IFDC

Developing Agriculture from the Ground Up

STRATEGY 2020–2030

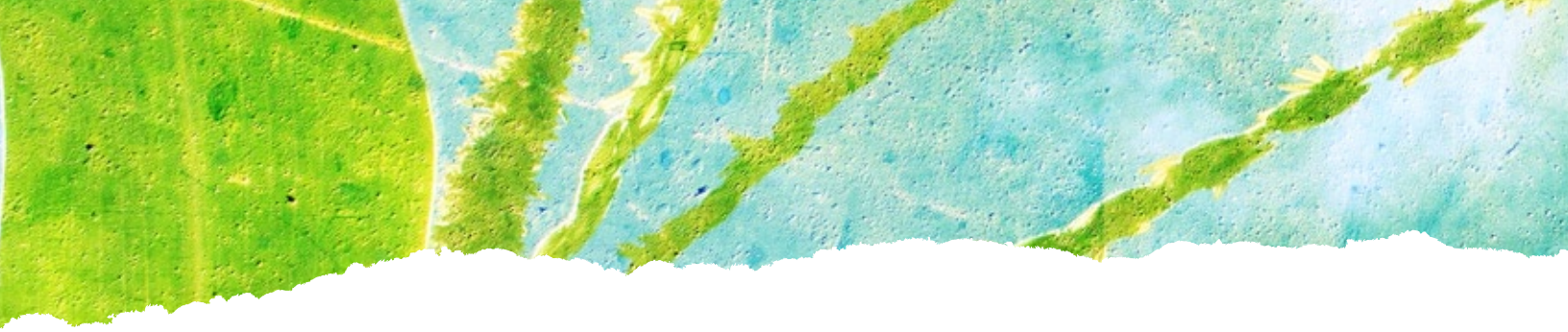


TABLE OF CONTENTS

FOREWORD

Fundamental changes in our global agricultural systems are urgently required if we want to increase production to feed a growing population while dramatically reducing agriculture's environmental impact. Improving soil health and plant nutrition lies at the very heart of this great challenge. Plant nutrition is key to increasing crop yields, but excess nutrient runoff from current nitrogen, phosphate, and potassium (NPK) fertilizers is now a major factor in the declining health of the world's oceans and waterways. In addition, losses from N fertilizers contribute to greenhouse gas emissions. It is also clear that NPK fertilizers alone cannot meet the broader nutrition and management requirements of degraded soils.

IFDC is well-positioned to take on these critical challenges. During its 45-year history, IFDC's leadership has greatly expanded the availability and affordability of fertilizers to smallholder farmers around the world. The NPK fertilizers on which the world depends are now over 70 years old. More nutrient-efficient, environmentally sustainable fertilizers, developed by IFDC and other research organizations in collaboration with the fertilizer industry, are beginning to emerge. Going forward, IFDC will focus on adapting these new technologies for smallholder systems and work with partners to develop solutions to restore degraded soils.

IFDC will go beyond its fertilizer expertise to work directly with farmers and markets. We will seek to identify fertilizers and related soil management strategies that work well in smallholder agricultural systems, connect farmers to robust input and commodity markets, and strengthen enabling policies and regulations. IFDC's distinctive approach will bridge the traditional gap between research and markets, which is critical to achieve and sustain impact at scale.

IFDC's future work will feature expanded partnerships with the private sector, which is pioneering many of the exciting soil and plant nutrition advances that remain largely untested in smallholder environments. IFDC's unique Pilot Plant complex and its affiliated engineers and scientists can help determine the technical and financial feasibility of manufacturing and blending new fertilizer products at varying production scales. IFDC will also expand its partnerships with international and national research organizations and universities, where new investments to deepen the understanding of fundamental processes at the interface of soil and cropping systems will be critical to advancing pragmatic technologies over the longer term.

Innovation and impact – whether in the lab, on the farm, in markets, or at the policy level – are not sustainable without local know-how and leadership. That is why smallholder farmers, local and national governments, and the private sector in low-income countries will remain IFDC's most important partners. IFDC will continue to place its highest priority on strengthening the capacity of these partners.

IFDC's greatest resource is its people, collaborating as "one IFDC" from offices throughout the world. We are dedicated to common principles and values, including science-backed innovation, locally driven solutions, gender and youth equity, private sector engagement, and sustainable impact. IFDC is also firmly committed to accountability and good stewardship of the public funds entrusted to us.

This new IFDC strategy for 2020-2030 was developed over eight months and featured extensive internal and external consultations. I am grateful to IFDC's Board of Directors, senior management and project directors, sector thought leaders, and external consultant Dr. Julie Howard for their contributions.

Albin Hubscher
IFDC President and CEO

EXECUTIVE SUMMARY

Fundamental improvements in soil and plant nutrition will be required to meet the challenge of sustainably feeding 10 billion by 2050. Global population growth will drive a substantial increase in food demand, while climate change is already accelerating risks to food production, especially in poorer regions. Major changes in agricultural systems – especially improvements in nutrient use efficiency – will be required to meet our shared challenge of creating a more food-secure, environmentally sustainable world.

VISION

Healthier soils and plants for a food-secure and environmentally sustainable world.

MISSION

Bring together innovative research, market expertise, and strategic public and private sector partners to identify and scale sustainable solutions for soil and plant nutrition that benefit farmers, entrepreneurs, and the environment.

THE CHALLENGE: IMPROVE NUTRIENT USE EFFICIENCY

NPK adoption has significantly expanded yields since the 1960s, but inefficient fertilizer use has had a high ecological cost. Over the last 70 years, nitrogen, phosphorus, and potassium (NPK) fertilizers, combined with improved seed varieties and agronomic practices, fueled spectacular increases in agricultural productivity for major staples across Asia, North and South America, and Europe, improving the lives of billions. However, the inefficient use of fertilizers in some regions has contributed to escalating nitrate and phosphate losses to the environment. More than half of the estimated 120 million tons of nitrogen fertilizers used in global agriculture each year is estimated to seep into waterways. Agriculture, forestry, and land-use change also contributed an estimated 23% of global annual greenhouse gas emissions during 2007-2016.

In sub-Saharan Africa and South Asia, deficiencies of secondary and micronutrients such as zinc, boron, and sulfur reduce the capacity of plants to use NPK efficiently and limit profitability for farmers, contributing to very low fertilizer adoption rates and a vicious cycle of soil degradation. Poor soil fertility is a major contributor to low agricultural productivity and poverty in sub-Saharan Africa, and rates of fertilizer use are the lowest in the world. Soil and environmental degradation occurs as nutrients are continually extracted through cropping but are not replaced and as agricultural production is extended onto new, often marginal, lands. Declining soil fertility limits biomass production and surface cover, resulting in poor soil structure and increased runoff and erosion.

IFDC's Strategic Approach: Achieving impact at scale requires research and technology that have been adapted to smallholder needs but must go beyond technology development. IFDC experts and their partners work across the discovery-to-consumer continuum. This includes testing of advanced fertilizers and related nutrient management technologies; design of fertilizer manufacturing and quality control processes; market systems development; gender and youth empowerment; and applied policy and regulatory analysis.

With an emphasis on working with strategic partners and strengthening local capacity, IFDC bridges the traditional gaps between research, technology dissemination, and market systems that often undermine efforts to innovate, achieve results, and

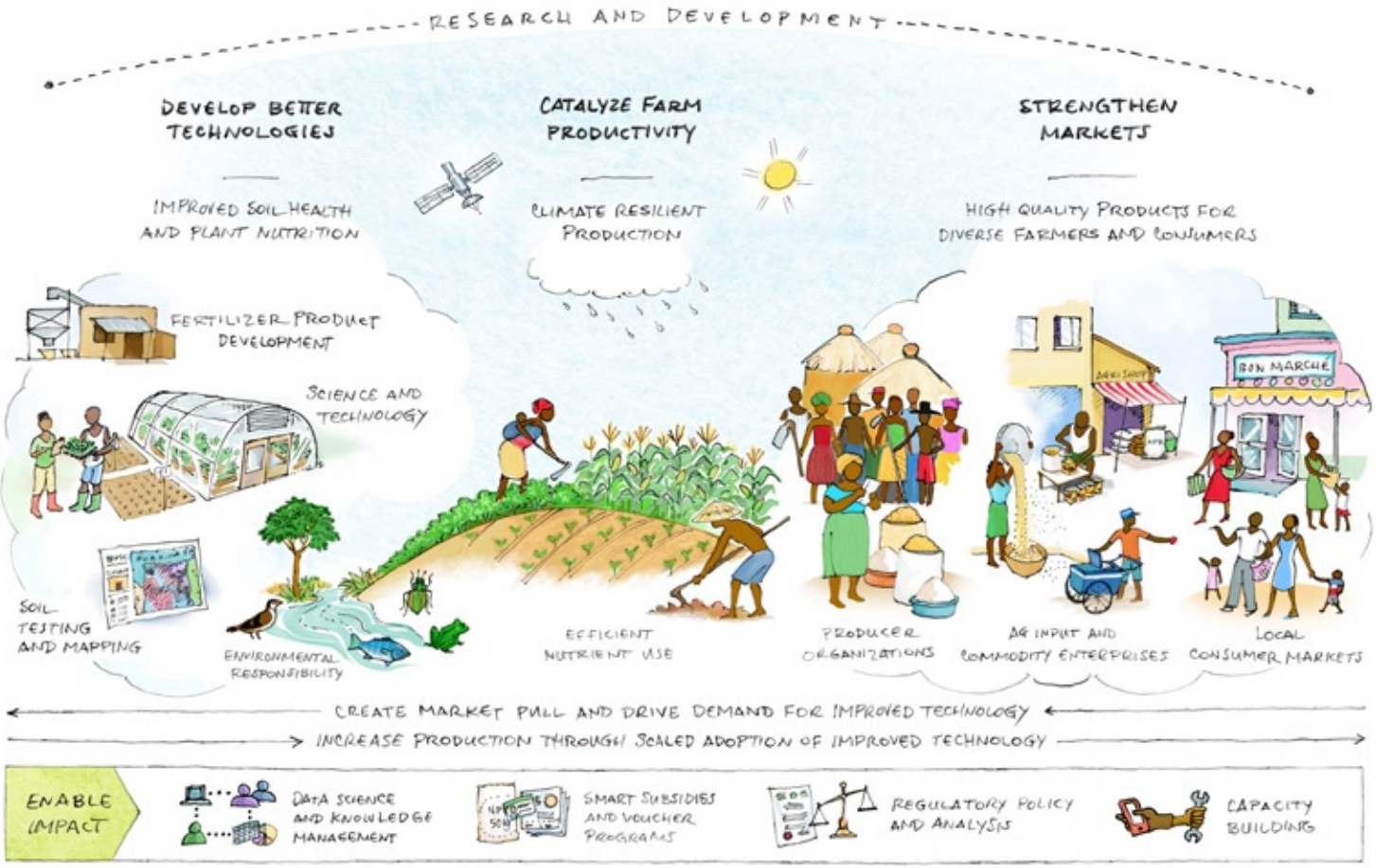
sustain impact at scale. IFDC's strategy focuses on coordinating and integrating project-level research and development efforts across four priority areas.

1. **Develop, test, and adapt technologies that improve soil health and plant nutrition.** A new generation of soil and plant health technologies is emerging as scientific understanding of critical soil-plant-ecosystem relationships improves. Yet, these currently target advanced large-scale farming systems in high-income countries. Working with national, regional, and international partners, IFDC will focus on testing and adapting promising technologies for smallholder systems.

   ✓ **Develop more nutrient-efficient, environmentally sound fertilizers.** IFDC will test and adapt advanced fertilizers including stabilizers, inhibitors, and biodegradable polymer and micronutrient coatings to regulate nutrient release and reduce runoff, leaching, and greenhouse gas emissions.

   ✓ **Identify soil and crop system nutrient deficiencies.** IFDC is working with emerging technologies that will significantly improve fertilizer recommendations. These include spectral soil and crop analysis, satellite imagery showing spatial variation in yield and water use efficiency, improved soil test kits, and information and communication technologies (ICT) that share instant, site-specific crop management recommendations at low cost. IFDC will validate these technologies at the field level by undertaking experimental trials with national partners to develop tested, profitable fertilizer recommendations for farmers.

MISSION IN ACTION



- ✓ **Scale up the production and adoption of new fertilizers.** IFDC will use its Soil-SMaRT framework (Soil testing, Mapping, Recommendations development, and Technology transfer) to map soils at national and regional levels, evaluate balanced fertilizers through crop trials and modeling, and guide the scaling up of private sector-led production of new tailored fertilizers. IFDC's Pilot Plant team will work with private sector partners to test the technical and financial feasibility of manufacturing improved fertilizer blends, coatings, and compounds at different production scales.
- ✓ **Refine and scale Integrated Soil Fertility Management (ISFM).** Fostering a Green Revolution in Africa will require rebuilding degraded soils with inorganic fertilizers, organic materials, and other soil amendments. ISFM strategies developed by IFDC and partners in the 1990s emphasized ex-situ organic materials, but the extra labor required to source, transport, and integrate these materials proved costly and challenging for smallholders and limited ISFM adoption. Going forward, the emphasis will change to creating and integrating organic biomass from the field itself to nourish the soil, combined with the application of balanced inorganic fertilizers to address soil nutrient deficiencies. Key approaches will include production ecology modeling; designing organic/inorganic fertilizers and complementary management strategies that work with the soil microbiome; managing biomass and its impact on soil health and plant nutrition; and developing fertilizers produced with local resources.

2. **Increase farm productivity, profitability, and sustainability of target smallholder agricultural systems.** IFDC will assess the performance of emerging technologies under smallholder conditions, working with national research agencies, the private sector, and local stakeholders. IFDC will focus on expanding the participation of women and youth across all activities.
   - ✓ **Conduct on-farm research and demonstrations.** IFDC will engage smallholders as research and demonstration partners for new technologies, including new fertilizers and complementary seed, pest management, and post-harvest technologies. IFDC will work with country partners to test, extend, and track the impact of key practices on the environment and

climate resilience, including soil and water conservation techniques, no-till farming, relay cropping, cover crops, and organic matter recycling methods.

- ✓ **Expand engagement of women and youth.** IFDC will increase training for women and youth and work to address constraints that limit their access to productive resources and services. A key objective will be to help identify and enable their successful participation in new agribusiness partnerships on and off the farm.
- ✓ **Use innovative behavior change and ICT to scale and sustain adoption of improved technologies.** IFDC will harness mobile phones and software applications to change how farmers access and use information about market products and prices, weather and pest forecasts, crop management advice, and business management information. IFDC will engage youth to play a key role in modeling the use of new technologies and training others.

3. **Strengthen market systems to scale technologies and improve livelihoods, environmental outcomes, and climate resilience.** To scale up the adoption of an improved technology, the technology must expand or improve the production of a commodity that is in demand by the market, and it must be profitable for farmers to use.
   - ✓ **Conduct scaling assessments** to identify opportunities to develop inclusive markets offering the best potential for scaled adoption and impact of promising new technologies. Detailed scalability analyses conducted with local partners provide estimates of financial and economic

profitability, analyze the business case for new technologies at smallholder, input dealer, and commodity market levels, and assess environmental outcomes. Scaling pathways identify key partners and potential risks and opportunities.

- ✓ **Develop agribusiness clusters to drive the development of target commodity systems and scale technology adoption.** IFDC strengthens farmer associations and develops "agribusiness clusters," groups of smallholders, commodity buyers, agro-input dealers, banks, service providers, and processors. IFDC works to develop entrepreneurship opportunities, especially for youth and women, and ensures the supply of quality commodities to private sector buyers and processors. Working within clusters builds trust and long-term relationships that expand access to input, finance, and output markets for smallholders, youth, and women.

4. **Enable impact by improving policies, strengthening capacity, and sharing knowledge.** IFDC is committed to providing technical support and training to help countries improve their investments in soil fertility and plant health. IFDC will strengthen the capacity of national policymakers, scientists, agencies, and private sector partners to identify and implement key agricultural system changes.

   - ✓ **Support global, regional, and national dialogues** to increase investment in soil fertility and plant health.
   - ✓ **Strengthen national and regional capacity to develop and implement evidence-based policies and regulations with stakeholder engagement.** IFDC will facilitate the development of fertilizer industry and agro-dealer network platforms to identify and address policy and regulatory issues and environmental concerns; improve public and private sector capacity to assess market demand and supply, analyze marketing margins, and develop cost buildup studies; provide ongoing technical support to assess impacts and inform adjustments to policies and regulations; and strengthen the capacity of national standards authorities and research systems to conduct quality assessments for new and existing fertilizer products.
   - ✓ **Improve the technical capacity of public and private sector partners.** Key activities include IFDC's respected International Training Program Series for academic, industry, and government participants; structured training on fertilizer production and quality assurance provided by IFDC's Pilot Plant scientists and engineers; and training for national and international scientists to expand the use of advanced crop and soil system simulation modeling techniques. In addition, hands-on training, mentoring, and the increasing delegation of responsibilities to local partner organizations are built into every IFDC project.
   - ✓ **Share new knowledge and data related to soil and plant health.** IFDC is committed to making its scientific, economic, and policy analyses available through the IFDC website, in scientific publications, and by cross-posting to relevant agronomic and policy platforms.

FEEDING THE WORLD:

A NEW FOCUS ON SOIL HEALTH AND PLANT NUTRITION FOR SUSTAINABLE FOOD SYSTEMS

Over the coming decades, global population growth will drive a substantial increase in food demand. By 2050, our world will need to feed almost 10 billion people – 2.3 billion more than today. By 2100, Africa and South Asia together will be home to 9 billion of the 11 billion people on the planet.[1]

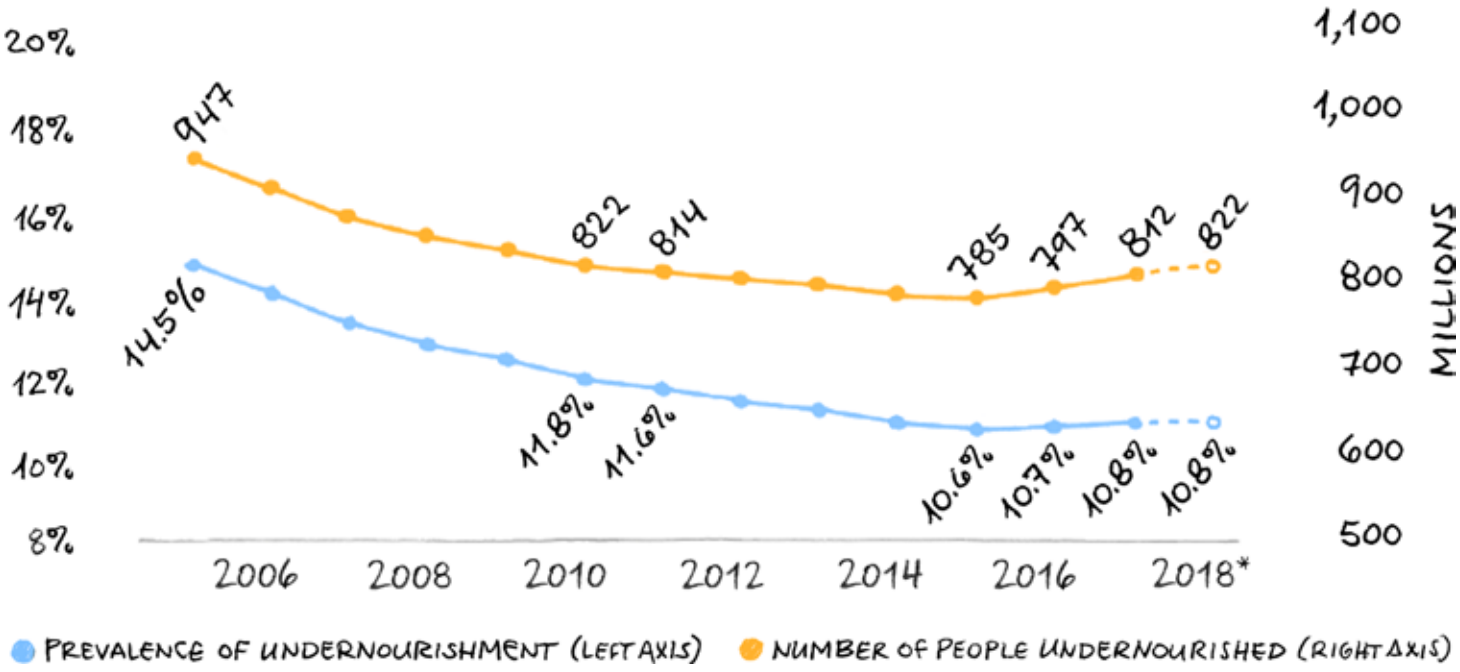
Global hunger is now beginning to tick upward again after a decade of progress (Figure 1). Sixty-three percent of the world's undernourished live in Asia, with one-third in South Asia alone. Another third of the hungry are in sub-Saharan Africa, where undernourishment is rising rapidly in regions affected by drought and conflict.[2]

As food demands rise, global agricultural systems are facing accelerating risks due to climate change and increasingly limited land and water resources. These pressures, together with rapid urbanization, rising incomes, and changes in consumer preferences, will require fundamental changes in agricultural systems to nourish a growing population while reducing agriculture's environmental impact.

THE ROLE OF AGRICULTURE AND SOIL FERTILITY IN MEETING RISING HUNGER AND POVERTY CHALLENGES

A wealth of studies conducted over decades has shown that agricultural growth is two to three times more effective in reducing poverty as growth in other sectors.[4] Agricultural growth has been a key factor in the rapid decline of global poverty since the 1950s.[5] The development and spread of improved, high-yielding seed varieties and fertilizers,

Figure 1. The Number of Hungry People in the World is Increasing Again[3]



** Values for 2018 are projections as illustrated by dotted lines and empty circles. Source: FAO*

BOX 1: IFDC AND THE SDGs

The United Nations Sustainable Development Goals for 2030 (SDGs) have sharpened the world's focus on agriculture's role in ending poverty and hunger, achieving food security and improved nutrition, and promoting sustainable agriculture. IFDC activities in sub-Saharan Africa and Asia contribute to many of the 17 SDG goals, but focus especially on five:

SDGs 1 & 2: Boost crop production, close the yield gap, and increase market linkages to improve family incomes and nutrition.

SDG 5: Improve women's access to agricultural knowledge and tools to empower them and increase their production to provide food security for up to 150 million people.

SDG 12: Reduce post-harvest losses through new practices and tools and provide balanced fertilizer application rates by soil and crop.

SDG 13: Promote judicious fertilizer application and test/disseminate climate-smart fertilizer practices and technologies.

combined with agronomic management, were the drivers for dramatic increases in agricultural productivity in the U.S. and Europe during the 1950s and in Asia and Latin America during the 1960s and 1970s. Between 1960 and 2000, "Green Revolution" seed and fertilizer technologies were responsible for yield increases of 208% for wheat, 109% for rice, 157% for maize, 78% for potatoes, and 36% for cassava across Asia and Latin America. In many regions, Green Revolution intensification also saved new land from conversion to agriculture and allowed marginal lands to be released from agricultural production and regenerated to woodlands and other natural areas.[6]

Global fertilizer consumption expanded dramatically as a result of the Green Revolution. Inorganic nitrogen fertilizer use has increased by 800% since 1961,[7] especially in Asia, which now consumes nearly 60% of the world's fertilizer nutrients, led by China and India.[8]

In contrast, farmers in sub-Saharan Africa have been slower to adopt the fertilizers that were so critical to agricultural transformation in other regions. Although fertilizer consumption on the continent is increasing (from 12.3 kilograms per hectare [kg/ha] of arable land in 2003 to 16.2 kg/ha in 2016[9]), rates remain very low compared to other regions: 160 kg/ha in South Asia, 158 kg/ha in the European Union, 127 kg/ha in North America, and 140 kg/ha in Latin America and the Caribbean.[10] Sub-Saharan Africa uses only 2.2% of the world's fertilizers.[11]

Fifty-four percent of Africans are employed in the agriculture sector, the highest proportion of any region in the world.[12] While agriculture has provided an effective ladder out of poverty for large numbers of people in Asia and Latin America, the number of very poor, defined as living on $1.90/day or less, is continuing to rise in sub-Saharan Africa (Figure 2). By 2030, 9 out of 10 extremely poor people will live in sub-Saharan Africa.[13]

Poor soil fertility in sub-Saharan Africa is a major contributor to low productivity and poverty. Nutrient balances for many farming systems are negative, i.e., the crops grown are extracting more nutrients than are returned to the soil through inorganic and organic fertilizers. Increases in food production still come primarily from the expansion of agriculture onto new, often marginal, lands, and yield gaps remain high.[14]

The low level of NPK use across most of sub-Saharan Africa has been insufficient to address macronutrient deficiencies. In addition, deficiencies in secondary and micronutrients, including sulfur, zinc, and boron, also limit the capacity of plants to use NPK efficiently, reducing crop yields and the profitability of fertilizer use.[15]

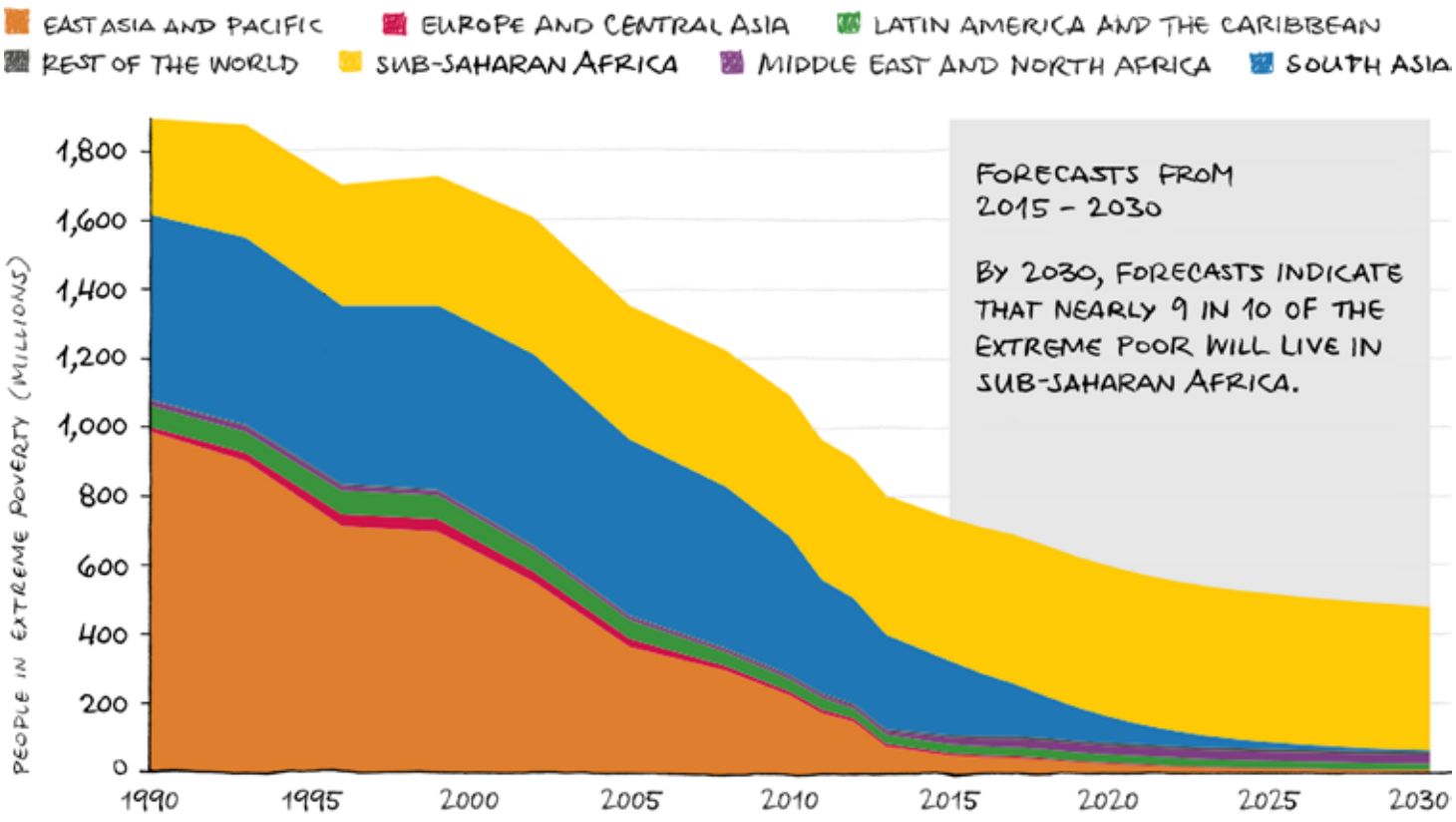
Increasing the application of nutrients – inorganic and organic, balanced with secondary and micronutrients to meet specific soil needs – can improve the productivity of low-input farming systems and reduce their vulnerability to climate stress.[16] Declining soil fertility limits biomass production and reduces the amount of available crop residue, root biomass, and soil organic matter. The resulting poor soil structure and reduced surface cover affect soil water holding capacity, increasing runoff, erosion, and leaching losses (Box 2). These factors are interconnected and are major contributors to the cycle of poverty.[17]

Intensification of agricultural production through the efficient use of organic resources and inorganic fertilizers, including improved crop and soil management, is required to meet the food needs of the growing population. Smart agricultural intensification can also control or reverse encroachment into forested and marginal areas, halt further soil and environmental degradation, and improve the ability of farmers to cope with climate stress.

AGRICULTURE AND THE ENVIRONMENT

The rapid rise in the use of inorganic fertilizers in many parts of the world over the past six decades has improved the lives of billions, but at a high ecological cost. The inefficient use of fertilizers in some regions is contributing to escalating nitrate and phosphate losses to the environment – causing

Figure 2. The Number of Poor People Continues to Rise in Sub-Saharan Africa[13]



Source: World Bank PovCalNet and Poverty & Equity Data Portal

ever-greater incidences of red tides and dead zones in rivers and oceans. More than half of the estimated 120 million tons of nitrogen fertilizers used in global agriculture each year is thought to flow into waterways.[18] Climate change-driven increases in rainfall could boost nitrogen runoff even more, potentially by as much as 20% over the next 80 years in the United States.[19] Prevailing policies and regulations have also contributed to overapplication of nitrogen fertilizers in some regions. Some South Asian governments, for example, heavily subsidize the price of nitrogen, ensuring that fertilizer is affordable for smallholders but creating incentives for inefficient use.

In addition to nitrate and phosphate runoff into waterways, expanding agricultural production also contributes directly to climate change through emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) greenhouse gases and as forests and other non-agricultural lands are converted for agricultural use. Agriculture, forestry, and land-use change contributed an estimated 23% of global annual greenhouse gas emissions during 2007-2016.[20] Increasing greenhouse gas emissions are believed to be a key factor in rising global temperatures and more erratic rainfall, which directly affects crop growth and exposes farmers, especially smallholders, to increasing risk.

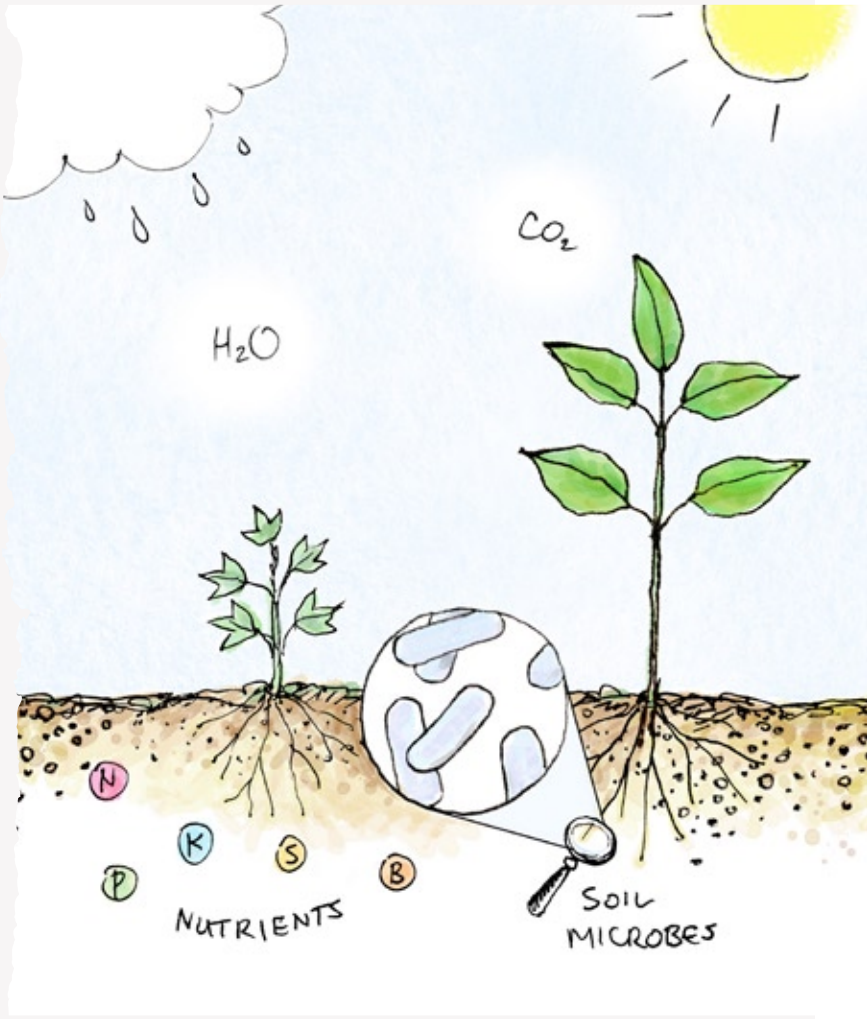
BOX 2: THE SOIL-PLANT ECOSYSTEM

Through photosynthesis, plants use solar energy to convert carbon dioxide (CO_2), water (H_2O), and nutrients into oxygen and organic materials, and ultimately into food and feed. Sunlight and CO_2 are abundantly available, while water and nutrients are often insufficient and limit plant growth.

Plants have co-evolved with soil microbes into a symbiotic relationship. Plants provide nourishment to soil microbes through substances secreted by their roots (exudates). In turn, an amazing diversity of soil microbes fix biological nitrogen, decompose soil and plant organic matter and soil minerals into plant-available forms of nutrients, and transport these nutrients to plant roots.

Conventional tillage farming substantially disturbs the processes of creating organic matter and reduces the soil's capacity for absorbing water and holding nutrients. Monocrops, even in rotations, result in fewer plant species and support a lower microbial population and diversity. While decomposition of accumulated organic matter can provide some nutrients, their availability cannot be sustained. Nutrients removed from fields – as crop harvest and residues used for cooking, animal feed, and building materials – rapidly deplete soils.

Under such conditions, the balanced application of organic and inorganic inputs in minimum and no-till systems can sustainably achieve greater yields and restore healthy soils. Conservation agriculture (i.e., a farming system that promotes maintenance of a permanent soil cover, little or no tillage, and diversification of plant species) can slow or reverse organic matter degradation, improve the retention and delivery of plant nutrients, increase water holding capacity, and protect the soil from erosion.



FROM SCIENCE TO IMPACT:
IFDC STRATEGIC PRIORITIES AND ACTIVITIES

Moving from **Food Deficits**, **Poverty**, and **Environmental Degradation** to **Food Security**, **Prosperity**, and **Ecosystem Regeneration: IFDC's Role**

Scientific understanding of critical soil-plant-ecosystem relationships is rapidly expanding. The advances are fueling the development of a new generation of soil and plant health innovations by IFDC, universities, international research centers, and the private sector. These innovations hold the potential to significantly boost the production of higher quality food, using less land and water; improve the climate resilience of farming systems; and significantly reduce the environmental impact of agriculture.

Improving soil fertility will also have positive effects on human health and nutrition through increasing yields, food security, and crop nutrient content. There is mounting evidence that application of N, P, K and sulfur (S) fertilizers not only improves yields but generally enhances the nutritional quality of crops. Fertilizer use increases the concentration of protein in cereals and pulses, oil in oilseed crops, starch in tubers, and essential amino acids and vitamins in vegetables.[21] Adding micronutrients to fertilizers may also offer a promising avenue to address human micronutrient deficiencies (particularly zinc)[22] along with other approaches including biofortification through plant breeding, dietary diversification, micronutrient supplementation, and food fortification.

New agricultural technologies and innovations are critically important in the quest to expand environmentally sound global food production, but most efforts today target advanced large-scale farming systems in high-income countries. IFDC focuses on smallholder farming systems in low- and middle-income countries. Most of IFDC's efforts will concentrate on sub-Saharan Africa and South Asia, where global poverty, hunger, and soil health and fertility challenges are greatest. Specifically, IFDC will work to strengthen the capacity of public and private institutions in these regions to identify, adapt, and spread transformative soil and plant health technologies for their smallholder farming systems.

VISION

Healthier soils and plants for a food-secure and environmentally sustainable world

MISSION

Bring together innovative research, market expertise, and strategic public and private sector partners to identify and scale sustainable solutions for soil and plant nutrition that benefit farmers, entrepreneurs, and the environment

Working with national, regional, and global partners, IFDC will focus on testing and adapting promising technologies to ensure they are effective and profitable, respond to market needs, and are environmentally sustainable in smallholder farming systems. IFDC experts work across the whole lab-to-consumer continuum. This includes testing of advanced fertilizers and related management interventions; design of fertilizer manufacturing and quality control processes; market systems development; and applied policy and regulatory analysis. With its emphasis on working with strategic partners and strengthening local capacity, IFDC is able to bridge the traditional gap between research, technology dissemination, and market systems that often undermines efforts to innovate, achieve results, and sustain impact at scale.

Critically, IFDC programs link technologies to markets at an early stage so they respond to feedback from smallholders, input industry and commodity market partners, and consumers. Technologies that impact commodities demanded by the private sector and consumers, as well as those that meet smallholder technical needs, are prioritized. IFDC then identifies

potential scaling pathways and constraints, as well as policy and regulatory changes needed, and connects programs with key partners to foster sustained adoption and impact at scale.

THEORY OF CHANGE

IFDC's theory of change is that providing farmers with more nutrient-efficient, profitable technologies, and strengthening related marketing systems and policies, will lead to improved livelihoods, increased food security, and better environmental outcomes. The theory of change is conceptualized in Figure 3.

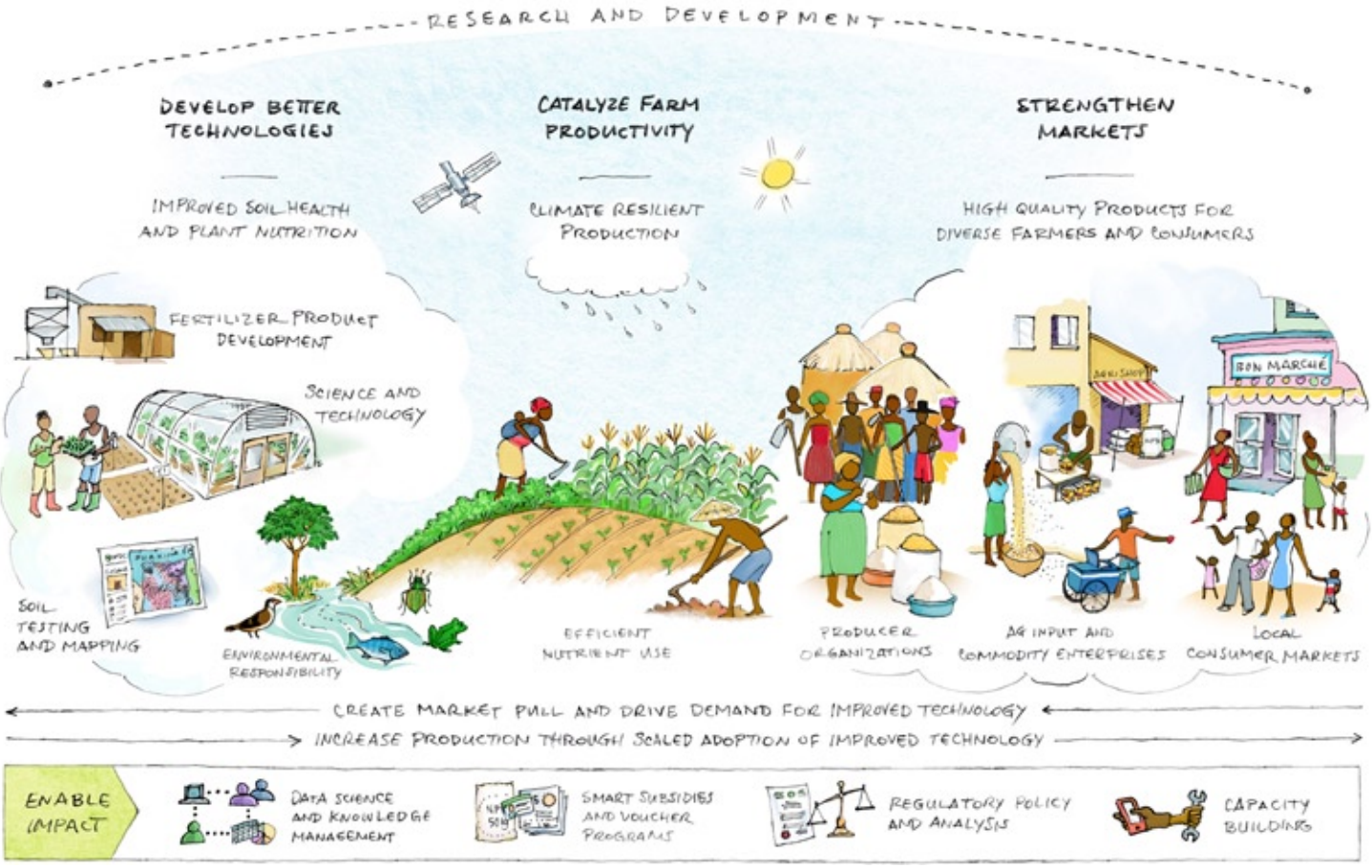
Strategic priorities. IFDC is guided by four strategic priorities for research and development:

1. **Develop Better Technologies** – Develop, test, and adapt technologies that improve soil health and plant nutrition.
2. **Catalyze Farm Productivity** – Increase farm productivity, profitability, and sustainability of target smallholder agricultural systems.
3. **Strengthen Markets** – Strengthen market systems to scale technologies and improve livelihoods, environmental outcomes, and climate resilience.
4. **Enable Impact** – Enable impact by improving policies, strengthening capacity, and sharing knowledge.

IFDC will coordinate its work across these priorities to effectively connect individual projects, programs, and partners.

IFDC's research and development activities are the means through which we will accomplish our strategic priorities and improve the productivity, profitability, climate resilience, and environmental sustainability of target smallholder systems.

Figure 3. Mission in Action



STRATEGIC PRIORITY 1: DEVELOP, TEST, AND ADAPT TECHNOLOGIES THAT IMPROVE SOIL HEALTH AND PLANT NUTRITION

More efficient fertilizers. Productivity has increased in much of the developed world without increasing, and in some cases decreasing, the land area required for that production, while fertilizer use per land unit has dropped substantially over the last decade. In Asia, agricultural productivity has increased, but fertilizer overuse is prevalent. In sub-Saharan Africa, most smallholder farmers have access to NPK fertilizers only, often accompanied by blanket recommendations covering multiple crops and environments. Yet the situation is evolving, with advances in fertilizer coatings and application technologies that control nutrient release and add micronutrients; innovations to facilitate the production and marketing of more balanced, higher quality fertilizer blends; and geo-informatic and diagnostic tools to identify area-specific soil deficiencies and provide tailored recommendations.

Integrated soil management strategies can supply balanced amounts of nutrients to improve crop productivity and reverse soil degradation while improving environmental services. The target is the development of system-specific strategies tailored to soils, crops, and water availability, while minimizing losses to the environment. These integrated strategies feature combinations of balanced fertilizers, incorporation of crop residues into soils, crop diversification using rotations, relay crops and intercrops, minimum and no-till systems, introduction of legumes, integration of crop and livestock systems, and nutrient recycling.

Restoring environmental services. The transition to more efficient fertilizers and effective soil management strategies will improve the uptake of nutrients by plants and reduce environmentally damaging runoff and leaching. Improving soil health and fertility facilitates agricultural intensification on lands suited to cropping, saving marginal lands from cultivation and avoiding the discharge of additional CO_2 to the atmosphere.

With intensive agricultural systems, substantial amounts of plant residues remain in the field after harvest. Instead of removing these residues through burning or feeding the plant material to animals, leaving them in the field or incorporating residues into the soil can improve soil health, water management, and productivity, reduce erosion, and build soil organic matter that can sequester large amounts of CO_2 from the air. Sub-Saharan Africa has the potential to become an important player in greenhouse gas (GHG) mitigation. Minimal fertilizer use and poor management practices have led to soil degradation and decreasing soil organic carbon. Balanced fertilizer use and improved soil management increases farming system productivity while contributing to climate change mitigation.[23] Recent advances in the use of blockchain technology to track and create markets for sequestered soil carbon may open future opportunities for farmers to receive compensation for farmed carbon.

Big data, geo-informatics, and ICT for knowledge generation. New technologies are rapidly transforming our ability to harness vast data streams and generate knowledge that can better diagnose plant and soil nutrient deficiencies, assess the implications of climate change and more extreme weather conditions for plant and soil health, and develop more effective, environmentally sound soil management recommendations for smallholders. These advances include cloud-based services, ground sensors, drone imagery, remotely sensed land, climate, and short-term weather information, early warning systems, climate services, and cellphone-based services.

RESEARCH & DEVELOPMENT ACTIVITIES

1. **Develop and test more nutrient-efficient, environmentally sustainable fertilizers for smallholder environments.**

Most NPK fertilizers in use today were developed 70 or more years ago. IFDC will work with partners to develop, test, and evaluate the next generation of enhanced efficiency fertilizers. These next-generation fertilizers regulate nutrient release and reduce runoff, leaching, and GHG emissions through the introduction of stabilizers and inhibitors, reduced water solubility, and biodegradable polymer coatings.

To increase their efficacy, fertilizers need to be adapted to soil-specific conditions. IFDC will test micronutrient coatings, such as zinc and boron, and advanced delivery and application methods. These innovations will not only regulate NPK release but provide missing nutrients that allow the plant to better utilize NPK and produce higher yields with less fertilizer. IFDC will draw on its history of successful experiences in developing and disseminating nutrient-efficient fertilizer technologies such as fertilizer deep placement (Box 3).

IFDC will also refine the methods it has developed for measuring nutrient uptake efficiency, carbon sequestration at the field level, and emissions of greenhouse gases from fields under different conditions (Box 4).

IFDC's Pilot Plant facilities and engineering team will work with private sector partners to test the technical and financial feasibility of manufacturing high-quality improved fertilizer blends, coatings, and compounds at different production scales – from large-scale to smaller, local facilities.

2. **Strengthen the capacity of private and public sector partners to test the feasibility of producing improved fertilizer blends, coatings, and compounds and verify their quality and efficacy at the farm level.**

Promising new concepts to improve soil and plant nutrition are emerging from the fertilizer industry and public research institutions, including new organic, inorganic, and mixed products and technologies. Using the unique Pilot Plant facilities in Muscle Shoals, IFDC's engineers and scientists assist fertilizer industry and public sector partners to turn new ideas into commercially viable next-generation products and technologies that make sense for farmers and the environment (Box 5).

BOX 3: NUTRIENT-EFFICIENT FERTILIZERS

IFDC has extensive experience with developing and transferring nutrient-efficient technologies to farmers.

- **Fertilizer deep placement (FDP)** is the application of large, compressed fertilizer briquettes below the soil surface near the root zone of the plant. In Bangladesh, the adoption of deep-placed urea briquettes has reduced nutrient losses, increased rice yields by 15-20%, and allowed farmers to use one-third less fertilizer than traditional application methods.[24] An estimated 2 million farmers in South Asia currently use FDP, and the methods are being tested across West and East African countries.[25]
- **Controlled-release fertilizers** are created by coating the fertilizer with natural or synthetic materials that can release nutrients at a predictable rate to match the nutrient demand of a crop depending on the temperature.
- **Stabilized urea products** are products that have been amended to reduce transformation rates and increase nutrient availability to plants. These include urease inhibitors, nitrification inhibitors, and pH-modifiers.
- **Balanced fertilization** ensures crop production is not limited by lack of essential nutrients. Incorporating secondary or micronutrients can improve the efficiency of NPK use by crops, improve stress tolerance, and increase mineral content.

IFDC is dedicated to strengthening capacity related to fertilizer production and quality assessment and offers regular international training programs on the fundamentals of fertilizer production for industry stakeholders. IFDC also works with national-level standards authorities and research institutions to improve their national capacity to assess the quality and efficacy of new fertilizer products.

3. Improve methods to identify soil and crop system nutrient deficiencies and develop balanced fertilizers to address them.

New technologies are emerging that promise to significantly improve fertilizer and crop management recommendations in the future. Advanced spectral soil and crop analysis methods and field-level soil test kits are providing new insights on nutrient deficiencies and other soil properties such as pH, soil organic matter, and water holding capacity in crop and soil systems. Satellite imagery can be converted into meaningful information, such as spatial variation in yield and water use efficiency, that allows better targeting of interventions. The wide availability of ICT increasingly facilitates customizing and sharing rapid, site-specific crop management recommendations at low cost.

The validation and application of these promising technologies is still at an early stage. For example, neither traditional nor newer sensing technologies for measuring soil properties are in themselves adequate to arrive at reliable fertilizer recommendations. More investment is needed in experimental trials to develop better fertilizer recommendations for farmers. IFDC is well placed to collaborate with national partners and private laboratories to design and implement these critically important validation trials and financial feasibility studies.

In this context, IFDC has developed the Soil-SMaRT framework (Soil testing, Mapping, Recommendations development, Technology transfer) that includes regional soil nutrient and pH mapping and the development, evaluation, and targeting of balanced fertilizers through crop trials and modeling. Soil-SMaRT outlines the steps needed to scale up private sector-led production and distribution of these tailored fertilizers (Box 6). This information can serve as a guide for fertilizer producers to assess the potential demand for region- and crop-specific fertilizer products, for market actors to target their operations, and for policymakers to develop fertilizer policies and regulations.

4. Develop methods and technologies to restore degraded soils and improve nutrient availability to plants.

Large areas of the African continent have degraded soils that are less responsive to fertilizers and subject to erosion. Fostering a Green Revolution in Africa will require a broader approach to restore these soils that integrates mineral fertilizers with organic materials and other soil management practices.

Refining and scaling Integrated Soil Fertility Management (ISFM) will be central to addressing these conditions and improving soil health. In the late 1990s, IFDC and other research partners developed ISFM strategies that emphasized the integration of ex-situ organic materials to improve soil health and fertility.[26] The extra labor required to source, transport, and integrate these materials proved both costly and challenging for smallholders and limited the uptake of integrated systems. Going forward, IFDC will focus on nourishing the soil by creating and managing organic matter from the field itself, combined with the application of inorganic fertilizers balanced to address soil nutrient deficiencies.

Managing organic matter implies:

- ***Producing sufficient biomass***, such as crop residues, that is returned to the soil rather than fed to animals, burned, or removed to be used for building materials. Fertilized crops help produce more crop residues and root biomass.
- ***Utilizing mixed cropping***, which encourages the microbial diversity necessary for healthy soils and can fix nitrogen, e.g., with legumes.
- ***Applying good agricultural practices*** that retain organic matter, including surface cover from residues, minimum tillage, and erosion control practices.

Many of these management practices have become widespread in developed country agriculture and have helped rebuild soil organic carbon stocks. They have not yet been widely tested or adapted for the African and South Asian contexts.

IFDC will build on its deep experience to develop and test a next generation of ISFM technologies (Box 7) at the interface of soil fertility, cropping systems agronomy, and environmental sustainability in partnership with farmers, universities, national and international researchers, and the private sector.

Key approaches will include:

- ***Production ecology models*** that simulate the effect of key processes on crop growth and yields. These models can provide insights to guide decisions on fertility management, including adaptation to more extreme weather conditions brought on by climate change.
- ***Lab and field tests*** of organic and mixed organic-inorganic fertilizers. These fertilizers work with the soil microbiome to increase nutrient bioavailability, improve soil health, and boost plant resilience to drought and disease.
- ***Field tests of alternative methods*** for producing and managing biomass and their impact on soil health and plant nutrition. These include mixed cropping, minimum tillage, and erosion control practices.
- ***Development and evaluation*** of fertilizers produced with local resources. For example, phosphate rock activation can make locally sourced phosphate more readily bioavailable to crops than the untreated rock and provide a more economical alternative to conventional phosphate fertilizers.

BOX 4: MEASURING NUTRIENT RUNOFF AND GHG EMISSIONS

Quantifying and mitigating nutrient runoff and GHG emissions from fertilizers are major IFDC priorities. In our labs, greenhouses, and research fields, IFDC uses an automated gas sampling and analysis system to evaluate the effect of inhibitors, coatings, and additives on GHG emissions, as well as their contributions to improving fertilizer use efficiency.[27] The tests also analyze emission changes under alternative water management and fertilizer application methods.

We test the impact of nutrient-efficient technologies under smallholder conditions in the field. For example, field trials undertaken by IFDC in Bangladesh have examined the impact of urea deep placement combined with the alternate wetting and drying (AWD) irrigation method used to reduce irrigated water consumption. The study demonstrated that the combined technologies improve nitrogen and water use efficiency, without increasing nitrous oxide and nitric oxide emissions.[28]

IFDC is also evaluating the benefits of efficient fertilizer technologies in areas affected by climate stress, including drought, flooding, and salinity. Initial results indicate that fertilizer-efficient technologies can improve resilience to climate stresses by reducing the amount of fertilizer required and increasing yields, even under stressed conditions.

Capacity building of national research institutions, scientists, and the private sector is critical for improving research on climate change effects and resilience. In Bangladesh, for example, IFDC works closely with researchers from the Bangladesh Agricultural University and Bangladesh Rice Research Institute.

BOX 5: IFDC'S ENGINEERING AND PILOT PLANT SERVICES

IFDC's unique suite of capacities allows it to test the production feasibility, scalability, and efficacy of any new fertilizer product. Its fully continuous pilot-scale granulation plants have production capacities ranging from 10 to 1000 kg per hour. These plants can produce any combination of granular N, P, and/or K fertilizers using solid and/or liquid feedstocks.

IFDC laboratory services can evaluate the feasibility of granulating novel raw and recycled materials and characterize the physical and chemical properties of new ingredients and products.

IFDC serves both industry and public sector clients and maintains strict confidentiality in all process and product development work. Our engineers can also assist in developing, testing, and setting up production facilities for new fertilizer plants and blending facilities. IFDC offers process design assistance for basic and detailed engineering, equipment inspection during fabrication, and assistance during commissioning and start up. Technical assistance and training encompass solving common production problems, on-site technical assistance including optimization of processes and equipment, analysis of materials handling, identification of housekeeping and safety issues, personnel assessment, tailored training, and international training programs on fundamentals of fertilizer production.

BOX 6: SOIL-SMaRT

Soil testing — Conduct full-quality soil analyses throughout region of interest

Mapping — Map nutrient deficiencies and soil acidity constraints

Recommendations development — Develop, target, and refine better fertilizers (vs current): yield, financial returns

Transfer to farmers — Scale up production and distribution

Adjust fertilizer regulations and policy to accomodate balanced fertilizers into a competitive market

Soil-SMaRT, developed by IFDC, provides a step-by-step framework that can be used by public and private sector partners to identify and map nutrient deficiencies, develop and disseminate recommendations, and deliver balanced fertilizers to farmers.

Soil testing/analyses by qualified laboratories can identify major nutrient gaps. These analyses must be conducted on a broad scale, using thousands of samples that represent a wide range of agro-ecologies and soil types.

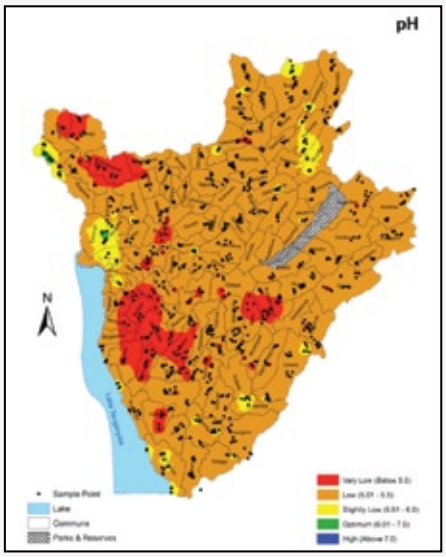
Soil maps show soil nutrient deficiencies and soil pH constraints. They guide fertilizer producers to assess the potential demand for new fertilizer products that meet the needs of major soil types and crops across a region. For example, the map shown illustrates soil pH levels in Burundi.

Recommendations development involves determining which nutrients belong in specific fertilizers, where fertilizers should be targeted, and the most appropriate nutrient rates, sources, and manufacturing processes. Research trials and field evaluations are critical in this step.

In Mozambique, for example, the primary fertilizer recommended for maize was NPK 12:24:12, but smallholders often experienced low yields and profits. Nutrient omission trials and demonstrations were developed using the Soil-SMaRT approach. IFDC found that a fertilizer blend of nitrogen, phosphorus, sulfur, and zinc was more effective and profitable for smallholders growing hybrid maize.[29]

Technology transfer involves establishing farmer demand and meeting it through efficient supply channels.

Additional steps in getting better fertilizers into farmers' hands include understanding the policy and regulatory environment and creating platforms for collaboration among key stakeholders in public and private sectors.



BOX 7: TOWARD THE NEXT GENERATION OF ISFM

Integrated Soil Fertility Management (ISFM) is a set of practices, adapted to local conditions, to improve soil quality, nutrient and water use efficiency, and crop productivity. Increasing the productivity of already cropped areas can reduce agricultural expansion onto new and marginal lands.

ISFM strategies combine the use of:

- ✓ Inorganic fertilizers and improved seeds.
- ✓ Organic resources (crop residues, compost, and various manures).
- ✓ Locally available soil amendments (lime and phosphate rock).
- ✓ Good agricultural practices.

Early ISFM focused on bringing external organic inputs to a field through manures, cut-and-carry agroforestry, and other green manure sources, including composts.

Challenges included:

- ✓ Scarcity of materials.
- ✓ Cost and labor to gather and transport organic materials.
- ✓ Competition for organic resources from alternative uses, e.g., cooking fuel, animal feed, and building materials.
- ✓ Unintentional degradation of non-agricultural areas and distant fields as organic materials were transported.

The next generation of ISFM will place increasing focus on generating and managing organic matter in situ and recycling nutrients from wastes. Judicious use of balanced fertilizers will be essential to generating increased crop and root biomass, replacing nutrients removed in harvested products, and improving soil health.

STRATEGIC PRIORITY 2: INCREASE FARM PRODUCTIVITY, PROFITABILITY, AND SUSTAINABILITY OF TARGET SMALLHOLDER AGRICULTURAL SYSTEMS

The scientific advances described above give rise to optimism about the potential for improving smallholder farming systems in Asia and sub-Saharan Africa. However, the emerging fertilizers and complementary technologies are targeted primarily to high-income countries and advanced farming systems. It is critical to assess how well these technologies perform under smallholder conditions and get early feedback from farmers and other local stakeholders. IFDC expert staff will work to strengthen the capacities of national agricultural research and extension systems, standards authorities, and private sector partners to evaluate the technical, financial, economic, and environmental impacts of new technologies under smallholder conditions.

Successful adoption and impact of these new technologies at scale will also depend on engaging women and youth, who are under-represented in current agricultural development efforts. IFDC is committed to expanding the successful participation of women and youth in its country-level programs and helping to address the underlying factors that constrain technology adoption and market participation by both groups.

Women provide an estimated 40% of farm labor in sub-Saharan Africa[30] and 35-50% in East and South Asia.[31] Yet, they are less likely to adopt fertilizers and other improved technologies than male farmers.[32] IFDC's flagship 2SCALE program is strengthening its focus on gender to reflect lessons learned during its first phase. Beyond setting quantitative targets for women's participation (half of beneficiaries across all activities), IFDC programs will now work more directly to strengthen women's economic empowerment (Box 8).

Africa has the youngest population in the world. Almost 200 million Africans – a number that is expected to double by 2045 – are between the ages of 15 and 24.[33] Job creation has not kept pace, unfortunately, and 60% of Africa's unemployed are youth.[34] Without economic and employment opportunities, the youth could pose a threat to social cohesion and political stability, especially in fragile states, where one in two youths joining rebel movements cite unemployment as a key motivation.[35] The modernization of agriculture in sub-Saharan African countries provides a critical opportunity to harness youth talent for employment and entrepreneurship opportunities on and off the farm, in addition to expanding agricultural production and improving climate resilience and environmental sustainability.

The general constraints that affect farmers and entrepreneurs in agribusiness, including access to finance, land, markets, and technologies, are exacerbated for women and youth. Agriculture is also widely perceived by African youth to be a back-breaking, low-profit, and generally unappealing activity. A promising way forward is to professionalize agriculture and assist youth and women to participate in a spectrum of new, profitable businesses connected to agro-inputs, production, marketing, processing, packaging, and food services at all stages of the agrifood system, on and off the farm. In addition, assisting youth and women to organize themselves into associations or cooperatives may also help to overcome constraints in access to land and finance (Box 9).

Youth can play a critical role in socializing the use of advanced agricultural technologies in their communities. The digitalization of agriculture and expanding use of ICT tools for gathering weather information and accessing agricultural extension knowledge and market information will open a set of new opportunities for them. The IFDC/2SCALE model of working with private agribusiness clusters (Box 11) will also help improve youth employability, facilitating youth access to experiential skills training and mentoring, the lack of which has been identified as a major constraint to expanding youth employment and entrepreneurship in agriculture.[26]

RESEARCH & DEVELOPMENT ACTIVITIES

1. **Conduct on-farm research and demonstrations.**

IFDC will work to engage smallholders as research and demonstration partners for new technologies, including new fertilizer and complementary seed, pest management, and post-harvest management technologies.

2. **Confirm and extend fertilizer recommendations for smallholder cropping systems.**

Working alongside local research partners, the private sector, and smallholders, IFDC will revise soil maps and fertilizer recommendations using Soil-SMaRT and complementary approaches such as spectral analysis. IFDC will work with country partners to demonstrate and disseminate validated recommendations.

3. **Incorporate 4R Nutrient Stewardship into all smallholder projects.**

IFDC will adopt the 4R Nutrient Stewardship Framework – the right fertilizer source, at the right rate, at the right time, and in the right place – to improve inorganic fertilizer management and nutrient use efficiency (Box 10). Good agricultural practices (GAPs) for fertilizers will be tailored to match nutrient supply with crop requirements and minimize nutrient losses from fields.

4. **Demonstrate, extend, and measure the environmental impact of improved agronomic practices to enhance soil fertility and plant nutrition**.

Together with country partners, IFDC will test and extend practices to improve soil quality, plant nutrition, and environmental sustainability, including soil and water conservation techniques, no-till farming, relay cropping, the use of cover crops, and other organic matter recycling technologies.

IFDC will track the impact of improved technologies on soil, greenhouse gas emissions, and nutrient losses at the field level using novel sensing technologies, data analytics, and decision support tools.

5. **Demonstrate and extend best available seed, pest management, and post-harvest technologies to improve productivity and sustainability.**

IFDC and its partners will work with smallholder farmers to demonstrate how farm productivity can be enhanced through technologies such as nutrient-efficient, stress-tolerant seeds, GAPs, and improved post-harvest practices.

6. **Use innovative behavior change and ICT to scale and sustain adoption of improved technologies, with a special emphasis on engaging youth.**

Behavior change and ICT will play an increasingly important role in IFDC smallholder programs aimed at integrating smallholders into commercial markets and strengthening resilience. IFDC will focus on harnessing mobile phones and user-friendly software applications to change how farmers access and use information about market products and prices, weather and pest forecasts, business management information, and other agricultural technologies. Youth, as early adopters of ICT, will play an important role in demonstrating new technologies and training others.

7. Facilitate women's economic empowerment through field programming.

IFDC will strive for gender equity across its programs, with women and girls representing 50% of program beneficiaries. In addition, throughout its programs, IFDC will seek to ensure inclusion of women in private businesses and organizations, foster women's access to productive resources, improve gender-responsive services from public and private service providers, and strengthen women's ability to influence decisions, negotiate, and control a fair share of the benefits.

8. Expand youth engagement in emerging agrifood system opportunities.

IFDC will systematically expand youth engagement in its programming, from on-farm testing of new soil fertility, plant health, and ICT technologies, to enabling youth participation and success in new agribusiness partnerships on and off the farm.

BOX 8: EMPOWERING FEMALE ENTREPRENEURS: THE CASE OF AVPI

IFDC empowers women with training and tools to improve farm productivity, income, and family nutrition. Many women-led businesses have grown into profitable small and medium enterprises with support from IFDC programs that improved their business and product management capacity. Our projects also address social equity, financial inclusion, and policy reform.

For example, through the Accelerating Vegetable Productivity Improvement (AVPI) project, funded by the Walmart Foundation, IFDC helped female vegetable and fruit farmers improve yields and income through good agricultural practices and enhanced marketing skills. AVPI also helped female participants play a stronger role in family decision-making.

Shafiya Akhter, 39, is an AVPI entrepreneur. After attending an AVPI training program, Shafiya and her husband purchased a fertilizer briquetting machine for their agro-input shop, with co-financing from the project. Shafiya learned how to operate the machine and gained a stronger role in her family's business. Shafiya is the only female briquette machine owner in her area. "Now, everybody knows me," said Shafiya. "I am really turning into an entrepreneur."

BOX 9: ENGAGING YOUTH IN AGRICULTURE: YINKA ADESOLA'S YOUTH TRAINING FARM

The future of food security depends on the next generation. IFDC programs harness the potential of young people through capacity building in good agricultural practices (GAPs) and business management, access to finance and storage, participation in value chains, and networking and association building.

2SCALE, for example, engages youth in agribusiness clusters and links them to profitable value chains.*

Early in her career, Yinka Adesola attended 2SCALE trainings on GAPs, ISFM, and business management strategies. The project linked her with East-West Seed, a company that develops high-quality vegetable seeds for tropical conditions.

Now Adesola operates a three-month training farm for young farmers in Nigeria. "I wanted to hold other trainings to attract more youth to agriculture," said Adesola. Trainees across Nigeria come to her farm to learn vegetable production and farm management. She tells her students that "farming is a lucrative business if you know your market and if you can meet its requirement in volume and quality."

* *2SCALE is coordinated by IFDC and implemented with consortium partners BoP Innovation Center and SNV, with funding by the Directorate General of International Cooperation of the Dutch Ministry of Foreign Affairs. As of 2020, 2SCALE is active in eight sub-Saharan African countries.*

BOX 10: 4Rs OF NUTRIENT STEWARDSHIP

The 4Rs of Nutrient Stewardship guide producers to use best management practices to maximize yields and reduce nutrient losses. To reach smallholder producers, IFDC has incorporated the core 4R principles into its Soil-SMaRT approach and ISFM methodologies, which consider local context.

RIGHT SOURCE
Matches fertilizer type to crop needs.

RIGHT RATE
Matches amount of fertilizer to crop needs.

RIGHT TIME
Makes nutrients available when crops need them.

RIGHT PLACE
Keeps nutrients where crops can use them.

4R logo and images courtesy of The Fertilizer Institute.

BOX 11: 2SCALE'S AGRIBUSINESS CLUSTERS IN ACTION: THE CASE OF PROMO FRUITS

IFDC's 2SCALE project is the largest incubator of inclusive agribusiness in Africa. Since 2012, it has successfully engaged the private sector to improve farm productivity and link producers to processors and last-mile consumers.

2SCALE develops agribusiness clusters (ABCs) – composed of smallholders, commodity buyers, agro-input dealers, banks, service providers, and processors – to integrate smallholder farmers into target value chains. ABCs help establish better access to agro-inputs and services, provide coordination and co-innovation of business, marketing, and farming activities, and improve farmers' bargaining power.

The Promo Fruits partnership in Benin is an example of the ABC approach in action. Promo Fruits processes pineapples into juice and recently upgraded its processing capacity. Its work with IFDC strengthened smallholders' ability to grow more pineapples, expanded the number of farmers supplying Promo Fruits, and assisted with the marketing and distribution of new products.

By organizing nine ABCs and recruiting 27 extension workers and agribusiness coaches, 2SCALE helped improve the technical skills of farmers. Pineapple yields increased from 35 to 55 tons per hectare and quality improved. ABC farmers learned to plan better – taking flowering and harvest times into account – to ensure a more regular supply of pineapples. They participated in a credit and reimbursement program supported by local financial organizations and Promo Fruits. Farmers accessed agricultural inputs and negotiated better interest rates – 12% interest per year, compared to the prevailing rate of 24%.

STRATEGIC PRIORITY 3: STRENGTHEN MARKET SYSTEMS TO SCALE TECHNOLOGIES AND IMPROVE LIVELIHOODS, ENVIRONMENTAL OUTCOMES, AND CLIMATE RESILIENCE

To scale up the adoption of an improved technology, the technology must expand or improve the production of a commodity that is in demand by the market and be profitable for farmers to use. Farmers must be connected to input markets that supply the technology, and to output markets that sell the target commodity, to encourage their continuing investment and boost incomes and employment.

IFDC works with local partners to assess the potential for scaling up the target technology; identify constraints, opportunities, risks, and organizations that can play a key role in scaling; and develop the inclusive input and output markets that are essential to scaling up improved technologies sustainably.

Developing market systems requires the cooperation of multiple partners operating across the food system. The prime drivers in food systems are agribusinesses of all sizes: farmer cooperatives, input or service providers, processers, traders, or large multi-national agrifood companies. Smaller players face challenges including unclear business models, limited access to financial resources and market information, and other constraints. Larger actors face the challenge of sourcing agricultural commodities at scale in quantities that are reliable and of consistent quality.

Intermediary organizations strengthen the capacity of market actors to develop resilient and sustainable business models and connect to one another. IFDC functions as a trusted facilitator, assisting farmers to navigate the demands of new technologies and market requirements, on one hand, and helping input providers, commodity buyers, and processors work with producers more effectively, on the other. IFDC lays the groundwork for cooperation by helping to build enduring relationships between farmers, different partners, and consumers in market systems where demand for farmer commodities is generated.

IFDC also works with the private sector to develop agro-input networks and last-mile service delivery models to reach smallholder farmers, using innovative channels such as ICT and village-based advisors. IFDC strengthens the capacity of these local partners to work together to address policy and regulatory issues affecting new product registration, trade, sales, quality oversight, and broader infrastructure needs.

Throughout its activities, IFDC puts special focus on improving the capacities of women and youth to take advantage of new technologies and emerging income-generating opportunities in the transforming agricultural economy. Increasing incomes and urbanization are creating growing consumer demand for a diverse array of fruits, vegetables, fish, and chicken. These changes provide openings for women- and youth-led agribusiness services, including agro-input provision, extension, contracted fertilizer and pesticide application, harvesting, and processing.

RESEARCH & DEVELOPMENT ACTIVITIES

1. Conduct scaling assessments.

IFDC targets commodities and markets that offer the best opportunities for scaled adoption of new soil fertility, plant nutrition, and related technologies.

Detailed scalability analyses conducted with local partners provide background information and a stakeholder process to facilitate informed decision-making about commodity market systems. They also provide estimates of financial and economic profitability, analyze the business case for new technologies at smallholder, input dealer, and commodity market levels, and assess environmental outcomes. Scaling pathways identify key partners and potential risks and opportunities.

2. Develop agribusiness clusters.

IFDC develops sustainable business models that improve profitability for smallholders and small- and medium-sized entrepreneurs and ensure consistent supply of improved technologies and target commodities. IFDC strengthens farmer associations and develops "agribusiness clusters" composed of key market system partners – smallholders, commodity buyers, agro-input dealers, banks, service providers, and processors (Box 11).

The aim of agribusiness clusters is to build trust, long-term relationships, and problem-solving capacity. Successful agribusiness clusters lead to increased incomes and expanded opportunities for cluster actors through: a) better smallholder access to input, finance, and output markets; b) scaled soil-related technologies; c) improved profitability for smallholders and key market system partners; and d) better environmental outcomes.

The agribusiness cluster links promising technologies to market opportunities and is a key vehicle for achieving sustained adoption and impact at scale. IFDC works closely with cluster partners – providing a pre-competitive space, analyses, and training – to enable partners to collaboratively solve problems and improve production and market systems.

3. Strengthen the capacity of agribusiness clusters.

Sample activities include:

- Working with smallholder associations, processors, vendors, transporters, wholesalers, and retailers to develop and implement market-led strategies for providing inputs to and sourcing products from smallholders, including those at the "last mile."
- Identifying financing options for smallholders and small- and medium-sized entrepreneurs, with a special focus on youth and women.
- Facilitating work by private sector buyers and processors with smallholder associations to ensure consistent supply of commodities from smallholder farms (e.g., quantity, quality, timeliness, and traceability if required). This includes capacity building to facilitate the adoption of GAPs, access to credit, and organization of bulk delivery of commodities to processors.
- Identifying and developing entrepreneurship opportunities in the transforming agricultural economy, focusing especially on youth and women. This includes providing training, mobilizing finance, and assisting new entrepreneurs to access markets.

STRATEGIC PRIORITY 4: ENABLE IMPACT BY IMPROVING POLICIES, STRENGTHENING CAPACITY, AND SHARING KNOWLEDGE

IFDC is committed to providing technical support and training to help countries galvanize support for increased investment in soil fertility and plant health and better equipping policymakers, national scientists, and private sector partners to lead the major agricultural system changes required. We will work alongside country partners to strengthen their capacity to undertake scientific trials, financial assessments, and demonstrations, as an integral part of improving the scientific evidence base needed to assess the feasibility of new technologies and fertilizer recommendations in smallholder environments. And we will support government- and stakeholder-led efforts to improve policies and regulations to facilitate scaled adoption of key technologies.

A recent IFDC study of fertilizers used in African countries and Myanmar, most of them imported, found nutrient shortages in many products, as well as other quality issues, including heavy metal contamination, in some fertilizer products.[37] Increasing country-level capacity to evaluate, monitor, and regulate the quality of imported and locally produced fertilizer products will be a special area of focus for IFDC going forward, particularly as new products and blends are developed and enter the marketplace.

RESEARCH & DEVELOPMENT ACTIVITIES

1. **Support global, regional, and national dialogues to increase investment in soil fertility and plant health in low- and middle-income countries.**

   Sample activities include:

   - Contributing scientific and economic analyses in support of an anticipated African Union summit on priorities for improving soil health and fertility. IFDC played a lead role in the 2006 African Fertilizer Summit in Abuja, Nigeria (Box 12).
   - Participating in global, regional, and national public and private fora to share evidence and mobilize support for increased investment in soil fertility and plant health as a critical factor in achieving the SDGs.

2. **Strengthen national and regional capacity to develop and implement evidence-based policies and regulations**

   Sample activities include:

   - Working with national governments and stakeholders to conduct analyses and identify options to inform better land use and soil management choices (Box 13).
   - Providing ongoing technical support as new policies and regulations are implemented to assess impacts and inform adjustments.
   - Conducting fertilizer quality assessments and strengthening the capacity of national standards authorities and research systems to assess the effectiveness of new and existing fertilizer products and monitor quality on an ongoing basis.
   - Facilitating the development of fertilizer industry and agro-dealer network platforms to collaboratively identify and address policy and regulatory issues and environmental concerns (Box 14).

- Improving public and private sector capacity to assess market demand and supply, analyze marketing margins, and develop cost buildup studies (i.e., from port to farm gate) for the fertilizer value chain (Box 15).

3. Improve the technical capacity of public and private sector partners

Sample activities include:

- IFDC's International Training Program Series: IFDC offers a regular series of recognized training courses to academic, industry, and government participants on a range of topics (Box 16).
- Training national and international scientists in advanced crop simulation modeling programs, such as Decision Support System for Agro-Technology Transfer (DSSAT), and Geospatial Information System (GIS) applications to expand the use of computer modeling to simulate crop growth and yield, soil and plant water, and nutrient and carbon dynamics in smallholder contexts.
- Providing structured training, hands-on instruction, and mentoring as core components of every IFDC project.

This includes training for:

- ✓ National research, extension, and private sector partners as part of testing new and existing fertilizer products and developing recommendations.
- ✓ Fertilizer producers by IFDC Pilot Plant engineers to guide the development of new fertilizer products and blends cost-effectively and with consistent quality.
- ✓ National standards authorities and the private sector to assess fertilizer product quality.
- ✓ Private sector partners, farmers, and youth to improve financial management, develop business opportunities, and improve client services.

4. Widely share new knowledge and data related to soil and plant health.

IFDC is committed to making its scientific, economic, and policy analyses available through the IFDC website, by linking to other agronomic and policy platforms, and through scientific publications. Data management and sharing services will be organized based on the principles of FAIR (easily Findable, Accessible, Interoperable, and Reusable).

BOX 12: 2006 AFRICA FERTILIZER SUMMIT

In 2006, IFDC played a leading role in organizing one of the largest meetings in history to focus on Africa's food issues. The Africa Fertilizer Summit, held in Abuja, Nigeria, elevated fertilizer on a global scale as a critical component of food security. The event drew more than a thousand participants, including heads of state, agriculture ministers, directors of international organizations, private sector leaders, and researchers.

At the conclusion of the Summit, participants issued the *Abuja Declaration on Fertilizer for an African Green Revolution*, which called for the elimination of all taxes and tariffs on fertilizer and outlined 12 resolutions designed to significantly increase fertilizer use in 10 years. The Summit's follow-up policy actions and investments led to important gains in fertilizer use, but average level of 16.2 kg/ha remains the lowest in the world and fall far below the Summit target of 50 kg/ha.

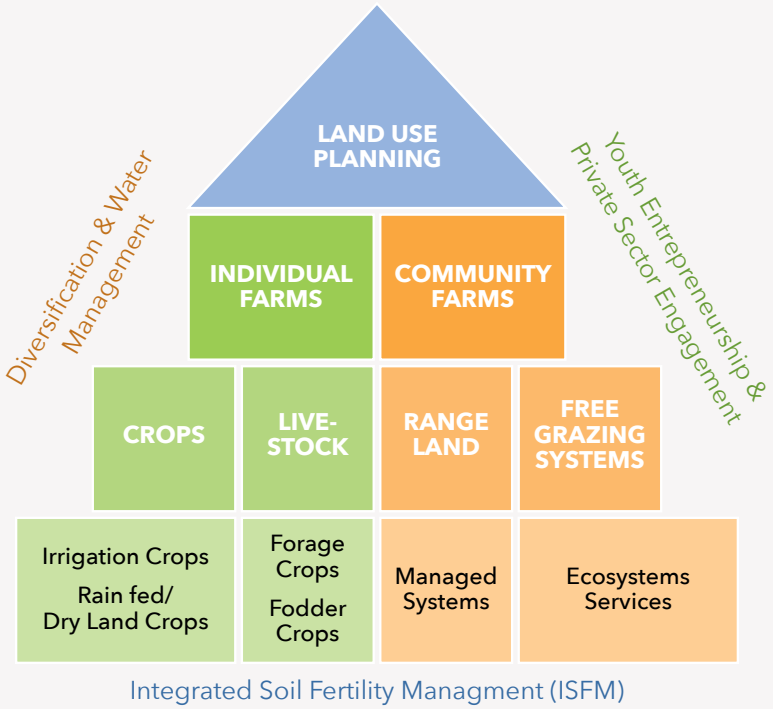
It is now clear that in addition to increased NPK use, a holistic approach that addresses balanced crop nutrition, soil fertility management, and climate-resilient practices is needed to improve and sustain agricultural productivity and livelihoods on the continent. A follow-up event building on the 2006 Africa Fertilizer Summit is being planned by the African Union to highlight the imperative of improving soil health and plant nutrition, discuss technical and policy issues, and galvanize African and global leaders around critically needed investments.

BOX 13: SOILS CONSORTIUM

The Sustainable Opportunities for Increasing Livelihoods with Soils (SOILS) Consortium was established in 2019. SOILS is a collaborative platform that provides research and analytical support to national governments and private sector partners on land use, soil fertility and plant nutrition investment, and policy.

The SOILS Consortium is led by IFDC and funded by the U.S. Agency for International Development (USAID) Bureau for Resilience and Food Security through the Feed the Future Soil Fertility Technology Adoption, Policy Reform, and Knowledge Management (BFS-SFT) project. Early efforts will focus on Niger and Ethiopia, but SOILS is expected to expand to additional countries and partners in the future.

Government and technical partners include senior officials from national Ministries of Agriculture, CORAF and other regional agricultural research institutions, ICRISAT and other CGIAR centers, and the U.S. Department of Agriculture – Agricultural Research Service. University partners include Kansas State University, Michigan State University, University of Colorado, and Auburn University.



Collaborative Research & Policy Activities Framework – Niger

BOX 14: IMPROVING POLICIES AND PERFORMANCE THROUGH STAKEHOLDER-LED PLATFORMS

Throughout its history, IFDC has worked to develop inclusive fertilizer sector platforms where stakeholders can gather for informed, evidence-based discussions and action related to soil and fertilizer sector development priorities and improving the policy and regulatory enabling environment. Two recent examples are IFDC's national-level work in Kenya and its regional platform in West Africa.

In October 2018, IFDC worked with Kenya's Ministry of Agriculture, Livestock, Fisheries and Irrigation and fertilizer sector partners to organize an initial Kenya Fertilizer Roundtable (KeFERT), aimed at better coordinating efforts to expand smallholder access and use of fertilizers. Public and private stakeholders subsequently agreed to form the Kenya Fertilizer Platform and work together to develop a roadmap for fertilizer sector development and address priority issues identified by KeFERT. Issues include regulatory standards, fertilizer quality, counterfeit products, and logistics and transport bottlenecks.

Efforts to organize a regional fertilizer platform in West Africa began in in 2013, when USAID's West Africa Fertilizer Program initiated an annual West Africa Fertilizer Forum (WAFF), a networking event for fertilizer industry stakeholders. By 2019, WAFF had attracted 200 participants from 30 countries and the West Africa Fertilizer Association (WAFA) assumed responsibility for organizing the event. Created with IFDC support in 2016, WAFA has emerged as the leading voice of the fertilizer industry in West Africa.

BOX 16: IFDC INTERNATIONAL TRAINING PROGRAMS

IFDC trains more than half a million people every year through field projects. In addition, IFDC offers specialized international training programs. Since 1974, more than 11,000 farmers, private sector investors, professionals from international development agencies, researchers, and government officials have benefited from over 700 formal workshops, study tours, and training programs. In addition to technical training, these programs also provide a platform for IFDC training participants to exchange ideas and build networks.

Trainers bring up-to-date knowledge on the latest fertilizer technologies, manufacturing processes, nutrient management methods, delivery of improved products to farmers, and more. Recent training topics include:

- ✓ Delivering balanced crop nutrition to smallholder farmers
- ✓ Production of slow-release, controlled-release, and stabilized fertilizer products
- ✓ Production of phosphate-based fertilizers
- ✓ Technology advances in agricultural production and water and nutrient management
- ✓ Linking farmers to markets
- ✓ Crop simulation modeling

BOX 15: INFORMING EVIDENCE-BASED POLICY IMPROVEMENTS IN WEST AFRICA

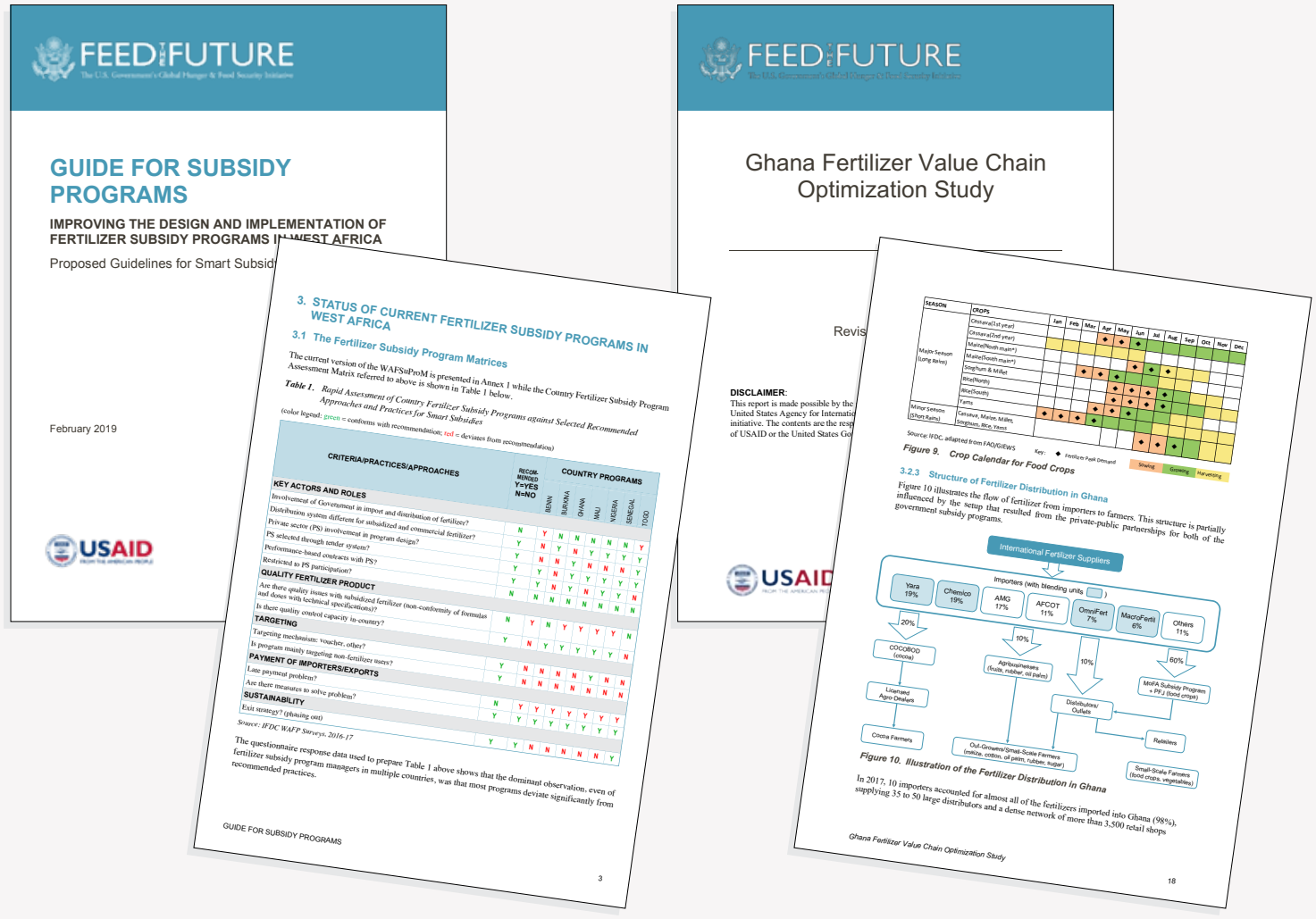
IFDC works with African-led regional institutions and national governments to address roadblocks to fertilizer supply and use through the Feed the Future Enhancing Growth through Regional Agricultural Input Systems (EnGRAIS) project, funded by USAID. EnGRAIS provides support to the Economic Community of West African States (ECOWAS) and its Member States to implement harmonized fertilizer policies and regulations. Improving the enabling environment for fertilizer region-wide will enhance the business environment and facilitate the transition to a private sector-led fertilizer market – which is vital to improving fertilizer supply and use.

To support regional harmonization, in 2018-19 EnGRAIS developed the Regional Fertilizer Subsidy Program Guidance and offered technical assistance to help countries reform their fertilizer subsidy programs. The guide is now having a major impact in Ghana, Niger, Burkina Faso, and Mali.

Through EnGRAIS, IFDC and its country partners have conducted cost buildup studies across four major fertilizer trade corridors in West Africa. The studies identify the bottlenecks to getting fertilizer in farmers' hands and suggest potential steps to reduce marketing costs and fertilizer prices to farmers. The cost buildups are guiding national policymakers in the reform of subsidy programs and related policies, including logistics and infrastructure concerns.

At the request of the Government of Ghana, EnGRAIS conducted a comprehensive Ghana Fertilizer Value Chain Optimization Study. The study included fertilizer cost buildups, formulations, use by region and crop, subsidy programs, recent developments, and a suggested way forward. The government is using this study to guide future policy decisions.

Access to finance is a major constraint to fertilizer sector development throughout the region because of perceived high levels of risk in agricultural lending. EnGRAIS provides policy analyses and options to reduce risk and transaction costs in the fertilizer supply chain and improve stakeholder access to trade and investment finance for fertilizer procurement, building manufacturing plants or blending units, and other infrastructure investments.



MEASURING OUR IMPACT

IFDC's 2020-2030 strategy focuses on coordinating and integrating project-level efforts across four priority areas to achieve significant impacts. The corresponding results framework, indicating detailed outputs and outcomes, is shown in Figure 4. IFDC will track a core set of indicators across all programs that reflect this results framework.

Our strategy is based on the theory of change that providing farmers with more nutrient-efficient, profitable technologies, and strengthening related marketing systems and policies, will lead to improved livelihoods, increased food security, and better environmental outcomes. Work under IFDC's four strategic priorities for research and development will be integrated across multiple levels. By connecting its programs on science and technology, farmers and markets, and knowledge and capacity building, IFDC and its partners will create the conditions for sustained, scaled adoption of soil-related technologies.

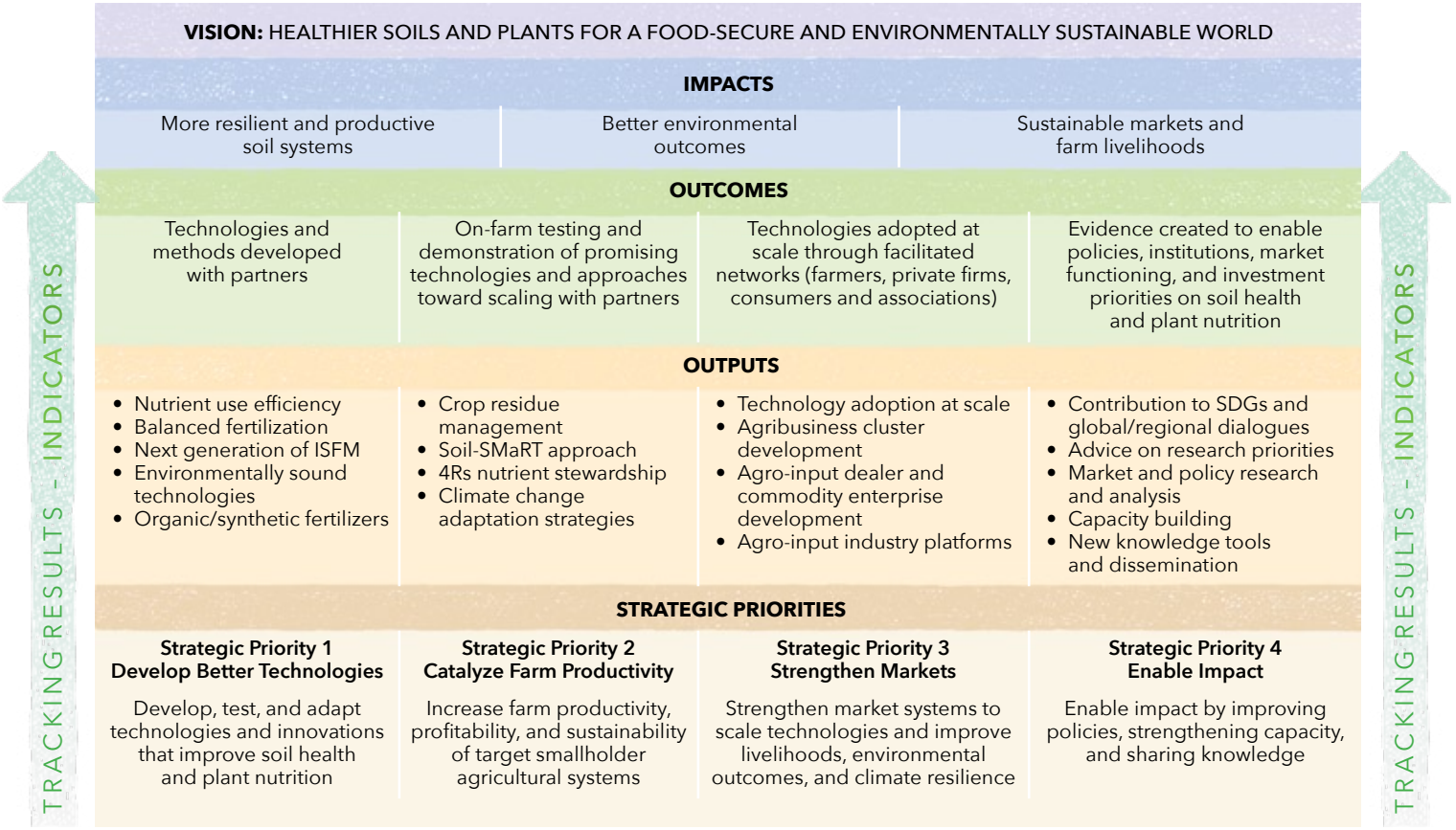
Reflecting our strategic objectives, the results framework highlights three stages:

Outputs are the direct results of our research priorities, for which we are accountable.

Outcomes are the use of such outputs, either through IFDC's activities or through networks and partners. This involves testing for validation and scaling among a wider audience through extensive knowledge sharing and dissemination.

Finally, **impacts** are the valued and aggregated results of the selected outcomes. Impacts are

Figure 4. Strategies to Results Framework (2020-2030)



received by consumers (farmers, stakeholders, etc.) and sustained and supported through engaged partners over time.

In addition, each strategic objective and its associated activities will deliver quantifiable outputs that include improved technologies, products, and tools; enhanced capacity building; new knowledge resources; and other valuable information. Through partnerships and networks, the outputs will be scaled at different levels and result in the use or adoption of technologies and tools, better policies and regulations, and improved functioning of markets and actors, based on sound scientific advice and evidence.

Specific indicators to track progress at different levels of the results framework, i.e., from outputs to outcomes to impacts, will be outlined with appropriate metrics of measurement and tools to reflect the progress of each strategic objective. Key milestones will be established to monitor and evaluate progress, including the number of new balanced fertilizer formulations, recommendations, and products developed from research.

As these outcomes are further reinforced through development activities, with support from global, regional, and national partners, IFDC will achieve the desired impacts: more resilient and productive soil systems, with better environmental outcomes, and improved and sustained markets and livelihoods.

PRINCIPLES AND VALUES

Throughout the world, in all IFDC offices, and with all of our staff and project beneficiaries, IFDC maintains principles and values that are woven through everything we do. These big ideas underscore our commitment to ensuring sustainable growth – whether in agricultural systems, last-mile communities, and even our staff's professional development.

Our Principles of Engagement serve as the foundation on which our work is built. These ideas guide our decisions, in setting research priorities, assessing business opportunities, and measuring our effectiveness. Our complementary Organizational Values describe how we approach our work and our relationships with stakeholders, donors, and our global staff.

PRINCIPLES OF ENGAGEMENT

✓ ***Science-Backed Innovation***

IFDC embraces new discoveries – its own or others' – and works with public and private partners to test their applicability in smallholder systems. We deliver scientific evidence that provides a foundation for the adaptation and responsible scaling of technologies and innovations. We use evidence and data to make decisions, learn from results, and share our knowledge.

✓ ***Environmental Stewardship***

IFDC prioritizes improving soil fertility and crop nutrition practices, technologies, and policies in order to reduce agriculture's environmental impact. We strive to strengthen the resilience of farmers to cope with increasing climate volatility.

✓ ***Locally Driven Solutions***

IFDC adapts technologies and innovations to meet local requirements and ensures they are profitable for farmers. In all activities, we focus on training and strengthening the regional and local institutions and actors who are ultimately responsible for scaling up adoption and making sustainable agricultural transformation a reality.

✓ ***Gender and Youth Equity***

We are committed to improving the lives of women, youth, and other vulnerable populations involved in agriculture so that they reap the economic and social benefits of development. Empowering women and youth with the tools, knowledge, household parity, and training to pursue agriculture as a business is essential to achieving social equity.

✓ ***Private Sector Engagement***

IFDC believes an engaged private sector is the key to sustainable development. We prioritize building private enterprises' capacity and facilitating public-private partnerships. The objective is to increase investment, strengthen markets, and improve the policy enabling environment in order to scale up innovations for smallholder farming systems.

✓ ***Impact-Driven Approaches***

Our impact is consistently measured, documented, and reported through research and development project indicators. Progress is reviewed on a regular basis, and data and intermediate findings are used to revise project approaches as needed.

ORGANIZATIONAL VALUES

✓ ***Inclusivity and Empowerment***

IFDC strives to create an inclusive environment where all staff members are encouraged to share knowledge and opinions and in which staff feel empowered to contribute ideas and assume responsibility for the development of innovative initiatives.

✓ ***Transparency and Accountability***

IFDC will employ the highest standards of integrity and honesty to safeguard public and private funds entrusted for its use. IFDC will report results and data from research and development activities using accepted scientific norms and in a transparent manner.

Data will be openly shared except in special cases where a confidentiality agreement has been negotiated.

✓ ***Collaboration and Cooperation***

IFDC staff work together in support of IFDC's Vision and Mission. They freely and enthusiastically exchange relevant information and resources to facilitate the achievement of everyone's goals and objectives. In so doing, they form a unified IFDC to partners, donors, and the staff members themselves.

✓ ***Innovation and Improvement***

Challenging the status quo and encouraging responsible risk-taking will lead the organization to deliver new and innovative solutions. Novel ideas must address problems that are within the purview of IFDC to tackle.

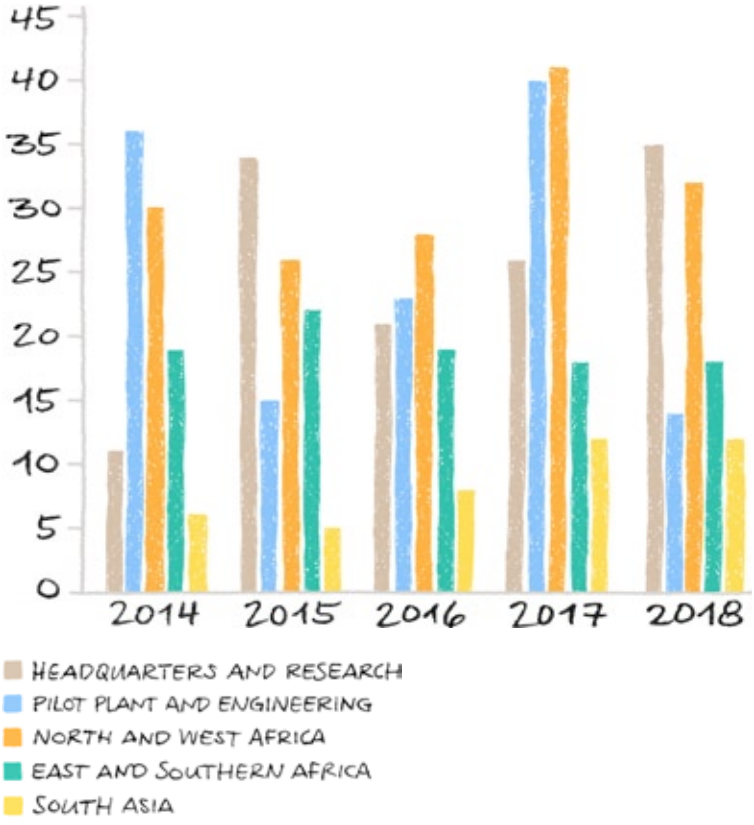
✓ ***Efficiency and Effectiveness***

The organization strives to become more effective by focusing on activities that further IFDC's Vision and Mission, adopting lessons learned, and implementing new ways of delivering solutions.

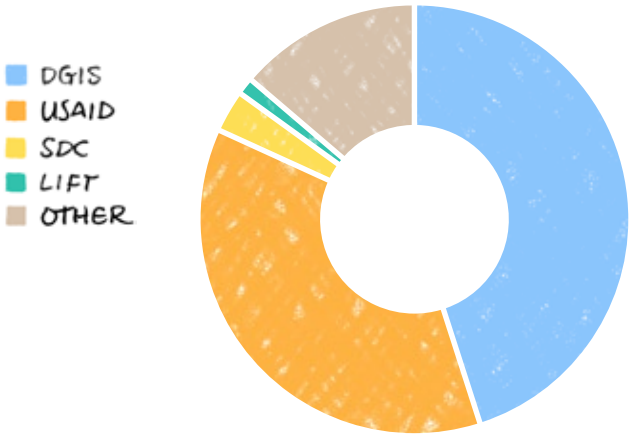
IFDC AT A GLANCE

IFDC's work focuses on bridging the gap between research, development, and markets with the ultimate goal of improving soil health and livelihoods in developing nations. Throughout our history, our work has spanned the world. IFDC currently employs staff across more than 20 countries. By working with donor organizations, public-private partnerships, and local entrepreneurs, we strive to achieve a shared vision of a world without hunger.

NUMBER OF PROJECTS

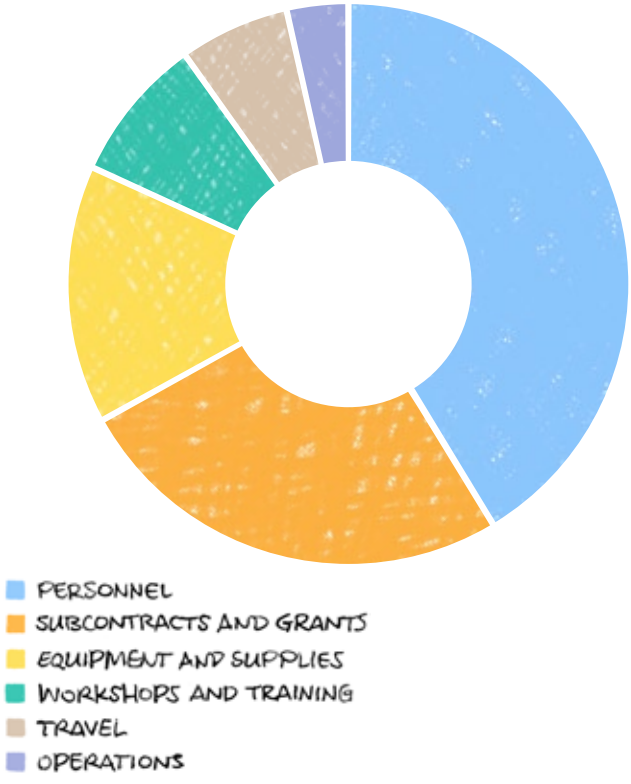


5-YEAR CUMULATIVE FUNDING SOURCES



DGIS *Netherlands Directorate-General for International Cooperation*
USAID *United States Agency for International Development*
SDC *Swiss Agency for Development and Cooperation*
LIFT *Livelihoods and Food Security Fund*

2018 FUNCTIONAL EXPENSES



IFDC, AN AIRCA MEMBER

AIRCA
Association of International Research and Development Centers for Agriculture

IFDC is a founding member of AIRCA, with its secretariat located in Nairobi, Kenya.

www.airca.org

IFDC HISTORY

Since 1974, IFDC has played a critical role in the development and transfer of affordable, effective fertilizer technologies around the world. IFDC's contributions span a wide spectrum of research and development work, including production process research, applied research on soil systems, development of innovative fertilizer products and application technologies, market systems development to strengthen input and output value chains, and policy analysis to enable fertilizer importation, business development, and smallholder adoption of fertilizer and other soil fertility technologies.

OUR REACH

BANGLADESH | BENIN | BURKINA FASO
BURUNDI | CÔTE D'IVOIRE | ETHIOPIA
GHANA | INDIA | KENYA | MALI
MOZAMBIQUE | MYANMAR | NEPAL | NIGER
NIGERIA | SENEGAL | TOGO | UGANDA

1974 – U.S. Secretary of State Henry Kissinger proposes the "establishment of an international fertilizer institute" during the United Nations General Assembly.

1974 – Dr. Donald McCune, IFDC's first Managing Director, files articles of incorporation for IFDC in Birmingham, Alabama.

1977 – President Jimmy Carter, by Executive Order, elevates IFDC to a Public International Organization.

1978 – IFDC Pilot Plant Complex begins operations on the IFDC headquarters campus.

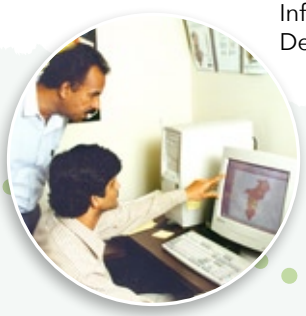
1986 – First field trials of fertilizer deep placement (FDP) commence in Bangladesh.

1987 – IFDC opens Togo office, establishing a permanent presence in West Africa.

1990 – IFDC introduces Integrated Soil Fertility Management (ISFM).

1992 – IFDC establishes Asia Division with permanent office in Dhaka, Bangladesh.

1994 – Nobel Laureate Norman Borlaug joins the IFDC Board.



2000 – IFDC launches Information Management and Decision Support Program.

2006 – Africa Fertilizer Summit transpires in Abuja, Nigeria.


AFRICA FERTILIZER SU
AFRICAN UNION SPECIAL SUMMIT OF THE HEADS
ABUJA, NIGERIA, 13 JUNE
Abuja Declaration
For The African Gree

2009 – IFDC establishes new Africa Divisions.

2009 – IFDC projects train more than 1 million in a single year.

2013 – U.S. President Barack Obama and USAID Administrator Rajiv Shah promote fertilizer deep placement in Africa.

2019 – Highly successful 2SCALE program launches second phase.

2020 – IFDC opens an office in India.

IFDC

Developing Agriculture from the Ground Up

2020-2030

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