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

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List of Acronyms

AAPI	Accelerating Agriculture Productivity Improvement
AFAP	African Fertilizer and Agribusiness Partnership
AGRA	Alliance for a Green Revolution in Africa
ARDB	Agronomic Research Database
ATT	Agriculture Technology Transfer
AU	African Union
AUC	African Union Commission
AWD	Alternate Wetting and Drying
B	Boron
BFS	Bureau for Food Security
BMPs	Best Management Practices
BPS	Bulk Procurement System
C	Carbon
C&F	Clearing and Forwarding
Ca	Calcium
CA	Cooperative Agreement
CAADP	Comprehensive Africa Agriculture Development Programme
CAN	Calcium Ammonium Nitrate
CERES	Crop Evaluation Through Resource and Environment Synthesis
CIF	Cost, Insurance, and Freight
CO_2	Carbon Dioxide
COMESA	Common Market for Eastern and Southern Africa
Cu	Copper
DAP	Diammonium Phosphate
DPP	Department of Policy and Planning
DREA	Department of Rural Economy and Agriculture
DSSAT	Decision Support System for Agrotechnology Transfer
DST	Decision Support Tool
ECOWAS	Economic Community of West African States
FAI	Fertiliser Association of India
FAO	Food and Agriculture Organization of the United Nations
FDP	Fertilizer Deep Placement
FQA	Fertilizer Quality Assessments
FTF	Feed the Future
FY	Fiscal Year
GAEC	Ghana Atomic Energy Commission
GHG	Greenhouse Gas

GIS	Geographic Information Systems
ha	hectare
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
IDF	Import Declaration Form
IFDC	International Fertilizer Development Center
ILSAFARM	Improved Livelihoods for Sidr-Affected Rice Farmers
ISFM	Integrated Soil Fertility Management
ISP	Input Subsidy Program
ISPM	*Instituto Superior Politecnico de Manica*
JICA	Japan International Cooperation Agency
K	Potassium
K_2O	Potassium oxide
KBS	Kenya Bureau of Standards
kg	kilogram
KNO_3	Potassium nitrate
LC	Letter of Credit
LCA	Life Cycle Analysis
LIV	Local Improved Varieties
LRP	Locally Recommended Fertilization Practice
m	meter
M&EDB	Monitoring and Evaluation Database
MAFAP	Monitoring and Analyzing Food and Agricultural Policies
MALF	Ministry of Agriculture, Livestock and Fisheries
MCP	Monocalcium Phosphate
ME&P	Markets, Economics and Policy
MD	Microdosing
Mg	Magnesium
Mn	Manganese
MoA	Ministry of Agriculture
MOU	Memorandum of Understanding
MSU	Michigan State University
N	Nitrogen
N_2O	Nitrous Oxide
NAAIAP	National Accelerated Agricultural Inputs Access Program
NML	New Markets Lab
NH_3	Ammonia
NH_4Cl	Ammonium Chloride
NH_4-N	Ammonium-N
NO	Nitric Oxide

NPK	Nitrogen, Phosphate, and Potassium
NUE	Nitrogen Use Efficiency
OC	Organic Carbon
P	Phosphorus
PU	Prilled Urea
PVoC	Pre-Export Verification of Conformity
QA/QC	Quality Assurance/Quality Control
REC	Regional Economic Community
ReNAPRI	Regional Network of Agricultural Policy Research Institutes
RP	Extension-Recommended Practice
SARI	Savanna Agricultural Research Institute
SFT	Soil Fertility Technology
SO_4-S	Sulfate-Sulfur
SRDI	Soil Resource Development Institute
SSA	Sub-Saharan Africa
STV	Stress-Tolerant Varieties
TAFAI	The Africa Fertilizer Access Index
TFRA	Tanzania Fertilizer Regulatory Authority
TN	Technical Networks
UDP	Urea Deep Placement
USAID	U.S. Agency for International Development
USG	Urea Supergranules
WAFP	West Africa Fertilizer Program
ZARI	Zambia Agriculture Research Institute
Zn	Zinc
ZOI	Zone of Influence

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).

One year into the agreement, USAID and IFDC staff met to discuss realigning the project's results framework and focusing Workstream 1 activities to develop and validate technologies to improve soil fertility, plant nutrient management, and best management practices for smallholders. This followed agreement that the original Workstream 1 related to scaling out technologies was beyond the CA's available resources. It was also agreed that IFDC would organize into the two workstreams specifically related to nutrient management technologies and policy reforms with learning agendas and knowledge management being incorporated with other cross-cutting issues into both workstreams.

Under the awarded agreement and in collaboration with USAID, IFDC will conduct a range of activities and interventions prioritized for each annual work plan from the agreed-upon workstreams. A summary description of the major activities proposed for each workstream over the remaining life of the CA is presented below.

Workstream 1: Developing and Validating Technologies, Approaches, and Practices: IFDC's Soil and Plant Nutrition Program is developing and validating technologies that address nutrient management issues and promote advancement of sustainable agricultural intensification. Moreover, these technologies (e.g., fertilizer deep placement, balanced plant nutrition), alone or in combination with other technologies (e.g., stress-tolerant varieties), are important for building climate resilience at the smallholder level as well as for agriculture in general. In FY17, IFDC will devote time and resources to:

- Fertilizer technologies refined and adapted for increased nutrient use efficiency and climate resilience for upland and lowland crops, including crops grown in areas subject to stress (e.g., flooding, drought, salinity).
- Balanced soil-plant nutrition programs leading to improved fertilizer recommendations, including completing the assessment of the reliability and practicality of quick kit soil analysis correlating results with laboratory (wet chemistry) analysis.
- Fertilizer quality assessments for eastern and southern African markets to support policy efforts to harmonize fertilizer regulations.

Workstream 2: Supporting Policy Reforms and Market Development: Under Workstream 2, IFDC will conduct evidence-based policy analysis 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 will be useful in strategically and tactically shaping the necessary changes in policy and, hence, market developments that will have significant impact on technology choices by farmers. The ultimate goal of such an approach would be to strengthen the capacity of stakeholders in the value chains to ensure increased access to inputs by farm households.

IFDC's work under policy and markets will reflect the objective outlined through conducting studies related to three broad categories: policy reforms, impact assessments, and economic studies. These comprise IFDC's efforts to support the development of fertilizer markets and value chains that allow greater private sector participation and investment with appropriate public sector regulatory oversight. Together with Workstream 1, the proposed work will add value to IFDC's existing knowledge management systems, contributing to databases to provide useful information, draw lessons learned, and identify gaps for further action or research. The data and output from these efforts will provide a strong foundation for IFDC to join and participate in partnerships with other research and development institutions in areas of mutual interest, including policy dialogue with decision makers and other stakeholders in various countries. The following is a summary of the proposed activities that would fall under each of these categories:

- **Policy Reform Processes:** (a) Technical support for promoting fertilizer policy and regulatory reforms based, in part, on results from fertilizer quality surveys conducted under Workstream 1; (b) technical support for fertilizer market development to countries; (c) capacity building for policy reforms utilizing advocacy approaches, including initiating and engendering dialogue among businesses, farmer associations, and policymakers through workshops and seminars; and (d) engagement with the African Union (AU) and other regional economic community (RECs) forums in influencing fertilizer reform processes. This will involve participation and contribution to policy deliberations sponsored by AU or institutions engaged in reform processes aimed at strengthening AU capacities to implement continental resolutions related to fertilizer markets.
- **Impact Studies:** (a) Harmonization of fertilizer quality and regulatory frameworks building on the fertilizer quality surveys conducted under Workstream 1; (b) effects of tariff and non-tariff barriers on trade and on costs and imports of fertilizers; (c) impact of agro-dealer development; and (d) effects of market intervention activities with regard to fertilizer market development.
- **Economic Studies:** (a) Fertilizer cost build-ups and (b) economics of technology rollout or scaling up of various fertilizer products.
- **Identification of Fertilizer Trends and Outlook for Sub-Saharan Africa:** (a) initiation of development of The Africa Fertilizer Access Index (TAFAI) and (b) projections of fertilizer supply/demand in sub-Saharan Africa (SSA).

Cross-Cutting Issues Including Learning Agendas and Knowledge Management: IFDC will undertake additional activities that will allow the organization to further capture, document, analyze, and disseminate the knowledge that results from the many soil fertility systems and activities/technologies that the organization employs to improve productivity and increase food security. The work conducted under Cross-Cutting Issues will include:

- Completion of the IFDC database, which will allow for systematic data collection/access to all IFDC project outputs and dissemination of existing knowledge and lessons learned via publications, technical reports, training manuals and modules.
- Workshop on the “Role of Fertilizers in Addressing Climate Change.”

- Updated manuals on fertilizer physical properties and proper bulk blending.
- Collaboration with universities.

Under the awarded agreement, IFDC conducts a range of activities and interventions prioritized by the 2017 annual work plan developed from the agreed-upon workstreams. This report summarizes the activities from October 1, 2016, to March 30, 2017.

1. Workstream 1 – Improved Soil Fertility and Plant Nutrient Management Technologies and Practices Made Available for Dissemination by IFDC and Other Public and Private Sector Actors

For the millions of smallholder farmers who must contribute up to 85% of the predicted 60-70% increase in food demand in developing countries, increasing yields and transitioning to commercially oriented intensified agriculture requires increased access to agro-inputs and improved technologies, linkages to markets and information and knowledge on management techniques that improve their production efficiency. Against this backdrop, these smallholders face additional and enormous challenges (land degradation, land use pressures, climatic uncertainties, availability of water, etc.) to increasing production while reducing the negative environmental impacts of agriculture on the natural resource base. Under such conditions, nutrient use strategies that combine mineral fertilizers with organic amendments must be embedded in an Integrated Soil Fertility Management (ISFM) approach that incorporates access to other agro-inputs and best management practices (BMPs [i.e., crop rotations, residue management, and improved water management]). A major focus of Workstream 1 is to develop and validate ISFM (including urea deep placement [UDP]) technologies and practices that promote improved soil fertility and sustainably increase crop productivity and farm livelihoods. Below is a summary of activities for this reporting period.

1.1 Technologies Refined and Adapted for Climate Resilience

Fertilizer management is a major challenge for rice cultivation in stress-prone environments subject to drought, submergence, salinity, etc. Farmers in these areas have poor control over water and fertilizer application. For conventional split application of nitrogen, farmers are often unable, in the case of flooding, or unwilling, in the case of flooding and drought, to apply the follow-on splits. Fertilizer deep placement could be a better alternative since it could be done before or at planting, eliminating the need for additional applications and ensuring higher yields. However, this higher upfront fertilizer cost could be unattractive to risk-averse farmers

1.1.1 *Technologies and Best Management Practices Developed and Validated*

A. Adaptive Trials for Fertilizer Management for Stress-Tolerant Rice Cultivars in Asia and Sub-Saharan Africa

Eight field trials were established during the *Aman* season 2016 in Bangladesh, four each under drought and submergence conditions to evaluate the effects of UDP compared to farmer's practice and extension-recommended fertilizer practices. Table 1 presents the treatment details for drought and submergence trials in Bangladesh. The nitrogen (N) rate for farmer's practice was the average of 10 neighboring farmers around each trial. Survey data show that farmers were using more than double N under drought condition. Similarly, two trials were established in Myanmar under submergence condition, but the data has not been processed.

Treatments		N Rates (kg/ha)	
Variety	Fertilizers	Drought (*Aman* 2016)	Submergence (*Aman* 2016)
Local improved (V1)	Farmer's practice	120±5	45±10[†]
	Recommended	53	-
	UDP	52	52
Stress resistant (V2)	Farmer's practice	130±10[†]	60±10[†]
	Recommended	60	-
	UDP	52	52

[†] N rates for farmer's practice varied with trials.

Table 1. Experimental Treatments Used for Drought and Submergence Conditions in Bangladesh During Aman 2016. Treatments are Combination of Fertilizer Practices and Rice Varieties

Under submergence condition, the effects of UDP on grain yields varied with crop variety. In general, UDP increased grain yields of submergence-tolerant variety but not of local variety. Most farmers in submergence-prone areas in Bangladesh cultivate the local variety, which has lower yield potential than that of the stress-tolerant variety. Results confirm that UDP at 52 kilograms (kg) N per hectare (ha) is excessive for the local variety. Unlike with the local variety, UDP performed better than farmer's practice for the stress-tolerant variety in some locations (Table 2). For stress-tolerant varieties, farmers typically apply N fertilizer when submerged water recede from the fields, particularly for tidal flood-prone areas. Since broadcast urea and the UDP treatment had similar N rates and produced similar grain yield, it is possible that the N rate for UDP chould be lower than 52 kg N for submerged rice. If so, this would promote wider adoption by farmers, due to fertilizer savings.

Fertilizer	Plant Height, cm			Panicle, m$_{-2}$			Yield, kg ha$_{-1}$		
	LIV	STV	Average	LIV	STV	Average	LIV	STV	Average
Amtoli, Barguna									
FP	147	116	132b	264	266	265b	2210	4055	3133a
UDP	148	117	133a	269	282	276a	2261	4129	3195a
Barguna Sadar, Barguna									
FP	153	116	134a	203	315	259a	3073a	4455b	3764b
UDP	159	117	138a	205	324	264a	3089a	4570a	3829a
Kolapara, Patuakhali									
FP	139	115	127b	252	221	237b	2427	4630	3528a
UDP	142	117	129a	261	230	245a	2479	4841	3660a
Pataukhali Sadar, Patuakhali									
FP	145	116	130a	177	249	213a	3020	3957	3488b
UDP	145	116	130a	180	298	239a	3072	4231	3652a

Within a column and location, means followed by the same letters are not significantly different at $P<0.05$; FP, farmer's practice; UDP, urea briquette deep placement.

Table 2. Comparison of Plant Height, Number of Panicles, and Grain Yields Between Farmer's Practice and UDP Under Local Improved (LIV) and Stress (Submergence)-Tolerant Varieties (STV) at Different Locations in Bangladesh

Under drought condition (Figure 1), UDP produced significantly higher average grain yields compared to the government-recommended rate (RP) at three of the four sites (Table 3). Across all sites, except Damarhuda, farmer's practice produced similar yield with UDP. But farmers use about 130% higher N than with UDP. The higher use has drastically reduced N use efficiency (NUE). Though farmers use urea in multiple splits, the timing of application may not be synchronized with plant demand. Therefore, the farmer's practice of fertilizer application is often very inefficient and not economic. Moreover, NUE under rainfed drought condition could be very low due to subsequent wetting and drying of the field. These early results suggesting that UDP applied at a rate 55% less than farmer's practice while producing similar to slightly higher grain yields is encouraging.

Figure 1. *UDP Performance Evaluation Trial Under Rainfed Drought Condition at Chuadanga Sadar, Bangladesh*

Fertilizer	Plant Height, cm			Panicle, m^{-2}			Yield, kg ha^{-1}		
	LIV	STV	Average	LIV	STV	Average	LIV	STV	Average
Chuadanga Sadar, Chuadanga									
FP	96	98	97a	277	183	230a	4185	3054	3620a
RP	91	90	91b	291	206	249a	3784	2417	3100a
UDP	95	96	95a	270	176	223a	3878	2781	3329a
Damarhuda, Chuadanga									
FP	105a	110a	108	271	258	264a	5306	4350	4828a
RP	97c	105b	101	237	206	221b	4105	3485	3795c
UDP	101b	111a	106	259	247	253a	4486	4139	4313b
Meharpur Sadar, Meharpur									
FP	104a	104b	104	319a	298a	309	5030	4530	4780a
RP	93c	98c	95	243c	254b	248	3876	4023	3949b
UDP	101b	107a	104	286b	320a	303	4671	4935	4803a
Gangni, Meharpur									
FP	92	105	99a	250	292	271a	4156	4103	4130a
RP	89	102	95b	226	288	257a	3803	3966	3884b
UDP	91	107	99a	265	302	284a	4349	4237	4293a

Within a column and location, means followed by same letters are not significantly different at $P<0.05$; FP, farmer's practice; RP, extension recommended practice; UDP, urea briquette deep placement.

Table 3. *Comparison of Plant Height, Number of Panicles, and Grain Yields Between Farmer's Practice and UDP Under Local Improved (LIV) and Stress (drought)-Tolerant Varieties (STV) at Different Locations in Bangladesh*

In the *Boro* season 2017, four field trials were established under saline-prone areas in Bangladesh. Eight treatment combinations from fertilizer practice and varieties (Table 4) were tested in each trial to compare performance of UDP with and without micronutrient (Zn) with farmer's practice and extension-recommended fertilizer rates and method of application. In this trial, one additional treatment, i.e., deep placement of granular urea (Figure 2), is added to compare with deep placement of urea briquettes. Deep placement of both urea briquettes and granular urea was done manually by hand. Plots were too small to use UDP applicator. These trials are in progress and will be reported in the semi-annual report.

Treatments		N Rates (kg/ha)
Variety	Fertilizers	Saline Soils (*Boro* 2017)
Local improved (V1)	Farmer's practice	155±10*
	GU-deep placement	78
	UB-deep placement	78
	UB-deep placement (-Zn)	78
Stress resistant (V2)	Farmer's practice	155±10*
	GU-deep placement	78
	UB-deep placement	78
	UB-deep placement (-Zn)	78

Same N rates were used for both varieties. GU, granular urea; UB, urea briquette.

Table 4. Experimental Treatments Used for Saline Trials in Bangladesh During Boro 2017 (treatments are combination of fertilizer practices and rice varieties)

Figure 2. Deep Placement of Granular Urea by Hand in a Saline-Prone Area (Satkhir District) in Bangladesh

In the past three years, IFDC headquarters' technical staff has provided assistance to the USAID Feed the Future Ghana Agriculture Technology Transfer (ATT) project to develop UDP technologies for irrigated rice production systems. This technology is being scaled out extensively by the project within the irrigations schemes located in the Northern, Upper East, and Upper West regions of Ghana, with the intention of expanding the technology to lowland rainfed rice production areas. The challenge, however, is that the frequent flooding occurring in some parts of the region has serious consequences for lowland rainfed rice production where resource-poor smallholder farmers rely on annual precipitation for their cropping operations. Average rice productivity in these unfavorable areas is very low, averaging less than 2.5 tons/ha, and even much lower in flood-prone areas, at 1.5-2.2 tons/ha, compared to the average yield of irrigated ecosystems of 4-7 tons/ha. The frequently flooded areas stand to gain considerably from the immediate use of submergence-tolerant rice varieties and appropriate nutrient management practices. Previous efforts to improve productivity in rainfed areas focused mainly on varietal improvement. However, there is the need to find a technological fit between genotypes and the most fitting and best agronomic practices based on specific environmental conditions. With increasing incidence of flooding in Northern Ghana that threatens rainfed rice production, the

IFDC Fertilizer Research Division, in collaboration with AfricaRice and Savanna Agricultural Research Institute (SARI), is developing appropriate soil fertility management technology tailored for submergence-prone areas, using submergence-tolerant rice varieties.

During the rainy season of FY16, seven adaptive trials were established to evaluate the effectiveness of the UDP technology using NERICA L-19 and NERICA L-49 in submergence-prone areas of the three northern regions of Ghana. In each trial, the UDP technology was compared with the microdosing (MD) technology in which the granular/prilled fertilizer was incorporated into the soil in small doses directly to the root zone of the plants, and with the locally recommended fertilizer management practice. The adaptive trials were conducted in seven communities within the USAID FTF zone of influence (ZOI) in the three northern regions of Ghana. The experiment was laid in a split plot design with an individual plot size of 10 m × 10 m. The first factor, rice variety, was randomized on the main plot and the second factor, nutrient management technology, was randomized on the subplot. The treatments comprised of two submergence-tolerant rice varieties, NERICA L-19 and NERICA L-49, and three fertilization technologies: (a) the UDP technology, (b) the MD technology, and (c) locally recommended fertilization practice (LRP). The effectiveness of the UDP technology was compared with the other two technologies on each of the two submergence-tolerant rice varieties. Each treatment combination was replicated four times in a randomized complete block design.

The rice seeds were nursed and transplanted 18 days after emergence. Prior to transplanting, land was prepared first by plowing and followed by harrowing and/or rotavation. Each plot was appropriately bunded and had independent drainage points, so as to prevent the spread of water and fertilizers between plots. The rice seedlings were transplanted in a 20 x 20 cm geometry with one seedling per hill. For all treatments, basal NPK (15-15-15) fertilizer was applied at a recommended rate of 250 kg of product/ha three days after transplanting. For the UDP-treated plots, the 1.8-g sized urea supergranules (USG) were applied seven days after transplanting. One USG was placed in between four rice plants (resulting in application rate of 113 kg of product/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 the fertilizer application. For this treatment, the granular urea was measured with a "coke cap" and applied per plant by incorporating into the root zone of the rice plant (resulting in application rate of 96 kg of product/ha). Similarly, for 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 (resulting in application rate of 150 kg of product/ha) was broadcast into each plot the rice field. 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. Weeds were intensively controlled throughout the growing period, prior to the flooding, and at maturity, the crop was harvested to determine grain yield and the biomass analyzed for N content to calculate N uptake. Other crop yield parameters measured include plant height, number of tillers per plant, and number of productive panicles per plant. At physiological maturity, an area measuring 5 m x 5 m was randomly selected in each plot and manually harvested. The harvested rice was threshed and the grains were weighed and the moisture content measured for the determination of grain yield. All grain yields were adjusted to a moisture content of 14% to eliminate the confounding variable of non-uniform moisture content to enable treatment comparison. Samples of the harvested grain and biomass were oven-dried, ground, and digested for the determination of N content. The product of the N content and biomass yield was used to calculate N uptake per plot.

The experiment was conducted in seven different locations but the results obtained from all locations followed a similar trend in grain yield (Appendix A, Figures A.1-A.7) and N uptake (Appendix A, Figures A.8-A.14). However, depending on the extent of the flooding of the field and the period of time required for the water to recede from the field, the impacts of the treatments differed among the seven locations. The effects of the nutrient management technologies on the two rice varieties were similar, although the NERICA L-49 produced slightly higher yields than the NERICA L-19 variety across all locations but the differences in grain yield between the two varieties were not statistically significant. The initial results showed that the greatest yields were obtained from the UDP treatment across all seven locations, followed by the MD treatment and the LRP treatment in that order. The average grain yield obtained from the UDP treatment was 4 tons/ha and 4.2 tons/ha for the NERICA L-19 and NERICA L-49 varieties, respectively; the yield from the MD treatment was 3.1 tons/ha and 3.4 tons/ha for the NERICA

L-19 and the NERICA L-49, respectively, whereas the average yields obtained from the LRP treatments were 2.4 tons/ha and 2.6 tons/ha for the NERICA L-19 and the NERICA L-49, respectively (Figure 3).

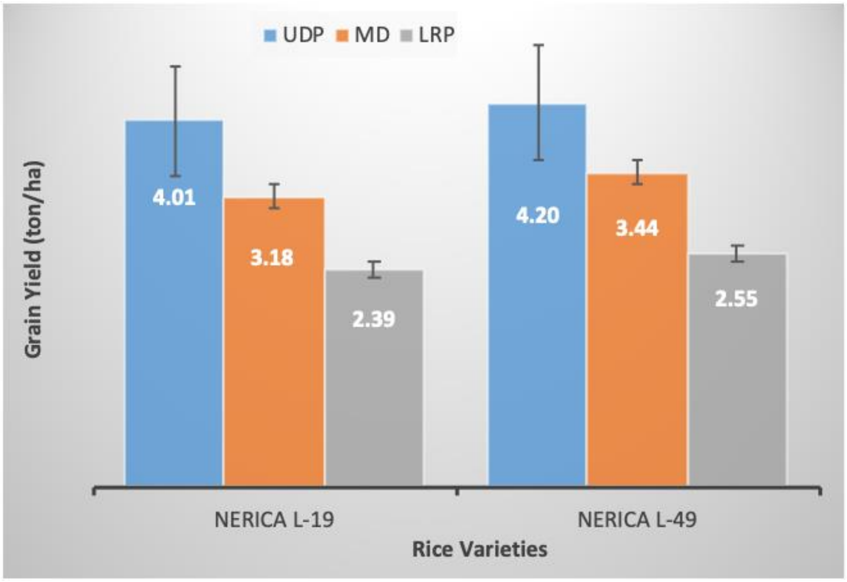

Figure 3. Average Grain Yield of Submergence-Tolerant Rice Varieties Grown at Seven Locations in the Three Northern Regions of Ghana Under the UDP, Microdosing (MD), and Locally Recommended Fertilizer Practice (LRP) Treatments

The USG for the UDP technology was applied 7 days after transplanting but the briquettes dissolved slowly to match the N release to N uptake by the plants; hence, at the time of the flooding, the plants were robust enough to produce elongated productive panicles above the flooded water. On the other hand, the MD and LRP were applied 6 weeks after transplanting (per recommendations) so at the time of the flooding, the plants were not robust enough to withstand the effects of the submergence. In some cases, the flooding came immediately after applying the fertilizer and leached the applied urea before the plants could make use of them. At other instances, the flooding occurred much earlier in the season, and the flooded water delayed in receding, which eventually delayed the supplemental urea application. Therefore, at the time the site was ready for application, the already stunted rice plants had begun booting, and could not make efficient use of the applied fertilizer. In all these scenarios, the MD treatments still produced significantly greater yields than the LRP treatments. This could be attributed to the fact that with the MD treatments, the fertilizer was incorporated directly into the soil with the root zone of the rice plants, whereas with that of the LRP treatment, the fertilizer was broadcast onto the field. Therefore, the effectiveness in utilization of the N applied was much improved with the MD over the LRP treatment, which is the commonly used fertilizer application method by the local farmers.

Consistent with the results observed for the grain yield, the N uptake data followed similar trends (Figure 4). Average N uptake across all seven locations from the UDP treatments was about 34 kg/ha. Considering the fact that urea was applied at 113 kg product/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% of the applied N. The average N uptake from the MD treatments was about 20 kg/ha, and considering the urea application rate of 96 kg product/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 the N application rate of 150 kg of urea product/ha (~65 kg N/ha), N recovery from this treatment was less than 30% of the applied N.

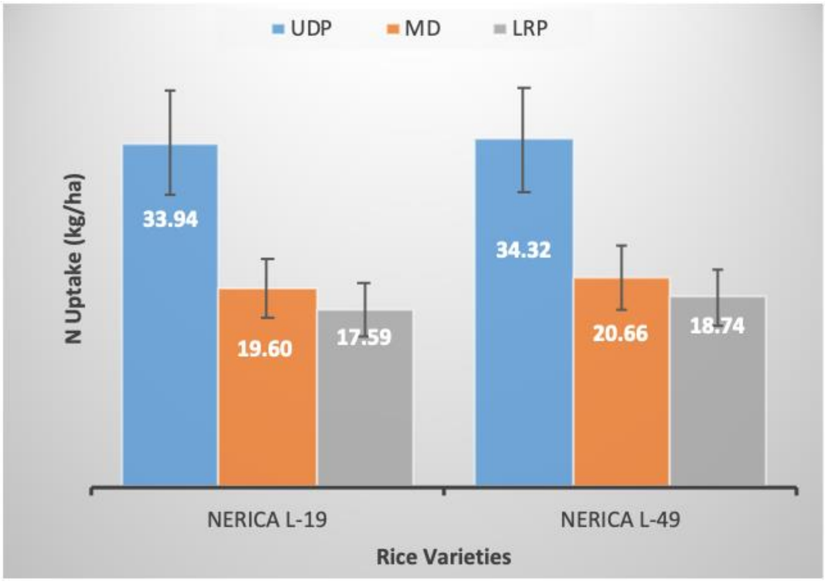

Figure 4. Average N Uptake of Submergence-Tolerant Rice Varieties Grown at Seven Locations in the Three Northern Regions of Ghana Under the UDP, Microdosing, and Locally Recommended Fertilizer Practice Treatments

From the preliminary results, it is obvious that the response of both submergence-tolerant rice varieties to the UDP technology was consistent and produced significantly greater yields and N uptake than those of the microdosing and the locally recommended fertilizer management. Thus, the first season results from the experiment clearly suggest that the UDP technology could be an appropriate soil fertility management technology for submergence-prone areas, using submergence-tolerant rice varieties. However, there is a need to repeat this trial for more investigations to validate the results. Based on the results obtained in FY16 and FY17, a training module (and update for the UDP Manual) will be developed to introduce the technology to submergence-prone areas across SSA.

IFDC and numerous other organizations use decision support tools (DSTs) as a means to improve the understanding of processes and factors determining crop responses and to predict site-specific crop performance under a wide range of agro-ecological conditions. One of the primary tools used is the Decision Support System for Agrotechnology Transfer (DSSAT) suite of crop models. Modeling provides an extremely powerful tool for evaluating the impact of climate change and variability. It can also help provide information on mitigating greenhouse gas emissions and reducing nutrient losses, particularly nitrogen, to the environment. However, these models continue to evolve to reflect new information. For example, many processes that have been modeled have not been subjected to extreme heat and drought stresses.

Rice is not only one of the most widely grown crops in the world, but it is also grown in a wide range of agro-environments and soil hydrology. This makes rice one of the most vulnerable crops to changes in climate and climate variability and one with great adaptation potential. Overall, the impacts of climate change on rice production will be negative and are associated with heat stress, rising sea levels, exposure to salinity, and frequent severe climate extremes.

CERES-Rice (developed in 1986-1989) is one of the most widely used rice models. It has recently been updated to include applications for climate change adaption. Prior to this update, there had been no major revision since the 1990s. Inclusion of field and greenhouse data generated in past years were used to improve the capability of the model to simulate extreme temperatures and water stress effects. Also, greenhouse gas (GHG) emission data was used to develop the capability of the model to simulate N_2O emissions. The latter was done in partnership with University of Florida and Queensland University of Technology, Australia. Finally, ongoing rice field trials in Bangladesh, Ghana, and Myanmar are providing robust data from extreme environments to evaluate the CERES-Rice model.

Using new information and data, the model performed well under a wide range of temperature regimes. Results indicated grain yield was drastically reduced due to heat stress as mean temperatures approached 35°C. As temperatures increased, the effective grain-filling duration was shortened with no grain set at >34°C. Heat- and cold-tolerant and -intolerant cultivars were evaluated (Figure 5).

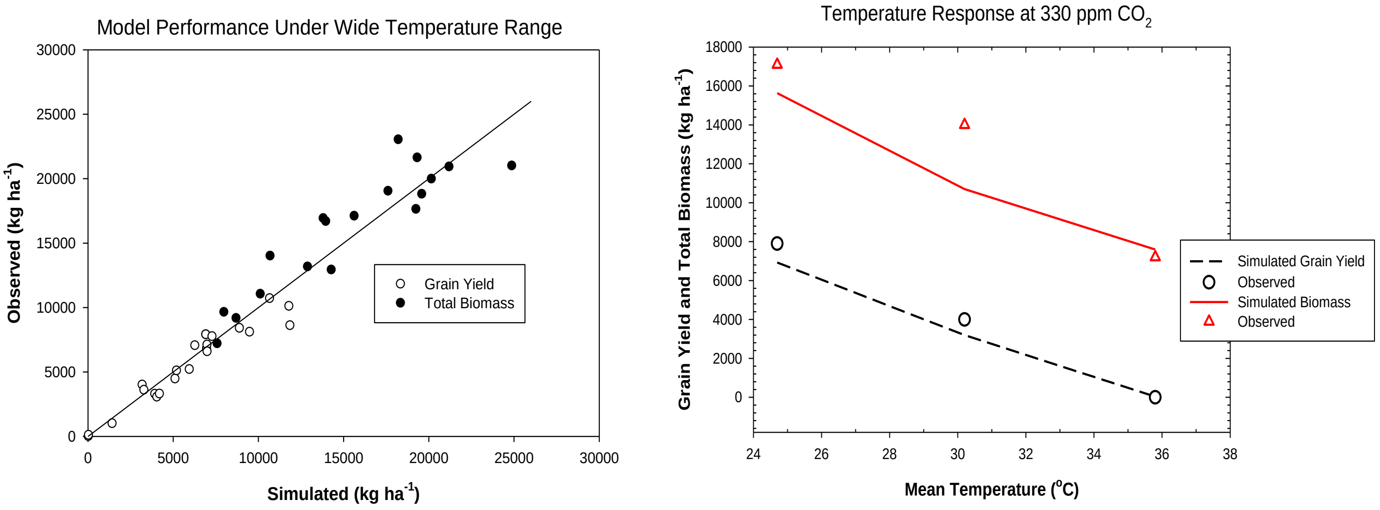

Figure 5. CERES-Rice Performance Under High Temperature Environment

The CERES-Rice model was also evaluated for simulating the effect of CO_2 on biomass production and yield (Figure 6). Increasing CO_2 concentration with no increase in temperature (under controlled conditions) resulted in increased rice biomass and grain yield production. Ongoing activities include the evaluation of N_2O emissions under field conditions with different water and N regimes.

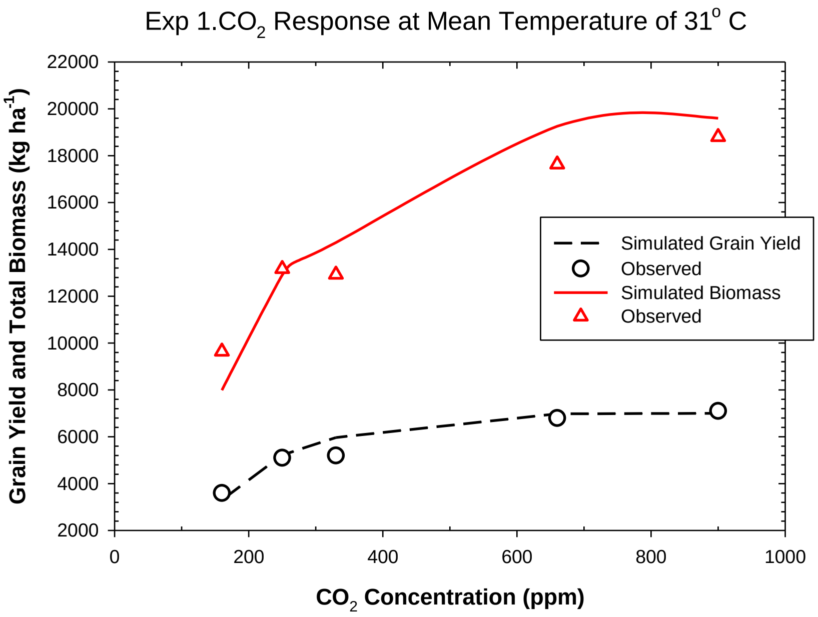

Figure 6. Impact of Increasing CO_2 Concentration Rice Growth and Yield

IFDC staff in collaboration with the University of Florida conducted an Advanced DSSAT training program entitled "Assessing Crop Production, Nutrient Management, Climatic Risk, and Environmental Sustainability with Simulation Models" in Arusha, Tanzania (October 5-12, 2016). The program was attended by 28 participants (including five women) representing 12 countries: Botswana, Burkina Faso, Ethiopia (3), Kenya (5), Malawi (2), Mozambique, Nigeria (8), South Africa (2), Tanzania, Uganda, United Kingdom, and Zimbabwe. The diverse group included agribusiness specialists, agronomists, plant breeder, climate system analyst, data managers, ecologist, GIS experts, insect physiologist, and soil scientists from the public and private sector.

B. Adaptive Trials to Develop N Management Strategies for Upland Maize and Vegetables in Sub-Saharan Africa

Maize has a high potential to address critical food security problems and could play a key role in any future strategy to reverse declining trend in per capita food production in sub-Saharan Africa (SSA). However, the strong dependence on maize as a food and cash crop in SSA is of great concern and requires effective soil fertility options to minimize the declining trends in yields. Major factors that limit productivity of maize in SSA, among others, are erratic rainfall and depletion of soil fertility. Long-term changes in the patterns of rainfall and more extreme droughts, that are part of climate change, are expected to shift production seasons, pest, and disease patterns, and modify the set of feasible crops, thereby affecting production, prices, incomes, and, ultimately, livelihoods and lives. The annual maize yield loss from drought is estimated at 30% but localized losses might be much higher in marginal areas where annual rainfall is below 500 mm and soils are bare or shallow. Adapting to climate change, among other interventions, may involve the use of varieties that have the ability to cope with higher temperatures, drier conditions, and emerging pests and diseases. Hence, a range of maize varieties (open-pollinated varieties and hybrids) purported to be early maturing and/or drought-tolerant have been developed and are being introduced to farmers.

Efforts to improve productivity of these newly introduced maize varieties should be concentrated on improving soil nutrient and physical conditions. Nutrient replenishment in maize production system is achieved through application of inorganic fertilizer. Most farmers apply these fertilizers to maize in at least two splits, i.e., basal NPK application at planting or shortly after seedling emergence, and supplemental N application (mostly urea or ammonium sulfate) about six weeks after planting. Urea is one of the cheapest commercially available solid N fertilizer sources commonly used by smallholder farmers in SSA. Although its high analysis (46% N) allows considerable saving in transport and handling costs, the current application method of surface broadcast leads to excessive losses through volatilization, resulting in GHG emissions. One effective means of improving urea efficiency is to adopt sub-surface application including UDP technology. Although the technology has proved to be a highly effective N fertilizer saving package and economically sound for irrigated and lowland rice production, it has not been validated for upland maize production systems. Limited studies have been conducted to evaluate the effectiveness of the technology for upland maize production in SSA. Therefore, it is important to evaluate sub-surface placement of urea including the UDP technology for upland maize production in SSA and other developing countries.

Last year, IFDC headquarters' technical staff provided technical support to the ATT project to conduct adaptive trials to evaluate the effectiveness of the UDP technology to increase maize production in the FTF ZOI in Ghana. Preliminary results showed that response of the maize varieties to the USG application differed, with the medium and late maturing varieties responding better, in terms of increased yields, than the early maturing variety, possibly due to the time of application of the USG. With the emphasis on early maturing maize varieties and drought-tolerant hybrids to mitigate the effects of the impact of climate change on maize production, during the first quarter of the FY17, 15 sites were selected in the three northern regions of Ghana (six in Northern region, four in Upper East region, and five in Upper West region) to conduct adaptive trials to refine the UDP technology for these climate-resilient maize varieties. Protocols have been prepared and sites will be planted with the beginning of the 2017 rains. Treatments will include a comparison of both the UDP technology and sub-surface placement of granular urea against farmers' practice and extension service recommendations.

In SSA, Women are heavily involved in vegetable production; thus, the introduction of technologies that increase productivity of vegetable production could increase household incomes, and make the enterprise more attractive. However, the declining soil fertility is becoming a major constraint for vegetable production. In spite of this constraint, there has been a sharp increase in demand and cultivation of vegetable crops for domestic markets in recent years. Such growth in the vegetable industry has placed significant pressure on natural resources, particularly as over 80% of the population is dependent upon the land for income and their basic food needs. Therefore, intensification of vegetable production based on effective nutrient management is required. The low nutrient recovery in vegetable crop production and associated environmental problems resulting from high rates of fertilizer use on vegetables in many countries has prompted research to re-examine nutrient management practices to ensure reasonable yield of quality produce based on judicious fertilizer application.

One nutrient management strategy that has gained widespread interest and acceptability is FDP of multi-nutrient (NPK+) briquettes. This FDP practice has proved to be profitable in different upland crops such as tomato, cabbage, cauliflower, potato, maize, and banana in various IFDC target areas, including Bangladesh, Mali, and Burkina Faso. Results to date have shown that 10-20% of the N (usually as urea) could be saved with FDP technology with a simultaneous +10% yield increases relative to the conventional fertilizer application practices for upland crops. Work on cabbage in Bangladesh suggests that the placement of NPK briquettes at 10-cm depth in the soil maintained a high level of NH_4-N during the crop's active absorption period. In Burkina

Faso yield increases resulting from the FDP technology have been reported on tomato (26% increase), cucumber (22%), and yard long bean (9%), compared to conventional fertilizer application practice. Further, preliminary reports suggest that NH_3 volatilization losses resulting from surface application of prilled urea are very high. Deep placement or sub-surface placement the NPK+ briquettes appears to be a promising option to minimize production cost without decreasing yields.

During the FY16 cropping season, the effectiveness of NPK briquette in increasing yields and thus in increasing fertilizer use efficiency was evaluated on chili peppers and eggplant in the Kumbungu district of Northern Ghana. Preliminary results show that there was a two-fold yield increase in pepper, and ~80% increase in eggplant yields, with better quality fruits from the NPK briquette plots, relative to the conventional farmer practice of broadcast prilled urea (only). During the first quarter of FY17, 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 a number of vegetable crops (okra, pepper, eggplant, tomato, and onion) and to validate preliminary results. The study will also evaluate the synergetic effects of the FDP technology and organics on the growth, development, and production of the vegetables. At the conclusion of the this years, trial the plan is to produce a technical report of the results and a production guide on upscaling the FDP technology for climate-smart upland vegetable production for smallholder farmers.

1.1.2 *Quantify Climate Mitigation Role of Enhanced Efficiency Fertilizers and Practices*

A. Carbon and Nitrogen Sequestration Based on N Management Strategies

It has been commonly observed that a 15-25% yield increase occurs with UDP compared to broadcast urea (split-applied). Even if all aboveground residues are removed, scientists have speculated that root biomass accumulation would be at least 10% more for UDP plots/fields relative to their broadcast counterparts. The plants from fields/plots treated with deep-placed urea not only have higher yield, but also have higher straw N content (evident from greener leaves at maturity and nutrient content data). Hence, the first hypothesis is that, due to higher biomass (including root biomass), organic matter build-up is expected to be higher in fields/plots fertilized with UDP vs. broadcast urea. The deep placement of urea has been shown to reduce/eliminate the diffusion of NH_4-N into floodwater and, hence, substantially reduce NH_3 volatilization loss. It is also expected that deep placement slows the diffusion of CO_2 formed during hydrolysis of urea into the floodwater and the atmosphere. This expectation leads to the second hypothesis that UDP increases soil organic matter build-up through the utilization of CO_2 (C sequestration) by algae, rice, and weeds.

A total of 180 topsoil and 360 subsoil samples were collected from rice fields in Bangladesh that have been under UDP practice from three to 15 years and from rice fields where only broadcast application of prilled urea was used. The fields included the former project sites of the Improved Livelihoods for Sidr-Affected Rice Farmers (ILSAFARM) and Accelerating Agriculture Productivity Improvement (AAPI). All 540 samples were analyzed for: organic carbon, total N, and soil pH. All the soil samples were analyzed in two laboratories, Soil Resource Development Institute (SRDI), Bangladesh, and IFDC. The results for the topsoil organic carbon from both laboratories and two methods – Walkley-Black used at both laboratories and Combustion Analysis (used only at IFDC Lab) – are presented in Figure 7. Overall, there is good agreement between the laboratories and the methods. The combustion measurements gave similar correlation and R_2 (coefficient of determination) with wet chemistry (Walkley-Black) results from SRDI and IFDC laboratories. Some analyses will be repeated for the outlier values in Figure 7.

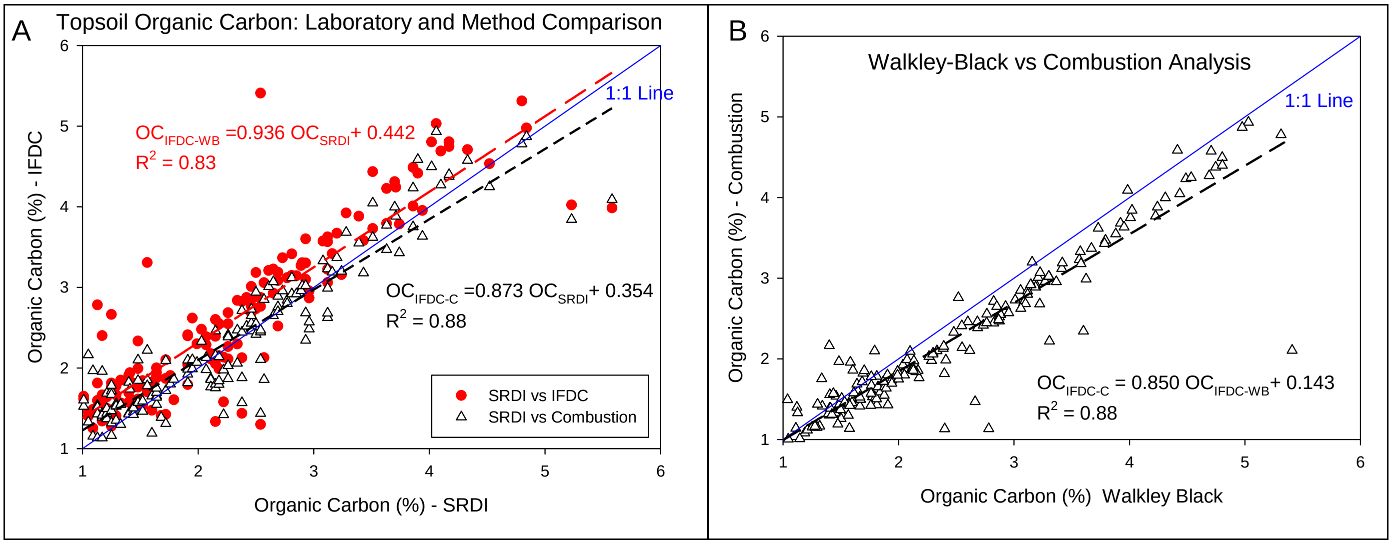

Figure 7. Comparison of Walkley-Black (wet-chemistry) from (A) SRDI and IFDC and (B) Combustion (IFDC) for Topsoil Organic Carbon Content

The results for changes in soil organic carbon content with UDP and broadcast prilled urea application are shown in Figure 8. Gournadi and Agailjhara sites in Barisal are characterized by single rice cropping during *Boro* (dry season). Due to continuous submergence and poor drainage, no rice is grown during the wet season (T. *Aman*). In Gournadi, topsoil from UDP had higher soil organic carbon content than PU applied fields. On the other hand, there was no visible difference between UDP and PU plots at Agailjhara. For the doubled cropped rice (*Boro*-T. *Aman*), soil organic carbon content showed an increasing trend with the number of years under UDP practice with Jessore at three years compared to Tangail at > 10 years. At Tangail, soil organic C was generally higher for UDP fields. A few samples will be re-analyzed followed by statistical analysis of the results. Complete results including subsoil organic carbon content will be presented in the FY17 Final Report.

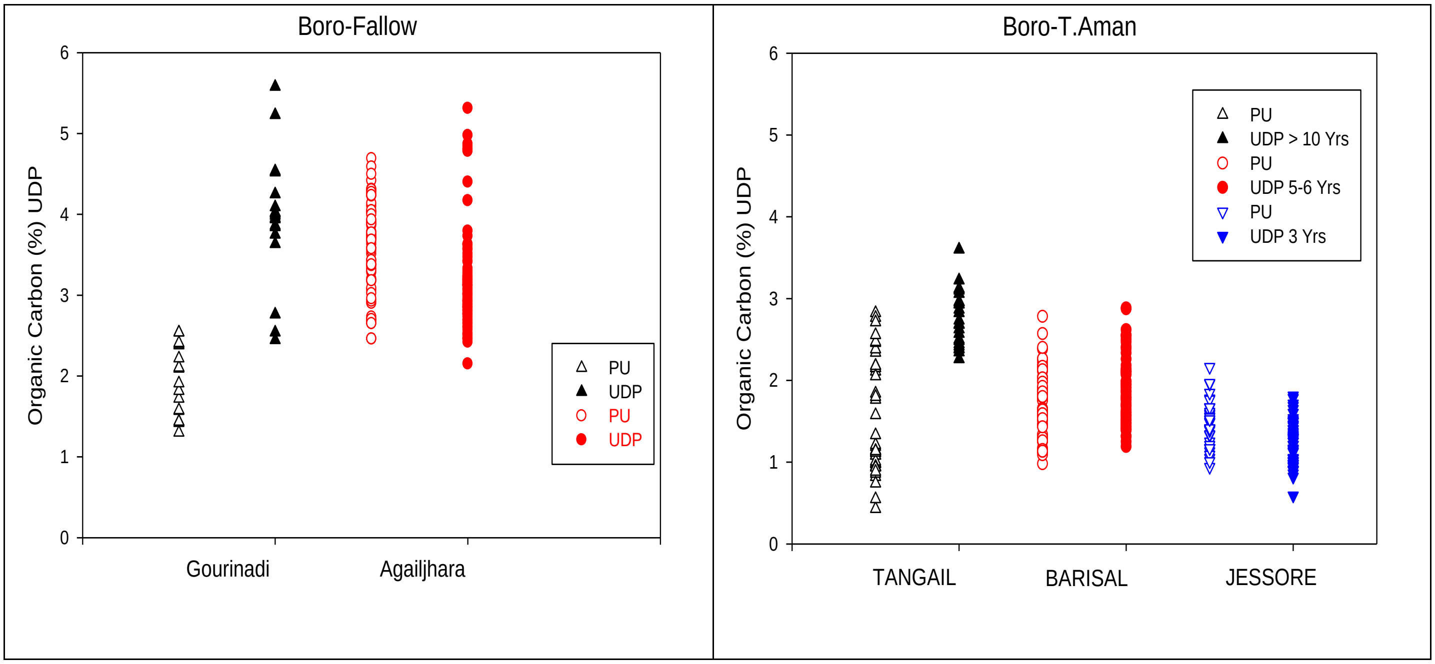

Figure 8. **Effect of Cropping System, Location, Number of Years of Application on Soil Organic Carbon for UDP Versus Broadcast Prilled Urea (PU) Application**

B. Quantifying Carbon Dioxide Emission from Different N Fertilizers

Urea is the most widely used fertilizer at 192 million tons annually. Urea hydrolysis results in conversion of urea to ammonia and CO_2 as a byproduct. The CO_2 is the primary GHG emitted, accounting for 82% of the emissions from human activities. Urea hydrolysis accounts for 140 million tons of CO_2 annually. Besides the negative effects, increasing CO_2 can have a beneficial effect on C_3 plants such as rice, wheat, and legumes. However, urea hydrolysis is a rapid reaction which is completed within 5-7 days after urea application. Therefore, to improve the fixation of CO_2 from urea, its release must be prolonged.

As shown in Figure 9, fertilizers that reduce ammonia volatilization, such as deep placement and urease inhibitor-based products (Agrotain), can also help reduce and/or prolong the duration of CO_2 emission during urea hydrolysis. A reduced emission rate over a longer period will improve the opportunity for CO_2 fertilization. This would imply that efficient N fertilizers are improving both N and C fertilization for improved crop growth. Results from indirect effect of CO_2 fertilization due to urea application on soybean yield are currently being analyzed and will be included in the April-October 2017 Report.

Figure 9. **Effect of N Fertilizers and Application Method on NH_3 (left column) and CO_2 Emission (right column)**

C. Effect of Water and Nutrient Management on Quantification of N_2O and NO Emission from Rice-Based Cropping Systems

Results from field trials assessing the effect of nitrogen placement on nitrous oxide and nitric oxide emissions and nitrogen use efficiency in lowland rice fields was submitted for possible publication in *Nutrient Cycling in Agroecosystems*. In summary, the effects of two nitrogen placement methods (broadcast prilled urea and deep-placed urea briquettes) in irrigated lowland rice systems were determined for nitrous oxide (N_2O) and nitric oxide (NO) emissions, nitrogen use efficiency, and grain yields. Dynamics of emissions were significantly affected by N fertilizer treatments. Broadcast prilled urea produced significant N_2O and NO emission peaks after topdressing, but due to very high variability in emission data, they were not sufficient enough to contribute a significant difference to total seasonal emissions between broadcast prilled and urea deep placement. Effects of N placement on grain yields and NUE were site- and season-specific. Of the N placement methods, UDP increased grain yields by 13% ($p<0.05$) during the *Aman* season and gave similar yields in spite of lower N application during the *Aus* season.

The results from the ongoing GHG experiment quantifying the N_2O and NO emissions with different N sources when applied to rice crop will be presented in the next report. The experiment results will help understand the effect of wetting-drying cycles in controlling N_2O and NO emissions from different N sources. Crop development and growth parameters, such as heading date, SPAD (leaf chlorophyll), tiller numbers, panicle numbers, grain yield, straw yield, and uptake of N, P, and K, are being determined. The experiment includes the following treatments: (1) UDP applied (deep-placed) at 25 days after planting of pre-germinated seeds; (2) KNO_3 split broadcast applied at 25 days after planting followed by topdressing 30 days later; (3) urea split broadcast applied at 25 days after planting followed by topdressing 30 days later; (4) urea + DCD (nitrification inhibitor) deep-placed at 25 days after planting of pre-germinated seeds; and (5) Zero N (check).

1.2 Balanced Plant Nutrition through Improved Fertilizer Product Recommendations

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 are now deficient in S, Mg, Zn, and other secondary and micronutrients. In Asia and SSA, several blends of fertilizers are available, with more expected to enter the supply chain. Assuming the fertilizer quality is not an issue, such fertilizers generally have a positive impact on crop productivity. However, the availability of a given nutrient within a multi-nutrient fertilizer granule is strongly affected by the presence of other nutrients and their respective interactions. With synergistic combination of macro- and micronutrients in a fertilizer 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.

1.2.1 *Evaluation of Micronutrients to Increase N Use Efficiency*

Greenhouse studies were conducted between October 2016 and March 2017 to evaluate the use of micronutrients to enhance fertilizer efficiency, especially N. The first study used a sorghum crop to assess the effect of zinc (Zn) fertilization (via soil vs. foliar applied Zn) on sorghum productivity and sorghum use of N, P, and K at different application rates. To this end, Zn sulfate salt and Zn oxide nano-particles (both at 6.25 mg Zn/kg soil) representing two Zn types were compared in soil and foliar treatments, under high and low NPK application regimes (N, 200 and 100 mg/kg: P, 100 and 50 mg/kg: K, 150 and 75 mg/kg). The preliminary findings indicate increase in sorghum yield and Zn accumulation using either Zn sulfate and Zn oxide nano-particles, and differential effects of the Zn types and NPK regimes on cropuptake of NPK. Some of the results are presented below. In Figure 10, it is shown that in comparison with NPK-only treatments, sorghum grain yield was significantly increased by Zn fertilization, regardless of Zn type (salt or nano-particles) and application method (soil or foliar). However, grain yield was higher in the high NPK+Zn treatment. Also, significant difference between ionic (salt) and nano-particulate Zn was only evident in foliar application at the high NPK rate. In conclusion, for grain yield, it would appear that increasing NPK rate only does not necessarily translate into increased sorghum yield. However, sorghum productivity could be increased by using low NPK rates + Zn to substitute for a high NPK-only application, suggesting the presence of Zn increase macronutrient uptake. This could be an interesting strategy where NPK costs are high (sub-Saharan Africa).

Figure 11 shows uptake of N within the shoot and subsequent translocation into grain as influenced by Zn fertilization. With shoot, there was no significant effect of Zn fertilization from soil on N uptake at low NPK. However, at high NPK regime, Zn fertilization lowered N uptake, which was significant only with Zn salts. In the foliar treatment, Zn fertilization slightly lowered shoot N uptake at low NPK, but had no effect on N uptake at high NPK regime. With grain, slightly more N was translocated under both soil and foliar Zn fertilization at low NPK application. In contrast, grain translocation of N was significantly improved by Zn fertilization at high NPK, regardless of Zn application route. Taken together (shoot uptake + grain translocation), at the low NPK regime, total N accumulation into sorghum was increased about 18% for Zn salt and 9% for Zn nano in soil treatment; and about 9% and 4% in foliar treatment, compared to the absence of Zn. At the high NPK regime, N accumulation was increased about 21% for Zn salt and 16% for Zn nano in soil treatment; and about 38% for Zn salt and 34% for Zn nano in foliar treatment.

Zn deficiency is a global health issue, particularly in many developing countries, where soils are poor in Zn and little or no replenishment via fertilization occurs. Zn uptake by plants and subsequent translocation into the grain may thus be strategic for improving the Zn nutritional quality of grain staples. Figure 12 indicates that in soil treatment, Zn uptake into shoot was significantly stimulated by Zn salts and less so by Zn nano at low and high NPK regimes. In foliar treatment, Zn uptake was also significantly promoted, slightly more at low than at high NPK regime. Translocation of Zn from shoot to grain was significantly stimulated across the board. The response was greater at the high NPK regime and also greater with Zn salt than Zn oxide nano fertilization.

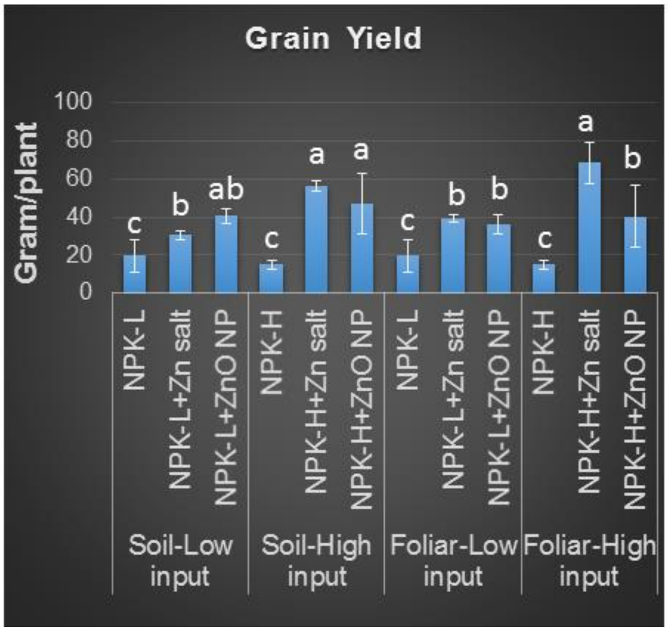

Figure 10. ***Effect of Zn Fertilization on Sorghum Yield Under Different NPK Regimes (separately for soil and foliar treatments, bars followed by different letters are significantly different at $P<0.05$)***

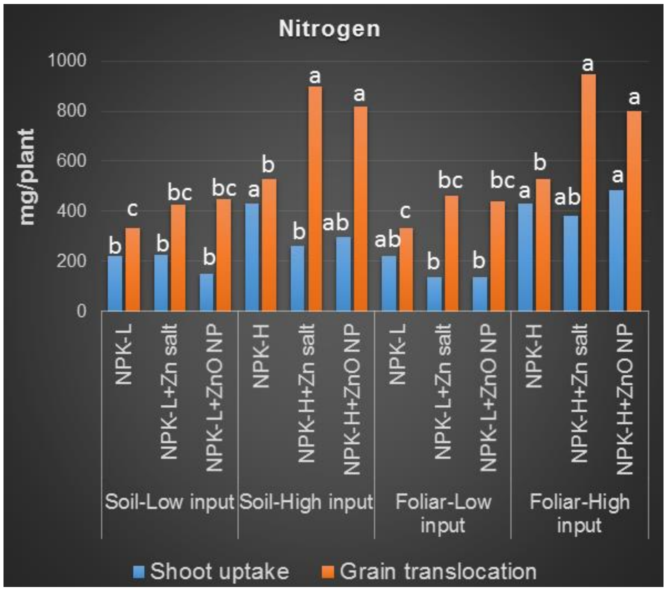

Figure 11. ***Effect of Zn Fertilization on Shoot Uptake and Grain Translocation of N in Sorghum Under Different NPK Regimes (separately for soil and foliar treatments and for shoot and grain measurements, bars followed by different letters are significantly different at $P<0.05$)***

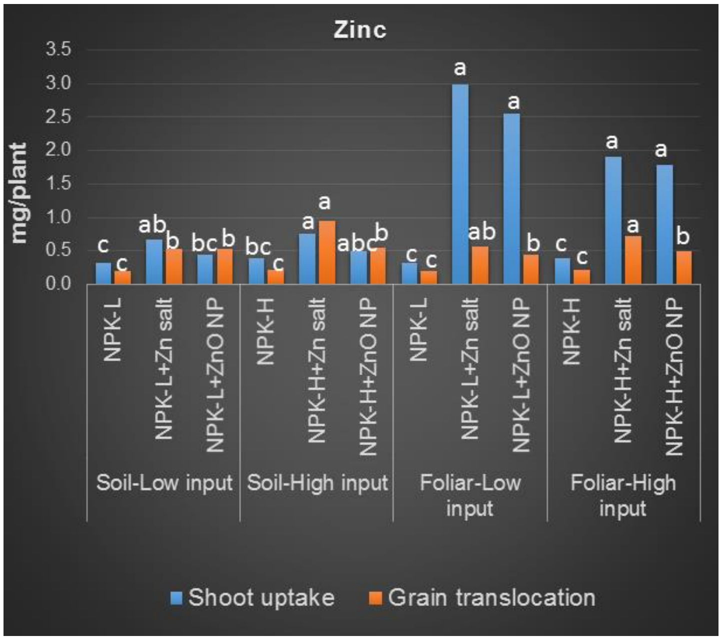

***Figure 12.* Zn Shoot Uptake and Grain Translocation in Sorghum Under Different NPK Regimes (separately for soil and foliar Zn treatments and for shoot and grain measurements, bars followed by different letters are significantly different at P<0.05)**

In addition to the sorghum study, greenhouse studies were established to evaluate the effectiveness of Zn and manganese (Mn) on wheat productivity. For these studies, Zn sulfate and Zn oxide powder were compared in fresh soil as well as in residual soil from previous Zn applications. In the case of Mn, Mn sulfates, bulk Mn oxide, and nano Mn oxide are being compared. The wheat studies are currently ongoing with no preliminary data available at this time.

Two micronutrient omission trials, one each under submergence- and drought-prone areas (Table 5), were established to determine the limiting micronutrient for rice cultivation in Bangladesh. Fertilizer rates (except N) were used as per recommended by government extension agency. For N, urea briquettes were deep-placed at 52 kg N ha$_{-1}$ instead of broadcast application in all the treatments.

Results show that both Zn and copper (Cu) slightly increased grain yields under both submergence and drought conditions. However, the effects were below statistical significance. In

Bangladesh, farmers use Zn at least once a year, particularly during *Boro* rice cultivation. Therefore, the lower response could be due to residual effects of the previously applied Zn.

Treatments	Plant Height, cm	Panicles/m^2	Grain Yield, kg ha^{-1}
Amtoli, Barguna (submergence-prone area)			
NPKSZnBCu (All)	114a	229a	5,113a
All (-Zn)	107b	215a	4,638a
All (-B)	112a	227a	5,055a
All (-Cu)	112a	227a	4,965a
Meharpur Sadar, Meharpur (drought-prone area)			
NPKSZnBCu (All)	101a	406a	5,680a
All (-Zn)	99a	361c	5,363a
All (-B)	102a	378b	5,570a
All (-Cu)	100a	369bc	5,523a

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

Table 5. Effects of Zinc, Boron (B), and Copper on Rice Yields Under Stress-Prone Environment in Bangladesh

In Mozambique, smallholder farmers often cultivate maize with more than one legume crop in the same field. It is against this background that IFDC Mozambique is demonstrating Climate Smart Agricultural practices for sustainable intensification of smallholder farmers' maize-based farming systems in Beira Corridor. The focus of recent cropping season activities were on cereal-legume intercropping systems focused in two districts, Macate and Sussundenga, with multiple farm types to cover the existing biophysical and economic variation among farms. The two districts are located in a region with high agroecological potential for maize crop production, the Manica Plateau.

One objective of the field trials is to demonstrate simple technologies that can easily be tailored into existing farming systems. In collaboration with *Instituto Superior Politecnico de Manica* (ISPM), priority was given to the establishment of demonstration trials combined with group discussion with farmers in both districts together to ensure a participatory approach. From the discussion we learned that farmers often plant cowpeas in middle or late January while pumpkins are planted at the same time as maize in late November or middle December. Given the need to make the most use of the earlier rains, the experiments were designed to incorporate pumpkins instead of cowpeas.

Prior to establishing the field demonstrations, a total of 80 georeferenced soil samples were collected from farmers' fields and sent to SGS Lab in South Africa for analysis. Based on the soil analyses, appropriate fertilizer formulations were developed. Additionally, in support of use of DSSAT, multiple layer soil samples (three depths) were taken from 24 farms for exploratory study.

The standard 12:24:12 fertilizer was purchased from the fertilizer manufacturer company (Mozambique Fertilizer Company [MFC]) located in Gondola District, Manica Province. The improved blends were made from raw ingredients also purchased at MFC. The ingredients were further mixed at the IFDC office in Chimoio using a cement mixer. Maize seeds were purchased from local agro-dealers were pigeon pea seeds were provided by Phoenix Seed Company located in Vanduzi District. Pumpkin seeds were provided by the farmers.

A total of 23 on-farm trials were established on farmers' fields based on their willingness to participate, as well as to account for as much of soil variability as possible within the site area. The following treatments were considered:

1. Maize with NPK 12:24:12 (actually NPK 14:12:24 + 6.5S blend).
2. Maize with improved fertilizer (15:31.6:10 + 5S + 0.5Zn + 0.2B).
3. Maize-pigeon pea with improved fertilizer (15:31.6:10 + 5S + 0.5Zn + 0.2B).
4. Maize-pigeon pea-pumpkins with improved fertilizer (15:31.6:10 + 5S + 0.5Zn + 0.2B).

This design will allow farmers to a) compare the value of the improved blend relative to NPK 12:24:12; b) assess the value of adding pigeon pea into the systems in terms of both food security and income; c) assess the value of adding pumpkins to the maize-pigeon pea mixed system. Preliminary observations revealed a relatively better performance of improved blend against NPK 12:24:12, which was more visible on sandy soils. On clay soils, the difference was smaller. The maize-pigeon pea treatment performed as well as maize-pigeon pea-pumpkins. A possible explanation was timely rains, so moisture was not a limiting factor. The idea behind the triple crop systems was to (a) capture as much moisture and (b) provide earlier food for farmers by harvesting the leaves. Further investigation followed once concern surfaced about the small differences which appeared on clay soils. The MFC was contacted, and it was learned that the

MFC received a request from Zimbabwe for 14:12:24 + 6.5S blend in November. The leftover fertilizer from that order was sold as 12:24:12 and was used for the IFDC demonstrations. What was presented on the bag as NPK 12:12:24 was indeed NPK 14:12:24 + 6.5S blend. So, the slightly better performance of IFDC improved blend can be attributed to Zn and B, and perhaps some P as well. However, final conclusions will be drawn at harvesting time.

During the last part of this semester, a total of 19 out 23 on-farm maize trials established in both sites were harvested at maturity in net plots of 14.4 m_2, respectively (the two middle rows in each plot, excluding border rows). Fresh yield will be sun dried for late measurement of the dry yield. Four on-farm trials were affected by late rains and strong wind that damaged some plants, making the harvesting impossible.

1.2.2 *Improving Agronomic Efficiency of Locally Available Phosphate Rock to Cost-Effectively Improve Agricultural Productivity in Marginal Soils*

During the FY16, 2,010 georeferenced soil samples were collected from the USAID FTF ZOI in the three northern regions of Ghana (Upper West, Upper East, and Northern). The most important use of the data generated from this exercise is to commence the development of soil fertility maps to aid generation of site- and crop-specific fertilizer recommendations, but the soils data is also being incorporated into the Phosphate Rock Decision Support System (PRDSS) to determine if locally available phosphate rock can be used as an alternative or supplemental source of P. Soil pH and soil Bray P from Ghanaian soil samples (Figure 13) were used to identify and recommend whether the Kodjari phosphate rock (PR) from neighboring Burkina Faso could be used as an alternative P source to imported P fertilizers.

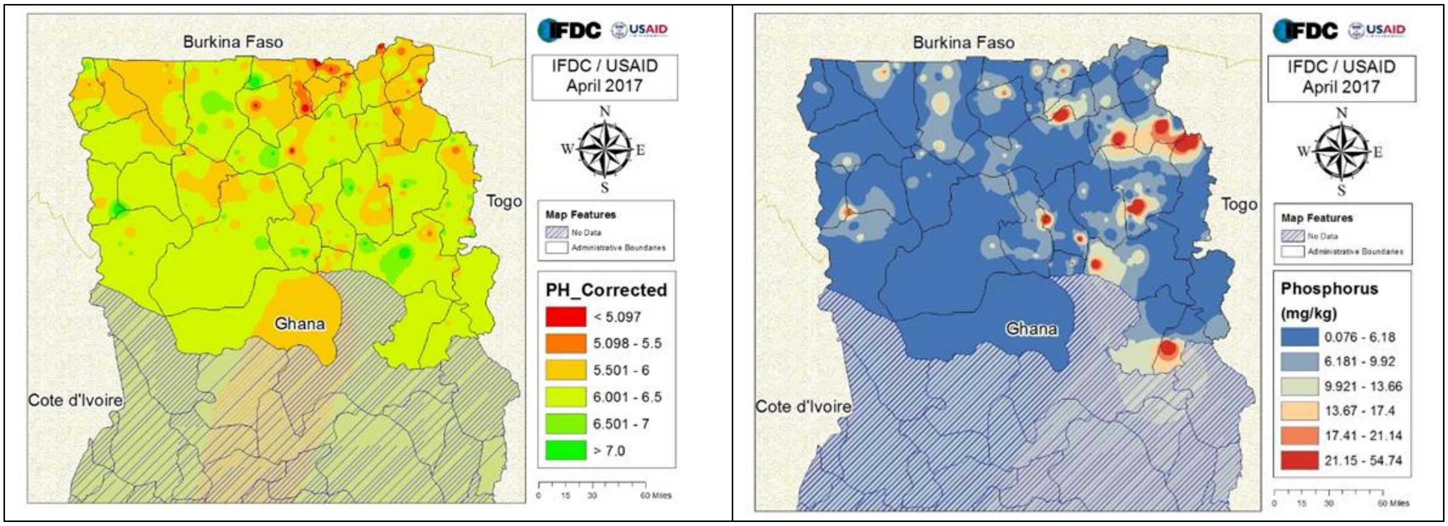

Figure 13. Soil pH and Available P for Selected Soils in Ghana

Using the PRDSS, results indicated that in areas with soil pH < 5.5 and available P (Bray 1) of < 6.2 ppm, Kodjari PR application on maize will approximately be 30% as effective as water soluble P sources such as triple superphosphate (Figure 14). Since P is one of the most limiting nutrients for crop production in this region, use of local PR (assuming availability) may provide an alternative to improve crop productivity in the absence of accessible P fertilizers. The PR response will be higher for legumes and longer duration crops such as cocoa and cassava. Recommendations for other crops using PRDSS continue to be generated.

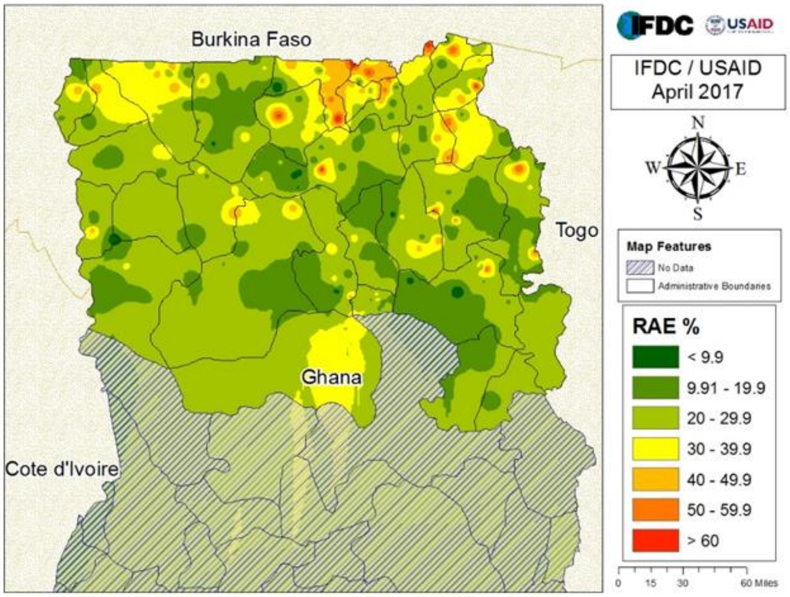

Figure 14. Relative Agronomic Effectiveness of Kodjari PR on Maize

1.2.3 Development of Soil Fertility Maps to Facilitate Site- and Crop-Specific Fertilizer Recommendations for Smallholder Farmers for Increased Economic and Environmental Benefits from Fertilizer Use

As of March 30, 2017, the IFDC lab has analyzed the 1,020 soil samples collected in 2016 for pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium, calcium, and magnesium. A total of 870 samples have also been analyzed at the Ghana Atomic Energy Commission (GAEC) laboratory for pH, organic carbon, available phosphorus, exchangeable potassium, calcium, and magnesium, sulfur, zinc, and boron. The remaining samples at GAEC are being analyzed. Soil pH was analyzed using the 2:1 DI water method, total N by the Kjeldahl and combustion methods, SO_4-S by MCP extraction, “available” P by the Bray-1 P method, exchangeable K, Ca, and Mg by 1 N NH_4Cl extraction method, organic C by the Walkley-Black method, Zn by the DTPA extraction method, and B by the hot water procedure.

A major limitation associated with soil testing is that it typically accounts for the plant-available nutrient pool present in the surface (4 to 6 inches) soil layer. However, the subsoil can be an important source of water and nutrients, particularly in perennial crop systems. In addition, some nutrients are highly mobile in the soil and can easily leach into subsoil, resulting in nutrient accumulation at deeper soil depths. Unlike soil testing, plant tissue analysis can account for the plant-available nutrient pools present at multiple soil depths, including deeper horizons because of the extensive root system in some plants. Plant analysis is a complement to the soil test and helps to better assess the overall nutrient status of a perennial system while revealing imbalances among nutrients that may affect crop production. Crop nutrient uptake is influenced by many factors other than the soil test. Soil testing and plant analysis are designed to work together. Soil testing identifies the soil’s nutrient reserves and predicts the nutrient needs, while plant analysis identifies the actual nutrient uptake. When used in conjunction with soil testing, tissue analysis will improve site- and crop-specific fertilizer recommendations. Thus, during the first quarter of FY17, 1,250 plant tissue samples were taken (from sites where soil samples were previously taken or from sites where an additional 750 soil samples were collected in 2017. Total soil samples collected to date number 2,760. Both the plant tissue samples and the additional soil samples collected are being analyzed.

Results to date confirm previous results suggesting that across all the three regions of the USAID FTF ZOI, the soils are deficient in P, S, Zn, and B, with very low organic matter and nitrogen contents (Tables 6-7 and Appendix B Tables B.1-B.8 and Figures B.1-B.3). Therefore, to increase productivity in such soils, efforts must be made by farmers and their input dealers to supply balanced fertilizer formulations that contain not only macronutrients, but also essential secondary and micronutrients. Once the soil and plant tissue analyses are completed, soil fertility maps will be developed and when combined with results from nutrient omission trials (to be conducted later), site- and crop-specific fertilizer recommendations will be provided to increase productivity within the ZOI.

Region	District	Samples Collected	Samples Analyzed	pH	OC (%)	N (g/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	Zn (mg/kg)	B (mg/kg)
Northern	Bole	52	47	5.94	0.15	1.20	10.64	104.07	1.56	0.20	0.21
	Bunkpurugu-Yunyoo	55	34	5.98	0.13	1.20	11.50	114.25	0.87	0.18	0.16
	Central Gonja	66	51	5.89	0.21	1.25	9.54	130.68	1.10	0.17	0.18
	Chereponi	63	49	5.86	0.16	1.30	10.34	130.16	1.47	0.20	0.16
	East Gonja	48	33	5.99	0.13	1.08	10.53	98.08	1.37	0.21	0.35
	East Mamprusi	49	42	5.86	0.18	1.39	10.94	121.81	1.30	0.27	0.16
	Gushegu	45	34	5.89	0.21	1.07	11.66	138.77	1.69	0.19	0.21
	Karaga	51	48	5.93	0.21	1.05	11.27	141.64	1.17	0.23	0.23
	Kpandai	52	47	5.82	0.22	1.10	9.43	150.76	1.17	0.21	0.19
	Kumbungu	49	49	5.89	0.26	0.96	10.14	117.12	1.32	0.19	0.18
	Mamprugo Moaduri	51	44	5.78	0.25	1.14	12.46	130.94	1.33	0.21	0.30
	Mion	45	30	5.94	0.30	1.31	11.60	103.81	1.10	0.22	0.21
	Nanumba North	49	12	4.98	0.26	1.08	10.26	123.90	1.31	0.22	0.19
	Nanumba South	47	36	5.89	0.36	1.13	11.55	118.94	1.75	0.20	0.21
	North Gonja	49	33	5.82	0.32	1.10	11.21	141.37	2.68	0.39	0.18
	Saboba	60	34	5.82	0.28	1.28	12.71	156.50	1.34	0.18	0.24
	Sagnarigu	51	20	5.89	0.25	0.90	11.76	119.20	1.28	0.23	0.35
	Savelugu-Nanton	54	21	5.25	0.26	0.72	11.21	104.07	1.16	0.23	0.20
	Sawla-Tuna-Kalba	45	33	5.87	0.23	1.44	10.11	118.94	1.46	0.24	0.17
	Tamale Metropolitan	74	42	5.78	0.22	0.90	11.33	124.68	1.33	0.23	0.24
	Tatale Sangule	58	38	5.86	0.16	1.15	12.74	239.21	1.46	0.39	0.21
	Tolon	51	41	5.84	0.19	0.96	11.28	135.37	1.52	0.34	0.19
	West Gonja	49	22	5.91	0.27	1.10	11.36	98.08	1.39	0.27	0.18
	West Mamprusi	48	30	5.92	0.32	0.96	9.55	77.73	1.59	0.24	0.21
	Yendi Municipal	49	30	5.98	0.24	1.21	10.70	116.07	1.58	0.20	0.20
	Zabzugu	52	33	5.94	0.26	1.12	11.75	117.38	1.40	0.25	0.17

Table 6. Updated Results of Soil Analysis in the Northern Region of Ghana

Region	District	Samples Collected	Samples Analyzed	pH	OC (%)	N (g/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	Zn (mg/kg)	B (mg/kg)
Upper East	Bawku Municipal	54	39	5.74	0.24	0.64	11.26	121.81	1.10	0.14	0.16
	Bawku West	59	20	5.75	0.32	0.81	11.19	118.94	1.52	0.13	0.13
	Binduri	56	35	5.74	0.27	0.86	12.64	124.68	2.68	0.16	0.13
	Bolgatanga Municipal	59	41	5.89	0.19	0.95	11.12	239.21	1.40	0.19	0.14
	Bongo	59	20	5.01	0.16	0.96	11.67	138.77	1.33	0.14	0.18
	Builsa	59	43	5.77	0.26	0.97	12.61	119.20	1.17	0.26	0.12
	Builsa South	56	50	5.56	0.25	0.98	11.12	130.16	1.34	0.14	0.18
	Garu-Tempane	48	20	5.76	0.28	0.99	11.46	118.94	1.39	0.23	0.22
	Kassena Nankana East	60	18	5.58	0.32	1.02	10.18	103.81	1.69	0.16	0.15
	Kassena Nankana West	54	49	5.76	0.25	1.03	11.51	141.37	1.59	0.13	0.14
	Nabdam	59	43	5.66	0.26	1.08	12.36	123.90	1.37	0.18	0.15
	Pusiga	55	12	5.63	0.22	1.15	10.45	156.50	1.10	0.16	0.25
	Talensi	60	48	5.68	0.21	1.17	10.26	135.37	1.46	0.14	0.13
Upper West	Daffiama Bussie Issa	55	40	6.23	0.28	0.77	9.99	123.05	1.43	0.14	0.12
	Jirapa	60	43	6.34	0.32	0.66	8.88	115.16	1.26	0.13	0.24
	Lambussie Karni	55	40	6.23	0.44	0.43	10.78	131.18	1.25	0.16	0.14
	Lawra	58	19	6.02	0.32	0.54	11.00	98.14	1.36	0.14	0.13
	Nadowli	62	45	6.65	0.37	0.64	10.18	117.13	2.41	0.26	0.21
	Nandom	60	44	6.48	0.30	0.66	9.70	133.65	1.20	0.14	0.14
	Sissala East	58	53	6.79	0.33	0.78	8.95	127.61	0.99	0.23	0.16
	Sissala West	62	55	6.32	0.23	0.58	11.03	147.95	1.05	0.16	0.13
	Wa East	58	53	6.45	0.19	0.63	9.11	112.69	1.52	0.18	0.12
	Wa Municipal	63	54	6.45	0.27	0.68	9.76	112.44	1.23	0.16	0.12
	Wa West	66	53	6.34	0.27	0.72	10.78	226.15	0.99	0.14	0.15

Table 7. Updated Results of Soil Analysis in the Upper East and Upper West Regions of Ghana

1.3 Fertilizer Quality Assessments (and Laboratory Surveys) to Support Policy Efforts to Harmonize Fertilizer Regulations in East and Southern Africa

Using the experiences and lessons learned during the development of a fertilizer quality regulatory system for the Economic Community of West African States (ECOWAS) and the performance of fertilizer quality assessments (FQAs) in member countries, IFDC initiated activities in FY16 that will support a harmonized fertilizer regulatory system for the member countries of the Common Market for Eastern and Southern Africa (COMESA). Performing FQAs in key countries of the sub-region will provide a fertilizer quality diagnostic analysis that, together with data and interactions with COMESA and member states’ policymakers, will be valuable for the design and promotion of a regionally harmonized fertilizer quality regulatory system.

1.3.1 *Kenya*

IFDC is conducting a series of FQAs in Eastern and Southern Africa. Kenya was selected to be the starting country because its large fertilizer market and complex distribution chain provide a good opportunity to test and adjust the methodology for assessment of fertilizer quality in other member states of COMESA and the East African Community (EAC). This work builds on previous and ongoing efforts by IFDC to assist ECOWAS in West Africa to implement a harmonized fertilizer regulatory framework.

The objective of the studies is to conduct fertilizer quality diagnostics in these countries to support the development and implementation of a fertilizer trade and quality regulatory system for these regional economic communities (RECs).

In Kenya, the fertilizer quality assessment team used a random approach to select fertilizer dealers and collect samples for analysis. Data were also collected on fertilizer markets, dealers, products, and storage conditions in the country.

Important findings included:

- Conventional granulated fertilizers represent 96% of the fertilizers traded in Kenya, while crystal and liquid fertilizers represent 2.6% and 1.4%, respectively.

- DAP represents 46% of the fertilizers traded. Urea, CAN, NPK 23-23-0, and NPK 17-17-17 represent 23%, 13%, 7%, and 5% of the market, respectively.
- No evidence of adulteration or severe physical degradation was found in any of the granulated fertilizers. This suggests that cases of total N, P_2O_5, or K_2O content out of compliance likely originated in the manufacture of imported fertilizers.
- The odds ratio of nutrient content compliance for a rural market is 0.28 times that of an urban market.
- The odds ratio of nutrient content compliance is 3.27 times higher for dealers that serve all types of farmers and retailers than for those with only small-scale farmer customers.
- The severity of nutrient shortages in liquid fertilizers is four times higher than granulated fertilizers. Crystal fertilizers have a nutrient shortage severity two times higher than granulated fertilizers.
- The cadmium content (three highest samples were 12.5, 11.8, and 6.2 mg Cd kg^{-1} P_2O_5) found is lower than the maximum content allowed by the European Union, which ranges from 20 to 60 mg Cd kg^{-1} P_2O_5.
- The chances of finding an intentionally underweight bag are 33.5% (one out of three), 23.5%, and 14.5% for 10-kg, 25-kg, and 50-kg bags, respectively.
- Fifty percent of the warehouses evaluated did not reduce temperature relative to temperature outside during the hottest hours of the day. Thirty-seven percent did not reduce the relative humidity with respect to the relative humidity outside.
- The odds ratio of having moist fertilizers is six times higher when the bag seam is loose than when it is tight. The odds ratio of having moist fertilizers is 1.5 times higher when pallets are not used than when sufficient pallets are used.
- The percentage of fines increases with distance from Mombasa, the port of entrance. The crushing, impact, and abrasive forces that produce granule degradation accumulate as the products are handled along the distribution chain.

Recommendations for improving fertilizer quality and quality control resulting from the assessment included:

- Quality control of liquid and crystal fertilizers during manufacture must be imposed and regular inspection both at the manufacture and sale points must be included in the country's fertilizer quality regulations.
- The results from the diagnostics analysis of the fertilizer samples point to the need for establishing a credible system to ensure more stringent pre-export verification of conformity (PVoC) 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. Targeted inspections along the domestic value chain especially at retail, also capturing re-bagged products, which have been identified to have higher likelihood of poor quality, 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.

1.3.2 *Zambia*

A training on methodologies for implementation of FQAs was conducted September 26-30, 2016. It was attended by 25 participants from the following organizations: Zambia Agriculture Research Institute (ZARI), Competition and Consumer Protection Commission, Zambia Bureau of Standards, Zambia Environmental Management Agency, and the Zambia Weights and Measures Agency. The three main areas of instruction were: (1) concepts about fertilizers and their chemical and physical properties, concepts about quality of fertilizers, and methodology for the conduction of fertilizer quality surveys; (2) data collection during the conduction of fertilizer quality surveys; and (3) fertilizer quality policy and national/regional regulatory systems. The theoretical concepts were complemented by extensive practice of the methodologies for fertilizer sampling and data collection, both at the training venue and in an agro-dealer shop. In the afternoon of the last training day on Friday, September 30, each of the four teams of inspectors received the list with the random sample of agro-dealers to survey, the survey equipment, and the funds to conduct the survey.

The survey for FQA in the fertilizer markets of the country was performed during October 1-10, 2016. Ninety-seven agro-dealers were visited and 311 fertilizer samples were collected during the survey. Data consisting of characteristics of markets, dealers, fertilizer products, and storage conditions were captured using smart mobile phones. Supervision of the survey teams was performed by the IFDC team, which visited the inspectors without previous announcement to make sure they were applying the survey methodologies properly. The data collected by the inspectors in fertilizer dealers' warehouses/shops were transmitted via Internet to computers of the IFDC coordinators in real-time as the inspectors were working in the agro-dealers' shops. The real-time data transmission provided an additional opportunity to supervise the inspectors working in the field. Through this continuous remote supervision, several data collection errors were identified and corrected by the inspectors after IFDC staff advised them of the issues and suggested means to ameliorate.

The laboratories of the University of Zambia and ZARI were evaluated on October 3-4. Equipment and staff knowledge about chemistry and their experience analyzing fertilizers was observed/discussed. Each laboratory received three "blind" fertilizer samples to analyze for total N, P_2O_5, K_2O, Zn, and Cu as a practical assessment of their analytical capabilities.

The laboratory at the University of Zambia showed very limited capability to analyze fertilizers in the quantity that a fertilizer quality regulatory system would generate. Only one of the professors showed knowledge about the chemistry of fertilizers and methodologies for their analysis. The university lab had some capability to analyze fertilizer samples using wet-chemistry procedures.

The lab from ZARI had a couple of technicians with proficiency to analyze fertilizers and old spectrometry and combustion analysis equipment that were still functioning. Results from the blind sample analyses corroborated the higher capability of the ZARI lab compared to the university lab. Fifty fertilizer samples were given to the ZARI lab for analysis. Duplicates of these 50 samples and the remaining samples collected were taken to the IFDC labs in Muscle Shoals, Alabama. Approximately six months later after leaving the samples at the ZARI lab, they have been unable to do the analysis due to equipment malfunctioning.

The 311 samples collected during the fertilizer quality survey in Zambia are being analyzed in the IFDC labs. After obtaining these results, data will be analyzed, and the report will be ready for release in October 2017.

1.3.3 *Uganda*

Final preparations for conducting the FQA in Uganda were carried out in cooperation with the Uganda Ministry of Agriculture during March 2017. Fertilizer quality inspectors underwent training during the last week of April 2017. The fertilizer quality survey in fertilizer markets of Uganda will be performed in the week following the inspector's training.

2. Workstream 2 – Supporting Policy Reforms and Market Development

2.1 Policy Reform Process

IFDC has been involved in activities to provide support to policymakers by providing information on strategic options to improve the agriculture sector by developing input markets. In the period under review, IFDC has been working on building collaborative synergies with other partners to shed light on subsidy programs in Africa and Asia in order to develop improved approaches to the design and implementation processes.

2.1.1 *Documenting Policy Reform Processes and Fertilizer Market Development*

The overall purpose is to contribute to influencing policy reforms through active engagement with stakeholders, such as research institutions, private and public sectors, and in-country missions, through wider dissemination forums. IFDC's dissemination strategy for the upcoming years includes active engagement with stakeholders and with existing regional/national platforms in discussions on policy and regulatory frameworks, trade barriers, etc., and advocacy for favorable business environments. Regional/national platforms include: USAID West Africa Fertilizer Program (WAFP) platforms in West Africa; African Fertilizer and Agribusiness Partnership (AFAP), Michigan State University (MSU), and International Food Policy Research Institute (IFPRI) in East and Southern Africa; and the AU Comprehensive Africa Agriculture Development Programme (CAADP) Malabo implementation networks launched in 2016. For FY17, one policy brief is anticipated.

Through a series of meetings initiated after a meeting of USAID Policy Partners in Washington, D.C., in December 2015, IFDC began discussions with a number of organizations for potential activities that could be undertaken jointly.

IFDC signed onto three partnerships during this period:

1. Food and Agriculture Organization (FAO) of the United Nations-IFDC: This partnership was initiated earlier but became more urgent and was signed during this period when the Tanzania Ministry of Agriculture requested assistance from FAO, which then requested support from IFDC. A summary of the report resulting from this collaboration is detailed in 2.1.2.
2. Alliance for a Green Revolution in Africa (AGRA)-IFDC: This Memorandum of Understanding (MOU) was signed when the two institutions started working on assessing subsidy programs in 10 African countries during early 2016. IFDC supported country consultants by reviewing their draft reports before a validation workshop, which was held in Nairobi in November 2016. A synthesis report capturing key aspects from the 10 countries and country-specific draft reports were under review. The validation meeting was attended by Ministry of Agriculture representatives and country consultants from the 10 countries under assessment and other stakeholders, including IFDC and AGRA. Currently, AGRA and IFDC are in discussions on how to provide country support to deal with filling the gaps identified in these countries’ policies and strategies in order to improve access to fertilizers. This is expected to involve in-country technical support working closely with stakeholders; AGRA is using its networks in these countries to set up this next phase.

3. IFDC engagement with MSU-sponsored Alliance for African Partnership: Since mid-2016, IFDC and AFAP, New Markets Lab (NML), ReNAPRI, and MSU have been forging an alliance to work together on policy analysis and advocacy issues in SSA. After a number of meetings and consultations, this alliance has just been formally completed with a joint $200,000 grant proposal drafted by the alliance partners and submitted to MSU, which has accepted this proposal. The relevant contractual documents between MSU and the group members were signed in 2017 and actual implementation of proposed activities begins in May 2017 and extends to September 2018. This has been a successful beginning of an alliance borne out of the 2015 USAID Policy Partners meeting in Washington, D.C.

IFDC's Markets, Economics and Policy (ME&P) staff continue to develop a series of briefs titled "Documenting Policy Reforms Process for Fertilizer Market Development" initiated in 2015. A second brief was issued on Ghana under the title "Transitioning from Government Control to a Larger Private Sector Participation in the Ghanaian Fertilizer Market."

The key conclusion of the brief is that the Ghana Fertilizer Subsidy Program (FSP), on its own and with the participation of the private sector, is temporarily necessary but not sufficient to develop a sustainable fertilizer market, or to increase long-term fertilizer use and crop productivity by smallholder farmers. Overall, a strategy, congruent with Ghana's Medium-Term Agriculture Sector Investment Plan (METASIP), should seek to transform the agriculture sector by training farmers on sustainable land use and on the proper use of productivity-enhancing inputs. More importantly, the strategy must focus on investing in infrastructure to incentivize private investment to expand businesses into rural areas to provide services and supply productivity-enhancing technology closer to farmers at lower and more affordable costs to farmers. This same investment will also help reduce costs related to long-distance travel, allowing farmers better access to agro-dealers, to agricultural extension offices, and most importantly, to output markets. In addition, government policies should aim to increase farmers' access to credit by supporting credit for the use of fertilizer and to address the macroeconomic imbalance, which is greatly impacting high interest rates.

A third brief has been drafted on Uganda under the title “Increasing Fertilizer Consumption through Government Programs Leading to Agriculture and Private Sector Growth in Uganda.” The key message of the brief is that the implementation of a subsidy on fertilizer to incentivize a higher use of fertilizer in agricultural production, can be justified under economic, social, and environmental grounds. The subsidy would boost farmers’ output, increase farmers’ living standards and reduce environmental degradation by addressing soil nutrient mining and promoting sustainable intensification.

However, the brief highlighted any subsidy program on fertilizer in Uganda should not be implemented in isolation but as an integral component of a market development strategy intended to increase fertilizer use, efficiency, and effectiveness, and therefore profitability for farmers. Thus, a subsidy should be implemented primarily on behalf of and for the benefit of farmers, while allowing the private sector to do business as usual without government interference, in order to support development and sustainability for the overall fertilizer market.

This approach reflects the need for a paradigm shift regarding how fertilizer subsidy programs are viewed. Many governments see subsidies as a necessary recurring expenditure. Instead, governments (as well as farmers and other stakeholders) should think of subsidy programs as a short-term expenditure in the agriculture sector to achieve a long-term effect, accompanied by continuous public and private sector investments toward making agriculture sector development self-sustaining.

2.1.2 *Technical Support for Fertilizer Subsidy Reforms and Market Development in Tanzania*

In the third quarter of 2016, IFDC signed an MOU with FAO to enable joint efforts, harness diverse capabilities, and build synergies among the two organizations in areas covering policy and markets in Africa. In October 2016, the Monitoring and Analyzing Food and Agricultural Policies (MAFAP) program of the FAO was requested by the Tanzania Ministry of Agriculture, Livestock and Fisheries (MALF) to assess the fertilizer market with a special focus on the possibility of establishing a bulk procurement system (BPS) to replace its current subsidy program, which is becoming unsustainable.

In November 2016, IFDC provided technical assistance to MALF and FAO to assess a plan to establish a program for bulk procurement of fertilizer. The aim of the plan is to reduce the cost of procurement and importation, reduce the government financial burden for the fertilizer subsidy, and continue supplying fertilizer needs to the Tanzanian farmers at reasonable prices.

An IFDC Markets, Economics, and Policy (ME&P) staff member participated in collaboration with FAO-MAFAP to assist in kick-starting discussions between the Government of Tanzania, MAFAP, and private sector stakeholders, on fertilizer bulk procurement plans from the Ministry of Agriculture of Tanzania. The discussion was on the potential benefits and/or costs of bulk procurement in the context of market development, the savings or lack thereof from bulk procurement, and the analysis that FAO-MAFAP would be carrying out in collaboration with IFDC and an international senior fertilizer market expert. Additionally private sector stakeholders expressed opinions on the expected impact of a bulk procurement system and the options to be considered.

A team of experts (including FAO and IFDC staff) was assembled to conduct an assessment of the BPS for fertilizer during February/March 2017. The objectives of this assessment were twofold:

- Gather lessons learned from analysis of relevant BPSs in other countries.
- Map fertilizer marketing chain in Tanzania, with a special focus on implementing a bulk procurement system for fertilizers.

The team met with over 100 stakeholders from both public and private sectors and the farming community from February 6 through March 5, 2017, and conducted field visits to Arusha and Mbeya. Debriefings were given at meetings organized by the MALF Department of Policy and Planning (DPP) and the Tanzania Fertilizer Regulatory Authority (TFRA). The team shared the following initial recommendations in the Draft report for discussion:

- The proposed fertilizer BPS is unlikely to achieve the intended effect of reducing fertilizer prices for farmers and, if implemented, is likely to disrupt the present market system.
- The government should set up a market information system to provide farmers and traders with information to make informed choices.

- If the government chooses to implement the BPS despite the concerns expressed in the report, then to minimize anticipated negative effects, the team advised that they implement a pilot system with one or two products (e.g., CAN, 15-15-15) that have lower consumption so as not to disrupt the market (after stakeholder consultations).
- As an alternative to implementing a full-fledged BPS, the team recommended several short-term measures to increase the efficiency of the value chain and reduce prices such as:
    - Explore priority discharge at the port of Dar es Salaam for vessels carrying 25,000 tons or more of fertilizers.
    - Accelerate the establishment of the "one-stop clearance center" at the port to reduce transaction costs.
    - Clearly define the roles and responsibilities of the Tanzania Bureau of Standards (TBS) and TFRA and avoid duplication in their functions.

After the debriefing meetings, the team shared a draft report with MALF in mid-March for distribution/discussion with stakeholders (including the USAID Tanzania Mission) for feedback, before finalizing the report. Positive feedback was received from World Bank and the USAID Mission, but the draft report has and continues to generate considerable discussion.

After receiving feedback from all stakeholders, the team will finalize the report (including all recommendations) and share with MALF and FAO. This report was initially due April 15 but the team is still awaiting feedback from some stakeholders. FAO extended the due date for the final report to May 3.

During the in-country assessment process, FAO requested IFDC staff to participate in conference "The Role of Agri-Food Systems in Promoting Industrialization in Tanzania" held in Dar es Salaam on March 1-3, 2017. The conference was organized by several organizations and donors including USAID, the World Bank, JICA, and Michigan State University. A ME&P staff member participated as a panelist during the session on "Agricultural Input Policy" and provided a presentation on "Improving Efficiency of Fertilizer Supply Chain." There were over 300 participants discussing various themes under the broad umbrella of "Enhancing Linkage of

Upstream and Downstream Value Chain Activities in the Context of Agricultural Transformation."

2.1.3 *Engagement with Partners in Support of Policy Reforms at Country and Regional Level*

Technical Support to CAADP-Malabo

Engagement with AU CAADP-Malabo Technical Networks of the African Union Commission (AUC)/Department of Rural Economy and Agriculture (DREA): IFDC was involved in the launching of the Technical Networks that will support the Malabo Implementation Strategy in Nairobi in September 2016. These networks are collaborative platforms for harnessing and channeling technical support and capacity development to relevant CAADP implementation agencies. IFDC is a member of three technical networks supporting the AU CAADP Malabo Implementation Strategy:

- Markets and regional trade.
- Resilience, risk management, and natural resources management.
- Knowledge management, policy analysis, and accountability for results.

The Knowledge Management, Policy Analysis, and Accountability Network has held two meetings in 2017 and members have been requested to participate in country-level meetings aimed at strengthening the Country National Agricultural Investment Plans in alignment with the CAADP Compact signed by these countries.

IFDC ME&P staff recently participated in Skype meetings and discussions of the CAADP Technical Networks (TN) on Markets and regional trade. One objective of the CAADP-TNs is to develop mechanisms and support tools for the implementation of the Malabo Declaration through training and technical advice in specific content areas to national and regional agriculture sector governance entities. This includes support policies, programs and practices that can accelerate achievement of national, regional and continental agriculture productivity and production, and therefore contribute to achieve food security goals related to Malabo Declaration and the CAADP. In the context of the CAADP-TN on markets and regional trade, a report on "Regionalization of Agro-inputs Markets" in SSA is being prepared for publication on the IFDC website. This report may have use as a tool for training and capacity building under the TN activities.

AGRA-IFDC Africa Subsidy Review

Following detailed discussions with AGRA's policy team in mid-December 2015, IFDC and AGRA generated a Terms of Reference (ToR) to implement the subsidy studies in 11 countries in SSA. IFDC agreed to provide in-kind support for the activity entitled "Evaluation of Fertilizer and Seed Delivery System in Sub-Saharan Africa: Towards a Third Generation Subsidy Model" covering 11 countries in Africa (Mozambique, Malawi, Kenya, Tanzania, Rwanda, Uganda, Mali, Malawi, Ghana, Burkina Faso, and Nigeria).

IFDC established a collaboration agreement with AGRA, to undertake studies in multiple SSA countries, to revise a document that synthesizes SSA countries' experiences in the procurement, importation, and distribution of fertilizer and to assess existing fertilizer programs. The document will make recommendations to enhance fertilizer and seed subsidy programs with larger private sector involvement and with the ultimate goal to reduce farm-gate prices.

The field implementation of the work began in March 2016. IFDC has provided technical support to this process by: (1) contributing to the development of the ToRs; (2) contributing to the development of instruments for gathering data and information by consultants; (3) participating in a scoping meeting in Nairobi to build capacity of consultants to undertake this activity; (4) sharing lessons and experiences and that of other institutions in the form of existing literature covering these areas; and (5) providing support to the exercise on an ongoing basis whenever technical assistance is required. The data and other relevant information related to existing subsidy programs in 11 countries were collected, and a synthesis report has been prepared and is currently under review for further revisions.

2.1.4 Fostering Policy Dialogue

Input Subsidy Studies

There is a growing interest in developing "smart" or improved subsidy programs that lessen the burden on public budgets by encouraging more private sector participation and investments in fertilizer markets. IFDC has developed two promising collaborations on this general theme using resources from this CA to complement substantial investments made by AGRA and the fertilizer industry itself.

AGRA-IFDC Africa Subsidy Review

An AGRA-IFDC co-sponsored workshop was conducted in Nairobi in mid-November, 2016. An ME&P staff member participated in the multi-stakeholder workshop in representation of IFDC, serving as moderator and making presentations, to discuss the different modalities of subsidy implementation in SSA and to validate the findings from the assessment of programs in SSA countries where some type of subsidy on fertilizer has been or is being implemented. One of the major conclusion reached during the workshop, was that each country should be analyzed individually to assess the most appropriate modality of subsidy implementation, depending also on the objectives of the programs. If the modality to implement is targeted subsidies by means of voucher, major efforts should be placed on the design and implementation of voucher programs to make them more effective and efficient to reach the target population and therefore make the subsidy program more effective. In addition, governments should consider increasing public investment, especially in those areas that will help the effectiveness of the private sector to deliver the subsidized product and reach the intended farmer population.

FAI-IFDC Asia-Africa Subsidy Review

Starting in early 2015, IFDC staff began a collaboration with FAI to produce a book analyzing fertilizer subsidy policies in five Asian countries (China, India, Indonesia, Pakistan, and Bangladesh) and four sub-Saharan African countries (Nigeria, Malawi, Rwanda, and Tanzania). The book reviews fertilizer subsidy policies with a view toward understanding their impact on countries' fiscal budgets, on crop productivity and soil nutrient management, and on the efficiency of fertilizer value chains. The original work was commissioned by IFA. During this reporting semester, the Executive Summary was completed and the book entitled "Fertilizers Subsidies: Which Way Forward" was published electronically in January 2017. The publication is available free of charge from the IFDC website.

MSU-IFDC Subsidy Review

Michigan State University and IFDC co-authored the following article "Taking Stock of Africa's Second-Generation Agricultural Input Subsidy Programs, 2000-2015," which was submitted to the World Development Journal in March 2017. A policy brief authored April 2017 under the same title has been submitted to USAID by MSU. This work was supported by the World Bank, the Bill and Melinda Gates Foundation under the Guiding Investments in Sustainable Agricultural Intensification Grant from USAID.

This study provides the most comprehensive review of recent evidence to date regarding the performance of second generation input subsidy programs (ISPs), synthesizing nearly 70 studies from seven countries (Ghana, Nigeria, Kenya, Tanzania, Malawi, Zambia, and Ethiopia). The authors reviewed the evidence on ISP targeting, the programs' effects on total fertilizer use, crop production, food prices, wages, and poverty, and the political economy of ISPs. The report also considered measures that could enable ISPs to more cost-effectively achieve their objectives. The empirical record suggests 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 smaller than expected. Two characteristics of program implementation consistently attenuate 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. If these challenges could be addressed, ISPs could more effectively mitigate the concurrent challenges of rapid population growth and climate change in SSA

2.2 Impact Assessment Studies

To support policy reforms for the development of input markets and value chains, IFDC conducts impact studies not only to provide feedback on performance of policy changes and supporting programs but also to provide lessons learned for future policy reforms and implementation. During the reporting period, the following activities were conducted.

2.2.1 *Support to ECOWAS Countries on Fertilizer Policies and Input Subsidy Issues: USAID-WAFP Regional Results and Experience-Sharing Workshop*

The ME&P unit has been providing technical support to the USAID-funded West Africa Fertilizer Program (WAFP) in its assessments of the progress by individual member countries in adopting the harmonized fertilizer quality and regulatory framework signed by ECOWAS in 2012, including the demand from policymakers for solutions to improving subsidy programs or providing alternative options to increase access to fertilizers.

To this end, WAFP has been analyzing the various policies and subsidy programs in the region working in partnership with ECOWAS to provide lessons/experiences that will support these governments.

WAFP conducted a workshop in Bamako, Mali, on “Fertilizer Subsidy Programs: How Can Better Use of the So Called ‘Necessary Evil’ Be Made?” on February 21-22, 2017, with participants from ECOWAS and private and public sector fertilizer value-chains to;

- Share results from review of subsidy programs in West Africa.
- Identify criteria to assess these programs.
- Share successful experiences within the region and beyond.
- Discuss policy and other related issues and propose recommendations for designing improved programs.

The main objective was to discuss practical approaches to addressing the challenges which hamper increased supply, distribution and use of quality fertilizers in West Africa, with specific focus on lessons learned from studying various subsidy programs across the continent and the resulting implications for West African countries. ME&P participated to present lessons learned from East and Southern Africa region subsidy programs. Group discussions were summarized into the way forward and recommendations for improved performance of subsidy programs were made.

2.2.2 *Fertilizer Quality Assessment/Survey to Support Policy Efforts to Harmonize Regulatory Standards in East and Southern Africa*

The ME&P unit has been supporting Fertilizer Quality Assessments (FQA) undertaken under Workstream 1 with the purpose of conducting country fertilizer quality diagnostics that can be used to support the development of a COMESA fertilizer quality regulatory framework. The ME&P has been contributing to training inspectors on the policy aspects and also in making an assessment of the challenges that need to be tackled to strengthen the frameworks.

The first FQA among the Common Market for Eastern and Southern Africa (COMESA) countries was performed in Kenya between March 25 and April 22, 2016. The next was undertaken in Zambia during the last quarter of 2016. In the Month of March/April 2017, the team is undertaking a similar study in Uganda.

The policy and regulatory issues have been incorporated into the draft report for discussion with the Kenyan Ministry of Agriculture and IFDC-Nairobi staff. These include a number of policy and regulatory recommendations that have been proposed based on the findings of the fertilizer quality survey. See Section 1.3.1.

In summary, updating the current quality regulatory framework, with clear roles for relevant agencies in addition to harmonizing regulations across countries will support all recommendations and increase access to fertilizers.

2.3 Economic 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 conducting stakeholder analyses and assessment of cost build-ups and market margins to identify value chain constraints and market analysis of the supply and demand of fertilizers.

2.3.1 *Fertilizer Cost Build-Up Studies*

Ghana Fertilizer Cost Build-Up

After the field work (to collect data and information through interviews of stakeholders in Ghana) activity which took place early in 2016, an analytical report was written on the fertilizer supply chain cost structure. The main findings of the assessment are the following:

- A key issue facing the fertilizer supply chain in Ghana is the high cost of finance and access to credit, particularly by agro-dealers and smallholder farmers. High cost is explained in part by the crowding out effect from the GoG borrowing in the domestic financial market to finance the fiscal and budgetary deficit. The low access to credit by farmers is due to the high risk inherent in agricultural activities which compel financial institutions to lend funds for investments in activities that offer higher rates of return and are less risky, in an effort to protect their lending portfolio.
- The subsidy program, intended to increase the use and consumption of fertilizer in Ghana, is not serving its intended purpose because the market/retail prices negotiated by MoFA and importers is presumably much lower than the actual/estimated cost of supplying fertilizer all the way to retail. Although these prices might be enough to provide importers incentive to import the fertilizer under the GoG subsidy programs, it does not provide an incentive for the domestic supply chain to deliver all the fertilizer where and when it is needed most. Furthermore, these prices provides even less incentive to private stakeholders, to deliver fertilizer quantities beyond what the GoG can afford under the subsidy program.
- The process of negotiating prices between MoFA and importers and the system of delivering fertilizer, allows importers and wholesalers to reduce their costs, and more importantly, it allows importers to transfer the inherent risk of the domestic market to the domestic distribution network. Domestic distribution network is expected to cover their combined costs and risks of delivering fertilizer to farmers, with a commissions of GHS 7-9 allotted under the MoFA-importer negotiated retail price, for every fertilizer bag sold after importation to retail.

Kenya Fertilizer Cost Build-Up

In FY16, data and information on cost build-up were collected for Kenya toward the end of the reporting period. The report is being written to be submitted in the current FY17. The objective of the activity is to assess the cost of supplying fertilizer from procurement to distribution to farmers and to identify constraints that are contributing to higher transaction costs and recommend policies and strategies to address them.

The Kenya fertilizer law and regulations are outdated and need updating; there is a draft policy document that has been put together with stakeholder consultations but is yet to be signed and gazetted. Kenya has a fairly evolved fertilizer market with competitive private sector consisting of several importers and distributors and many retailers or agro dealers. The fertilizer market was liberalized in early 1990s and prices are determined by private sector players in a competitive market. Kenya also provides the seaport through which landlocked countries procure their fertilizers; about 30,000 tons of fertilizers is re-exported to other East African countries. The main crops that use fertilizer in Kenya include; maize, coffee, tea, sugar, and horticultural crops. Kenya national consumption of fertilizers is approximately 600,000 tons mostly consisting of DAP and CAN, with about 90,000 tons going to tea sector (NPK 25:5:5). There are a number of blending facilities in the country that produce various fertilizer formulations.

Though the market is liberalized, the government runs subsidy programs that raise risks for the private sector, creating uncertainty in timing of procurement, delivery time, and level of subsidy provided. There are two subsidy programs; the National Accelerated Agricultural Inputs Access Program (NAAIAP), a voucher based program targeting smallholder farmers through the private sector distribution system, and the Fertilizer Subsidy Program, a government-run program selling fertilizers at reduced prices to all farmers at their stores, mostly in high potential agricultural areas.

The initial analysis of the collected data and information provides a few key results with implications for improving markets and raising access to fertilizers:

- *Logistics*: Road transport is the main mode of transporting fertilizers in Kenya. Transport to Nairobi is approximately Shs 180/50-kg bag of urea, Shs 250/bag to Nakuru and Shs 300/bag to Kitale on the other side of the country.[1] This is 12% of the price at Kitale or viewed as a percentage of domestic costs (post-CIF) this is 30% of domestic components of retail prices.

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[1] Exchange rate is U.S. $1=100 shillings.

Kenya is currently constructing a Standard Gauge Railway from Mombasa to the border with Uganda. Already the Mombasa-Nairobi portion has been completed. The cost of transport by rail has been estimated at a third that of road.

- Approximately 41% of the retail price at Kitale is the domestic component, implying that domestic costs and margins are significant part of the retail price. Therefore, as a cost-cutting strategy, ways of reducing these costs should be explored, since international costs are fixed and not influenced by countries that consume relatively small quantities of fertilizers.
- *Financing*: Financing costs consists of acquiring letter of credit (LC) and interest rates on LCs for about three months which amount to approximately 7% of the domestic components of retail price at Kitale. Interest rates are usually above 10% and can rise as high as 30%; however, recently, the government has put a cap on interest rates at 4% above the base lending rate from the central bank. This has caused a number of banks to lay off staff blaming the tight lending rules. Financing mechanisms that do not burden businesses and farmers with high charges need to be explored and implemented.
- About 22% of the internal component is composed of clearing and forwarding (C&F) charges. The major elements in C&F include: import declaration form (IDF), shore handling, wharfage; Kenya Bureau of Standards (KBS) fee and radiation inspection account for 10% of clearing and forwarding costs. Therefore, reduction in these fees and other costs can reduce farm-gate prices.

The Kenya fertilizer market is well developed and has enough investors to take care of not only the Kenya market but regional markets if the regulations and policies are harmonized to allow for trade.

2.3.2 *Economics and Environmental Implications of Fertilizer Technology Using the Life Cycle Analysis Approach*

In FY17, the ME&P staff will complement the agronomic work carried out in quantification of GHG emissions by initiation of the life cycle analysis (LCA) approach in quantification of energy equivalents (in turn, carbon credits and monetary terms associated) consumed across different types of fertilization in a paddy-rice system in Bangladesh. The proposed work will be carried out along with Workstream 1 team, with data support from the AAPI project in

Bangladesh. One of the major advantages of using LCA can be in selecting environmentally friendly technologies that optimally utilize resources for fertilizer production and use, e.g., by comparing alternative products and/or technologies. LCA methods provide a way to quantify the climate impacts of a food product by accounting for all GHG emissions associated with its production, including upstream and downstream from the farm.

Beginning in the fall of 2017 a candidate graduate student from Rutgers University will work with IFDC scientists to evaluate the economic and environmental impact of Urea Deep Placement and GHG emission in rice paddy system using the LCA Approach (LCAA).

2.4 Identification of Fertilizer Trends and Outlook for Sub-Saharan Africa

IFDC Markets, Economics, and Policy (ME&P) staff, along with colleagues and partners in the field, will continue to collect, analyze, and provide market information on the supply and demand of fertilizers in a number of countries in West Africa. This information will contribute to a collaborative effort being initiated with AFAP to develop a comprehensive index on the access to fertilizers in sub-Saharan Africa. IFDC ME&P staff will also continue to engage with the FAO, industry, and other stakeholders to prepare and present projections on fertilizer consumption/demand and production/supply in order to estimate supply-demand balances at the world and regional levels.

2.4.1 *TAFAI-The African Fertilizer Access Index*

African countries have made substantial progress in liberalizing and deregulating their fertilizer markets since the Abuja Declaration 2006, with more participation of private sector at all levels of the supply chain – import, wholesale, and retail levels. In spite of such policy reforms on fertilizer sector, still the input markets are at a nascent stage of development, in many parts of the continent, mainly fragmented, so access to fertilizers still remains a challenge for smallholder farmers. The above efforts notwithstanding, there is currently no initiative that undertakes systematic monitoring and reporting on the status of fertilizer market development in Africa.

In accordance with the mutual accountability requirements, as outlined in CAADP-NAIPs, there is considerable appetite for reliable, accurate and consistently available information on the status of the fertilizer markets by African governments, the private sector, development organizations and donors. This information should be presented in a form that is relatively simple and pragmatic, but which will allow one to characterize and compare the level of market maturity for fertilizers across the continent.

IFDC and AFAP also require this type of tool to improve the quality and relevance of the policy advice and technical assistance we provide the regional economic communities (COMESA, ECOWAS, and SADC) and in our regular discussions with the fertilizer industry, and national governments. The proposed TAFAI index will be a consolidated measure of various factors influencing and responsible for creating an enabling environment for fertilizer markets (research and development, fertilizer policy and regulatory frameworks, market access, industry competitiveness, fertilizer quality, and those that can be used to assess fertilizer use (farm-gate price, input-output ratios, fertilizer consumption rates and levels, nutrient appropriateness).

Goal and Objectives of TAFAI

The goal is to establish and maintain a simple, transparent, accurate, up-to-date index of measurement that keeps a running scoreboard on fertilizer sector development in Africa. The overall objective is to promote the creation of enabling environment for competitive private sector-led fertilizer market systems, that improves smallholder farmers' access to fertilizers at affordable prices and quality, available at the right time and place, and suitable for their crop and soil nutrition.

The proposed objective will be accomplished by developing a set of indictors that measures the: (i) status of the enabling environment for fertilizer markets in sub-Saharan African countries; (ii) impact on their performance (in terms of accessibility, availability and affordability by smallholder farmers); and (iii) provide detailed recommendations and key information to assist African governments, the fertilizer industry and donors in making well-informed decisions towards making investments in fertilizer sector in improving smallholder farmer welfare.

Activities Since October 2016

i. With the above background, IFDC and AFAP initiated the TAFAI conceptualization and implementation process, followed by the approval of work plans under the BFS-SFA project. The initial concepts on TAFAI were presented at the Argus-FMB Fertilizer Forum Meetings in Cape Town, South Africa, in February 2017 by AFAP and IFDC to get feedback from the stakeholders for further refinement.

   The presentation also demonstrated a simplified, preliminary scoring on fertilizer access, using the existing data generated from four eastern and southern African countries (i.e., Ethiopia, Malawi, Mozambique, and Tanzania). For example, the following factors were measured using qualitative rankings ranging from excellent, good, fair, and poor based on the impact of various enabling factors on market performance in a country. These scores were tracked and compared over time, which resulted in the constructed TAFAI measurement. The preliminary indicators along with variables considered for scoring include:

   - *Research and development*: looking at issues such as number of producers and blenders, number of fertilizer products in the market, number of new fertilizer products introduced in the past three years.
   - *Fertilizer quality*: looking at issues such as incidence of adulteration, mislabelling, nutrient deficiency, number of fertilizer inspectors.
   - *Market access*: looking at issues such as whether there are taxes or tariffs on fertilizer, magnitude of transport costs and port fees and charges.
   - *Institutional Support services*: availability of extension services for SSF; existence of fertilizer trade and agro-dealer associations; existence of PPD platforms.
   - *Fertilizer policy and regulatory framework*: existence of updated fertilizer policy, laws and regulations; registration and licensing requirements.

ii. Following the stakeholder forum, the TAFAI group from IFDC and AFAP convened a three-day workshop in Nairobi between March 28-30, 2017, to discuss further the design and methodologies of measuring fertilizer access in SSA countries. Since TAFAI as a concept has been derived from and is closely related to another measure which is currently in operation (i.e., The African Seed Access Index [TASAI]) and was conceptualized and implemented by Cornell University, AGRA, and Market Matters, we invited the expertise of Dr. Edward Mabaya from Cornell University to guide us through the TAFAI implementation process. He outlined the steps and salient features for building an effective index and shared lessons learned from TASAI to inform the TAFAI measurement. Dr. Mabaya also had a brainstorm session with the TAFAI team, considering the differences between seed and fertilizer, and helped to further outline the steps to be carried out sequentially to achieve the TAFAI objectives and outreach.

It was concluded that TASAI and TAFAI could complement each other in future endeavors, from data partnerships to outreach. Ideally, once the indicators of seed and fertilizer access are completed, both TASAI and TAFAI will be viewed as credible and viable instruments by stakeholders and will become the go-to instruments by continental bodies like the African Union (CAADP, Malabo Declaration) to monitor and report on performance of the seed and fertilizer industries in Africa. In addition, they can become a part of the input strategy of the respective organizations involved in the process, including donors and implementing institutions.

The workshop in Nairobi also provided an opportunity to come up with a joint work plan between IFDC and AFAP for the next few months toward implementing TAFAI. It was decided by September 2017, the working group on TAFAI would have finalized the following steps in TAFAI implementation process:

- An expanded concept note for peer review.
- Extensive literature review on fertilizer access, methods and measurement.
- Brainstorming with stakeholders on proposed indicators.
- Designing surveys for online responses from key stakeholders.
- Finalizing tools of measurement and indicators list with definition.
- Preparing for piloting of indicators in ESA and WA region.

3. Cross Cutting Issues Including Learning and Knowledge Management and Sharing

Through mutual agreement with USAID BFS, IFDC is undertaking additional actions that will allow the organization to document and share information generated from USAID BFS funding for this CA. During the reporting period, IFDC further captured, documented, and analyzed the knowledge that resulted from the many soil fertility systems and the associated activities and technologies that the organization employs to improve productivity and increase food security.

3.1 Conduct Systematic Data Collection and Analysis of IFDC Information

IFDC projects and individuals have produced large amounts of data in the pursuit of program and project objectives over the life of the institution. In the early days of the institution, all data were housed and analyzed at IFDC headquarters in large part due to the research nature of early activities. Once IFDC's implementation activities were decentralized by region and projects moved from a pure research focus to a research-agribusiness focus, not all project-generated data required robust statistical analysis. As a consequence, over time data were lost.

With support from the CA, an IFDC database (tentatively named Database for Fertilizer Information Services [DFIS]) is being developed that will institutionalize all data at a central location and will ensure physical data preservation.

In October 2016, IFDC reported against the FTF Monitoring & Evaluation (M&E) indicators for this project. The final results framework was approved by USAID, and the revised project management plan for the project is underway with completion slotted for May 2017.

During the process of development of the M&E database, the internal IFDC team attempting to coordinate the database development encountered major difficulties, including time available to dedicate to the effort and the lack of homogeneity of M&E collected by the various field projects. Recognizing the need for a timely and robust M&E database, IFDC entered into discussions with DevResults for obtaining their M&E software package.

IFDC's recently recruited a new programmer/database developer who is a computer scientist by training with extensive programming experience in languages used for non-relational databases and with familiarity of the non-relational database structure (e.g., AgMIP project). The programmer will be tasked with supporting the M&E effort, as well as further developing the IFDC institutional database.

During the reporting period, IFDC staff continued to disseminate information via training programs, publications in refereed journals, technical reports and policy briefs, and presentations. One international training program entitled "Promoting Agriculture Technology to Improve Productivity and Net Returns for Smallholder Farmers" was conducted in Accra, Ghana, on January 23-27, 2017. The program was attended by 43 participants (including nine women) representing nine countries (Ethiopia, Ghana, Kenya, Lesotho, Mozambique, Nigeria, Rwanda, Uganda, and USA). Publications by IFDC staff members included:

1. Agyin-Birikorang, S., J. Fugice, U. Singh, J. Sanabria, and S. Choudhuri. 2017. Nitrogen Uptake Kinetics for Key Staple Cereal Crops in Different Agro-Ecological Regions of the World. *Journal of Plant Nutrition*, 40(7):995-1023.
2. Dimkpa, C., P. Bindraban,, J. Fugice,, S. Agyin-Birikorang,, U. Singh,, and D. Hellums. 2017. Composite Micronutrient Nanoparticles and salts Decrease Drought Stress in Soybean. *Agronomy for Sustainable Development*, 37:5.
3. Winings, J.H., X. Yin, S. Agyin-Birikorang, U. Singh, J. Sanabria, H.J. Savoy, F.L. Allen, and A.M. Saxton. 2017. Agronomic Effectiveness of an Organically Enhanced Nitrogen Fertilizer. *Nutr. Cycl. Agroecosyst.* DOI: 10.1007/s10705-017-9846-x.
4. Winings, J.H., X. Yin, S. Agyin-Birikorang, U. Singh, J. Sanabria, H.J. Savoy, F.L. Allen, and A.M. Saxton. 2017. Changes of Soil Microbial Population and Structure Under Short-Term Application of an Organically Enhanced Nitrogen Fertilizer. *Soil Sci.*, 181(11-12):494-502.
5. Gaihre, Y.K., U. Singh, I. Jahan, and G. Hunter. 2017. Improved Nitrogen Use Efficiency in Lowland Rice Fields for Food Security. *Fertilizer Focus*, March/April, 48-51.

6. Nand, M.M., V. Iese, U. Singh, M. Wairiul, A. Jokhan, and R. Prakash. 2016. Evaluation of Decision Support System for Agrotechnology Transfer SUBSTOR Potato Model (v4.5) Under Tropical Conditions. *The South Pacific Journal of Natural and Applied Sciences*, 34(1):1-11.
7. Huda, A., Y.K. Gaihre, M.R. Islam, U. Singh, M.R. Islam, J. Samaria, M.A. Satter, H. Afroz, A. Halder, and M. Jahiruddin. 2016. Floodwater Ammonium, Nitrogen Use Efficiency and Rice Yields with Fertilizer Deep Placement and Alternate Wetting and Drying Under Triple Rice Cropping Systems. *Nutr. Cycl. Agroecosyst.*, 104(1):53-66.
8. Islam, S.M.M., Y.K. Gaihre, A.L. Shah, U. Singh, M.I.U. Sarkar, M.A. Satter, J. Sanabria, and J.C. Biswas. 2016. Rice Yields and Nitrogen Use Efficiency with Different Fertilizers and Water Management Under Intensive Lowland Rice Cropping Systems in Bangladesh. *Nutr. Cycl. Agroecosyst.*, 106:143-156.
9. Nagarajan, L., A. Naseem, and C. Pray, 2016. The Political Economy of Genetically Modified Maize in Kenya. *AgBioForum*, 19(2):198-214.

3.2 Workshop-Role of Fertilizers in Climate Smart Agriculture

Agricultural intensification has been a major engine of growth for global development and the overall global economy. Productive agriculture has provided the foundation for food security, preservation of marginal or biodiverse lands and improved livelihoods for rural populations. However, agriculture places significant pressure on fertile land and water resources and requires significant amounts of energy (including energy required for the production of mineral fertilizers), resulting in environmental consequences. Agriculture not only contributes to climate change through its contribution to greenhouse gases (GHGs), but it is also affected by climate change. Some of the most detrimental effects are predicted for developing countries exposed to rising sea levels (e.g., Bangladesh, Myanmar) or erratic heavy rainfall followed by longer duration droughts in a number of countries in SSA.

During this reporting period, work was initiated on a document explaining the role of fertilizers in addressing climate change. This document will serve as the basis for organizing the workshop currently planned for the final quarter of 2017. In addition, a paper highlighting the importance of fertilizers to food security for the increasing global population in the face of changing climatic conditions was prepared for presentation at the International Fertilizer Society meeting in June.

3.3 Prepare Updated Manuals for Fertilizer Physical Properties Testing and Bulk Blending

With the increasing need for balanced plant nutrition, a number of fertilizer bulk blending facilities are being promoted and built in SSA. Previous studies by IFDC in West Africa indicated that adulteration of straight fertilizers was not a widespread issue and that fertilizer quality issues were primarily related to blended products. Similar results are being found for granular fertilizers in East and Southern Africa (specifically Kenya). In order to assist in assessing fertilizer quality and the production of quality fertilizers blends, IFDC is preparing two updated manuals. The first manual focuses on testing the physical properties of fertilizers and represents an update of the last IFDC *Manual for Determining Physical Properties of Fertilizers* published in the early 1990s. This new manual is complete except for new data on physical properties of various fertilizers. Currently, a number of fertilizer products produced in North America are being subjected to physical properties testing. Data generated from these tests, along with additional data to be generated over the next several months, will be used to complete the remaining tables in the manual. The second manual focuses on correct procedures, formulations, and appropriate technologies for producing fertilizer blends. No activity occurred during this reporting period.

3.4 Collaboration with Universities

During the last decade, IFDC has suffered the loss of considerable scientific staff due to retirements/superannuation. Due to limited funding for research activities, IFDC was not able to replace this expertise. In an effort to rebuild research capabilities and provide additional expertise, IFDC is seeking collaborative relationships with universities to gain additional scientific guidance and senior-level expertise in areas no longer represented at IFDC (e.g., organic/polymer chemist, process engineering, geologist, marketing specialist). It is anticipated that these collaborations will strengthen IFDC’s scientific work and reputation.

IFDC has initiated collaboration with the Universities of Florida and Tennessee. Activities are designed to update and design new tools for assessing crops' climate resilience and Zn nutrition in staple crops. Discussions are planned for early May to discuss a major collaborative activity with Kansas State University.

Table 8. Summary of Activities and Deliverables for Workstreams 1, 2, and 3 for FY17 (October 1, 2016-March 30, 2017)

Theme/Activities	Countries	Output/Deliverable
Workstream 1: Improved Soil Fertility and Plant Nutrient Management Technologies and Practices Made Available for Dissemination by IFDC and Other Public and Private Sector Actors		
1.1 Technologies Refined and Adapted for Climate Resilience		
1.1.1 Technologies and best management practices developed and validated	Bangladesh, Myanmar, Ghana	Protocols, field trials to identify appropriate nutrient management strategies promoting climate resilience in rice, maize, and vegetables, scientific publications
1.1.2 Quantifying climate mitigation role of enhanced efficiency fertilizers and practices	Global	Protocols for rice and wheat, quantification of N_2O and NO emissions for specific management practices
1.2 Balanced Plant Nutrition Through Improved Fertilizer Product Recommendations		
1.2.1 Evaluation of micronutrients to increase N use efficiency	Global	Protocols, greenhouse trials evaluating the impact of secondary and micronutrients on N use efficiency, evaluation of micronutrient formulations and methods of application, improved fertilizer blends for maize-legume cropping systems, scientific publications
1.2.2 Improved agricultural efficiency of locally available phosphate rock to cost effectively improve agricultural productivity in marginal soils	Global	Using Ghana soils data and PRDSS to determine expected relative agronomic efficiency of Kodjari PR as a source of P
1.2.3 Development of soil fertility maps to facilitate site- and crop-specific fertilizer recommendations for smallholder farmers for increased economic and environmental benefits from fertilizer use	Ghana	Report on value of portable soil test kits, completion of soil analyses, collection of tissue samples
1.3 Fertilizer Quality Survey to Support Policy Efforts to Harmonize Fertilizer Regulations in East and Southern Africa		
1.3.1 Fertilizer quality assessments to support policy efforts to harmonize fertilizer regulations	Zambia and Uganda	Completion of Kenya technical report; completion of Zambia FQA survey; analysis of Zambian fertilizer samples; preparation for Uganda FQA survey

Theme/Activities	Countries	Output/Deliverable
Workstream 2: Fertilizer Market Development, Policy Reforms, and Regulatory Structures Promoted		
2.1 Supporting Policy Reform Processes and Market Development		
2.1.1 Documenting policy reform processes and fertilizer market development	Specific countries in SSA and Asia (potentially Tanzania in collaboration with AFAP)	Two policy briefs – Ghana and Uganda (draft)
2.1.2 Providing technical support to policy reform and fertilizer market development processes (country level)	Kenya or Tanzania	FAO/IFDC collaboration to assess impact of centralized procurement of fertilizers in Tanzania; Final technical report
2.1.3 Engagement with partners in support of policy reforms (both country and regional level).	Department of Rural Economy and Agriculture (DREA), African Union Commission (AUC) – Malabo-CAADP technical networks Participating in various policy forums in partnership toward policy reforms and implementation with WAFP, AFAP, COMESA, IFPRI, MSU, ECOWAS, AU consortium, etc.	A number of presentations and contributions made to network technical support efforts to implement the Malabo Strategy Participation in a number of three policy reform meetings
	Collaboration with AGRA to assess/review fertilizer subsidy implementation in 11 countries in SSA	One synthesis report on fertilizer subsidy model(s) with recommendations in SSA (in partnership with AGRA)
2.1.4 IFDC – Alliance for African Partnership	Policy research study on the impact of fertilizer regulatory reforms in SSA	Proposal developed/awarded
2.1.5 Fostering policy dialogue – A joint policy workshop with AGRA on various models of fertilizer subsidies and the way forward in implementing fertilizer subsidies in Africa and elsewhere.	SSA	Proceedings from the dialogue; presentation at workshop IFDC-FAI Asia-Africa Subsidy Review published MSU-IFDC Subsidy Review published

Theme/Activities	Countries	Output/Deliverable
2.2 Impact Studies		
2.2.1 Agro-dealer development on input adoption, input market development, and access and sustainability	Zambia and Tanzania	Two country-level reports
2.2.2 Harmonization of fertilizer quality and regulatory frameworks (in collaboration with BFS-Workstream 1 activity on fertilizer quality), focusing on status of fertilizer quality regulatory frameworks in the East and Southern Africa region, specifically Kenya and Zambia, to identify potential benefits and costs of reforms	Zambia, Kenya	Presentation on the impact of fertilizer quality and harmonized regulatory policies in the ECOWAS region – WAFP workshop
2.3 Economic Studies		
2.3.1 Fertilizer cost-build-up/market margin analysis	Ethiopia, Ghana, Rwanda, Kenya, and Malawi	Fertilizer Cost Build-Up report for Kenya and Ghana completed One regional policy brief (West African countries)
2.3.2 Economics of soil- and fertilizer-related technologies (in collaboration with BFS-Workstream 1 activity on GHG emissions study/AAPI, Bangladesh)	Bangladesh	Graduate student (Rutgers) identified to work on LCA of urea deep placement

Theme/Activities	Countries	Output/Deliverable
2.4 Document Data on Fertilizer Markets and Trade		
2.4.1 The African Fertilizer Access Index (TAFAI) in partnership with AFAP, AGRA SSTP, and IFDC West Africa	SSA	IFDC/AFAP organizational meeting and workplan meeting
2.4.2 Documenting data on fertilizer markets and trade at the regional level for dissemination	SSA	Preparation for FAO-FOWG meeting
Cross-Cutting Issues Including Learning and Knowledge Management		
3.1 Conduct systematic data collection and analysis of IFDC information	Global	Nine journal articles published, six journal articles submitted for possible publication, three policy briefs published, ten presentations made at scientific and industry meetings, three abstracts submitted for "*International Conference on Bioeconomy in Transition*"
3.2 Conduct workshop on "Role of Fertilizers in Climate-Smart Agriculture"	Global	White paper for conference being drafted.
3.3 Updated manuals for fertilizer physical properties and bulk blending	Global	Physical properties determination for fertilizer samples from North America underway; two additional sets of samples to be analyzed for physical properties. Results will allow for completion of Fertilizer Manual
3.4 Collaboration with universities	Global	Collaborative activities with UF and UT
3.4.1 Literature review on effective nutrient management of compost and organic matter	SSA	On-going
3.5 Engagement in training and capacity-building activities related to nutrient management, balanced plant nutrition, fertilizer quality surveys, fertilizer market development, fertilizer market interventions, policy reforms and regulations (in collaboration with BFS-Workstream 1 activity on fertilizer quality)	SSA	Conducted International Training Program "Promoting Agriculture Technology to mprove Productivity and Net Returns for Smallholder Farmers"

Theme/Activities	Countries	Output/Deliverable

Appendix A. Effect of UDP Technology on Grain Yield and N Uptake of Submergence-Tolerant Rice Varieties in Northern Ghana

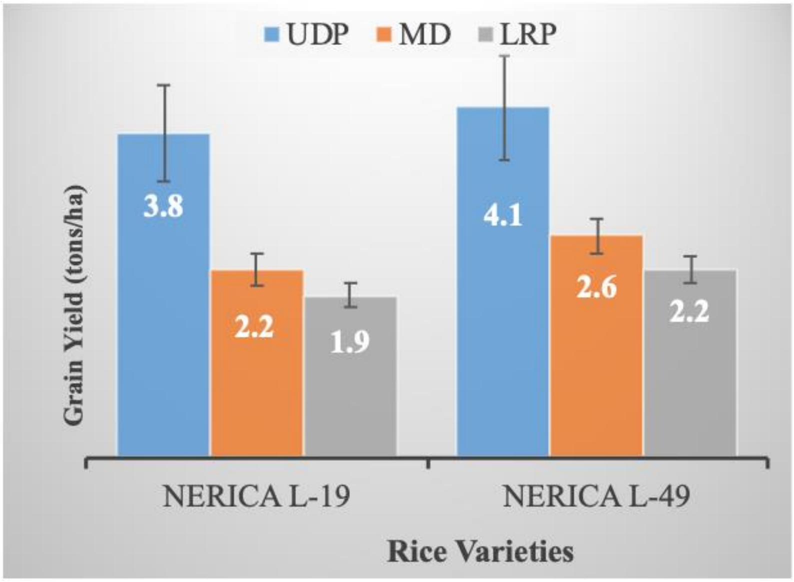

Figure A.1. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kpatarabogu in Northern Region

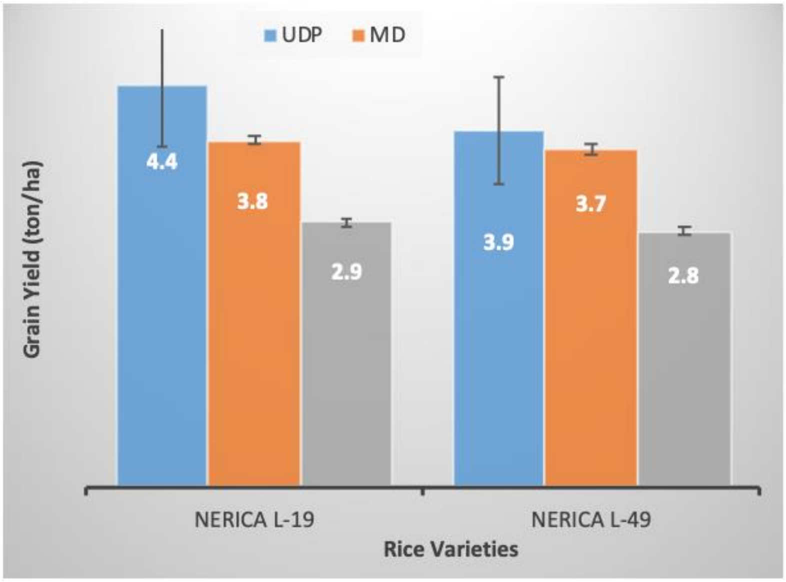

Figure A.2. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Bondando in Northern Region

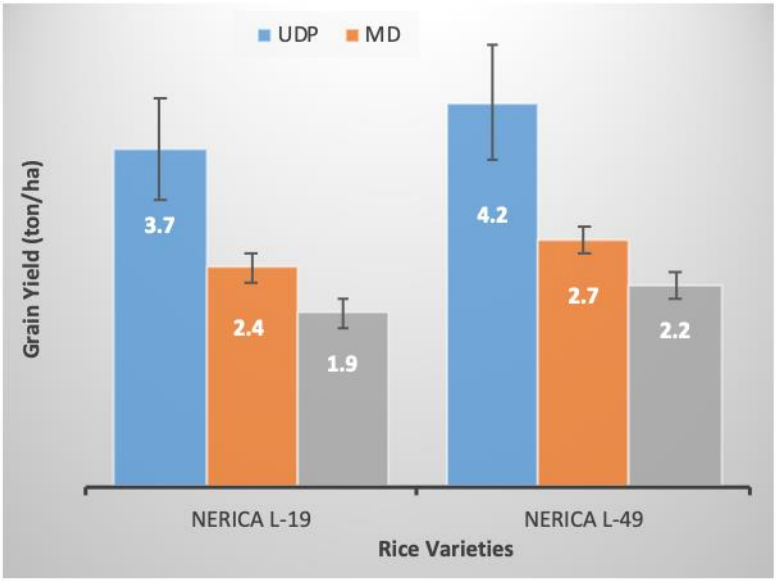

Figure A.3. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kpandu in Northern Region

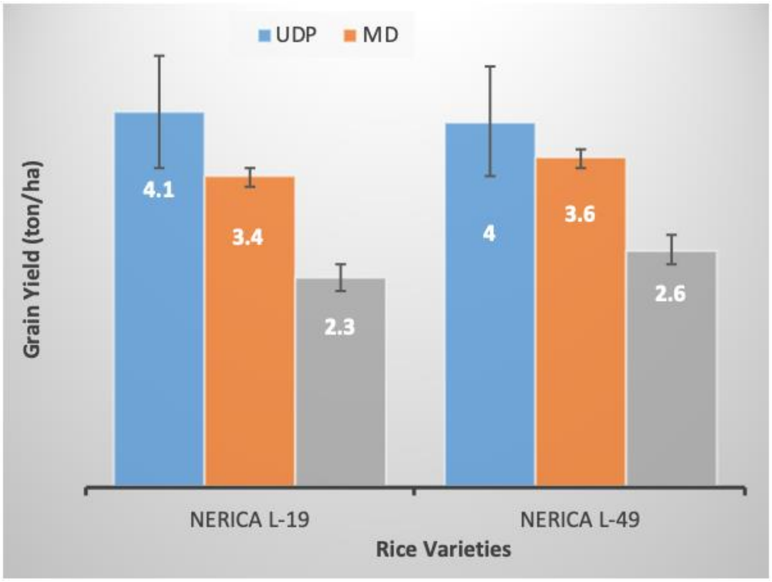

Figure A.4. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Chaggu in Upper East Region

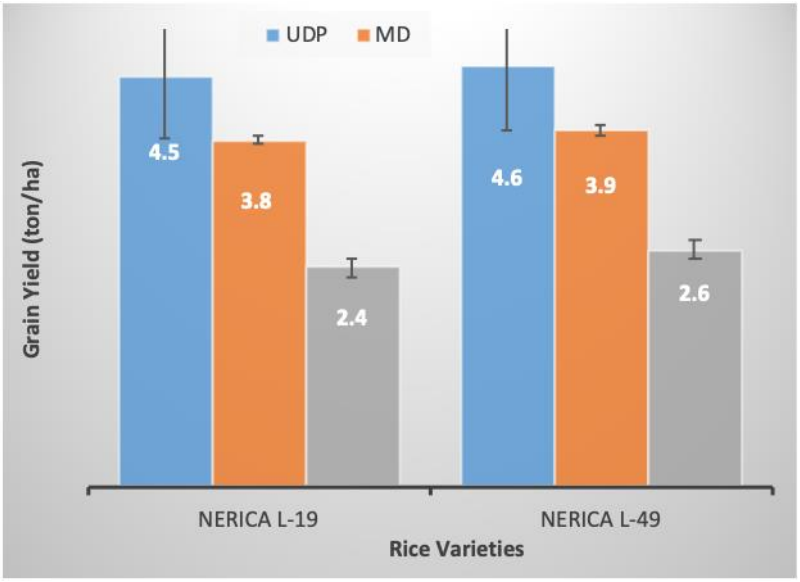

Figure A.5. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Nagli in Upper East Region

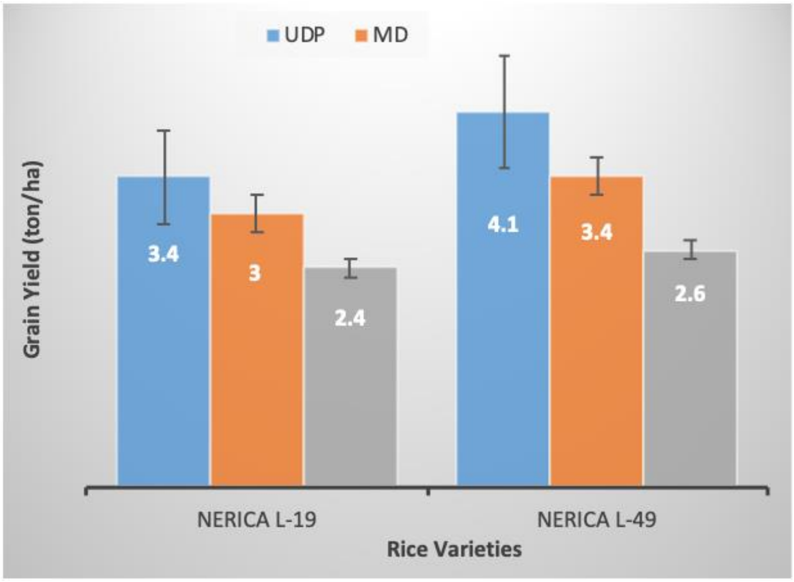

Figure A.6. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Widnaba in Upper West Region

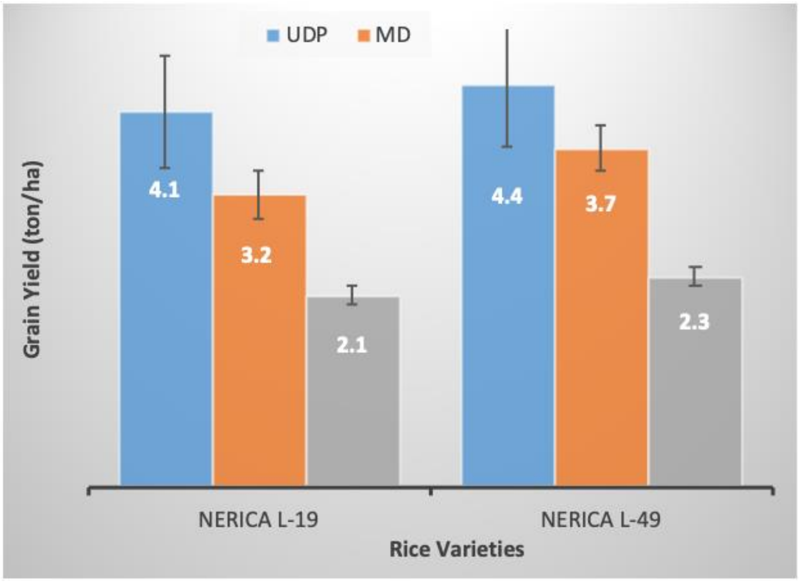

Figure A.7. Effects of UDP Technology Grain Yield of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kalbeo in Upper West Region

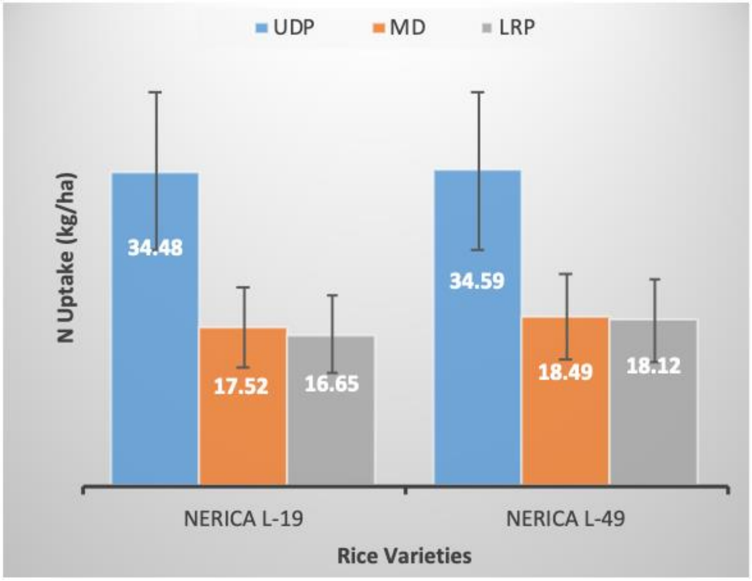

Figure A.8. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kpatarabogu in Northern Region

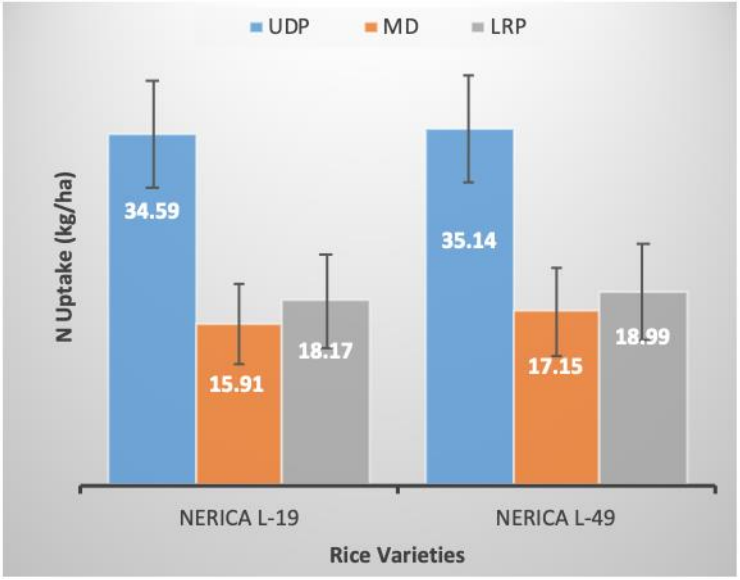

Figure A.9. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Bondando in Northern Region

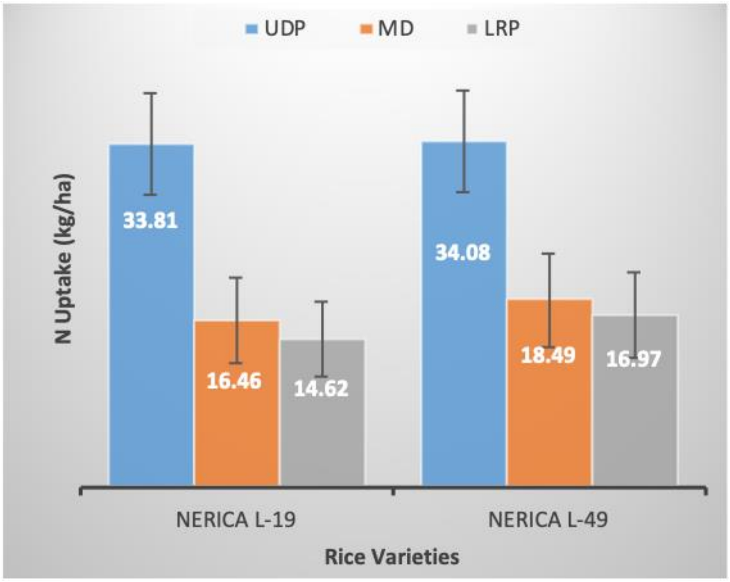

Figure A.10. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kpandu in Northern Region

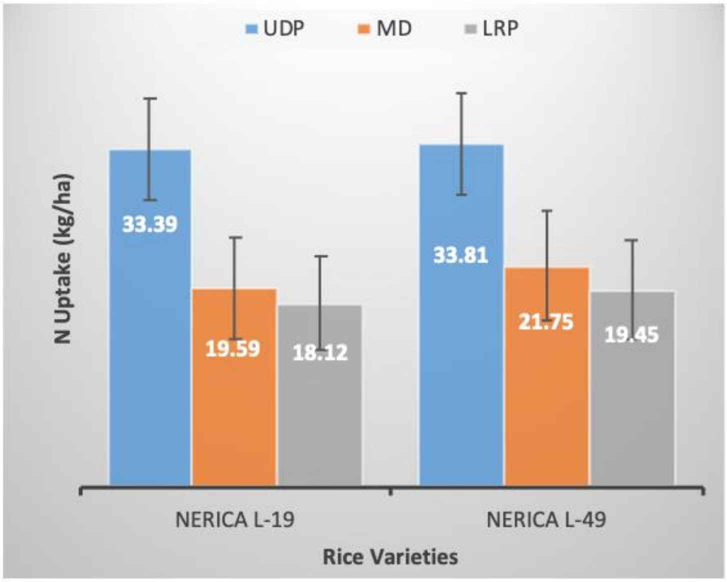

Figure A.11. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Chaggu in Upper East Region

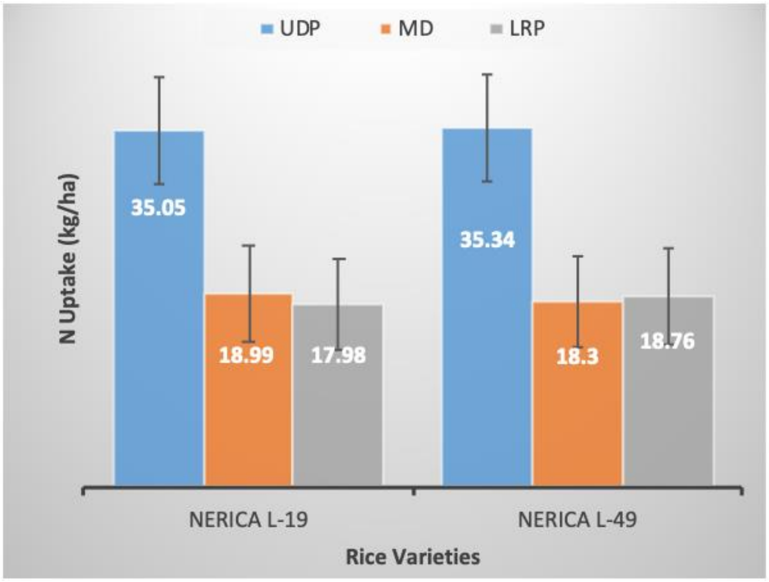

Figure A.12. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Nagli in Upper East Region

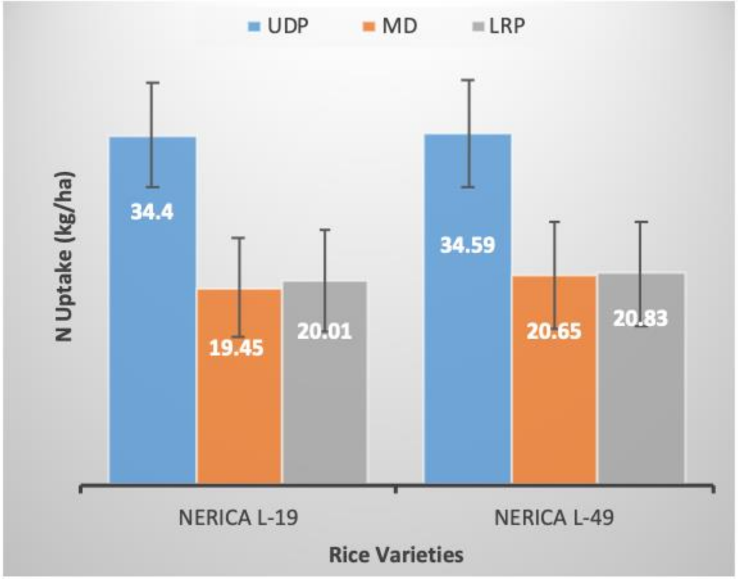

Figure A.13. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Widnaba in Upper West Region

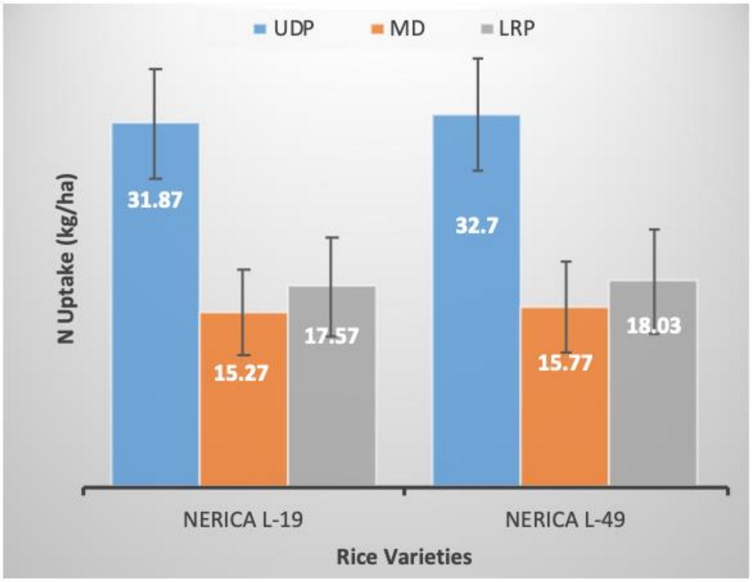

Figure A.14. Effects of UDP Technology N Uptake of Submergence-Tolerant Rice Varieties Grown at a Submergence Prone Site at Kalbeo in Upper West Region

Appendix B. Updated Results of Soil Analyses from Northern Ghana

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
Northern	Bole	52	47	4.84	6.42	6.14	5.94
	Bunkpurugu-Yunyoo	55	34	4.73	6.24	6.11	5.98
	Central Gonja	66	51	4.86	6.87	6.13	5.89
	Chereponi	63	49	4.69	7.03	5.99	5.86
	East Gonja	48	33	5.09	6.14	6.02	5.99
	East Mamprusi	49	42	4.93	6.34	6.14	5.86
	Gushegu	45	34	4.90	6.98	6.13	5.89
	Karaga	51	48	5.01	7.05	6.11	5.93
	Kpandai	52	47	5.00	6.43	6.21	5.82
	Kumbungu	49	49	4.91	6.54	6.11	5.89
	Mamprugo Moaduri	51	44	4.92	6.53	6.11	5.78
	Mion	45	30	4.90	6.72	6.13	5.94
	Nanumba North	49	12	4.83	5.98	6.21	4.98
	Nanumba South	47	36	4.97	7.06	6.14	5.89
	North Gonja	49	33	4.99	6.33	6.03	5.82
	Saboba	60	34	4.86	6.82	6.03	5.82
	Sagnarigu	51	20	4.76	6.34	6.06	5.89
	Savelugu-Nanton	54	21	4.95	7.00	6.12	5.25
	Sawla-Tuna-Kalba	45	33	4.92	6.98	6.16	5.87
	Tamale Metropolitan	74	42	5.10	6.54	6.09	5.78
	Tatale Sangule	58	38	5.12	6.34	6.10	5.86
	Tolon	51	41	4.95	6.43	6.00	5.84
	West Gonja	49	22	4.93	6.57	5.99	5.91
	West Mamprusi	48	30	5.11	6.24	6.02	5.92
	Yendi Municipal	49	30	5.02	6.89	6.12	5.98
	Zabzugu	52	33	4.99	6.33	6.11	5.94
Upper East	Bawku Municipal	54	39	4.54	6.77	5.89	5.74
	Bawku West	59	20	4.52	6.69	5.86	5.75
	Binduri	56	35	4.65	6.88	5.67	5.74
	Bolgatanga Municipal	59	41	4.55	6.78	5.89	5.89
	Bongo	59	20	4.53	6.15	5.68	5.01
	Builsa	59	43	4.57	6.34	5.71	5.77
	Builsa South	56	50	4.22	6.58	5.56	5.56
	Garu-Tempane	48	20	4.54	6.39	5.74	5.76
	Kassena Nankana East	60	18	4.51	6.03	5.66	5.58
	Kassena Nankana West	54	49	4.56	6.38	5.64	5.76
	Nabdam	59	43	4.38	6.13	5.67	5.66
	Pusiga	55	12	4.56	6.54	5,78	5.63
	Talensi	60	48	4.56	6.19	5,59	5.68
Upper West	Daffiama Bussie Issa	55	40	4.72	6.85	5.97	6.23
	Jirapa	60	43	4.76	6.73	6.21	6.34
	Lambussie Karni	55	40	4.72	6.67	6.15	6.23
	Lawra	58	19	4.74	7.14	5.98	6.02
	Nadowli	62	45	4.69	6.45	6.56	6.65
	Nandom	60	44	4.78	6.56	6.40	6.48
	Sissala East	58	53	4.68	7.06	6.78	6.79
	Sissala West	62	55	4.77	6.54	5.99	6.32
	Wa East	58	53	4.76	7.09	6.23	6.45
	Wa Municipal	63	54	4.77	6.56	6.34	6.45
	Wa West	66	53	4.79	6.48	5.89	6.34

Table B.1. Updated Results of Soil Analysis for Soil pH

Region	District	# samples collected	# samples analyzed	Min	Max	Median	Mode
				---------------------% -----------------			
Northern	Bole	52	47	0.05	0.20	0.09	0.15
	Bunkpurugu-Yunyoo	55	34	0.07	0.16	0.12	0.13
	Central Gonja	66	51	0.05	0.32	0.11	0.21
	Chereponi	63	49	0.03	0.29	0.09	0.16
	East Gonja	48	33	0.02	0.21	0.10	0.13
	East Mamprusi	49	42	0.02	0.35	0.14	0.18
	Gushegu	45	34	0.05	0.33	0.14	0.21
	Karaga	51	48	0.04	0.42	0.13	0.21
	Kpandai	52	47	0.05	0.37	0.12	0.22
	Kumbungu	49	49	0.03	0.54	0.09	0.26
	Mamprugo Moaduri	51	44	0.04	0.53	0.08	0.25
	Mion	45	30	0.05	0.46	0.11	0.30
	Nanumba North	49	12	0.03	0.23	0.13	0.26
	Nanumba South	47	36	0.03	0.55	0.13	0.36
	North Gonja	49	33	0.04	0.34	0.16	0.32
	Saboba	60	34	0.06	0.53	0.13	0.28
	Sagnarigu	51	20	0.04	0.45	0.08	0.25
	Savelugu-Nanton	54	21	0.02	0.52	0.12	0.26
	Sawla-Tuna-Kalba	45	33	0.03	0.39	0.16	0.23
	Tamale Metropolitan	74	42	0.05	0.44	0.09	0.22
	Tatale Sangule	58	38	0.02	0.34	0.11	0.16
	Tolon	51	41	0.06	0.52	0.09	0.19
	West Gonja	49	22	0.05	0.57	0.08	0.27
	West Mamprusi	48	30	0.04	0.45	0.12	0.32
	Yendi Municipal	49	30	0.02	0.57	0.11	0.24
	Zabzugu	52	33	0.05	0.48	0.14	0.26
Upper East	Bawku Municipal	54	39	0.03	0.48	0.08	0.24
	Bawku West	59	20	0.02	0.57	0.13	0.32
	Binduri	56	35	0.04	0.45	0.16	0.27
	Bolgatanga Municipal	59	41	0.05	0.57	0.13	0.19
	Bongo	59	20	0.04	0.52	0.13	0.16
	Builsa	59	43	0.03	0.45	0.11	0.26
	Builsa South	56	50	0.05	0.53	0.11	0.25
	Garu-Tempane	48	20	0.02	0.34	0.09	0.28
	Kassena Nankana East	60	18	0.02	0.55	0.16	0.32
	Kassena Nankana West	54	49	0.03	0.23	0.12	0.25
	Nabdam	59	43	0.05	0.52	0.16	0.26
	Pusiga	55	12	0.03	0.34	0.13	0.22
	Talensi	60	48	0.05	0.44	0.13	0.21
Upper West	Daffiama Bussie Issa	55	40	0.04	0.63	0.16	0.28
	Jirapa	60	43	0.02	0.41	0.16	0.32
	Lambussie Karni	55	40	0.04	0.54	0.13	0.44
	Lawra	58	19	0.04	0.47	0.10	0.32
	Nadowli	62	45	0.06	0.63	0.11	0.37
	Nandom	60	44	0.05	0.45	0.13	0.30
	Sissala East	58	53	0.04	0.43	0.11	0.33
	Sissala West	62	55	0.06	0.26	0.19	0.23
	Wa East	58	53	0.02	0.35	0.15	0.19
	Wa Municipal	63	54	0.02	0.39	0.15	0.27
	Wa West	66	53	0.04	0.69	0.17	0.27

Table B.2. Updated Results of Soil Analysis for Soil Organic Carbon (OC) Concentration

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
				----------------------g/kg-------------------			
Northern	Bole	52	47	0.45	1.79	1.13	1.20
	Bunkpurugu-Yunyoo	55	34	0.45	2.04	1.12	1.20
	Central Gonja	66	51	0.30	2.13	0.75	1.25
	Chereponi	63	49	0.38	2.25	0.95	1.30
	East Gonja	48	33	0.52	2.38	1.31	1.08
	East Mamprusi	49	42	0.92	2.69	1.19	1.39
	Gushegu	45	34	0.48	2.05	1.20	1.07
	Karaga	51	48	0.46	1.78	1.15	1.05
	Kpandai	52	47	0.40	1.79	1.00	1.10
	Kumbungu	49	49	0.46	2.02	1.15	0.96
	Mamprugo Moaduri	51	44	0.60	1.96	1.51	1.14
	Mion	45	30	0.54	1.68	1.36	1.31
	Nanumba North	49	12	0.46	2.43	1.15	1.08
	Nanumba South	47	36	0.48	2.23	1.19	1.13
	North Gonja	49	33	0.40	2.11	1.00	1.10
	Saboba	60	34	0.50	1.68	1.26	1.28
	Sagnarigu	51	20	0.45	1.33	1.13	0.90
	Savelugu-Nanton	54	21	0.58	1.99	1.45	0.72
	Sawla-Tuna-Kalba	45	33	0.54	2.32	1.37	1.44
	Tamale Metropolitan	74	42	0.53	2.04	1.34	0.90
	Tatale Sangule	58	38	0.47	2.09	1.17	1.15
	Tolon	51	41	0.38	2.01	0.95	0.96
	West Gonja	49	22	0.50	2.43	1.26	1.10
	West Mamprusi	48	30	0.50	2.24	1.26	0.96
	Yendi Municipal	49	30	0.44	2.59	1.10	1.21
	Zabzugu	52	33	0.40	2.14	1.00	1.12
Upper East	Bawku Municipal	54	39	0.41	1.84	0.43	0.64
	Bawku West	59	20	0.43	1.23	0.55	0.81
	Binduri	56	35	0.42	1.55	0.78	0.86
	Bolgatanga Municipal	59	41	0.44	1.95	0.67	0.95
	Bongo	59	20	0.41	1.89	0.69	0.96
	Builsa	59	43	0.41	1.89	0.66	0.97
	Builsa South	56	50	0.46	1.96	0.69	0.98
	Garu-Tempane	48	20	0.43	1.86	0.79	0.99
	Kassena Nankana East	60	18	0.46	2.25	0.58	1.02
	Kassena Nankana West	54	49	0.40	2.20	0.67	1.03
	Nabdam	59	43	0.42	2.07	0.64	1.08
	Pusiga	55	12	0.42	1.81	0.65	1.15
	Talensi	60	48	0.27	1.65	0.73	1.17
Upper West	Daffiama Bussie Issa	55	40	0.31	1.70	0.45	0.77
	Jirapa	60	43	0.31	1.14	0.51	0.66
	Lambussie Karni	55	40	0.21	1.44	0.51	0.43
	Lawra	58	19	0.36	1.80	0.60	0.54
	Nadowli	62	45	0.33	1.75	0.42	0.64
	Nandom	60	44	0.32	1.74	0.49	0.66
	Sissala East	58	53	0.33	2.08	0.53	0.78
	Sissala West	62	55	0.31	2.04	0.50	0.58
	Wa East	58	53	0.33	1.92	0.34	0.63
	Wa Municipal	63	54	0.35	1.68	0.61	0.68
	Wa West	66	53	0.35	1.53	0.56	0.72

Table B.3. Updated Results of Soil Analysis for Soil Total Nitrogen (N) Concentration

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
				---------------------mg/kg-----------------			
Northern	Bole	52	47	1.76	54.34	9.43	10.64
	Bunkpurugu-Yunyoo	55	34	1.82	34.23	10.19	11.50
	Central Gonja	66	51	1.77	26.44	8.45	9.54
	Chereponi	63	49	1.98	23.32	9.16	10.34
	East Gonja	48	33	2.01	34.57	9.33	10.53
	East Mamprusi	49	42	3.22	27.89	9.69	10.94
	Gushegu	45	34	1.78	43.22	10.33	11.66
	Karaga	51	48	1.84	37.33	9.98	11.27
	Kpandai	52	47	1.93	45.39	8.35	9.43
	Kumbungu	49	49	1.98	43.44	8.98	10.14
	Mamprugo Moaduri	51	44	2.01	45.38	11.04	12.46
	Mion	45	30	1.87	29.43	10.28	11.60
	Nanumba North	49	12	1.74	34.56	9.09	10.26
	Nanumba South	47	36	1.86	41.47	10.23	11.55
	North Gonja	49	33	1.92	43.55	9.93	11.21
	Saboba	60	34	1.78	29.87	11.26	12.71
	Sagnarigu	51	20	1.98	34.36	10.42	11.76
	Savelugu-Nanton	54	21	2.01	37.45	9.93	11.21
	Sawla-Tuna-Kalba	45	33	2.03	39.72	8.96	10.11
	Tamale Metropolitan	74	42	1.89	41,22	10.04	11.33
	Tatale Sangule	58	38	2.23	25.26	11.29	12.74
	Tolon	51	41	1.89	27.42	9.99	11.28
	West Gonja	49	22	1.78	43.22	10.06	11.36
	West Mamprusi	48	30	1.94	39.48	8.46	9.55
	Yendi Municipal	49	30	1,88	46.38	9.48	10.70
	Zabzugu	52	33	1.79	39.62	10.41	11.75
Upper East	Bawku Municipal	54	39	1.62	33.08	11.30	11.26
	Bawku West	59	20	1.72	20.99	11.22	11.19
	Binduri	56	35	2.03	19.34	12.68	12.64
	Bolgatanga Municipal	59	41	1.83	28.67	11.16	11.12
	Bongo	59	20	1.81	26.30	11.71	11.67
	Builsa	59	43	1.62	22.87	12.65	12.61
	Builsa South	56	50	1.75	33.34	11.16	11.12
	Garu-Tempane	48	20	1.70	31.74	11.49	11.46
	Kassena Nankana East	60	18	1.59	26.46	10.21	10.18
	Kassena Nankana West	54	49	1.71	22.53	11.55	11.51
	Nabdam	59	43	1.83	34.74	12.40	12.36
	Pusiga	55	12	1.83	26.46	10.48	10.45
	Talensi	60	48	1.81	17.85	10.29	10.26
Upper West	Daffiama Bussie Issa	55	40	1.21	34.45	8.03	9.99
	Jirapa	60	43	1.23	31.74	8.18	8.88
	Lambussie Karni	55	40	1.23	43.17	9.68	10.78
	Lawra	58	19	1.07	37.53	7.97	11.00
	Nadowli	62	45	1.14	54.72	8.97	10.18
	Nandom	60	44	1.18	52.10	8.70	9.70
	Sissala East	58	53	1.09	43.42	9.87	8.95
	Sissala West	62	55	1.21	57.01	9.13	11.03
	Wa East	58	53	1.37	43.43	9.90	9.11
	Wa Municipal	63	54	1.16	29.30	8.76	9.76
	Wa West	66	53	1.14	43.17	8.76	10.78

Table B.4. Updated Results of Soil Analysis for Available Phosphorus (P) Concentration

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
				---------------------mg/kg-----------------			
Northern	Bole	52	47	4.50	416.30	47.58	104.07
	Bunkpurugu-Yunyoo	55	34	4.45	456.99	41.53	114.25
	Central Gonja	66	51	2.98	522.72	55.51	130.68
	Chereponi	63	49	3.76	520.63	47.58	130.16
	East Gonja	48	33	5.19	392.30	31.09	98.08
	East Mamprusi	49	42	9.17	487.25	39.23	121.81
	Gushegu	45	34	4.78	555.06	46.43	138.77
	Karaga	51	48	4.56	566.54	39.23	141.64
	Kpandai	52	47	3.99	603.06	56.55	150.76
	Kumbungu	49	49	4.57	468.47	49.56	117.12
	Mamprugo Moaduri	51	44	6.00	523.76	46.85	130.94
	Mion	45	30	5.42	415.25	48.72	103.81
	Nanumba North	49	12	4.56	495.59	54.15	123.90
	Nanumba South	47	36	4.75	475.77	47.68	118.94
	North Gonja	49	33	3.98	565.50	52.38	141.37
	Saboba	60	34	5.02	626.01	56.65	156.50
	Sagnarigu	51	20	4.49	476.81	46.95	119.20
	Savelugu-Nanton	54	21	5.78	416.30	60.31	104.07
	Sawla-Tuna-Kalba	45	33	5.43	475.77	41.63	118.94
	Tamale Metropolitan	74	42	5.32	498.72	41.63	124.68
	Tatale Sangule	58	38	4.67	956.86	45.70	239.21
	Tolon	51	41	3.76	541.50	95.69	135.37
	West Gonja	49	22	4.99	392.30	62.60	98.08
	West Mamprusi	48	30	5.01	310.92	52.06	77.73
	Yendi Municipal	49	30	4.38	464.29	52.27	116.07
	Zabzugu	52	33	3.99	469.51	49.87	117.38
Upper East	Bawku Municipal	54	39	18.26	427.08	47.68	121.81
	Bawku West	59	20	20.70	444.87	54.15	118.94
	Binduri	56	35	20.74	498.25	46.43	124.68
	Bolgatanga Municipal	59	41	18.15	428.01	46.95	239.21
	Bongo	59	20	35.03	561.94	56.65	138.77
	Builsa	59	43	17.42	372.75	48.72	119.20
	Builsa South	56	50	15.20	507.62	52.38	130.16
	Garu-Tempane	48	20	17.15	467.35	47.58	118.94
	Kassena Nankana East	60	18	14.36	858.93	45.70	103.81
	Kassena Nankana West	54	49	17.84	486.08	95.69	141.37
	Nabdam	59	43	19.18	427.08	41.63	123.90
	Pusiga	55	12	14.36	437.38	39.23	156.50
	Talensi	60	48	20.32	447.68	41.63	135.37
Upper West	Daffiama Bussie Issa	55	40	2.47	279.07	42.24	123.05
	Jirapa	60	43	6.03	312.56	36.21	115.16
	Lambussie Karni	55	40	3.14	352.51	44.19	131.18
	Lawra	58	19	3.57	268.49	36.62	98.14
	Nadowli	62	45	3.00	233.83	38.01	117.13
	Nandom	60	44	2.62	318.43	40.85	133.65
	Sissala East	58	53	3.30	293.17	37.11	127.61
	Sissala West	62	55	2.95	538.81	35.65	147.95
	Wa East	58	53	3.57	267.91	32.47	112.69
	Wa Municipal	63	54	3.07	274.37	30.60	112.44
	Wa West	66	53	5.76	252.13	35.78	226.15

Table B.5. Updated Results of Soil Analysis for Soil Exchangeable Potassium (K) Concentration

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
				---------------------mg/kg------------------			
Northern	Bole	52	47	0.86	10.22	1.73	1.56
	Bunkpurugu-Yunyoo	55	34	1.08	10.11	0.97	0.87
	Central Gonja	66	51	1.08	6.77	1.30	1.10
	Chereponi	63	49	1.14	8.54	1.49	1.47
	East Gonja	48	33	1.15	11.79	2.99	1.37
	East Mamprusi	49	42	1.15	12.84	1.49	1.30
	Gushegu	45	34	1.26	10.86	1.77	1.69
	Karaga	51	48	1.28	10.36	1.22	1.17
	Kpandai	52	47	1.29	9.06	1.63	1.17
	Kumbungu	49	49	1.29	10.38	1.43	1.32
	Mamprugo Moaduri	51	44	1.31	13.63	1.69	1.33
	Mion	45	30	1.31	12.31	1.52	1.10
	Nanumba North	49	12	1.31	10.36	1.22	1.31
	Nanumba South	47	36	1.34	10.79	1.30	1.75
	North Gonja	49	33	1.37	9.04	1.45	2.68
	Saboba	60	34	1.38	11.40	1.63	1.34
	Sagnarigu	51	20	1.44	10.20	1.77	1.28
	Savelugu-Nanton	54	21	1.44	13.13	1.88	1.16
	Sawla-Tuna-Kalba	45	33	1.44	12.34	1.30	1.46
	Tamale Metropolitan	74	42	1.49	12.09	1.56	1.33
	Tatale Sangule	58	38	1.53	10.61	1.63	1.46
	Tolon	51	41	1.56	8.54	1.46	1.52
	West Gonja	49	22	1.56	11.34	1.95	1.39
	West Mamprusi	48	30	1.66	11.38	1.49	1.59
	Yendi Municipal	49	30	1.73	9.95	1.55	1.58
	Zabzugu	52	33	2.64	9.06	1.47	1.40
Upper East	Bawku Municipal	54	39	1.61	8.47	1.77	1.10
	Bawku West	59	20	1.21	6.38	1.56	1.52
	Binduri	56	35	1.50	7.92	1.55	2.68
	Bolgatanga Municipal	59	41	1.75	9.21	1.69	1.40
	Bongo	59	20	1.86	9.81	1.63	1.33
	Builsa	59	43	1.53	8.06	1.49	1.17
	Builsa South	56	50	1.47	7.75	2.99	1.34
	Garu-Tempane	48	20	1.29	6.77	1.22	1.39
	Kassena Nankana East	60	18	1.47	7.74	1.49	1.69
	Kassena Nankana West	54	49	1.54	8.11	1.30	1.59
	Nabdam	59	43	2.95	15.56	1.88	1.37
	Pusiga	55	12	1.67	8.80	1.52	1.10
	Talensi	60	48	1.21	6.38	1.22	1.46
Upper West	Daffiama Bussie Issa	55	40	1.23	7.68	1.17	1.43
	Jirapa	60	43	1.24	9.54	1.34	1.26
	Lambussie Karni	55	40	1.49	11.09	2.69	1.25
	Lawra	58	19	0.97	9.80	1.59	1.36
	Nadowli	62	45	1.21	9.70	1.10	2.41
	Nandom	60	44	1.34	8.15	1.52	1.20
	Sissala East	58	53	0.97	9.31	1.37	0.99
	Sissala West	62	55	1.40	9.76	1.10	1.05
	Wa East	58	53	2.37	10.73	1.69	1.52
	Wa Municipal	63	54	1.18	11.60	1.40	1.23
	Wa West	66	53	1.03	7.68	1.39	0.99

Table B.6. Updated Results of Soil Analysis for Soil Sulfur (SO_4-S) Concentration

Region	District	# samples collected	# samples analyzed	Min	Max	Median	Mode
				--------------------mg/kg-----------------			
Northern	Bole	52	47	bdl+	0.46	0.29	0.20
	Bunkpurugu-Yunyoo	55	34	bdl	0.53	0.22	0.18
	Central Gonja	66	51	bdl	0.89	0.27	0.17
	Chereponi	63	49	bdl	1.04	0.31	0.20
	East Gonja	48	33	bdl	0.67	0.38	0.21
	East Mamprusi	49	42	bdl	0.56	0.44	0.27
	Gushegu	45	34	bdl	0.52	0.27	0.19
	Karaga	51	48	bdl	0.48	0.27	0.23
	Kpandai	52	47	bdl	0.62	0.26	0.21
	Kumbungu	49	49	bdl	0.54	0.27	0.19
	Mamprugo Moaduri	51	44	bdl	0.58	0.21	0.21
	Mion	45	30	bdl	0.61	0.45	0.22
	Nanumba North	49	12	bdl	0.49	0.23	0.22
	Nanumba South	47	36	bdl	1.02	0.25	0.20
	North Gonja	49	33	bdl	0.53	0.25	0.39
	Saboba	60	34	bdl	0.51	0.24	0.18
	Sagnarigu	51	20	bdl	0.72	0.21	0.23
	Savelugu-Nanton	54	21	bdl	0.63	0.24	0.23
	Sawla-Tuna-Kalba	45	33	bdl	0.48	0.26	0.24
	Tamale Metropolitan	74	42	bdl	0.55	0.22	0.23
	Tatale Sangule	58	38	bdl	0.62	0.31	0.39
	Tolon	51	41	bdl	0.58	0.24	0.34
	West Gonja	49	22	bdl	0.63	0.23	0.27
	West Mamprusi	48	30	bdl	0.61	0.20	0.24
	Yendi Municipal	49	30	bdl	0.56	0.21	0.20
	Zabzugu	52	33	bdl	0.71	0.23	0.25
Upper East	Bawku Municipal	54	39	bdl	0.65	0.26	0.14
	Bawku West	59	20	bdl	0.80	0.25	0.13
	Binduri	56	35	bdl	0.92	0.30	0.16
	Bolgatanga Municipal	59	41	bdl	0.57	0.35	0.19
	Bongo	59	20	bdl	0.55	0.26	0.14
	Builsa	59	43	bdl	0.48	0.50	0.26
	Builsa South	56	50	bdl	0.44	0.27	0.14
	Garu-Tempane	48	20	bdl	0.50	0.43	0.23
	Kassena Nankana East	60	18	bdl	0.55	0.31	0.16
	Kassena Nankana West	54	49	bdl	0.46	0.24	0.13
	Nabdam	59	43	bdl	0.64	0.34	0.18
	Pusiga	55	12	bdl	0.49	0.30	0.16
	Talensi	60	48	bdl	0.48	0.27	0.14
Upper West	Daffiama Bussie Issa	55	40	bdl	0.39	0.27	0.14
	Jirapa	60	43	bdl	0.38	0.34	0.13
	Lambussie Karni	55	40	bdl	0.45	0.28	0.16
	Lawra	58	19	bdl	0.39	0.29	0.14
	Nadowli	62	45	bdl	0.75	0.38	0.26
	Nandom	60	44	bdl	0.41	0.47	0.14
	Sissala East	58	53	bdl	0.66	0.33	0.23
	Sissala West	62	55	bdl	0.47	0.30	0.16
	Wa East	58	53	bdl	0.52	0.33	0.18
	Wa Municipal	63	54	bdl	0.45	0.54	0.16
	Wa West	66	53	bdl	0.41	0.28	0.14

Table B.7. Updated Results of Soil Analysis for Soil Zinc (Zn) Concentration

Region	District	# Samples Collected	# Samples Analyzed	Min	Max	Median	Mode
				---------------------mg/kg-----------------			
Northern	Bole	52	47	bdl	0.76	0.30	0.21
	Bunkpurugu-Yunyoo	55	34	bdl	0.59	0.27	0.16
	Central Gonja	66	51	bdl	0.71	0.24	0.18
	Chereponi	63	49	bdl	0.82	0.25	0.16
	East Gonja	48	33	bdl	1.01	0.30	0.35
	East Mamprusi	49	42	bdl	1.16	0.26	0.16
	Gushegu	45	34	bdl	0.70	0.25	0.21
	Karaga	51	48	bdl	0.71	0.34	0.23
	Kpandai	52	47	bdl	0.69	0.49	0.19
	Kumbungu	49	49	bdl	0.70	0.27	0.18
	Mamprugo Moaduri	51	44	bdl	0.54	0.23	0.30
	Mion	45	30	bdl	1.18	0.34	0.21
	Nanumba North	49	12	bdl	0.60	0.42	0.19
	Nanumba South	47	36	bdl	0.66	0.29	0.21
	North Gonja	49	33	bdl	0.66	0.26	0.18
	Saboba	60	34	bdl	0.64	0.29	0.24
	Sagnarigu	51	20	bdl	0.56	0.32	0.35
	Savelugu-Nanton	54	21	bdl	0.64	0.26	0.20
	Sawla-Tuna-Kalba	45	33	bdl	0.69	0.25	0.17
	Tamale Metropolitan	74	42	bdl	0.58	0.29	0.24
	Tatale Sangule	58	38	bdl	0.81	0.23	0.21
	Tolon	51	41	bdl	0.62	0.48	0.19
	West Gonja	49	22	bdl	0.60	0.23	0.18
	West Mamprusi	48	30	bdl	0.52	0.25	0.21
	Yendi Municipal	49	30	bdl	0.54	0.22	0.20
	Zabzugu	52	33	bdl	0.61	0.29	0.17
Upper East	Bawku Municipal	54	39	bdl	0.56	0.42	0.16
	Bawku West	59	20	bdl	0.62	0.52	0.13
	Binduri	56	35	bdl	0.49	0.59	0.13
	Bolgatanga Municipal	59	41	bdl	0.72	0.37	0.14
	Bongo	59	20	bdl	0.64	0.36	0.18
	Builsa	59	43	bdl	0.90	0.31	0.12
	Builsa South	56	50	bdl	0.55	0.29	0.18
	Garu-Tempane	48	20	bdl	1.03	0.33	0.22
	Kassena Nankana East	60	18	bdl	0.53	0.36	0.15
	Kassena Nankana West	54	49	bdl	0.73	0.30	0.14
	Nabdam	59	43	bdl	0.62	0.41	0.15
	Pusiga	55	12	bdl	0.51	0.32	0.25
	Talensi	60	48	bdl	0.53	0.31	0.13
Upper West	Daffiama Bussie Issa	55	40	bdl	0.74	0.19	0.12
	Jirapa	60	43	bdl	0.85	0.18	0.24
	Lambussie Karni	55	40	bdl	0.52	0.22	0.14
	Lawra	58	19	bdl	0.51	0.19	0.13
	Nadowli	62	45	bdl	0.44	0.37	0.21
	Nandom	60	44	bdl	0.47	0.20	0.14
	Sissala East	58	53	bdl	0.51	0.32	0.16
	Sissala West	62	55	bdl	0.42	0.23	0.13
	Wa East	58	53	bdl	0.59	0.25	0.12
	Wa Municipal	63	54	bdl	0.46	0.22	0.12
	Wa West	66	53	bdl	0.44	0.20	0.15

Table B.8. Updated Results of Soil Analysis for Soil Boron (B) Concentration

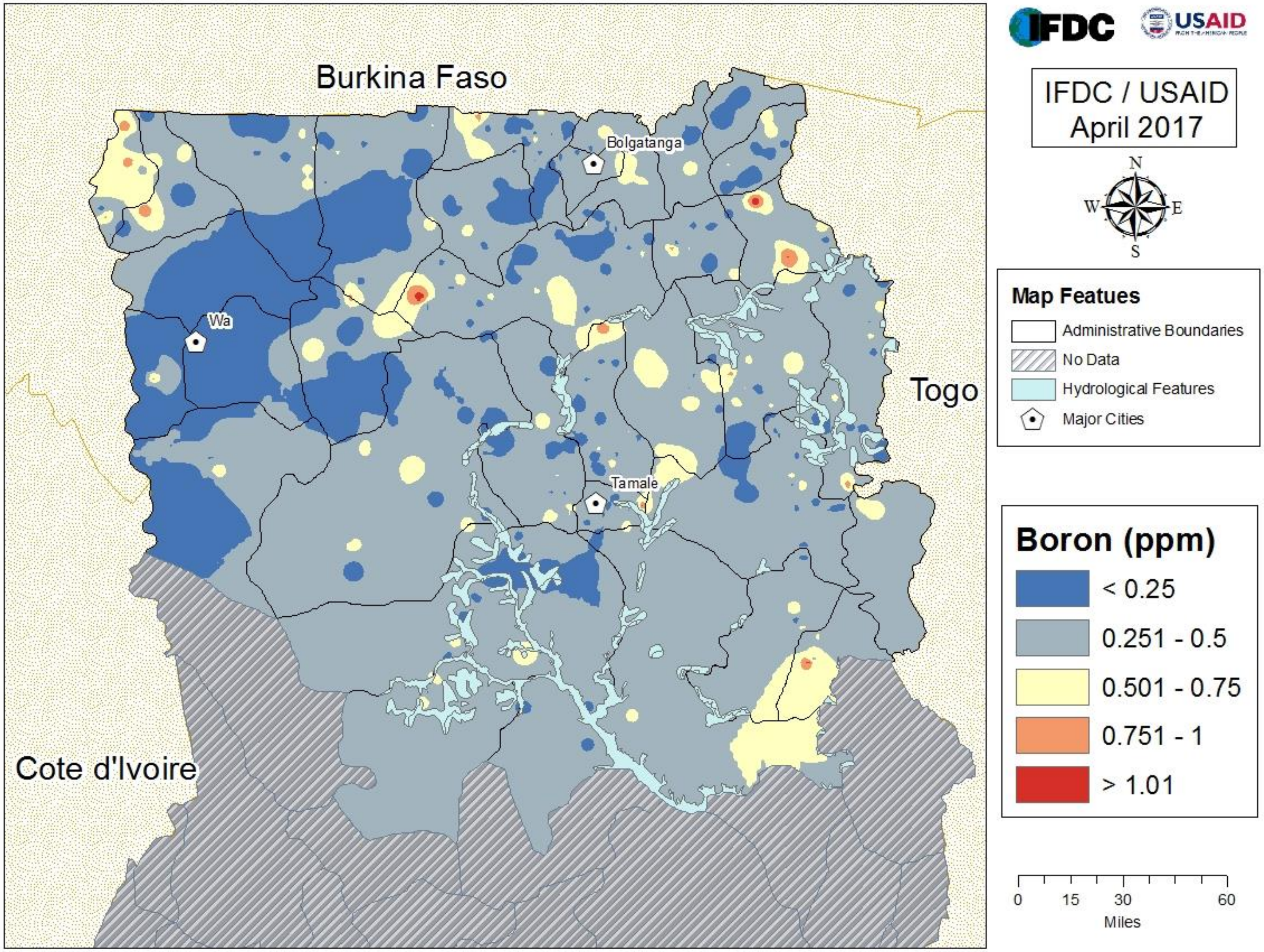

Figure B.1. *Soil Boron Levels for Selected Soils in Ghana*

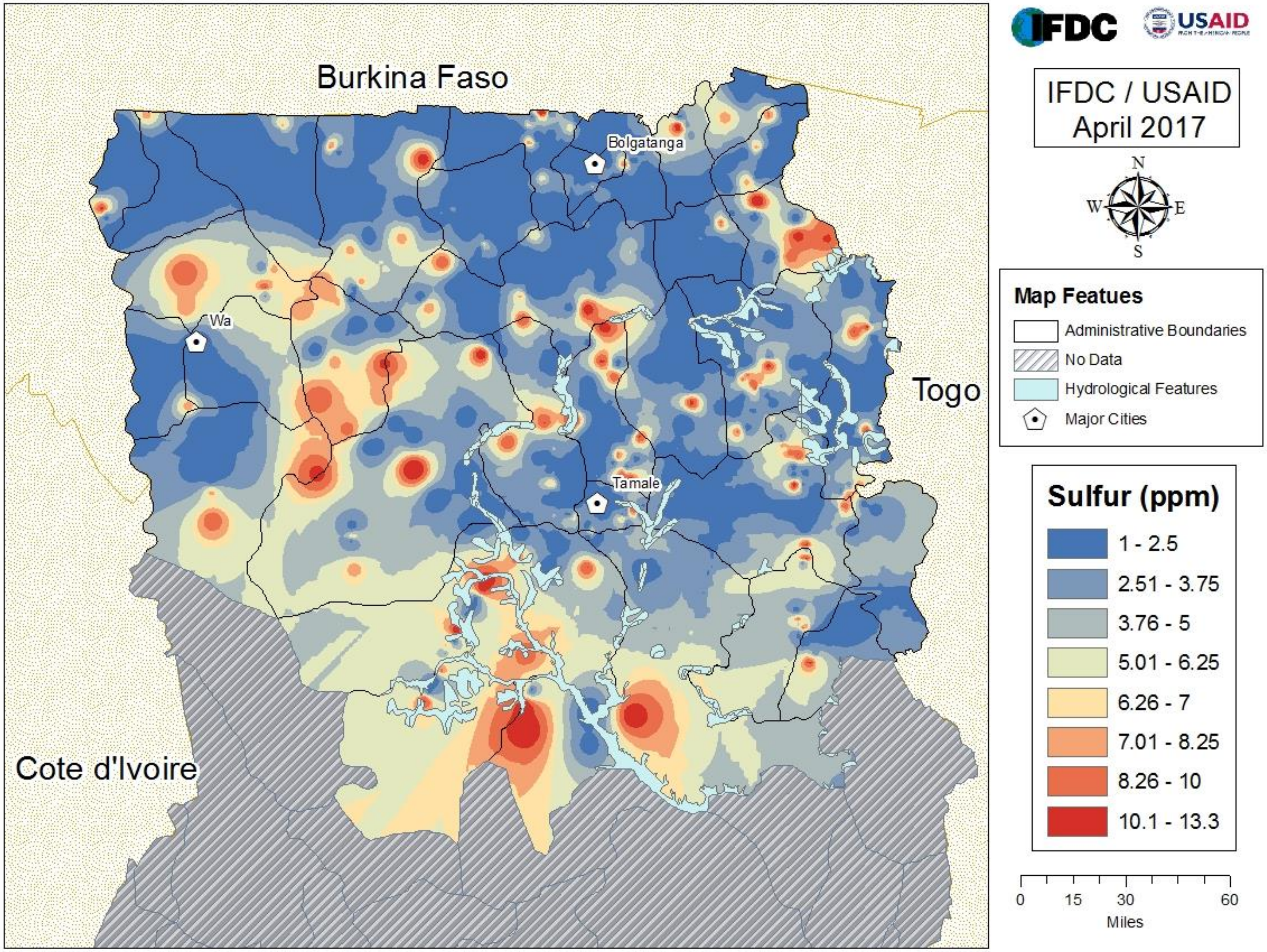

Figure B.2. Soil Sulfur Levels for Selected Soils in Ghana

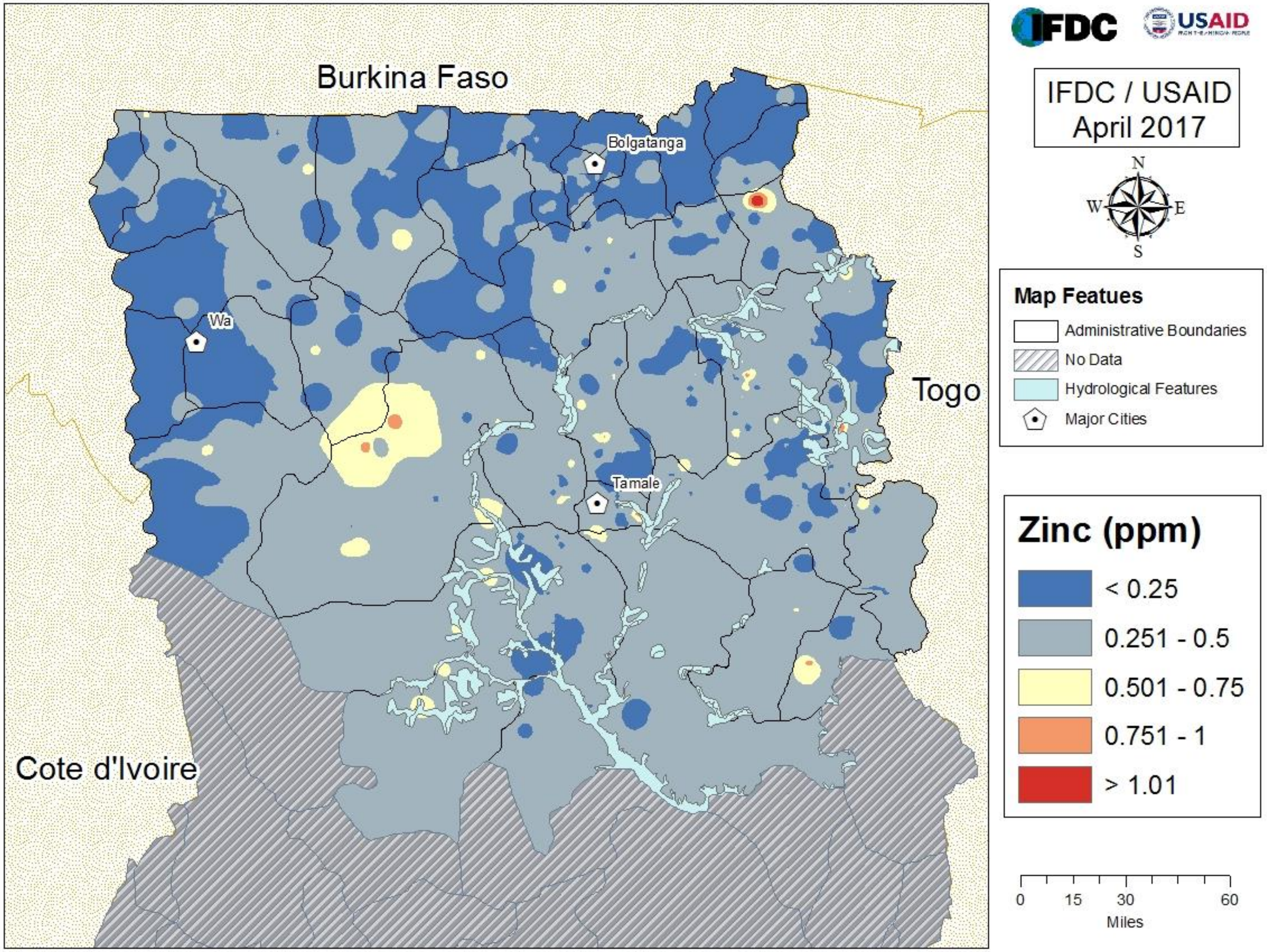

Figure B.3. Soil Zinc Levels for Selected Soils in Ghana www.feedthefuture.gov