FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Feed the Future Soil Fertility Technology (SFT) Adoption, Policy Reform and Knowledge Management Project

Semi-Annual Performance Report

October 1, 2017 – March 31, 2018

Cooperative Agreement No. AID-BFS-IO-15-00001

April 2018

USAID FROM THE AMERICAN PEOPLE

IFDC

Contents

Annexes

Tables

Figures

List of Acronyms

AAPI	Accelerating Agriculture Productivity Improvement
AFAP	African Fertilizer and Agribusiness Partnership
AFU	Agricultural and Forestry University
AgMIP	Agricultural Model Intercomparison and Improvement Project
AGRA	Alliance for a Green Revolution in Africa
AGRIFOP	Agribusiness Focused Partnership Organization
Al	Aluminum
AN	Ammonium Nitrate
AS	Ammonium Sulfate
AU	African Union
B	Boron
BARI	Bangladesh Agricultural Research Institute
BFS	Bureau for Food Security
BRRI	Bangladesh Rice Research Institute
CA	Cooperative Agreement
CAADP	Comprehensive Africa Agriculture Development Programme
CERES	Crop-Environment Resource Synthesis
CIF	Cost, Insurance, and Freight
cm	centimeter
cm	centimeter
CO_2	Carbon Dioxide
CoCoFe	Code of Conduct for Fertilizer Management
COMESA	Common Market for Eastern and Southern Africa
DAP	Diammonium Phosphate
DRA	*Direction Regionale de l'Agriculture*
DSR	Direct-Seeded Rice
DTPA	Diethylenetriaminepentaacetic Acid
FAO	Food and Agriculture Organization of the United Nations
FDP	Fertilizer Deep Placement
FMC	Field Moisture Capacity
FP	Farmers' Practice
FQA	Fertilizer Quality Assessment
FTF	Feed the Future
FTRT	Fertilizer
FY	Fiscal Year
g	gram
GHG	Greenhouse Gas
ha	hectare
HOI	Honduras Outreach Inc.
IFA	International Fertilizer Association
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
ISFM	Integrated Soil Fertility Management
ISP	Input Subsidy Program
K	Potassium

Ke-Fert	Kenya Fertilizer Roundtable
kg	kilogram
LCA	Life Cycle Analysis
LCC	Leaf Color Chart
LCI	Life Cycle Inventory
LIV	Local Improved Varieties
LRP	Locally Recommended Fertilizer
m	meter
M&E	Monitoring and Evaluation
MAP	Monoammonium Phosphate
MD	Microdosing
MELS	Monitoring, Evaluation, Learning and Sharing
Mg	Magnesium
mg	milligrams
Mn	Manganese
MOALF	Ministry of Agriculture, Livestock and Fisheries
MOU	Memorandum of Understanding
MSU	Michigan State University
MSU	Michigan State University
mt	metric tons
N	Nitrogen
N_2O	Nitrous Oxide
NARES	National Agricultural Research Extension Systems
NGO	Non-Governmental Organization
NO	Nitric Oxide
NP	Nitrogen and Phosphorus
NPK	Nitrogen, Phosphate, and Potassium
NUE	Nitrogen Use Efficiency
OS	Optical Sensor
P	Phosphorus
PEMEFA	Partnership for Enabling Market Environments for Fertilizer in Africa
ppm	parts per million
PR	Phosphate Rock
PS	Permanent Secretary
PU	Prilled Urea
PUDP	Prilled Urea Deep Placement
PVoC	Pre-Export Verification of Conformity
RADD	Rwanda Agro-Dealer Development
RCBD	Randomized Complete Block Design
ReNAPRI	Regional Network of Agricultural Policy Research Institutes
RP	Recommended Practice
S	Sulfur
SARI	Savanna Agricultural Research Institute
SIRS	Strickland Irrigation Research Station
SMaRT	Soil Testing, Mapping, Recommendations Development, and Technology Transfer
SOP	Potassium Sulfate

SOW	Scope of Work
SRI	Survey Research Institute
SSA	Sub-Saharan Africa
STV	Stress-Tolerant Varieties
TAFAI	The Africa Fertilizer Access Index
TASAI	The African Seed Access Index
ToR	Term of Reference
TSP	Triple Superphosphate
UB	Urea Briquette
UDP	Urea Deep Placement
UGA	University of Georgia
USAID	U.S. Agency for International Development
WSP	Water-Soluble Phosphorus
Zn	Zinc
ZnO	Zinc Oxide
$ZnSO_4$	Zinc Sulfate
ZOI	Zone of Intervention

Progress Toward Cooperative Agreement Award Objectives

The International Fertilizer Development Center (IFDC) enables smallholder farmers in developing countries to increase agricultural productivity, generate economic growth, and practice environmental stewardship by enhancing their ability to manage mineral and organic fertilizers responsibly and participate profitably in input and output markets. On March 1, 2015, the U.S. Agency for International Development (USAID) and IFDC entered into a new cooperative agreement (CA) designed to more directly support the Bureau for Food Security (BFS) objectives, particularly as related to Feed the Future (FTF).

Under the awarded agreement and in collaboration with USAID, IFDC conducted a range of activities and interventions prioritized from each annual work plan for the agreed-upon workstreams. The current reporting period reflects a transition to more coordinated field-based work in FTF countries with scientific support and expertise from IFDC headquarters. Some of the activities reported here are a continuation of work initiated in FY17. A summary description of the major activities is presented below.

Workstream 1: Developing and Validating Technologies, Approaches, and Practices

Under Workstream 1, IFDC continued to develop and validate technologies, approaches and practices that address nutrient management issues and advance sustainable agricultural intensification. These technologies are important for building climate resilience at the smallholder level as well as for improving agricultural productivity and nutrition. During this reporting period, IFDC devoted time and resources to:

- Technologies refined and adapted for mitigating stress and improving nutrient use efficiency, particularly for crops grown in areas subject to drought, submergence, salinity, acidity, and other constraints. This included:
  - Adaptive trials to evaluate the effectiveness of fertilizer management practices on rice production in submergence-prone areas in Ghana.
  - Field trials to determine the best management options for stress-tolerant rice varieties in Bangladesh, Nepal, and Myanmar.
  - Field and greenhouse experiments on methods to improve nutrient use efficiency with subsurface application of fertilizer, particularly in sub-Saharan Africa.
  - Study to evaluate wheat response to micronutrient fertilization.
  - Experiment to determine the role of enhanced efficiency fertilizer products and practices in slowing carbon dioxide emission and improving carbon sequestration.
- Balanced plant nutrition research to improve fertilizer recommendations that increase crop yields, protect soil health, and improve farmer profitability. This included:
  - Soil testing and plant tissue analysis to validate and update soil fertility maps in SSA.
  - Planning for a workshop on the status of soils in northern Ghana and fertilizer types, availability, and farm-level utilization in the country.

- Laboratory incubation and greenhouse studies to quantify the efficiency of secondary and micronutrients and their delivery.
- Greenhouse trial on the efficiency of phosphatic fertilizers and activation of phosphate rock.

- Fertilizer quality assessments for East and Southern Africa and Myanmar. Progress included:
    - Fertilizer quality assessment for Uganda in final stages of completion.
    - Fertilizer quality and value chain analysis for Myanmar completed.
    - Organization of a training program in Tanzania on improving fertilizer quality and balanced nutrition.

Workstream 2: Supporting Policy Reforms and Market Development

Under Workstream 2, evidence-based policy analysis was conducted to support reform processes and other initiatives that are focused on accelerating agricultural growth through the use of improved technologies, particularly fertilizers and complementary inputs. This analytical approach enables IFDC to support the development of fertilizer markets and value chains that allow greater private sector participation and investment with appropriate public sector regulatory oversight. The following is a summary of activities during the reporting period:

- Documenting policy reform processes and fertilizer market development. Activities included:
    - Support for a fertilizer roundtable meeting and policy reform in Kenya.
    - Presentation on agricultural input policies for a USAID BFS agriculture core course.
    - Workshop on the design and implementation of subsidy programs.
    - Contribution to a global consultation on the Code of Conduct for Fertilizer Management.
    - Participation as a consortium member of the Partnership for Enabling Market Environments for Fertilizer in Africa.
    - Review of input subsidy programs in SSA.
- Impact assessment studies on the performance of policy changes and supporting programs and lessons learned for future policy reforms and implementation. The following activities were conducted:
    - Assessment of Kenya fertilizer subsidy program.
    - Assessment of agro-dealer development programs in Rwanda.
- Economic studies to inform public and private decision-making and identify policy-relevant areas for intervention to streamline the flow of fertilizers at reduced prices for smallholder farmers. Activities included:
    - Organization of a workshop to disseminate findings of a Myanmar fertilizer quality, regulatory system, and value chain analysis.
    - Initiation of a consolidated report on West African fertilizer supply cost buildup assessments.

- Initiation of a graduate research study on greenhouse gas emissions under a rice-paddy system in Bangladesh and IFDC headquarters.

Cross-Cutting Issues Including Learning Agendas and Knowledge Management

Under the awarded agreement, IFDC conducted a range of activities and interventions prioritized by the 2018 annual work plan, including greater partnership with U.S. universities. This section summarizes the various associated outreach activities and the methods of disseminating research outcomes and findings. These are reported in Annexes 1 and 2.

1. Workstream 1 – Developing and Validating Technologies, Approaches, and Practices

Since technology/methodology development and field evaluation generally take more than a year, some of the activities reported are a continuation of work from the previous year. This report is therefore transitional and covers completing previous commitments and conducting new research with greater focus on testing new and innovative technologies that can improve the productivity and profitability of smallholder farmers while providing a greater degree of resilience to abiotic and biotic stresses. All reported activities are being conducted in FTF countries or targeted for FTF countries, and the majority are field evaluations. The research activities carried out at IFDC headquarters support and complement field activities. Below is a summary of activities for this reporting period.

1.1 Technologies Refined and Adapted for Mitigating Stress and Improving Nutrient Use Efficiency

Fertilizer management is a major challenge for crop production in stress-prone environments subject to drought, submergence, salinity, acidity, and other constraints. The research trials reported here were conducted under on-farm, greenhouse, and laboratory conditions to: (1) evaluate whether fertilizer best management practices can improve stress tolerance, (2) quantify the effect of subsurface fertilizer application on improved nutrient use efficiency, (3) improve nitrogen (N) use efficiency of organic and inorganic fertilizers, and (4) quantify the carbon dioxide (CO_2) mitigation role of enhanced efficiency fertilizers and practices.

1.1.1 Can Fertilizer Best Management Practices Improve Stress Tolerance?

1.1.1.1 Rice Production in Submergence-Prone Areas – Ghana

Most rice cultivars die within days of complete submergence, which often results in total crop loss. These losses disproportionately affect rice farmers in rainfed and flood-affected areas where alternative livelihood and food security options are limited. Optimal nutrition of rice seedlings before submergence and post-submergence is necessary to equip plants with cellular and metabolic requirements essential for survival of flooding and for fast recovery after floodwater recedes. The use of N-efficient urea briquettes could be an effective means of supplying N to submergence-tolerant rice cultivars to cope better under the vagaries of the flooded conditions. Previous efforts to improve rice productivity in submergence-prone areas focused mainly on varietal improvement. However, there is the need to find a technological fit between genotypes and identify the most fitting and best agricultural practices based on specific environmental conditions.

In collaboration with AfricaRice and Savanna Agricultural Research Institute (SARI), IFDC is developing appropriate soil fertility management technology tailored for submergence-prone areas using submergence-tolerant rice varieties. During FY17, adaptive trials were established in nine communities in northern Ghana to evaluate the effectiveness of urea deep placement (UDP) technology in improving rice productivity in submergence-prone areas using submergence-tolerant rice varieties, NERICA L-19 and NERICA L-49, as test varieties. In each trial, the effectiveness of UDP technology was compared with microdosing (MD) technology and the locally recommended fertilizer management practice (LRP). Although the preliminary results suggested that UDP technology could be an appropriate soil fertility management technology for submergence-tolerant rice varieties in submergence-prone areas, these were results from only one season. Therefore, during the last quarter of FY17, the trials were repeated at nine locations to validate the results, draw conclusions, and make recommendations. For this second season, the LRP treatment was modified whereby the granular urea was incorporated into the soil rather than surface application.

Each plot was appropriately bonded and had independent drainage points to prevent the spread of water and fertilizers between plots. The rice seedlings were transplanted in a 20-x-20-centimeter (cm) area with one seedling per hill. For all treatments, basal NPK (15-15-15) fertilizer was applied at a recommended rate of 250 kilograms per hectare (kg/ha) (two 50-kg bags/acre) three days after transplanting. For the UDP-treated plots, the 1.8-gram (g) urea briquette was applied seven days after transplanting. One briquette was placed between four rice plants (resulting in an application rate of 113 kg/ha) at a depth of 7-10 cm. For the MD treatment, granular urea was applied six weeks after transplanting, if applicable; otherwise, the application was delayed until the field had drained enough to allow for fertilizer application. For this treatment, the granular urea was measured using a “beer top” and applied per plant by incorporating it into the root zone of the rice plant (resulting in an application rate of 96 kg/ha). Similarly, for the LRP treatment, granular urea was applied six weeks after transplanting, if applicable; otherwise, it was delayed until the field had drained enough to allow for fertilizer application. For this treatment, 1.5 kg of granular urea was used (resulting in an application rate of 150 kg/ha). A furrow was made in between two rows and a pre-determined quantity of granular urea (150 kg/ha) was placed in the furrows and covered with soil. Although the urea application rates differed with each technology, no attempt was made to equalize the application rate because the intent of the trial was to compare the different technologies on rice production in submergence-prone areas. During the first quarter of FY18, these nine trials were harvested (at anthesis and at maturity to determine N content and grain yield, respectively). The total above-ground N uptake and nutrient use efficiency were determined.

Results obtained in the second year were consistent with the first year. The average yields across all nine locations showed that the greatest yields were obtained from the UDP treatment, followed by the subsurface-applied LRP and the MD treatments in that order (Figure 1). However, the differences in yield between the UDP treatment and the subsurface-applied LRP were not statistically different. Regardless, the fact that about 25% less urea was utilized in the UDP treatment than in the LRP treatment still makes the UDP technology superior to the LRP treatment. An economic analysis is being performed on the data to ascertain the profitability associated with each treatment. The results of the economic analysis will be presented in the annual report. Improvements in applicators will be beneficial to both subsurface placed granular fertilizer and briquettes.

Consistent with the results observed for the grain yield, the N uptake data at anthesis followed similar trends (Figure 2). Average N uptake across all nine locations from the UDP treatments was about 33 kg N/ha for NERICA-19 and 36 kg N/ha for NERICA L-49. Since urea was applied at 113 kg/ha (~52 kg N/ha) and with a very low native soil N content of 0.045% to 0.18%, N recovery by the rice plants from the UDP treatment was about 65% and 67% of the applied N, respectively, for NERICA L-19 and NERICA L-49. The average N uptake from the MD treatments was about 20 kg/ha, and with the urea application rate of 96 kg/ha (~44 kg N/ha), N recovery by the rice plants from the MD treatment was about 45% of the applied N. For the LRP treatment, the average N uptake was about 18 kg/ha, and with an N application rate of ~65 kg N/ha (150 kg of urea per hectare), N recovery from this treatment was less than 40% of the applied N. From the results, it is obvious that the response of both submergence-tolerant rice varieties to UDP technology was consistent and produced significantly greater yields and N uptake than their response to microdosing and the locally recommended fertilizer management practice. Thus, from the combined results of the past two years, it can be concluded that UDP technology could be an appropriate soil fertility management technology for submergence-prone areas, using submergence-tolerant rice varieties.

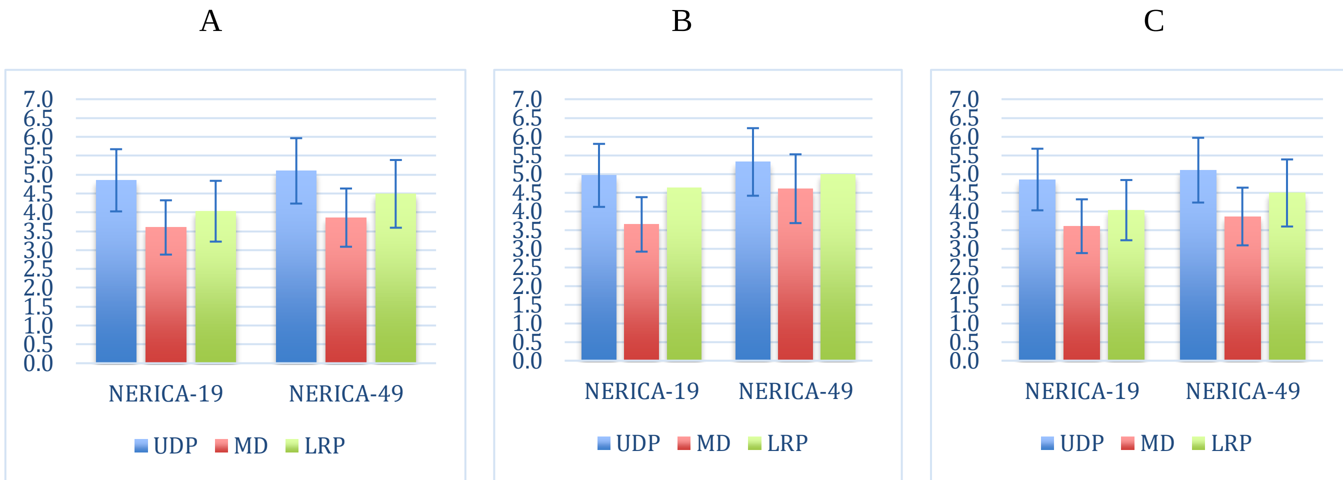

Figure 1. ***Average grain yield (mt/ha) of submergence-tolerant rice varieties grown at three locations each in the (A) Northern, (B) Upper West, and (C) Upper East regions of Ghana under UDP, MD, and LRP treatments. Bars represent average of 3 locations X 4 replicates; error bars represent standard error.***

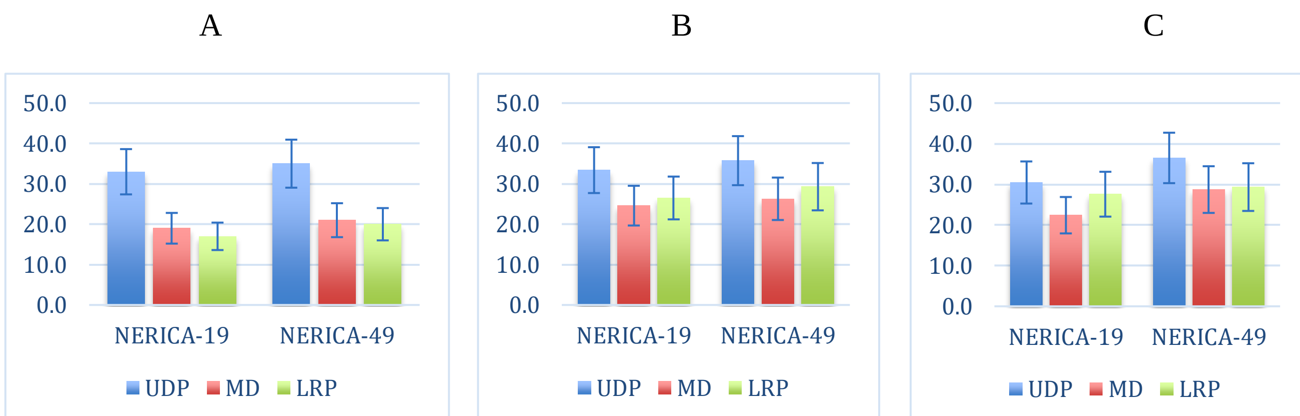

Figure 2. ***Average N uptake (kg/ha) of submergence-tolerant rice varieties grown at three locations each in the (A) Northern, (B) Upper West, and (C) Upper East regions of Ghana under UDP, MD, and LRP treatments. Bars represent average of 3 locations X 4 replicates; error bars represent standard error.***

1.1.1.2 Developing Appropriate Soil Fertility Management Technologies for Stress-Tolerant Rice Cultivars – Bangladesh, Myanmar, and Nepal

Drought and Submergence Trials in Bangladesh

During the 2017 wet season (called "*Aman*" season in Bangladesh), eight field trials were established (four drought trials and four submergence trials) in Bangladesh. Six to eight treatment combinations of fertilizer practice and rice varieties (Table 1) were tested in each trial to compare the performance of UDP with farmers' practice (FP). The deep placement of prilled urea was added to the trials to compare it with the deep placement of urea briquettes. The deep placement of both urea briquettes and prilled urea was done by hand under drought trials and by an "injector-type" applicator under submergence trials.

Table 1. Experimental treatments used for drought and submergence trials in Bangladesh during Aman 2017.

Treatments		N Rates (kg/ha)	
Variety	**Fertilizer**	**Drought**	**Submergence**
Local improved (LIV)	Farmers' practice	90±5†	60±10†
	Recommended practice	60	-
	PU deep placement	52	52
	UB deep placement	52	52
Stress-tolerant (STV)	Farmers' practice	90±5†	60±10†
	Recommended practice	60	-
	PU deep placement	52	52
	UB deep placement UDP	52	52

The treatments are combinations of fertilizer practices and rice varieties.
PU: prilled urea; UB: urea briquette.
†N rates for farmers' practice varied with trials.

Figure 3. Transplanting rice seedlings at a drought trial in Meharpur district, Bangladesh.

Figure 4. Transplanting rice seedlings (left) and granular urea deep placement under submerged condition in Barisal region in Bangladesh.

Under drought condition, UDP increased grain yields consistently over FP and recommended practice (RP) treatments in both varieties. While the UDP yields were consistently higher than prilled urea deep placement (PUDP), differences in yield were not significant (Table 2). These results confirm previous findings (*Aman* 2016). Farmers used almost double the amount of N compared to deep placement. While farmers use urea in multiple splits, the timing of application may not be synchronized with plant demand. Therefore, the farmers' practice of fertilizer application is very inefficient and probably not economical (based on lower yields and higher urea use). Economic analyses of these results will be presented in the next report.

Across all submergence experiment sites, the submergence-tolerant variety produced significantly higher grain yields over local varieties. However, fertilizer and variety had no interaction effects on grain yields. As under drought condition, UDP and PUDP significantly increased grain yields compared to FP in both varieties (Table 3).

These results suggest that PUDP may give comparable yields to UDP. Deep placement, however, is very challenging and not possible without complete mechanization. In the submergence trials, the injector applicator was equally as effective in deep-placing prilled urea as urea briquettes because it was possible to avoid direct contact between floodwater and prilled urea. Otherwise, applied urea dissolves in water immediately and rises to the soil surface and into the floodwater. The current injector applicator also requires a measured amount (by weight or volume) of prilled urea per placement. When smallholder farmers have access to urea briquettes, it is a more viable option than PUDP.

Soil Acidity Trials in Bangladesh

Different site-specific nutrient formulations, including compound fertilizers, were tested in northern Bangladesh in partnership with the Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI) under a project funded by OCP Foundation. This research will determine site-specific nutrient management packages, including the use of secondary and micronutrients, combinations of organic and inorganic fertilizers, and the use of lime for rice and non-rice crops. The field trials for *Boro* 2018 are in progress and will be reported in the next reporting period.

Table 2. Comparison of plant height, number of panicles, and grain yields with farmers' practice, recommended practice, prilled UDP, and UDP (briquette) under local improved varieties (LIV) and stress-tolerant varieties (STV) at drought-prone areas in Bangladesh.

	Plant Height (cm)			Panicles per m^2			Yield (kg/ha)		
Fertilizer	**LIV**	**STV**	**Average**	**LIV**	**STV**	**Average**	**LIV**	**STV**	**Average**
Damarhuda, Chuadanga									
FP	113	115	114c	249	247	248c	4,226	4,787	4,506b
RP	115	116	115b	247	227	237d	4,194	4,488	4,341c
PUDP	116	118	117a	271	260	266b	4,720	4,886	4,803a
UDP	116	119	118a	287	278	283a	4,764	5,078	4,921a
ANOVA (p value)									
Variety	0.0041			0.1763			0.0379		
Fertilizer	0.0000			0.0000			0.0000		
Variety x Fertilizer	0.0877			0.1976			0.0913		
Meharpur Sadar, Meharpur									
FP	113	114	114d	230	309	269c	4,113	5,293	4,703b
RP	115	116	116c	246	299	272c	4,348	5,212	4,779b
PUDP	117	119	118b	262	331	296b	4,579	5,471	5,025a
UDP	119	121	120a	294	341	317a	4,644	5,580	5,111a
ANOVA (p value)									
Variety	0.0591			0.0019			0.0096		
Fertilizer	0.0001			0.0000			0.0000		
Variety x Fertilizer	0.8863			0.1029			0.0513		
Chuadanga Sadar, Chaudanga (Mamudjoma)									
FP	114	117	116c	249	276	262c	3,894c	4,922c	
RP	115	116	116bc	251	287	269c	4,100b	5,018bc	
PUDP	116	118	117b	278	300	289b	4,564a	5,119ab	
UDP	118	121	120a	294	312	303a	4,526a	5,276a	
ANOVA (p value)									
Variety	0.0853			0.1085			0.0049		
Fertilizer	0.0001			0.0000			0.0000		
Variety x Fertilizer	0.3132			0.4379			0.0084		
Chuadanga Sadar, Chaudanga (Vultia)									
FP	113	115	114c	260	249	255c	4,212	4,733	4,473c
RP	114	117	115b	276	261	268b	4,437	4,870	4,653b
PUDP	115	118	117a	283	275	279a	4,509	5,130	4,819ab
UDP	115	120	118a	291	286	288a	4,618	5,220	4,919a
ANOVA (p value)									
Variety	0.0135			0.0707			0.0111		
Fertilizer	0.0000			0.0000			0.0006		
Variety x Fertilizer	0.1876			0.6986			0.6423		

Within a column and location, means followed by the same letters are not significantly different at $P<0.05$.

Table 3. Comparison of plant height, number of panicles, and grain yields with farmers' practice, prilled UDP, and UDP (briquette) under local improved varieties and stress-tolerant varieties at submergence-prone areas in Bangladesh.

Fertilizer	Plant Height (cm)			Panicles per m^2			Yield (kg/ha)		
	LIV	STV	Average	LIV	STV	Average	LIV	STV	Average
Amtali, Barguna									
FP	146	117	131b	242	279		3,258	4,202	
PUDP	148	119	133a	250	287		3,368	4,322	
UDP	149	119	134a	256	280		3,409	4,486	
ANOVA (p value)									
Variety	0.0000			0.0274			0.0002		
Fertilizer	0.0055			0.2026			0.0624		
Variety x Fertilizer	0.2877			0.3429			0.6104		
Potuakhali Sadar, Patuakhali (Poshuribunia)									
FP	153	115	134b	149	230	189b	3,442	3,907	3,675b
PUDP	163	117	140a	164	240	202a	3,636	4,208	3,922a
UDP	162	117	140a	166	252	209a	3,681	4,346	4,013a
ANOVA (p value)									
Variety	0.0010			0.0054			0.0327		
Fertilizer	0.0460			0.0031			0.0017		
Variety x Fertilizer	0.2108			0.4511			0.3317		
Potuakhali Sadar, Patuakhali (Pokkhia)									
FP	158c	115b		190	224	207b	3,195	3,822	3,508b
PUDP	161b	116a		207	237	222a	3,548	4,177	3,862a
UDP	164a	117a		209	238	223a	3,663	4,249	3,961a
ANOVA (p value)									
Variety	0.0001			0.0007			0.0036		
Fertilizer	0.0000			0.0061			0.0016		
Variety x Fertilizer	0.0050			0.7704			0.9750		
Bakerganj, Barisal									
FP	156c	115a		229b	225a		3,351	3,549	3,450b
PUDP	161b	116a		293a	235ab		3,722	3,965	3,844a
UDP	167a	117a		303a	239a		3,858	4,101	3,980a
ANOVA (p value)									
Variety	0.0003			0.0075			0.1741		
Fertilizer	0.0005			0.0000			0.001		
Variety x Fertilizer	0.0061			0.0000			0.9104		

Within a column and location, means followed by the same letters are not significantly different at $P<0.05$.

Drought Trial in Nepal

The experiment under drought-prone areas (rainfed condition) was also conducted in Nepal. This research was conducted in partnership with Agricultural and Forestry University (AFU). The objective of the experiments was to determine the optimum method of N fertilizer placement for different rice varieties, including LIV, drought-tolerant, and hybrid varieties. Five fertilizer treatments were tested in split plot design, with rice varieties as main plots and fertilizers as sub-plots. The five fertilizer treatments were control (0 kg N ha^{-1}), urea broadcast (78 and 100 kg N ha^{-1}), and granular and urea briquette deep placement (78 kg N ha^{-1}). Both granular and briquette urea were deep-placed manually by hand (Figure 5).

Figure 5. Deep placement of granular urea and urea briquette in drought trial, Nepal.

UDP produced significantly higher grain and straw yields and agronomic nitrogen use efficiency (kg grain/kg N) across all varieties (Table 4). Though variety and fertilizer interaction on grain yields was not significant, the yield increment with UDP at 78 kg N ha^{-1} was higher with the drought-tolerant variety (40%) compared to the improved (17%) and hybrid (10%) varieties. Grain yields between broadcast urea and PUDP were similar. Surprisingly, the hybrid variety did not increase grain yield compared to the improved and stress-tolerant varieties. Grain yields of improved varieties (6-7 mt ha^{-1}) could be approaching yield potential while yields of hybrid varieties could be limited by nutrient.

A separate experiment was conducted to compare the effects of UDP with different decision support tools for optimum N management. The amount and frequency of N were determined by optical sensor (green seeker), SPAD meter, leaf color chart (LCC), recommended practice, and UDP rate. Use of optical sensor reduced the amount of fertilizer compared to other treatments. However, among all treatments, UDP produced higher yields. Complete results will be presented in the next report.

In addition to a field trial, a farmers' survey was conducted to determine the knowledge gap between farmers' fertilizer management practice and the government recommendation. Survey data are under analysis. A scientific paper will be prepared for journal publication. Preliminary findings show that most farmers have no access to extension advice regarding fertilizer use (amount and timing). The main driver of fertilizer use was economic; rich farmers buy more fertilizers compared to poor farmers.

Table 4. Comparison of number of panicles, grain yield, straw yield, and nitrogen use efficiency with fertilizer types and rates under local improved varieties and stress (drought)-tolerant varieties in Nepal.

Fertilizer	Panicles per m^2				Grain Yield (t/ha)			
	LIV	STV	Hybrid	Average	LIV	STV	Hybrid	Average
Control-N0	222	193	193	203c	3.91	2.95	3.61	3.49c
Broadcast-N78	232	209	218	220bc	5.75	4.18	6.46	5.46b
PUDP-N78	240	198	222	220bc	5.14	4.91	5.48	5.17b
UDP-N78	294	281	307	294a	6.76	5.87	7.13	6.58a
Broadcast-N100	258	238	272	256b	6.83	5.48	6.37	6.23a
ANOVA (p value)								
Variety	0.5554				0.1016			
Fertilizer	0.0002				0.0000			
Variety x Fertilizer	0.9829				0.2431			
Fertilizer	**Straw Yield (t/ha)**				**NUE (kg grain/kg N applied)**			
	LIV	**STV**	**Hybrid**	**Average**	**LIV**	**STV**	**Hybrid**	**Average**
Control-N0	6.40	4.94	7.07	6.14c				
Broadcast-N78	7.72	6.89	7.97	7.53bc	24	16	36	25b
PUDP-N78	10.45	8.28	6.59	8.44b	15	25	24	22b
UDP-N78	10.23	10.87	9.77	10.29a	37	37	45	40a
Broadcast-N100	9.46	7.66	9.14	8.75b	29	25	28	27b
ANOVA (p value)								
Variety	0.6296				0.2804			
Fertilizer	0.0001				0.0011			
Variety x Fertilizer	0.1661				0.2667			

Within a column and response variable, means followed by the same letters are not significantly different at $P<0.05$.

Salinity and Submergence Trials in Myanmar

In the dry season of 2017, two field trials were conducted in Myanmar in saline-prone areas (Bogale and Pyapon). Four fertilizer treatments, namely farmers' practice at 114 kg N/ha, recommended practice at 85 kg N/ha, and prilled urea deep placement and urea briquette deep placement, both at 58 kg N/ha, were tested in combination with local and saline-tolerant variety, Pyi Myanmar Sein.

Fertilizer treatments had no interaction effects with variety on grain yields. UDP increased grain yield significantly compared with FP and RP at both locations. Grain yield with UDP was 32% and 61% higher than FP at Bogale and Pyapon, respectively. Although granular urea deep placement (PUDP) is not possible by hand, its effect on grain yields was comparable with UDP. These results suggest that deep placement is equally as effective under stress environment (saline soils) as in irrigated rice fields.

Table 5. Comparison of plant height, number of panicles, and grain yields with farmers' practice, recommended practice, prilled UDP, and UDP (briquette) under local improved varieties and stress-tolerant varieties in salinity-prone areas of Myanmar.

Fertilizer	Plant Height (cm)			Panicles per m^2			Yield (kg/ha)		
	LIV	STV	Average	LIV	STV	Average	LIV	STV	Average
Bogale									
FP	71b	90b		432	398	415b	3,246	3,650	3,450b
RP	70b	85b		415	373	394b	2,440	3,130	2,790c
PUDP	78a	104a		480	510	495a	4,410	4,390	4,400a
UDP	77a	103a		543	520	532a	4,546	4,553	4,550a
ANOVA (p value)									
Variety	0.0045			0.3584			0.0769		
Fertilizer	0.0000			0.0051			0.0000		
Variety x Fertilizer	0.0339			0.7268			0.2893		
Pyapon									
FP	75	97	86b	358	478		2,503	3,970	3,240c
RP	81	107	94a	487	628		2,793	5,173	3,980bc
PUDP	89	109	99a	523	538		3,726	5,133	4,430ab
UDP	85	105	95a	530	491		4,646	5,776	5,210a
ANOVA (p value)									
Variety	0.0063			0.4697			0.0327		
Fertilizer	0.0128			0.0797			0.0034		
Variety x Fertilizer	0.8420			0.2787			0.4859		

Within a column and location, means followed by the same letters are not significantly different at P<0.05.

Field trials were initiated during the wet season (July 2017) at three submergence-prone areas in Myanmar. However, due to early flooding and heavy loss of seedlings, the trials at one location were abandoned. Two fertilizer treatments, farmers' practice at 75 kg N/ha and urea briquette deep placement at 50 kg N/ha, were tested in combination with local improved variety and submergence-tolerant variety, Swarna sub1.

The overall effect of varieties, fertilizer treatments, and locations, and their interactions on grain yield and number of panicles is summarized in Table 6. At both locations, Swarna sub1 outperformed local varieties in yield and panicle numbers (Figure 6). Only at Kungyangon, UDP gave significantly higher grain yield than FP. At the high-yielding location (Kwin Yar), basal application of diammonum phosphate (DAP) followed by three split applications of urea improved the efficiency of broadcast application to give similar yield as UDP. BMPs in favorable environment could be as effective as UDP to give similar yields. However, other impacts of UDP are lower fertilizer dosage, reduced N losses to the environment and one-time application of N fertilizer – with overall higher gross margin[1]. A scientific paper comparing the results of field trials over the past two years under drought and submergence conditions from Myanmar and Bangladesh will be prepared for journal publication. Ongoing efforts are also being made for

[1] Kaw, D and G. Hunter (2017). UDP technology and rice yields among farmer beneficiaries of rainfed lowland project areas in Myanmar. IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 135-149, IFDC and DAR, Myanmar.

collecting additional input cost and output price data to complete economic analyses of the stress trials. The economic results may be used for a separate publication or combined with the agronomic paper.

Table 6. Comparison of variety, fertilizer, and location, and their interactions on number of panicles and grain yields for submergence-prone areas in Myanmar.

Effect	Grain Yield		Number of Panicles	
	F Value	Pr > F	F Value	Pr > F
Location	185.85	<.0001	3.32	0.0946
Variety	45.54	0.0006	8.38	0.0141
Location *Variety	1.46	0.2745	0.35	0.5669
Fertilizer (FTRT)	8.59	0.0272	10	0.0086
Location *FTRT	6.41	0.0458	0.01	0.9165
Variety*FTRT	0.56	0.4821	0.1	0.7535
Location *Variety *FTRT	0.19	0.6781	1.52	0.2424

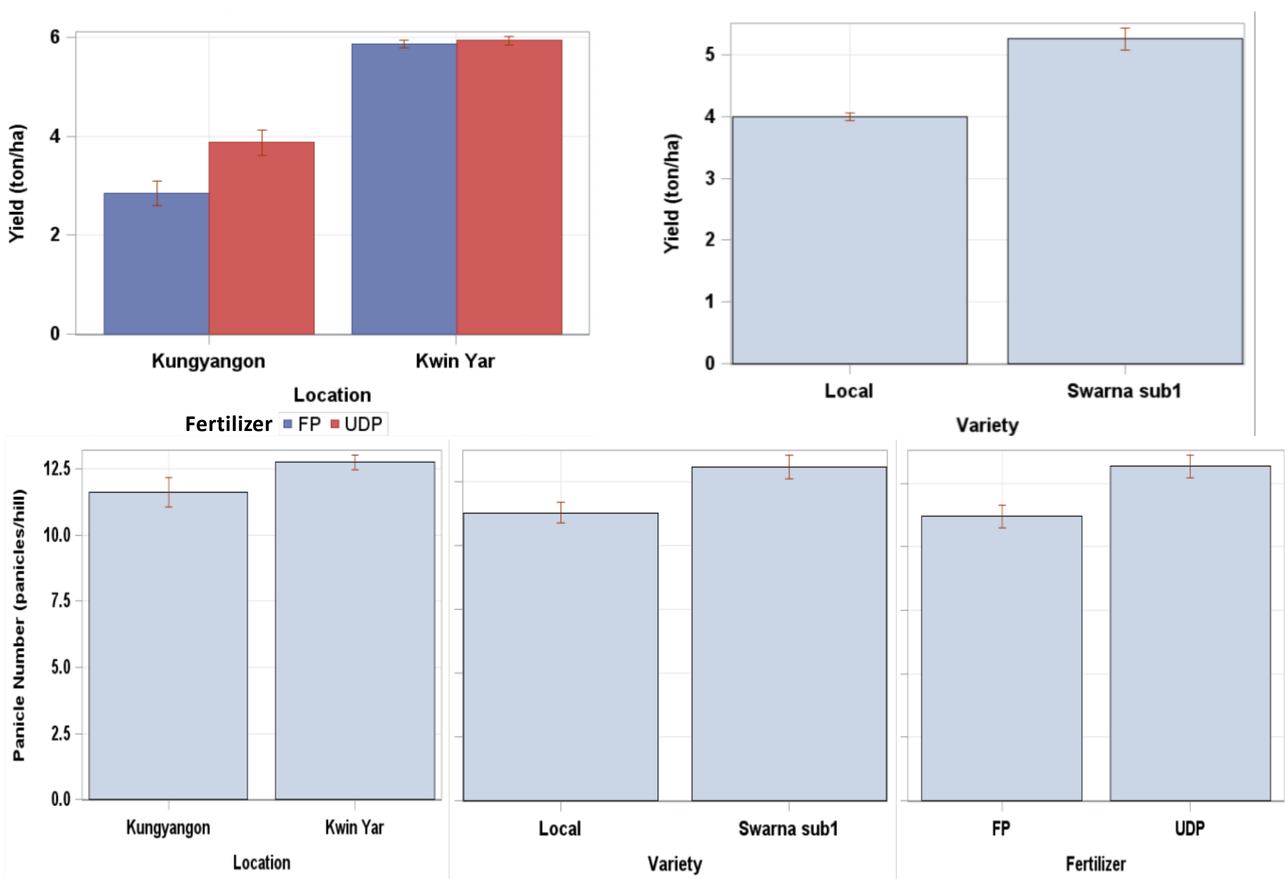

Figure 6. Effect of fertilizer treatment (UDP versus FP), variety (submergence-tolerant versus local improved variety) and location on grain yield and number of panicles under submerged conditions in Myanmar.

1.1.2 Improved Nutrient Use Efficiency with Subsurface Fertilizer Application

Subsurface fertilizer application improves nutrient use efficiency by improving the availability of nutrients for crop uptake and/or reducing nutrient losses.

1.1.2.1 Comparison of Agronomic and Economic Performance of FDP (NP, NPK, and Urea Briquettes) on Paddy Rice Under Irrigated and Lowland Cropping Systems in Mali

Since 2014, the FTF USAID Scaling Up Fertilizer Deep Placement and Microdosing Technologies in Mali (FDP MD) project has been demonstrating and promoting the use of UDP in rice production systems, particularly in lowland and irrigated systems, in Mali. Results for FY17 showed an average increase in rice paddy yield of 1.2 mt/ha and 2.3 mt/ha for lowland and irrigated systems, respectively, relative to farmers' practice (the conventional broadcast of prilled urea). The increase in gross margin was $340/ha for lowland paddy rice and $1,376/ha for irrigated rice, demonstrating a clear profitability increase associated with the use of UDP in rice farming systems. Similar results were reported in previous years under the FDP MD project.

Additional field work in selected locations is being conducted in FY18 in partnership with *Direction Regionale de l'Agriculture* (DRA) and non-governmental organizations (NGOs).

1.1.2.2 Adapting Balanced FDP (NP and NPK Briquettes) to Intensive Rice Cropping Systems (SRI) in West Africa (Mali, Togo, and Burkina Faso)

The proposed activity will be conducted for two seasons starting in FY18 in partnership with the Cornell SRI initiative, national agricultural research extension systems (NARES), and NGO extension services. The FY18 season activities will be supported partially by the FDP MD project. Preparation for the field activities include interacting with partners to finalize the demonstration protocol as well as developing an activity budget to support the FDP SRI activity.

1.1.2.3 Agronomic and Economic Evaluation of Deep Placement on Maize and Winter and Off-Season Vegetables in Mali and Ghana

Vegetable Trials in Mali

The vegetable trials in Mali began in the winter season of 2017, but the experiment suffered from improper application of fertilizer treatments in the field. There was a discrepancy between the NPK fertilizer used to make the briquettes and the one used for basal broadcasting in the control treatments. Therefore, the data resulting from the test for that season did not receive full statistical analysis.

The FY18 on-station trials are being conducted in partnership with the World Vegetable Center (WorldVeg) through the FDP MD project to improve fertilizer use on vegetables in Mali. The activity will quantify vegetable crop yield and quality as affected by rate and placement of fertilizer briquettes (NP and NPK).

For the off-season crops, eggplant, onion, and tomato were grown at three locations. For each crop species, the field layout was a split plot design with four replicates. The main plot was placement of fertilizer with three levels (surface, 5-cm deep, and 10-cm deep) and four subplots for the rate of fertilizer application (no fertilizer, RP – broadcast incorporated, two-thirds of the RP rate as briquettes, and one-half of the RP rate as briquettes).

Data collection is in progress and data include crop yield, fruit number and mean weight per treatment, quality of fruits as measured by size, fiber, and nutrient content. In addition, data for economic assessment of treatments are being collected. The off-season vegetable trials are expected to end in early April.

Maize Trials in Ghana

To improve N use efficiency, smallholder farmers have been taught by the local extension services, supported by IFDC, to avoid the traditional surface broadcast application and apply fertilizers at the subsurface, near the root zone of the maize plants. This practice requires farmers measuring the fertilizer required for each plant, applying it to a hole dug near the plant, and covering the hole after application. Although this procedure has shown to be effective in increasing nutrient use efficiency and consequently maize yields, the practice is cumbersome and labor intensive. Farmers are therefore reluctant to adopt the practice. An innovative approach could be *a priori* briquetting of the quantity of fertilizer required by the plant and applying the briquettes to the plants, thereby eliminating the measuring of the granular fertilizer before applying it to the plant. However, additional research is required on improving briquette handling properties and strength before out-scaling of the "custom-blend briquetting". With the current emphasis on early-maturing maize varieties and drought-tolerant hybrids to mitigate the impact of drought and erratic rainfall on maize production, during FY17, 15 sites were selected in the three northern regions of Ghana (six in the Northern region, four in Upper East region, and five in Upper West region) to conduct adaptive trials to refine urea briquette application for these climate-resilient maize varieties.

The experiments were laid in a randomized complete block design (RCBD) with an individual plot size of 10 x 10 meters. Treatments were three fertilizer application methods: (i) subsurface application of granular urea; (ii) subsurface application of urea briquettes; and (iii) microdosing fertilizer technology. For all treatments, basal NPK (23-15-10) fertilizer was applied at a recommended rate of 250 kg/ha (two 50-kg bags/acre) at planting (~60 kg N, 40 kg P_2O_5, and 25 kg K_2O per ha). Also, all plots received equal amounts of sulfur (S), zinc (Zn), and boron (B) at a blanket application of 16 kg S, 5 kg Zn, and 2.5 kg B per hectare.

The plants have been harvested for the determination of grain and biomass yields. A sampling at anthesis was taken for total dry matter and for determining N content. Complete results and recommendations will be provided in the next report.

Upland Vegetable Production in Ghana

This trial was conducted to improve nutrient use efficiency in vegetable production, thereby reducing the cost of production and increasing farm profitability. In SSA, women are heavily involved in vegetable production; thus, the introduction of technologies that increase the productivity of vegetable production could increase household incomes and make the enterprise more attractive to all women (100%) engaged in vegetable production. Yield increases resulting from the FDP technology (urea and NPK briquettes) have been reported in Burkina Faso on tomato (26% increase), cucumber (22%), and yardlong bean (9%), compared to the conventional fertilizer application practice.

In 2017, nine sites were selected in the three northern regions of Ghana (three in each region) to evaluate the effect of the FDP technology on yield and nutrient use efficiency of vegetable crops (okra, pepper, eggplant, tomato, and onion). The study also evaluated the synergetic effects of the FDP technology and organics on the growth, development, and production of the vegetables. All vegetables have been harvested to determine crop yields and quality. The full description of the trials and the results will be presented in the next report.

Greenhouse Quantification of Subsurface Urea Application

Subsurface application (deep placement) of urea briquettes results in a substantial reduction in N losses, which results in higher availability of N for plant uptake and higher yield. Production of urea briquettes is considered a constraint. Research is needed to determine if the deep placement of prilled urea can achieve the same results as urea briquettes and if prilled urea deep placement will work under standing water conditions. The proposed greenhouse trial with rice quantified the effectiveness of the deep placement of prilled urea with an applicator, perfect placement (manually sealing the deep-placement site), and under saturated condition with no standing water versus 3 cm of standing water (Table 7). In addition, the effectiveness of ESN (polymer-coated controlled-release product) as an efficient N source was evaluated. All treatments received blanket application of other nutrients including micronutrients. Measurements included floodwater N (urea-N and NH_4-N) for 13 days after application of urea, rice grain yield, total dry matter, and N uptake.

Table 7. Experiment description for greenhouse trial on rice comparing subsurface application of prilled urea with urea briquettes (UDP) on flooded and saturated soils.

Trt	Description	Water	Method	N Rate (g/m^2)	P Rate (g/m^2)	K Rate (g/m^2)	S Rate (g/m^2)	Mg Rate (g/m^2)
1	Check-CF	Flooded	None	0	10	25	10	3
2	UDP-CFA	Flooded	Applicator	20.7	10	25	10	3
3ǂ	UDP-SatA-DSR	Saturated	Applicator	20.7	10	25	10	3
4	Prilled Urea-CFA	Flooded	Applicator	20.7	10	25	10	3
5	Prilled Urea-CFP	Flooded	Perfect	20.7	10	25	10	3
6!	Prilled Urea-CFB	Flooded	Broadcast	20.7	10	25	10	3
7*	ESN-CFB	Flooded	Broadcast	20.7	10	25	10	3
8	UDP-SatA	Saturated	Applicator	20.7	10	25	10	3
9	Prilled Urea-SatA	Saturated	Applicator	20.7	10	25	10	3
10	Prilled Urea-SatP	Saturated	Perfect	20.7	10	25	10	3

CF: continuously flooded; DSR: direct-seeded rice; A: applicator; Sat: saturated; B: broadcast; P: perfect

ǂ All treatments were with transplanted rice except Trt 3, which was DSR. N application on DSR was at 15 days after emergence, while for all others N was applied at 5 days after transplanting.

! Broadcast application at five days after transplanting (50%), maximum tillering stage (25%), and prior to heading (25%).

* All ESN was surface broadcast applied in a single application at five days after transplanting.

Floodwater urea-N and ammonium-N concentrations were significantly higher under flooded conditions both as broadcast and subsurface application, reflecting greater potential for N losses due to runoff and volatilization (Figure 7). Floodwater N concentrations were significantly reduced when subsurface application was on saturated soil prior to flooding (Table 8). The "perfect" placement also reduced floodwater N concentration, enforcing the need for a faster (mechanized) and better applicator. One-time application of ESN gave lower floodwater-N concentrations throughout the measurement period, reflecting controlled-release of urea over time. Subsurface application of urea briquettes resulted in the lowest potential N loss.

Subsurface application on saturated soil was more effective for both urea briquette and prilled urea than on flooded soil, resulting in significantly higher grain yield (Table 9). Under both water regimes, UDP was significantly better than subsurface application of urea. Subsurface prilled urea application on saturated soil and with "perfect" placement under flooded conditions gave similar grain yield as UDP under flooded conditions. Under favorable conditions and a high-yield environment, as in this study and a submergence trial from Kwin Yar, Myanmar, broadcast split application of urea gave similar yield as UDP under flooded conditions (Table 10 and Figure 6). However, grain and total N uptake was significantly higher with UDP treatments. Fertilizer N recovery efficiency was the highest for subsurface application of urea briquettes (transplanted and direct-seeded rice) at 69.6% followed by subsurface application of prilled urea on saturated soil at 55.5%, subsurface prilled urea under flooded conditions at 30.2% using applicator and at 43.4% with perfect sealing. Three-split broadcast application gave N recovery of 38.9% compared to a one-time broadcast application of high efficiency ESN fertilizer at 31.1%.

Overall, the results from greenhouse conditions confirm that where urea briquettes are not available for subsurface application under lowland rice cultivation, prilled urea, particularly on saturated soils or with good water management, can be effectively subsurface applied. The results also emphasize that similar yield results to UDP can be obtained under good management conditions with timely split application. However, when one considers the full impact of N fertilization in terms of yield, N uptake, N losses, and N recovery efficiency UDP was superior to all N applications tested, including the use of controlled-release ESN.

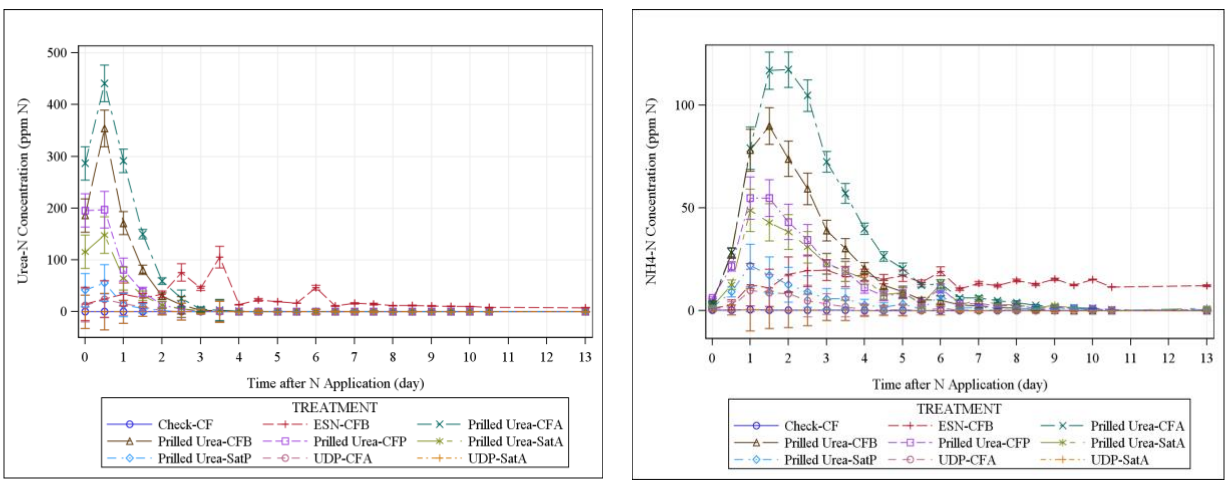

Figure 7. Effect of subsurface application of urea and urea briquettes on urea-N and ammonium-N concentration when applied on saturated versus flooded soils.

Table 8. Contrast means of floodwater urea-N and ammonium-N comparing subsurface application of prilled urea and urea briquettes (UDP) on flooded and saturated soils.

Mean Contrast		Floodwater Urea-N Mean Concentration (ppm)	F Value	Pr > F	Floodwater Ammonium-N Mean Concentration (ppm)	F Value	Pr > F
UDP	Flooded	2.812	0.56	0.454	1.915	1.93	0.1672
	Saturated	0.027			0.195		
Prilled urea	Flooded	39.22	114.7	<.0001	22.60	255.45	<.0001
	Saturated	11.08			8.627		
Flooded	UDP	2.812	127.9	<.0001	1.915	373.16	<.0001
	Prilled urea	39.22			22.60		
Saturated	UDP	0.027	11.8	0.0007	0.195	61.99	<.0001
	Prilled urea	11.08			8.627		

Table 9. Contrast means of rice grain yield and grain N uptake comparing subsurface application of prilled urea and urea briquettes (UDP) on flooded and saturated soils.

Mean Contrast		Mean Grain Yield (g/m_2)	F Value	Pr > F	Mean Grain N Uptake (g/m_2)	F Value	Pr > F
UDP	Flooded	1,069	4.61	0.0442	11.79	0.95	0.3412
	Saturated	1,136			12.23		
Prilled urea	Flooded	948	13.41	0.0015	8.73	36.93	<.0001
	Saturated	1,029			10.66		
Flooded	UDP	1,069	19.95	0.0002	11.79	61.75	<.0001
	Prilled urea	948			8.73		
Saturated	UDP	1,136	15.65	0.0008	12.23	16.18	0.0007
	Prilled urea	1,029			10.66		

Table 10. Contrast means of rice grain yield and total N uptake comparing subsurface application of prilled urea and urea briquettes (UDP) on flooded and saturated soils.

Tukey Grouping for TRT Least Squares Means (Alpha=0.05)
LS-means with the same letter are not significantly different.

Treatment Description	Mean Grain Yield (g/m2)		Mean Total N Uptake (g/m2)	
UDP – saturated soil with applicator	1,135.8	A	21.38	A
UDP – flooded with applicator	1,068.8	AB	21.52	A
Subsurface prilled urea – saturated soil	1,035.6	BC	19.07	AB
Broadcast prilled urea – flooded split application	1,033.7	BC	15.02	CD
Subsurface prilled urea – saturated soil with applicator	1,022.4	BCD	17.86	BC
Subsurface prilled urea – flooded	984.0	BCD	15.95	CD
Broadcast single application of ESN – flooded	950.9	CDE	13.40	D
Subsurface prilled urea – flooded with applicator	912.7	DE	13.22	D
UDP – saturated soil with applicator for DSR	842.4	E	21.04	A
Check – flooded	582.8	F	6.97	E

1.1.3 Improving Nitrogen Use Efficiency of Organic and Inorganic Fertilizers

The proposed activities to be conducted in partnership with universities (Auburn University, Clemson University, and University of Florida) and the private sector are in the planning stages. The activity reported here was conducted in partnership with the U.S. Department of Agriculture. It is a 3-year USDA NIFA-funded project being executed in collaboration with The Connecticut Agricultural Experiment Station (as the lead) and The University of Texas in El Paso. It started in March 2016 and ends on February 2019.

Yield Responses of Wheat to Micronutrient Fertilization

This is an ongoing study with the objective to evaluate the responses of wheat to fertilization with micronutrients, including zinc (Zn) and manganese (Mn), in order to understand how micronutrient fertilization influences crops' use of NPK and confer tolerance to biotic and abiotic environmental stresses in crops. In separate experiments, the micronutrients were applied as ZnO nanopowder or Zn-sulfate (salt) and MnO nanopowder, bulk MnO powder, or Mn-chloride (salt). The rate of Zn used was 6 mg/kg soil, and that of Mn was 10 mg/kg soil. N, phosphorus (P), and potassium (K) rates were 200, 75, and 200 mg/kg soil, respectively. In the Zn study, the experiment was conducted using fresh soils and used soils (previously treated with the same Zn types and amount and cropped with sorghum) to demonstrate whether Zn as nanopowder or salts (ions) have any residual value as fertilizer for subsequent crops, compared to fresh Zn applications. The soil used in the studies is a sandy loam with a near-neutral pH of 6.87, which suggests the pH is nearing the upper boarder line for optimum soil Zn and Mn bioavailability. The initial Zn level of 0.1 mg/kg was below the critical level for Zn of 0.5 to 1.0 mg/kg and likewise the Mn level of 6.4 mg/kg was below the critical level of 50-100 mg/kg.

Preliminary results showed that freshly applied Zn treatments as nanopowders or salt on the "fresh" soil increased grain yield by 15% or 18.5%, respectively, compared to the control – NPK only (Figure 8). Wheat grain yield was similarly increased by the residual Zn nanopowder and Zn salt compared to the control in the used (residual) soil by 10.5% and 12.5%, respectively. These findings indicate that Zn treatment has both immediate and residual effects on wheat productivity.

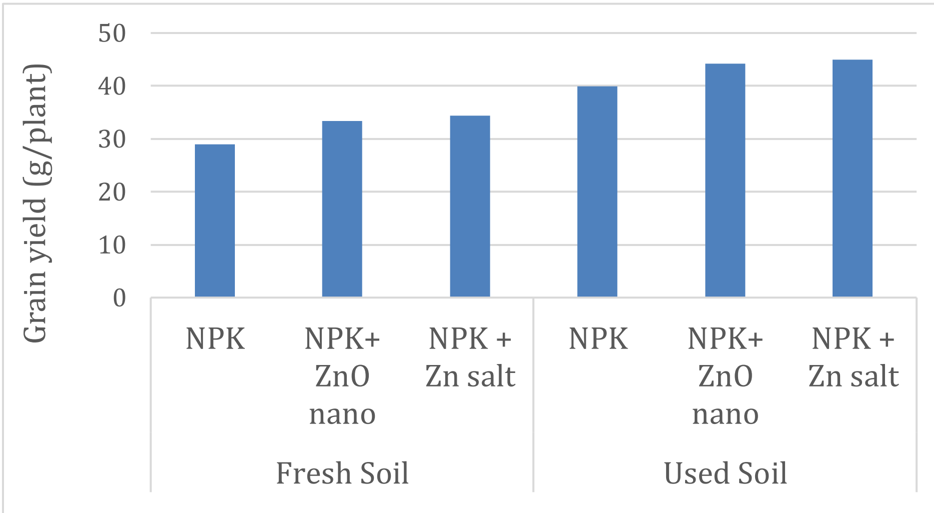

Figure 8. Response of wheat to ZnO nanopowder and Zn salt in fresh and used soils.

Figure 9 shows response of wheat to Mn. Compared to the control (i.e., NPK only), Mn treatment in soil as nanopowder, salts (ions), or bulk Mn increased grain yield by 16%, 9%, and 12%, respectively. In addition, the Mn nanopowder resulted in 4.6% more grain yield when applied as a foliar treatment compared to soil application. These findings indicate that nanopowder of Mn are more effective than other Mn forms in enhancing wheat grain yield. Also, compared to soil application, foliar application of nanopowder of Mn may be more effective for increasing grain yield.

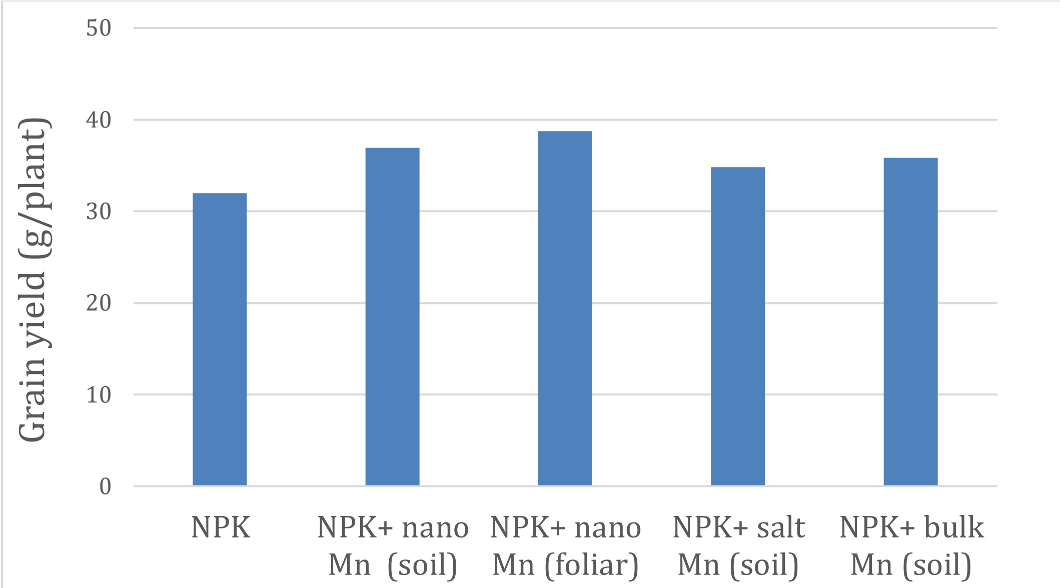

Figure 9. Response of wheat to Mn as nanopowder oxides, bulk particle oxides, and salts.

Additional data are currently being generated in both experiments. Specifically, NPK levels in the root, shoot, and grain are being determined, together with residual levels of these elements in the soil after plant harvest. The levels of Zn and Mn in the root, shoot, and grains are also being determined. We anticipate different effects of Zn and Mn on NPK uptake into shoot and their translocation into grain. It is expected that more Zn or Mn will be present in grains of plants treated with these nutrients. Ultimately, by tracking N, P, K, Zn, and Mn from soil through the root, to shoot, and grain, we hope to establish a mass balance of these nutrients through source to sink. Such outcomes can provide useful information for improving nutrient and fertilizer management in cropping systems, especially in SSA where low NPK application warrants strategies for crops to more efficiently use the small amounts applied. Furthermore, in the case of Zn, information pertinent to the frequency of Zn application will be gained from the residual studies. We will also understand the differences, if any, between nano-scale and ionic Zn or Mn on wheat responses.

1.1.4 CO_2 Mitigation Role of Enhanced Efficiency Fertilizers and Practices

Application of urea, independent of the method of application, results in CO_2 emission during urea hydrolysis. In broadcast-applied urea, all CO_2 emissions (0.73 kg/kg urea) to the atmosphere occur within five to seven days, contributing to the greenhouse gas (GHG) pool. Although CO_2 emission has a negative impact as a GHG, it also increases dry matter and grain yield, particularly in C3 plants, such as rice, wheat, and legumes, due to its positive effect on photosynthesis. However, to have the latter effect, CO_2 emission must occur over a prolonged period as with controlled-release fertilizers.

Results presented in Figure 10 show a net increase in CO_2 emission compared to ammonium nitrate (AN) for three soils – Hiwassee (pH 5.5), Greenville (pH 6.2), and Brownfield (pH 6.9) – incubated at 50% field moisture capacity (FMC) for 20-27 days (480-750 hours). The application of AN takes into account the effect of N fertilization on microbial activity; however, unlike urea-based products (UDP, Agrotain, ESN), there is no direct CO_2 emission from AN. Enhanced efficiency fertilizer, such as ESN, in addition to controlling the release of N, slowed the rate of CO_2 emission. Such reduction in the CO_2 emission rate may improve the opportunity for CO_2 capture by plants and soil microflora. A full report based on the ongoing thesis work will be presented in the next report.

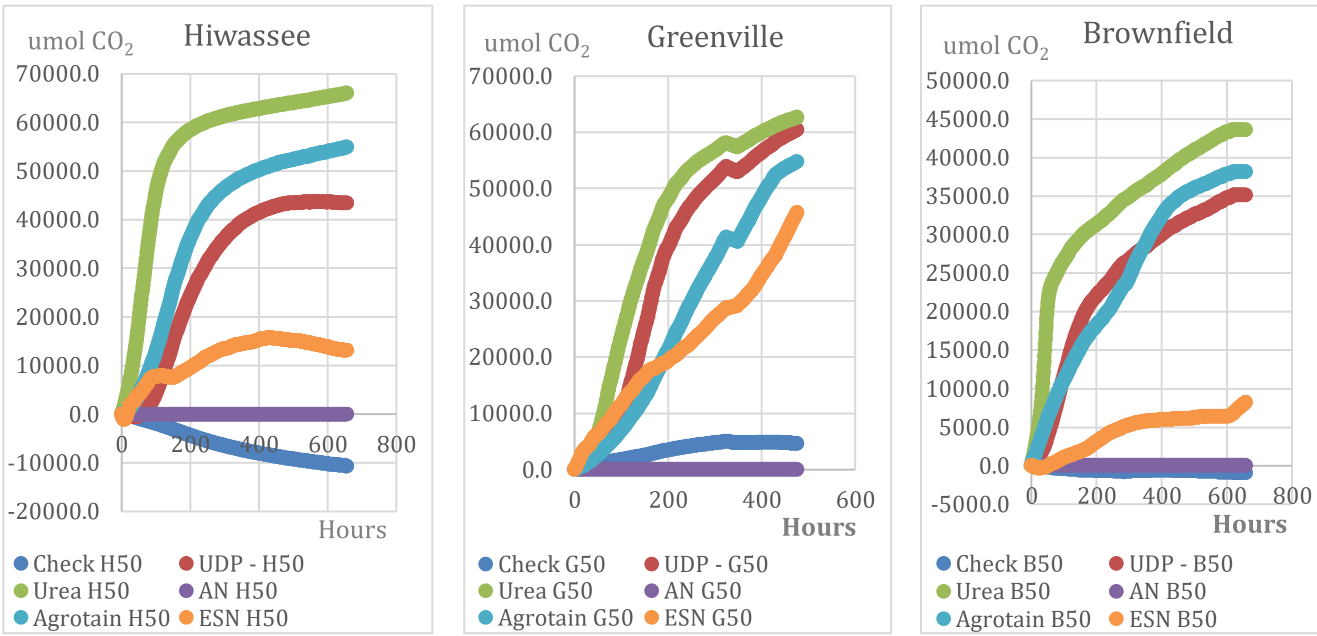

***Figure 10.** CO_2 emission (µmol) on application of urea-based fertilizers on Hiwassee, Greenville, and Brownfield soils at 50% FMC.*

1.2 Balanced Plant Nutrition Through Improved Fertilizer Product Recommendations (Cross-Cutting with Workstream 2.3)

For sustainable crop intensification and protection of natural resources, balanced nutrient management/fertilization is critical. Balanced fertilization is also important in the efficient use of fertilizers, soil health, and crop resilience. In addition to N, P, and K, many soils in SSA are now deficient in S, magnesium (Mg), Zn, and other secondary and micronutrients. These deficiencies are being confirmed by the results from the ongoing soil analyses of the FTF zones of intervention for the three northern regions of Ghana.

In Asia and SSA, several blends of fertilizers are available, and more will come into the supply chain. Assuming the fertilizer product has not been adulterated, such fertilizers generally have a positive impact on crop productivity. However, the availability of a given nutrient within a granule of fertilizer is strongly affected by the presence of other nutrients and the interactions of various nutrients within the granule or as the granule dissolves when applied. With synergistic combination of macro- and micronutrients in a granule, the plant availability and efficiency of fertilizer use can be increased. Conversely, antagonistic effects can result in reduced plant availability of critical nutrients and lower use efficiency. The progress of IFDC’s ongoing work on balanced plant nutrition through improved fertilizer product recommendations is presented.

1.2.1 Facilitate Site- and Crop-Specific Fertilizer Recommendations for Increased Economic and Environmental Benefits from Fertilizer Use

Updates of Soil Fertility Maps and Establishment of Nutrient Omission Trials to Validate the Fertility Maps

Farmers in developing countries regularly harvest crops yielding far below their biological potential. Although pests and diseases take their toll, and water shortages are widespread, nutritional disorders are probably the most pervasive constraint to crop yields in the tropics. This is the result of either inherently low soil fertility or nutrient depletion, soil acidity, and organic matter decline caused by repeated cropping without replacing what has been taken from the soil. To mitigate this problem, most farmers apply fertilizers to their field. However, current fertilizer recommendations in most developing countries are based on blanket fertilizer applications. Thus, to increase productivity, it is critical to consider the spatial soil fertility variability in order to redesign soil fertility recommendations to achieve sustainable growth in productivity, particularly in SSA.

Using geostatistical tools, soil fertility maps were developed during FY17 for pH, organic matter, N, P, K, Zn, S, and B with soil analytical data collected from the three northern regions of Ghana. These soil fertility maps will serve to provide the basis for soil- and crop-specific fertilizer recommendations, evaluation of the Soil testing, Mapping, Recommendations development, and Technology transfer (SMaRT) approach, and refinement of the GSSAT software (geographic information systems crop model application). The maps will be dynamic living maps that will be updated and fine-tuned periodically as more data become available. During the first quarter of FY18, the remaining soil samples collected were analyzed to update the soil maps. The updated maps did not deviate from the results of the previous maps. As stated in FY17, (i) across all three northern regions, particularly in the Upper East region and the northwestern corner of the Upper West region, the soils are generally acidic to slightly acidic with very few isolated cases where the soil pH is near neutral, and (ii) large portions of the total land area have soils deficient in P (<10 mg/kg), S (<6 mg/kg), Zn (<1 mg/kg) and B (<1 mg/kg). Thus, to increase productivity in such soils, and to realize the full benefits of investments in fertilizers, efforts must be made to supply farmers with fertilizers containing these essential plant nutrients and also make farmers aware of these nutrients for healthy crops. However, the quantities of the nutrients to supply will depend on the results of the nutrient omission trials.

In addition to the soil samples, analyses of 1,500 plant tissue samples were completed to validate the results of the soil analysis. The data from the plant tissue analyses are being used to develop separate maps for comparison with the soil maps. In general, the data of the plant tissue analyses showed a consistent match with the soil chemical analyses, as shown in Figure 11, for available soil P and tissue P content. On the other hand, except for a few isolated cases encountered so far, most of the soils in the entire zone of intervention have high K content (Figure 12), which should be adequate for the production of most crops. However, tissue K content from Western and Eastern Regions were low despite adequate soil K content. In some areas (seven in Northern, five in Upper East, and 12 in Upper West), the N, P, and K contents of the unfertilized plant tissue samples were greater than expected (Figures 11-13) due to plant roots accessing nutrients from deeper levels (beyond the top 6 inches analyzed). To confirm this and to aid in accurate fertilizer recommendations, soil samples from deeper horizons from these communities are being sampled for analysis.

Given the above results, a nutrient omission plot technique is needed to verify the soil test and plant tissue results and estimate fertilizer requirements. During the second quarter of FY18, separate omission plots are being established for each nutrient for the FTF crops of interest in northern Ghana (maize, rice, and soybean). Seventy-five sites were selected and demarcated for the establishment of the nutrient omission trial during the rainy season in the three northern regions of Ghana.

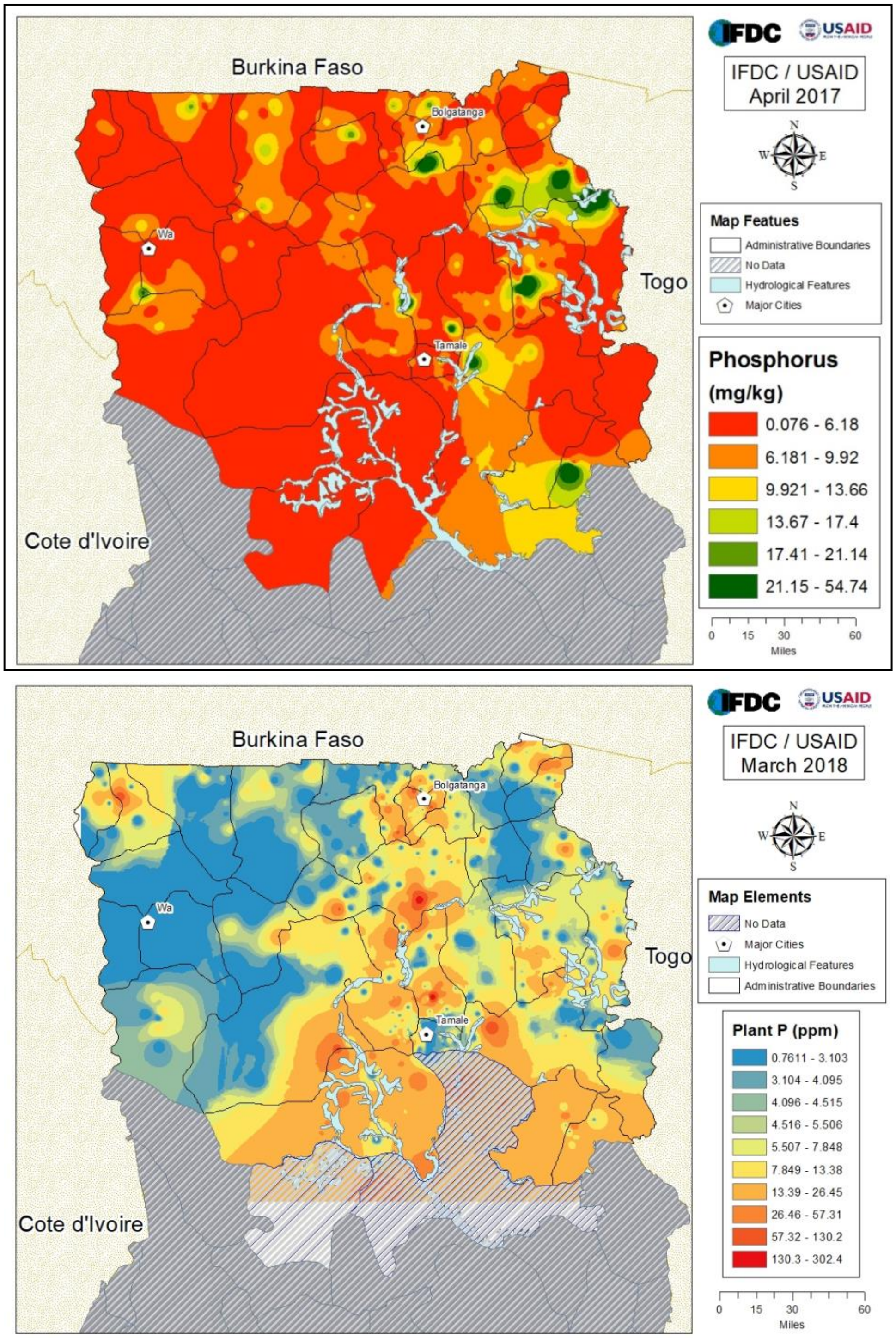

Figure 11. Comparison of soil P and plant P content (ppm) maps of the three northern regions of Ghana.

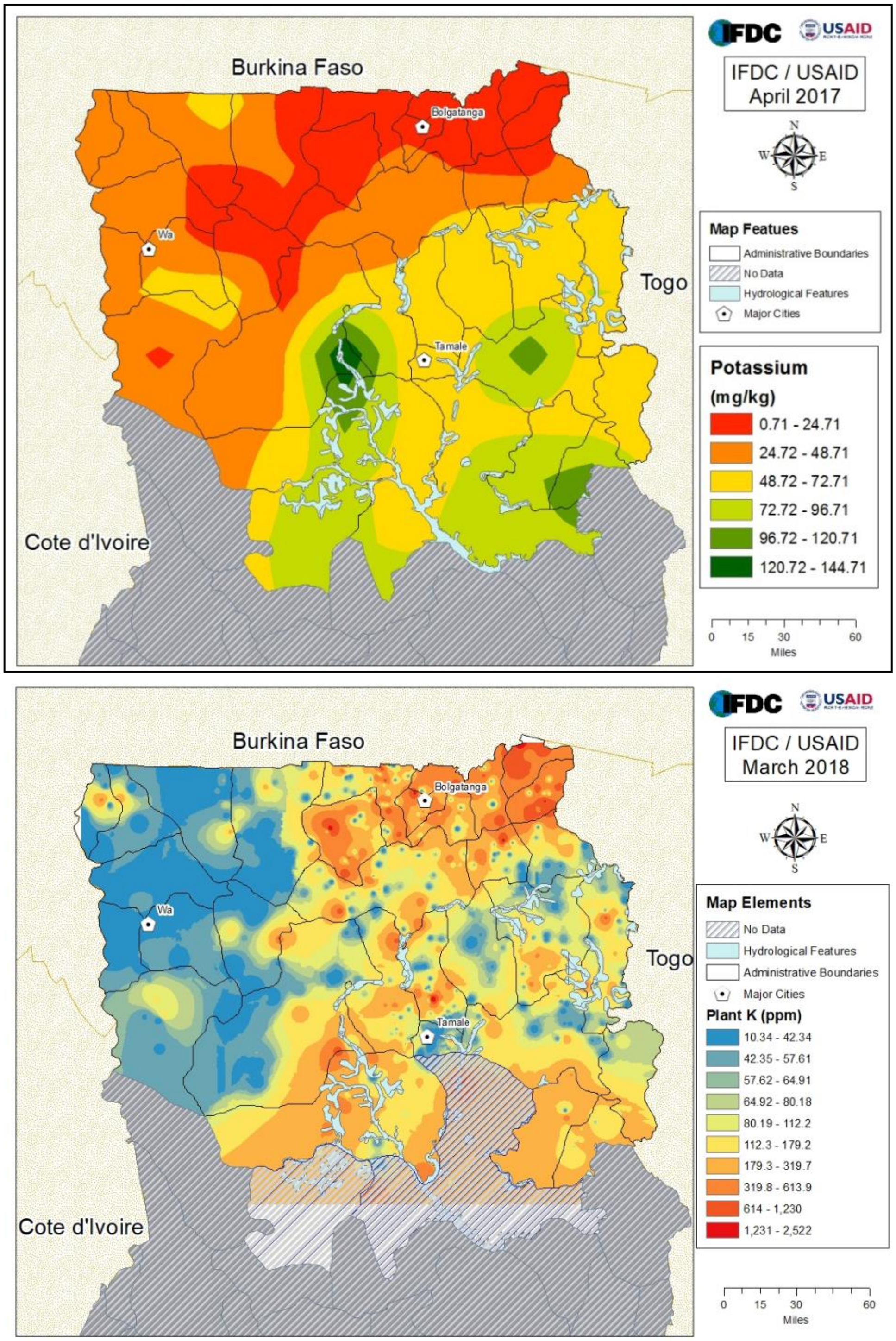

Figure 12. Comparison of soil K and plant K content (ppm) maps of the three northern regions of Ghana.

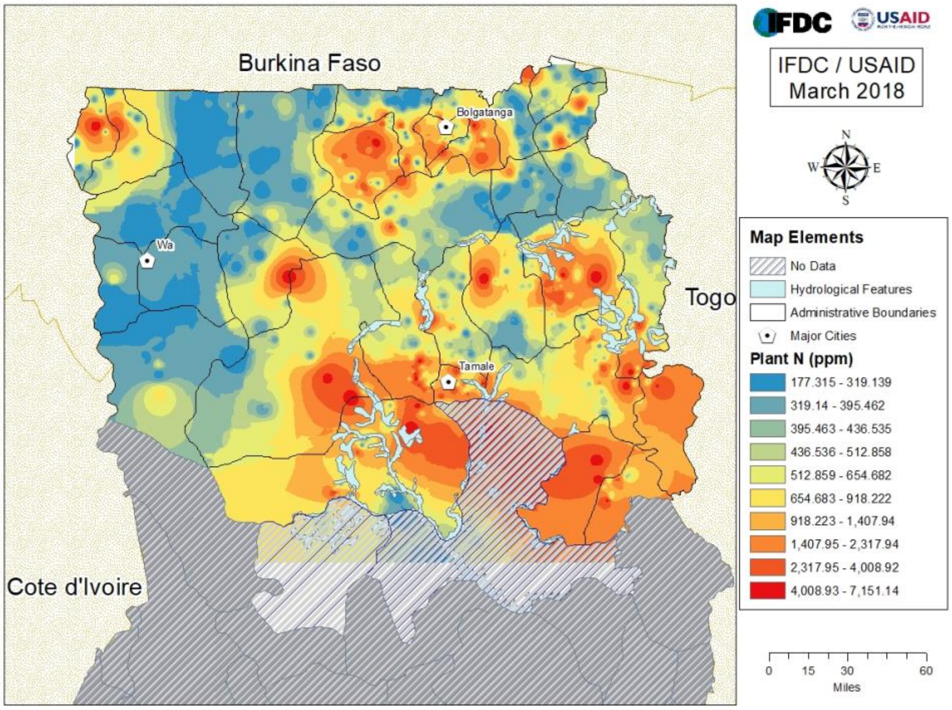

Figure 13. Plant N content (ppm) map of the three northern regions of Ghana.

1.2.2 Workshop on the State of Soil Fertility in Northern Ghana, Fertilizer Recommendations, Utilization, and Farm-Level Access

A workshop was proposed to be conducted in collaboration with the USAID Feed the Future Ghana Agriculture Technology Transfer project and the African Fertilizer and Agribusiness Partnership (AFAP) in March 2018. However, due to scheduling issues and the availability of key stakeholders, the workshop has been moved to the week of April 9, 2018. The purpose is to inform the agricultural community, government policymakers, and industry leaders about the status of soils in northern Ghana based on the latest scientific analyses and to raise awareness of fertilizer recommendations, practices, and availability. Expected participants that cut across the fertilizer industry will include policymakers (Plant Protection and Regulatory Services Directorate, Ministry of Food and Agriculture, Ghana Environmental Protection Agency), importers and blenders, distributors, researchers (SARI, Soil Research Institute), private soil labs, retailers, farmers, and special government initiatives (Planting for Food and Jobs, Youth Initiative in Agriculture). During this workshop, "undisclosed" information on the status of northern Ghana's soils as well as fertilizer types, availability, and farm-level utilization will be shared with forum participants, expanding their understanding of soil fertility and fertilizer issues in the region. Selected presentations will stimulate dialogue among forum participants regarding identified soil deficiencies and fertilizer recommendations, usage, and availability. It is anticipated that any gaps and weaknesses in the fertilizer value chain in northern Ghana will be identified by the workshop participants. They will adopt a proposed Action Plan to be implemented by identified responsible parties to address highlighted priority issues in the fertilizer value chain.

1.2.3 *Improved Nutrient Delivery from Multi-Nutrient Fertilizer Granules for Improved Yield, Quality, and Nutrition*

The availability and accessibility of multi-nutrient fertilizers to smallholder farmers will go a long way toward overcoming imbalanced fertilizer application. The activities involving university partnerships are expected to commence later in FY18. The field work in Ghana, Nepal, and Mozambique will begin at the onset of the rainy season. New proposed activities in Myanmar have been postponed indefinitely.

1.2.3.1 Quantify the Efficiency of Secondary and Micronutrients and Their Delivery Using N-, NP-, and NPK-Based Fertilizers

Laboratory incubation and greenhouse studies were conducted to quantify the availability of Zn when incorporated/granulated with: (i) monoammonium phosphate (MAP) and elemental S (MES-10SZ), (ii) ammonium sulfate (AS) and zinc sulfate (AS+$ZnSO_4$), (iii) AS and zinc oxide (AS+ZnO), (iv) AS+$ZnSO_4$+ZnO, and (v) potassium sulfate and ZnO (SOP+ZnO). The incubation study was conducted for six weeks, and greenhouse studies were conducted with maize grown for 10 weeks and soybean grown to maturity.

The incubation study showed that, in general, the soil Zn content tended to decline from the time of application to six weeks after application independent of soil type and product applied (Figure 14). The choice of products applied – AS+$ZnSO_4$, AS+$ZnSO_4$+ZnO combination, and MES-10SZ – did not have a significant effect on soil Zn content in the highly acidic Hartsells soil (pH 4.8). The SOP+ZnO product gave significantly lower soil Zn content than AS+ZnO in samples taken at two and six weeks after fertilizer application. The effect of Zn products was more evident in the neutral Greenville soil (pH 6.2) than Hartsells; however, after six weeks of incubation, all products (including SOP+ZnO) gave similar Zn content in the Greenville soil. The greatest variation in soil Zn content due to product differences was in the alkaline Sumter soil (pH 7.9). Overall, the soil Zn content after application of AS+$ZnSO_4$+ZnO products > AS+ZnO > SOP+ZnO > MES-10SZ. The commercially available MES-10SZ, with 1% Zn as $ZnSO_4$, had the lowest available soil Zn content in the Sumter soil.

Based on the incubation study, AS+$ZnSO_4$+ZnO products are a more efficient source of available Zn than MES-10SZ. The study also showed that Zn carrier fertilizers (whether MAP [as in MES-10SZ], AS [as in AS+$ZnSO_4$+ZnO products], or potassium sulfate [as in SOP+ZnO]) did influence the availability of Zn, as determined by DTPA extraction.

These results were further confirmed by greenhouse studies on Brownfield soil (pH 6.9). Although Zn application gave significantly higher dry matter yield after 10 weeks of growth, the differences between AS+$ZnSO_4$ and MES-10SZ were not significant. With soybean (grown to maturity), grain was significantly lower with MES-10SZ compared to AS+$ZnSO_4$ and AS+$ZnSO_4$+ZnO. MES-10SZ also gave significantly lower tissue and grain Zn concentration and Zn uptake for maize and soybean (Figure 15).

Multi-nutrient granular fertilizers do help smallholder farmers by supplying nutrients for balanced fertilization and better distribution of micronutrients; however, antagonistic interaction within/around the granular fertilizer immediately after application may reduce the availability of essential nutrients.

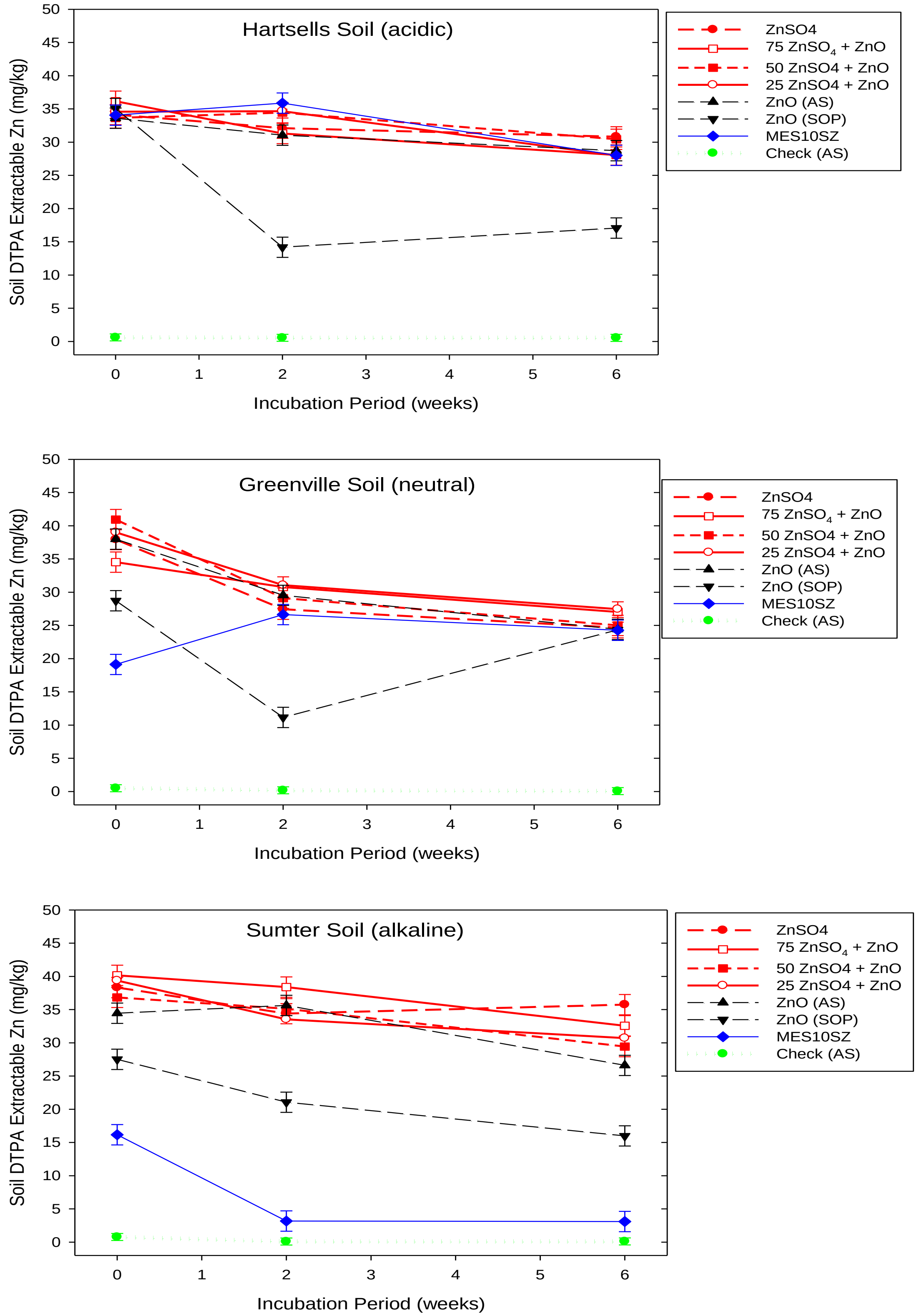

***Figure 14.** Soil Zn content (mg/kg) as influenced by Zn product and incubation period in Hartsells, Greenville, and Sumter soils.*

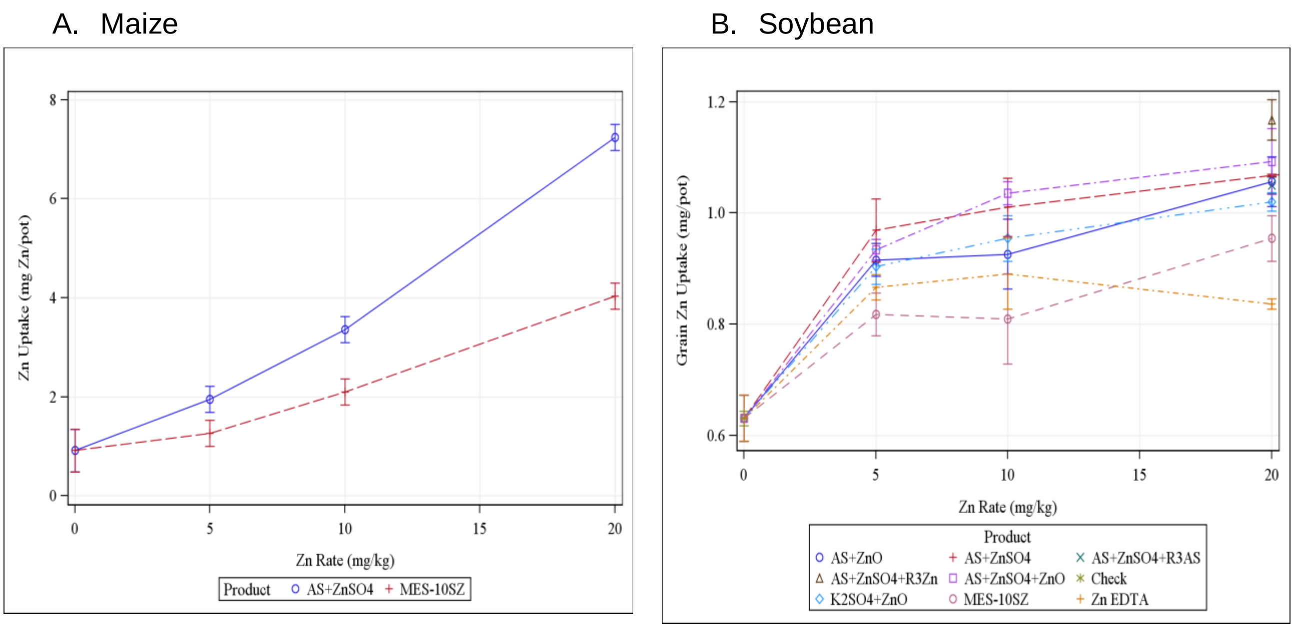

Figure 15. Total Zn uptake in maize and grain Zn uptake in soybean (mg Zn/plant) as influenced by Zn rate and Zn products on Brownfield soil (pH 6.9).

1.2.3.2 Quantify the Improvement in Grain/Product Quality from Field and Greenhouse Studies

The activity, in partnership with Johns Hopkins University and/or Tennessee State University, will begin in the final quarter of FY18.

1.2.3.3 Evaluate the Role of Legumes in Rice-Based Farming Systems for Nutrition Improvement, Soil Health, and Income Generation

The activity, with partial support from the Swedish International Development Agency, will begin in October 2018 with a target planting date in November-December.

1.2.4 International Training Program on Bringing Balanced Crop Nutrition to Smallholder Farmers in Africa

Due to commitments that developed in the early part of 2018, the training has been rescheduled to mid-November, with preparations beginning in June. The likely venue is Abuja, Nigeria.

1.2.5 Improved Efficiency and Accessibility of Phosphatic Fertilizers

Phosphorus is one of the most limiting nutrients in weathered soils found in SSA. As with other fertilizers, the lack of a well-developed domestic P fertilizer industry and limited foreign exchange for fertilizer imports constrain P fertilizer use. Many of the phosphate rock (PR) deposits in SSA have not been developed because the deposits are too small to warrant the investment needed for mining and processing, while impurities in some PRs prevent the production of water-soluble phosphorus (WSP) fertilizers using conventional industrial processing technology. However, many of these constraints do not apply to direct application of reactive PRs or PR compacted with WSP fertilizers. One innovative and practical approach to enhancing PR agronomic efficiency is dry compaction of PRs with minimal WSP (~20%) fertilizers. The compacted/activated PR is a more cost-effective product of the wet granulation process and holds considerable promise in SSA countries and other regions that have deposits of low- to medium-reactivity PR.

Several studies were conducted with a combination of finely ground PR and triple superphosphate (TSP) at a ratio of 1:1 PR/TSP. However, the effectiveness of these products was limited to neutral and mostly acidic soils. Ongoing greenhouse trials with only 20% DAP or MAP at a PR:DAP ratio of 4:1 have shown excellent response on the yield of wheat, soybean, and rice.

1.2.5.1 Production of Activated Phosphate Rock for Field and Greenhouse Studies

A commonly available PR from SSA, Togo PR was used to make 100 kg each of Togo PR:DAP and Togo PR:DAP:urea. The activated products supplied 80% P from Togo PR and the remaining 20% from DAP. The products have been shipped to Kenya and Ghana for field trials that are expected to begin in the upcoming rainy season.

Small quantities of activated PR products were made using Cabinda PR from Angola for greenhouse studies, with P supply from PR ranging from 50% to 75% and the remaining P supplied by MAP.

1.2.5.2 Field Evaluation of Activated Phosphate Rock in Kenya and Ghana

The trials are expected to begin during the upcoming rainy season with wheat in Kenya and maize in Ghana.

1.2.5.3 Greenhouse Evaluation of Activated Phosphate Rock on Highly Acidic Soil

Many soils in SSA are acidic (pH <5) and deficient in P. Lime as a soil amendment is not readily available. PR can be used as a soil acidity amendment where the dissolution of PR proceeds with the consumption of H^+ and thereby increases soil pH. However, aluminum (Al) toxicity can overwhelm the plant growth, particularly when P is not available immediately for root growth and development, as with low reactivity PR. An ongoing greenhouse study is evaluating the impact of activated low reactivity Cabinda PR from Angola with MAP on wheat grown in an acidic (soil pH 4.8) Hartsells soil (Figure 16). The preliminary results clearly showed that low reactivity PR, such as Cabinda PR or Cabinda dust (byproduct with little direct application value), when activated with MAP, was more effective in supplying P and partially overcoming Al toxicity than MAP or PR alone. The study is partially supported by a private company. Complete results will be presented in the next report.

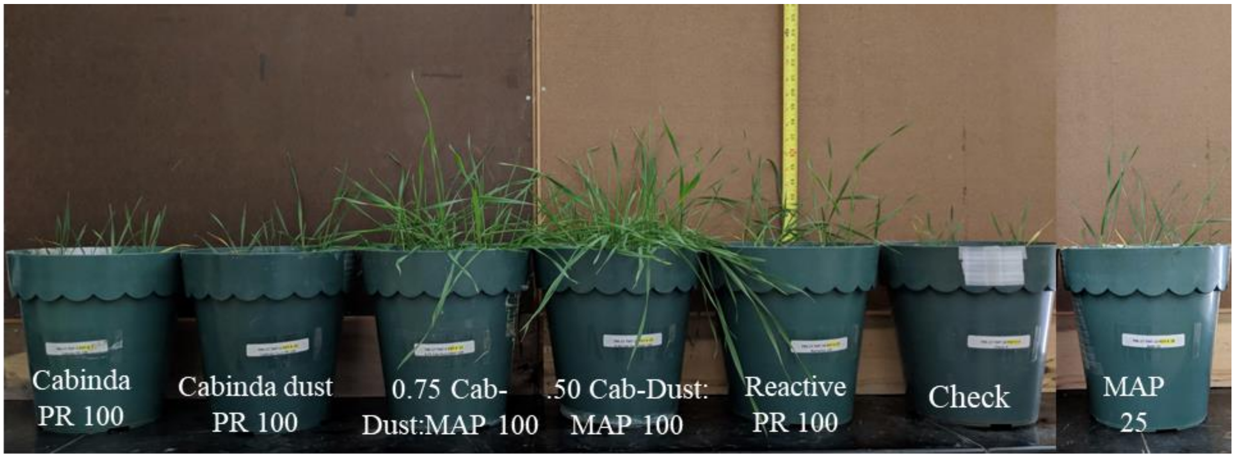

Figure 16. Comparison of wheat growth on Hartsells soil with Cabinda PR, reactive Namphos PR, MAP (25 mg P/kg), and activated Cabinda dust with MAP at 75:25 and 50:50 P ratio.

1.3 Fertilizer Quality Assessments: Support Policy Efforts to Harmonize Fertilizer Regulations (Cross-Cutting with Workstream 2.3)

IFDC has conducted a series of fertilizer quality assessments (FQAs) in East and Southern Africa with the purpose of making country fertilizer quality diagnostics and identifying factors, either directly associated with fertilizer properties or with characteristics of the distribution chain, that help explain the quality problems. The FQAs also propose solutions to address these factors. Information collected from these studies at the country level is being used by the Common Market for Eastern and Southern Africa (COMESA) to develop and implement a harmonized fertilizer quality regulatory system for its Member States. The current progress of the major activities is presented below.

1.3.1 Complete Ongoing Assessments for Stakeholder Consultations and Dissemination

1.3.1.1 Uganda FQA Report

The fertilizer quality assessment report is close to completion. The highlights of the report are summarized here:

- Uganda does not have provisions for tolerance limits to be used in the assessment of the different quality parameters, such as nutrient shortages, bag weight, and presence of heavy metals. The tolerance limits from the Kenya Fertilizer Quality Regulatory System were used as reference to assess the different quality aspects identified in the Ugandan value chain. It is urgent for the Ugandan Government to develop a regulatory system harmonized with regulatory systems from the COMESA state members.
- The nutrient shortages out of compliance were more frequent and severe in fertilizers of low trade than among the fertilizers of high trade. No fillers or foreign substances that suggest adulteration by dilution of nutrients were found, not even in the low percentage of re-bagged fertilizers. No severe degradation of granule integrity that could cause uneven distribution of nutrients inside the fertilizer bags were identified. The most probable explanation for the

nutrient shortages being out of compliance in the granulated products, both of high and low trade fertilizers, is that the nutrient deficiencies originated during the manufacture. The effective inspection of imported products in points of entrance to the country is necessary.

- Ten percent of the bags weighed during the survey showed weight shortages larger than 1% of the weight specified on the label.
- The liquid products have the most serious nutrient shortages as indicated by the combination of high frequencies and severities of shortages out of compliance. Regulations for quality assurance of liquid fertilizers, imported or locally manufactured, must be part of a Ugandan and regional fertilizer quality regulatory system.
- The maximum cadmium content found in fertilizers containing P_2O_5 was in a DAP sample with 23 ppm of Cd, or 10.6 mg Cd/kg P_2O_5. These values are below the Kenyan tolerance limit of 30 ppm and the European tolerance limit of 20 mg Cd/kg P_2O_5.
- The good quality of the bags used in Uganda preserves the fertilizers from physical property degradation despite the high relative humidity that predominates in the storage facilities. Ninety percent of the bags have an inner impermeable layer and a strong woven exterior that allow the bag to withstand the rough treatment associated with manual and individual handling.

These results have implications for fertilizer policy, regulations, and institutional structure. It is important to establish a system that ensures pre-export verification of conformity (PVoC) is carried out by reputable and internationally accredited companies. This should be followed by confirmatory inspections at the destination port, especially for products that have a history of poor quality or whose origins are suspect. Routine targeted inspections along the domestic value chain, particularly at retail, will help maintain quality. In addition, training of distributors and agro-dealers on best practices in handling fertilizers and maintaining appropriate storage facilities will provide further support. The capacities of agencies in charge of quality regulations, including laboratory equipment and human or technical expertise, need to be improved. Finally, it is crucial to have a mechanism in place for farmers and other stakeholders to share their complaints on quality to relevant authorities/agencies for action. Therefore, updating the current quality regulatory framework in addition to harmonizing regulations across countries will support the above recommendations and increase access to quality fertilizers.

1.3.1.2 Zambia FQA Report

Highlights of the Zambia FQA work will be presented in the next report.

1.3.1.3 Myanmar Fertilizer Quality and Fertilizer Value Chain Analysis

This activity was funded by the World Bank with some central funding (10%) from BFS. Its implementation was based on the experiences gained from BFS funded activities in SSA. The findings suggest that the Myanmar Fertilizer Regulatory System requires significant improvements to protect farmers and stakeholders against the adverse effects of substandard fertilizer products in the markets. The following are the main improvements needed:

- Develop mechanisms to collect enough revenue to finance the regulatory activities needed along the fertilizer value chain.
- Develop an effective mechanism for the registration of fertilizer products after they are evaluated for efficacy for crop production and safety for the environment.

- Prepare a body of professional inspectors to identify and quantify the presence of substandard fertilizers in the markets.
- Equip laboratories and train personnel to analyze large numbers of fertilizer samples during the implementation of a regulatory system.

The following are the main findings from the FQA:

1. There is an excessive number of fertilizer products in Myanmar; 11 products account for about 50% of the fertilizer trade while 144 products account for the remaining trade share. Many of the 144 products of low trade are very similar in composition and grade. The highest frequencies and severities of nutrient shortages happen among the products of low trade. Still, the 11 products of high trade have nutrient shortages out of compliance that are explained by deficient manufacture of imported products and serious deficiencies in product registration and port inspections by the Myanmar Government.
2. Secondary and micronutrient shortages out of compliance were found with high frequencies and severities across granulated, powder, and liquid fertilizers. Under these conditions, the fertilizers available in Myanmar are not appropriate to deliver balanced crop nutrition.
3. Twelve percent of the bags were underweight by at least half a kilogram. While this practice deceives individual farmers in an apparent low quantity, it substantially defrauds society as a whole, with some manufacturers deriving large profits from this fraud.
4. Evidence of the risks associated with heavy metal contamination in the fertilizers has been found. This risk is higher in fertilizers with a high organic component, especially if they are imported from China. The regulators should be attentive to the heavy metal contamination that can occur both in organic fertilizers and in fertilizers manufactured with phosphate rock.

In addition to the improvements listed above, capacity building of agro-input dealers, extension staff, and NGOs involved in agriculture is critical for improving the quality of fertilizers and other agri-chemicals and for educating farmers on good agricultural practices, such as ISFM and balanced nutrition.

1.3.2 Training Program on Improving Fertilizer Quality for Highly Productive Agriculture and Balanced Nutrition

The international training program on improving fertilizer quality for highly productive agriculture and balanced nutrition is planned for May 7-11, 2018, in Arusha, Tanzania. The training program will include the complete process for fertilizer quality and value chain analyses and a synthesis of results from multiple locations (Kenya, Myanmar, Uganda, and Zambia). Training preparation is in progress with 47 participants already registered.

A manuscript containing a summary of IFDC fertilizer quality assessments and achievements in Africa and Asia is in preparation. The manuscript will be submitted to a scientific journal.

Figure 17. Observing the bag weight controls in a granulation plant in Myanmar.

1.4 Agronomic and Socioeconomic Database Management and Decision Support Systems – Cross-Cutting with Workstream 2

Over the years, IFDC has lost expertise in database management and programming. In partnership with the University of Florida, IFDC will utilize a database platform developed for the global Agricultural Model Intercomparison and Improvement Project (AgMIP). The partnership with the University of Florida will also be used to improve the existing soil dynamics model in the Decision Support System for Agrotechnology Transfer (DSSAT) program using the soils and agronomic data generated by IFDC over the past years. The geospatial addition to the DSSAT software, GSSAT, was originally developed by IFDC and will be refined and validated using spatial soil data from Ghana and Burkina Faso. The database and decision support tools will help in making timely and reliable recommendations on fertilizers, sowing dates, and other management inputs covering a wide range biophysical and socioeconomic conditions. This activity will continue upon availability of funds.

2. Workstream 2 – Supporting Policy Reform Processes, Advocacy, and Market Development

Under Workstream 2, IFDC conducts research and analysis for evidence-based policies and to support reform initiatives for market development focused on accelerating agricultural growth through the use of improved technologies, particularly fertilizers and complementary inputs. All the activities under this workstream are implemented through partnerships with different stakeholders with similar interests, namely, in promoting policies and reforms aimed at improving fertilizer access, availability and use among small holders in the FTF focus countries, under varied political, social, economic, and environmental conditions. IFDC being the ‘go to institution for soil and fertilizer technologies, policies and advocacy’, most of the activities and associated outcomes are identified by IFDC scientists and economists for further exploration in partnership with leading stakeholder institutions (academic, research, policy think tanks, public and private firms) to present evidence-based research studies for further scaling up and dissemination.

The costs associated with BFS to fund the activities under this workstream are shared either on cost or kind basis from the partnering institutions to achieve the maximum outreach and impact in the following three major areas of focus. The three broad categories related to soil technologies and fertilizer management taken up under this workstream include:

a. Support developing and implementation of fertilizer / soil related policies, reforms and regulations;
b. Assessing impacts of soil and fertilizer related technologies, policies and market interventions to improve access and use by farmers; and
c. Conducting studies to show the economic and financial feasibility of soil/fertilizer related technologies, fertilizer access and market systems (incl. fertilizer demand and supply and associated margins)

Together with Workstream 1 and other field-based IFDC operations, these studies add to IFDC’s knowledge management system, contributing to databases that provide useful information to draw lessons learned and identify gaps for further action or research. The data and output from these efforts provide a strong foundation for IFDC to join and participate in partnerships with other research and policy institutions in areas of mutual interest, including policy dialogue with decision-makers and other stakeholders in various countries.

2.1 Document Policy Reforms and Market Development

The work on policy processes is to support efforts that provide the necessary impetus to catalyze reforms to existing policies in these countries to create an environment that encourages private sector investments that will result in increased access to input markets by smallholder farm households. With BFS support, IFDC worked with organizations and stakeholders at various levels in countries that showed high potential for policy change to: (i) support the reform processes, utilizing evidence-based approaches, and (ii) build the capacity of stakeholders toward effective implementation of reforms. Details are provided below.

2.1.1 Support for Kenya Fertilizer Roundtable Meeting and Policy Reform Processes

During the last quarter of 2017, the Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), in collaboration with IFDC, commenced the planning of a Kenya roundtable fertilizer (Ke-Fert) stakeholder workshop. The objective of the roundtable workshop was to review the major constraints to farmer access and use of fertilizers and soil amendments (particularly lime) and reach consensus on the need to address these challenges through the formation of a multi-disciplinary Kenya Fertilizer Platform. The fertilizer platform is a public-private mechanism composed of key stakeholders involved in fertilizer access, quality, and use, whose purpose is to resolve issues and facilitate dialogue, coordination, and information exchange. The intended fertilizer platform is to facilitate policy actions around key fertilizer issues through multi-stakeholder dialogues and public-private task force consultations periodically to influence fertilizer policies in Kenya. The above objective is in line with the 2016 signed memorandum of understanding (MOU) between the MoALF and IFDC in which the two parties agreed on:

- Developing increased agricultural productivity through introduction of appropriate technologies toward increased productivity.
- Developing innovative and economically sound interventions in agribusiness approaches.
- Developing the fertilizer sector.
- Integrating soil fertility management interventions.

In addition to a working MOU, a more formalized Kenya-Fertilizer Workshop has been planned in Nairobi in May-June 2018, for which preparatory work has been undertaken. Meetings have been held across private and public stakeholders from the fertilizer sector through several formal and informal consultations by IFDC and MoALF officials, explaining the motive behind the workshop. In turn, stakeholders responded by forming a steering committee to spearhead the process at the higher level, with elected representatives, and exclusively put together a sub-committee for actual planning of the proposed workshop. The sub-committee responsible for the workshop is in constant contact with other members of the steering committee, who have completed the task of developing a concept note and outlining the objectives and intended outcomes from such a workshop. Following the concept note, a memorandum was drafted and has been presented to the Permanent Secretary (PS) of MoALF, stating the intention of the workshop and requesting him to invite the President of Kenya as the guest of honor; currently, the steering committee is waiting for feedback from the PS. IFDC also engaged a consultant to spearhead the process of finalizing the agenda of the workshop and budget, in addition to holding consultative meetings with partners to operationalize both the Ke-Fert and Fertilizer platform.

Ongoing/pending activities include the following:

- Finalizing the date of the workshop and the plenary speaker, once the PS has confirmed the availability of the guest of honor. The Ke-Fert workshop is expected to take place in the second half of 2018.
- Inviting speakers/stakeholders. The participants will be invited once all the logistics preparation is finalized.
- Finalizing the budget and other logistics; a meeting with the partners has been scheduled to discuss budget and have partners commit to it.

Expected outcomes: The outcome of the Ke-Fert workshop will be the formation of the Fertilizer Platform. The fertilizer roundtable will be used to develop priorities for the fertilizer sector leading to an action plan for the Fertilizer Platform. More than 200 stakeholders from the public and private sectors will provide input and the roundtable is expected to become an annual event, as it was in previous years.

2.1.2 Capacity-Building Activities: Policy Reforms

2.1.2.1 USAID BFS Agriculture Core Course: Policy, Governance, and Standards – Agriculture Input Policy Analysis

At the request of BFS policy advisors in Washington, D.C., and in partnership with the Rutgers University FTF Policy Research Consortium, a presentation was given on the importance and impact of agricultural input policies during the USAID BFS-sponsored agriculture core course for staff from inter- and intra-agencies involved in U.S. Government international development activities. The training covered the importance of agro-input policies for seeds, fertilizers, pesticides, and agricultural machinery and discussed key impacts of input policy reforms on the respective sectors for better food security and improved incomes and welfare among smallholder farmers in specific countries. The training session content was prepared in collaboration with the BFS policy team and the Rutgers consortium.

The training was conducted as a participatory discussion on December 13, 2017, in Washington, D.C. The input policy session was attended by nine experienced development staff members posted in missions abroad and in the United States by the U.S. Government. A PowerPoint presentation along with a set of discussion questions were provided to the participants during the training program.

2.1.2.2 Developing Private Sector Agro-Input Markets: Lessons Learned and Emerging Perspectives on Subsidy Programs

At the request of Uganda's Ministry of Agriculture, Animal Industry and Fisheries, IFDC provided technical support by building the capacity of ministry staff and other stakeholders on aspects of the design and implementation of subsidy programs. IFDC invited expert speakers to share lessons learned and best practices from the latest research findings and recommendations from various research and assessments.

The five-day workshop was held on February 19-23 in Jinja, Uganda, on "Developing Private-Sector Agro-Input Markets: Lessons Learned and Emerging Perspectives in Subsidy Programs." More than 50 participants (primarily from the ministry and some donors and private sector representatives) were made aware of case studies from several SSA countries, the strengths and weaknesses of subsidy programs, and options for improving them to become "smart" subsidy programs. The workshop incorporated a one-day session on the importance of an enabling environment for private sector investment. This session was conducted jointly by a team from AFAP, IFDC, Michigan State University, New Markets Lab, and the Regional Network of Agricultural Policy Research Institutes (ReNAPRI).

The participants visited Uganda's only fertilizer blender, GrainPulse Ltd, in Mukono, and the adjacent Savannah Commodities to learn more about how the private sector is addressing fertilizer needs in the region. The company is manufacturing blended fertilizers that are targeted to specific crop needs and soil nutrient requirements with the objective of improving farmers' yields.

Based on the workshop evaluation feedback, the participants indicated they had gained more knowledge, made networking connections, and acquired better skills to help them in their jobs as a result of their participation in the workshop. More details regarding the program can be found at https://ifdc.org/developing-private-sector-agro-input-markets-designing-and-implementing-targeted-subsidy-programs/.

2.1.3 Documenting Fertilizer Trends and Outlook: Code of Conduct for Fertilizer Management

As part of the initial global consultation on the Code of Conduct for Fertilizer Management (CoCoFe), IFDC contributed toward the scope of the CoCoFe. The key issues are presented here.

IFDC believes the judicious use of fertilizer calls for a holistic approach, starting with good quality fertilizer products with reduced contaminants, which greatly depends on the source of nutrients, beneficiation of mined feedstock, and the production process. When supplied with good quality products and knowledge on their proper application, farmers can judiciously use fertilizer to produce sufficient, quality, nutritious, and safe food for a fast-growing population while addressing environmental concerns and human health hazards. With a finite amount of resources – land, fertile soil, and fresh water – and in the context of climate change, additional factors to consider for promoting the appropriate use of fertilizer are:

1. Increased investment for revamping agronomic and soil research for resilient agriculture, for innovating on nutrient cycling in the context of a circular economy, and for developing the next generation of fertilizer products with lower contaminants, greater efficiency, and balanced nutrients; congruent with advances in crop genetics, cropping technologies, and soil conditions.
2. A better policy, legal, and regulatory framework to guarantee the best quality fertilizer products, their distribution and rational use.
3. The revamping of extension services for better technical assistance and training to encourage responsible fertilizer recommendations by the supply chain stakeholders and fertilizer use by farmers.

In the context of developing the CoCoFe, IFDC suggests establishing clearer goals with fewer objectives to simplify its elaboration and facilitate its mainstreaming among stakeholders. The following objectives were suggested, which embrace the CoCoFe stated goals:

1. Increase food production by boosting yields to close the yield gap in developing countries and to supply the increasing global need of more, nutritious, and safer food.
2. Optimize the efficient use of (organic and inorganic) nutrients to maximize benefits of better natural resource conservation (land, soil, and water) and effectively promote sustainable agriculture production systems.
3. Minimize nutrient losses and the accumulation in the soil and in vegetative materials of contaminants and trace elements present in inorganic fertilizer and organic nutrient sources.

Considering the effects of climate change on agriculture, IFDC suggested a fourth objective:

4. Support the adaptation of crops to imminent environmental changes for more resilient agriculture production systems, considering balanced nutrient fertilizer products, nutrient recycling, and carbon sequestration.

In the context of optimizing the efficient use of inorganic and organic nutrient sources, considering the nature of organic materials – which comprises multiple sources with erratic nutrient content depending on the source – makes it difficult to standardize them and therefore regulate them. On the contrary, the standard physical and chemical characteristics of inorganic nutrient sources/fertilizer facilitate their regulation. Still, it is crucial to regulate organic materials (biosolids, compost, etc.) for contaminants and hazardous chemicals (heavy metals, pathogens, toxic organics etc.) – including pesticides. To that end, IFDC suggests developing a subset within the CoCoFe, clearly addressing the recycling of organic materials to be used as a source of nutrients for food crops.

In addition, recognizing that organic materials can be a valuable source of nutrients, in the traditional intensive production systems, they should be seen as soil amendments to improve soil structure and increase microbial activity, water retention, and cation exchange, among others, all of which facilitate the absorption of nutrients by the plant root; and second, as a source of nutrient supply to the soil and the plants. Nutrient supply from organic materials can be considered a positive externality in the context of a circular economy; therefore, organic materials should be supplementary to inorganic sources, not the main source of nutrients. The exception can be purely organic agricultural systems in which organic materials can be both soil amendments and the main source of nutrients. To improve nutrient use efficiency and to help achieve the stated environmental and perhaps human hazards objectives, the CoCoFe should also address the use of bio-stimulants, nitrification inhibitors, urease inhibitors, etc.

Furthermore, although IFDC recognizes the importance of policy and regulations for the responsible use of fertilizer, it is also important to recognize the regulatory burden of the CoCoFe implementation and the impact on the cost of supplying and using fertilizer. This has greater implications for developing countries, such as in SSA, considering that fertilizer production in these countries is almost non-existent, and its use is low to negligible, especially among small-scale agricultural producers, due in part to fertilizers' relatively high retail price resulting from high transaction costs along the international and domestic supply chains. Therefore, the resulting regulatory burden could hinder the efforts of international donors and government programs to reduce the cost of fertilizer at retail. Economic analyses may be needed to weigh the impact from the potential burden introduced by the CoCoFe as opposed to the impact of a lax regulatory system that will make countries vulnerable to questionable nutrient content in organic products and to hazardous contaminants and non-nutritious trace elements in inorganic fertilizers and organic products.

2.1.4 Partnership for Enabling Market Environments for Fertilizer in Africa

IFDC, as part of the Partnership for Enabling Market Environments for Fertilizer in Africa (PEMEFA), a Michigan State University (MSU)-led consortium of five organizations,[2] met on February 19-23 in Jinja, Uganda, to:

1. Present a draft synthesis report on the status of SSA enabling environment, which also identified existing gaps for further research.
2. Initiate activity on writing a proposal for funding the group's activities going forward.

[2] MSU, AFAP, ReNAPRI, New Markets Lab, and IFDC.

This synthesis report provides a brief summary of the existing policy and regulatory systems in SSA and identifies gaps that the group will provide information/recommendations to policymakers after successfully soliciting for funding. PEMEFA also has been conducting a lecture series to build consensus and get other organizations involved to build on synergies. A seminar was held on April 5, 2018 at MSU, East Lansing, Michigan, on "Agricultural Policy and Regulation in Sub-Saharan Africa: Lessons for Increasing Investment'. This meeting had 25 people in attendance including professors from the agricultural economics and other departments, graduate students, and staff from the Feed The Future Innovation Lab For Food Security Policy. Three presentations were made by PEMEFA principal investigators from IFDC, MSU, and NML. Another meeting is scheduled for April 17, 2018 (Georgetown University, Washington, D.C.) on "Understanding the Enabling Environment: How Laws, Regulations, and Government Programs Support Trade and Agricultural Development". Staff from the World Bank, International Food Policy Research Institute (IFPRI), and other relevant institutions will be invited.

2.1.5 Review of Input Subsidy Program Design in SSA

IFDC has been involved in collaborative policy and market research on fertilizer issues with other organizations, such as MSU, AFAP, and the Alliance for a Green Revolution in Africa (AGRA). From an assessment of various reports or studies, experiences and lessons learned from subsidy programs in SSA, IFDC and MSU reviewed these works to generate suitable policy recommendations. A peer-reviewed journal article ("Taking Stock of Africa's Second-Generation Agricultural Input Subsidy Programs [ISPs]") based on evidence of the impact of input subsidy programs with regard to targeting beneficiaries and private sector involvement in SSA has been accepted for publication in *Food Policy* and is expected to be published by mid-2018. The article provides the most comprehensive review of recent evidence to date regarding the performance of these second-generation ISPs, synthesizing nearly 70 ISP-related studies from seven countries (Ghana, Nigeria, Kenya, Tanzania, Malawi, Zambia, and Ethiopia). The review specifically evaluated ISPs' impacts on total fertilizer use, food production, commercial input distribution systems, food prices, wages, and poverty. Measures enabling ISPs to more cost-effectively achieve their objectives were also considered.

The key findings indicate that ISPs can quickly raise national food production, and that receiving subsidized inputs raises beneficiary households' grain yields and production levels at least in the short-term. However, the overall production and welfare effects of subsidy programs tend to be less than expected. Two characteristics of program implementation consistently mitigate the intended effects of ISPs: (1) subsidy programs partially crowd out commercial fertilizer demand due to difficulties associated with targeting and sale of inputs by program implementers, and (2) lower than expected crop yield response to fertilizer on smallholder-managed fields is often experienced. If these challenges could be addressed, ISPs could more effectively mitigate the concurrent challenges of rapid population growth and climate-induced stresses in SSA.

2.1.6 Policy Briefs on Fertilizer Policies and Market Development

IFDC's engagement in the fertilizer and input policy reform processes, particularly interventions or policies that have had significant impact on poverty and food security, will be captured and documented as short policy briefs, either through the IFDC team or through engagement with partners in Africa, Asia, and Latin America and the Caribbean (LAC), for wider dissemination.

Since 2015, policy briefs focusing on fertilizer market development through private sector participation were initiated (Ghana, Uganda, and Mali).

For the final reporting in FY18, IFDC anticipates one or two policy briefs to be generated through our partnership with several organizations in these countries.

2.2 Impact Assessment Studies

To support policy reforms for the development of input markets and value chains, IFDC conducts impact assessment studies not only to provide feedback on the performance of policy changes and supporting programs but also to provide lessons learned for future policy reforms and implementation. During FY18, this sub-activity will include research activities on (a) assessing the impact of Kenya's fertilizer subsidy program and (b) assessing the effectiveness and impact of agro-dealer development/input supplier networks toward improved access to and use of technologies among farmers and effects of market interventions in Rwanda.

2.2.1 Impact Assessment Study on the Kenya Fertilizer Subsidy Program

It is estimated that nearly 30-40% of the fertilizer consumed by Kenyan farmers is facilitated through the input subsidy programs; by the end of the 2016 long rainy season, the Kenyan subsidy program had distributed 928,430 mt at an estimated cost of Kshs. 24.7 billion or an average annual budget of Kshs. 3.1 billion (approximately U.S. $310 million). However, no comprehensive study has been undertaken evaluating the effectiveness of such subsidy program, detailing the costs of implementing such enormous initiatives, the benefits accrued, and the gains to smallholder farmers and the national economy. To get insights in these issues, Kenya's MoALF requested IFDC's support in carrying out an impact assessment of fertilizer subsidy program in the country. The purpose of such impact study is to re-evaluate the program and redesign the subsidy model to maximize impact by focusing on specific farmer needs. This was followed by several consultation meetings between IFDC and MoALF since October 2017. During this process, IFDC also decided to bring in Tegemeo Institute to support MoALF in conducting this assessment. Tegemeo Institute is a policy research institute under the division of research and extension of Egerton University. It was therefore agreed that the impact study will be carried out as a consortium of three institutions, namely IFDC, Tegemeo Institute, and MoALF, with a well-established approach developed by IFDC in consultation with the partner institutions.

The approach consists of the following elements:

1. Developing a concept note – in this context an initial concept note of ideas was developed by the MoALF officials and was shared with IFDC and Tegemeo for further review, refinement, and implementation. The MoALF wanted such an assessment to ensure scientific validity with experience drawn from global best practices on fertilizer subsidies for effective policy evidence and recommendations.
2. Followed by the initial concept note, IFDC and Tegemeo engaged in reviewing the ideas proposed by MOALF and prepared a detailed concept note based on an extensive literature review of the fertilizer subsidy programs in Kenya, SSA, and elsewhere.
3. IFDC, Tegemeo Institute, and ministry officials also are having discussions on the research tools to be used, guidance on qualitative and quantitative data collection, and geographical coverage of the study.

4. The terms of reference (ToR)/scope of work (SoW) draft was finalized in March 2018 after extensive consultations among the partners on various details of the SoW, including implementation, timeline, budget, and methodological approach toward final implementation of surveys in Kenya for the proposed study.
5. The TOR/SOW will be shared with MoALF for further feedback and way forward.

This activity was jointly conducted with IFDC staff in East and Southern Africa.

2.2.2 Effectiveness of Agro-Dealer Development Programs Toward Sustainable Input Supply and Technology Transfer in Sub-Saharan African Countries

The assessments focus on determinants of sustainability of input suppliers in general and their impact on input market development in selected countries in SSA. The analysis seeks to identify the attributes of successful agro-dealers; the existing input market policies and their effect on these supplier networks; and the role of input financing in building efficient networks.

During FY18, it was proposed to continue the field-level impact assessment of the Rwanda Agro-Dealer Development (RADD) programs implemented in two phases, during 2010-13 and 2014-16. This activity will be initiated with the Agribusiness-Focused Partnership Organization (AGRIFOP), a local Rwandan community service organization involved in capacity building of agro-dealer programs in Rwanda, and AGRA, who are engaged actively toward implementing agro-dealer development programs in Rwanda and elsewhere in Africa. The following progress was made during the first half of FY18.

In November 2017, consultations were initiated with Mr. Jean Bosco Safari, head of AGRIFOP, to seek his assistance in implementing the agro-dealer assessment study through his organization. Further, in this context, IFDC has been in discussions with AGRA's Nairobi office to seek their partnership and collaboration in conducting such study, which can mutually benefit IFDC and AGRA. Detailed discussions were held during January 2018 with Mr. Fred Muhuku, Agro-Dealer Programs Specialist at AGRA, through IFDC's East and Southern Africa regional office in Nairobi, to request AGRA's assistance in enabling logistics in Rwanda and data documentation (baseline and endline survey data from previous programs in Rwanda). AGRA has agreed in principle to share any relevant information regarding agro-dealer programs in Rwanda for this proposed study.

During the second half of FY18, IFDC plans to finalize the ToR for the proposed assessment with AGRA and AGRIFOP and initiate activities, such as sampling and survey details, to implement the research study in Rwanda.

2.3 Economic and Market Studies

IFDC's economic studies provide useful information for public and private decision-making and identify policy-relevant areas for intervention to streamline the flow of fertilizers at reduced prices for smallholder farmers. The economic studies include evaluation of various soil fertility-enhancing technologies in terms of economic returns and efficiency for small farm adoption and also financial returns to various actors in the value chain; conducting stakeholder analyses and assessment of cost buildups and market margins to identify value chain constraints; and market analysis of the supply and demand of fertilizers. IFDC's FY18 work in this sub-activity involves the following key areas; (a) documenting data on fertilizer cost buildups and market margins across different countries in SSA; (b) identifying select indicators of fertilizer use and access in SSA; (c) supporting policy efforts to harmonize fertilizer quality regulations, based on evidence-based scientific analysis; and (d) initiating a series of micro-economic research studies related to fertilizer technology use, markets, value chains, and environmental implications in partnership with land-grant universities, such as MSU, Rutgers, and the University of Georgia.

2.3.1 Fertilizer Quality Assessments (FQA): Support Policy Efforts to Harmonize Fertilizer Regulations (with Workstream 1)

This activity was conducted jointly with Workstream 1. The FQA draft report for Uganda is being shared with the Ugandan Ministry of Agriculture, Animal Industry and Fisheries. The final report for the Myanmar FQA was submitted to the World Bank. In addition to the FQA report, a training manual on building the capacity of stakeholders in Myanmar was developed based on weaknesses that were identified from the survey.

A workshop to disseminate findings of the report on "Myanmar Fertilizer Quality, Regulatory System, and Value Chain Analysis" is scheduled for April 30 in Nay Pyi Taw, Myanmar. The workshop participants are from the Myanmar Government and the private sector as well as representatives of the World Bank, USAID, and other international donors operating in Myanmar.

An additional workshop will be conducted during May 2-4, 2018 in Yangon, consisting mostly ministry staff, with the objective of building their capacity in the following areas:

- Improvements of the Myanmar fertilizer quality regulatory system.
- Identification of factors from the value chain that affect fertilizer quality.
- Scientific methodology for fertilizer quality assessment along the value chain.

2.3.2 Fertilizer Cost Buildup Studies and Marketing Margin Analysis

Literature on agro-input markets in SSA shows low consumption of fertilizer is partly due to high transaction costs of supply, which limit its access, especially to resource-poor farmers. Though there is information available on the physical and other structural constraints that contribute to high transaction costs along the fertilizer supply chain, little is known about the current cost structure of supplying fertilizers in SSA. Considering that similar studies have been implemented in the past, tracking changes in the supply cost structure over time will help trace the impact of policy reforms affecting the fertilizer sector and provide lessons learned for other countries to adopt. The objectives of this activity are: (a) to assess the cost of supplying fertilizer from procurement and importation to distribution to farmers in selected SSA countries; (b) to identify issues and constraints that are contributing to higher transaction costs; and (c) to envision recommendations that could lead to additional policy changes and the implementation of programs and investments.

2.3.2.1 West Africa Fertilizer Supply Cost Buildup Consolidated Report

Advances are being made to assemble a consolidated report for the West African region, based on country-specific fertilizer supply cost buildup assessments implemented between 2015 and 2016. The report also will make an inter-temporal analysis of the changes in the cost of supplying fertilizer, taking into consideration work done by IFDC since 2006 with Chemonics, later in 2009 with IFPRI, and more recently in 2015-16 under BFS funding.

Preliminary results indicate that fertilizer prices in the international markets have been declining, reflected in the reduction in cost of importation (Table 11). However, domestic supply cost has increased, especially at wholesale and retail, perhaps reflecting the increase in the cost of bagging and storage, domestic transportation, and financing, and to a minor extent, due to increases in port charges and overhead and margins. Differences in the increases or reductions in cost structure between countries are greatly influenced by how fertilizer subsidies are being implemented and whether the country is landlocked.

Table 11. Fertilizer supply cost buildup analyses for Ghana and Mali comparing 2006, 2009, and 2015-16.

	Urea	2006					2009					2015-16				
		Import	Wholesale	Retail	Total	%	Import	Wholesale	Retail	Total	%	Import	Wholesale	Retail	Total	%
Ghana	CIF cost	342.0			342.0	**70%**	292.2			292.2	**52%**	298.8			298.8	**36%**
	Port charges	10.6			10.6	**2%**	3.0			3.0	**1%**	53.1			53.1	**6%**
	Bagging and storage	26.6	6.0		32.6	**7%**	44.5			44.5	**8%**	94.3	21.5		115.8	**14%**
	Domestic transport		17.6	2.7	20.3	**4%**	6.4	39.9	9.8	56.1	**10%**	1.3	37.8	12.1	51.1	**6%**
	Taxes and levies	8.9			8.9	**2%**	10.3			10.3	**2%**	18.7			18.7	**2%**
	Finance	9.5	5.7	1.0	16.2	**3%**	6.1	36.2	41.9	84.2	**15%**	54.8	43.8	52.2	150.8	**18%**
	Overhead and margins	45.6	6.7	4.3	56.7	**12%**	36.3	23.7	16.5	76.5	**13%**	15.5	58.3	57.5	131.4	**16%**
	Total cost	443.2	36.0	8.0	487.3	**100%**	398.8	99.9	68.3	566.9	100%	536.5	161.4	121.8	819.7	**100%**
	Percent	**91%**	**7%**	**2%**	**100%**		**70%**	**18%**	**12%**	**100%**		**65%**	**20%**	**15%**	**100%**	
Mali	CIF cost	309.2			309.2	**57%**	320.5			320.5	**52%**	304.3			304.3	**51%**
	Port charges	9.4			9.4	**2%**	7.4			7.4	**1%**	26.5			26.5	**4%**
	Bagging and storage	11.7			11.7	**2%**	36.4			36.4	**6%**	39.9			39.9	**7%**
	Domestic transport		90.0		90.0	**16%**	108.0	20.0	8.7	136.7	**22%**	57.7	19.7	2.7	80.1	**14%**
	Taxes and levies	1.9	25.7		27.6	**5%**	16.0			16.0	**3%**	26.8			26.8	**5%**
	Finance	14.4	3.9		18.3	**3%**	18.0	16.8	17.5	52.3	**8%**	28.5	24.3	25.5	78.3	**13%**
	Overhead and margins	16.8	23.5	39.9	80.2	**15%**	34.1		18.1	52.1	**8%**	0.0	16.6	19.1	35.7	**6%**
	Total cost	363.3	143.0	39.9	546.3	100%	540.3	36.8	44.3	621.4	100%	483.8	60.6	47.3	591.7	**100%**
	Percent	**67%**	**26%**	**7%**	**100%**		**87%**	**6%**	**7%**	**100%**		**82%**	**10%**	**8%**	**100%**	

2.3.3 The African Fertilizer Access Index

The key objective of The African Fertilizer Access Index (TAFAI) is to promote the creation and maintenance of an enabling environment for competitive fertilizer systems serving smallholder farmers. The proposed TAFAI will be a consolidated measure of various factors (policy, market, research, and development) that influence and are responsible for creating an enabling environment. The activity will take advantage of the presence of partner organizations, such as AFAP, the International Fertilizer Association (IFA), and other private and public sector organizations in East and West Africa, for the purposes of data documentation and consultations.

No activities were conducted during this reporting period.

2.3.4 Economic and Environmental Implications of Fertilizer Technologies Using Life Cycle Analysis Approach

Under Workstream 1 and in collaboration with the completed USAID-funded Accelerating Agriculture Productivity Improvement (AAPI) project, an ongoing activity was conducted to document GHG emissions from UDP use along with different agronomic and crop management practices in paddy rice in Bangladesh. The results from the ongoing GHG mitigation research have shown that nitrous oxide (N_2O) and nitric oxide (NO) Life Cycle Inventory (LCI) emissions from fertilizers can be controlled via application strategy to levels associated with unfertilized plots. Thus, the quantification and reduction of GHG emissions associated with management practices in rice fields in Bangladesh may provide opportunities for farmers and policymakers to gain carbon credits. This work will complement the agronomic work carried out on the quantification of GHG emissions by the life cycle analysis (LCA) approach in quantification of energy equivalents (in turn, carbon credits and associated monetary terms) consumed across different types of fertilization in a paddy-rice system in Bangladesh.

For the purpose of the research study, a graduate student will use the data generated on GHG emissions under a rice-paddy system through greenhouse experiments in Muscle Shoals and in Bangladesh. In addition, the student also will utilize the economic data (primarily costing aspects) from urea briquette production and urea briquette uses (cost of cultivation) for calculating the economic and energy equivalents of different formulations of urea production and urea in the entire value chain to estimate the GHG emissions through the entire rice production process.

The following progress has been made toward implementing this activity: (i) a graduate-level student (Mr. Ming Zhe) from Rutgers University has been selected to carry out this research study as a part of his thesis requirement; (ii) a ToR has been developed with Rutgers for the proposed research collaboration; (iii) the graduate student has already initiated a detailed literature review on LCA approaches and is finalizing the approach for the present study; and (iv) a final detailed proposal along with methods and preliminary analysis will be provided near the end of FY18.

2.3.5 Economic Estimation of Fertilization Methods for Rice Paddy in Bangladesh – A Production Function Analysis

Data on the adoption and uptake of UDP by farmer households in Bangladesh have been documented by IFDC projects implemented in Bangladesh, with funding from USAID and Walmart over the last seven years. UDP technology has been adopted by rice paddy farmers and vegetable growers in Bangladesh, along with other crop management practices and fertilization methods (broadcasting, alternate wetting and drying, seed varieties, etc.). This research will utilize the existing data available from IFDC surveys on fertilizer adoption/use in Bangladesh to understand both technical efficiency of the uptake and sustenance of technology use by smallholders in adopting the UDP method of fertilizer application.

The following progress has been made during the first half of FY18: (i) a graduate student from Rutgers University (Ms. Selen Atilok) has been identified to undertake this as a part of her dissertation research and a ToR between Rutgers and IFDC is being finalized with SoW and budget details; (ii) the graduate student has already completed an extensive review of literature for the proposed study; (iii) a graduate thesis committee with representatives from Rutgers and IFDC has been further identified and is in the process of finalizing the research plan for the student; the first meeting was held March 8, 2018, with Rutgers Faculty; (iv) data sets from IFDC's Bangladesh office have been obtained to facilitate the research work of the student; it has been further proposed that the student will work with data sets from the AAPI project, a USAID-funded project from 2011 to 2016, for the conduct of the survey, utilizing the household farm-level information collected through the project during the baseline, mid, and final term of the project for the econometric investigations; and (v) the graduate student is expected to complete her preliminary analysis of the data and report toward the end of September 2018 for submission.

2.3.6 Enhancing the M&E Capacities of Soil Fertility Research Projects in IFDC

(Crosscutting all BFS-funded activities)

Professor Kay Kelsey from the University of Georgia (UGA) has been advising IFDC toward the design and establishment of exclusive monitoring, evaluation, learning, and sharing (MELS) systems within IFDC. In this regard, IFDC has an MOU with UGA to obtain Kelsey's advisory services for MELS conceptualization, capacity building services, and the design of evaluation tools and techniques for the program.

Under BFS, IFDC proposes to build the internal capacity of the field operations staff on MELS. An IFDC M&E specialist from Togo has been identified to enroll for a PhD program at UGA from Fall 2018 onward, to specialize in M&E approaches, gaining comprehensive knowledge on various evaluation tools and techniques to be applied in IFDC field operations upon training.

2.3.7 Encouraging Agribusiness Development in Sub-Saharan Africa: Fertilizer Value Chains and Policy Implications

In efforts to collaborate with universities, discussions have been initiated with faculty of MSU's Department of Agricultural, Food, and Resource Economics to conduct an economic research study on fertilizer-related issues using empirical and other data, applying scientific methods to generate policy-relevant briefs and reports that can be used for agricultural reforms and advocacy. The proposed research aims to collate available evidence on the performance of fertilizer input markets and value chains in SSA, identify challenges and gaps, and provide policy recommendations.

A number of Skype meetings were held with MSU to agree on topics and develop a scope of work. An in-person meeting was held on April 5 during a PEMEFA meeting at MSU (see Activity 2.1.4). The specifics of the joint effort and further development of ToRs were discussed with two professors and a graduate student. The idea is to utilize MSU analytical capacity to strengthen outputs, and therefore the partnership will harness the synergies between the two programs. Further discussions and development of TOR is on-going.

2.3.8 Improving Fertilizer Use, Access, and Market Development

2.3.8.1 Honduras

In early 2017, IFDC, in coordination with Honduras Outreach Inc. (HOI), a private NGO based in Georgia, undertook an outreach activity with the overall goal to help develop public-private partnerships and expand business outside IFDC's current regions of influence. Critical issues facing the Honduran agriculture sector that IFDC could address based on its institutional experiences were identified. HOI, in collaboration with the Government of Honduras, is in the process of establishing a research and demonstration farm on irrigation systems in the Agalta Valley, Honduras.

In February 2018, IFDC and HOI personnel and collaborators met at the University of Georgia Strickland Irrigation Research Station (SIRS) to: (i) observe Strickland's research activities, including irrigation and soil and crop fertility management; (ii) explore the possibility of forming a three-institution consortium (HOI, IFDC, UGA/SIRS); and (iii) seek funding opportunities for collaborative work in Honduras.

2.3.8.2 Guatemala

As initial steps toward implementing programs in Guatemala, a training program on fertilizer technologies and quality assurance is in the planning stages. This will be a joint effort between IFDC and a fertilizer industry partner in Guatemala. A meeting in May 2018 is scheduled at IFDC to develop the training program and other potential collaboration in FTF recipient countries in Central America.

Annex 1. University Partnership

Theme/ Activities	Work Planned	Countries	Status
1. Collaborative Model Improvement and Application and Database Development Project with University of Florida, Gainesville			
1.2.1, 1.4, and 2.3	1. Model improvement for soil C balance, N_2O and CH_4 emissions, and crop model improvements associated with heat/drought stress. 2. Data acquisition for modeling N_2O emissions and soil C and N dynamics (Long-Term Agroecosystem Research data, IFDC). 3. Improvements to GSSAT spatial modeling platform and linkage to SMaRT. 4. Development of IFDC database for biophysical and socioeconomic applications (harmonized with CGIAR data system).	Global	Work began in FY17 on database development. Contract to be signed for FY18 on availability of funds. Duration up to 2-3 years based on progress and funds.
2. Rapid Soil Test to Evaluate Nitrogen Mineralization in Tropical and Subtropical Soils in Collaboration with Auburn University			
1.1.3 and 1.2.1	1. Refine/evaluate soil N tests for subsequent fertilizer recommendations. 2. Compare lab incubation and field N mineralization studies using Solvita test and KCl extractable mineral N. 3. Assess the viability of these quick, simple tests for estimating N mineralization in highly weathered Ultisols and Oxisols.	Global	Scope of work being developed.
3. Developing Enhanced Efficiency Fertilizers in Collaboration with Tropical Research and Education Center (TREC), University of Florida, University of Central Florida, Oak Ridge National Laboratory, and Private Sector Partners			
1.1.3, 1.2.3, and 1.3.2	1. New generation of affordable, controlled-release fertilizers using agricultural wastes and/or other renewable and biodegradable materials as coating. 2. Multi-nutrient fertilizer granules with improved efficiency and synchronized release for plant bioavailability. 3. Biofertilizers – phosphorus/iron-solubilizing microorganisms will be cultured and deployed to make soil residual P available to plants. 4. Online course on new fertilizer technology for both graduate and undergraduate students.	Global	Scope of work with TREC approved.

Theme/ Activities	Work Planned	Countries	Status
4. Application of Remote-Sensing/GIS Methods for Fertilizer Recommendations in Collaboration with Alabama A&M University			
1.2.1, 1.2.2, and 1.4	1. Utilize the geo-referenced soil and tissue analyses and soil fertility maps of northern Ghana. 2. Combine with remote-sensing/GIS capabilities to determine the nutritional status and requirements of plants. 3. Link with soil and crop spatial modeling (GSSAT) to develop a predictive tool to help smallholder farmers make informed fertilizer decisions.	SSA/ South Asia	Scope of work being developed.
5. Improved Recycling of Nutrients and Wastes in Collaboration with Clemson University and Private Sector Partners (CHONEX Nutrient Recycling)			
1.1.3 and 1.2.3	1. Improve the efficiency of organic fertilizer production using rendered material (chicken feathers, blood, and other slaughterhouse waste). 2. Process poultry manure using biological processes (fly larvae) to improve quality (reduce water content to $<10\%$, pathogen-free). 3. Evaluate products and promote out-scaling.	USA	Scope of work being developed.
6. Mechanized Subsurface Application of Fertilizers in Collaboration with Mississippi State University and Private Sector Partners			
1.1.1, 1.1.3, and 1.2.3	Incorporate a deep-placement applicator into a rice transplanter.	Global	Discussion began FY17. Scope of work being developed.
7. Collaboration on Nutrient Omission Trials with Soybean Innovation Lab, University of Illinois			
1.2.1	Develop fertilizer recommendations for soybean in Northern Ghana.	Ghana	Ongoing.
8. Value-Added Gains Along the Peanut Value Chain in Partnership with the Peanut Innovation Lab, University of Georgia			
1.2 and 2.3	Improve production and quality of peanut with balanced fertilization, emphasizing Ca and S.	Global/ SSA	RFP released on March 14. Concept evaluation April 23-May 4, 2018.

Theme/ Activities	Work Planned	Countries	Status
9. Quantifying Improvements in Quality and Nutrition with Emphasis on Zn and S in Partnership with Tennessee State University, Nashville			
1.2.3	1. Evaluate protein quality as influenced by S and Zn fertilization. 2. Quantify the effect of balanced nutrition on anti-nutrient:nutrient ratio in grains.	Global	Discussion stage. Scope of work to be developed.
10. Developing a Highly Productive, Sustainable, and Mechanized Conservation Agriculture System in Collaboration with the Sustainable Intensification Innovation Lab, Kansas State University, and Private Sector Farm Mechanization			
Workstreams 1 and 2	1. Test innovative precision and conservation agriculture practices combined with ISFM and small-scale farm mechanization on rice-legume-cover crop-based systems. 2. Targeted areas: Northwestern Cambodia and parts of the Central Dry Zone in Myanmar. 3. Coordinated by a post-doc, with support from KSU and IFDC staff in Cambodia and Myanmar, respectively.	Cambodia, Myanmar	Scope of work developed.
11. Economic and Environmental Implications of UDP Production and Use in Bangladesh – A Life Cycle Analysis (LCA) Approach with Rutgers University			
2.3.4 (with 1.1)	1. Complement the agronomic work carried out on the quantification of GHG emissions in greenhouse studies in Muscle Shoals and field trials in Bangladesh using the LCA approach in quantification of energy equivalents consumed across different types of fertilization in a paddy rice system. 2. Utilize data from the completed USAID-funded Accelerating Agriculture Productivity Improvement (AAPI) project. 3. Utilize the economic data (primarily costing aspects) from urea briquette production and urea briquette use (cost of cultivation). 4. Research conducted by a graduate student.	Bangladesh	Scope of work developed. Graduate student identified. Contract to be signed.

Theme/ Activities	Work Planned	Countries	Status
12. Economic Estimation of Fertilization Methods for Rice Paddy in Bangladesh – A Production Function Analysis in Partnership with Rutgers University			
2.3.5 (with 1.1)	This research will utilize the existing data available from IFDC surveys on fertilizer adoption/use in Bangladesh to understand both technical efficiency of the uptake and sustenance of technology use by smallholders in adopting the UDP method of fertilizer application.	Bangladesh	Scope of work developed. Graduate student identified. Contract to be signed.
13. Partnership for Enabling Market Environments for Fertilizer in Africa (PEMEFA) and Fertilizer Value Chains and Agribusiness Development with Michigan State University (Alliance for African Partnership [AAP]) Consortium			
2.1.4 and 2.3.7	The proposed research aims to collate available evidence on the performance of fertilizer input markets and value chains in SSA, identify challenges and gaps, and provide policy recommendations.	SSA	Specifics of the joint effort and scope of work to be discussed in April.
14. Strengthening MELS Capacity in IFDC with University of Georgia			
Workstreams 1 and 2: Strengthening MELS capacity in IFDC	1. Professor Kay Kelsey from UGA has been advising IFDC on the design and establishment of an exclusive monitoring, evaluation, learning, and sharing (MELS) system within IFDC. 2. Ph.D. training for an IFDC M&E field staff.	Global	1. Scope of work being developed. 2. IFDC Togo staff to enroll in Ph.D. program at UGA in Fall 2018.

*Notes:

1. All university partnerships involve graduate students/post-doctoral fellows and faculty expertise.
2. In-person meetings were held at: (i) IFDC with the Clemson University team on March 5 (Dr. Christopher Kitchens, Dr. Nishanth Tharayil, and Mr. Bhupender Jatana [graduate student]); (ii) IFDC with the CHONEX team on March 21 (Mr. Michael Lynch and Christopher Samford) and Dr. Frank Franklin, University of Alabama at Birmingham; (iii) Alabama Green Industry Training Center, Birmingham, with the Auburn University team on February 13 (Drs. Audrey Gamble and Rishi Prasad), followed by a Skype call on March 21 (Gamble, Prasad, and Beth Guertal); (iv) Rutgers University with on Dr. Carl Pray and graduate students (Selen Altiok and Mingzhe Yu); (v) Alabama A&M University on February 12; and (vi) Michigan State University, East Lansing on April 5.
3. Skype meetings were held during February-March with: (i) University of Florida modeling and database team (Drs. Gerrit Hoogenboom and Cheryl Porter); (ii) Dr. Yuncon Li of TREC; and (iii) Drs. Vara Prasad and Gary Pierzynski, Sustainable Intensification Innovation Lab, Kansas State University.

Annex 2. List of Publications and Presentations

Adisa, I.O., V.L.R. Pullagurala, S. Rawat, J.A. Hernandez-Viezcas, C.O. Dimkpa, W.H. Elmer, J.C. White, J.R. Peralta-Videa, and J.L. Gardea-Torresdey. 2018 (unpublished). "Role of Cerium Compounds in *Fusarium* Wilt Suppression and Growth Enhancement in Tomato (*Solanum Lycopersicum*)."

Agyin-Birikorang, S., J.H. Winings, X. Yin, U. Singh, and J. Sanabria. 2018. "Field Evaluation of Agronomic Effectiveness of Multi-Nutrient Fertilizer Briquettes for Upland Crop Production," *Nutrient Cycling in Agroecosystems,* 110:395-406.

Agyin-Birikorang, S., W. Dogbe, and C. Boubakary. 2017. "Climate Resilient Soil Fertility Management Strategy for Rice Production in Submergence Prone Areas in Northern Ghana," presented at 2017 ASA, CSSA and SSSA International Annual Meeting, October 22-25, Tampa, FL.

Ariga, J.M. 2018. "Introduction: Understanding Subsidies," presented at the IFDC International Workshop on Developing Private Sector Agro-Input Markets – Lessons Learned and Emerging Perspectives on Subsidy Programs, February 19-23, 2018, Jinja, Uganda.

Ariga, J.M. 2018. "The Economic Rationale for Fertilizer Quality Regulations," presented on behalf of *The Partnership for Enabling Market Environments for Fertilizer in Africa (PEMEFA*) at the IFDC International Workshop on Developing Private Sector Agro-Input Markets – Lessons Learned and Emerging Perspectives on Subsidy Programs, February 19-23, 2018, Jinja, Uganda.

Ariga, J.M. 2017. "Fertilizer Value Chains in Developing Countries: A Summary of Key Economic, Policy, and Equity Issues," presented at a seminar sponsored by the Serve-Learn-Sustain program at Georgia Tech University, Georgia, on October 19, 2017, https://serve-learn-sustain.gatech.edu/our-mission-and-vision.

Ariga, J.M., N. Mason, and K. Kuhlmann 2018. "Preliminary Findings from the PEMEFA Synthesis Report," presented on behalf of PEMEFA at the IFDC International Workshop on Developing Private Sector Agro-Input Markets – Lessons Learned and Emerging Perspectives on Subsidy Programs, February 19-23, 2018, Jinja, Uganda.

Ariga, J.M. 2018. "Policy Reforms and Fertilizer Market Development: The Kenyan experience," presented at seminar on "Agricultural Policy and Regulation in Sub-Saharan Africa: Lessons for Increasing Investment' held on April 5, 2018 at MSU, East Lansing, Michigan,

Ariga, J.M. 2018. "Fertilizer Use and Value Chains in SSA," presented at seminar on "Agricultural Policy and Regulation in Sub-Saharan Africa: Lessons for Increasing Investment' held on April 5, 2018 at MSU, East Lansing, Michigan,

Aung, M., Z.Y. Myint, S. Thura, G. Hunter, U. Singh, and J. Sanabria. 2017. "Comparison of Yield Response and Nutrient Use Efficiency Between Urea Deep Place Technology and Farmers' Practice of Surface Broadcasting Urea on Transplanted Lowland Rice in Myanmar," pp. 47-54, IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, IFDC and DAR, Myanmar.

Bindraban, P.S., C.O. Dimkpa, J.S. Angle, and R. Rabbinge. 2018. “Unlocking the Multiple Public Good Services from Balanced Fertilizers,” *Food Security*, https://doi.org/10.1007/s12571-018-0769-4.

Dimkpa, C.O., D.T. Hellums, U. Singh, and P.S. Bindraban. 2017. “The Role of Mineral Fertilizers in Climate-Resilient Agriculture: Focus on Myanmar,” IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 221-241, IFDC and DAR, Myanmar.

Elmer, W.H., R. DeLaTorre Roche, L. Pagano, S. Majumdar, N. Zuverza-Mena, C. Dimkpa, J. Gardea-Torresdey. and J.C. White. 2018. “Effect of Metalloid and Metallic Oxide Nanoparticles on *Fusarium* Wilt of Watermelon,” *Plant Disease*, https://doi.org/10.1094/PDIS-10-17-1621-RE.

Fugice, J., S. Agyin-Birikorang, and C. Dimkpa. 2018. IFDC Evaluation of Portable Soil Testing Kits – Lessons Learned, IFDC, Muscle Shoals, AL.

Gaihre, Y.K., U. Singh, S.M.M. Islam, A. Huda, M.R. Islam, and J.C. Biswas. 2017. “Efficient Fertilizer and Water Management in Rice Cultivation for Food Security and Mitigating Greenhouse Gas Emissions,” IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 214-220, IFDC and DAR, Myanmar.

Islam, S.M.M., Y.K. Gaihre, J.C. Biswas, M.S. Jahan, U. Singh, S.K. Adhikary, M.A. Satter, M.A. Salaque. 2018. “Different N Rates and Methods of Application for Dry Season Rice Cultivation with Alternate Wetting and Drying Irrigation: Fate of N and Grain Yield,” *Agricultural Water Management*, 196:144-153.

Jahan, Ishrat. 2018. “Fertilizer Subsidy Policy of Bangladesh and Its Use,” presented at the Argus NPK, Water Soluble and Micronutrient Fertilizer Workshop in India 2018, New Delhi, India.

Jayne, T.S., N. Mason, W. Burke, and J. Ariga. 2018 (in press). “Taking Stock of Africa’s Second-Generation Agricultural Input Subsidy Programs,” *Food Policy*.

Nagarajan, L. 2017. On behalf of Rutgers University and IFDC, PowerPoint presentation at USAID BFS Agriculture Core Course: Policy, Governance, and Standards – Agriculture Input Policy training conducted on December 13, 2017, in Washington, D.C.

Nagarajan, L. 2017. On behalf of Rutgers University and IFDC, PowerPoint presentation at USAID BFS Agriculture Core Course: Policy, Governance, and Standards – Agriculture Input Policy training conducted on December 13, 2017, in Washington, D.C.

Nagarajan, L., and Carl E. Pray (2018). “Millets: Finding a way into our diet”; Interview published by SPANDAN India. http://www.spandan-india.org/cms/data/Article/A2018323112610_11.pdf

Nagarajan, L., A. Naseem and C.E.Pray. 2018. *Forthcoming*. “Contribution of Policy Change on Maize Varietal Development and Yields in Kenya”, *Journal of Agribusiness in developing and emerging economies*.

Nagarajan, L., A. Naseem and C.E.Pray. 2018. “The role of maize varietal development on yields in Kenya”, Paper accepted for oral presentation at the *International Conference for Agricultural Economists (ICAE)*, Vancouver, Canada (July 28 – Aug 2nd, 2018).

Nagarajan, L., A. Naseem and C.E.Pray. 2018. “The Transformation of India’s Agricultural Input Industries”. Accepted for presentation at the 22nd International Consortium on Applied

Bioeconomy Research (ICABR) Conference "Disruptive Innovations, Value Chains, and Rural Development" World Bank, Washington DC (June 12-15, 2018).

Rietra, R.P., J.J., M. Heinen, C.O. Dimkpa, and P.S. Bindraban. 2017. “Effects of Nutrient Antagonism and Synergism on Yield and Fertilizer Use Efficiency,” *Communications in Soil Science and Plant Analysis*, 48:16.

Sanabria, J., J. Wendt, and O. Nduwimana. 2017. “Modeling Spatial Variability across Farms to Estimate the Error in Experiments Replicated across Numerous Farms,” presented at the ASA, CSSA and SSA 2017 Annual Meeting, October 22-25, Tampa, FL.

Sanabria, J. 2016. “Fertilizer Quality Assessment in the Myanmar Dry Zone,” IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 243-255, IFDC and DAR, Myanmar.

Singh, U. 2017. “Fertilizer, Soil, Plant and Nutrient Dynamics Research at IFDC,” presented at Kingenta’s Research Center on Slow and Control Release Fertilizer, November 16, Shandong, China.

Singh, U. 2017. “Past, Present and Future of Fertilizer Technology Development,” presented at the International Symposium of Fertilizer Technology and Nutrient Management, November 21, organized by Shandong Agricultural University, Shandong, China.

Singh, U., M. Aung, and J. Fugice. 2017. “Role of Yield Potential and Yield-Gap Analyses on Resource-Use Efficiency Improvement,” IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 22-37, IFDC and DAR, Myanmar.

Singh, U., D. Hellums, W. Bible, V. Henry, J. Sanabria, and F. Yin. 2017. “Performance of Urea Enhanced with Sulfur,” presented at the ASA, CSSA and SSA 2017 Annual Meeting, October 22-25, 2017, Tampa, FL.

Thigpen, J. 2018. “Ongoing Improvements and Applications of the CERES-Rice Model,” *Agrilinks Newsletter*, February 28, 2018. https://www.agrilinks.org/post/ongoing-improvements-and-applications-ceres-rice-model.

Wendt, J., and L.W. Mbuthia. 2017. “A Conceptual Framework for Delivering Improved Fertilizers to Smallholder Farmers in Africa,” IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 169-175, IFDC and DAR, Myanmar.

Annex 3. Comments and Clarifications about the Report

1. Workstream 1 – Developing and Validating Technologies, Approaches, and Practices

1.1.1.1 Rice Production in Submergence-Prone Areas – Ghana

BFS: It would be interesting to see the impact of labor on the economic viability of the various treatments. Also, is there greater potential to subsurface place granular fertilizer than briquettes?

Response: (Incorporated in above section of the Report). An economic analysis is being performed on the data to ascertain the profitability associated with each treatment. The results of the economic analysis will be presented in the annual report. Improvements in applicators will be beneficial to both subsurface placed granular fertilizer and briquettes.

1.1.1.2 Developing Appropriate Soil Fertility Management Technologies for Stress-Tolerant Rice Cultivars – Bangladesh, Myanmar, and Nepal

Drought Trial in Nepal

Preliminary findings show that most farmers have no access to extension advice regarding fertilizer use (amount and timing).

BFS: Perhaps we should place a greater focus on extension. We could consider a pilot joint activity with our centrally funded extension mechanism led by Digital Green and IFPRI to see how information dissemination could be improved leading to better project outcomes.

Response: Yes, it is a good idea. IFDC has started disseminating this information under CIMMYT led project 'Nepal Seed and Fertilizer (NSAF)' by training of trainers – the intermediary service providers (agro-dealers/retailers) on ISFM (including balanced fertilization) and BMPs. NSAF is working in collaboration with another USAID project 'Knowledge-Based Integrated Sustainable Agriculture in Nepal (KISAN II)' to scale improved ISFM practices to farmers. Linking this work with other partners such as Digital Green would be pursued in FY 19 Workplan.

Salinity and Submergence Trials in Myanmar

At the high-yielding location (Kwin Yar), basal application of diammonium phosphate (DAP) followed by three split applications of urea improved the efficiency of broadcast application to give similar yield as UDP.

BFS: It seems that combining multiple BMP's can have as great an impact as UDP. This is similar to the situation in Burma that we talked about with Grahame with the FSI+ activity

Response: In general, nutrient management is highly site- and season-specific. However, UDP has been shown to perform equally well in stress and favorable environment. BMPs in favorable environment could be as effective as UDP to give similar yields. However, other impacts of UDP are lower fertilizer dosage, reduced N losses to the environment, one-time application of N fertilizer, and higher gross margin.[3]

[3] Kaw, D and G. Hunter (2017). UDP technology and rice yields among farmer beneficiaries of rainfed lowland project areas in Myanmar. IN *Myanmar Soil Fertility and Fertilizer Management Conference Proceedings*, pp. 135-149, IFDC and DAR, Myanmar.

1.1.2.3 Agronomic and Economic Evaluation of Deep Placement on Maize and Winter and Off-Season Vegetables in Mali and Ghana

Maize Trials in Ghana

To improve N use efficiency, smallholder farmers have been taught to avoid the traditional surface broadcast application and apply fertilizers at the subsurface, near the root zone of the maize plants.

BFS: Taught by who, the project or traditional extension efforts?

Response: Extension and IFDC (included in the Report). To improve N use efficiency, smallholder farmers have been taught by the local extension services, supported by IFDC, to avoid the traditional surface broadcast application and apply fertilizers at the subsurface, near the root zone of the maize plants.

An innovative approach could be a priori briquetting of the quantity of fertilizer required by the plant and applying the briquettes to the plants, thereby eliminating the measuring of the granular fertilizer before applying it to the plant.

BFS: Unless there was an opportunity for "custom blend briquetting" this would require a fairly generic blend and not be very site or soil specific.

Response: (Incorporated in the Report). The opportunity to produce custom-blend multi-nutrient briquettes exist (see Annex 2: Agyin-Birikorang et al., 2018); however, issues associated with briquette strength need fine-tuning before out-scaling of the process.

Upland Vegetable Production in Ghana

In SSA, women are heavily involved in vegetable production; thus, the introduction of technologies that increase the productivity of vegetable production could increase household incomes and make the enterprise more attractive to several women.

BFS: Several does not sound like a very ambitious goal.

Response: (Incorporated in above section of the Report). In SSA, women are heavily involved in vegetable production; thus, the introduction of technologies that increase the productivity of vegetable production could increase household incomes and make the enterprise more attractive to all women engaged in vegetable production.

1.1.3 Improving Nitrogen Use Efficiency of Organic and Inorganic Fertilizers

The activity reported here was conducted in partnership with the U.S. Department of Agriculture.

BFS: What is the length of this relationship with USDA?

Response: (Incorporated in the Report). It is a 3-year USDA NIFA-funded project being executed in collaboration with The Connecticut Agricultural Experiment Station (as the lead) and The University of Texas in El Paso. It started in March 2016 and ends on February 2019.

These findings indicate that Zn treatment has both immediate and residual effects on wheat productivity.

BFS: What were initial soil test levels, pH, Zn, texture, etc.? Impact of soil test levels and especially pH with Mn response.

Response: (Incorporated in the Report). The soil used in the studies is a sandy loam with a near-neutral pH of 6.87, which suggests the pH is nearing the upper boarder line for optimum soil Zn and Mn bioavailability. The initial Zn level of 0.1 mg/kg was below the critical level for Zn of 0.5 to 1.0 mg/kg and likewise the Mn level of 6.4 mg/kg was below the critical level of 50-100 mg/kg.

1.2.1 Facilitate Site- and Crop-Specific Fertilizer Recommendations for Increased Economic and Environmental Benefits from Fertilizer Use

This is the result of either inherently low soil fertility or nutrient depletion and organic matter decline caused by repeated cropping without replacing what has been taken from the soil.

BFS: I would add acidity to that list.

Response: (Incorporated in the Report). This is the result of either inherently low soil fertility or nutrient depletion, soil acidity, and organic matter decline caused by repeated cropping without replacing what has been taken from the soil.

N, P, and K contents of the unfertilized plant tissue samples were greater than expected (Figures 11-13) due to plant roots accessing nutrients from deeper levels (beyond the top 6 inches analyzed).

BFS: One of the main advantages of tissue testing is that it accounts for nutrients that are not reflected in soil testing including nutrients from deeper horizons that are sampled. Were the tissue samples all taken at the proper diagnostic stage of growth and at the same locations as the soil samples? Setting up a massive number of omission studies seems like a big lift. I would check to make sure tissue sampling protocols were followed and sample handling was done properly.

Response: Tissue samples were taken at the proper diagnostic stage of growth and at the same locations as the soil samples. Tissue sampling and sample handling protocols will be followed in the nutrient omission trials.

1.2.5.3 Greenhouse Evaluation of Activated Phosphate Rock on Highly Acidic Soil

PR can be used as a soil acidity amendment;

BFS: How is PR being used as a soil acidity amendment?

Response: PR dissolution reaction (Khasawneh and Doll, 1978; Kirk and Nye, 1986), results in the release of $H_2PO_4^-$ and Ca^{2+}.

$$Ca_{10}(PO_4)_6F_2 + 12H^+ \leftrightarrow 10Ca^{2+} + 6H_2PO_4^- + 2F^-$$

The consumption of H^+ would increase soil pH. Calcium can also reduce acidity by complexing Al-Fe oxides as on application of gypsum.

1.3.1.3 Myanmar Fertilizer Quality and Fertilizer Value Chain Analysis

This activity was funded by the World Bank.

BFS: Were central funds used for this? If so, it should be referenced. If not, then no need to list this work within this BFS report.

Response: This activity was funded by the World Bank with some central funding (10%) from BFS. Its implementation was based on the experiences gained from BFS funded activities in SSA.

2. Workstream 2 - Supporting Policy Reform Processes, Advocacy, and Market Development

BFS: How much each of these multiple workstream 2 activities costs are borne by this grant under IFDC BFS core funding, vs. other funding from BMGF, AGRA, etc etc?

Response: (Incorporated in the Report). All the activities under this workstream are implemented through partnerships with different stakeholders with similar interests, namely, in promoting policies and reforms aimed at improving fertilizer access, availability and use among small holders in the FTF focus countries, under varied political, social, economic, and environmental conditions.

IFDC being the 'go to institution for soil and fertilizer technologies, policies and advocacy', most of the activities and associated outcomes are identified by IFDC scientists and economists for further exploration in partnership with leading stakeholder institutions (academic, research, policy think tanks, public and private firms) to present evidence-based research studies for further scaling up and dissemination.

The costs associated with BFS to fund the activities are shared either on cost or kind basis from the partnering institutions to achieve the maximum outreach and impact in the following three major areas of focus. Three types of activities related to soil technologies, and fertilizer management have been taken up under this workstream;

a. support developing and implementation of fertilizer / soil related policies, reforms and regulations;
b. assessing impacts of soil and fertilizer related technologies, policies and market interventions to improve access and use by farmers; and
c. conducting studies to show the economic and financial feasibility of soil/fertilizer related technologies, fertilizer access and market systems (incl. fertilizer demand and supply and associated margins)

Workstream 2	Country	Activity	Partnership & Funding Sources (%)
2.1 Document Policy Reforms and Market Development			
2.1.1 Support for Kenya Fertilizer Roundtable Meeting and Policy Reform Processes	Kenya	Stakeholder consultations	BFS: 50 MoALF Kenya and other stakeholders: 50
2.1.2.1 USAID BFS Agriculture Core Course: Policy, Governance, and Standards – Agriculture Input Policy Analysis	Global	Training	BFS: 30 Rutgers University Consortium: 70
2.1.2.2 Developing Private Sector Agro-Input Markets: Lessons Learned and Emerging Perspectives on Subsidy Programs	Uganda	Training	BFS: 40; MSU: 20; AFAP: 10 MoA-Uganda: 10 IFDC training: 20

Workstream 2	Country	Activity	Partnership & Funding Sources (%)
2.1.3 Documenting Fertilizer Trends and Outlook: Code of Conduct for Fertilizer Management	Global/SSA	Consultations	BFS: 100 % (for the IFDC participation)
2.1.4 Partnership for Enabling Market Environments for Fertilizer in Africa	SSA	Consultations	BFS: 80 MSU led AAP consortium: 20
2.1.5 Review of Input Subsidy Program Design in SSA	SSA	Analysis and manuscript	BFS: 50 AGRA: 50
2.1.6 Policy Briefs on Fertilizer Policies and Market Development	SSA/Asia/ LAC	Technical write-ups	BFS: 90 Rutgers: 10
2.2 Impact Assessment Studies			
2.2.1 Impact Assessment Study on the Kenya Fertilizer Subsidy Program	Kenya	Field studies - households /firm	BFS: 33.3 MoA- Ke: 33.3; Tagemeo: 33.3
2.2.2 Effectiveness of Agro-Dealer Development Programs Toward Sustainable Input Supply and Technology Transfer in Sub-Saharan African Countries	Rwanda	Field studies - households /firm	BFS: 70 AGRA: 30 (under negotiation)
2.3 Economic and market studies			
2.3.1 Fertilizer Quality Assessments: Support Policy Efforts to Harmonize Fertilizer Regulations (with Workstream 1)	Zambia, Kenya, Uganda, Myanmar	Analysis	BFS: 100 (for all countries) Myanmar only: BFS: 10 World Bank: 90
2.3.2 Fertilizer Cost Buildup Studies and Marketing Margin Analysis	SSA	Analysis	BFS: 100% IFDC-AFO – In Kind only
2.3.3 The African Fertilizer Access Index	SSA	Design, indicators, analysis	BFS: 50 AFAP: 50 (could not participate)
2.3.4 Economic and Environmental Implications of Fertilizer Technologies Using Life Cycle Analysis Approach	Bangladesh	Data/analysis	BFS: 60 (for students/IFDC personnel) Rutgers University/Consortium: 40 (Rutgers personnel time)
2.3.5 Economic Estimation of Fertilization Methods for Rice Paddy in Bangladesh – A Production Function Analysis	Bangladesh	Data/analysis	BFS: 60 (for students/IFDC personnel) Rutgers University/Consortium: 40 (Rutgers personnel time)
2.3.6 Enhancing M&E capacities of soil fertility research systems in IFDC	Global	Training, Tools, analysis	BFS: 100 (for students/IFDC/UGA personnel)
2.3.7 Encouraging Agribusiness Development in Sub-Saharan Africa: Fertilizer Value Chains and Policy Implications	SSA	Literature review/analysis	BFS: 80 (for students/IFDC personnel) MSU: 20 (MSU personnel time)
2.3.8 Improving Fertilizer Use, Access, and Market Development: Case of Coffee Sector and Other Food Security Crops	Honduras/ Guatemala	Field studies	BFS: 100

BFS: Strategic approach: It's not clear what this all adds up to, or how these activities were selected, or what the medium term priorities or plan are?

Response:

The overall (strategic) approach for the work stream activities since beginning of the project in 2015 were to:

(1) Produce evidence – based research studies of economic nature on fertilizer policy reforms, market related interventions, and soil and fertilizer technologies
(2) Engage actively in advocacy forums and capacity building activities to influence stakeholders in fertilizer sector and soil management to improve access, availability and use of proven soil/fertilizer technologies and products through sustainable interventions considering economic and environmental implications
(3) Disseminate information and knowledge on soil and fertilizer related issues

The selection of activities (FY 2015-2018) since project initiation were based on extensive consultations with Activity Manager for the project and the Senior Policy Advisor (BFS) to reflect the emerging as well to fill in the void in producing evidence based economic, policy research on soil and fertilizer sector across the FTF countries, along with partners (academic, policy think-tanks, other public and private stakeholders).

Medium term priorities / plans (since FY 2018) and expected outcomes: As of now, the project has crossed midpoint of its implementation. Further to coordinate with the current strategic vision of IFDC since 2017 and to align with new BFS priorities (GFSS strategy etc.,) we have re-organized ourselves to focus on few key initiatives during the remaining part of the project; and consolidate activities to allow for organizing learning events. Thus, from mid FY 2018, new activities with focused outputs are being implemented.

***Activities that are expected to be completed by 2018 funding cycle include*:**

(1) Cost-build up (market margin analysis) for fertilizer supply. Initiated in 2015 with BFS funding, four country-level studies have been documented under this sub-activity in Kenya, Tanzania, Mali, and Ghana. With information been collected by AFO-IFDC and recently concluded USAID funded WAFP study, we propose to consolidate these studies for further dissemination.
(2) Fertilizer quality assessment studies. Conducted with Workstream 1 (laboratory and statistical analysis) with exclusive BFS funding in 3 countries – we further expect to consolidate the findings from all the 3 countries + Myanmar (complemented by WB funding)

Activities for focus in 2018/19 funding cycle include;

(1) Focus on producing evidence-based (empirical) policy briefs and reports on fertilizer market development; and soil/fertilizer policy reforms in FTF countries (in collaboration with networks and partners) – including ministry of agriculture in selected FTF countries, policy think tanks (AFAP, Tagemeo, AGRA) and regional economic forums (ECOWAS, COMESA, etc.).
(2) Expanding economic research on soil and fertilizer technologies with University partnerships: (including adoption studies, empirical economic studies etc,) with land-grant university partnerships (Rutgers, MSU, UGA etc.)

(3) Compliment workstream 1 activities with focus on: extension and improved information dissemination and conducting economic feasibility that lead to better project outcomes. Providing solid economic/financial basis for scaling adaptive technologies for wider adoption.

www.feedthefuture.gov