NUMBERS

CHALLENGE: GROWING MORE FOOD WITH FEWER NATURAL RESOURCES

2.6 BILLION PEOPLE DEPEND DIRECTLY ON AGRICULTURE FOR THEIR LIVELIHOOD.

BY 2050 THE GROWING WORLD POPULATION WILL REQUIRE **100% MORE FOOD.**

THE WORLD HAS LOST A THIRD OF ITS ARABLE LAND IN THE PAST **40 YEARS.**

90% OF THE GROWTH IN CROP PRODUCTION IS PROJECTED TO COME FROM HIGHER YIELDS AND INCREASED CROPPING INTENSITY.

1.3 BILLION TONS OF FOOD ARE WASTED GLOBALLY EACH YEAR. THAT IS ONE-THIRD OF ALL FOOD PRODUCED FOR HUMAN CONSUMPTION.

UP TO 40% OF POTENTIAL FOOD PRODUCTION IS LOST EVERY YEAR TO PESTS.

Adapted from Isoclast Active website. http://isoclast.eu/wildlife-and-environment/

Despite remarkable progress in the agricultural sector over the past decades, poverty and food scarcity are still major problems in many parts of the world. According to the 2018 report[1] of the world government summit, 700 million people remain extremely poor, 800 million face chronic hunger, and 2 billion suffer micronutrient deficiencies. Of the 800 million, the World Bank estimates that one-third live in rural areas in developing countries.

700 MILLION
PEOPLE LIVE IN EXTREME POVERTY.

800 MILLION
FACE CHRONIC HUNGER.

2 BILLION
SUFFER MICRONUTRIENT DEFICIENCIES.

Technological Solutions Transforming Agriculture

Technological advances are contributing to a more productive, resilient, and sustainable agriculture that responds to the increasing global food demand.

Feeding the 2050 global population requires producing 70% more food in an environmentally sustainable manner. This requires filling the around 593 million hectares of the land gap between global agricultural land area in 2010 and expected agricultural expansion by 2050[2]. As there are no adequate free lands to expand to, additional pressure on resources could lead to land degradation, which would compromise the effort to feed the increasing global population. A report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), for example, states that the degradation of Earth's land surface through human activities will cause negative impacts on the well-being of at least 3.2 billion people and will push the planet toward a sixth mass species extinction[3].

To tackle this potential crisis, there is a need to develop innovative approaches that provide win-win solutions with limited tradeoffs. Great strides have been made in agricultural innovations that resulted in a significant increase in global food production. New and more powerful technologies are being employed to transform traditional agricultural practices. The use of modern tractors, harvesters, combines, and other technologies have transformed the agricultural system toward precision agriculture supported by smart farming and irrigation.

1 World government summit, Report. 2018.
2 WRI (2019).
3 https://ipbes.net/assessing-knowledge

Tele-irrigation in Niger (photo by: Inés Magoum/Afrika 21 News)

CASE STUDY 1
Technological Innovations Transforming Agriculture

Tele-Irrigation in Niger

In Niger, "Tele-Irrigation" (from TECHINNOV) is a technological process that allows farmers to remotely control the irrigation system of their farm and follow an intelligent distribution of water (needs, quantity and time,), regardless of its geographic position and time, by means of their mobile phone and solar energy. Tele-Irrigation can also collect and disseminate real-time and remote meteorological and hydrological data including temperature, soil moisture content, rainfall, solar radiation and wind speed. This process allows the farmer (i) time and energy savings; (ii) increased irrigable area; (iii) increased production and income; and (iv) controlled water management.

The use of digital technologies, including the internet, mobile devices, temperature and moisture sensors, aerial images, GPS, drones, robots, etc., is reengineering the way food is produced. These technological advances are contributing to a more productive, resilient, and sustainable agriculture that responds to the increasing global food demand.

These technologies enable informed decisions-making in the entire agricultural value chain toward more efficient, profitable, and sustainable farming practices. With the advance of the Internet of Things and information and communication technologies, information can be provided to farmers and other agricultural stakeholders in real time and with precision, enabling them to make better decisions and take immediate action.

The foundation of the technologies and many more innovations in the agricultural sector is the paradigm shift toward data-driven agriculture. Farming will no longer need to depend on the blanket application of water, fertilizer, and other farm inputs. Future farms or the so-called "smart farms" will rely on location-specific information to target farming inputs and interventions, thus cutting the cost of inputs and labor substantially. Experiences across the world affirm that significant efficiency and productivity gains are obtained from smart and data-driven agriculture.

The Global Discourse on Big Data and Data-Driven Agriculture

Good decisions are based on evidence to increase the probability of success and real evidence comes from good data.

Agricultural stakeholders at all levels face decisions about investments of different kinds. Farmers must decide which agricultural inputs they should invest in or what kind of fertilizer they should apply. Producers and agro-dealers must decide which farm inputs to produce and sell to which consumers at what price. Government authorities must make policy and investment decisions to support agriculture and to improve the agricultural productivity of their nation. Donors and development partners must decide which agricultural projects where are variable to invest in. All these decisions require evidence to increase the probability of success and evidence comes from data. The amount, quality, and diversification of available data determine the quality of information that can be generated and used for decision-making.

The questions "where do we get the data to provide evidence for agricultural decisions?" and "how many data do we need to make decisions optimum?" lead to a discussion on the concept of "big data." The use of data to improve agriculture is not an entirely new concept. People and institutions have been generating and analyzing data for various agricultural purposes. However, specific crops were often the focus of data collection with few parameters in consideration. Agriculture is a dynamic and location-specific process affected by a multitude of factors. A study of specific variables falls short of providing a complete understanding of how to increase productivity. But analyzing location-specific data factoring in numerous variables and drawing from layering the wealth of data generated from numerous single-use data collection missions can offer much deeper and richer information that can inform the best agricultural decisions. Here is where the concept of big data comes into play.

The current trend undoubtedly confirms conquering the quest for sustainable and sufficient food production relying on the availability of high-quality and high-volume data (big data) as well as increased data storage and computing capability that can support the analysis of numerous and complex variables that are determinants for increasing productivity.

Increasing crop yield (photo by Kitovu Technology Company)

CASE STUDY 2
Data-driven agriculture for increased productivity
Kitovu: Increasing crop yield while providing access to markets

Background

Of the many practical difficulties facing Nigerian farmers in the agricultural market today, one is that many farmers struggle to afford soil tests for their produce in order to know how best to use their land. Another is the lack of interaction between farmers and the wider agricultural sector regarding best practices and advice. In addition, long input supply chains are made financially unattractive or unaffordable to farmers by creating additional levels of middlemen, thus increasing prices of inputs.

Approach

The Nigerian agricultural technology startup Kitovu uses its platform to accomplish two distinct goals that are important to Nigerian farmers: matching the right crop with the right soil composition and helping farmers access markets more directly through its wider network. The Kitovu platform collects geospatial data and soil and agronomic data related to various crops to provide recommendations to farmers based on their farm composition. Additionally, Kitovu collects commercial data about national farm production and agricultural market data in order to provide market access directly to farmers.

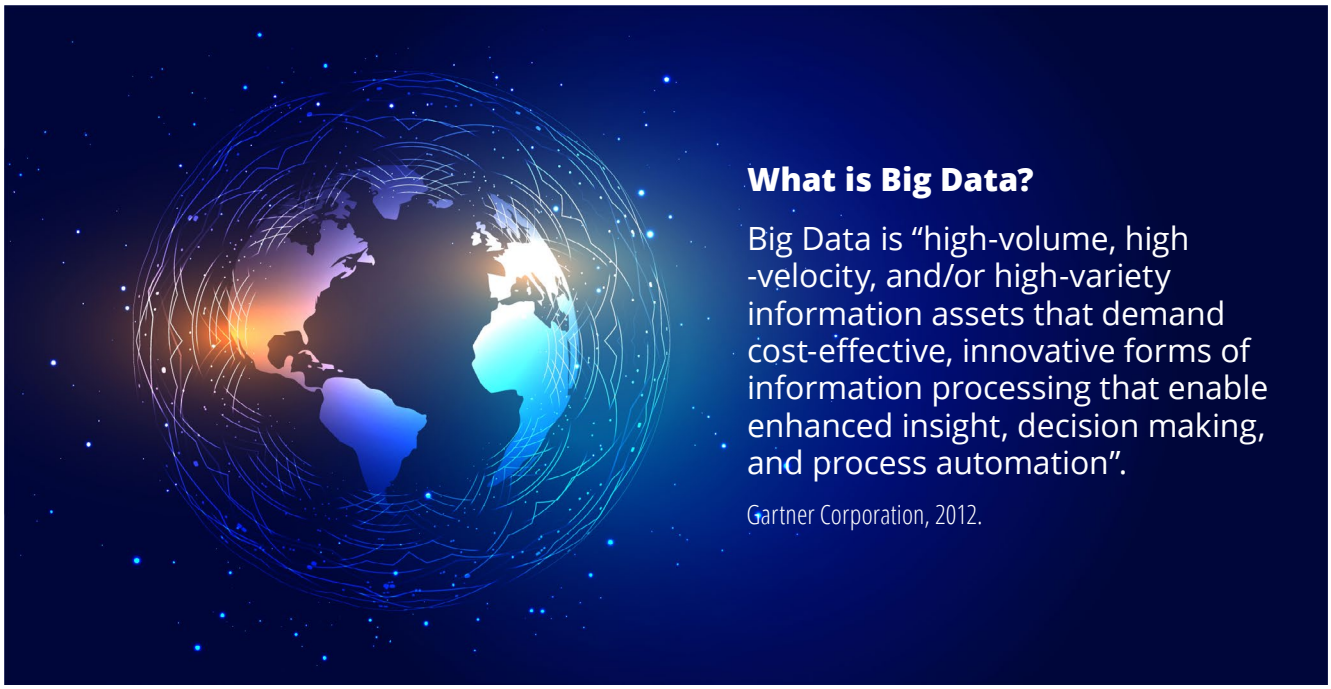
Results

Since its inception in 2016, Kitovu has been allowing farmers to share soil and agronomic data securely through its platform. The insights and information provided by the data-sharing platform have increased the yield of some of their participating farmers by more than 300%. To date, Kitovu has worked with more than 10,000 farmers across six states of Nigeria.

Share soil and agronomic data securely.

Increased yield by more than 300%.

You can read more at: Further reading - Disrupt Africa (2017), "Nigeria's Kitovu helps farmers improve yields, access markets" https://disrupt-africa. com/2017/12/nigeriaskitovu-helps-farmersimprove-yields-accessmarkets/



What is Big Data?

Big Data is "high-volume, high -velocity, and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation".

Gartner Corporation, 2012.

According to Forbes "There are 2.5 quintillion bytes of data created each day at our current pace, but that pace is only accelerating with the growth of the Internet of Things (IoT). Over 90 percent of the data in the world was generated over the last two years alone."

As the definition accurately informs, big data cannot be pursued independently of compatible infrastructure and competence to store, process, and analyze colossal data efficiently and generate relevant decision-making information promptly. About 80% of the data being generated today are unstructured and cannot be handled by our traditional technologies. The increasing prominence of big data is aided by the technological advances that boosted data storage, sharing, and analytical capability.

With this exponentially growing rate of data generation, it is fair to assume that agriculture-related data constitute a fair share of the global data wealth. Nevertheless, even in the developed countries, agriculture is a newcomer to the big-data revolution that is transforming businesses and industries. Yet, the transition to data-driven agriculture is happening undoubtedly and big-data analytics is offering powerful tools to conquer the challenge of global food shortage.

HOW BIG DATA SUPPORT AGRICULTURE

MONITORING NATURAL TRENDS TO FORECAST RISKS AND PREPARE FOR QUICK AND ADEQUATE RESPONSE.

RISK ASSESSMENT AND USE OF REAL-TIME DATA TO MINIMIZE DAMAGE.

SUPPORTING DATA-DRIVEN INDUSTRY THAT IS DEDICATED TO DEVELOPING DATA-DRIVEN SOLUTIONS.

AUTOMATION OF LABOR-INTENSIVE FARMING ACTIVITIES BY USING INNOVATIVE TECHNOLOGIES.

YIELD PREDICATION AND ALGORITHMS FOR BOOSTING FUTURE YIELD.

Effort to Embrace Digital Agriculture in Ethiopia

Ethiopian agriculture is dealing with the overwhelming challenge of producing more food for a fast-growing population on low-fertility soils under erratic climatic conditions.

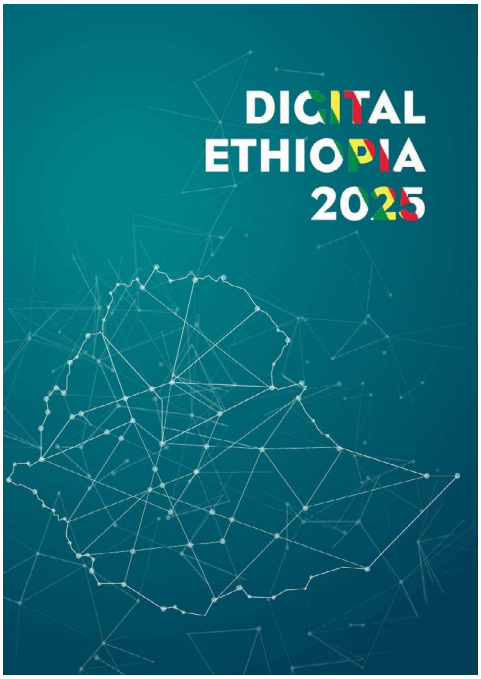
CIAT Report: 2019

Home to more than 100 million people, Ethiopia is the second most populous nation in Africa after Nigeria. It is also the most populous landlocked country in the world. With an annual population growth rate of 2.6%, the Ethiopian population is expected to reach 138 million by 2030 and 172 million by 2050. Ethiopia is among the fastest-growing economies of the world, achieving consecutive double-digit economic growth since 2007-2008. However, it is also one of the poorest nations in the world, with a per capita income of USD 790 and a considerable share of the population living under the poverty line.

By implementing pro-poor development programs that nurture broad-based economic growth, Ethiopia aims to reach lower-middle-income status by 2025. Agriculture is the main pillar of the economy expected to contribute a lion's share of the growth the country aspires to achieve. Currently, agriculture employs 85% of the labor force, accounting for 41% of GDP and 80% of exports. Despite its important economic and social role, agriculture is falling short of feeding the country's growing population. About 95% of Ethiopian agriculture is constituted by rainfed small-scale farming. Most smallholders practice low-input, low-output subsistence farming. Farming relies on rainfall, which is increasingly becoming erratic because of climate change. Agricultural techniques are outdated and often unsustainable given the unmitigated climate and ecological changes. Farming is labor-intensive and time consuming. Farm mechanization is underdeveloped and, as some argue, constrained by the small-scale farming practices and unaffordability of mechanization by subsistence farmers. Farm plots are quite small and, in most cases, fragmented across space, which diminishes the efficiency and benefits from economies of scale. Soil acidity and degradation are growing concerns in many parts of the country. Years of blanket application of fertilizer did not result in increased crop production.

In response to these challenges, Ethiopia's Agricultural Sector Policy and Investment Framework (PIF) aimed at a sustainable increase in rural income and national food security by producing more, selling more, nurturing the environment, eliminating hunger, and protecting the vulnerable against shocks. The four pillars of this strategy are (1) achieving a sustainable increase in agricultural productivity and production, (2) accelerating agricultural commercialization and agro-industry development, (3) decreasing degradation and improving the productivity of natural resources, and (4) achieving universal food security and protecting vulnerable households from natural disasters.

The policy and investment framework (PIF) was applicable for the period 2010-2020, and notable achievements have been gained through the ten years' strategy. Ethiopia made significant strides in improving agricultural productivity and ensuring national food security. However, a quick stock-taking of the state of agriculture today, which is also the last year of the strategy, reveals that a lot more needs to be done to transform Ethiopia's agriculture and to sustain the results achieved so far. Millions of people are still food-insecure and vulnerable to natural disasters. This situation is further aggravated by unprecedented and existential threats such as the COVID-19 pandemic. The facts in all directions call for transformation in agriculture that can be achieved only by a paradigm shift in the sector.

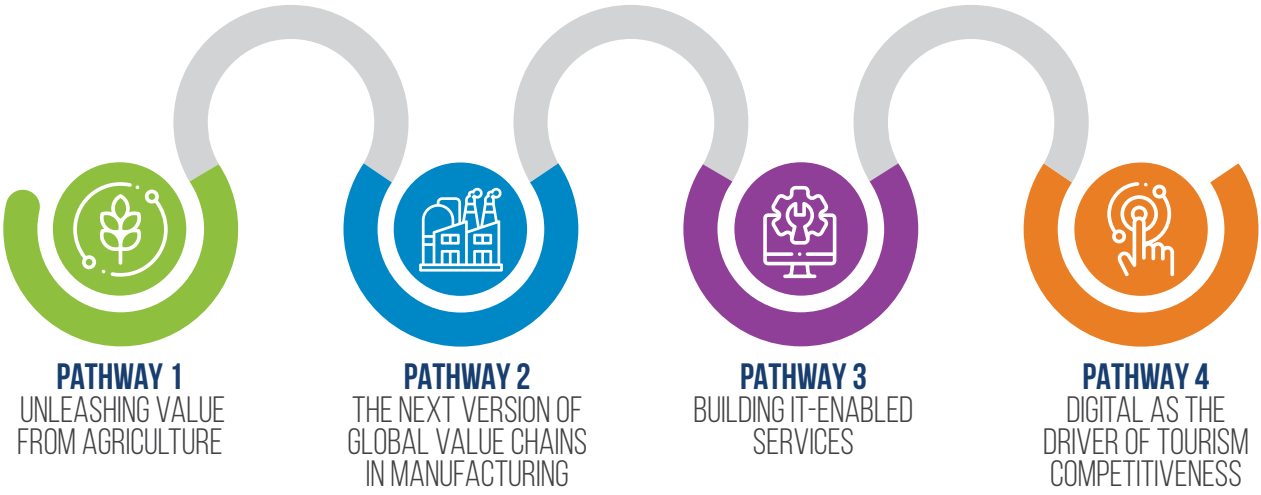


Ethiopian Digital Strategy

In 2020, the Council of Ministers approved the Digital Strategy for Inclusive Prosperity 2025, ushering in the era of digitalization in key sectors of the economy. Agriculture is one of the four prosperity pathways identified by the strategy. A digital agricultural platform that allows the use of new and advanced technologies integrated into one system is a key component of the strategy. The platform aims to enable small-scale farmers to increase their productivity and generate equitable economic benefits from the sector by providing them with access to digital technologies and information that support decision-making. Access to market information and financial services and exposure to modern farming services such as precision farming are some of the strategies that aim to bring farmers and stakeholders into the agricultural value chain. Support for ag-tech entrepreneurship to promote agricultural innovations and jobs and to build competitiveness in agricultural export elements of the strategy has already begun.

The availability of credible data and the capacity to analyze and derive decision-making information is at the heart of the digital strategy and is vital for its implementation. Building the digital infrastructure and capacity are the foundational interventions toward unleashing the potential of digitalization in the agricultural sector. In sync with the African Union's digital transformation strategy for Africa 2020-2030, Ethiopia is on the right path to embracing digital agriculture and preparing to reap the tremendous benefits of this transformation.

Four pathways, the framework of Ethiopia's Digital 2025 Strategy



A Coalition of the Willing

Powering Data-Driven Solutions for Ethiopian Agriculture

The advent of big data is pushing agricultural frontiers. Advances in data storage, processing, and sharing capacity as well as analytics and modeling competency are optimizing agricultural decision-making by predicting the various complexities involved in agricultural processes. The introduction of machine learning, drone technology, and robotics is paving the way for greater agricultural breakthroughs that were not possible before. Using data and technological innovations, farmers in many parts of the world can now practice precision agriculture and thus increase their productivity.

These scientific advances are good news to the developing world, especially Ethiopia, which is most threatened by land degradation, effects of climate change and food insecurity. Developing countries can plug into the fascinating world of big-data analytics to gain quick wins as well as enjoy sustainable benefits towards addressing their priority problems of food insecurity and environmental degradation. The Coalition of the Willing (CoW) is one of the thriving African initiatives toward data-driven agriculture in Ethiopia. The CoW is established and operates with the firm belief that curbing the increasing threat of food shortage can be tackled only by transitioning to data-driven agriculture. This transition requires unconstrained access to big data, analytical and computing capacities that can support high-volume multivariable analysis in real time. Despite the existence of high volume of agricultural data in Ethiopia collected over the past 60 years, no database contains these data in an accessible and interoperable format. Data access and sharing systems operating per the FAIR (findable, accessible, interoperable, and reusable) data principles are nonexistent or at a very early stage of development. As a result, complex analysis that can inform better agricultural decisions have been difficult to perform. This situation has undermined data-driven and knowledge-based decision-making, which ultimately affects the effectiveness of agricultural decisions and interventions.

In the quest to develop a data-driven site-specific fertilizer recommendation tool, Ethiopian soil and agronomy experts realized the challenges of data access. In response, they attempted to gather soil and agronomy data at their disposal as well as data from various researchers and institutions to build a database.

The experts undertook different measures in a cascading manner going from individual conversations to organizing meetings and workshops to discuss and substantiate the idea. Through the effort, they realized that they could succeed in bringing a significant national impact if handled more systematically and pursued sustainably. Discussions on how to support a systematic and institutionalized process of soil and agronomy data sharing and access culminated with the birth of the Coalition of the Willing (CoW).

This short information product introduces the CoW, its origin and rationale, aspirations and achievements to date.

The Coalition of the Willing (Cow)

Great Vision Powered by Will

Despite the Government of Ethiopia's attempts to achieve food security for its population, crop production and yield are still below capacity for several reasons. One of these is the inadequate management of the country's soil resources, particularly because of the absence of a comprehensive centralized soil data repository available to the relevant government ministries, national and international agricultural researchers, extension providers, and farmers alike. Not only are critical soil and agronomy data not structured to be accessible, the lack of appropriate data-sharing policies and frameworks has hindered both collaboration among researchers and institutions and the scaling-out of applications and lessons learned.

The CoW is a team of willing experts organized to support the development plan of Ethiopia by embracing digital solutions. The team started by accessing and sharing soil and agronomy data to benefit from the use of big-data solutions. The team passed through different processes to arrive at a stage in which tens of thousands of data are now in a database with the possibility to use machine-learning algorithms to make a detailed analysis and unravel otherwise hidden patterns.

During its initial endeavor, the CoW focused on creating awareness so that partners and individuals could share their data. Through iterative discussions and meetings, trust was built among the CoW members to exchange datasets and necessary ideas to transform the data into usable formats. A data-sharing guideline was being developed to facilitate data sharing in a more organized and formalized manner.

While exploring the shared data, an obstacle emerged: the data were not interoperable and preparing data had become a serious challenge. The CoW team took measures to overcome this challenge through the development of operational guidelines. This step resolved another complex puzzle of a more than 60-year-old problem.

To facilitate data access and sharing as well as analysis, the CoW developed a web portal. This portal is used to store, manage, query, and visualize soil and agronomy data, with the flexibility to expand to other subjects. This was another fundamental intervention that highlighted the commitment of the team to advance toward employing an advanced solution to tackle an old problem.

With these accomplishments, the CoW team has now moved to the next challenge: mine data, understand patterns and develop solutions that can enable transforming the agricultural system. The team explored different data-mining techniques, exchanged experiences, and developed frameworks that can facilitate further data analysis endeavors. This included building the capacity of national partners in advanced data analytics techniques.

Taking advantage of advances in data acquisition, storage, management, and analysis, the CoW will soon develop site-specific agro-advisory services. This will involve/integrate climate (onset of rains and planting data), fertilizer recommendations, disease surveillance, and early warning complemented by good agronomic practices. The packaged advisories will then be made available for the extension system to communicate to farmers using appropriate means. The CoW will team up with digital extension developers to properly marry content and dissemination mechanisms.

Upcoming interventions and engagements will aim to address key knowledge gaps through scalable innovations in the provision of reliable, timely, and actionable data and insights into soil health and crop performance at the farm and regional levels. Novel diagnostic approaches, data assets, decision aids, and better farm management practices will increasingly be scaled and integrated with other data, products, and services. These services can be integrated with solution-focused bundled services that support timely management and operational decisions by farmers as well as the input delivery systems that support them, including digitally enabled agricultural advisory services.

Expected results in the coming few years include national Soil Information Services (SIS) fully integrated with functioning agronomy research pipelines within key international and national research organizations; SIS solutions integrated with Agricultural Advisory Services (AAS) into overall decision agriculture platforms nationally and innovative diagnostic tools and decision aids increasingly used on the farm and regionally; and partners routinely applying FAIR data principles and practices. These will involve taking data and data use to the next level, whereby data are "translated" into information and farmer-relevant and gender-specific extension content and disseminated digitally and via analogue agricultural advisory services. At the same time, a concerted effort will be made to facilitate the co-creation of an improved farmer-research-extension-data linkage mechanism for improving the flow and exchange of information among male and female farmers, rural youth, researchers, and extension providers. In the end, enhanced information, feedback and linkages will enable extension service providers to improve the quality and efficiency of agricultural advisory services iteratively and continually, thereby contributing to transformative agricultural development in Ethiopia.

The CoW Origin and Evolution

The Coalition of the Willing (CoW) is the response of Ethiopian soil and agronomy experts to the fundamental question of how to harness the wealth of data and transform these data into information to support agricultural decision-making.

The notion "data is power" leaves room for some debate because, without being processed into digestible information, having fragmented data may not paint the whole picture. Without the big picture, knowing the missing parts of the puzzle is close to an arbitrary exercise. This is mainly because data are mostly generated to produce evidence for a certain hypothesis. The context that surrounds the data-gathering exercise and the evidence generated do not capture all dimensions that an informed decision-making requires. But several data "overdyed" could paint a holistic picture that offers complete or reasonably enough information to optimize decisions.

As established in the previous sections, the shortage of agricultural data is no longer a major barrier globally as well as in Ethiopia. The fundamental question is how to bring this wealth of data together and transform them into inputs that can inform agricultural decisions.

The CoW is the response of Ethiopian soil and agronomy experts to this fundamental question. The origin of CoW was indeed a great insight necessitated to solve a real-time problem. In December 2016, the International Center for Tropical Agriculture (CIAT) and partners initiated an ambitious mission of developing a fertilizer recommendation tool that could result in optimal yield response in different agroecological zones and farming systems of Ethiopia aligned with the diverse soil types. This emanates from the fact that advances in providing site- and context-specific inputs are key to enhancing agricultural productivity and contributing to national growth and development efforts. But the lack of optimum fertilizer recommendations nationally despite widespread and close to 60 years of research efforts related to "crop response to fertilizer application" in the country undermines boosting agricultural productivity. The serious bottleneck here is that data are scattered across institutions and/or individuals. As a result, duplication of efforts and waste of time and resources occur. This is unacceptable considering the limited resources the country possesses and the opportunity lost to support agricultural transformation through digital solutions. As a result, repeated discussions have been held by different partners and stakeholders on how to resolve the problems of the inability to bring datasets together and start making data-intensive and knowledge-based decisions. This deadlock seemed to start cracking when a group of concerned stakeholders

decided to give it "one more try" during a personal meeting on the International Livestock Research Institute (ILRI) campus of Addis Ababa.

This discussion evolved over time and, during 2015, several internal iterative discussions were held as to how data sharing could be approached. Those few interested groups were quite aware of the challenge and started to inquire through their connections: both to sell the idea and collect data from those who were willing to share. The journey to bring soil and agronomy data into a central database started through individual contacts, telephone calls, etc. However, the response was not encouraging as many hesitated to share data and some claimed that they did not have them anymore. The latter claim is even more tragic because it implies that the large proportion of data collected since the 1950s may not be traced or recovered. This is partly because data sharing was not a normal thing for the majority of those who were contacted by the team. Some of those who had attempted the exercise before even provided a more damning verdict: "the team is trying an impossible that many have tried and failed." The good thing was that these developments did not deter the team from continuing to pursue the challenge because they believed that the scattered efforts would not lead anywhere! As the discussions in small groups continued, CIAT, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and their partners, supported by the German Agency for International Cooperation (GIZ), took the initiative a step further in a more organized manner. With financial and technical support from GIZ, the Water, Land, and Ecosystems (WLE) program of CGIAR and the Africa RISING Program of the United States Agency for International Development (USAID), CIAT, ICRISAT, and their partners, mainly experts from the Ethiopian Institute of Agricultural Research (EIAR), started inquiring into the whereabouts of the crop response to fertilizer application-related datasets collected by national and international organizations, researchers, and students, as well as other players in the field.

As it was not possible to collate meaningful data through personal searches or individual efforts, the next step focused on collating available data from peer-reviewed publications mainly focusing on crop response to fertilizer application. This step aimed to use published data to demonstrate the value of using a larger dataset to make informed decisions. As a result, a template was prepared to collate detailed data related to crop response to fertilizer application from available peer-reviewed publications pertaining to Ethiopia. This effort resulted in the collation of a significant dataset from more than 150 peer-reviewed publications. Those data were then stored in a database and meta-data analysis was conducted to understand the patterns and spatio-temporal dynamics of crop response to input use. These analysis results were then presented at a national workshop in December 2016, at which more than 80 soil and agronomy experts from across the country attended. This was an eye-opening session whereby the experts came to realize the benefits of using larger datasets to understand patterns and dynamics across scales. The inspiring discussions and the willingness of EIAR management to support the effort were instrumental and encouraged and incentivized the efforts by CIAT and its partners. The preliminary results, discussions to provide inputs, and the dedication of the various experts who attended the workshop encouraged GIZ to continue its support, which can be considered a turning point for the associated developments made from that time onward.

Inspired by these developments and support from GIZ, WLE, and Africa RISING, the CIAT team continued to push frontiers, mainly expanding engagements and creating awareness toward data access and sharing. Various small and large meetings and workshops were held, which helped to create awareness and fostered collaboration. One of the critical events was the workshop held on 1-2 February 2018, under the theme 'Big Data Analytics and Data Sharing to Transform Ethiopian Agriculture.' The main aim of this workshop was to demonstrate the value of big-data analytics to national stakeholders and justify the need for data access and sharing. Key papers from internationally renowned experts on data access and sharing and big-data analytics were presented, which once more inspired the local scientists and experts to think about the idea of embracing digital solutions in agriculture. One of the key messages of the workshop stated that "the best solutions should be targeted to sectors that need them the most," implying that agriculture has serious complex challenges and should benefit from advancement in Earth observation, artificial intelligence, and other modern technological and analytical options.

A breakthrough during this workshop was the creation of the CoW, a team of experts willing to share data and support the processes of data access and sharing. Within a short time of its formation, more than 25 participants signed up to membership. This was an exciting step and a great achievement as now more than 100 members are supporting data sharing and advanced data analysis. As proven by its increasing membership, the CoW became a recognized professional network that attracted prominent soil and agronomy experts as well as national and international stakeholders within a short time.

CoW - Evolving with mission and objectives

The CoW's ultimate objective is to contribute to the improvement of agricultural productivity in Ethiopia by optimizing access to soil and agronomy data that can be used for decision-making by policymakers, farmers, and other stakeholders of the Ethiopian agricultural sector and providing analytical support. This involves ensuring that agricultural data are accurate, reliable, and found in a standard and interoperable form. The flip side of this mission is developing big-data computing and geospatial analysis capability at home. Enabling the Ethiopian agricultural sector to plug into the global advances in data mining, management, handling, and sharing is concurrent to CoW's objective of improving agricultural decision-making at all levels.

THE STRATEGIC AREAS WHERE COW IS MAKING TANGIBLE CONTRIBUTIONS

FACILITATING ACCESS AND SHARING OF SOIL AND AGRONOMY DATA AMONG STAKEHOLDERS OF THE ETHIOPIAN AGRICULTURAL SECTOR. THIS INCLUDES SUPPORTING THE ESTABLISHMENT OF A LEGAL FRAMEWORK AND DATA INFRASTRUCTURE AS WELL AS DEVELOPING EXPERTISE, SYSTEMS, AND PROCEDURES THAT ACCELERATE DATA MINING, STORAGE, AND SHARING.

INCREASING AWARENESS AN OPEN DATA ACCESS AND SHARING AMONG STAKEHOLDERS OF THE ETHIOPIAN AGRICULTURAL SECTOR. THIS INCLUDES PROMOTING INTRA-INSTITUTIONAL COOPERATION AND INITIATIVES ON OPEN DATA ACCESS AND SHARING.

SHAPING AND SUPPORTING NATIONAL POLICIES, LEGISLATIONS, AND PROGRAMS TOWARD FUNCTIONAL DATA ACCESS AND SHARING.

CAPACITY DEVELOPMENT AND SUPPORTING THE PROFESSIONAL DEVELOPMENT OF MEMBERS.

The CoW Governance

The CoW is a volunteer network of individuals and organizations willing to share and facilitate wider-scale soil and agronomy data access and sharing in Ethiopia and thus does not have a legal jurisdiction. To facilitate its operations and institutionalize its efforts, it was necessary to find a "home" for the coalition. This was of course a key question raised during one of the meetings of CoW members. Recognizing the CoW's efforts and the commitment of national experts to support their country, the EIAR was enthusiastic to host the CoW and to support and sustain its operations. As a result, the CoW will be hosted by the EIAR once formalities are finalized. The EIAR is the mandated government body to collect, organize, and disseminate national agricultural research data. The decision to host the CoW is not only a logical move but also a win-win relationship for the CoW and EIAR.

The EIAR is expected to serve as the central hub of agricultural research data. Furthermore, the EIAR is committed to supporting data access and sharing as constituted by its mandate. Since soil and agronomy data constitute a significant portion of the information needed for an informed agricultural decision, the data shared through the CoW network enrich and expand the EIAR's wealth of data. The members of the CoW drawn from different disciplines add substantial value to enhance the capacity of the EIAR in data analytics and management.

At the same time, CoW members will have legitimate access to data available in the EIAR's data repository. Most opportunely, the CoW's proven experience in data access and sharing at a small or medium scale will serve as a testing ground and springboard for national-level soil and agronomy data-sharing practice, which will later encompass other subsectors of agriculture. GIZ and the Alliance of Bioversity and CIAT will support the computational infrastructure, resources, and skills for big-data management and analytics.

Inception, establishment, and current operations of the CoW are facilitated and coordinated by the Alliance of Bioversity International and CIAT. Members of the CoW are from agriculture-related fields, mainly those in the national and regional research institutes, the Ministry of Agriculture (MoA), and universities. Later, geospatial analysis experts and data scientists in the country joined the CoW, which boosted its efficiency in terms of delivering outcomes. More partners are expected to support the efforts as the quick wins of the CoW have demonstrated flourishing benefits. The architecture of the CoW includes a general assembly (all members of the coalition), a secretariat, and the CoW task force.

The CoW General Assembly

The CoW general assembly consists of all CoW members including both individual and institutional members. The general assembly meets at least twice a year. The responsibilities of the general assembly include but are not limited to guiding the overall direction and strategic focus of the CoW, monitoring the work of its coordination task force, approving CoW action plans, and promoting the CoW in various local, regional, and global platforms. Members of the CoW general assembly are ambassadors representing and promoting the central objectives, mission, and principles of the CoW in their professional and personal endeavors. Members of the CoW also provide professional support when necessary and requested.

The CoW Secretariat

The origin and evolvement of the CoW has been facilitated by CIAT, the EIAR, and GIZ. These three institutions serve as the secretariat body of the CoW. The secretariat oversees the monitoring, evaluation, and reporting processes. The secretariat reports to the general assembly.

The CoW Task Force

Shortly after its formation in 2018, the CoW established a task force that has seven members. This task force is responsible for coordinating and implementing the day-to-day activities of the CoW. It defines strategic entry points (research, development, extension) that CoW members should focus on considering the reality on the ground and assessing emerging situations. The task force reports its progress to the general assembly, which endorses CoW plans, monitors implementation, and provides future directions, and to the task force every three months.

THE COW TASK FORCE WAS GIVEN THE FOLLOWING CORE RESPONSABILITIES

MAPPING
MAP POTENCIAL INSTITUTIONS AND INDIVIDUALS AND WHO USES WHAT KIND OF DATA AND IN WHAT FORMAT.

GUIDELINE
DEVELOP A GUIDELINE THAT CAN FACILITATE DATA ACCESS AND SHARING.

DATABASE
BUILD A CENTRAL SOIL AND AGRONOMY DATABASE.

POLICY
DEVELOP THE RULES AND REGULATIONS (POLICY) RELATED TO DATA ACCESS AND SHARING.

PROMOTE
PROMOTE PARTNERSHIP AND COMMUNICATION AMONG DIFFERENT PARTNERS AND STAKEHOLDERS.

COLLECT
DEVELOP AN INTERVIEW SCRIPT TO GUIDE ACTUAL DATA COLLECTION FROM DIFFERENT PARTNERS. THE "SCRIPT" SHOULD INCLUDE DATA TYPES, SOURCES, FORMAT, AND THE LIKE.

STANDARDIZE
STANDARDIZE SOIL AND AGRONOMY DATA COLLECTION TO FACILITATE ACCESS AND SHARING.

CoW - Membership

Membership in the CoW is voluntary and driven by the shared goal of improving Ethiopia's agricultural productivity through evidence-based and informed agricultural decision-making. Interested parties can join the CoW, free of charge, by submitting a complete membership application form.

CoW - Quick Wins & Achievements

The significant success of the CoW is in demonstrating how national data access and sharing can be implemented and maintain FAIR data principles. In doing so, it has inspired action by national agricultural stakeholders to open data access and sharing practices.

The CoW achieved remarkable results on many fronts within a short time of its establishment. It has driven policy actions toward wider and better practices of data access and sharing in the Ethiopian soil and agronomy field. It has demonstrated how data sharing can make a real-time difference in improving agricultural decisions and practices. It has put in place simple and effective systems and procedures and started the actual practice of data access and sharing among the volunteer individuals and institutions gathered under its objectives. Further, those products that showcase the benefits of data access and sharing have been piloted. The significant progress made toward developing site- and context-specific fertilizer recommendations is one of the many strides the CoW has made since its inception. What makes the achievements even more impressive is that they are all the output of the altruistic engagement of Ethiopian soil and agronomy professionals and data analysts determined to make a positive contribution to their country.

This section briefly describes the main achievements and products of the CoW[4].

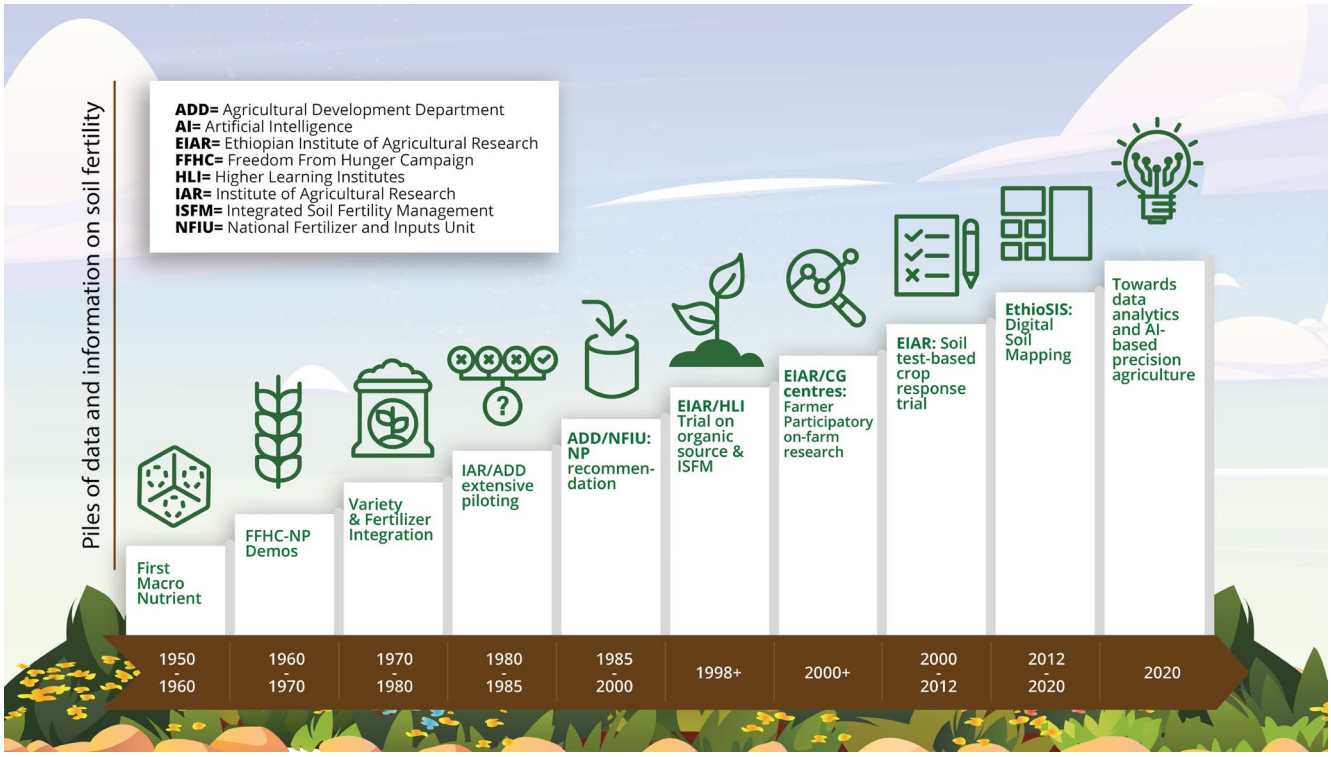
4 Additional information can also be found here: http://cgspace.cgiar.org/handle/10568/111778

Mapping and Characterization of Soil and Agronomy Data

Although soil and agronomy data have been collected in Ethiopia since the 1960s, the data are not available in a standard database. In addition, there is no clear information as to where the datasets are and in what format. This inhibited the efficient use of available data to facilitate data-driven solutions for agriculture. A review by the CoW team showed that 71% of the national datasets are available only in analog format or stored on individual computers, thus risking permanent loss.

The CoW's soil and agronomy data mapping and characterization study evaluated available soil and agronomy datasets according to FAIR data principles. The assessment showed that most of the data fulfill minimal reusability standards and fail to meet the requirements of findability, accessibility, and interoperability.

The availability of existing data and the standardized and systematic collection and storage of new data are the foundation of data access and sharing practices. It is believed that a wealth of soil and agronomy data from years of soil and agronomy research is available in Ethiopia. However, the whereabouts, format, validity, and ownership of these data was not sufficiently known.



Timeline of key events in soil fertility research and development in Ethiopia.

As a result, mapping and characterization of soil and agronomy data and understanding the data ecosystem were priority tasks of the CoW. The identification, cataloging, mapping, and characterization of the soil and agronomy data ecosystem were among the key priorities for obtaining a clear picture of who owns what kinds of data and in what format and assess the level of accessibility of those data. The CoW also aimed at investigating the thematic area, geospatial frame, format, accessibility, interoperability, and ownership

OBSERVATIONS FROM DATA MAPPING AND CHARACTERIZATION STUDY

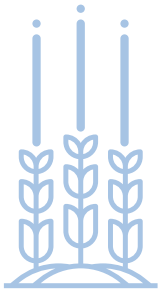
MOST NATIONAL SOIL/AGRONOMY DATA ARE PUBLISHED IN RESEARCH OR PROJECT REPORTS, JOURNALS, ARTICLES, TECHNICAL PAPERS, DISSERTATIONS, AND MAPS.

MOST SOIL/AGRONOMY DATA WERE PUBLISHED FROM 2001 TO 2019.

MOST OF THE DATA FULFILL MINIMAL REUSABILITY STANDARDS AND FAIL TO MEET FAIR DATA PRINCIPLES.

FOR THE AGRONOMY DATASETS, 71% ARE IN ANALOG FORMAT.

GEOREFERENCING SYSTEMS EMPLOY NOTABLE INCONSISTENCIES.



NO STANDARDIZATION AND HARMONIZATION MAKE IT DIFFICULT TO PROVIDE USEFUL INFORMATION.

HALF OF THE NATIONAL SOIL AND AGRONOMY DATA HOLDERS EXPRESSED WILLINGNESS TO SHARE DATA IN THEIR POSSESSION.

of the national soil and agronomy data. The source and features of the existing data were evaluated following FAIR data principles.

The team started its work by mapping the data ecosystem. This meant identifying who had what data and in what format[5]. Creating awareness about the need for data access and sharing was a pressing priority that needed to be addressed.

The study revealed that soil and agronomy data collected by various entities in Ethiopia since the 1960s are scattered in various organizations and are available in dissimilar formats. A bulk of soil and agronomy data has been located and mapped from research or development projects as well as watershed and sub-basin-based studies. Most of the national soil and agronomy data are published in research or project reports, journal articles, technical papers, dissertations, and maps.

The chronological status of the national soil and agronomy data spans from the 1950s to 2018. However, most data were published from 2001 to 2019. In most publications, the year of data acquisitionis not clearly defined. This means that the time of data collection and publication year can vary greatly, which can affect data integration during analysis.

It was observed that many of the research-based soil and agronomy data were officially published some years after the research was completed. This raises the concern that some publications may not be based on up-to-date data given the steadily changing soil and agronomy landscape. When evaluated in terms of FAIR data principles, most of the data fulfill minimal reusability standards and fail to meet the requirements of findability, accessibility, and interoperability.

About 71% of data are in analog format and the data available in digital format are mostly stored in standalone office or personal computers, and most of the data lack metadata or a catalog. Inconsistency in georeferencing is another major trait of the available data assets. Although a considerable amount of data is georeferenced, the systems employed are not consistent. Similarly, most on-station and on-farm research-based data are not properly georeferenced.

The soil and agronomy data that are somehow accessible are not standardized and harmonized, making it difficult to provide the information users need. Inaccessibility and lack of standardization and harmonization led to the collection redundant data and duplication of efforts.

Half of the national soil and agronomy data holders expressed willingness to share the data in their possession. However, accessibility and usability of these data proved to be difficult because of poor data management practices.

The data mapping and characterization exercise clearly revealed that the lack of national soil and agronomy metadata and lack of a functional soil database are major impediments in making important data accessible to advance evidence-based solutions for Ethiopia's agriculture. National capacity to systematically collect, store, and share data is limited and a strategic approach is lacking. The study recommended that institutions using public money to generate data need to be encouraged to establish an institutional data repository and share data timely with a nationally mandated public body. This would facilitate data access and avoid duplication of efforts and resource misuse.

Based on the analysis of the existing soil and agronomy data mapping and characterization exercise, the following key recommendations and measures are forwarded toward establishing a functional national soil and agronomy database:

- Support awareness creation campaign on soil and agronomy data sharing

5 https://hdl.handle.net/10568/110868

- Support the establishment of a functional national soil and agronomy database to facilitate data-driven solutions
- Facilitate the standardization and harmonization of soil and agronomy data through the development of guidelines and a data repository.

CoW - Internal Data-Sharing Guideline

After taking stock of the available soil and agronomy data, the CoW task force developed an internal data-sharing guideline for use by its members. In addition to paving the way for data sharing among CoW members, the guideline encouraged more soil and agronomy professionals to join the CoW.

Embarking on the age of digital agriculture depends on access to accurate and relevant agricultural data. Sharing data within the whole spectrum of agricultural stakeholders requires certain principles and procedures. Fairness, transparency, ownership, benefits, roles, and responsibilities, etc. need to be crafted and agreed upon among those in the data-sharing loop. Having a guideline outlining agreed data-sharing principles and procedures establishes trust and professionalism among actors and provides incentives that further encourage data to be shared.

Lack of a data-sharing guideline is one of the obstacles in building an agricultural data repository that can support big-data analytics in Ethiopia. Cognizant of this major barrier and affirming that data sharing should be governed by fair and transparent rules, the CoW has developed the first data access and sharing guideline to govern data sharing and access among its members. Lessons from international trends and practices were used to develop the CoW data-sharing guideline. These experiences were customized toward local contexts, challenges, and opportunities to deliver an effective and efficient instrument that will accelerate data access and sharing.

The development of the guideline was a consultative process led by the CoW task force. CoW members discussed, enriched, and refined the guideline through consultation and validation workshops. The guideline was endorsed by the CoW general assembly in October 2019 and has been distributed to members and put to use by the members. The guideline is unique as it is developed and applied in a context in which no national regulations govern data access and sharing in the Ethiopian agricultural sector.

The guideline (https://hdl.handle.net/10568/107988) addressed a wide range of topics pertinent to data sharing, including data security, privacy, data protection, intellectual property, and data-sharing incentives. Roles and responsibilities in collecting, sharing, and accessing agricultural data that are/will be stored in the CoW database are also detailed and clarified. Data infrastructure as well as access and sharing prerequisites are outlined in the guideline.

Shaping the National Soil and Agronomy Data-Sharing Policy

The launching of the national soil and agronomy data-sharing policy is a breakthrough in transitioning Ethiopia into the age of data-driven agriculture. This policy is the first step in a series of actions toward optimizing agricultural decisions based on accessible and reliable data.

By showcasing the need for and possibility of fair and transparent data access and sharing, the CoW has influenced national action that will change the course of agricultural research and its role in Ethiopia. The CoW's initiative and persistent efforts placed the data-sharing and access agenda at the center of Ethiopia's agricultural development discourse. One of the critical impacts of the data-sharing guideline is the inspirational role it played in encouraging the Ministry of Agriculture (MoA) to constitute its national task force to support the development of a national soil and agronomy data-sharing policy. In 2018, the MoA established a national task force to spearhead the process. The majority of the task force was constituted from the CoW task force members to draw on their lessons and experiences. Embedding key members of the CoW task force within the national task force facilitated sharing experiences and lessons. CoW members vigorously contributed throughout the open and collaborative process of crafting the policy. The national task force outlined steps for the development of the national data-sharing policy. The first effort was to review national and global experiences. Through this exploration, the task force and GIZ engaged CABI and the Open Data Institute (ODI) to support developing the policy. CABI and ODI facilitated consultation processes with CoW members and other national partners, which led to the drafting of the soil and agronomy data sharing policy. The draft policy was enriched through a multistage consultative process that engaged diverse stakeholders.

After iterative revisions and improvements, the national soil and agronomy data-sharing policy was officially launched in June 2019. This was a breakthrough in transitioning Ethiopia into the age of data-driven agriculture. The policy is an overarching framework that regulates fair and transparent soil and agronomy data sharing and access in Ethiopia. The policy aims at generating and amplifying data-driven value across the economy and society of Ethiopia. In doing so, it will contribute to increased agricultural productivity while maintaining soil health and sustainable agricultural practices. By enabling fair and transparent soil and agronomy data sharing, the policy will:

- Increase the availability and sharing of soil and agronomy data coherent with FAIR data principles
- Ensure optimum actionable use of available data
- Prevent duplication of efforts and waste of resources in data collection
- Promote data-driven digital and modern agriculture in Ethiopia.

The soil and agronomy data-sharing policy is the first step in a series of actions toward optimizing agricultural decisions based on accessible and reliable data. Having its roots in the soil and agronomy domain, the successful implementation of this policy will encourage similar practices in other subsectors of agriculture. From contributing to the policy dialogue to creating awareness on data accessibility to linking existing datasets to enhance big-data capability, the CoW continues to play a fundamental role in the popularization and implementation of the policy.

Steps are now underway to enact the policy and to start its implementation. Awareness creation and trainings will be organized to make sure that the soil and agronomy research and development community has buy-in and supports implementation of the policy. In addition, steps will be taken to make the national data-sharing policy a norm and new normal. The CoW, its task force members, the Alliance of Bioversity and CIAT, GIZ and other partners will continue to support this endeavor as it will significantly change the soil and agronomy research and development landscape in the country and beyond.

Standardization of Soil and Agronomy Data Collection and Laboratory Analysis

With more than 100 CoW members committed to applying the soil and agronomy data collection and laboratory analysis standards developed by the CoW, a critical mass of users is already guaranteed, thus giving the guidelines prominence.

Interoperability of data is a fundamental challenge in the big-data landscape that undermines data-sharing efforts and hinders the optimum use of available data. Different people and organizations collect data using dissimilar and non-compatible methods and formats. The variation in methods, approaches, standards, etc. is employed in the laboratory analysis stage. The soil and agronomy data mapping and characterization exercise has witnessed this gap and challenge.

The use of different data collection and laboratory analysis approaches poses a conspicuous impediment to the interoperability of data and thus inhibits the efforts to build a big-data platform that allows complex multivariable analysis. In addition, analysis of data collected using various methods and standards can lead to inaccurate results. Reaping the benefits of big-data analysis in agriculture depends on standardizing data at different stages of the collection and analysis process. Data standardizing should generally start from the collection phase. Standardizing already collected data is a daunting task that consumes sizable resources and time.

Activities conducted to train some of the CoW members on advanced data analysis using agronomy soil and agronomy data they collected demonstrated the serious challenge of non-standardized data collection and laboratory analysis as it took the team of data scientists a great deal of time to "prepare" the data and make it ready for analysis.

The problem was recognized in Ethiopia over decades ago, but little effort was made to address it. The CoW's response to this problem was a pragmatic one that capitalized on the will of its members to harmonize standardization efforts and build a big-data platform. Determined to offer solutions to a half-century-old problem of data standardization, the CoW has produced national data standardization guidelines in six thematic areas of soil and agronomy[6].

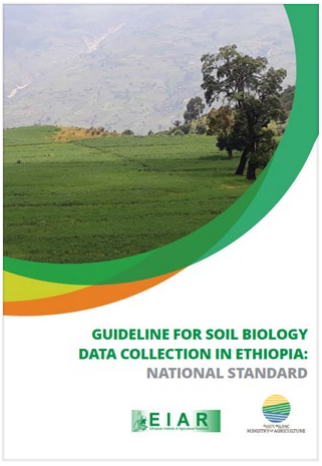
THEMATIC AREAS OF SOIL AND AGRONOMY DATA STANDARDIZATION GUIDELINES

- AGRONOMY AND SOIL FERTILITY
- SOIL SURVEY AND CHARACTERIZATION
- AGRICULTURAL WATER MANAGEMENT
- SOIL MICROBIOLOGY
- LABORATORY ANALYSIS (SOIL, WATER, AND PLANT TISSUE)
- INTEGRATED WATERSHED MANAGEMENT

Senior national experts were identified for each team to work on the guidelines. Each team consisted of three to five members, with one lead and an overall coordinator of the technical experts. The box above shows the themes for which standardization guidelines were developed. A write-shop was organized for the team to develop the respective guidelines. Each team worked for about a week tirelessly to develop comprehensive draft guidelines. The draft guidelines were then presented at a national workshop for comments, suggestions, and improvements. These provided critical inputs for the respective experts. After the comments were incorporated, the guidelines were thoroughly reviewed by independent reviewers. As of September 2020, two of the guidelines had already been published and two were ready for publication. The remaining two were undergoing improvement.

Although there is a need to develop standardization guidelines for the entire agricultural sector, the six thematic areas were prioritized by CoW members as vital. These guidelines are linked with the Soil and Agronomy Data Sharing (SADS) policy implementation guide and are expected to be used by future soil data creators and users in Ethiopia.

The CoW recognizes that standardization is a continuous process and requires stakeholder coordination. The failure of previous standardization efforts is partly attributed to the lack of a consultative and transparent process. In the absence of legal frameworks that make them mandatory, the use of soil and agronomy standards heavily depends on their benefit, simplicity



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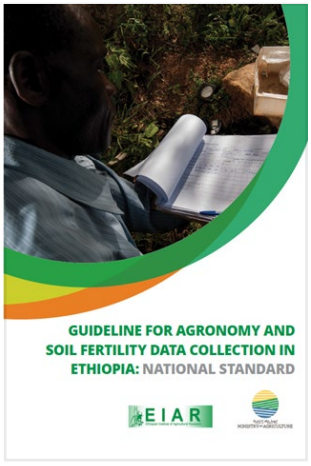

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6 Examples include *the Guideline for Soil Biology Data Collection in Ethiopia: National Standard* and *Guideline for Agronomy and Soil Fertility Data Collection in Ethiopia: National Standard.*

of use, as well as the inclusiveness of the process with which they were created. The six guidelines have a stronger probability of being used as they were developed by CoW members in a series of write-shops. The developers are specialists in the topics as well as primary users of the guidelines. With more than 100 members committed to applying these standards in the collection and analysis of their data, the CoW has already created a critical mass of users that will give the guidelines prominence. Data creators from the national and regional research institutes and data collectors of GIZ on-farm demonstration plots were trained on the use of the guidelines. The guideline is already widely used in research proposal development. This will have a snowball effect embracing more and more users applying the standards. The national adoption of the six guidelines is also a plausible scenario that has the potential to transform soil and agronomy data collection and laboratory analysis.

Building National Data Analytic Capacity

The CoW is spearheading the effort to apply advanced geospatial analysis and modeling tools to optimize decision-making in diverse areas of agriculture in Ethiopia. This initiative, driven by the optimism, determination, and skills of Ethiopian geospatial professionals, marks a new era for Ethiopian agriculture, for which the enormous gains of geospatial technologies are utilized.

Advances in Earth observation sciences, data management, and handling options as well as data-mining techniques enable exploring patterns that would not have been possible a few decades ago. Although the agricultural sector has benefited least from this fast development compared with other sectors, recognizable advances are being made, especially in developed regions. However, it is important to understand that new technologies, tools, and techniques should be applied in places where they are needed the most: developing regions. One approach to achieve this could be by facilitating data organization, management, access, and sharing mechanisms so that time and resources will be used effectively and efficiently. In this regard, the CoW team has made great strides in acquiring soil and agronomy data and has facilitated the creation of a database. The question then was what to do with the data.

Regarding this question, the CoW organized two training sessions for members of the coalition who shared data. The purpose was to build the capacity of the members and create an incentive for data sharing by developing papers for publication. In addition, the session was designed to conduct data analysis using advanced techniques and use the results as input for the development of a fertilizer recommendation tool.

The training participants included CoW members from the EIAR and regional agricultural research institutes (RARIs), mainly those who had shared data and were interested in participating in the training. The trainings were organized in the form of a write-shop in which the team of experts harmonized and analyzed data and developed scientific papers for publication. The first training lasted for five days and focused on data cleaning, harmonization, preparation and data analysis. The event was also used to discuss and agree on the content and structure of papers that come out of the exercise. The second event built on the first one and focused on detailed analysis and write-ups.

The two sessions combined generated great results and experience sharing among the team members. The sessions also resulted in the development of eight papers for publication.

The training was organized such that the trainers walked the participants through the step-by-step process of organizing data, cleaning, and querying. The participants were introduced to approaches on how to derive more informative indices such as nutrient-use efficiency (NUE), rain-use efficiency (RUE), and returns to investment in fertilizer, including value-cost ratio (VCR), benefit-cost ratio (BCR), and marginal rate of return (MRR). Then, the basic principles and practices of data analysis, including options for normal ANOVA designs, analysis of multi-site and multi-year data, and nutrient dose-response

modeling, were introduced, along with tips on selecting the correct statistical approach for analysis.

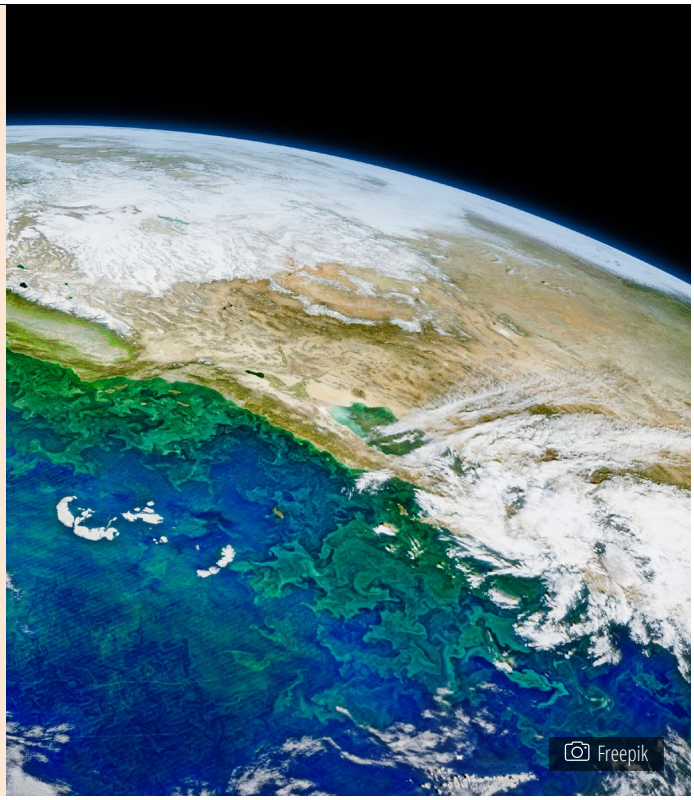
In addition, statistical packages were introduced to the participants. Since most participants were new to R, a short training session walked the participants step by step through data management and analysis in R. Essential R codes were provided and the participants received hands-on training on running R codes. This was followed by an explanation of the various outputs and practical data analysis and interpretation, including the application of statistical software involving SAS, STATISTIX, and R.

In total, four crops (wheat, barley, maize, and teff) had cleaned and complete datasets. Each dataset was accompanied by grain and biomass yield, soil type, agroecological zone, GPS coordinates, altitude, soil organic carbon content, and pH.

The key lesson from this write-shop and review of the draft manuscripts was the need for continuous training for national researchers on data preparation and data analysis as well as writing scientific papers. With further training, coaching, and continued support, it was possible to produce high-quality papers. These papers, along with other selected ones, will be published in the *Journal of Experimental Agriculture* as a Special Issue.

Enhancing Geospatial Analysis Capacity and Establishing a Community of Practice

With hundreds of observation satellites in orbit covering Earth from every angle, it is now possible to obtain precise information about any location on Earth with relative ease. By boosting our geospatial analysis capacity to make use of location-specific information, we can transform Ethiopian agriculture for the better.



In today's increasingly digitized world, a wide range of technologies and tools are offered by curious innovators to help in optimizing decision-making. Geospatial analysis and modeling tools capture a fair share of the innovations. Advanced technologies in geospatial science not only save time and cost in farming but can also transform agriculture by providing accurate location- and context-specific information for quick analysis.

Geospatial analysis complemented with big data analytics is playing a critical role in making advanced decisions by the private and public sectors worldwide. An increasing number of public and private businesses and services have embraced the use of digital technology to optimize their decision-making. Despite the proven benefits of decision-aiding technologies and their accessibility, they are the least used in agriculture. This is the case not only in Ethiopia but also in the developed world.

With hundreds of observation satellites covering Earth from every angle, it is now possible to obtain precise information about any location on Earth with relative ease.

CASE STUDY 3
CoW Building Data Analysis Capacities
Data Analysis of Crop Response to Fertilizer Application

CoW has stepped into demonstrating tangible results of soil and agronomy data sharing and analytics to draw specific recommendations. CoW held a training and write-shop session to enhance the data analytics capacities of members and to apply data-analytics to generate decision-making information.

Objective

To derive ex-ante site-specific input quantity recommendations that achieve profit maximization in each specific location within a country.

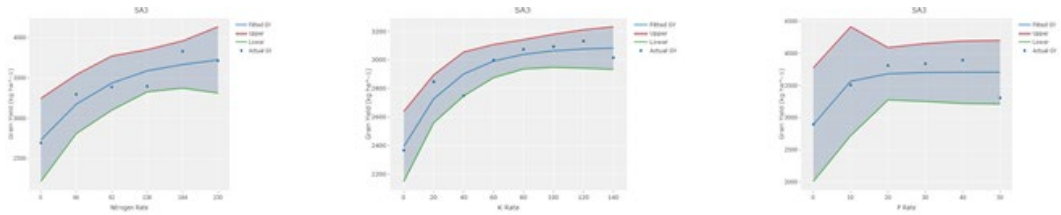
Approach

CoW members analyzed data available from members, EIAR, and generated from literature review to demonstrate the crop response to fertilizer application of four selected crops. A yield probability map for specific fertilizer application rates was developed through advanced analysis of data pooled and shared via CoW. The team used various machine learning (particularly Random Forest) approaches to predict yield by using spatially varying model coefficients – the parameters of the response function are specified to change continuously with those site variables.

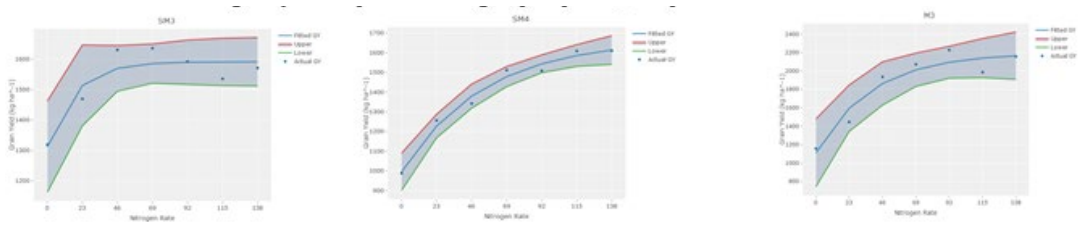
1. The analysis has established that the yield response to fertilizer application varies spatially with the site characteristic variables such as soil, water, topography, weather, and other factors.
2. The first wheat probability map with nitrogen (N) fertilizer application at a fixed rate of 60kg/ha (Figure 2) has been produced using the above steps.
3. The exercise provided a great experience exchange and learning opportunity for CoW members building their big-data analytics capacity.
4. The benefits and application of soil and agronomy data sharing to inform agricultural decisions were practiced and demonstrated in action.

Crop Response to Fertilizer Application

Maize grain yield response to nitrogen, phosphorus, and potassium rates



Teff grain yield response to nitrogen rates in different agro-ecological zones



In Ethiopia, with the launching of the soil and agronomy data policy, the CoW's effort to create a national soil and agronomy database as well as strides made in data standardization created favorable conditions for the availability of big data in the area of soil and agronomy. With the launching of Ethiopia's first Earth observation satellite (ETRRS_1) into space, the possibility of obtaining more data is even greater. Proper use of this wealth of data requires advanced geospatial analytical capacity.

Geospatial Experts Knowledge Sharing Platform

LAND SUITABILITY/ CAPABILITY ANALYSIS

MAPPING ACTUAL AND POTENTIAL IRRIGATION PRACTICES AND/OR SCHEMES

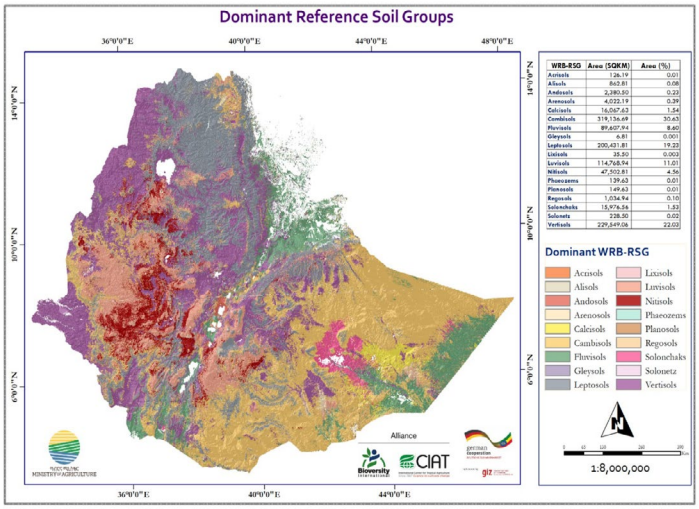
RECOMMENDATION DOMAIN TO FACILITATE TARGETING AND SCALING INTERVENTIONS

CROP YIELD ESTIMATION USING EARTH OBSERVATION DATA

KNOWLEDGE MANAGEMENT

Without qualified geospatial analysts, using big data to plan, target, and scale location-specific agricultural interventions is a futile effort. An important contribution of the CoW on this front was the launching of an experts' forum on geospatial analysis in June 2019. This forum brought together about 50 geospatial experts for the CoW to take stock of their expertise in modeling and geospatial analysis in the country and assess their level of engagement in the agricultural sector. Potentials and gaps in spatial data, database management, analysis, and modeling were also analyzed by this group of Ethiopian experts that came together under the umbrella of the CoW.

The experts' group established a community of practice around five prioritized and prominent issues of national importance that can benefit from solutions offered by geospatial analysis and modeling. The teams were tasked to employ analysis and modeling tools to generate location-specific information that could be used by agricultural decision makers. The teams consisted of professionals from government institutions, universities, research centers, and the private sector. They worked intensively and delivered products on five topics that are believed to be priority areas for intervention. The success of this initiative is instrumental in spearheading an increased use of advanced geospatial analysis and modeling tools to optimize decision-making in diverse fields of agriculture in Ethiopia. This initiative, driven by the optimism, determination, and skills of Ethiopian geospatial professionals, marks a new era for Ethiopian agriculture in which the enormous gains of geospatial technologies are used.



Digital soil resource map of Ethiopia.

In addition, the geospatial team is engaged in the development of a high-resolution Digital Soil Map and Soil ATLAS using the soil survey data collated by CoW. Under the leadership of the Soil Resource Information and Mapping Directorate of MoA, cleaning and harmonization of the data using standard templates and geospatial modeling is well underway. Over 17,000 soil profile data together with relevant covariates are used to develop the soil map using a machine learning approach. Compared to the currently used soil resource map, which was developed based on less than 2,000 profile data, this is a quantum leap in the soils research and development history of the country.

Design and Launch of Web-Portal and User Interface

Equipped with a web portal and user interface that is fit to purpose, the CoW is now advancing to new frontiers of effective and efficient data sharing and access in the Ethiopian Soil and agronomy landscape.

Having a functional and user-friendly web portal is essential to effectively delivering on CoW's objective of facilitating soil and agronomy data access and sharing. Recognizing the limitations of the database initially established and used by the EIAR and CoW, a significant overhaul was needed to bring the data base a standard that can accommodate CoW's current and future needs. Accordingly, the CoW taskforce recommended the development of a database with web-portal and visualization interface. A ToR was developed detailing the contents of the portal and associated attributes. The ToR was reviewed by experts from the Alliance. With financial support of GIZ, the CoW task force engaged an experienced national consultant to develop the web-portal. The consultant was asked to review and identify a state-of-the-art system that is flexible enough to ensure compatibility with other databases and portals. Based on the review and consultation with experts, the consulting firm has identified and recommended Dataverse for the CoW purpose. A web portal that can list, capture and showcase all relevant and useful datasets including geospatial and multimedia data was then developed and deployed at the EIAR. The system is built based on an open-source software platform maintained by Harvard (https://dataverse.org/).

The Dataverse framework has strong community of support across the globe and is customized in different countries and organizations. The portal developed for CoW has various functionalities and features including user interface, data exploration and visualization options, data quality control, licensing and permission features, user registration, search and visualization function, and the likes. It also supports multiple data type uploading and downloading. The portal will be up and running once the IP configuration is finalized. It will also be populated with the CoW data.

In 2020, the Coalition of the Willing developed and launched a national geospatial experts knowledge sharing and collaboration platform. The main purpose of this virtual platform is fostering communication and exchange of information among the Ethiopian geospatial community. The platform creates a landing page where members can connect with peers and share information and update on their current engagement in GIS/RS activities. The platform is an ideal place to get relevant information, notification and updates on new and ongoing and new geospatial activities in Ethiopia. Members can support in their professional engagement and access tasks assigned to them by the forum. Another value of the geospatial knowledge sharing and collaboration platform is increasing awareness on the use and impacts of geospatial information in agriculture.

Some of the projects envisaged through the collaboration platform are digital atlas building and creating geo-data repository for voluntary data submission by members.

A support forum for researchers and students, online document sharing and editing tools, as well as access to ESRI's ArcMap modeling tools are among the features of the platform.

To learn more about the Ethiopian geospatial knowledge sharing and collaboration platform, visit http://geoscow.org.et

CoW - Partnerships for Promoting Data Access and Sharing

Achieving the desirable level of data sharing and building an open data culture call for partnership among individual and institutional stakeholders with different roles to play.

Partnership with the Ministry of Science and Higher Education

Achieving the desirable level of data sharing and building an open data culture call for partnership among individual and institutional stakeholders with different roles to play. In the process of supporting the soil and agronomy data access and sharing policy, the CoW task force has reviewed local and international practices of data access and sharing. This review identified an important initiative by the Ministry of Science and Higher Education (MOSHE) that has already resulted in the development and implementation of an Open Data Access and Sharing Policy for Ethiopia's higher education sector.

Representatives from MOSHE, the Ministry of Agriculture, CIAT, and GIZ met to discuss and share experiences. The deliberation highlighted several similarities in the approach as well as the process of delivering the policies:

- The root of both policies is the initiatives of volunteers that are committed to bringing positive impact in their respective professional area.
- In both cases, a series of unofficial discussions and consultations was implemented to create awareness on the importance of data access and sharing.
- The initiators of both policies opted for implementing projects showcasing the benefits of data sharing to create and increase appeal on the topic.
- Different levels of consultations were necessary in the development of both policies.
- Experiences of different countries and institutions were explored to draw lessons and benchmarks for the policies.
- The need for champions that promote open data is acknowledged by both institutions. Addis Ababa University used champions that use their platform and experience to advance the topic. The champion of the MoA policy is the Coalition of the Willing. This has indicated the need for identifying more individual champions to promote the endorsement and implementation of the MoA's data access and sharing policy.

Technical and strategic areas of collaboration between the CoW and MOSHE were defined. At a technical level, the collaboration aimed at promoting data sharing and exchange between MOSHE and the MoA/CoW and building interoperable data-sharing tools capitalizing on AAU's capacity and experience in developing data infrastructure and training. Studying new ways of data use for impact in agriculture such as precision agriculture using existing data and building applications on top of data portals that support simple visualization of data for everyday users are additional fields of the technical collaboration.

Partnership with National Artificial Intelligence Experts

More than 70% of the population of Ethiopia is below the age of 30, most of which are relatively well educated. Experiences also show that youth in general and women in particular are less engaged in domains related to agriculture, livelihoods, and conservation (ALC) because of the limited rewards, the traditional way of doing business, and low profitability. This represents a serious threat to agricultural productivity with serious and negative economic consequences in the long run.

On the other hand, the young generation is heavily engaged in and is contributing to the advancement of digital technologies, mainly related to robotics, computing, engineering, and medical sciences. Like most young people in the world, Ethiopian youth are inclined and attracted to technologies. Considering the recent digital transformation in the areas of remote sensing, geographic information systems, data mining, and artificial intelligence, an opportunity exists to support transforming the country's agriculture (embracing technology-based digital agriculture) and attracting the large youth workforce toward it.

The CoW has partnered with iCog lab, a national artificial intelligence experts' team, to embed IT-

related advances in agriculture, environmental monitoring, and biodiversity conservation as a tool for attracting youth toward the ALC sector. Young women are the priority targets of the project. Six young women recruited by the iCog team and who are conversant in programming work with the CIAT team to apply Earth observation and IT technologies to tackle conservation-related challenges. In this exercise, the young women will gain knowledge and experience in ALC and environmental management as well as the application of IT technologies to solve ALC- and environment-related problems.

By piloting and supporting the integration of IT-related technologies with Earth observation and geospatial analysis techniques to solve real problems, the CoW and its partners are paving the way for the sustainable engagement of Ethiopian youth, particularly women, in ALC activities.

The CoW has Transcended Boundaries! Offering Data-Driven Solutions to Target Covid-19 Mass Testing and Isolation

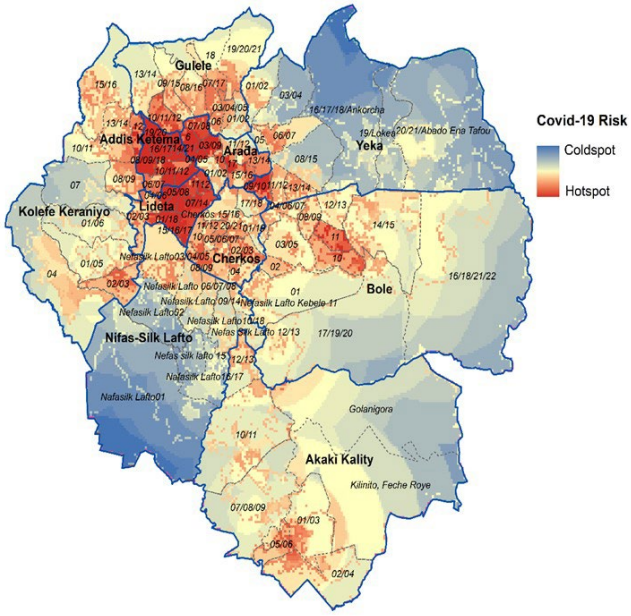
"Data are key to providing evidence-based solutions to various challenges, including emergencies such as the COVID-19 pandemic. Access to data was fundamental in supporting the Ethiopian government's COVID-19 response. The CoW's relentless efforts in formulating and implementing solutions to data-sharing bottlenecks proved to be essential in the effort to curb the spread of COVID-19 in Ethiopia."

Dr. Lulseged Tamene, Senior Scientist at the Alliance of Bioversity International and CIAT.

Since its formation, the CoW has been continuously evolving, anchoring its relevance and expanding its scope. The idea of bringing geospatial experts and data scientists into the coalition was a great initiative because this enabled the CoW to embark on new areas and spheres of influence. With the addition of new "bread" onto the team, the CoW transitioned toward contributing to emerging concerns beyond soil and agronomy. One emerging problem that the CoW team collaborated in to confront is COVID-19! Since it was first reported on 31 December 2019, COVID-19 has spread globally, entering almost all the countries of the world. The Government of Ethiopia under the Ministry of Health (MoH) is undertaking exemplary measures to tackle COVID-19, to both contain its spread and minimize its associated impacts.

Parallel to the standard measures of COVID-19 prevention, increasing the reach and speed of testing to identify

Hotspot areas of COVID-19 vulnerability in Addis Ababa



Hotspot areas of COVID-19 vulnerability in Addis Ababa show places where testing should be prioritized. The map is relevant to October 2020.

potential spreaders and isolate them to contain further spread is essential. Accordingly, the MoH is expanding its testing centers across the country and the number of tests per day has increased. However, the country has limited human and financial resources to test as large a number of people as possible. It is also operationally impossible to test everybody in the country. To minimize the cost of testing and make effective use of the country's human and economic resources, a framework was developed to undertake "bulk sampling." This means creating a composite of samples, testing those composites, and conducting more detailed analysis of the composites that have tested positive.

The CoW has partnered with the MoH, ILRI, the Alliance of Bioversity International and CIAT, and national institutes, including AHRI, EIAR, the Water and Land Resource Center (WLRC), and Addis Ababa University (AAU), to support the government's COVID-19 response. By availing of its data-sharing and geospatial analysis capabilities, the CoW is uniquely positioned in this highly valuable national effort. The support for the MoH mainly focuses on identifying and mapping potential hotspot areas and communities that require priority testing using geospatial analysis techniques. This exercise focused on Addis Ababa, the national COVID-19 hotspot.

After the mapping, hotspot areas that were likely to be susceptible to virus spread and areas at higher risk than others were identified and recommended for priority testing.

The availability of good-quality data was a major challenge in this exercise, proving once again the importance and relevance of the CoW's work. The team was able to overcome this challenge by building on the CoW's expertise in data access and sharing.

The first results of this partnership were presented to the MoH. While the analysis and results are based on data from secondary sources, which limits their level of accuracy, the results can provide overall guidance as to where limited resources might be focused during the fight against the pandemic. With more datasets and fine-tuning of the variables used in this analysis, there is a possibility to improve the overall quality and applicability. This approach is automated and can easily be updated as well as scaled to other parts of the country.

The Future of the CoW: Bigger, Stronger, Bolder, and Fit to Purpose

The CoW will continue to pursue local, regional, and global partnerships toward powering data-driven solutions for agricultural decision-making.

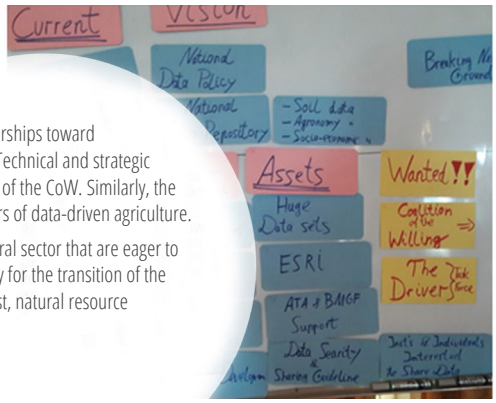
The CoW has achieved remarkable results within a short time since its formation. The key to the successful engagement of the CoW is its relevance for Ethiopian soil and agronomy stakeholders. The CoW approached old and complicated problems of the sector with pragmatic and well-sequenced interventions that appealed to individual professionals and institutions looking for simple and forward-looking solutions. Its increasing acceptance and popularity are driven by its timely agenda of powering data-driven solutions for Ethiopian agriculture. The CoW's carefully selected interventions have been highly effective in unclogging the path to data-driven agriculture with simple, cost-effective, and practical steps.

Going forward, the CoW will continue to advocate for open data sharing in the agricultural sector. Popularizing the national soil and agronomy data-sharing policy and supporting its implementation will remain the priority agenda of the CoW. Another major ongoing task is the building of a national data repository that will be managed by the Ethiopian Institute of Agricultural Research. Once this database is completed, CoW members will start migrating data to the repository. In the future, the CoW data repository will serve more stakeholders that support the data-sharing principles and values of the CoW, thus laying the foundation for a national agricultural data repository.

Developing a national fertilizer recommendation tool is another major project of the CoW. This dynamic decision support tool will save costs and maximize productivity by providing farmers with accurate information on the type and quantity of fertilizer they should apply for each homogeneous agroecological zone. This product will change the uneconomical and unsustainable trend of blanket fertilizer recommendations that has been the norm

in past decades. The CoW will continue to work on other actionable tools that will guide proper crop management such as disease surveillance and an early warning system. In this regard, the fertilizer decision support tool will be integrated with the existing agro-advisory and wheat rust disease surveillance tool to provide integrated advisories. These will also be linked with climate-smart agriculture and resource management packages. Ultimately, these packages can be tailored to address gender and youth dimensions.

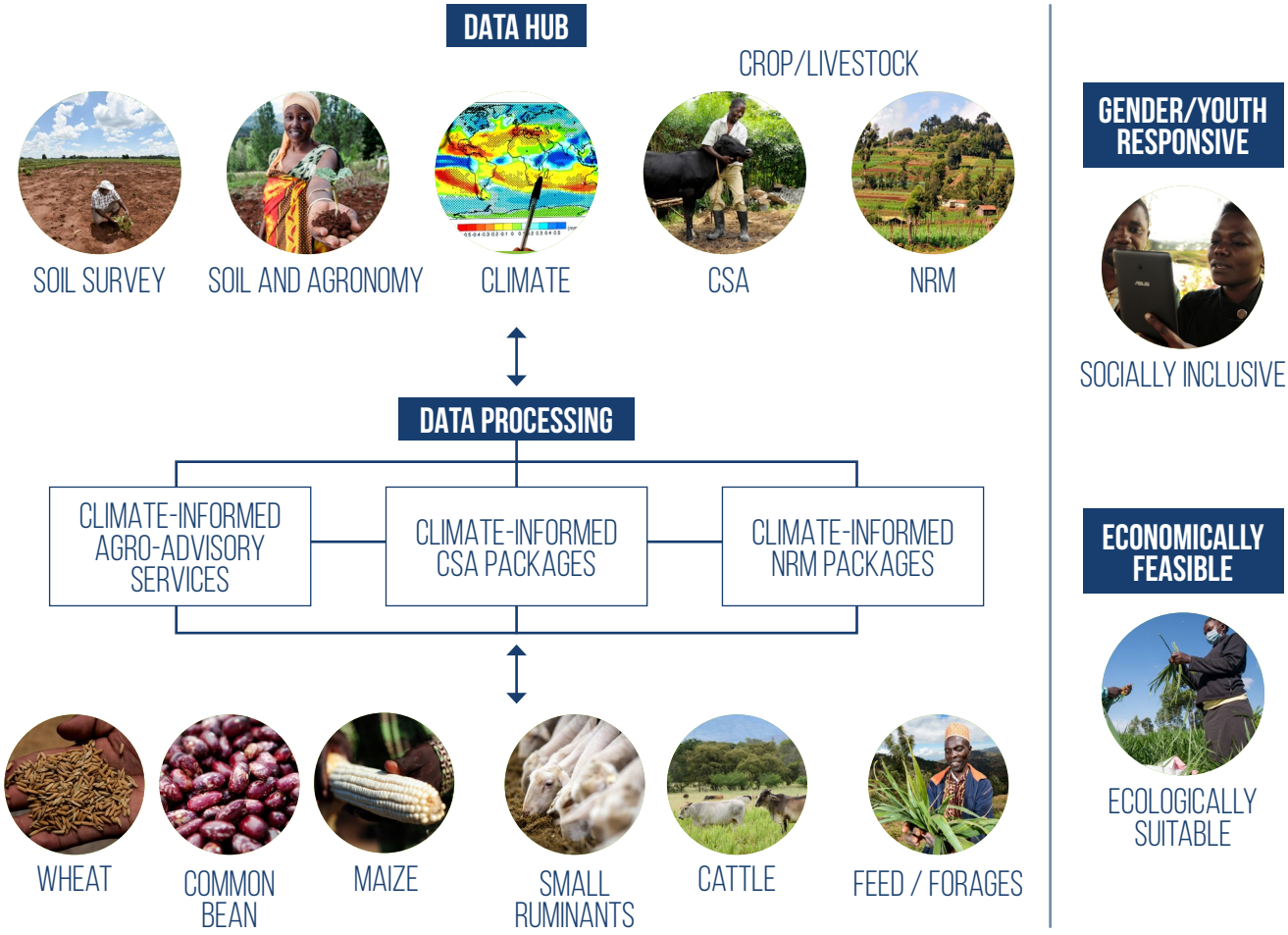
The CoW will support the strengthening of the linkages between the research-extension and farmers to enhance the flow of information, knowledge and feedback so that the agricultural advisory services are relevant and iteratively refined. While the Extension Directorate of MoA is working on strengthening of the linkage system in collaboration with its partners, the improved linkage system will be tested using the digital and analogue agricultural advisory services emerging from the geo-spatial modeling team of the CoW that is working on fertilizer decision support tool.



The CoW will continue to pursue local, regional and global partnerships toward powering data-driven solutions for agricultural decision-making. Technical and strategic collaboration with existing partners will be one of the focus areas of the CoW. Similarly, the CoW will actively seek new partnerships that will push the frontiers of data-driven agriculture.

The success of the CoW is attracting major players of the agricultural sector that are eager to reap the benefits of data-driven agriculture. This will pave the way for the transition of the CoW to all areas of agricultural data such as water, livestock, forest, natural resource management and other sectors.

A recently World Bank-funded project called Accelerating Impact of CGIAR Climate Research in Africa (AICCRA), for example, will build on the lessons and excrescences of the CoW towards building a national agriculture data hub.



Become a CoW member!

Join the data-sharing movement and the transition to data-driven agriculture.

Are you an agricultural expert?

Please join us by becoming a CoW member. We welcome you to the growing family of soil and agronomy data-sharing professions. CoW membership is a winning engagement that will benefit your company, organization, or business as well as your professional advancement through the fair and transparent sharing of and access to data.

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Alliance

Bioversity International and the International Center for Tropical Agriculture (CIAT) are part of CGIAR, a global research partnership for a food-secure future.

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